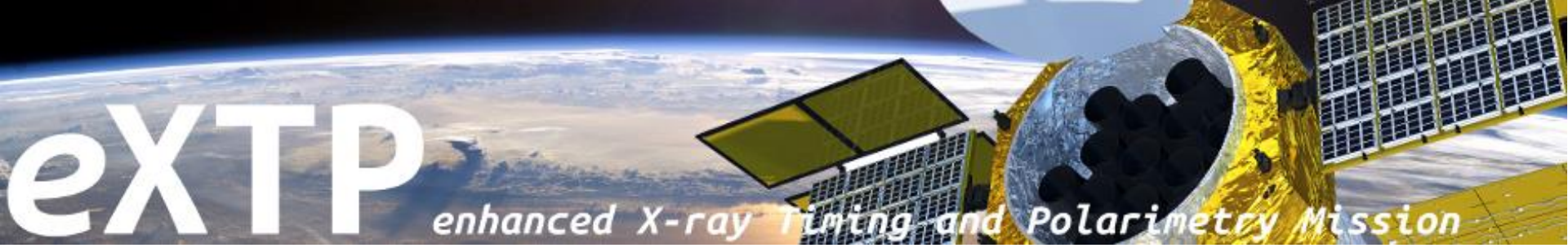
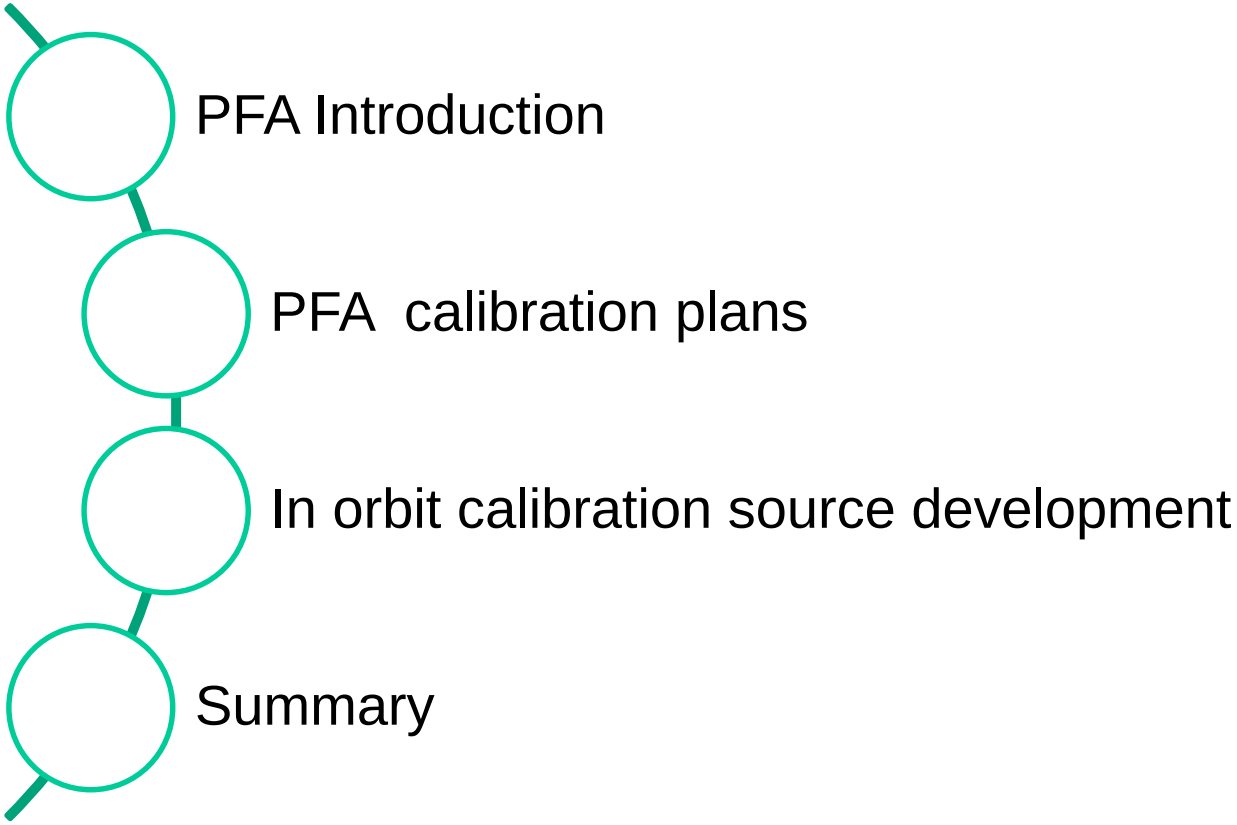


Calibration plans and developments of PFA onboard eXTP

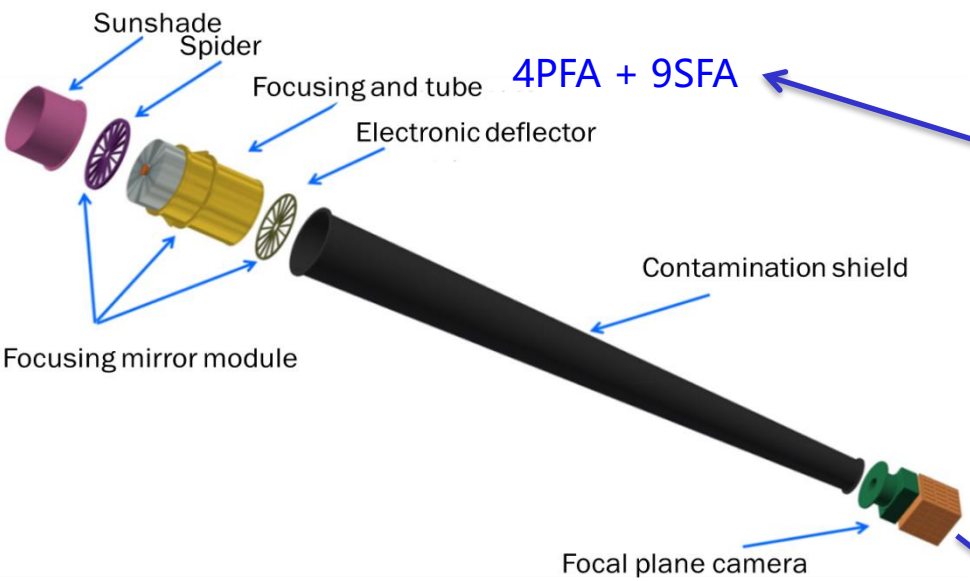
WeiChun Jiang(IHEP)
on behalf of the eXTP–PFA Consortium

14th Workshop of International Astronomical Consortium for High Energy Calibration
Shonan Village Center, Japan, 19-23 May 2019

