中国科学院高能物理研究所
Institute of High Energy Physics
Chinese Academy of Sciences

KLPA
中国科学院粒子天体物理重点实验室
KEY LABORATORY OF PARTICLE ASTROPHYSICS, CAS

EP-FXT Calibration

Chengkui Li

On be half of EP-FXT Calibration team

IHEP

2024.04.24

Outlines

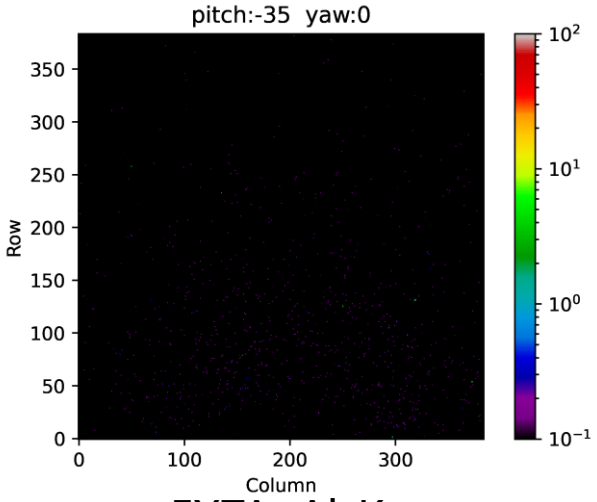
- FXT Calibration Results on ground
- Subjects of FXT in-orbit calibration
- Completed Calibration Observations and preliminary verifying of initial CALDB
- Upcoming Plans for the Following Months

FXT Calibration on ground

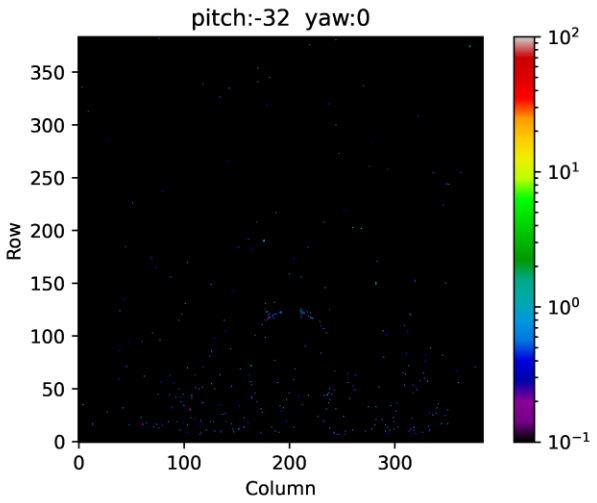
- Mirror
  - FOV/Focal length/Center pixel
  - PSF/ angular resolution
  - EA/ARF
  - Vignetting
- Transmission of Filter
- Focal plane cameras
  - Noise and threshold
  - Pattern Fraction
  - Gain/CTI
  - Energy resolution/RMF
  - QE
  - TM/PW mode

Mirror FOV/Focal length/Center on ground

- Mirror
  - FOV
  - Focal length
  - Center Pixel



FXTA Al-K

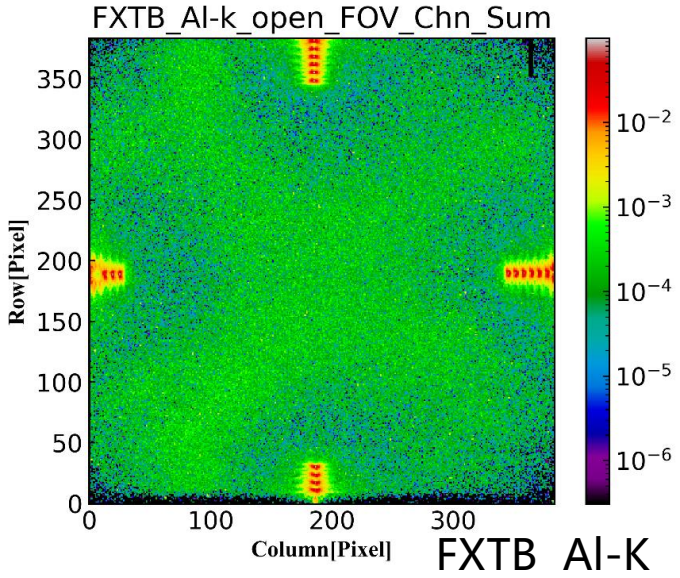


FXTA Cu-K

FXTA FOV: 0.98° ×0.98°
FXTB FOV: 1.02° ×1.02°

FXTA Focal Length: 1601.97 mm
FXTB Focal Length: 1601.83 mm

FXTA Center Pixel: 203,186
FXTB Center Pixel: 186,189



FXTB Al-K

Mirror PSF-- on ground

FXTA:

Open: C-k, Al-k,Ag-L,Ti-k, Cu-k

Thin: C-k, Cu-L, Al-k,Ag-L,Ti-k, Cu-k

Medium:C-k, Cu-L, Al-k,Ag-L,Ti-k, Cu-k

Hole: Al-k,Ag-L

FXTB:

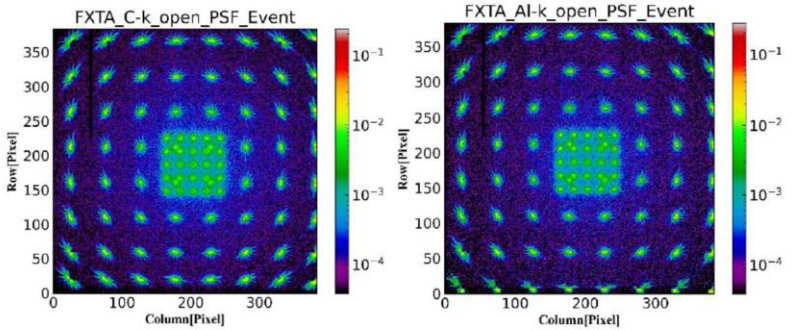
Open: C-k, Al-k,Ag-L,Ti-k, Cu-k

Thin: C-k, Cu-L, Al-k,Ag-L,Ti-k, Cu-k

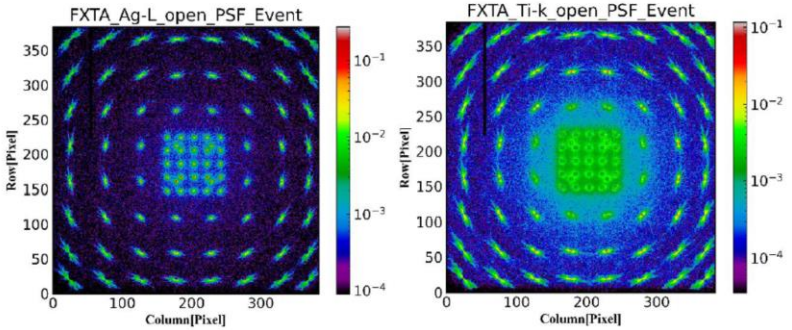
Medium:C-k, Cu-L, Al-k,Ag-L,Ti-k, Cu-k

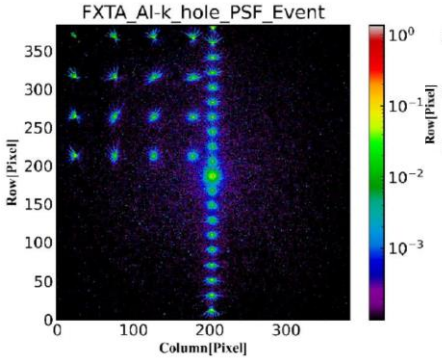
Hole: C-k, Cu-L, Al-k,Ag-L,Ti-k, Cu-k

PW mode: C-k, Al-k,Ag-L, Cu-k

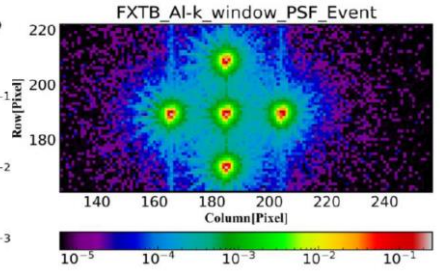


FXTA OPEN Filter



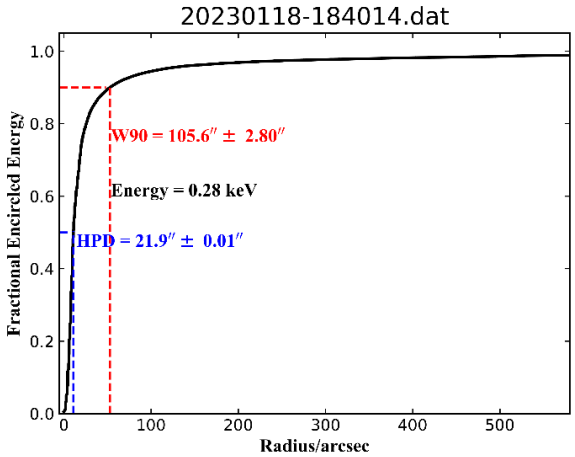


FXTA Hole Filter

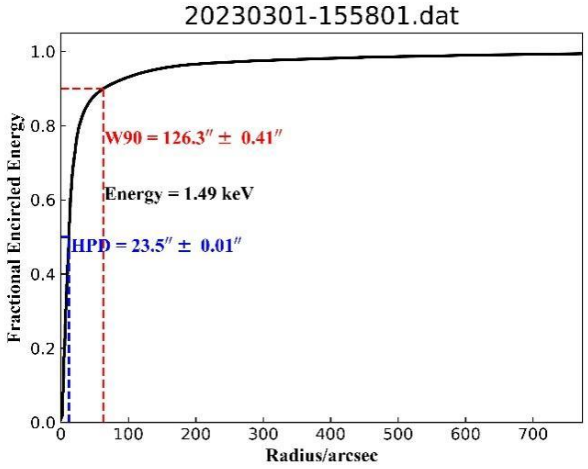


FXTB PW Mode

Mirror Angular resolution—on ground



EEF of FXT-A (C-K)



EEF of FXT-B (Al-K)

Energy/keV	HPD/″	W90/″
C-K: 0.28	21.9±0.01	105.6±2.8
Al-K: 1.49	21.9±0.01	104.1±5.3
Ag-L: 2.98	22.6±0.01	140.6±0.2
Ti-K: 4.51	23.5±0.01	198.5±1.2
Cu-K: 8.04	25.9±0.01	337.3±1.0

