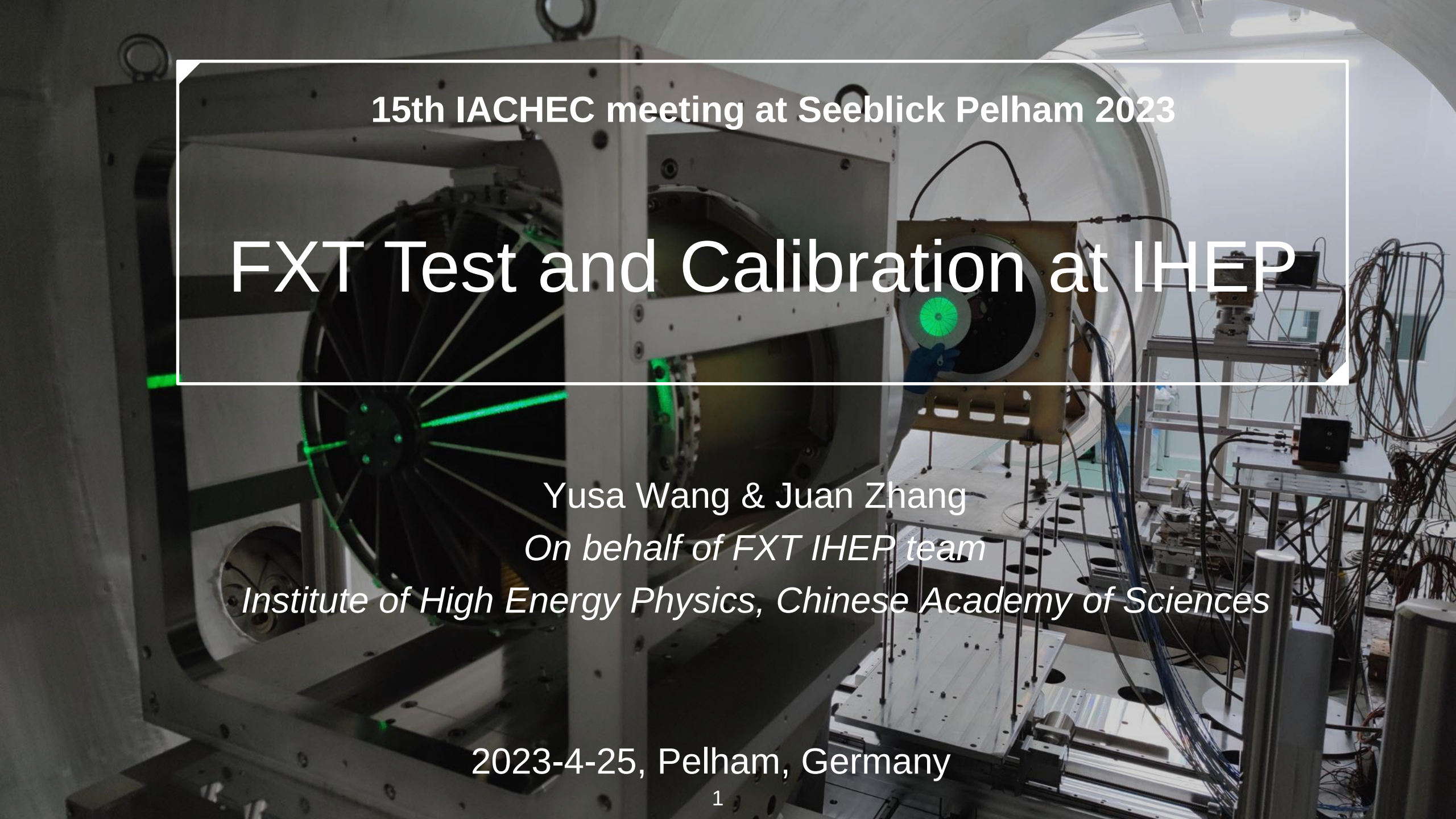


15th IACHEC meeting at Seeblick Pelham 2023

# FXT Test and Calibration at IHEP

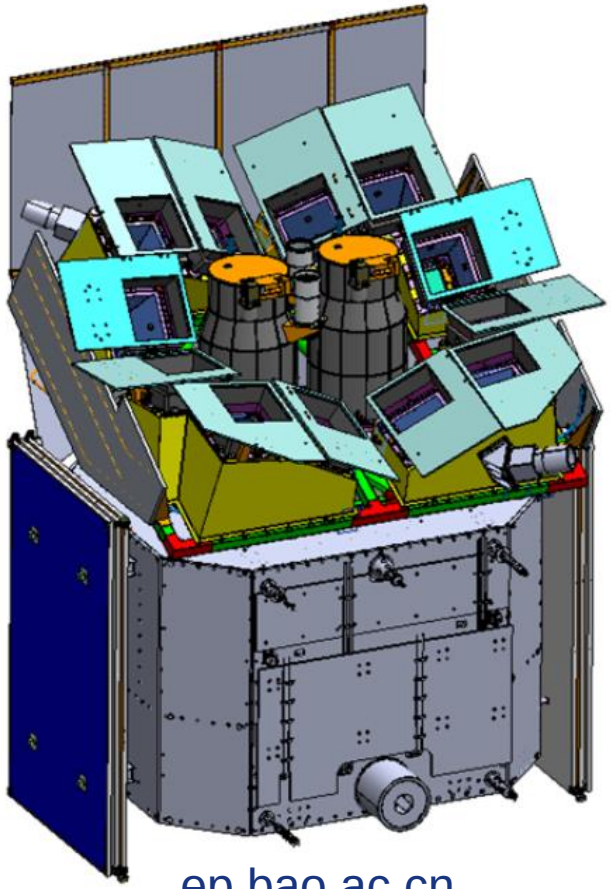
Yusa Wang & Juan Zhang

*On behalf of FXT IHEP team*

*Institute of High Energy Physics, Chinese Academy of Sciences*

2023-4-25, Pelham, Germany

# EP/FXT



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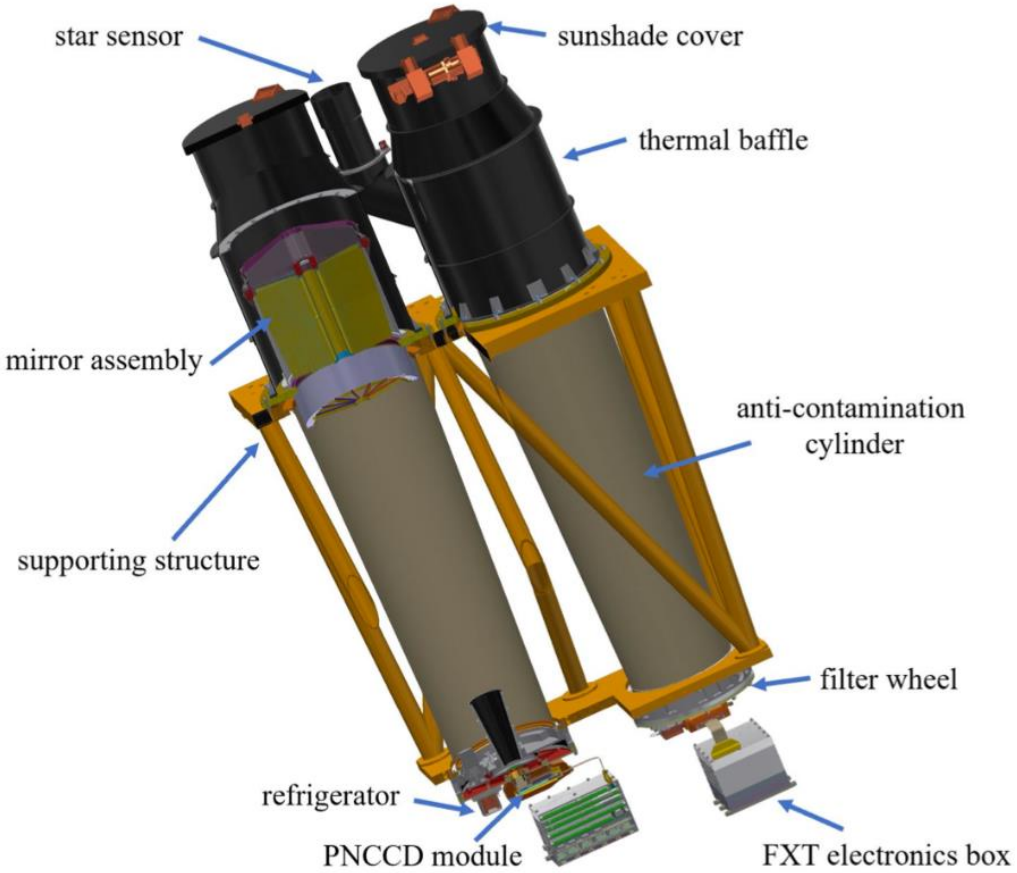
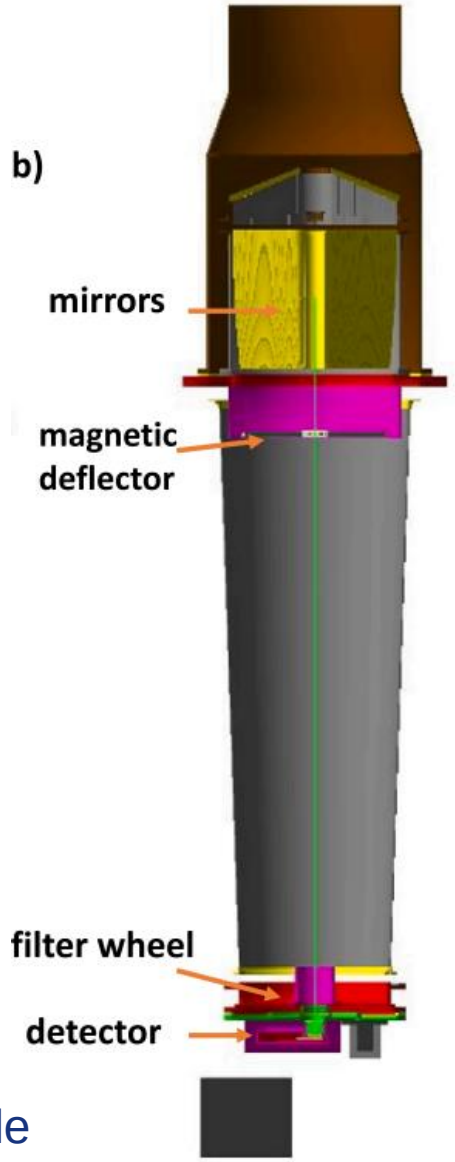
To be launched in Nov




pnCCD read-out directions: 90deg angle

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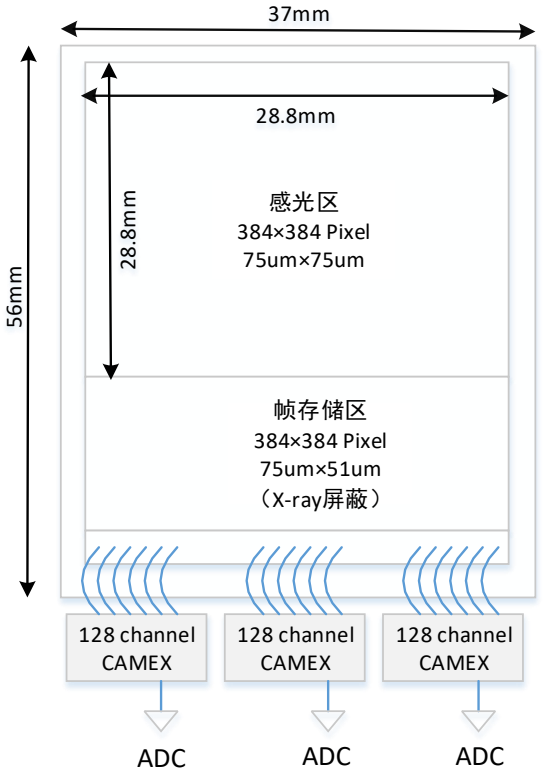
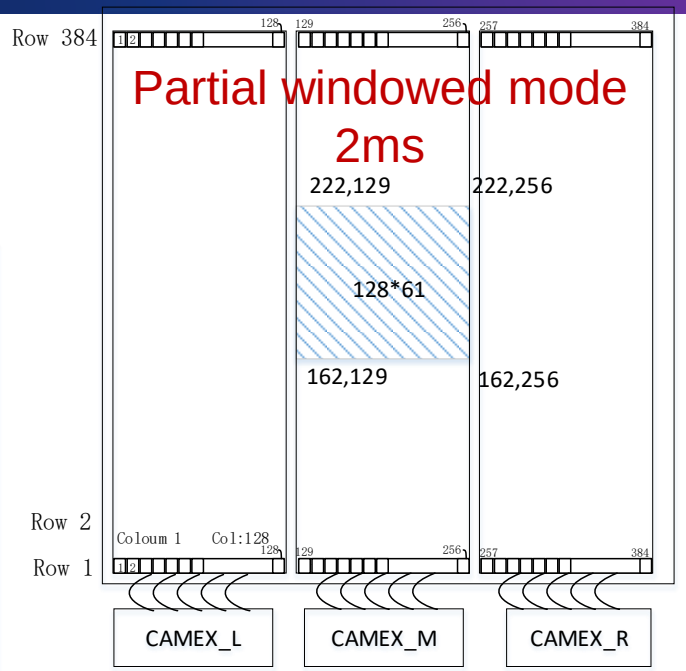
# EP/FXT