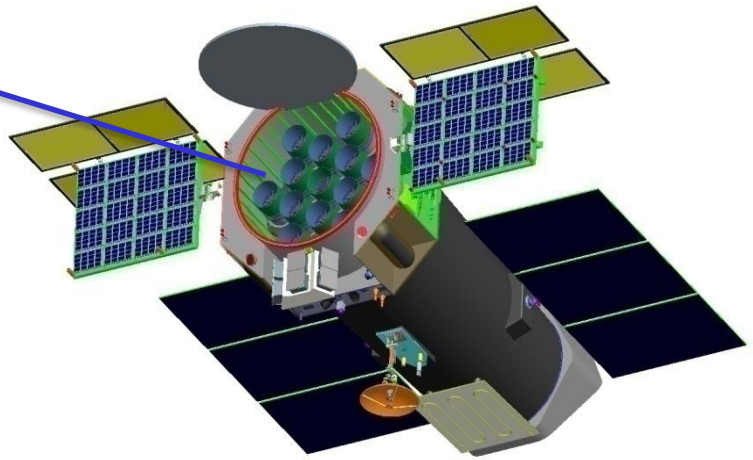
OUTLINE

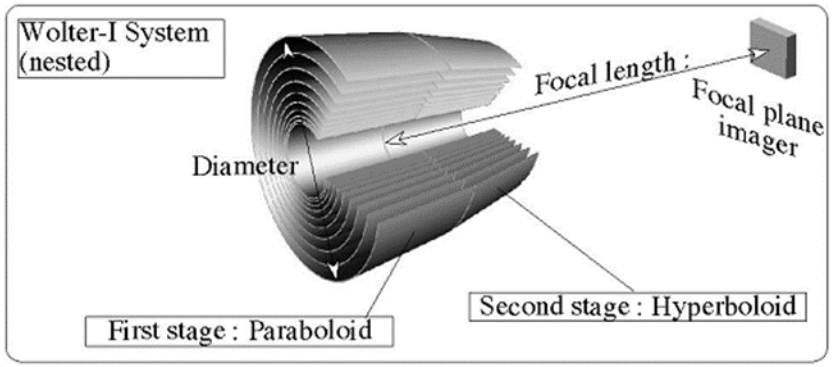

PFA Introduction
PFA calibration plans
In orbit calibration source development
Summary

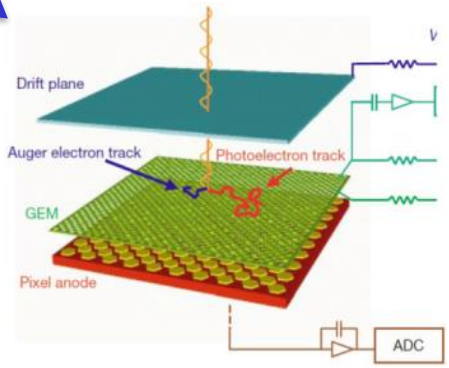
Polarimetry Focusing Array(PFA) onboard eXTP



4PFA + 9SFA







GPD

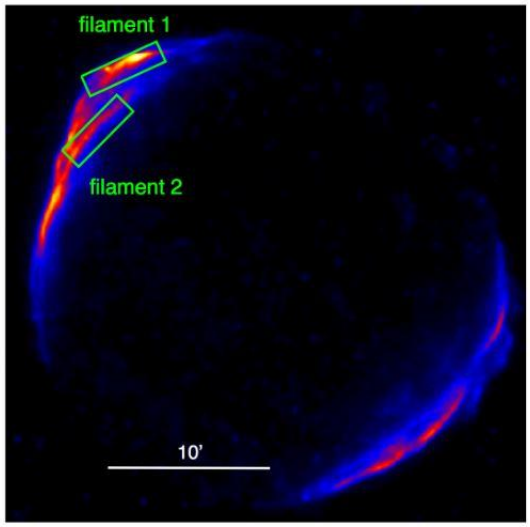
GPD is Designed by the INFN-Pisa group (Bellazzini et al.)

PFA : Wolter-I nickel mirrors + GPD

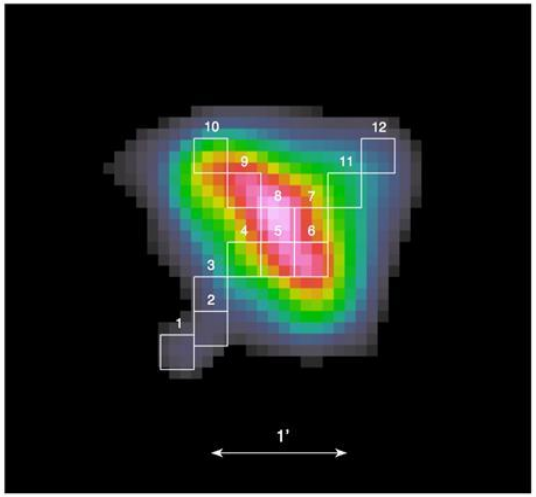
Polarimetry Focusing Array(PFA) onboard eXTP

What can PFA do:

- Imaging
- Polarimetry
- Timing
- Spectrometry



Simulating results of the imaging polarization for the SN1006



Simulating results of the imaging polarization for crab

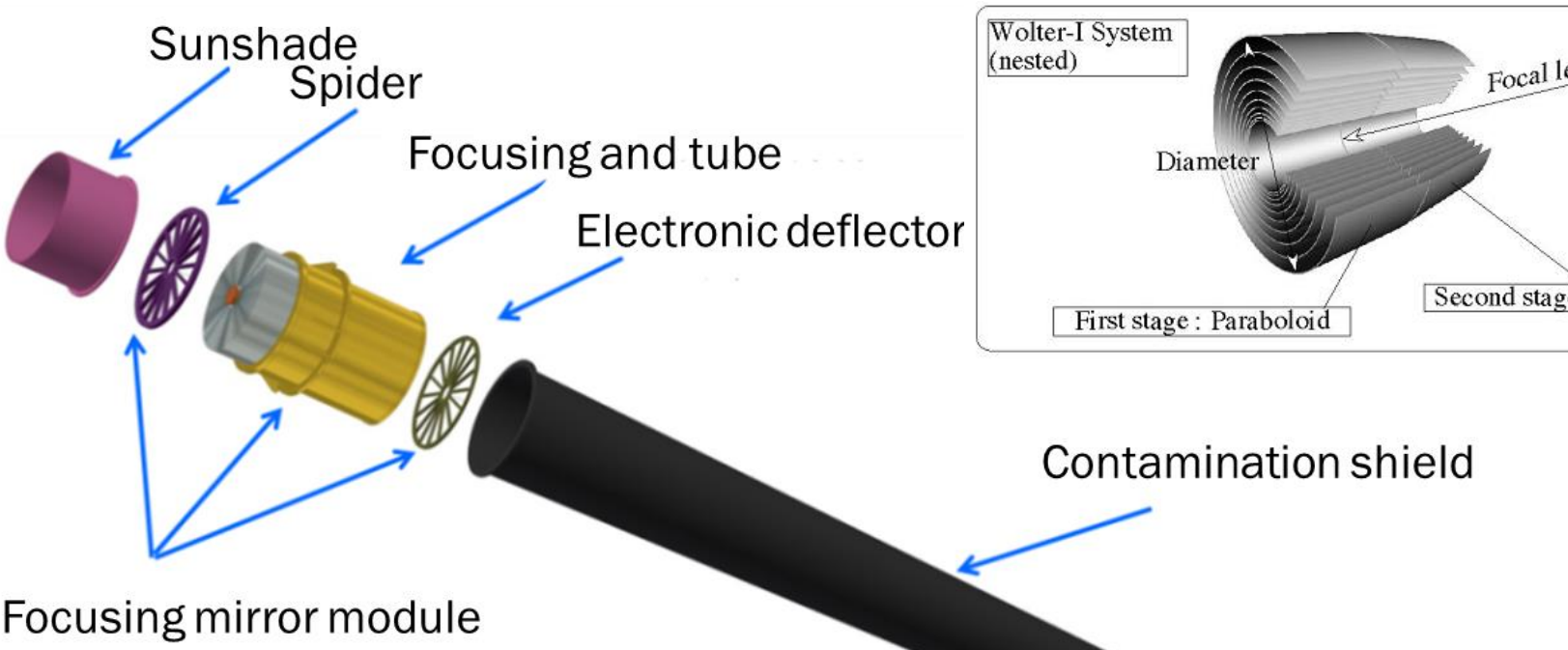
Instrument performance requirements

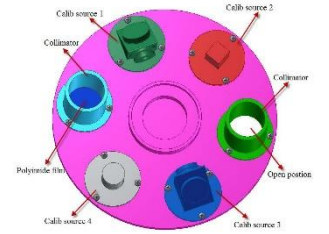
Item	Requirement	Goal
Energy range	2-8 keV	2-10 keV
Effective area（for 4 PFAs）	380 cm2 @ 3 keV	420 cm2 @ 3 keV
Field of view (FWHM)	8′×8′	8′×8′
Angular resolution	30″ (HPD)	15″ (HPD)
Point source localization	5″ (1σ) (TBC)	
Energy resolution	1.8 keV @ 6 keV	1.5 keV @ 6 keV
Modulation factor	≥50%@6keV	≥50%@6keV
Time resolution	≤ 10 μs	≤ 8 μs
Dead time	≤ 10% @ 1Crab	≤ 3% @ 1Crab
Background	≤ 0.01 cts/s (TBC)	≤ 0.006 cts/s (TBC)
MDP (minimum detectable polarization)	< 3%	< 2%
Maximum source flux	≥ 15 Crab (TBC)	≥ 20 Crab

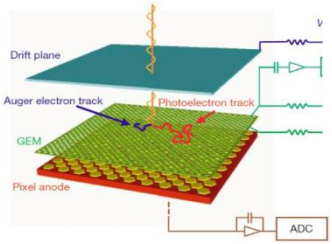
Preliminary schedule of PFA

- Phase A+ (10 months): March – Dec 2018
  - Key technology/components development (continue in B1)
  - Mission approval general review in China (May 2019)
- Phase B1 (12 months): Jan – Dec 2019
  - Continue key technology/componets development
  - New version ASIC debugging and testing
  - P/L SRR,
  - Commitment MoU, Mission adoption
  - engineering prototype of PFA focal plane camera development
  - 50 μm Be window GPD reliability testing and flight test
- Phase B2 (12 months): Jan – Dec 2020
  - SRR, PDR
- Phase C1 (12 months): Jan 2021 – Dec 2022
  - SM, EFM and STM development and system level test
- Phase C2 (24 months): Jan 2023 – Dec 2024
  - QM development and verification, CDR
- Phase D (30 months): Jan 2025 – June 2027
  - FM delivery, S/C AIT
- Phase E1: Launch (6 months): June – Dec 2027
- Phase E2/3 (60 + 60 months): Jan 2028 – Jan 2038

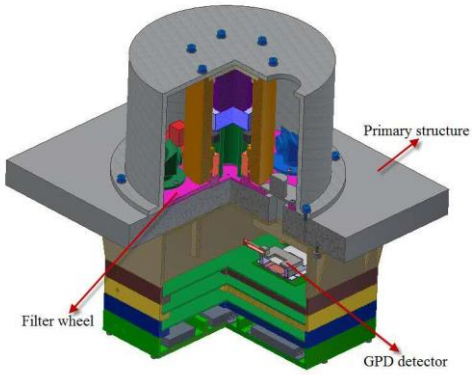
Preliminary Design for PFA







GPD for PFA



Performance of Focusing Mirror Module

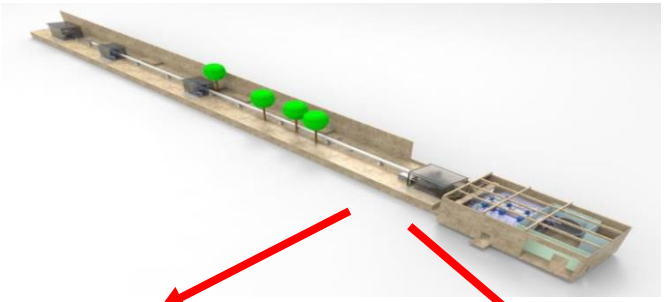
Item	Requirement	Goal
Focal length	5.25 ± 0.05 m	5.25 ± 0.05 m
Aperture	≤ 500 mm	≤ 500 mm
Envelope	≤ 600 mm	≤ 600 mm
Mirror length	600 ± 1.0 mm	600 ± 0.5 mm
On axis collecting area	≥ 840 cm^2 @ 3 keV ≥ 550 cm^2 @ 6 keV	≥ 840 cm^2 @ 3 keV ≥ 550 cm^2 @ 6 keV
Energy range	2~8 keV	2~10 keV
Field of view (FWHM)	> 12′	> 12′
Angular resolution（HPD）	≤ 30″	≤ 15″
Charged particle deflection requirements	≥ 1° for proton@10keV or electron @100keV	≥ 1° for proton@10keV or electron @100keV
Working temperature	20 ± 1℃（TBC）	≤ 30″
Mass	≤ 100 kg	≤ 100 kg

Performance of Focal Plane Camera

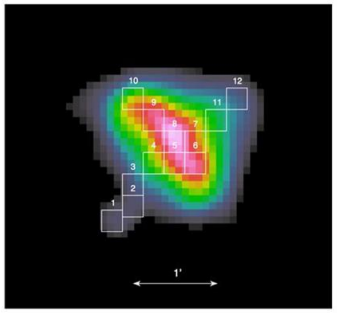
Item	Requirement	Goal
Energy range	2-8 keV	2-10 keV
Detection efficiency	≥ 11.5% @ 3 keV	≥ 14.0% @ 3 keV
Detector Area (for 1 PFA)	12×12mm^2	12×12mm^2
Position resolution	≤ 0.2 mm	≤ 0.1 mm
Energy resolution	1.8 keV @ 6 keV	1.5 keV @ 6 keV
Modulation factor	≥50%@6keV	≥50%@6keV
Time resolution	≤ 10 μs	≤ 8 μs
Dead time	≤ 500μs	≤ 100μs
Background	≤ 0.01 cts/s (TBC)	≤ 0.006 cts/s (TBC)
MDP (minimum detectable polarization)	< 3%	< 2%

Calibration plans of PFA

100m facility



Astrophysics source



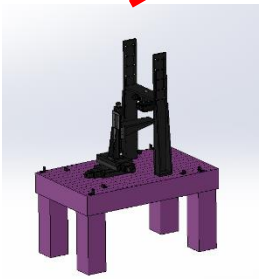
Mirror module calibration

Focal plane camera calibration

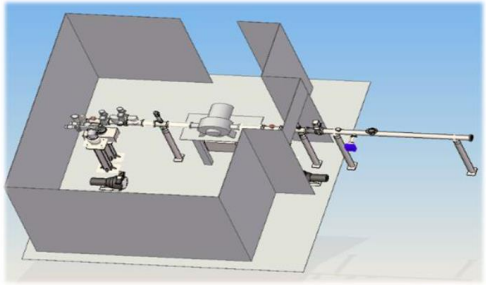
PFA alignment calibration

PFA in-orbit calibration

Mirror module calibraton and alignment calibration was talked by Yusa Wang.