Angular resolution of FXT-A

Energy/keV	HPD/″	W90/″
C-K: 0.28	19.3±0.01	46.6±0.01
Al-K: 1.49	23.5±0.01	126.3±0.41
Ag-L: 2.98	23.2±0.01	129.7±0.29
Ti-K: 4.51	22.6±0.01	134.9±0.17
Cu-K: 8.04	19.7±0.01	154.0±0.77

Angular resolution of FXT-B

Vignetting--on ground

FXTA:

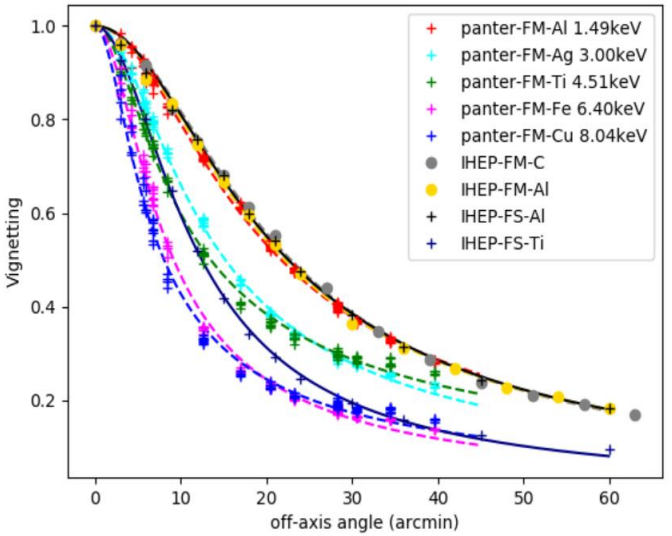
Normal: C-k, Al-k,Ag-L,Ti-k, Fe-k, Cu-k

Hole: Al-k,Ag-L

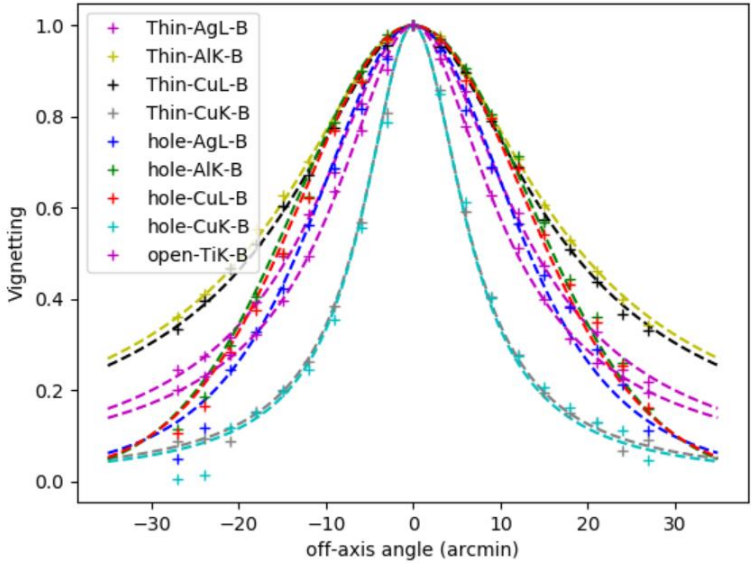
FXTB:

