Scientific Performance of SFA and LAD onboard eXTP

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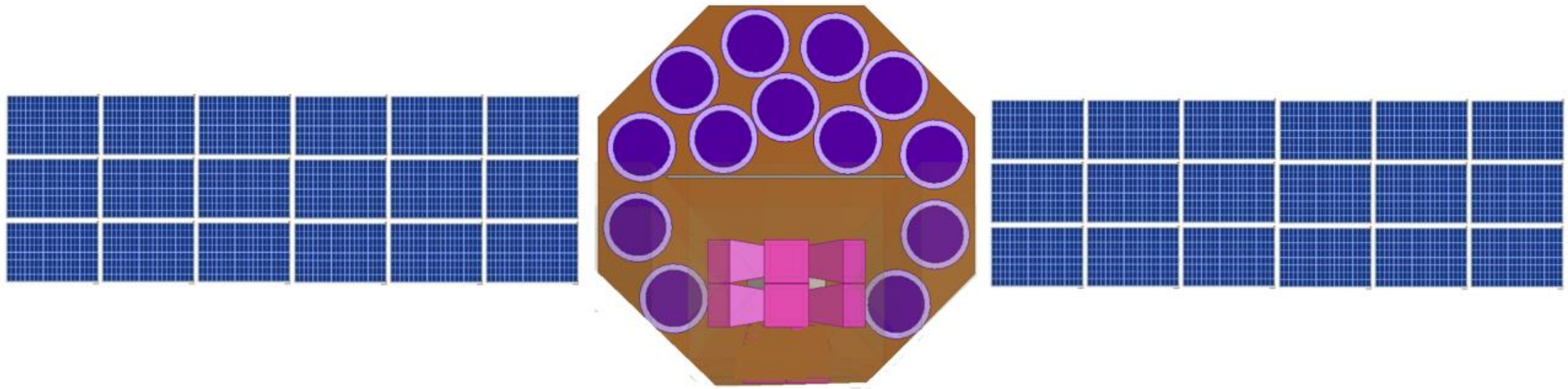

Payload	Components
Spectroscopic Focusing Array (SFA)	11 telescopes (SGO optics, Pixelated SDD)
Polarimetry Focusing Array (PFA)	2 telescopes (Nickel-based optics, GPD)
Large Area Detector (LAD)	40 modules (Collimator (lead glass), SDD)
Wide Field Monitor (WFM)	3 units (1.5D coded mask, SDD)

Payload	Specifications	Parameters
SFA	Energy range	0.5~20 keV
	Effective area (Block unconsidered)	> 9000cm^2 @1 keV > 7500 cm^2 @ 6 keV >1500cm^2@10keV >500cm^2@15keV
	Energy resolution	180 eV@6 keV
	FOV/HPD	12'/1'
	FPD	Pixelated SDD (19 pixels, pixel size of 26.6mm^2),
LAD	Energy range	2 ~ 30 keV nominal 30 ~ 80 keV (for out-FoV events)
	Effective area	~ 33800 cm^2
	Energy resolution	200eV@6keV
	FOV	1° (FWHM)
	Detector	40 LAD modules (640 SDD detectors)
PFA	Energy range	2-10 keV
	Effective collecting area	>1600 cm^2@2 keV
	Effective area	~250 cm^2@2 keV
	Energy resolution	1.8 keV@6 keV
	FOV/HPD	12'/15''
	FPD	GPD
WFM	Energy range	2-50 keV
	Energy resolution	<300 eV @6 keV
	FOV	1.33pi (20% of peak camera response)
	Angular resolution	<4.5 arcmin (FWHM)
	Localization accuracy	<1 arcmin
	Detector	SDD