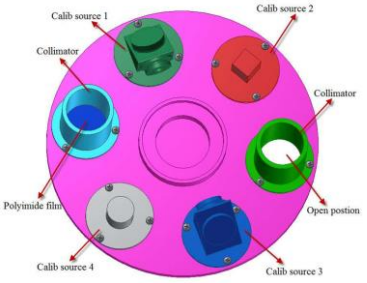


desktop facility



8m facility

Chinese synchrotron light source



Cal source on wheel

Calibration plans of focal plane camera

Calibration at desktop facility and 8m facility :

- Modulation factor at different energies and different polarizations
- Residual modulation for unpolarized x-ray at different energies
- Energy response (2-10keV) and low energy threshold
- Energy resolution
- Time accuracy and time resolution
- Position resolution at different energies
- The effect of incidence inclination angle of x-ray
- The effect of electron on SDD&GPD
- Performance of background rejection with multi-cells

Calibration at Chinese synchrotron light source

- Cross calibraton of Modulation factor
- GPD QE measurement
- Transmission of kinds of filters

In orbit calibration plans

Calibration with in orbit calibration source:

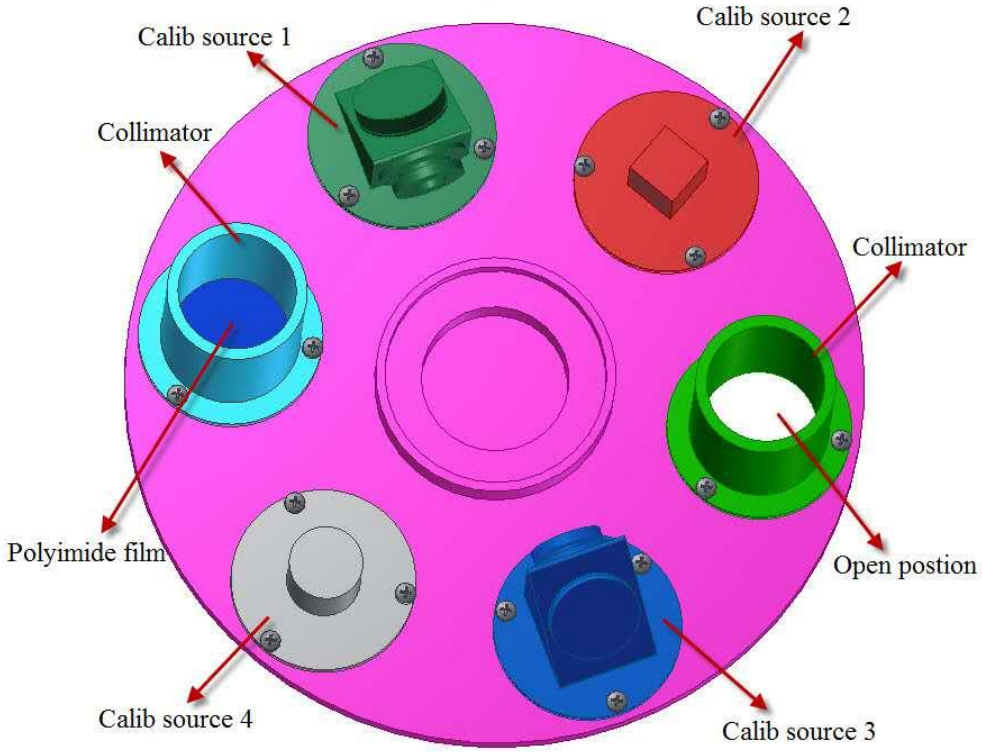
- Modulation factor at different energies and different polarizations
- Residual modulation for unpolarized x-ray at different energies
- Energy response
- Energy resolution
- Gain map

Calibration with Astrophysics source:

- Cross calibration of absolute timing resolution
- Pointing resolution
- Point source localization

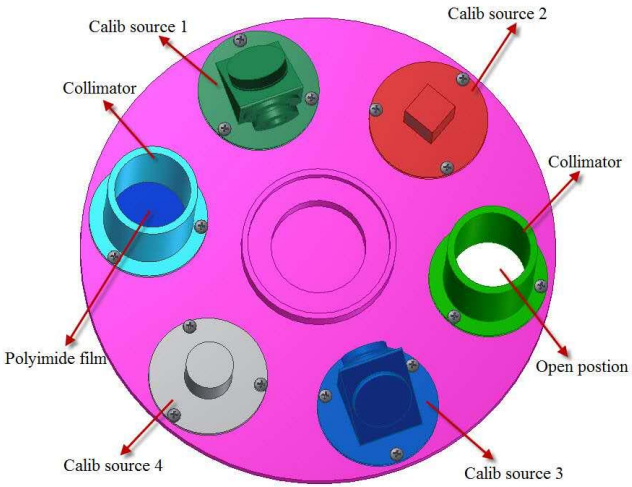
Preliminary Design of Filters wheel

- 1 or 2 polarized sources based on ^{55}Fe to provide X-ray with different energies and polarizations；
- A Φ1mm unpolarized ^{55}Fe source to monitor the residual modulation ；
- A Φ18mm unpolarized ^{55}Fe covered with PVC film to map the gain for different positions of GPD。

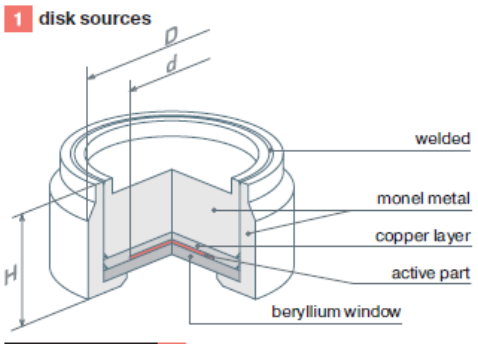


onboard polarized calibration X-ray source

- We can develop X ray polarized source based on the Bragg diffraction at nearly 45 °
- The key components of the polarized source is the x ray source, the diffraction crystal and a optional collimator.
- We employ lead-glass capillary plates as the collimator for the current version.
- The ^{55}Fe source employed in the calibration source is sealed sources meeting the ISO2919 level C64343.