Normal: Cu-L, Al-k, Ag-L, Ti-k, Cu-k

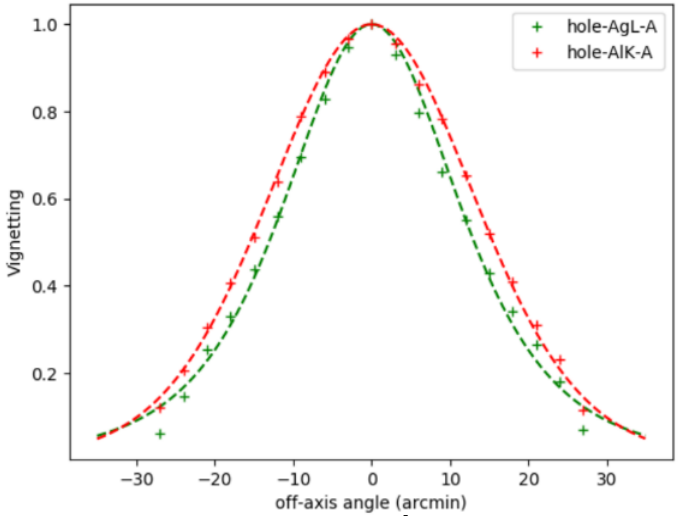
Hole: Cu-L, Al-k, Ag-L, Cu-k



FXTA Normal

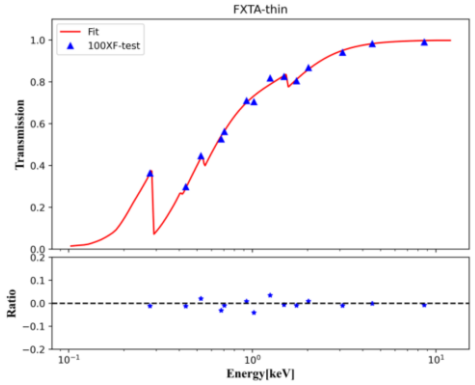


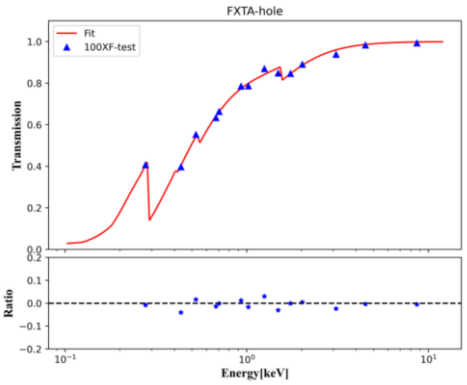
FXTB Normal and Hole

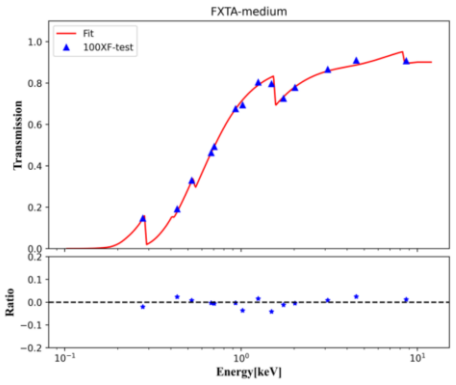


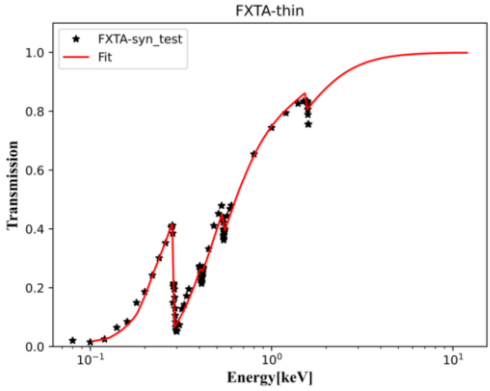
FXTA Hole

Transmission of filter—on ground

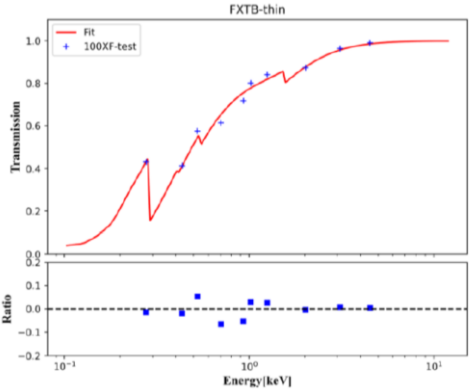


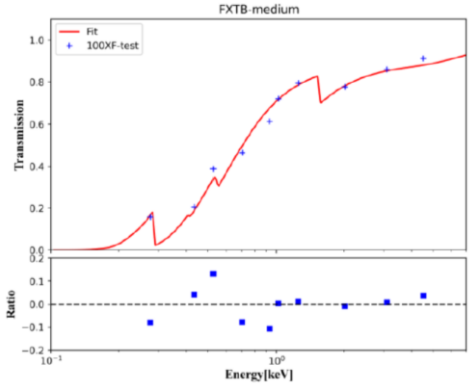


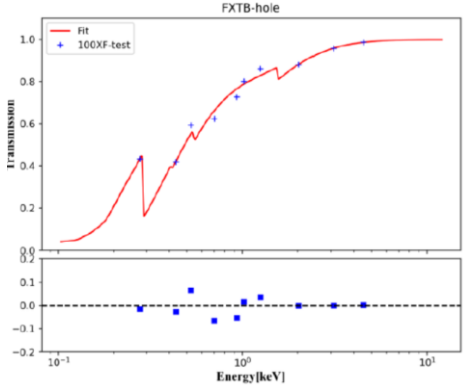


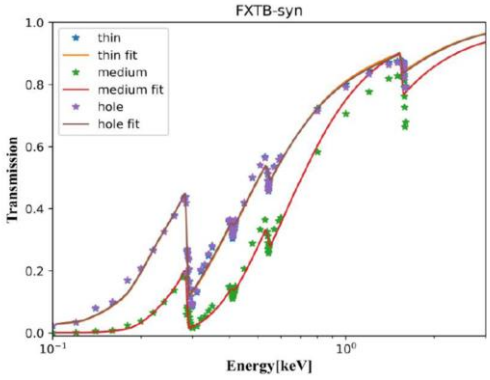


FXTA：Thin Filter　　hole Filter　　Medium Filter　　Synchrotron beamline



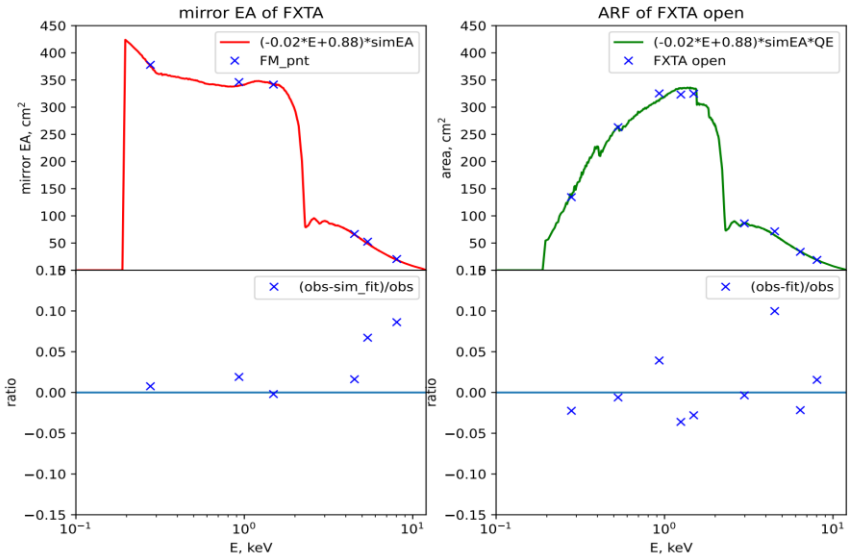




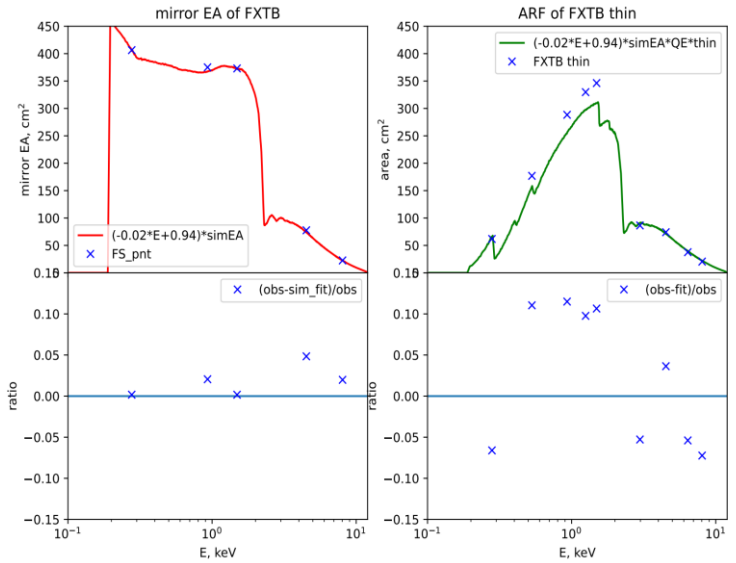


FXTB：Thin Filter　　hole Filter　　Medium Filter　　Synchrotron beamline

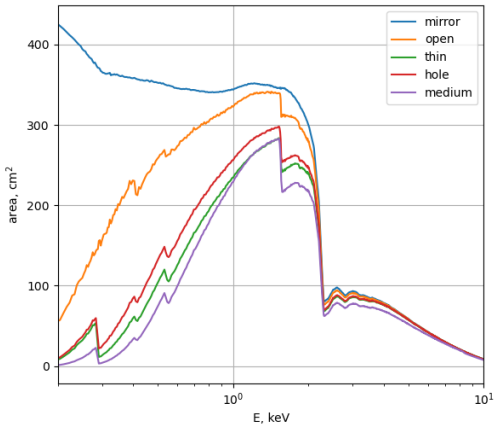
EA and ARF --on ground



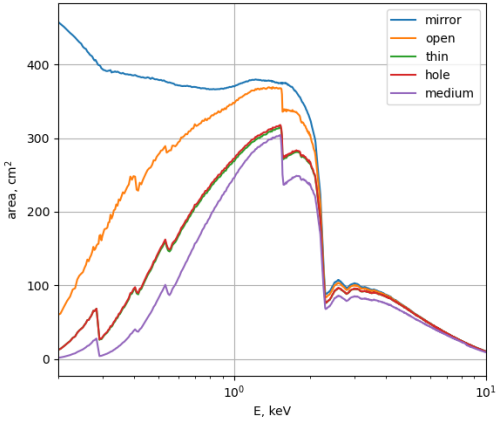
FXTA EA ARF （OPEN）



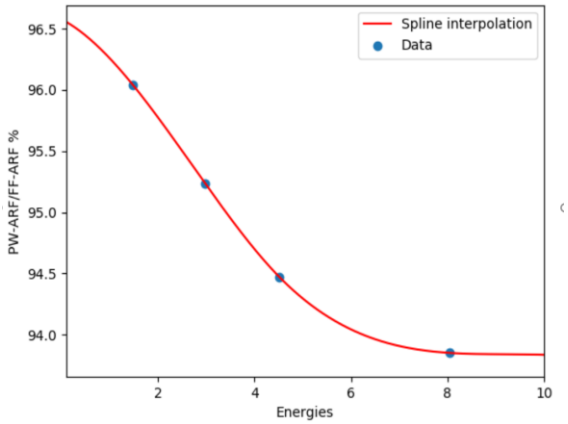
FXT-B EA ARF （Thin）



FXTA FF ARF in CALDB

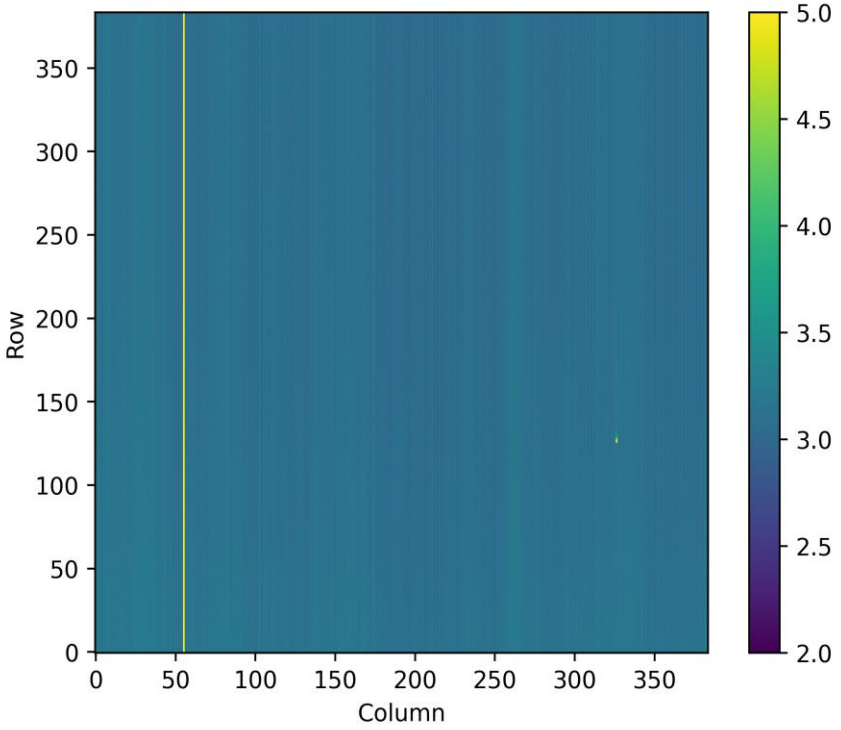


FXTB FF ARF in CALDB



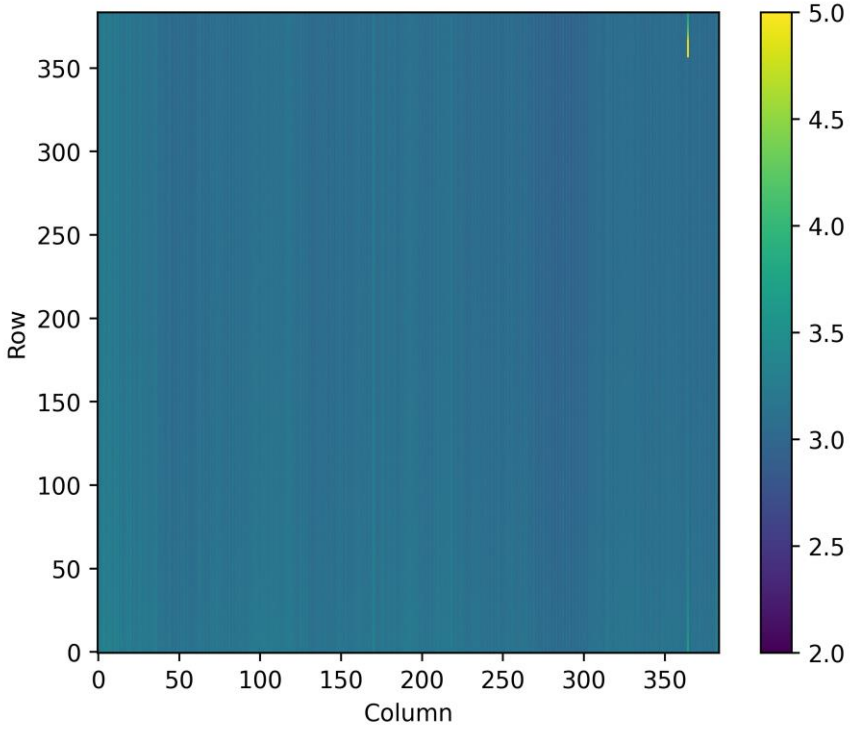
PW/FF mode ARF ratio

PNCCD-Noise and threshold-on ground



Read out noise of FXTA

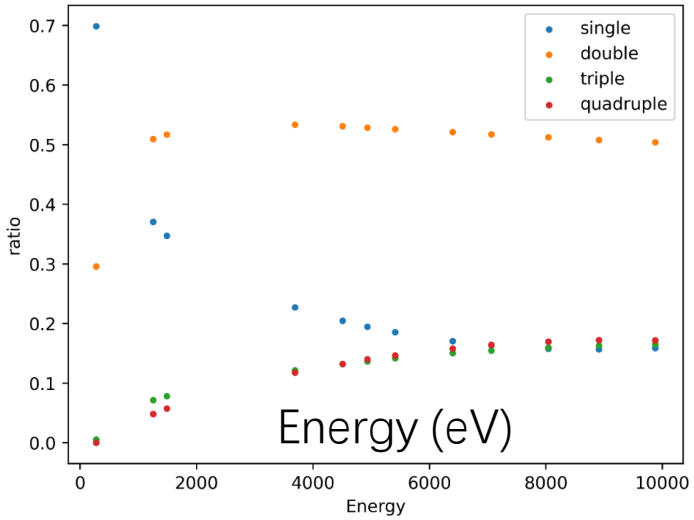
Bad pixel:
55 Col
326,127



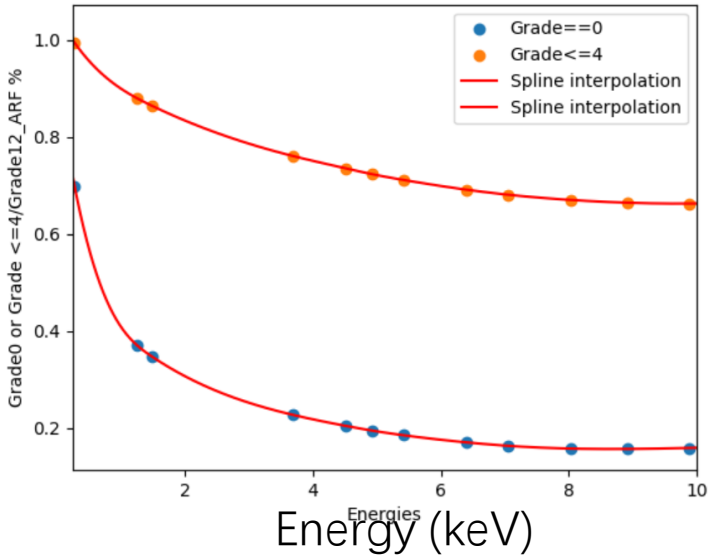
Read out noise of FXTA

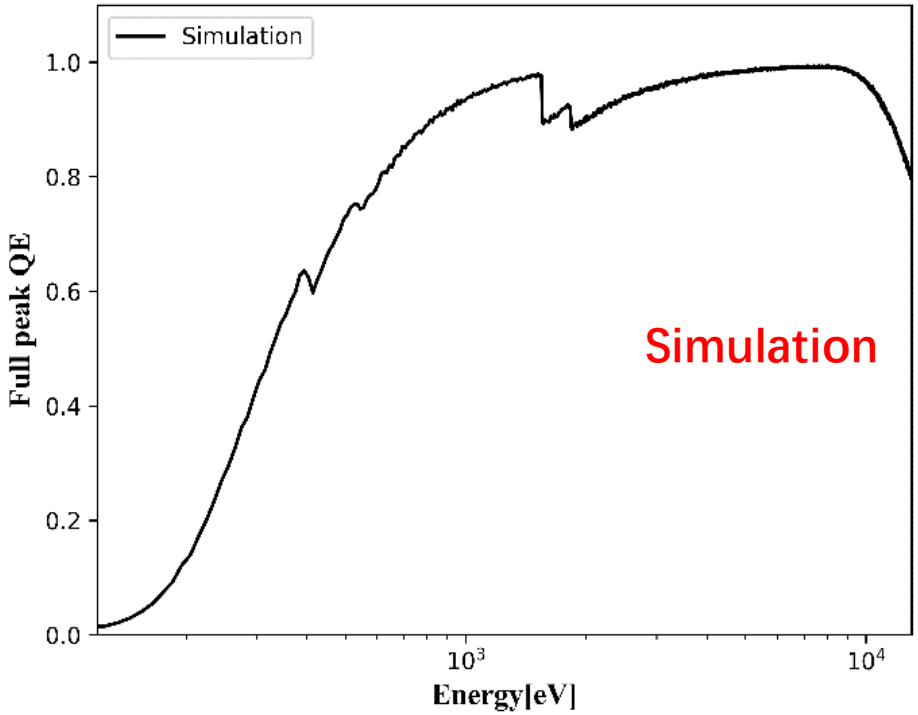
Bad pixel:
364,357

PNCCD-Pattern Fraction& QE--on ground



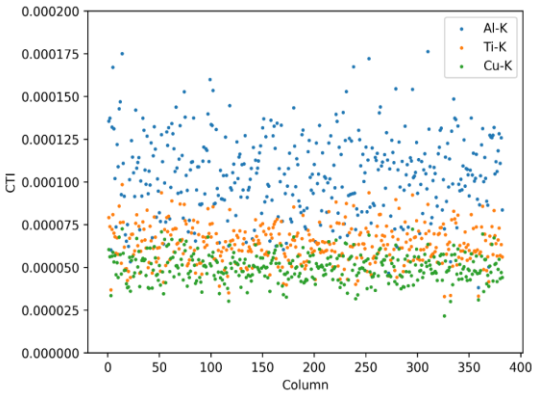
Pattern Fraction



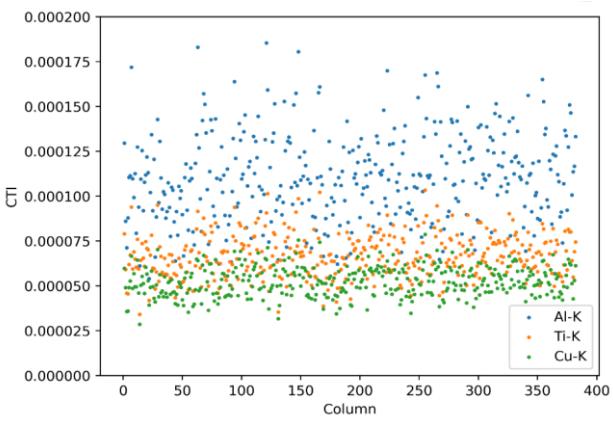


Quantum Efficiency