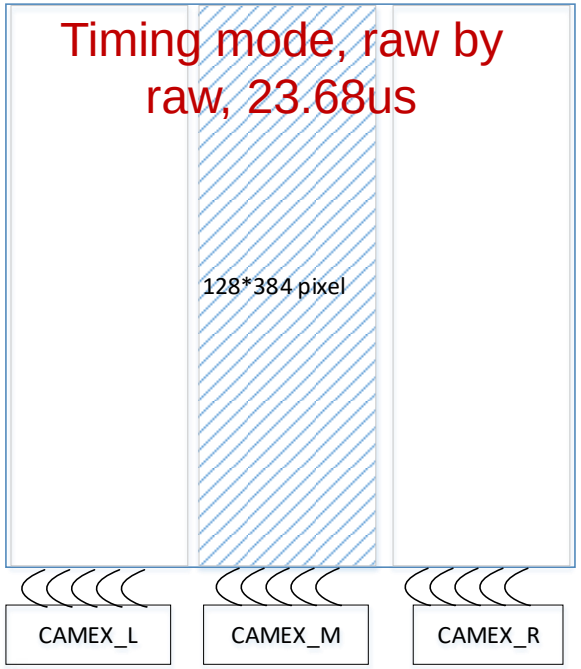
## Read out modes: FF, PW, TM



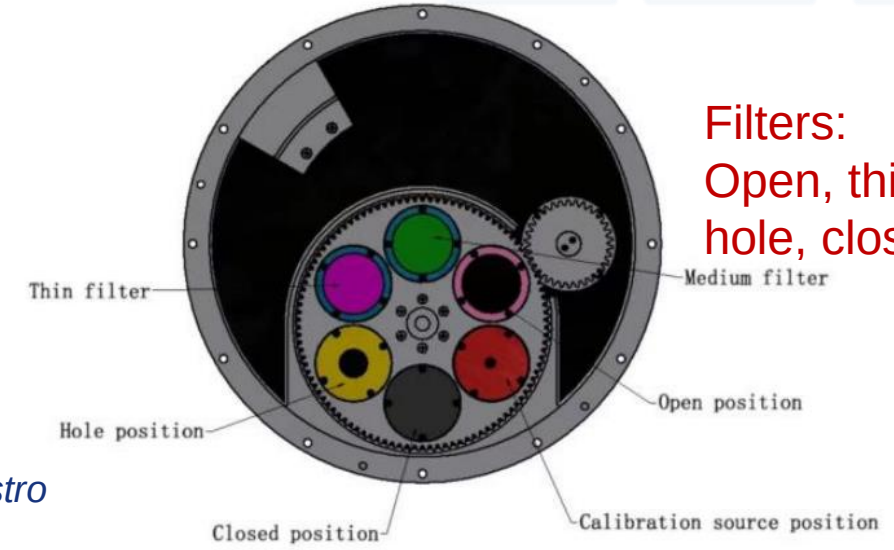

Full frame mode, 50ms




Partial windowed mode 2ms

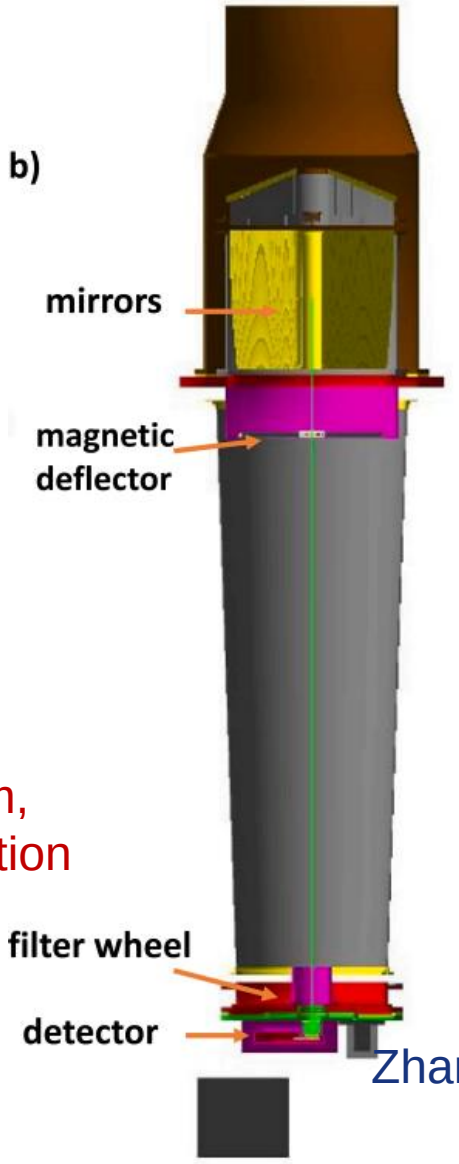



Timing mode, raw by raw, 23.68us




Filters:
Open, thin, medium, hole, close, calibration

*Cui et al. 2022，ExpAstro*

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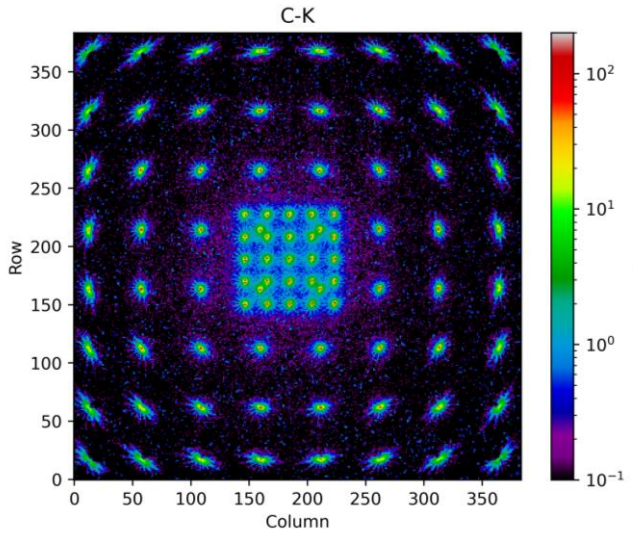
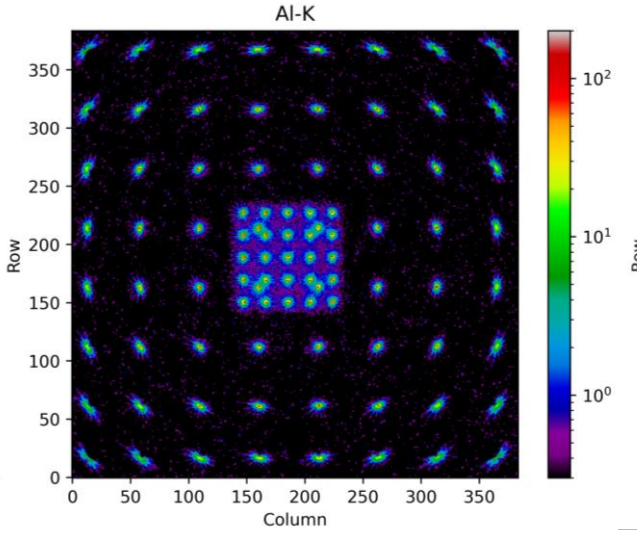
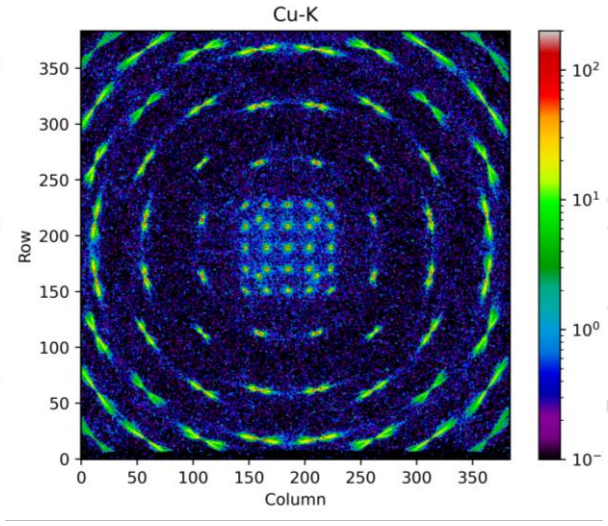
# Outline

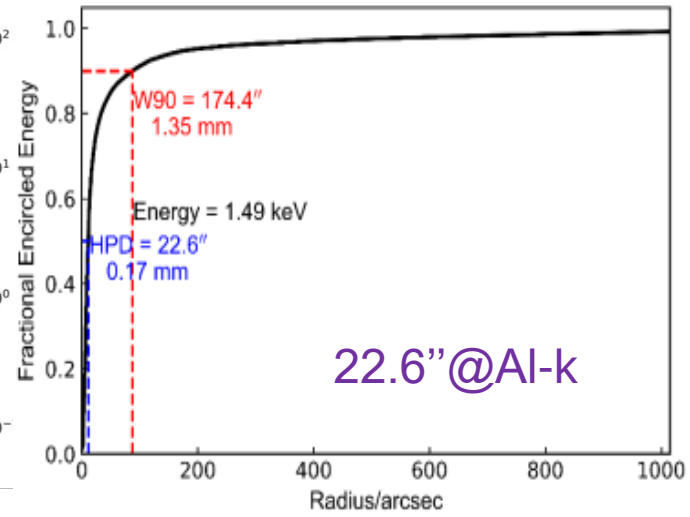
1. Test and Calibration of Mirror Assemblies
2. Test and Calibration of Focal Plane Cameras
3. Test and Calibration of Telescopes wangyusa@ihep.ac.cn
4. ARF Simulation of FXT zhangjuan@ihep.ac.cn