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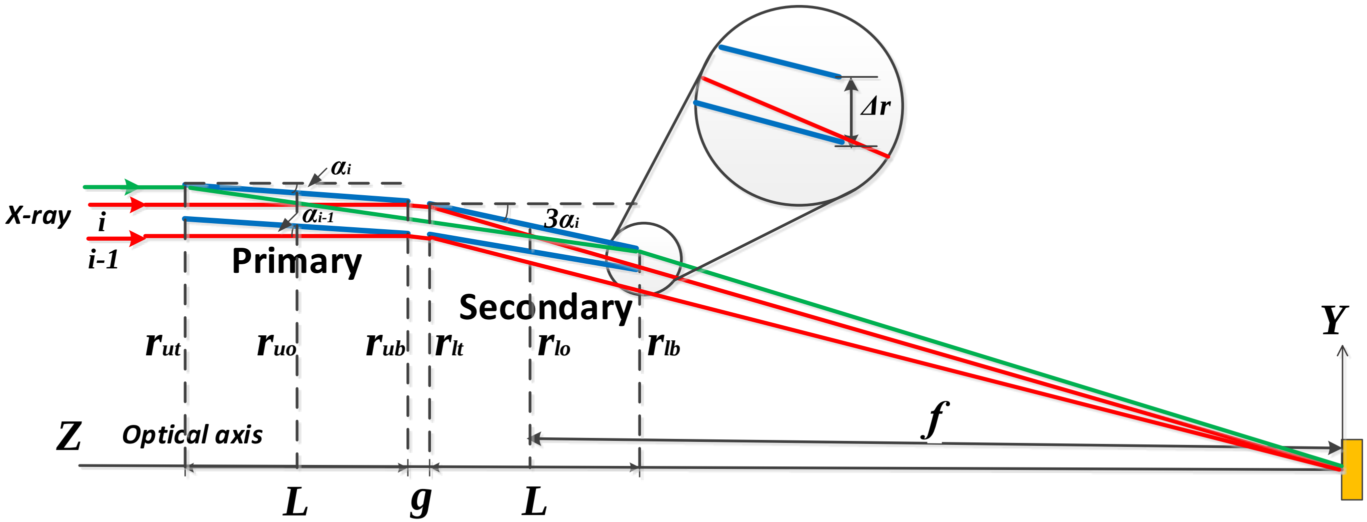
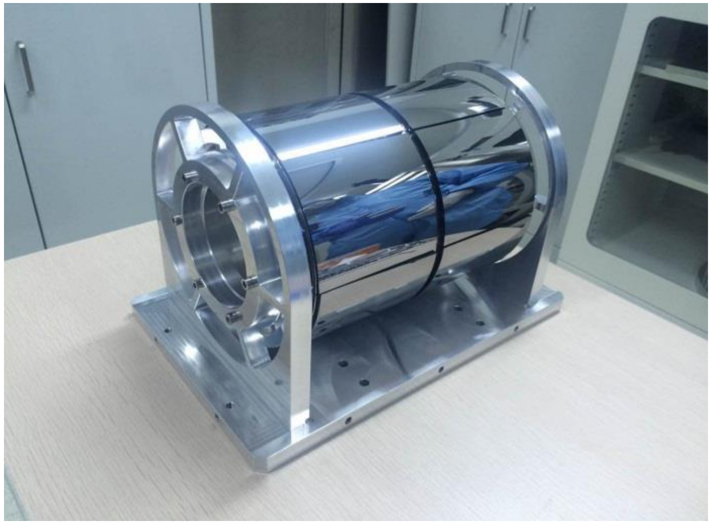
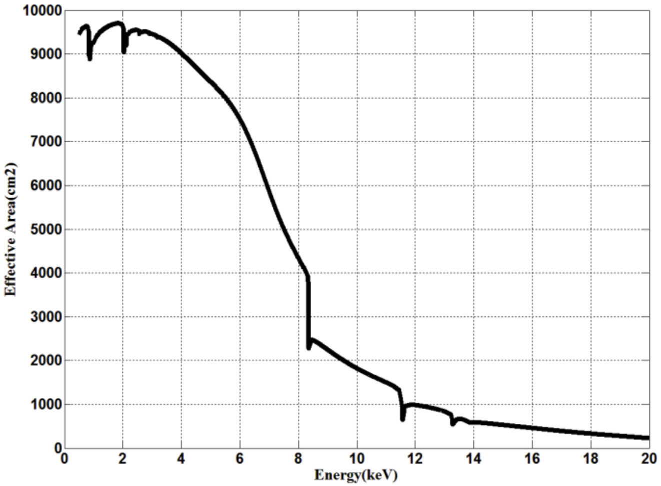
Configuration of SFA Mirror