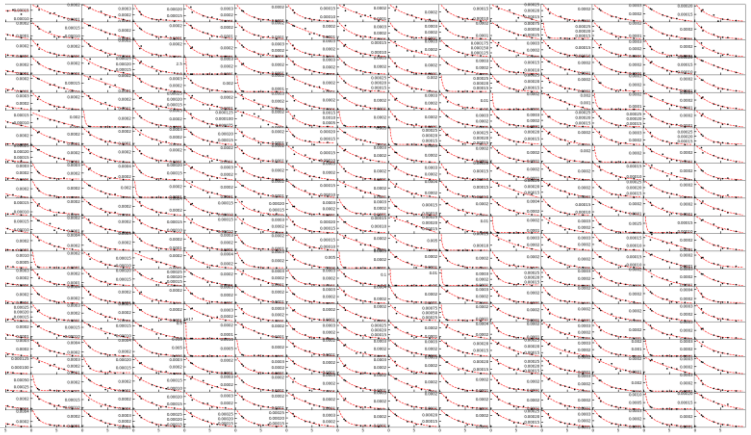
PNCCD-Gain/CTI--on ground



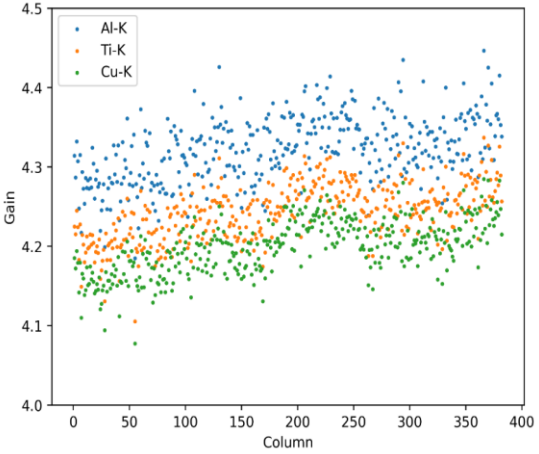
FXTA-CTI



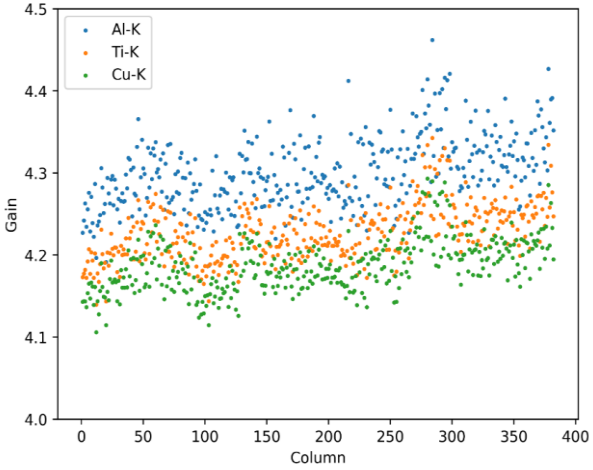
FXTB-CTI



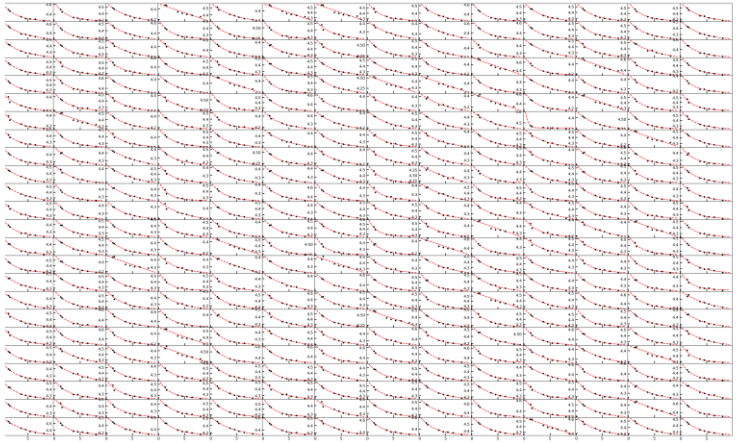
CTI Function in CALDB



FXTA-Gain

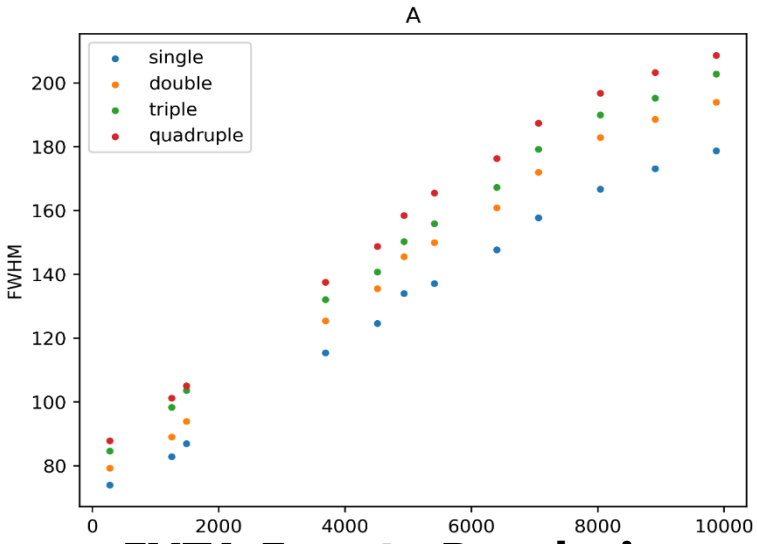


FXTB-Gain

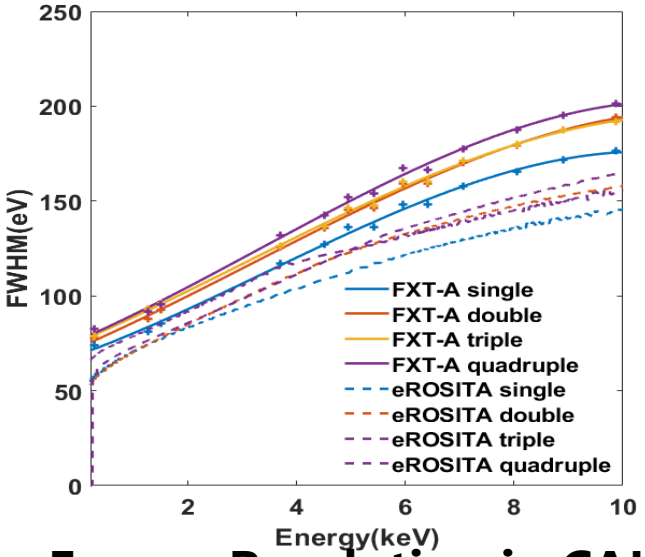


Gain Function in CALDB

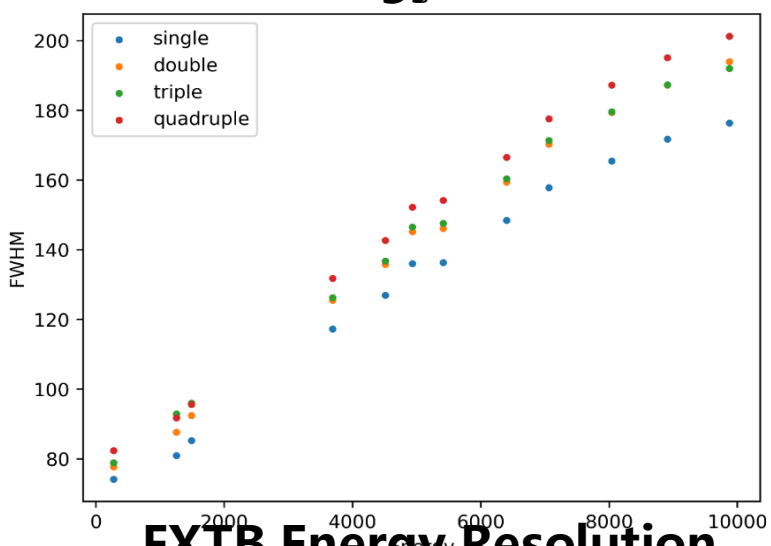
PNCCD-Energy resolution/RMF--on ground



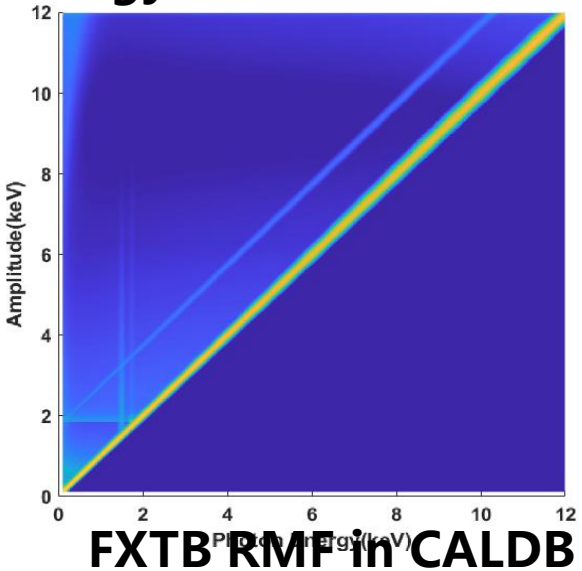
FXTA Energy Resolution



Energy Resolution in CALDB

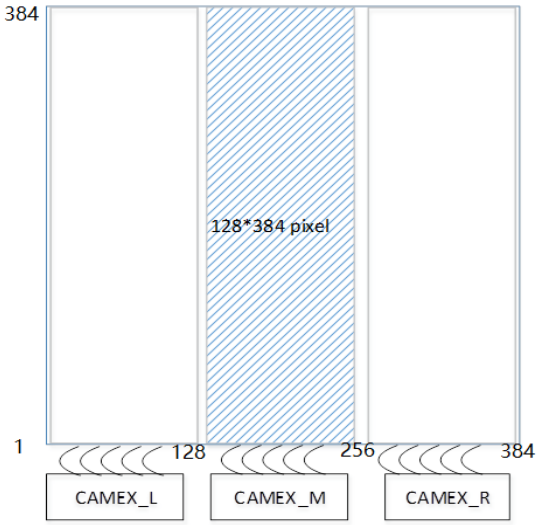


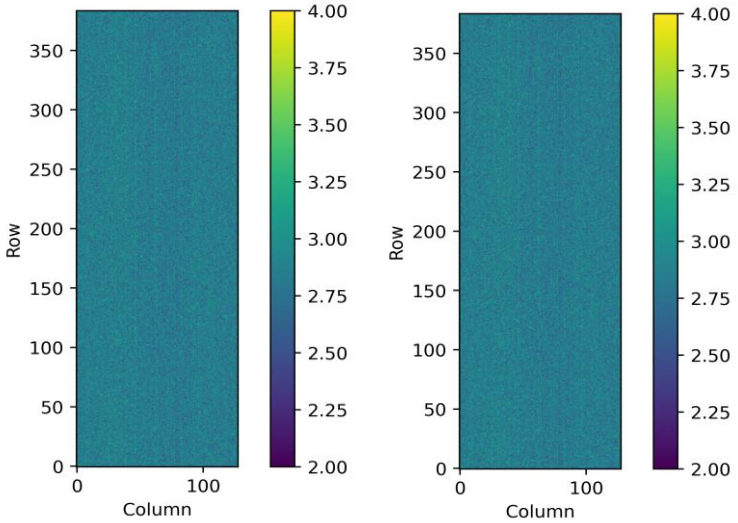
FXTB Energy Resolution



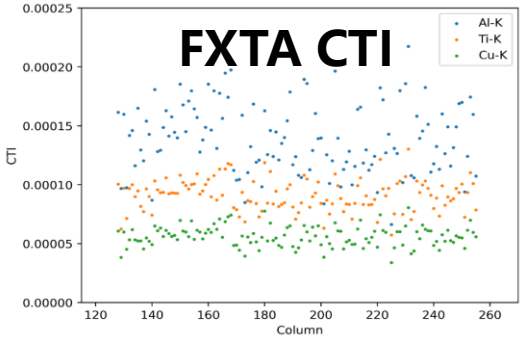
FXTB RMF in CALDB

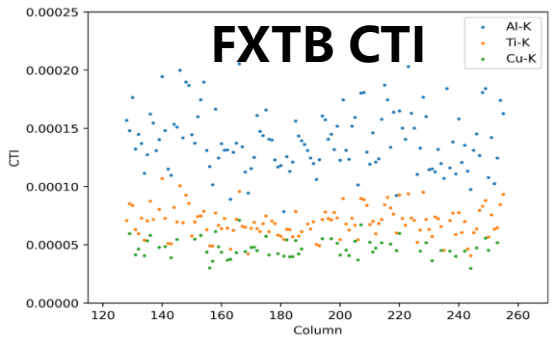
PNCCD-Timing Mode --on ground

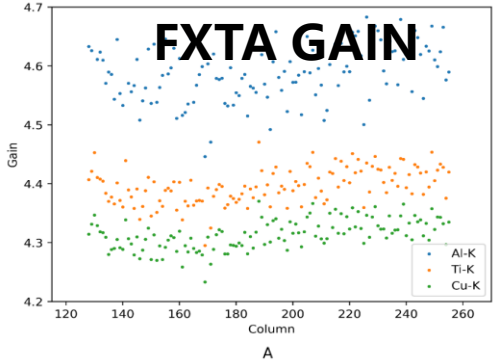


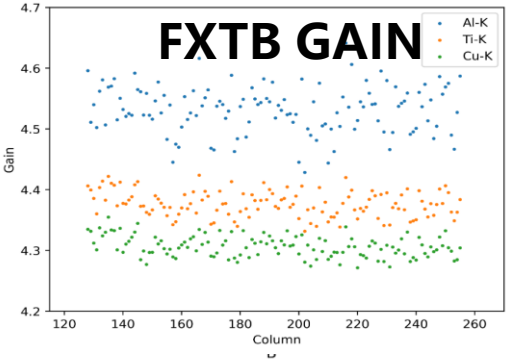


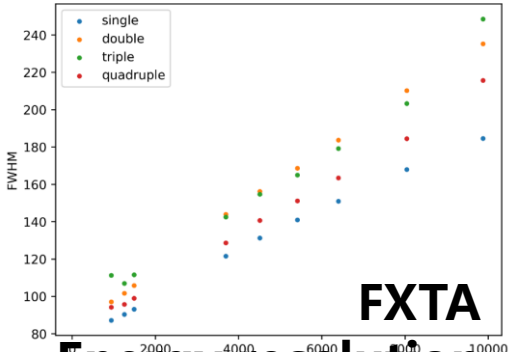
Read out noise of TM mode



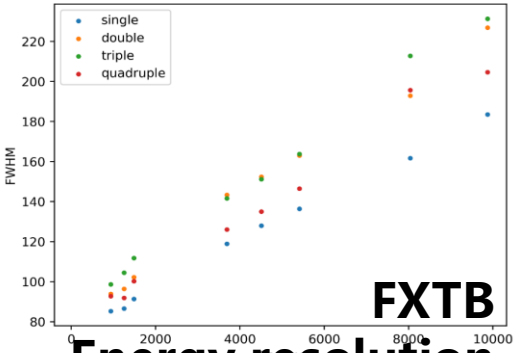






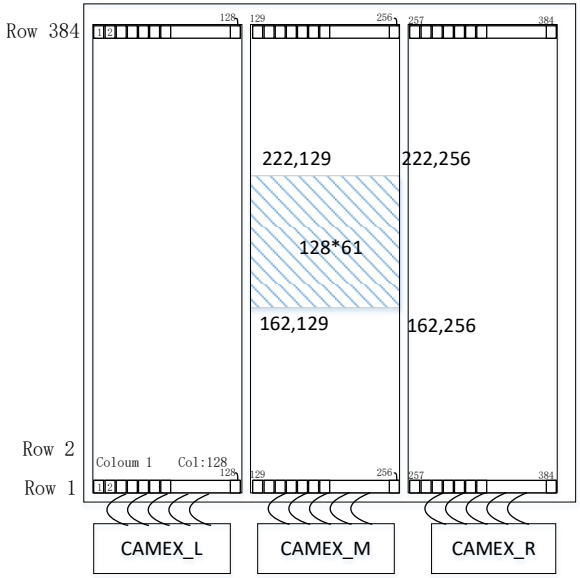


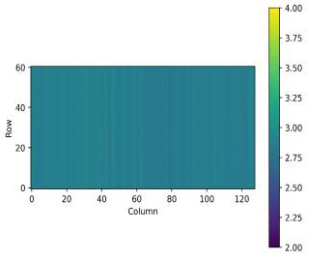
Energy resolution

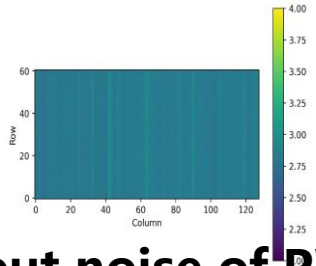


Energy resolution

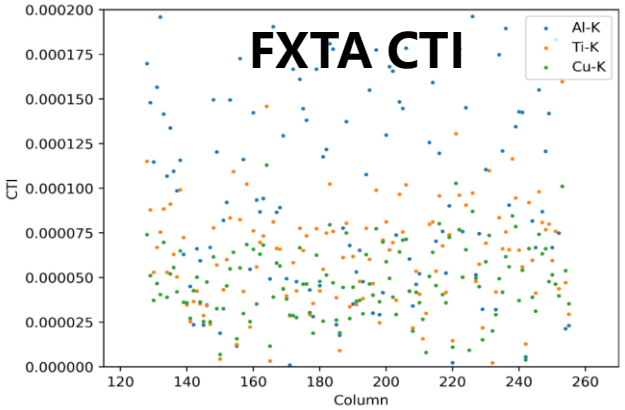
PNCCD-Partial Window Mode--on ground

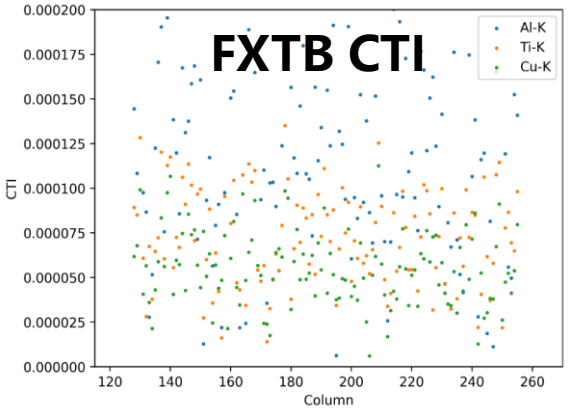


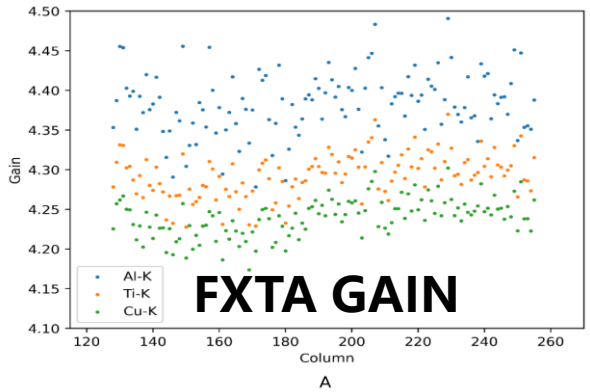


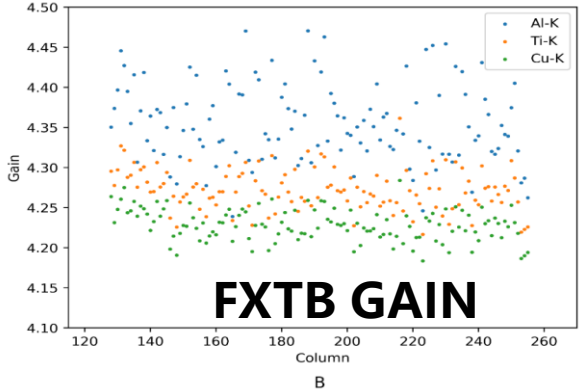


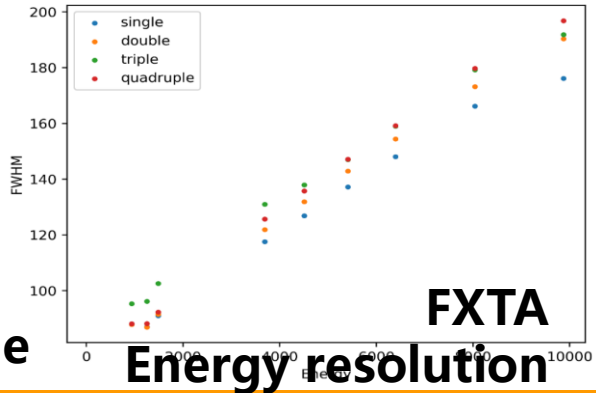
Read out noise of PW mode



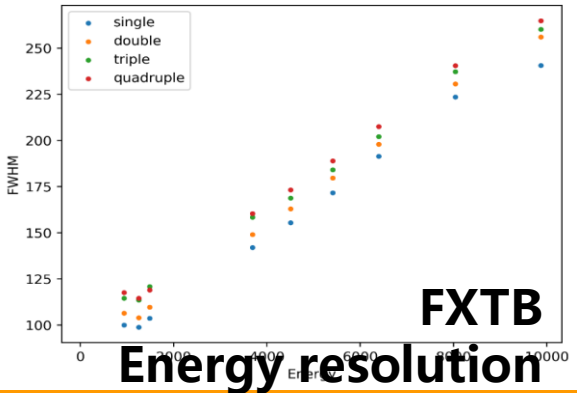








Energy resolution



Energy resolution