# PSF&HPD

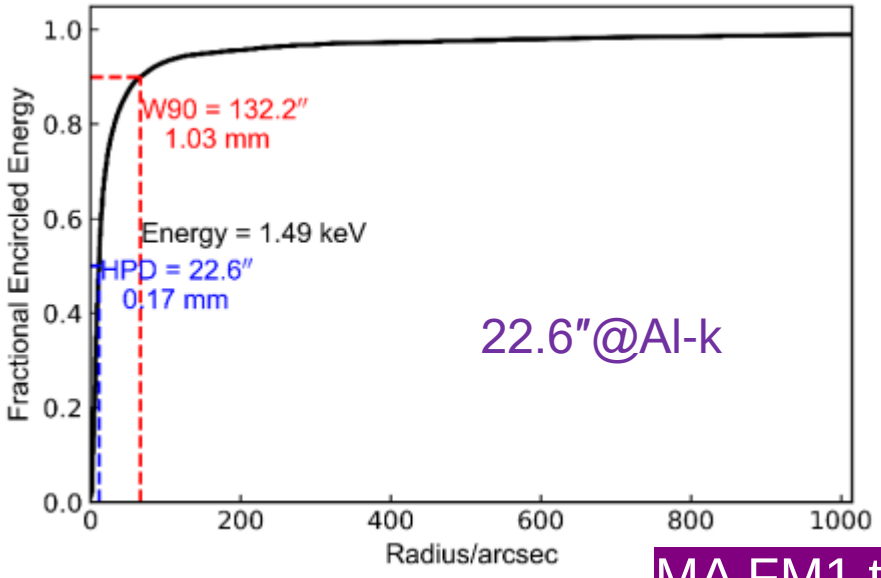


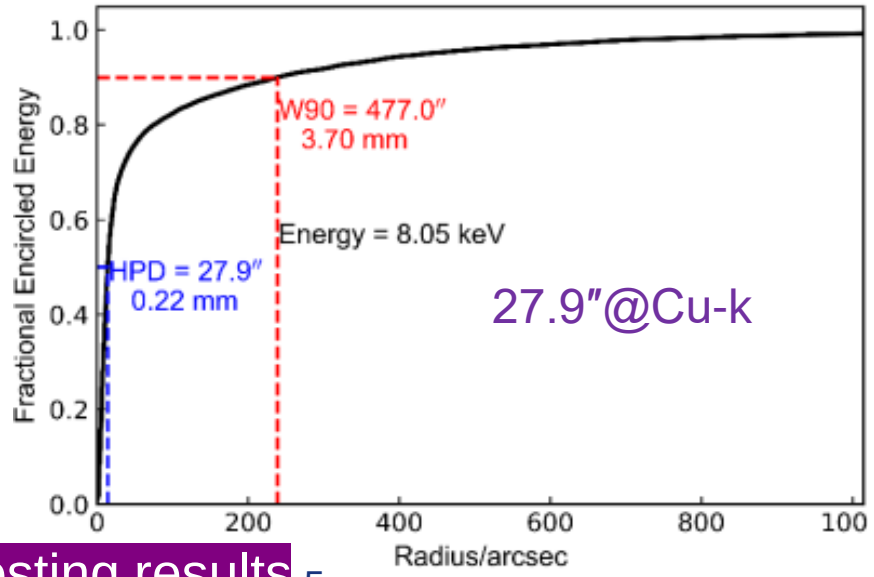



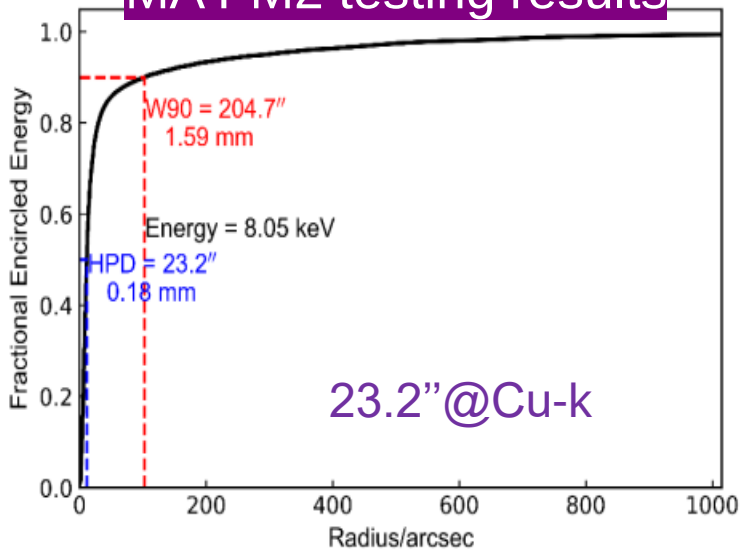




MA FM2 testing results

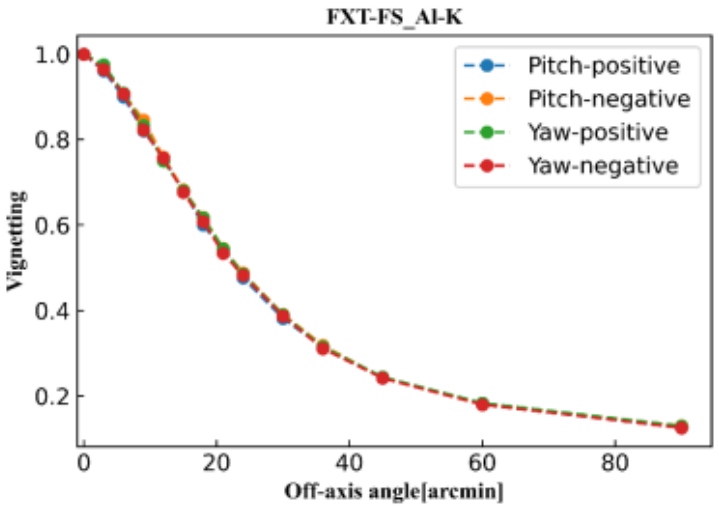


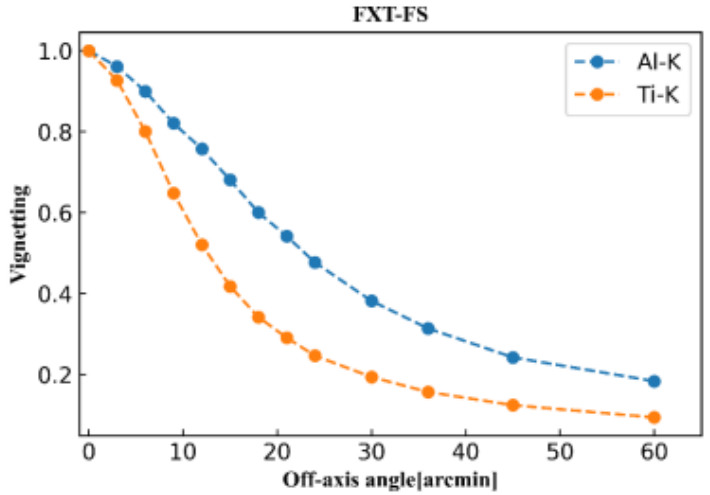



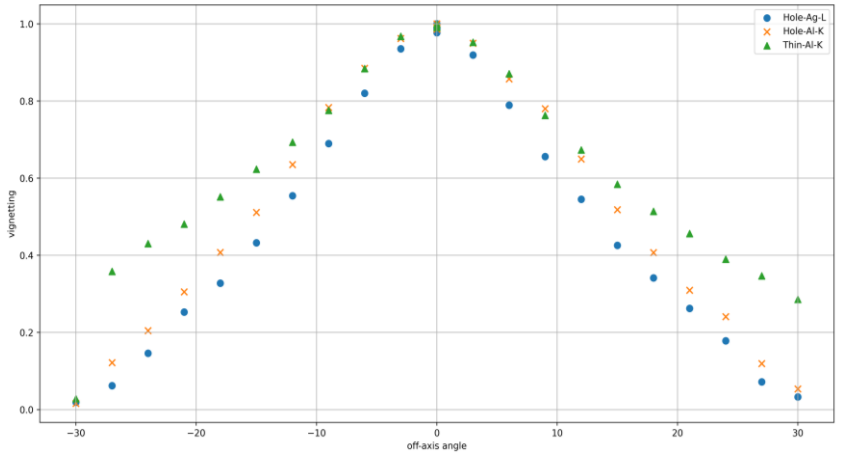




MA FM1 testing results

# Vignetting

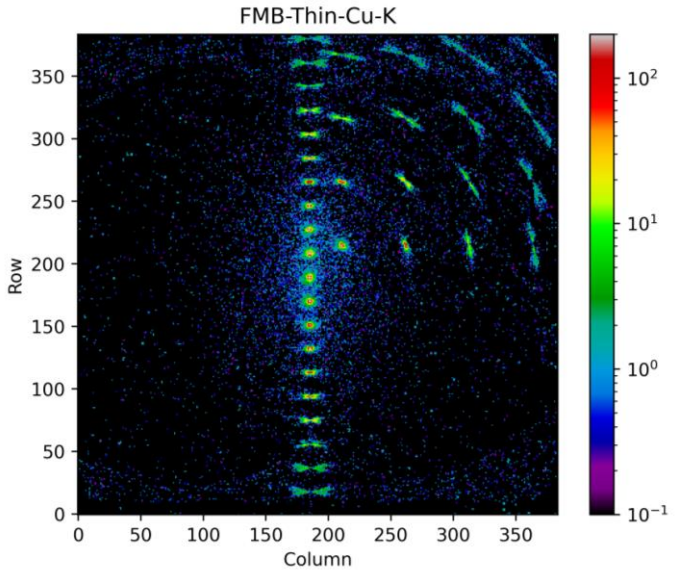


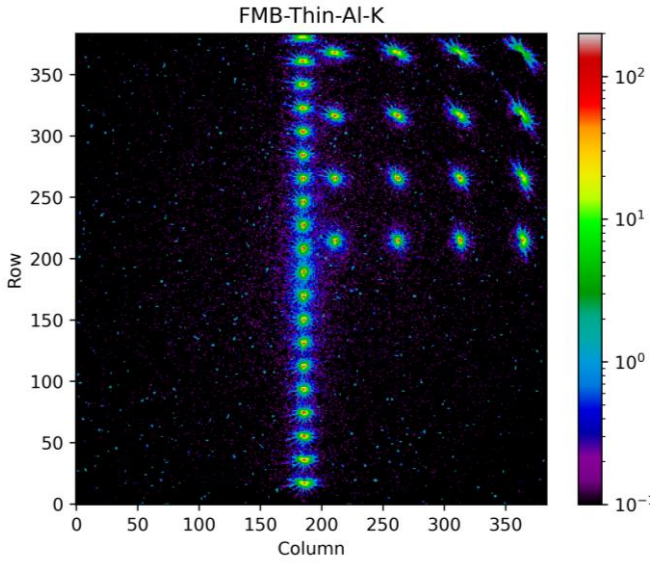



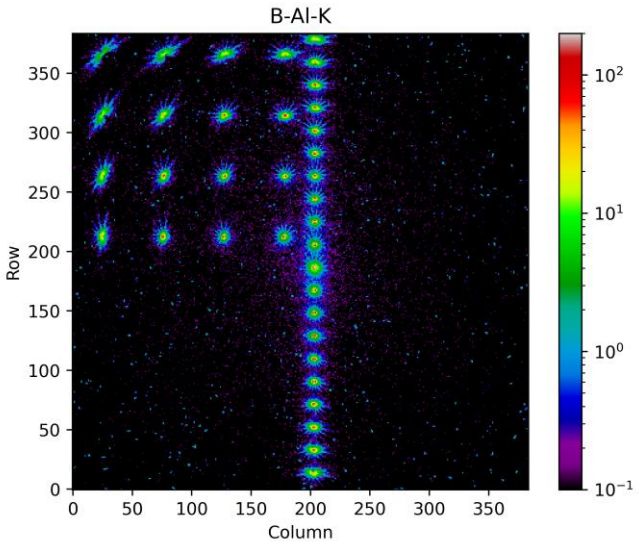




More details in Chengkui's talk

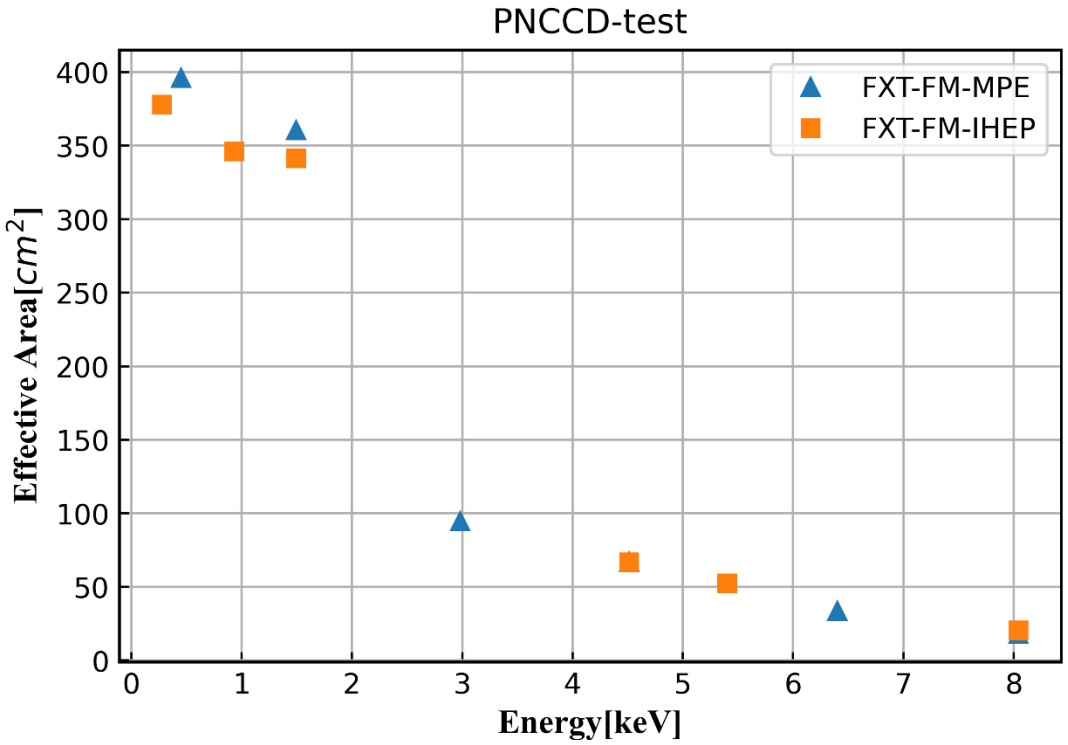
The vignetting function shows good azimuth symmetry.
--》
measured in one quadrant.

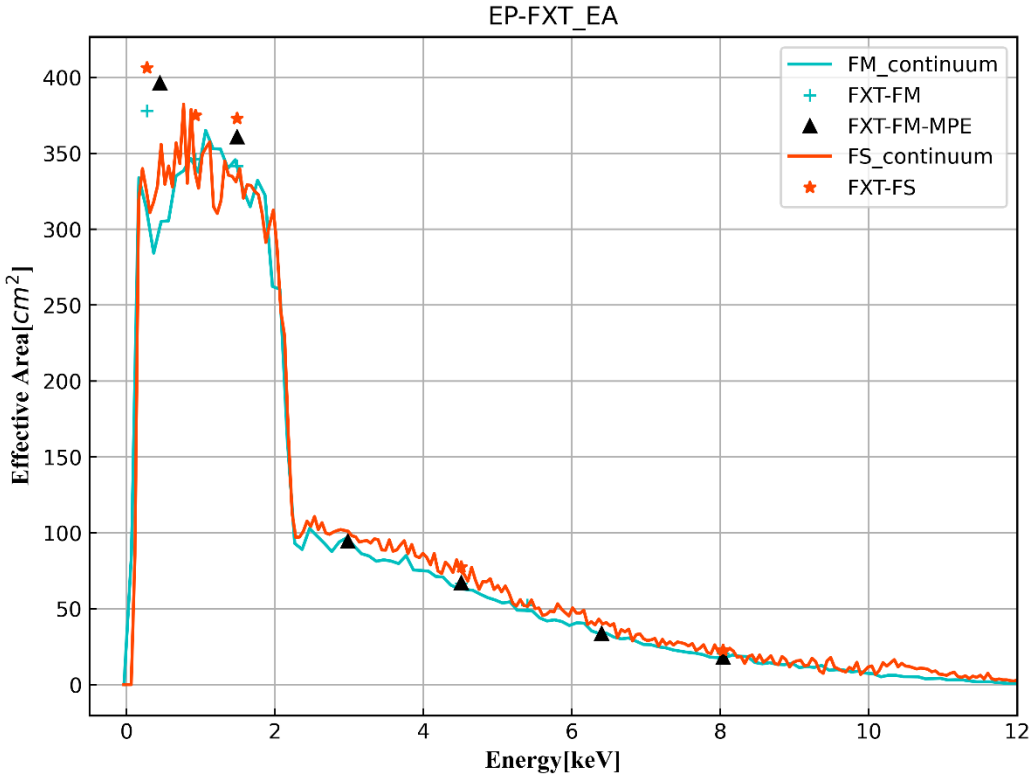


# Effective Area




Consistent except at low energies.

Pointed energy measurements~ pnCCD  VS  Continuum ~ commercial detector

# Outline

1. Test and Calibration of Mirror Assemblies
2. Test and Calibration of Focal Plane Cameras
3. Test and Calibration of Telescopes
4. Simulation of FXT

# Test and Calibration of Focal Plane Cameras

## Event Patterns and Ratio

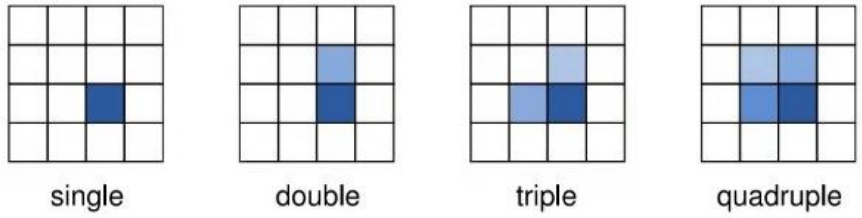
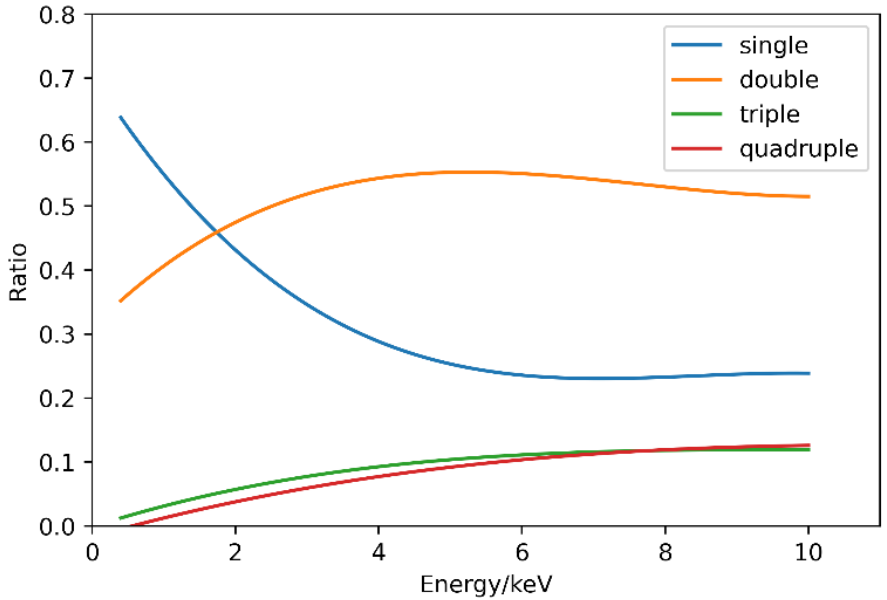
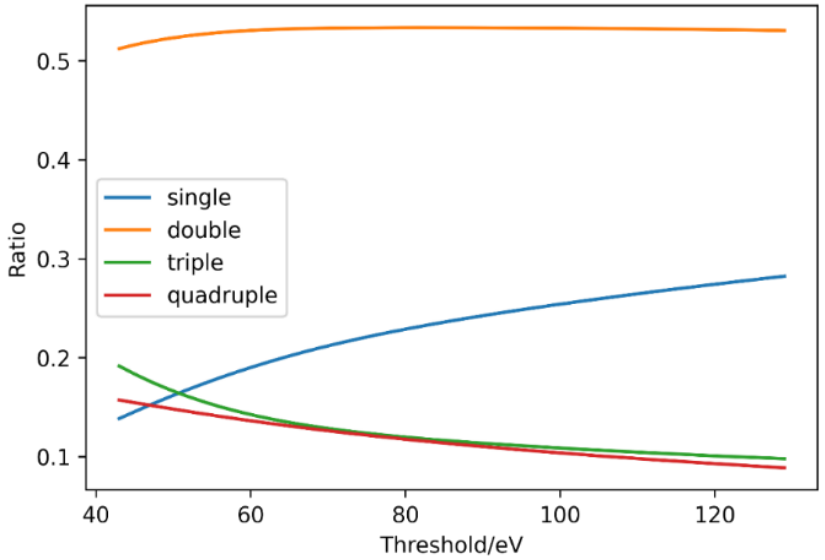


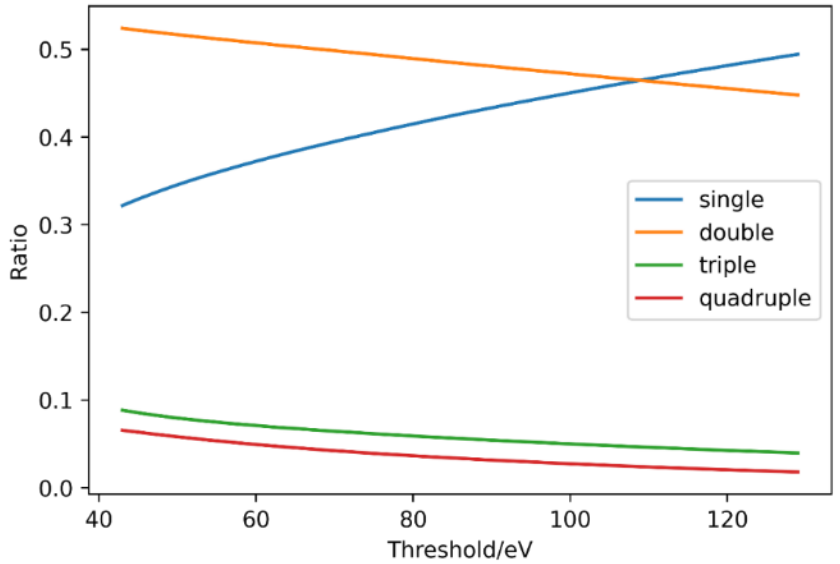

Figure 2.4: Valid split patterns. Also rotations of these patterns are valid.