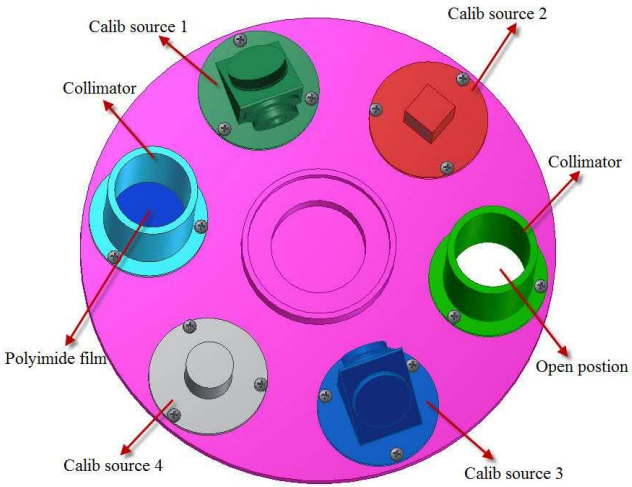


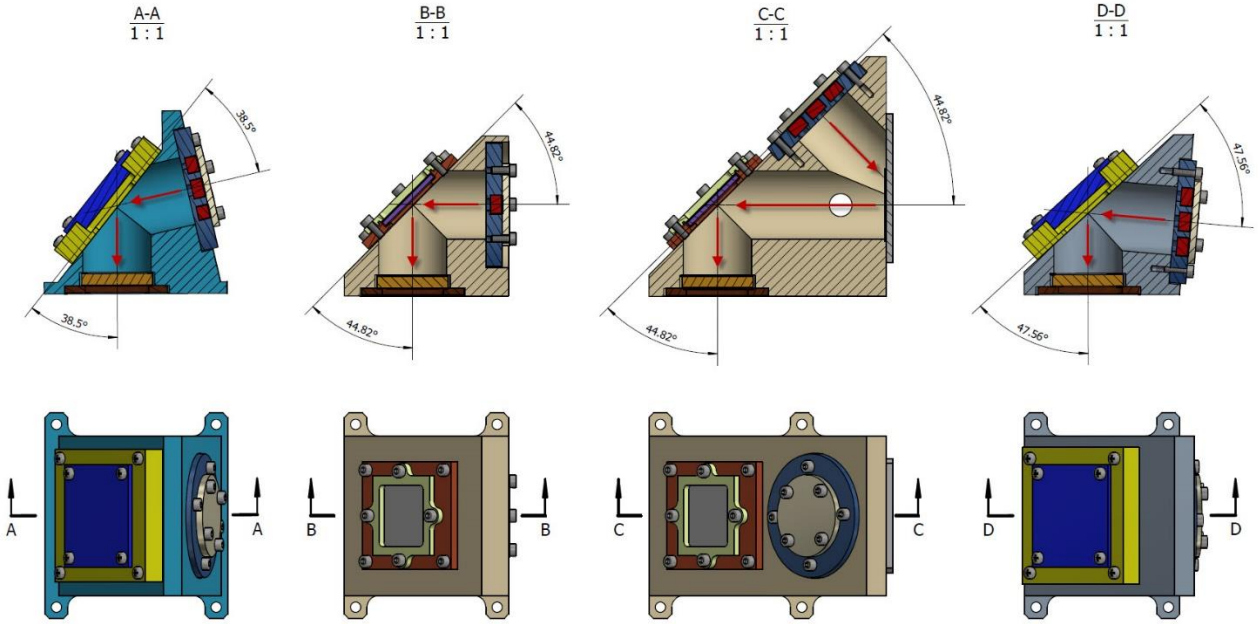
$$E = \frac{nhc}{2d \sin\theta}$$



onboard polarized calibration X-ray source

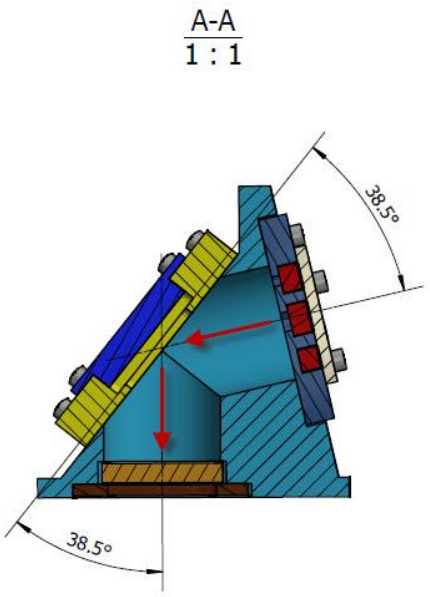
- Reference to the design of INAF (Fabio Muleri et al)，4 polarized calibration X-ray source was developed.





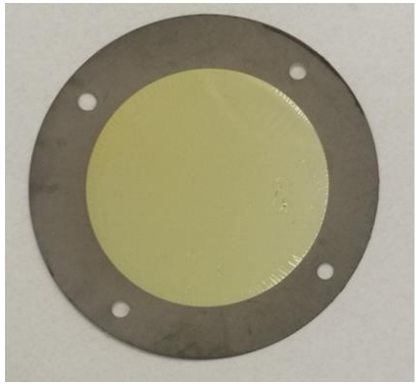
onboard polarized calibration X-ray source – source 1

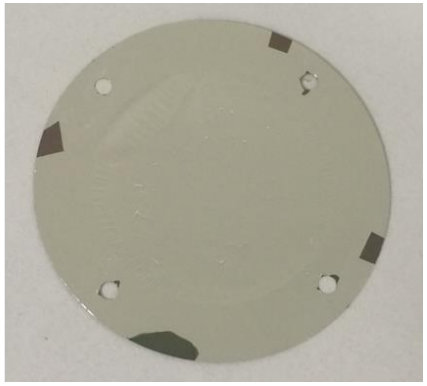
- Fe^{55}+1.6μm Ag foil
- Crystal:HOPG（002）
- Diffraction angle:38.5°

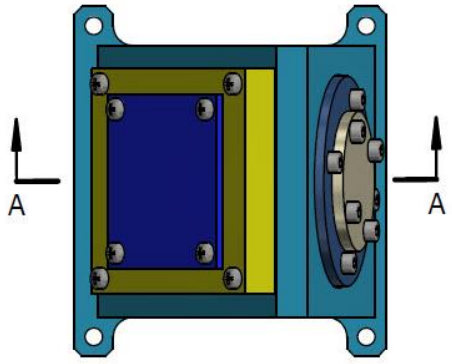


	3.0 keV X-rays	5.9 keV X-rays
Production	Fluorescence from Ag foil	Direct emission from ^{55}Fe
Diffraction angle on graphite crystal	38.3 deg	38.7 deg
Polarization of diffracted photons	67%	69%
Image on the detector	Strip, 4x15 mm^2	Strip, 4x15 mm^2

Table 3. Characteristics of X-rays produced by Cal A.