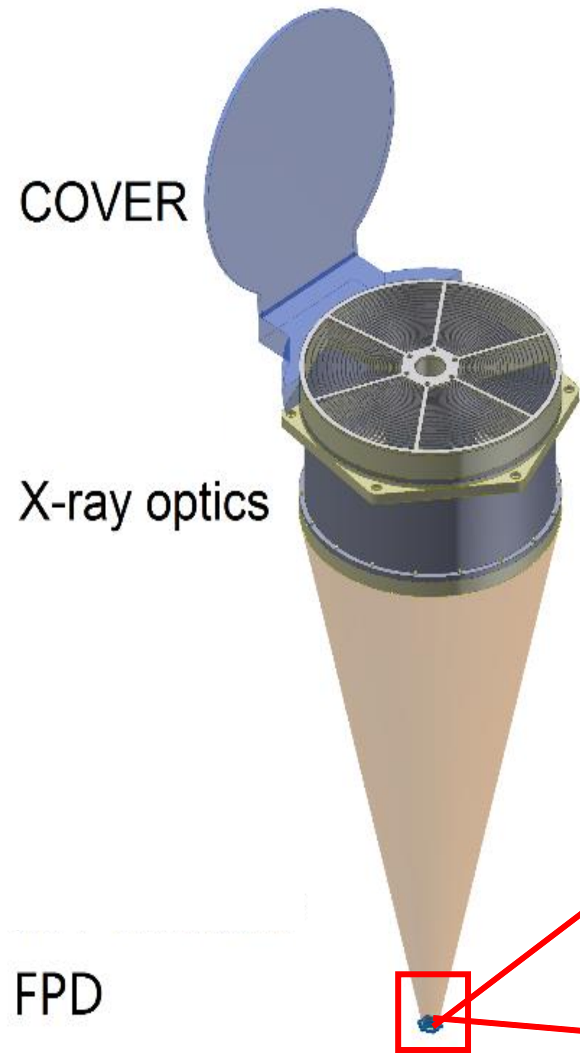
Conical wolter-I telescope with focal length of 4500 mm