The ratio of split events when the threshold is about 100eV

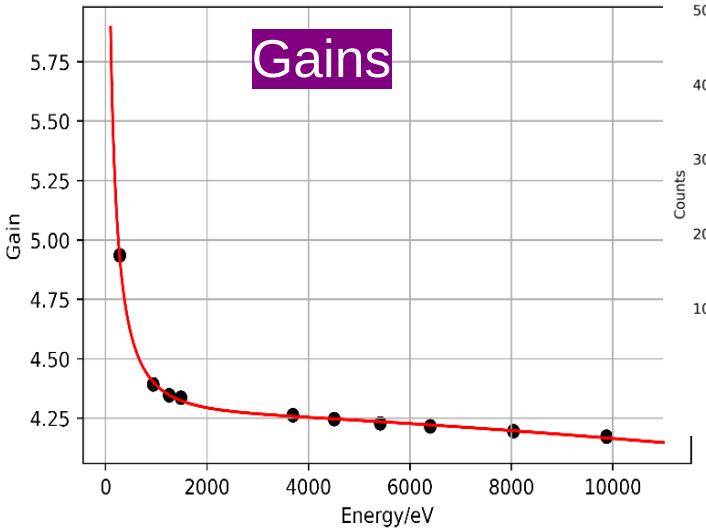


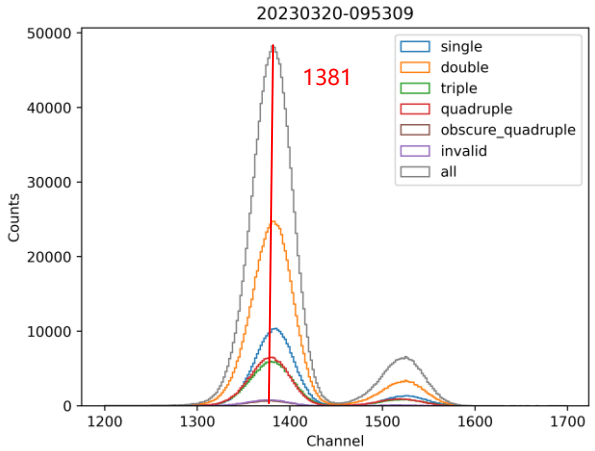

The ratio of split events vs Threshold @ Cr-kα

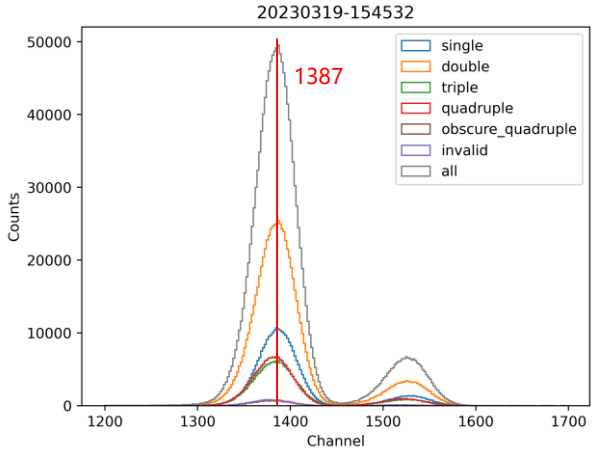


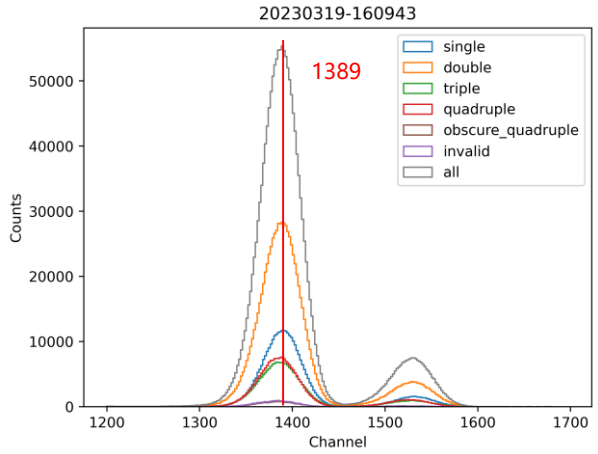

The ratio of split events vs Threshold @ Al-k

# Test and Calibration of Focal Plane Cameras

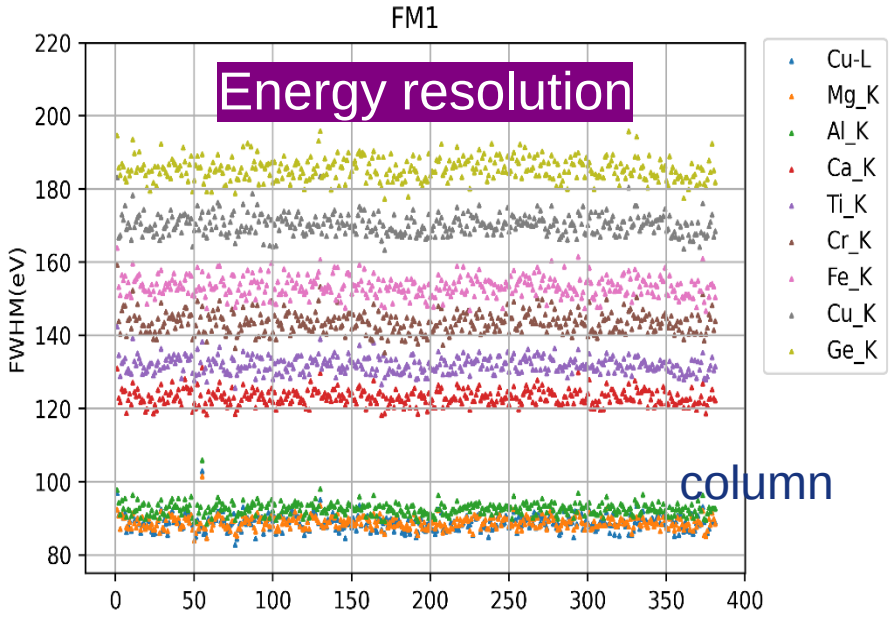


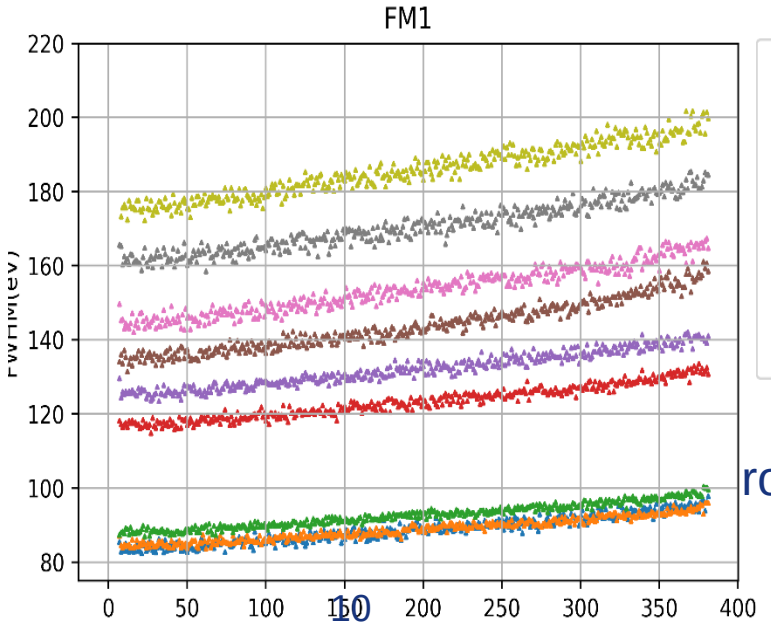



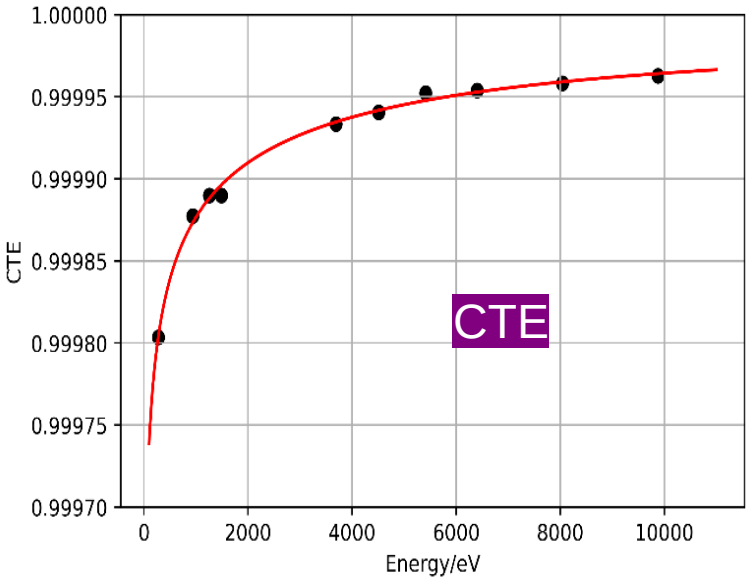

- -95℃~-85℃，the bias is 0.8Channel/℃，about 3.4eV/℃, at the same offset.




column




row



# Outline

1. Test and Calibration of Mirror Assemblies
2. Test and Calibration of Focal Plane Cameras
3. Test and Calibration of Telescopes
4. Simulation of FXT

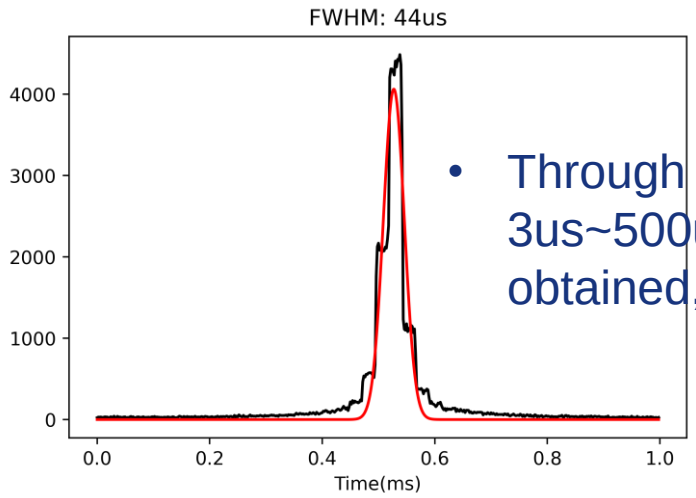
# arf @100XF focus

| EA ($cm^2$) | |
|---|---|
| Energy (keV) | FXT1 open filter |
| C-K: 0.28 | 137.57 |
| O-K: 0.53 | 269.29 |
| Cu-L: 0.93 | 332.96 |
| Mg-K: 1.25 | 330.87 |
| Al-K: 1.49 | 332.75 |
| Ag-L: 2.98 | 88.39 |
| Ti-K: 4.51 | 77.4 |
| Fe-K: 6.4 | 36.21 |
| Cu-K: 8.04 | 20.27 |

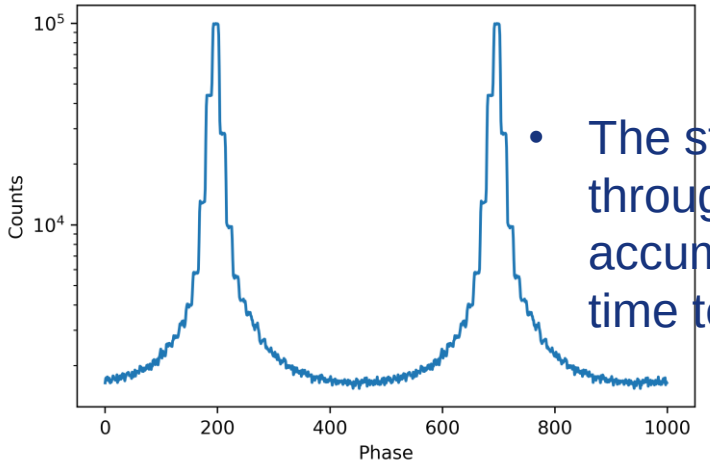
| EA ($cm^2$) | |
|---|---|
| Energy (keV) | FXT2 thin filter |
| C-K: 0.28 | 63.24 |
| O-K: 0.53 | 181.12 |
| Cu-L: 0.93 | 295.15 |
| Mg-K: 1.25 | 337.52 |
| Al-K: 1.49 | 354.81 |
| Ag-L: 2.98 | 88.65 |
| Ti-K: 4.51 | 80.22 |
| Fe-K: 6.4 | 41.3 |
| Cu-K: 8.04 | 22.5 |