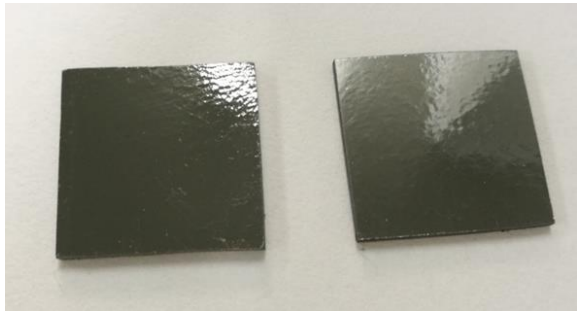




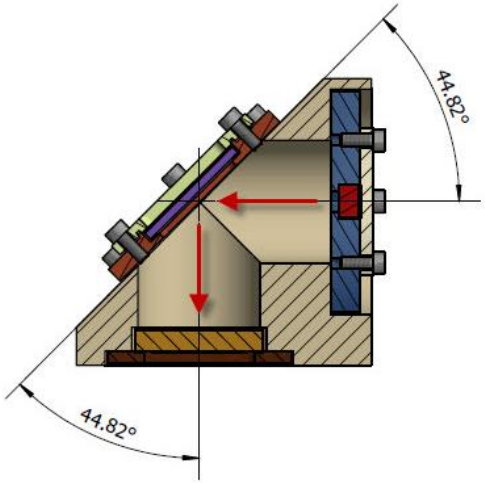


onboard polarized calibration X-ray source – source 2

- Fe^{55}+100μm PVC transmission
- Crystal:HOPG（002）



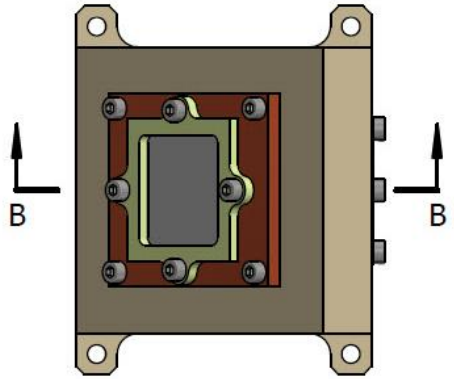
B-B
1 : 1



- Diffraction angle:44.82°

Table 1. Tuning between fluorescence lines and diffracting crystals. θ is the angle of diffraction and $\mathcal{P}$ the polarization of diffracted photons. Data from calculation performed by Henke et al.[7]

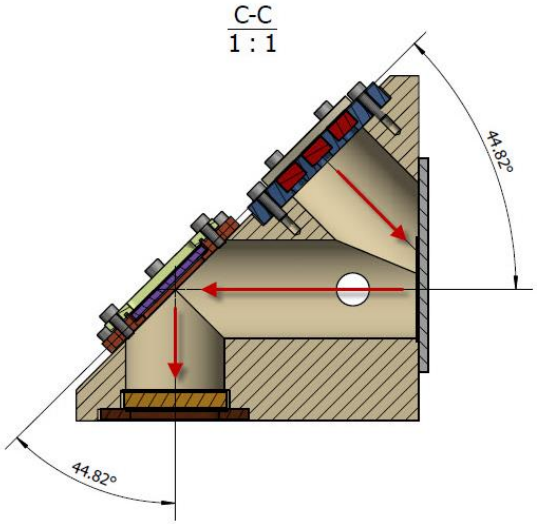
Line	Energy (keV)	Crystal	θ	$\mathcal{P}$
Lα Molybdenum	2.293	Rhodium (001)	45°.36	0.9994
Kα Chlorine	2.622	Graphite (002)	44°.82	0.9986
Lα Rhodium	2.691	Germanium (111)	44°.86	0.9926
Kα Calcium	3.692	Aluminum (111)	45°.88	0.9938
Kα Titanium	4.511	Fluorite CaF_2 (220)	45°.37	0.9994
Kα Manganese	5.899	Lithium Floride (220)	47°.56	0.8822



onboard polarized calibration X-ray source – source 3

- Fe^{55}+PVC reflection
- Crystal : HOPG（002）

- Diffraction angle:44.82°



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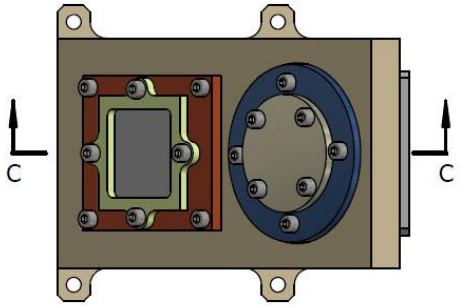
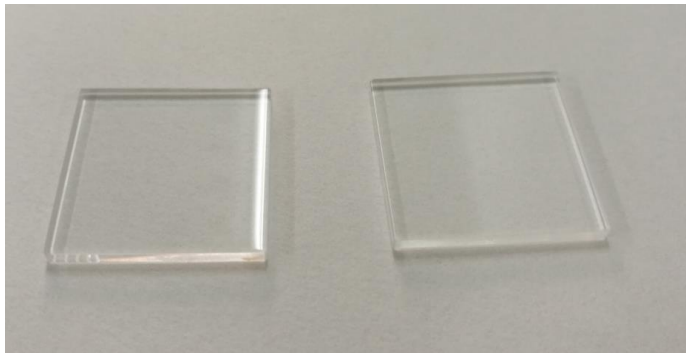
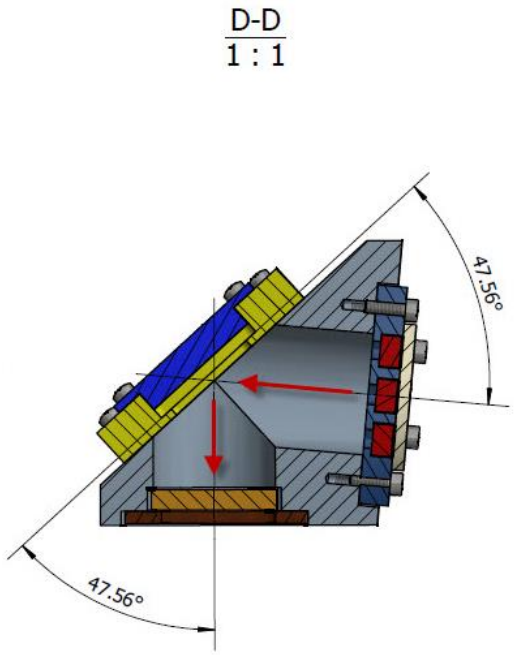