FXT CALDB--on ground

- PSF/EEF
- Vignetting
- ARF
- RMF
- Gain
- TelDef

FXTA+FXTB
Filter 0 1 2 3
FF/TM/PW
Grade 0 4 12

2x4x3x3

- PSF/ angular resolution
- Vignetting
- EA/ARF
- Transmission of Filter
- Noise and threshold
- Pattern Fraction
- QE
- Energy resolution/RMF
- Gain/CTI
- Focal Length
- Center pixel

FXT in-orbit calibration subjects

- Background
- Plate scale and boresight
- Filter integrity
- Soft X-ray response and contamination monitoring
- Gain and CTI
- PSF (on/off axis)
- Effective area ,QE, flat-fielding, and vignetting
- Optical loading
- Timing
- Power-law type spectrum
- Cluster of galaxies
- Coordinated observations

FXT In-orbit calibration Objects

- Background (Closed, blank sky, Lockman Hole)
- Plate scale and boresight (global/open cluster)
- Filter integrity (global/open cluster)
- Soft X-ray response and contamination monitoring(RXJ 1856)
- Gain and CTI (Puppis A, CasA, 1E0102)
- PSF(on/off axis) (PG 1634, 3c273, RXJ 1856)
- Effective area ,QE, flat-fielding, and vignetting(galaxy cluster, SNR)
- Optical loading (stars)
- Timing (Crab, other Pulsars)
- Power-law type spectrum (3c273, Coordinated obs)
- Cluster of galaxies (A1795, A3571)
- Coordinated observations (3c273)

FXT in-orbit calibration objects

1RXS J072025.1-312554	INS	110.1	-31.43	1024-0419	Contamination	1	50ks (ff/02)	
1RXS J185635.1-375433				0402-1004				
1RXS J170849.0-400910 (P=11 s)	Pulsar	162.54	-59.89	0115-0715	Timing	1	60ks (ff/02)	
PSR B1509-58 (p=150 ms)		228.48	-59.14	1213-0611		1	30ks (pw/02)	