# Test and Calibration of Telescopes

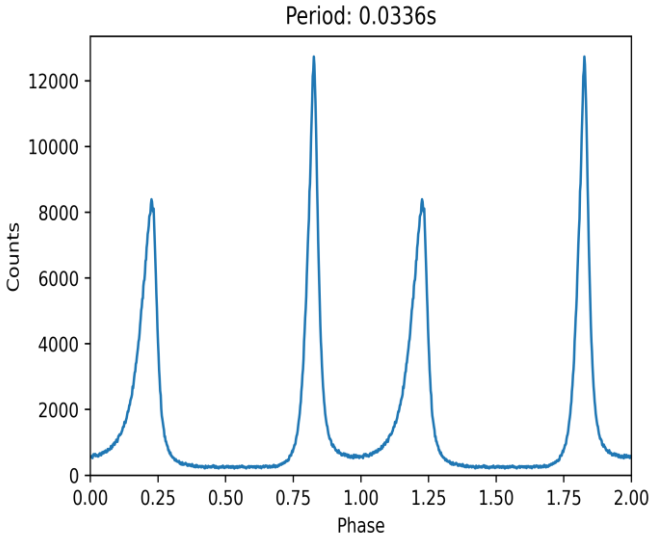
## Time resolution of the timing mode

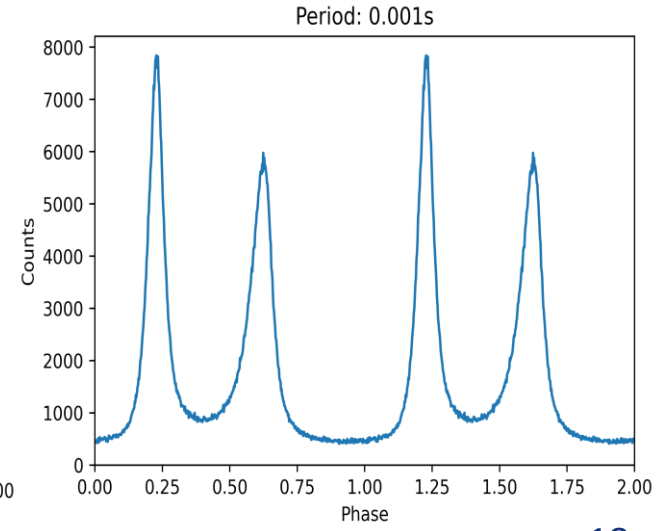


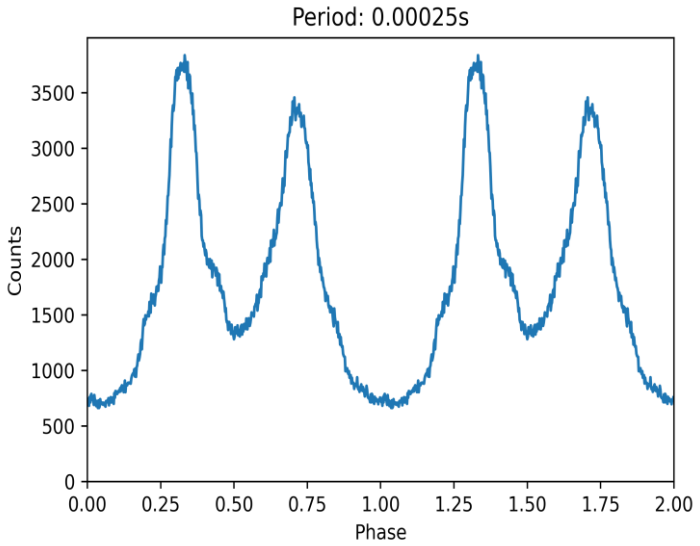

- Through the delta pulse with 3us~500us，time resolution is obtained, 44us




- The stability is good through analysis of the accumulation of a long time test



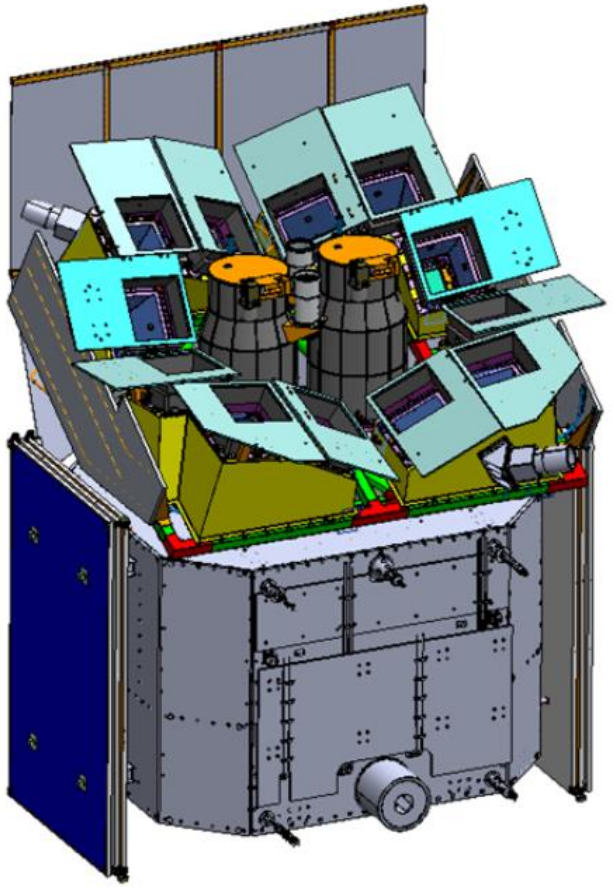



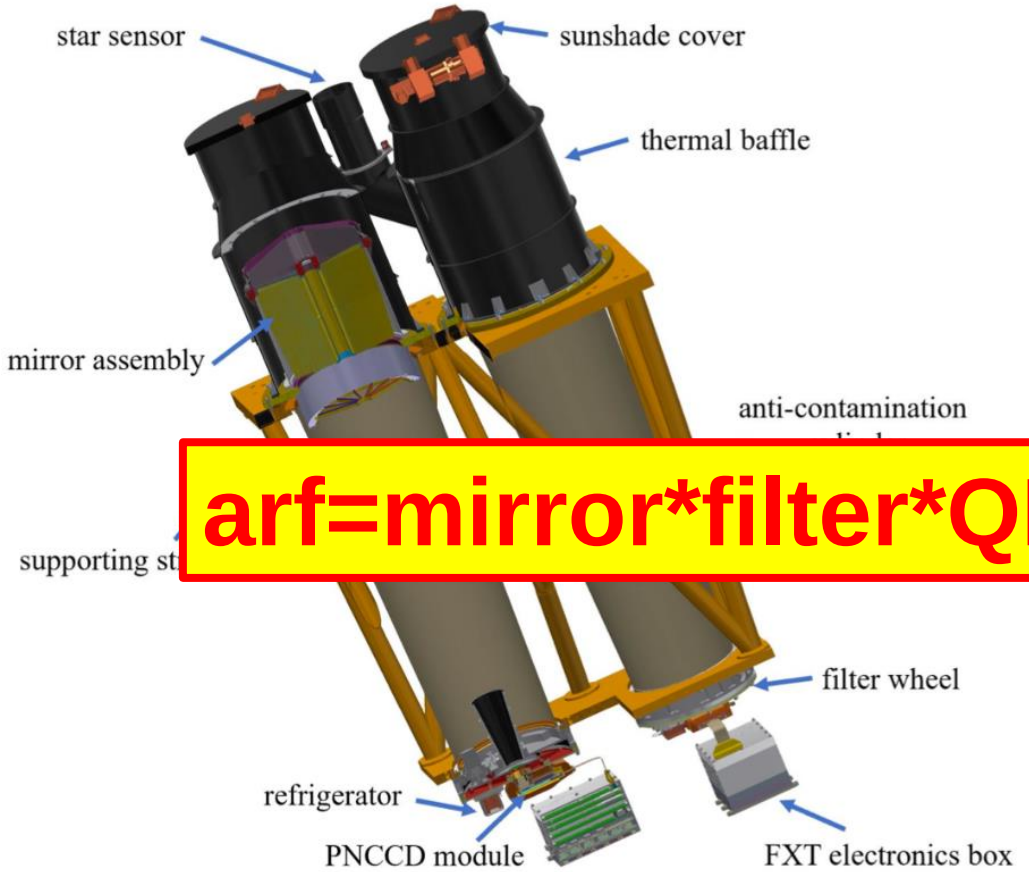

- Crab pulsation is constructed.
- Period<1ms，distortion happens.

# Outline

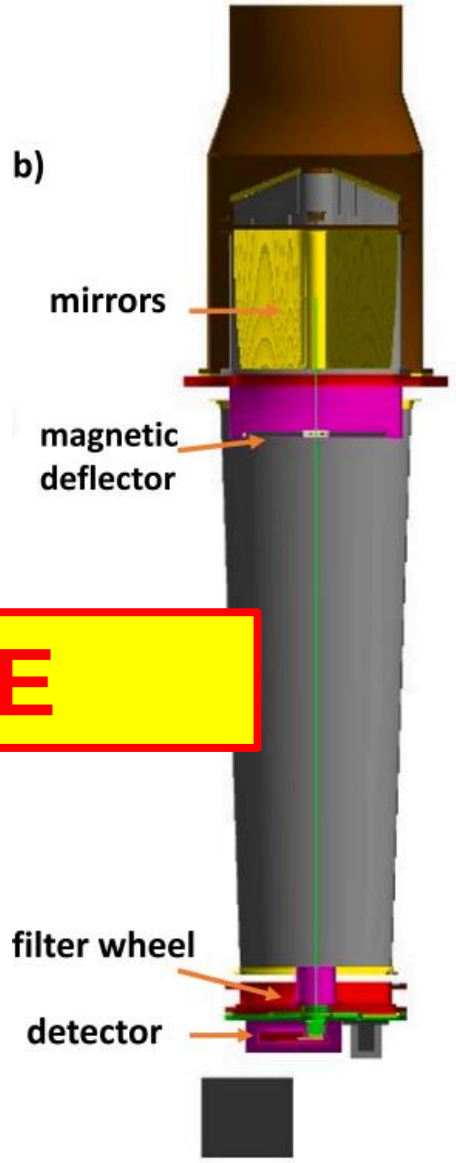
1. Test and Calibration of Mirror Assemblies
2. Test and Calibration of Focal Plane Cameras
3. Test and Calibration of Telescopes
4. ARF Simulation of FXT

# EP/FXT arf simulation






**arf=mirror*filter*QE**

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# Mirror

## Geant4 simulation (Qi et al., NIMA, 2020)

- G4Paraboloid + G4Hyperboloid Geometry
- G4XrayGrazingAngleScattering Physics
  - Figure error:  local surface normal perturbation
  - Microroughness：X-ray scattering

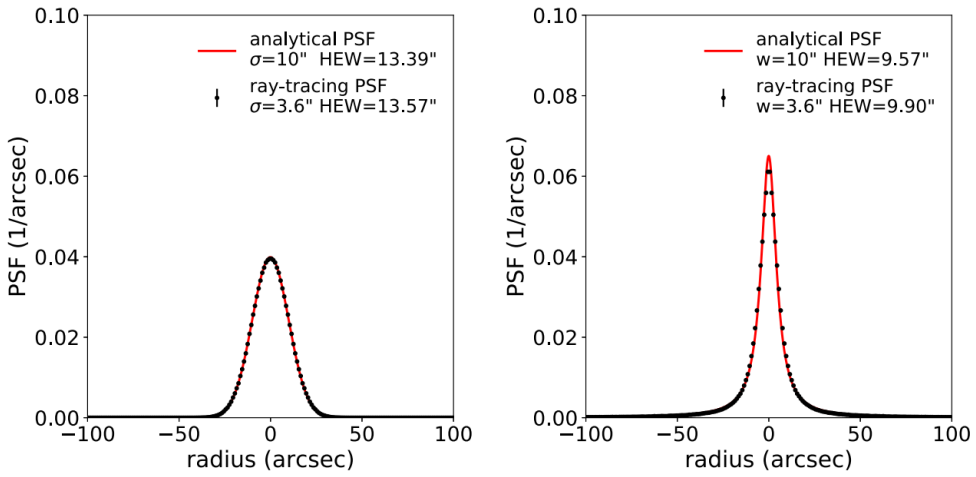



**Fig. 4.** PSFs obtained from the ray-tracing model of Geant4 and the analytical formula with the Gaussian shape (left) and the Lorentzian shape (right) slope perturbation functions.

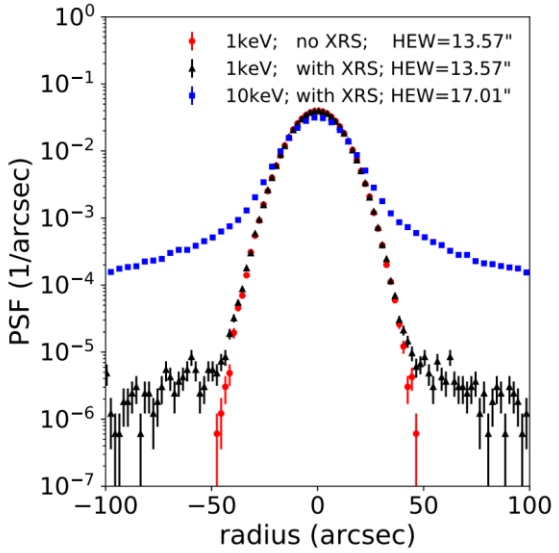
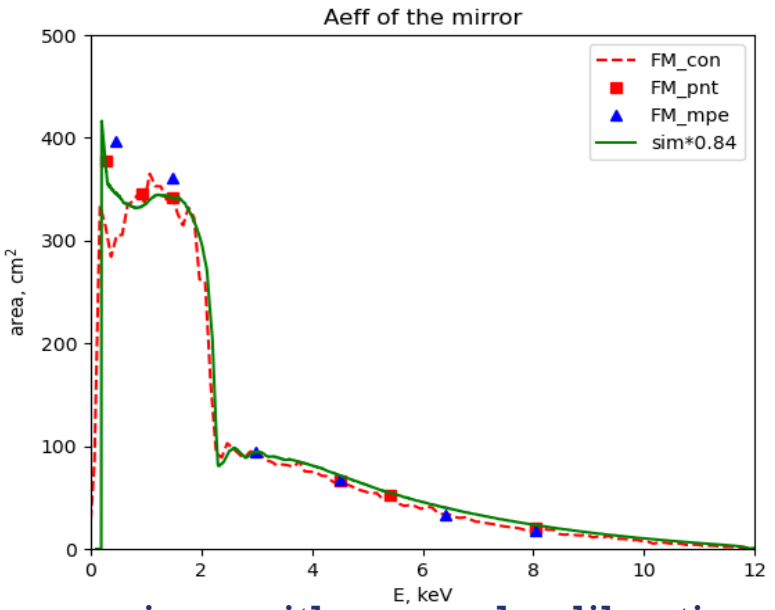
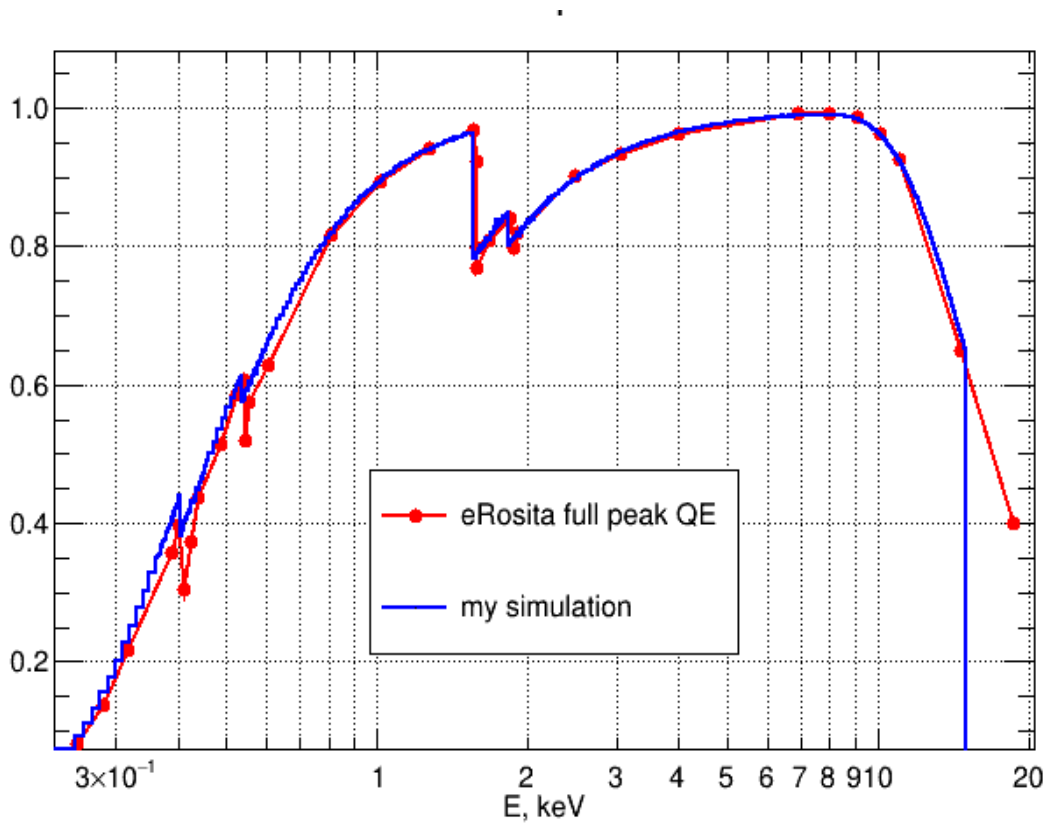