onboard polarized calibration X-ray source – source 4

- Fe^{55} X ray source
- Crystal:LiF（220）





- Diffraction angle:47.56°

Line	Energy (keV)	Crystal	θ	$\mathcal{P}$
Lα Molybdenum	2.293	Rhodium (001)	45°.36	0.9994
Kα Chlorine	2.622	Graphite (002)	44°.82	0.9986
Lα Rhodium	2.691	Germanium (111)	44°.86	0.9926
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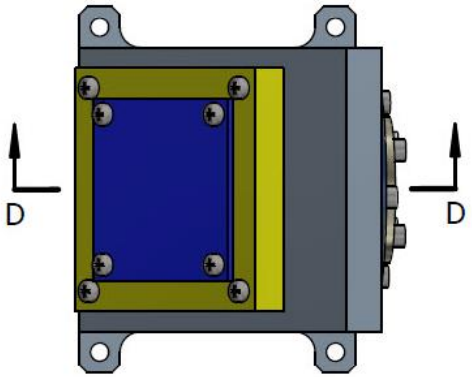
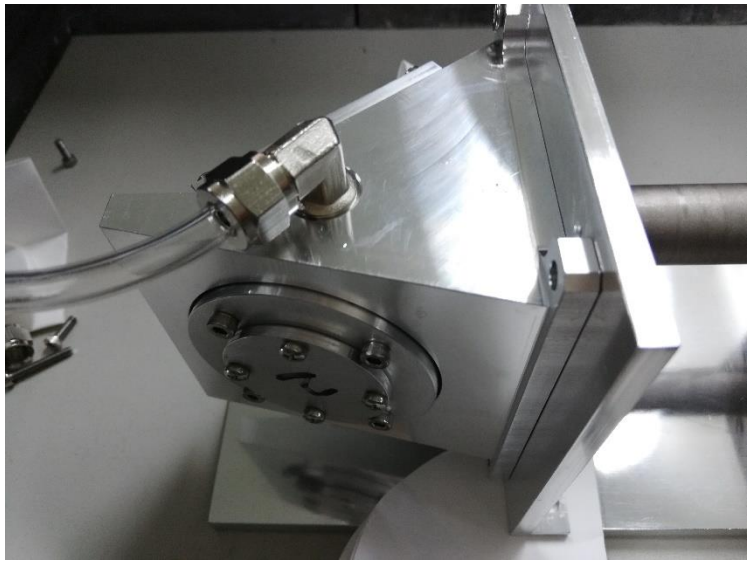
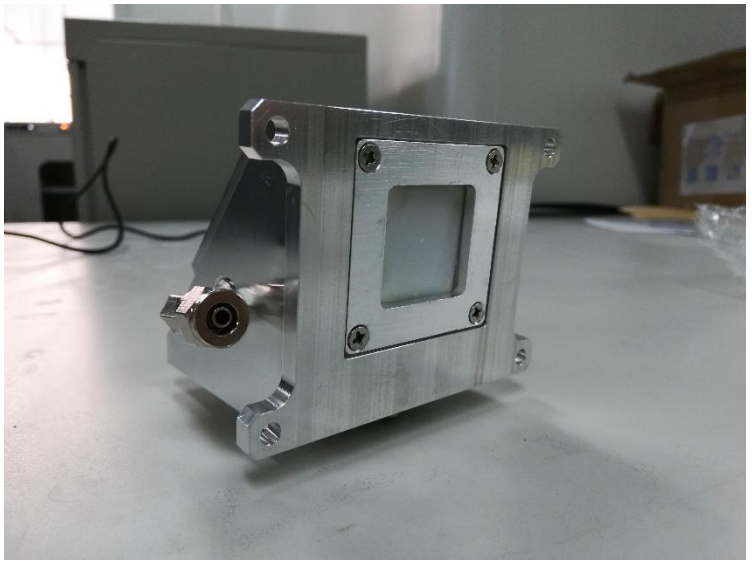
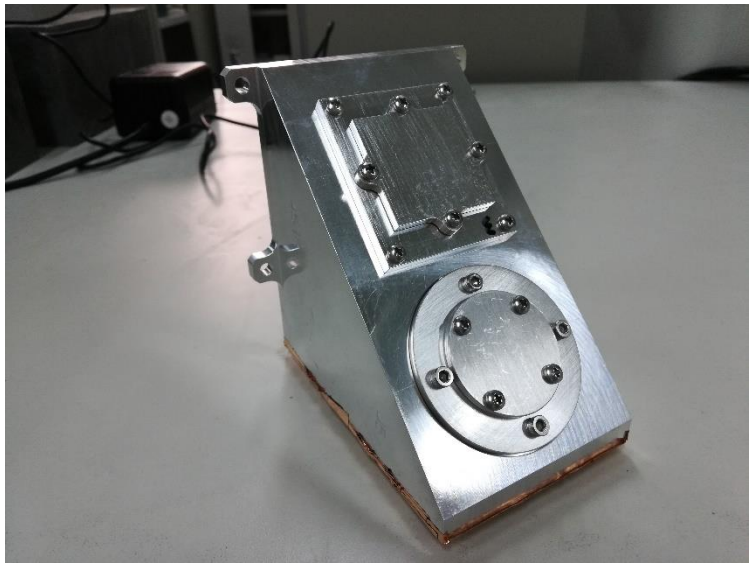
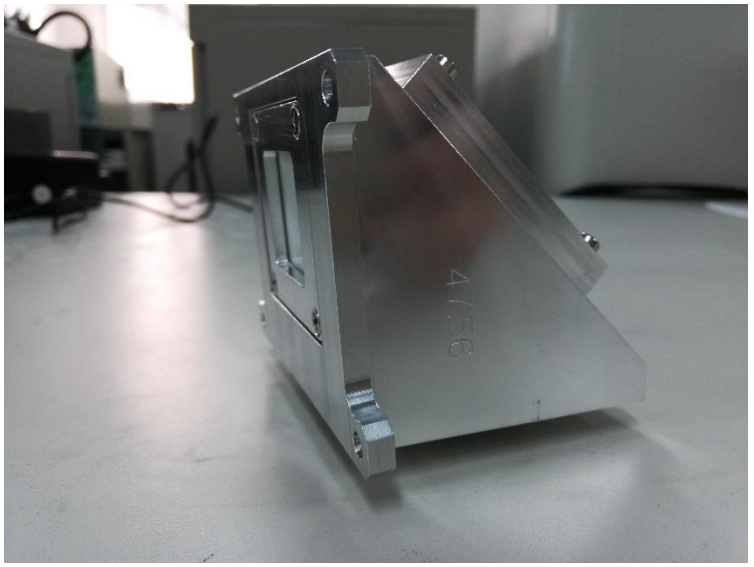