Puppis A	SNR	126.03	-43	1121-0519	Gain, CTI, RMF, ARF	2	80ks (ff/01)	
						2	80ks (pw/01)	
M87	AGN	187.71	12.39	1225-0624		6	20ks*7 (ff/01) *2 (a/b)	
						2	20ks*3 (pw/01) *2 (a/b)	
GX 301-2	HMXB/NS	186.66	-62.77	0201-0804		6	20ks*7 (tm/01) *2 (a/b)	
Vela SNR	SNR	128.5	-45.83	1127-0524				
B Fe55								
SN 1006	SNR	225.59	-42.1	0215-0818		2	80ks (ff/01)	
PG 1634+706	Quasar	248.62	70.53	1118-0508	PSF	8	40ks*8 (ff/02)	5',0',-5',-10',-15',-20',25',-30'
Lockman hole	Blank sky	161.25	581109-0506		background	2	80ks (ff/01)	
PSR J1231-1411 (p=3.68 ms)	Pulsar	187.8	-14.2	0104-0705	Timing	3	100ks (tm/01)	
						2	100ks (tm/03)	
1RXS J072025.1-312554	INS	110.1	-31.43	1024-0419	Contamination	1	50ks (ff/02)	
1RXS J185635.1-375433		284.15	-37.91	0402-1004		1	50ks (ff/02)	
Mkn 421 (Power law) PSR J1838-0655 (pl,)	BL Lac	166.11	38.21	1125-0522	ARF/RMF/EC	1	50ks (ff/01)	
						1	50ks (ff/02)	
						1	50ks (pw/01)	
						1	50ks (pw/02)	
PKS 0745-191/Ophiuchus	Cluster	207.25	26.59	0105-0706		1	50ks (ff/01)	
						1	50ks (ff/02)	
						1	50ks (pw/01)	
						1	50ks (pw/02)	
Sco X-1	LMXB/NS	244.98	-15.64	0226-0829	X-ray baffle	2	10ks*9 (ff/02)	30',50',70',90',110',130',150',170',190'
						1	10ks*2 (tm/02)	0', 5'
PSR B1937+21 (p=1.558ms)	Pulsar	294.92	21.62	0423-1025	Timing	2	100ks (tm/01)	
1E0102.2-7219	SNR	16	-72.03	0506-1107	Gain, CTI, RMF, ARF	6	20ks*7 (ff/01) *2 (a/b)	
						2	20ks*3 (pw/01) *2 (a/b)	
						6	20ks*7 (tm/01) *2 (a/b)	
						1	20ks*2 (ff/00)	
						1	20ks*2 (ff/02)	
						1	20ks*2 (ff/03)	