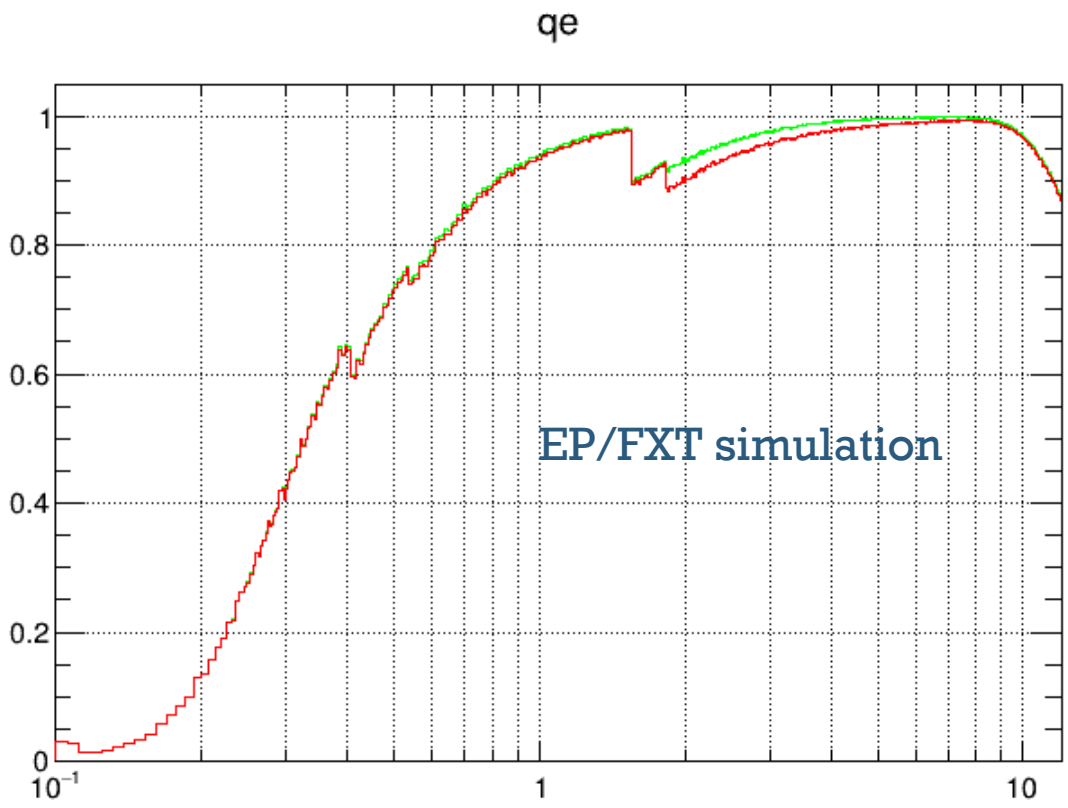

**Fig. 5.** PSFs at different photon energies and surface conditions.




## Comparison with ground calibration

# QE

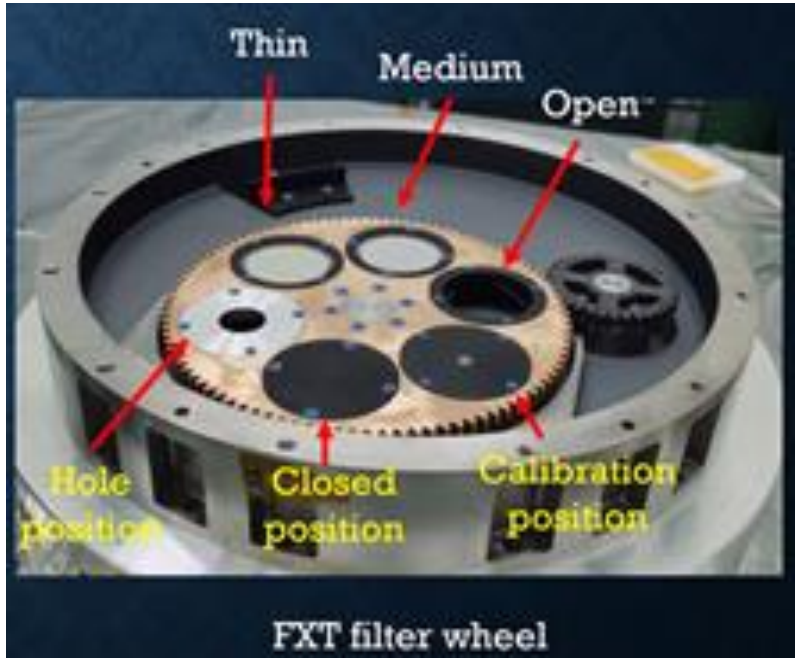


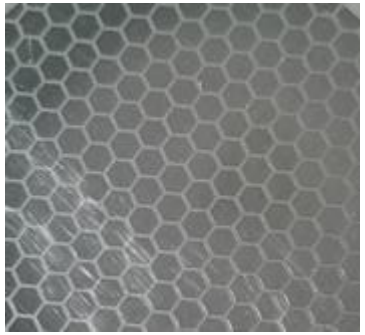



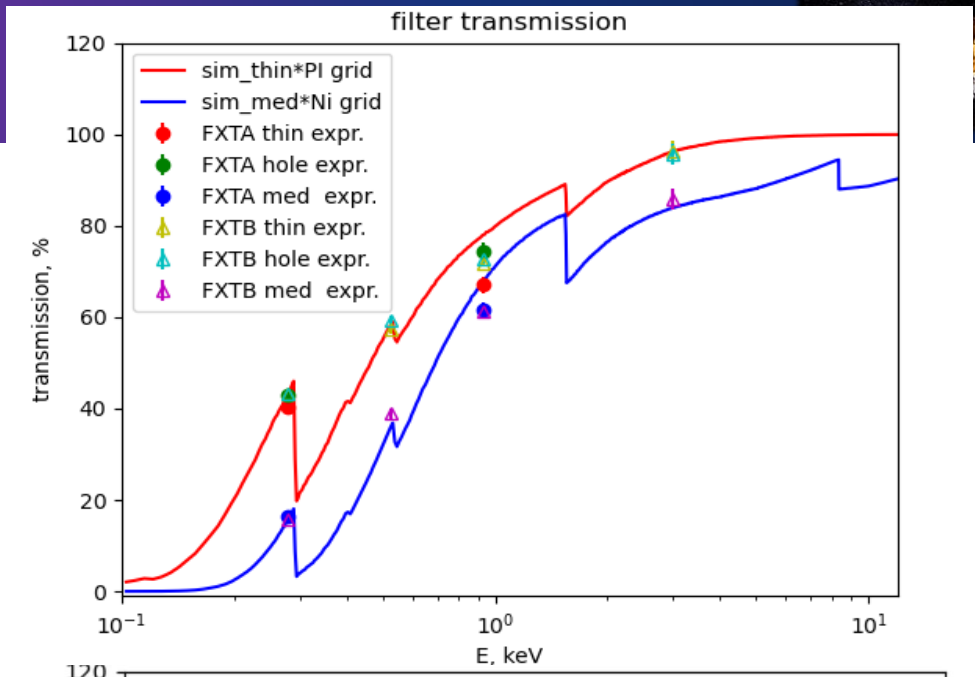

Currently, QE is given through simulation.
Experimental data will be available later using spare detector

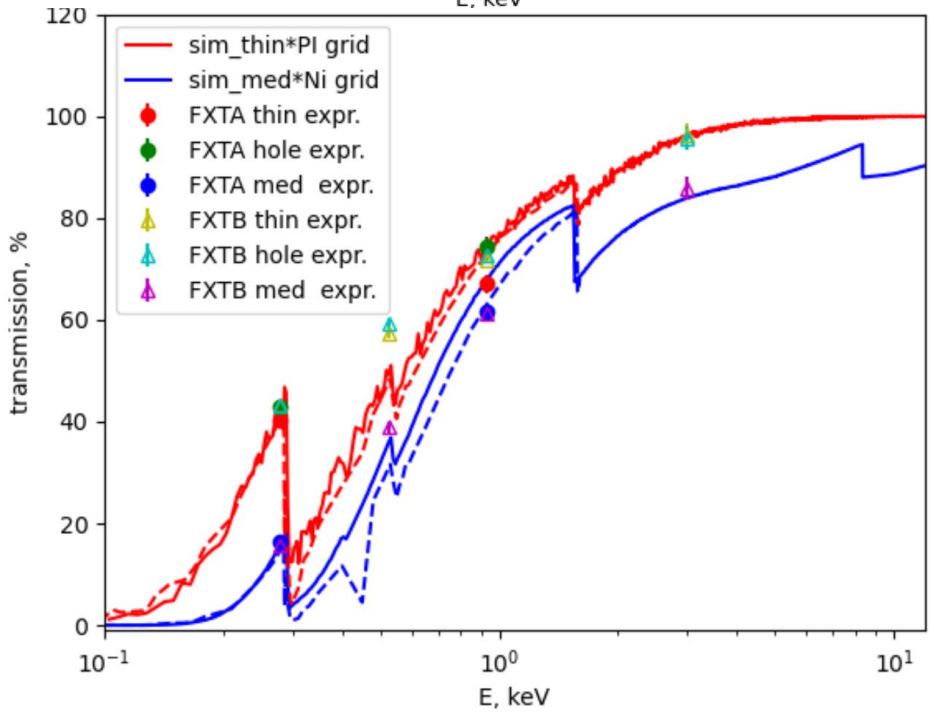
# Filter

- Simulation is not consistent with all of the measurement data now.
- More filters experiment in May

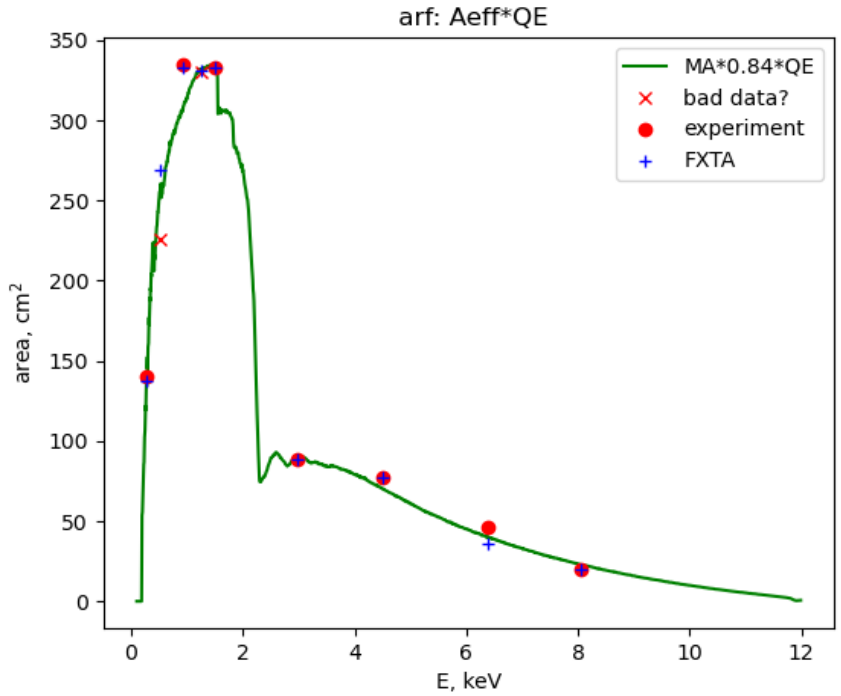


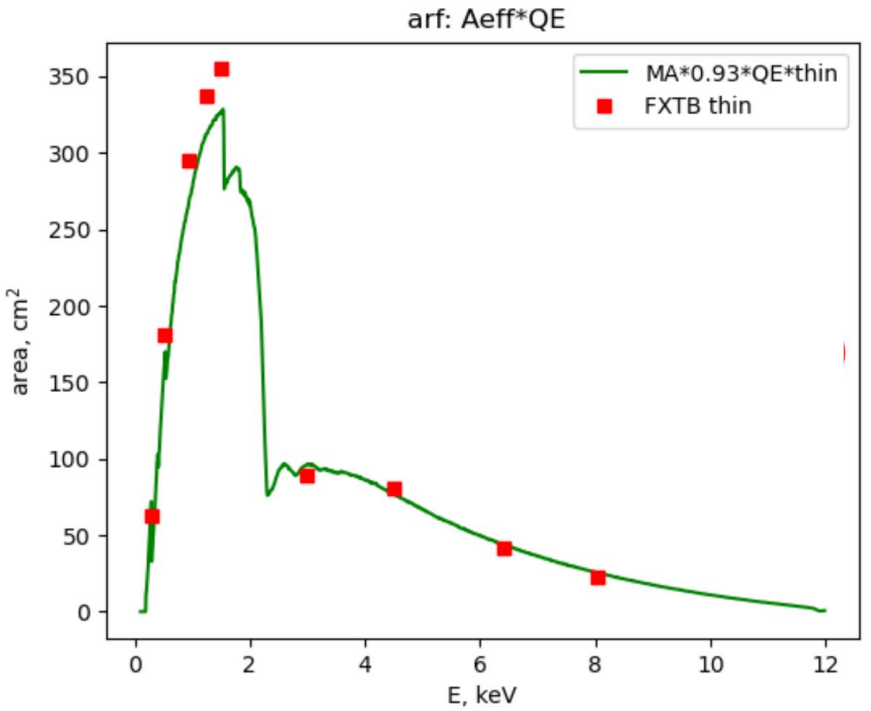





# ARF


arf: Aeff*QE
MA*0.84*QE
bad data?
experiment
FXTA
area, cm$^2$
E, keV
0
50
100
150
200
250
300
350
0
2
4
6
8
10
12


arf: Aeff*QE
MA*0.93*QE*thin
FXTB thin
area, cm$^2$
E, keV
0
50
100
150
200
250
300
350
0
2
4
6
8
10
12

# Summary & discussion

- **Ground calibration:**
  - ✓ The test of MA, focal plane cameras and telescope module was completed.
  - ✓ The whole FXT is being tested end to end at IHEP now

- **Simulation Arf=Aeff*QE*Filter**
  - Mirror: modified simulation to measurements
  - QE: simulation-> experiment later
  - Filter transmission: simulation vs data -> more measurements in May

- **Discussion: discrepancy between simulation and measurements**
  - ➢ In-orbit observation, all of the components are coupled together
  - ➢ Welcome and appreciated any suggestions and experience sharing to customize the arf and response, etc.

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**Thanks**

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# BACKUP SLIDES

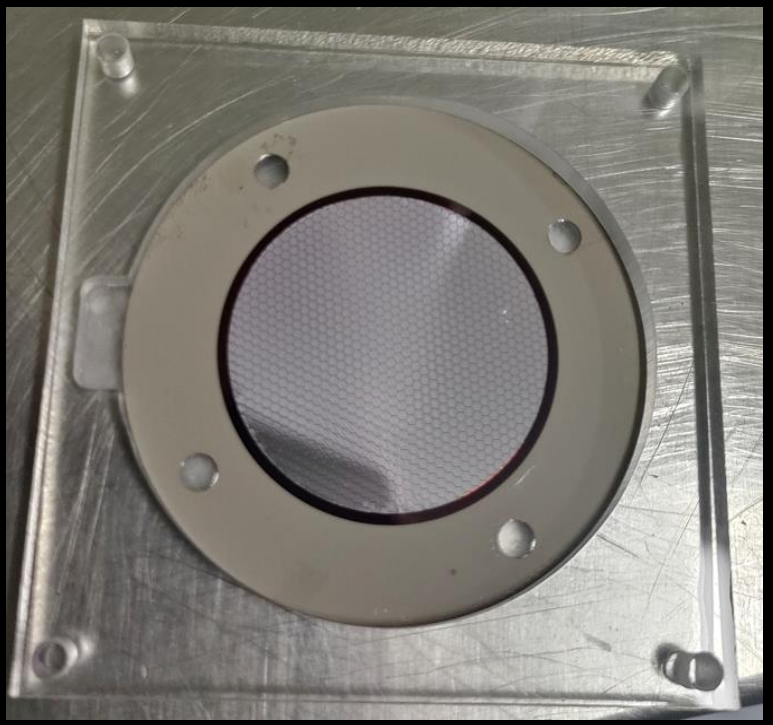
# FXT COLLIBRATION

- The development of FXT is a collaboration among the CAS, ESA and MPE. The Institute of High Energy Physics (IHEP), CAS is responsible for the overall design, development and test of the entire FXT instrument, while ESA and MPE contribute to the FXT development via provision of some of the key components of FXT including the mirror assemblies, use of the mirror design and mandrels, electron diverter, and CCD detector modules.
- ESA provides one set of the Mirror Assembly and the Electron Diverter, and MPE provides the eROSITA design information and use of the mandrels, one eROSITA Mirror Flight Spare and Mirror Demonstrator Model, and a number of detector modules plus CAMEX test module.