onboard polarized calibration X-ray sources





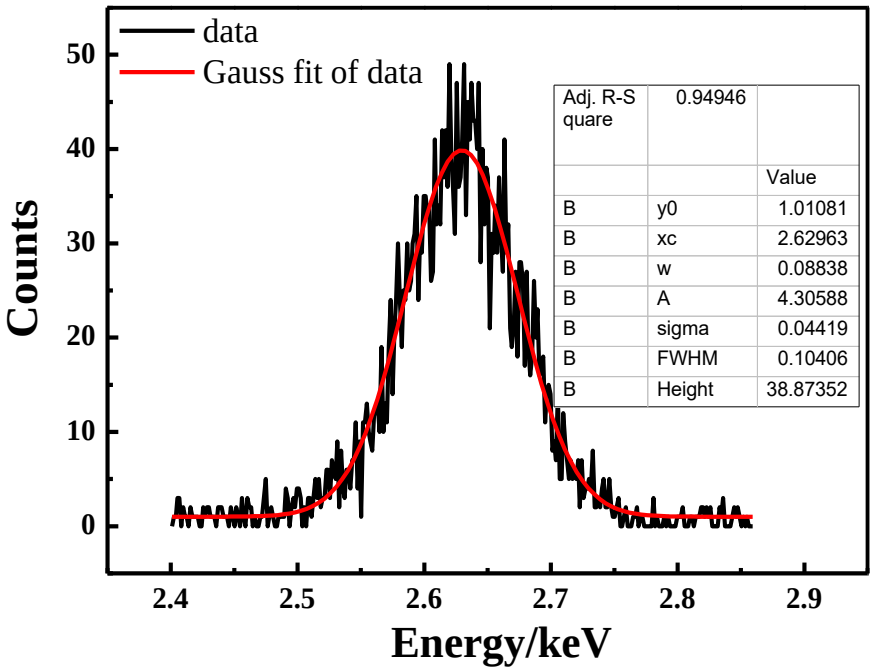


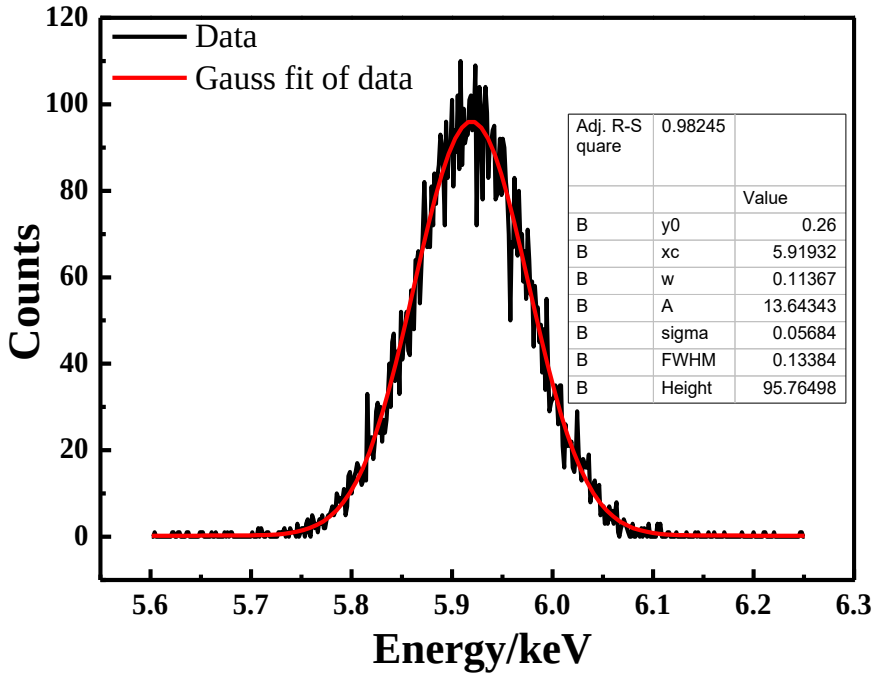


Test of polarized calibration X-ray source

Energy spectroscopy of polarized calibration X-ray source

- Source 2 and source 4

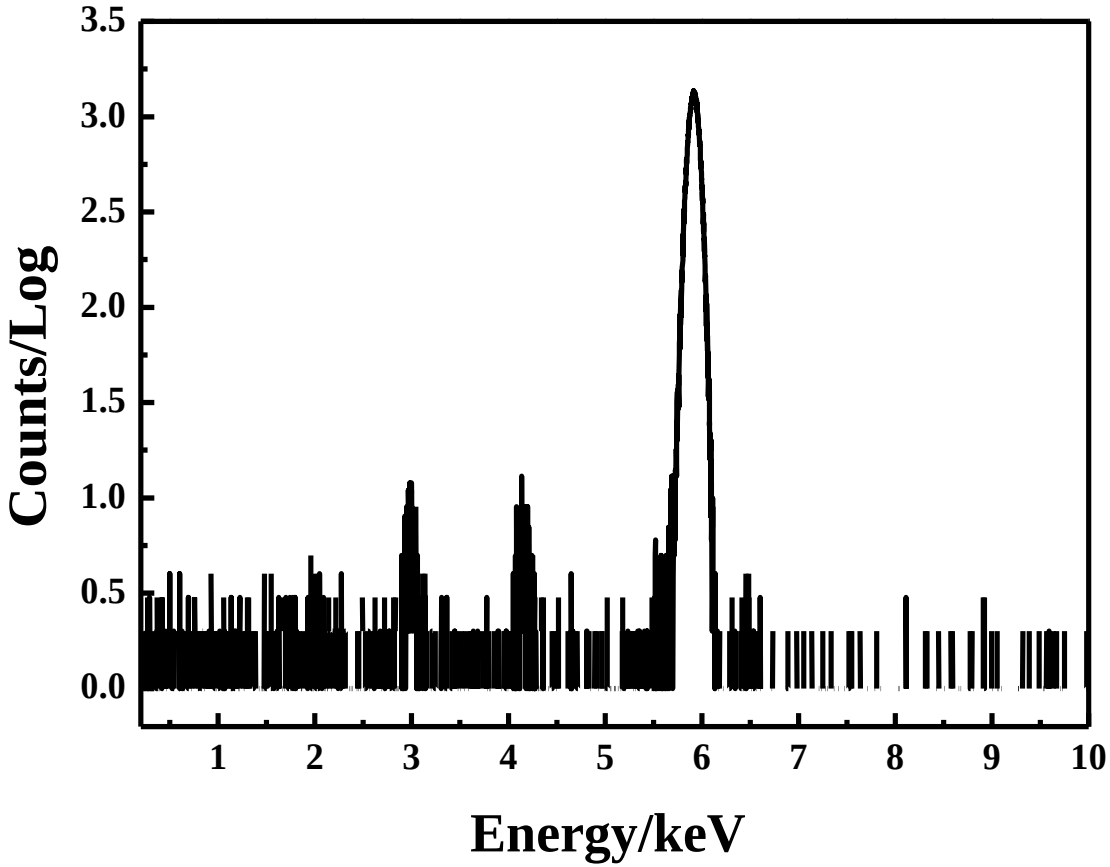




Peak number	Energy/keV	Area	FWHM/ eV	Cumulative counts	Cumulative time/h	Counting rate/h^{-1}
1	2.63	4.30588	104.06	2997.04	60	50.04
2	5.92	13.64343	133.84	9411.05	15	627.4

Energy spectroscopy of polarized calibration X-ray source

- Source 1



- Due to the very low count rate, we have not get the effective results of source 3.

What to do with the polarized source

- To increase the output intensity of the polarized source.

new version of the polarized source will be tested soon.

Summary

- PFA calibration flow and facility is talked.
- Ground calibration plans for focal plane camera is stated.
- In orbit calibration plans for PFA is considered.
- In orbit polarized calibration source is developed and need to be imporved.
- Thanks!