FXT In-orbit timeline

- The EP satellite was launched at 15:03 on January 9, 2024, from the Xichang Satellite Launch Center.
- - January 19, 2024: WXT was powered on, beginning in-orbit calibration observations.
- - January 25-26, 2024: FXTA was powered on.
- - February 6, 2024: FXTA & FXTB were powered on.
- - February 22, 2024: FXTA cover opened—FXTA observation.
- - February 28, 2024: FXTB cover opened—FXTA & FXTB observation.
- - March 4, 2024: WXT completed calibration observations.
- - March 5-19, 2024: FXT in-orbit testing.
- - March 20-23, 2024: WXT sky survey observations.
- - Mar 24 - Apr 5, 2024: EP-PV observations.
- - From April 5, 2024: FXT began in-orbit calibration observations.
- - Until June 2024: EP completed in-orbit calibration and began AO1.

FXT In-orbit calibration observations

Part 1: FXT In-Orbit Testing (March 5-19, 2024)

Target	Date	Filter	Notes
NGC 2516	05/03-08/03	Medium	Center pixel, Matrix
Crab	08/03-09/03	Medium	FF/TM/PW Timing
Omega Cen	09/03-11/03	Thin	Center pixel, filter integrity
3c 273	11/03-13/03	Medium	PSF, Power-law spec
Vela SNR	15/03-17/03	Thin	EC, ARF
M87	17/03-19/03	Thin	EC, ARF

Part 2: FXT In-Orbit Calibration Obs (From April 5, 2024)

M87 /Fe55	05/04-06/04	Medium	EC, ARF
RXS J 170849	06/04-07/04	Thin	Timing
Puppis A	07/04-08/04	Thin	8000s GTI,EC, image
Puppis A E Knot	08/04-09/04	Thin	EC
RXJ 1856	09/04-11/04	Thin	Low-E resp, contamination
3C 273	11/04-15/04	Medium	PSF off-axis
M87	15/04-16/04	Medium	EC, ARF
Puppis A	16/04-18/04	Thin Filter	EC, image,ARF
A1795	18/04-22/04	Thin/Medium	ARF

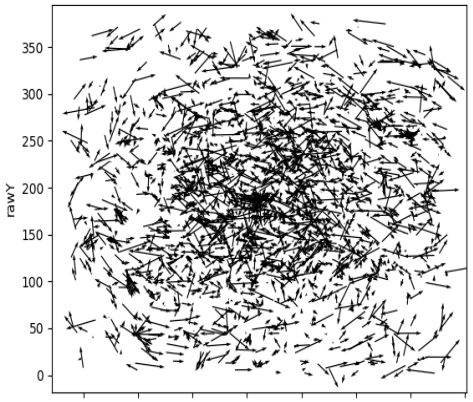
Preliminary verifying of initial CALDB

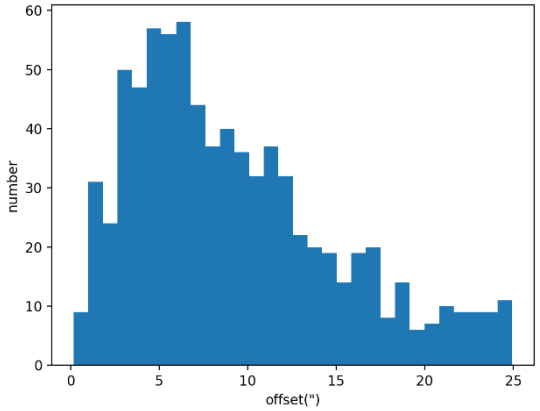
First Light: a positioning deviation of ~2′

Center Pixel：

an initial update was made (A: March 2nd; B: March 8th), with a deviation of **~10”** (on-axis).

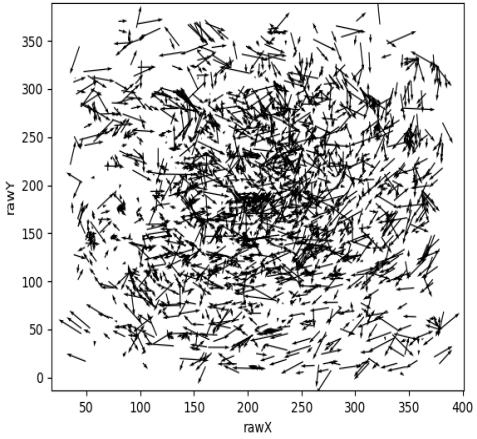
FXTA

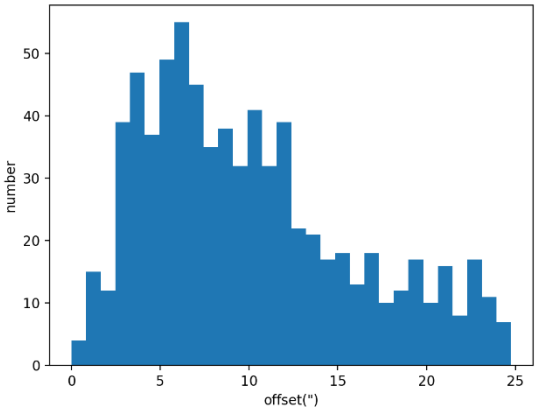




Deviation arrows (zoom in 10x)