# FXT FILTER GRID STRUCTURE

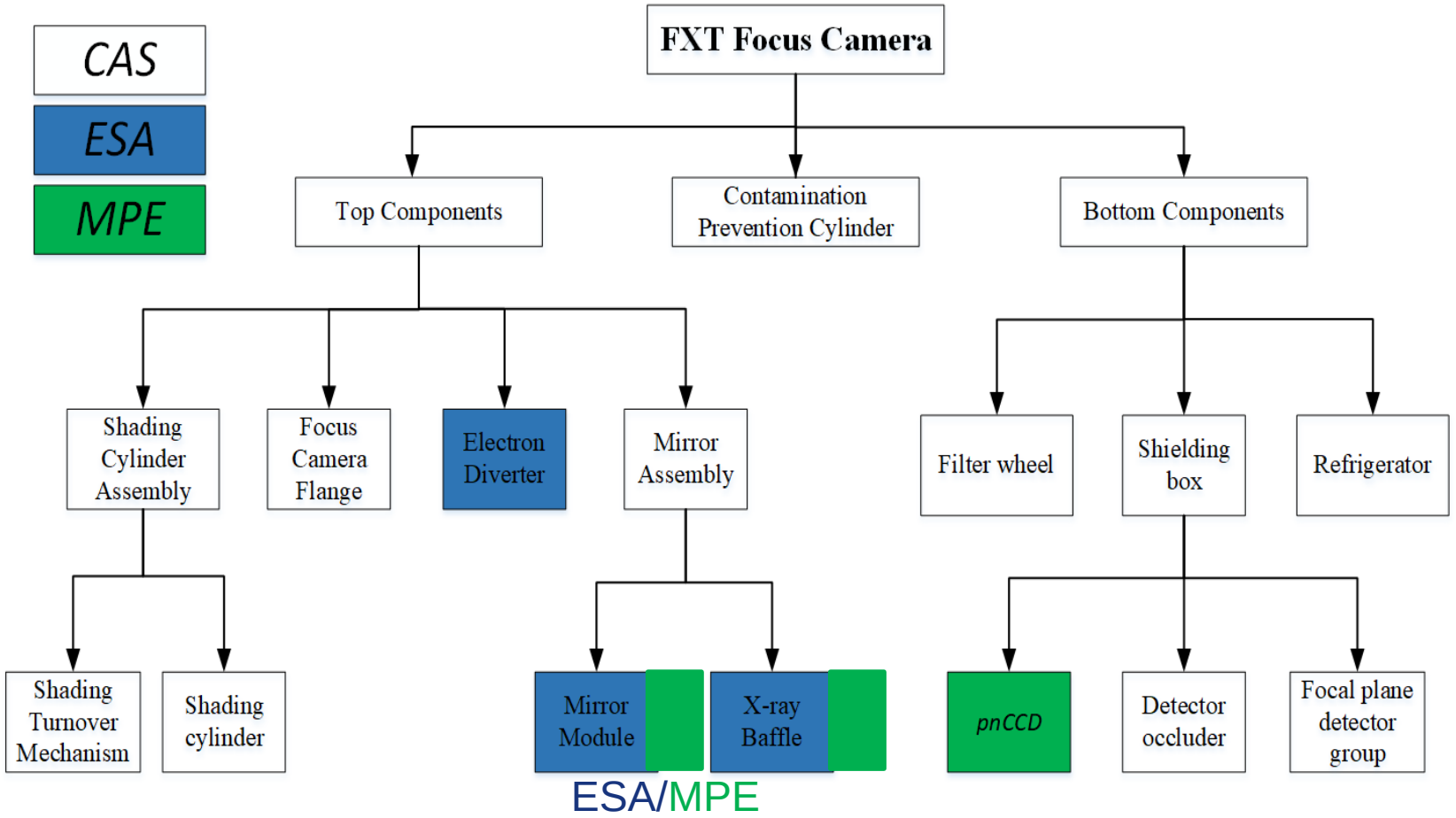
Ni grid

thin/medium filter



hole filter

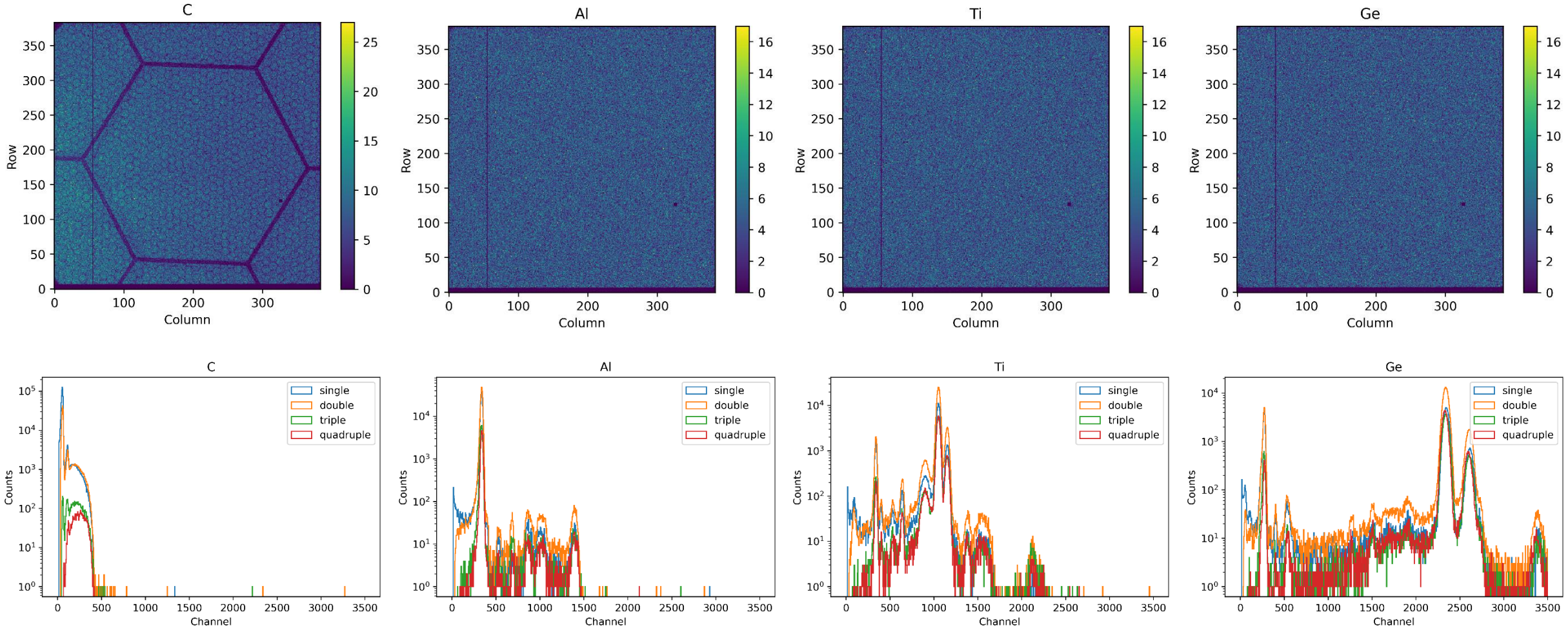
# Introduction to FXT




ESA provides one set of the Mirror Assembly and the Electron Diverter, and MPE provides the eROSITA design information and use of the mandrels, one eROSITA Mirror Flight Spare and Mirror Demonstrator Model, and a number of detector modules plus CAMEX test module.

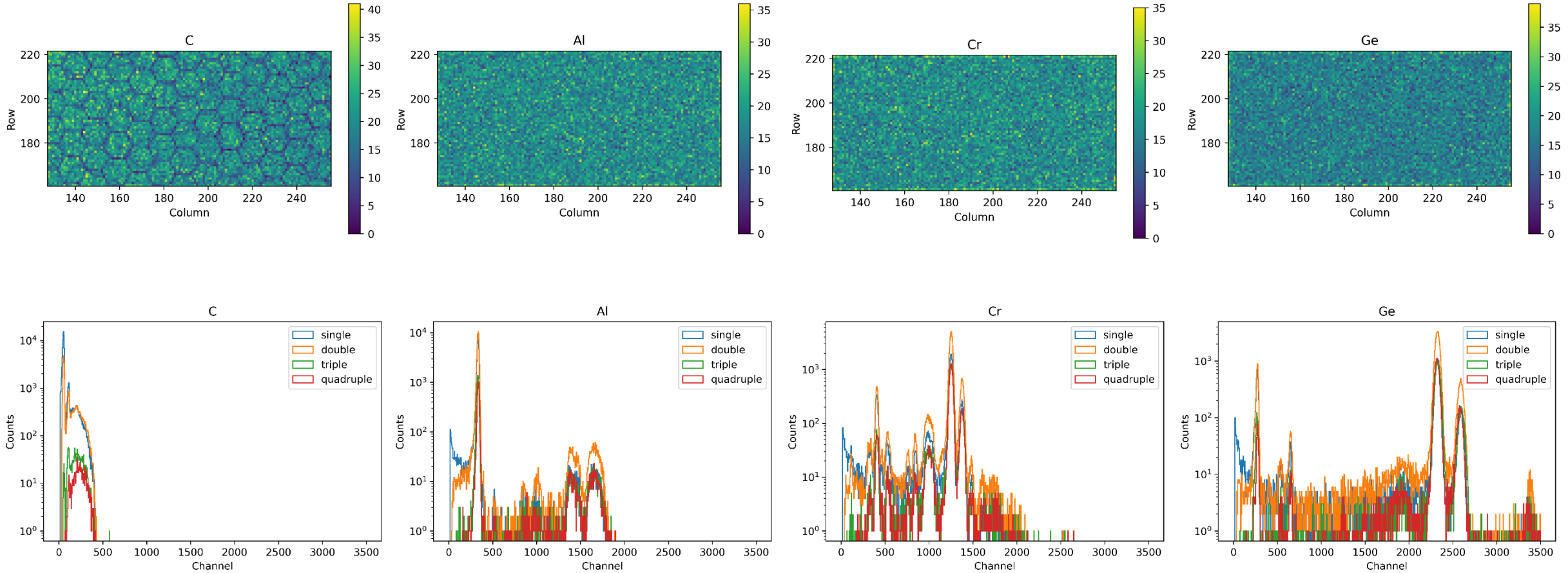
# Test and Calibration of Focal Plane Cameras

## Full frame images an spectrums



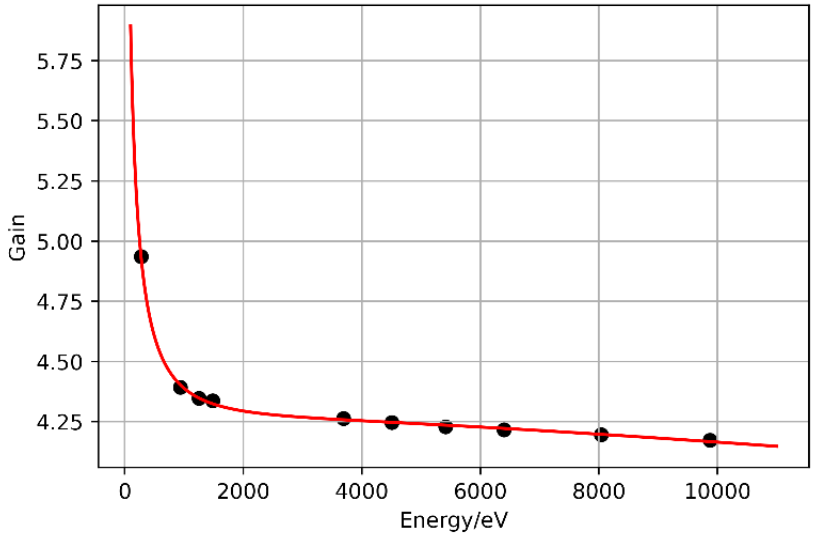
# Test and Calibration of Focal Plane Cameras

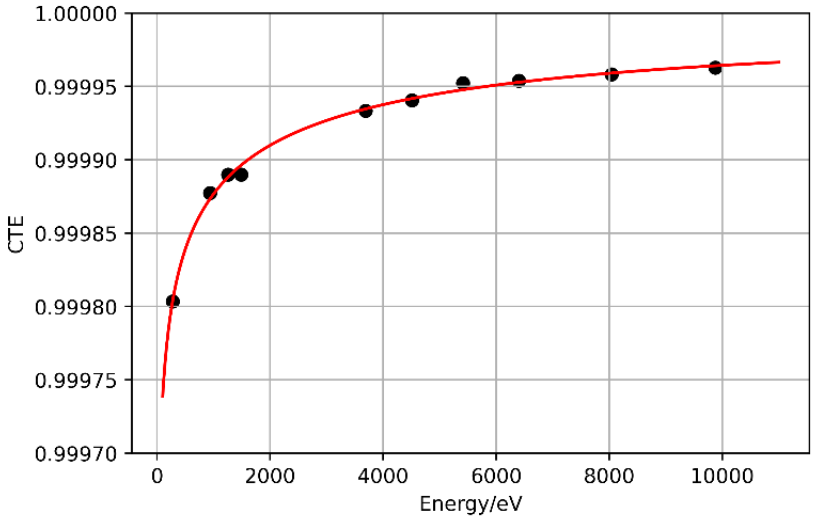
## Window images an spectrums

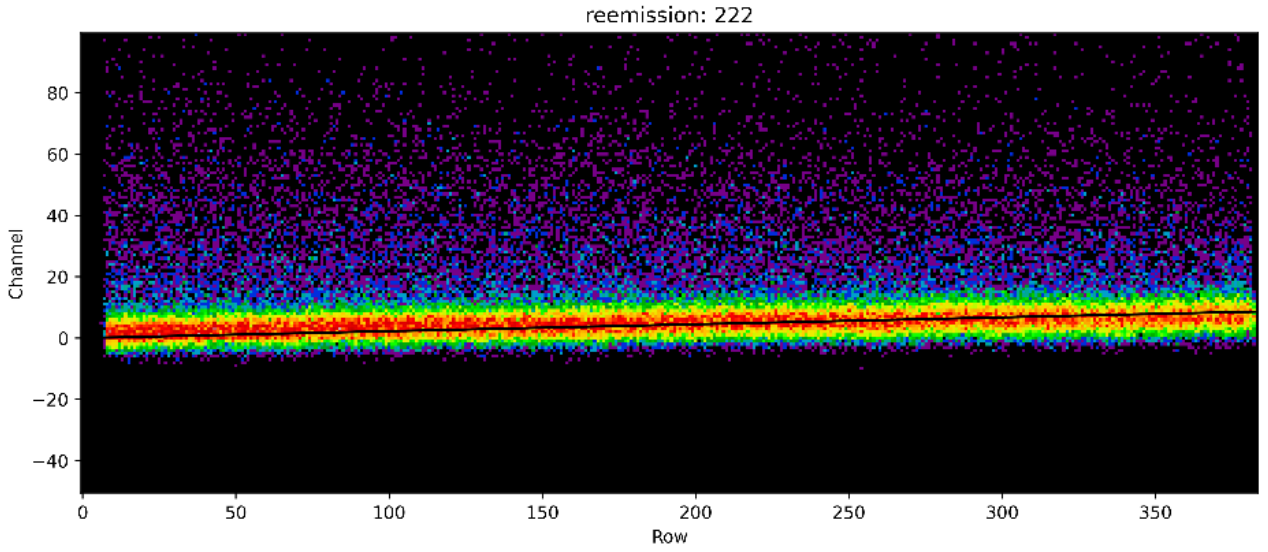


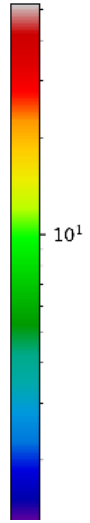
# Test and Calibration of Focal Plane Cameras