FXTB

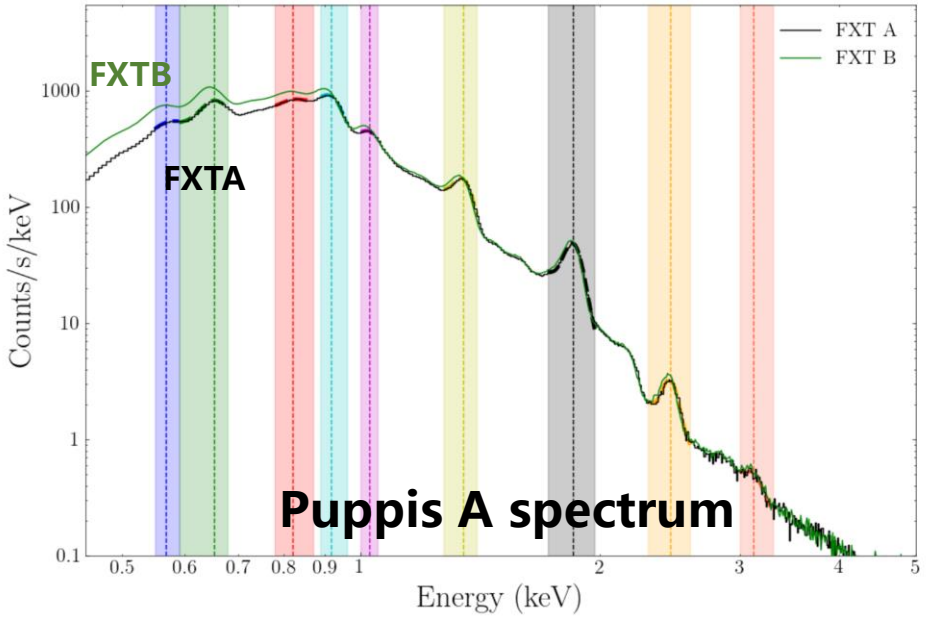




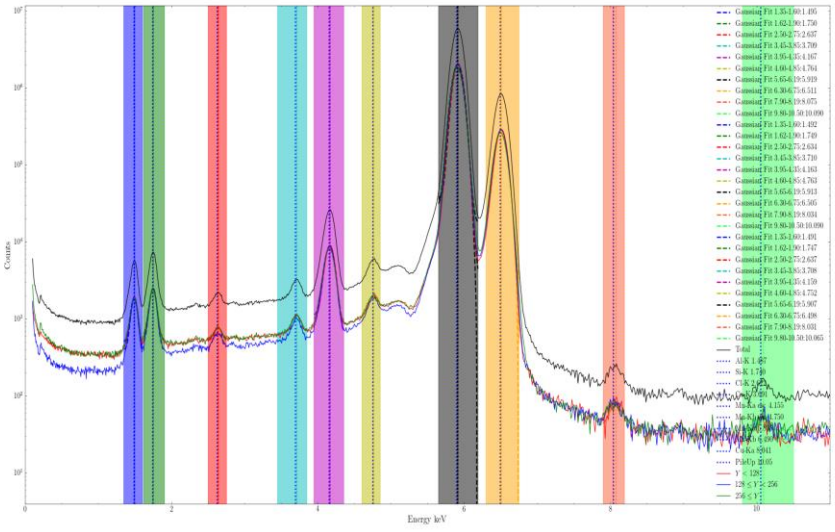
Preliminary verifying of initial CALDB

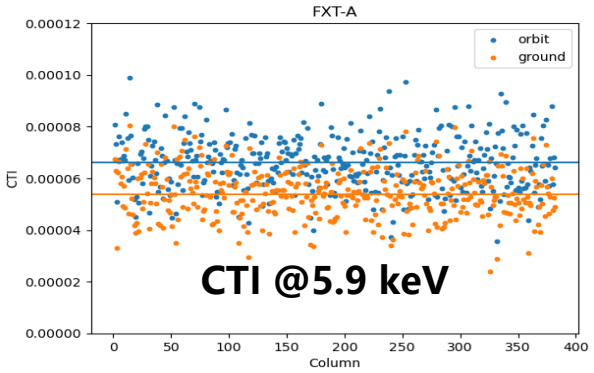
E-C verify: Fe55~10 eV

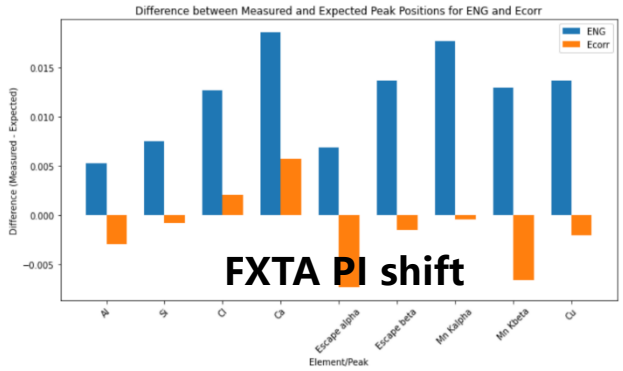
Temperature FXTA: -95° FXTB: -90°



FXTA Fe55 spectrum

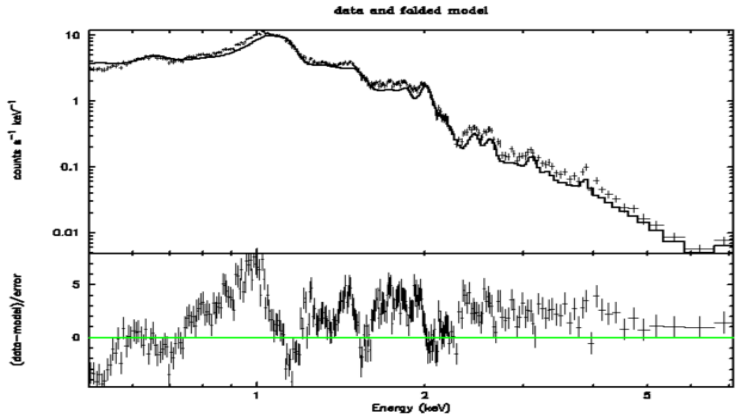




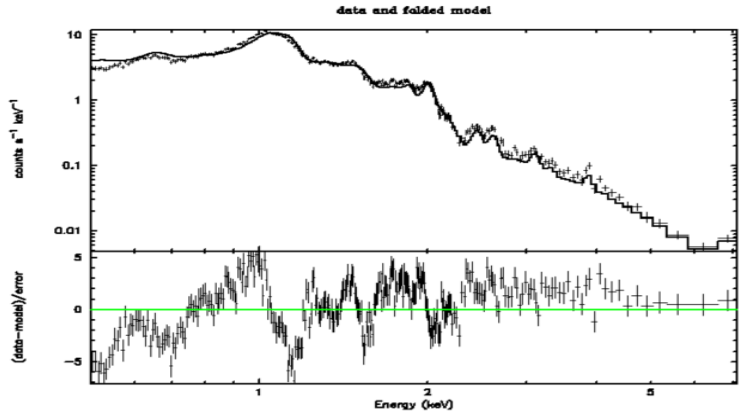


Preliminary verifying of initial CALDB

ARF verify：~10%

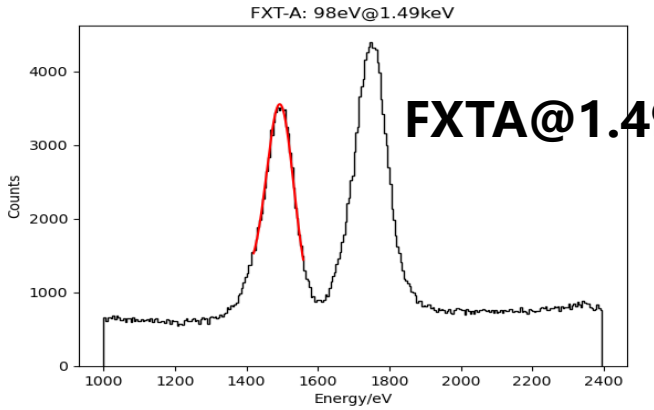


×1.08



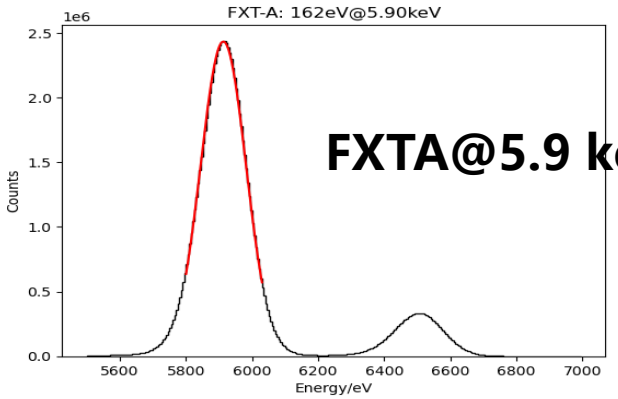
FXTA-M87 spectrum

RMF verify：



FXTA@1.49 keV

96eV （on ground）
98 eV （in orbit）

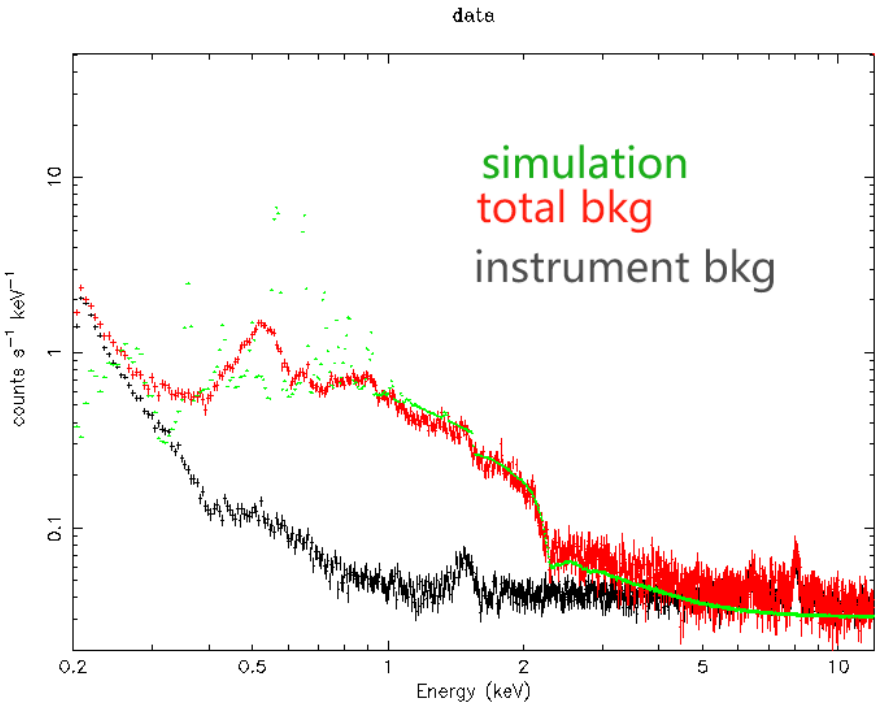


FXTA@5.9 keV

157 eV （on ground）
162 eV （in orbit）

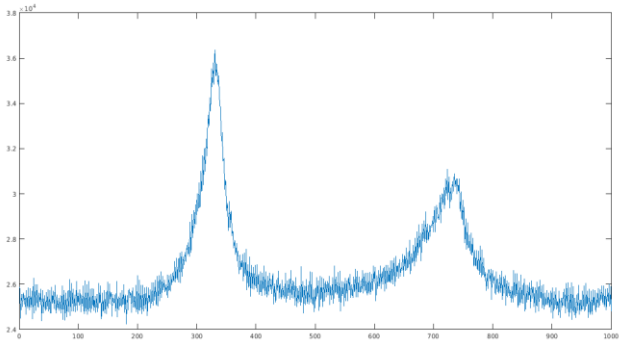
Preliminary verifying of initial CALDB

back ground verify:
Similar to simulation

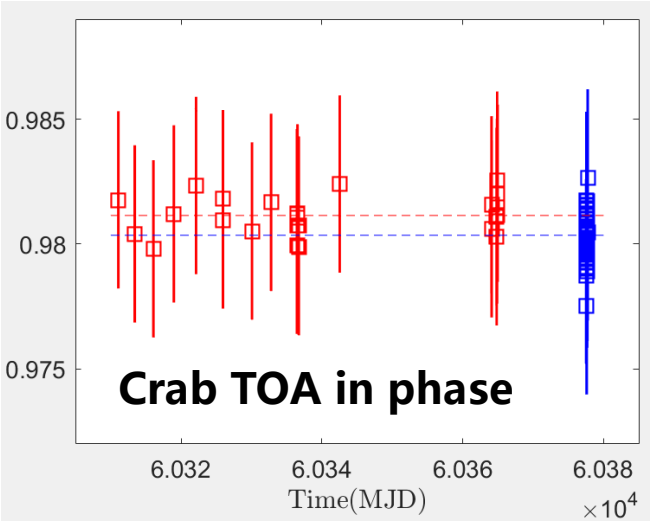


Blank sky and Closed position spectrum

Timing verify:



profile of Crab in timing mode



Temporal stability ~30μs
Absolute timing <30μs

FXT In-orbit Calibration Work Plan

- Plate scale and boresight (NGC2516, Omega Cen, already observed)
- Gain and CTI (Fe55, ~~CasA,~~ 1E0102, N132D)
- PSF(off axis) (~~PG 1634~~, 3c273, RXJ 1856)
- Effective area ,QE, flat-fielding, and vignetting(galaxy cluster, SNR)
- Timing (Pulsars: Crab, millisecond and other Pulsars)
- Coordinated observations (work with IACHEC)
- Monitoring every 6 month: RXJ1856, 1E0102, Fe55

summary

- **On-ground:**

The results of the ground calibration experiments have been extensively analyzed and entered into the calibration database. However, we may need to reanalyze and update the CALDB.

- **In-orbit:**

The in-orbit calibration observation have started for more than 10 days, and there are still over 50 days of calibration plan. Currently, the results have only been preliminarily verified, and the calibration database will need to be modified subsequently.

Thank you