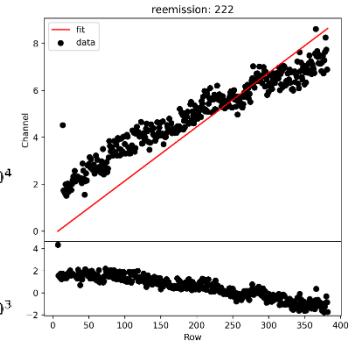
## Gains, CTE and Remission Correcti

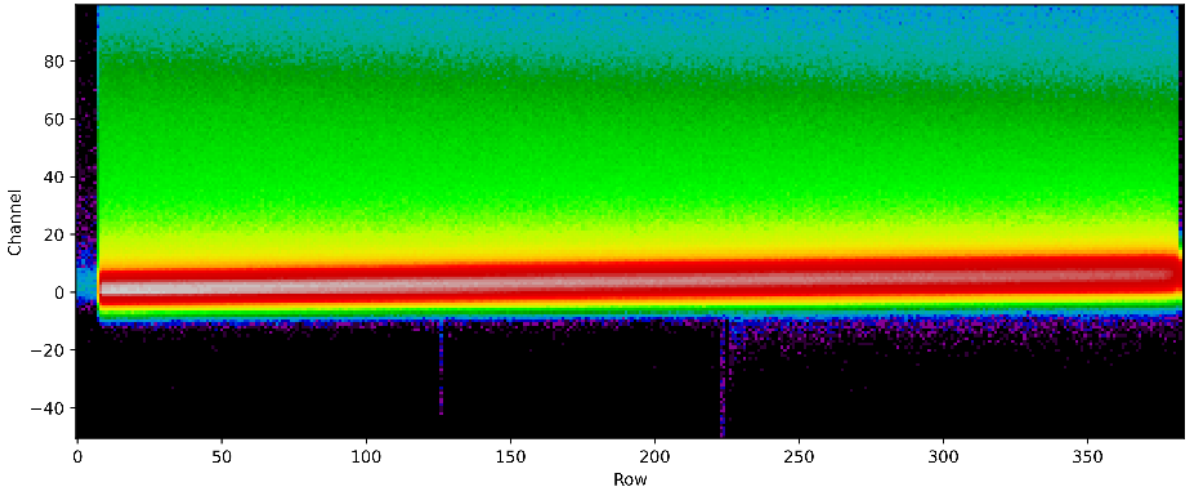


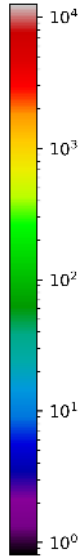





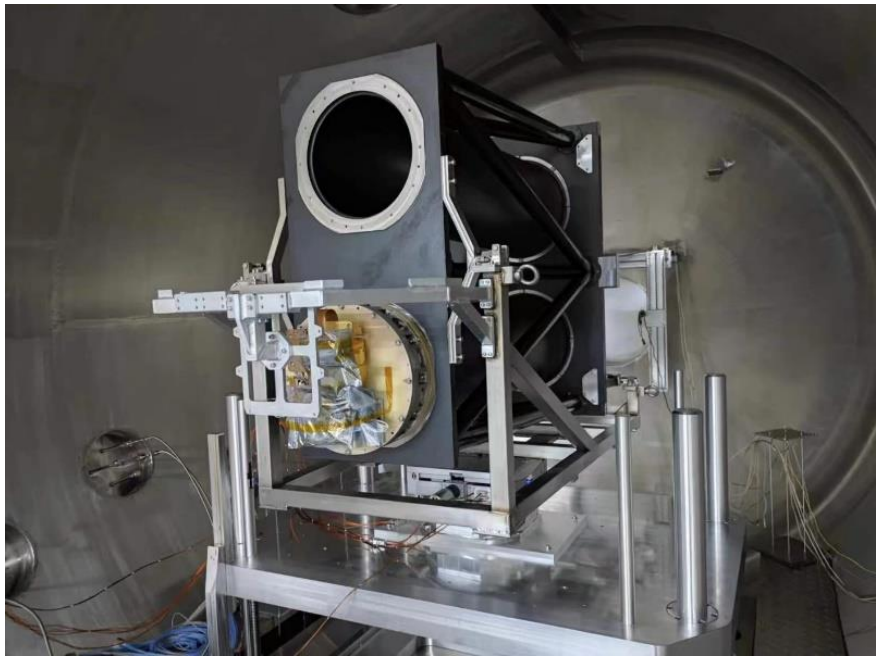



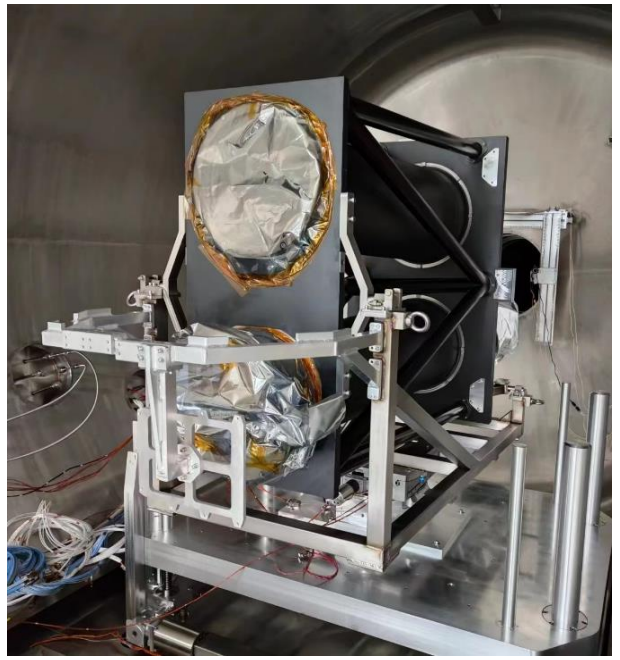
# Test and Calibration of Telescopes

## Telescope integration one by one and test

Jan.2023 FXT1 Integration



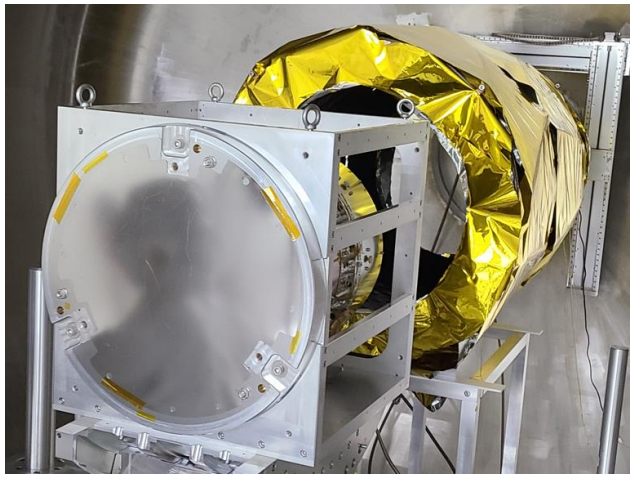
Jan-Feb. 2023 FXT1
Test and Calibration

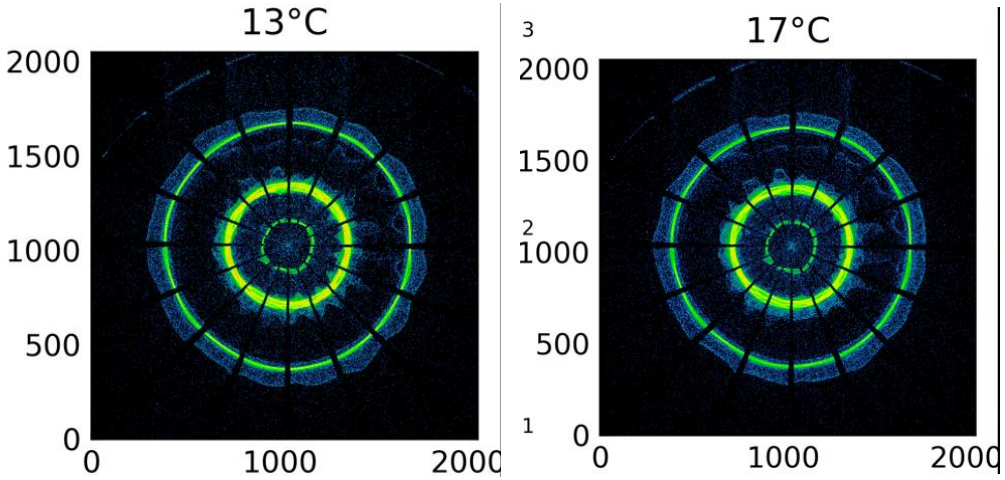


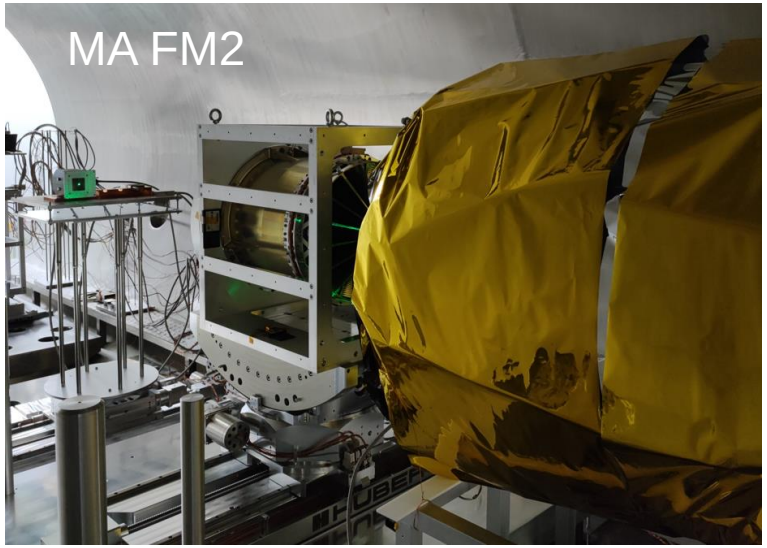
March. 2023 FXT2
Test and Calibration

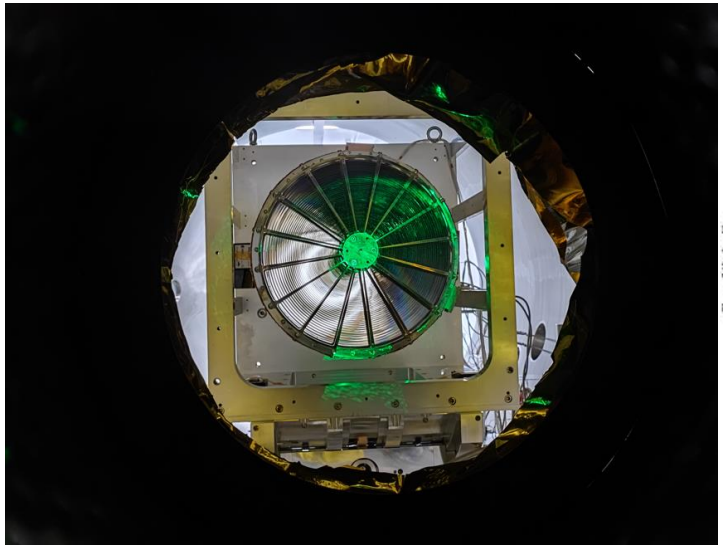
# Testing results of FXT MA FM2

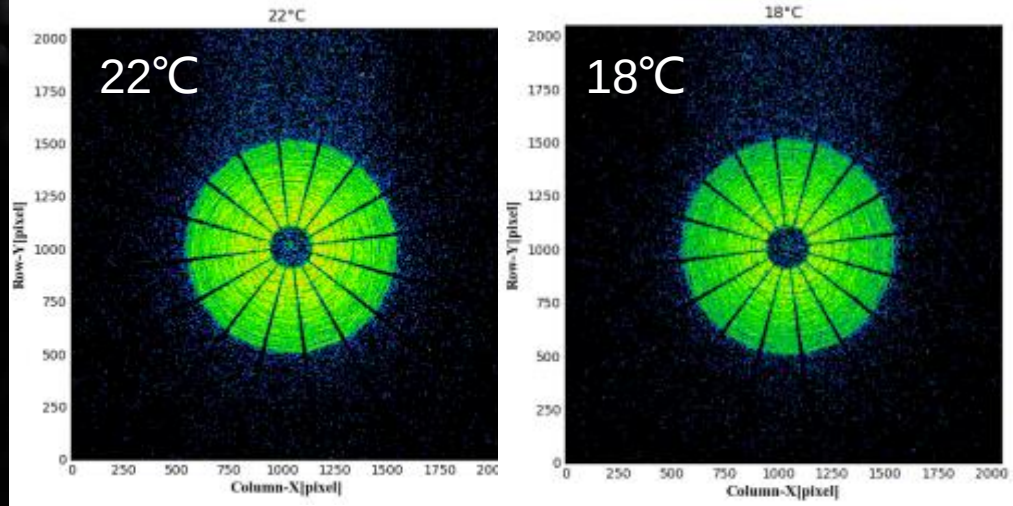
## MA FM2 Thermal X-ray test for Validation

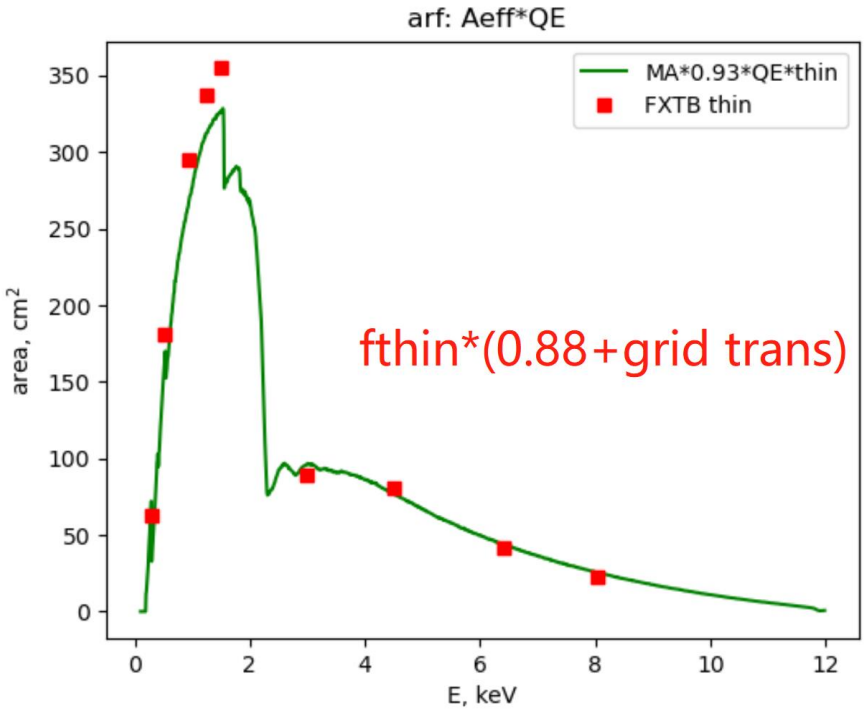


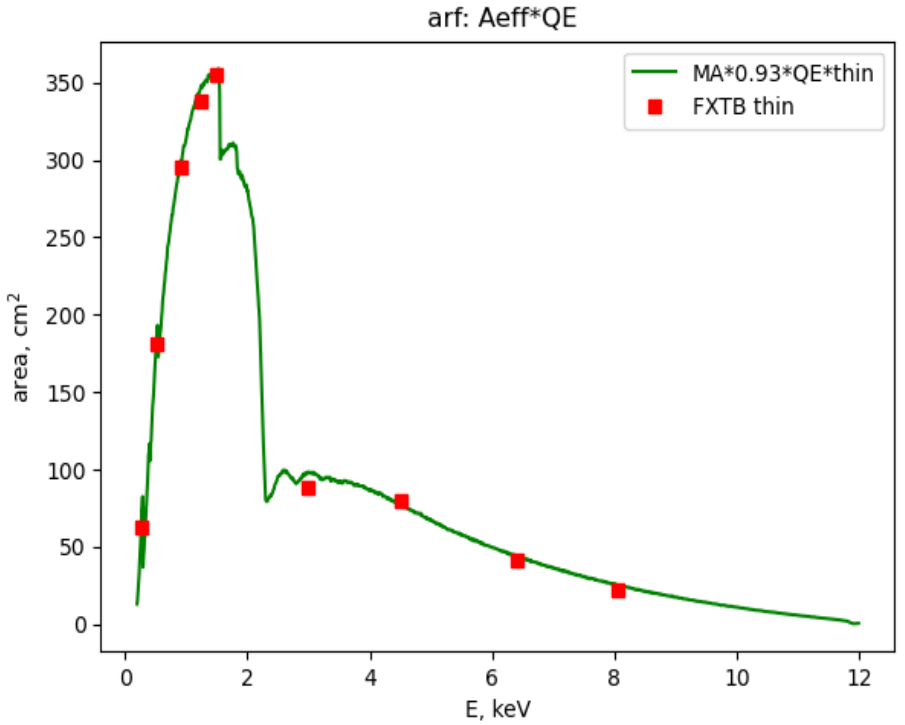





# ARF


arf: Aeff*QE
MA*0.93*QE*thin
FXTB thin
fthin*(0.88+grid trans)
area, cm$^2$
E, keV
0
50
100
150
200
250
300
350
0
2
4
6
8
10
12


arf: Aeff*QE
MA*0.93*QE*thin
FXTB thin
area, cm$^2$
E, keV
0
50
100
150
200
250
300
350
0
2
4
6
8
10
12