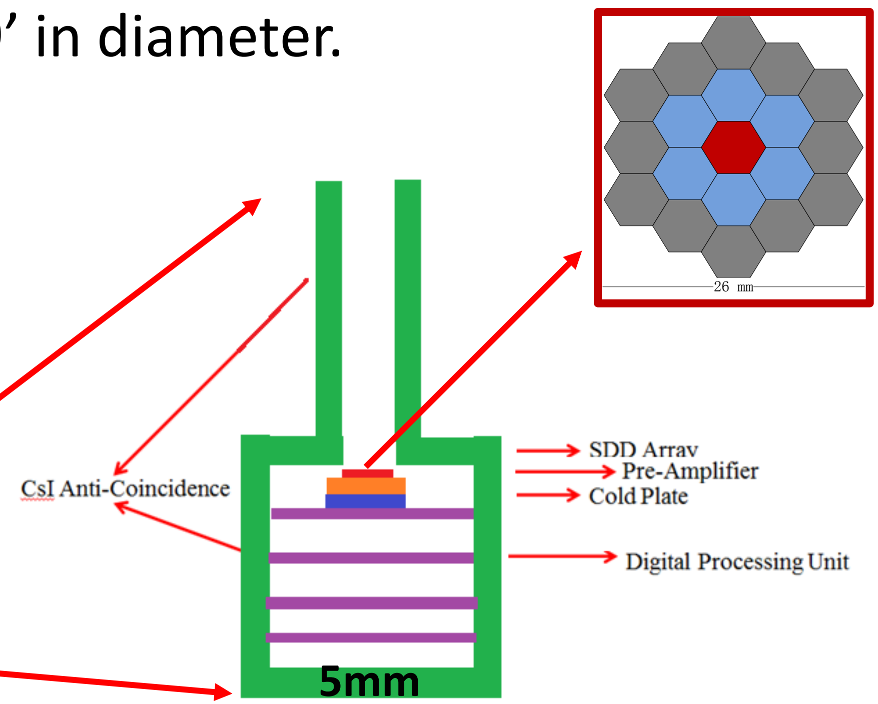


Total on-axis effective area of 11 telescopes

Configuration of SFA Focal Plane Detector

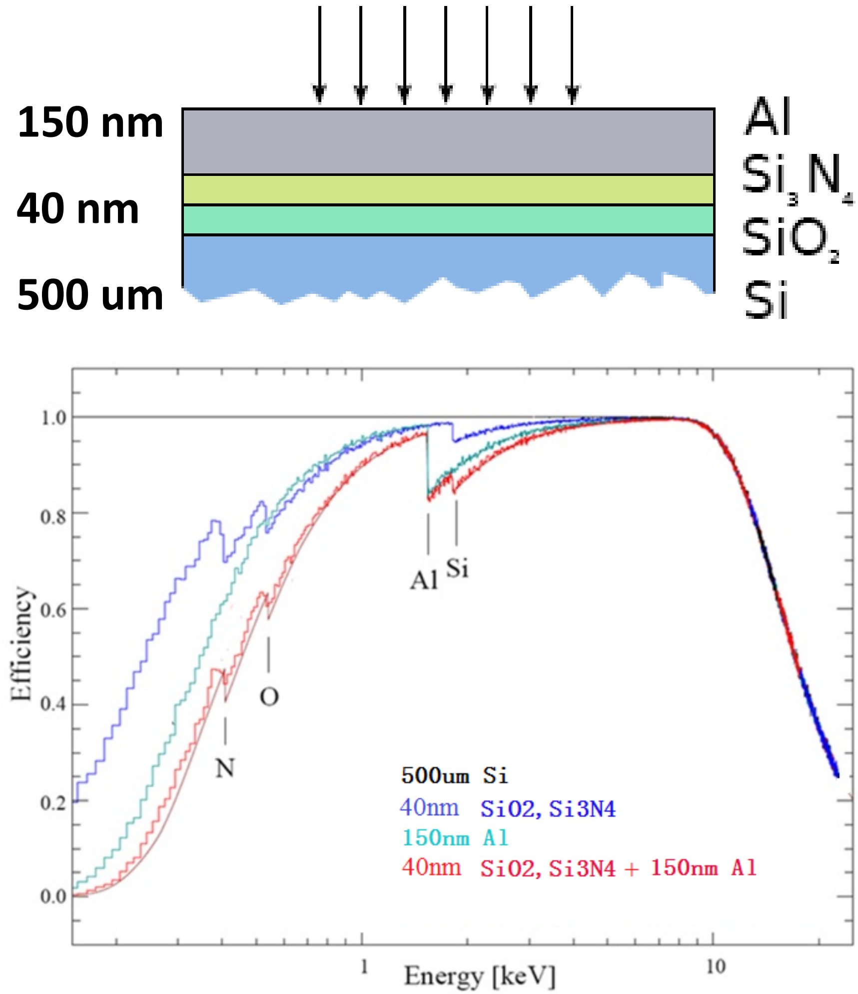


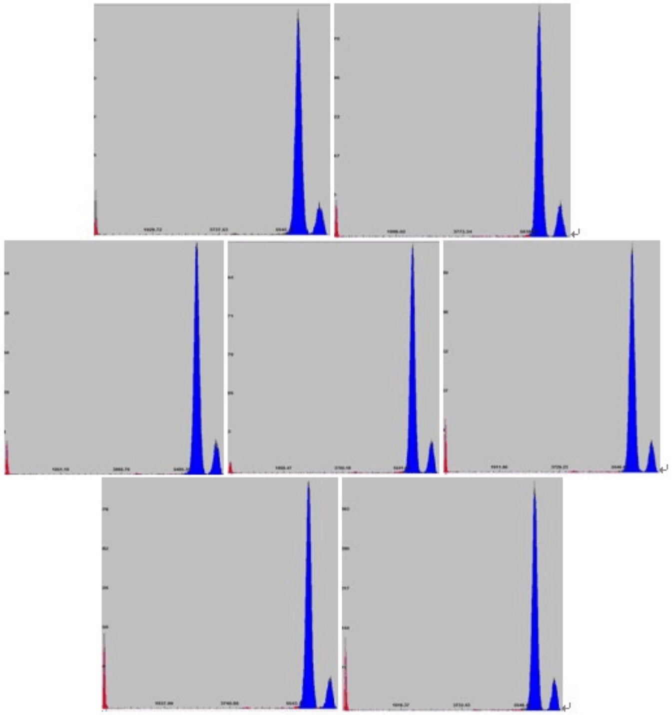
Pixelized SDD detector.
Hexagon pixels of a side length of 3.2 mm, 26.6 mm^2, 15.5 arcmin^2. The full FOV is 19’ in diameter.



A simple configuration of the FPD unit

Quantum efficiency of SDD

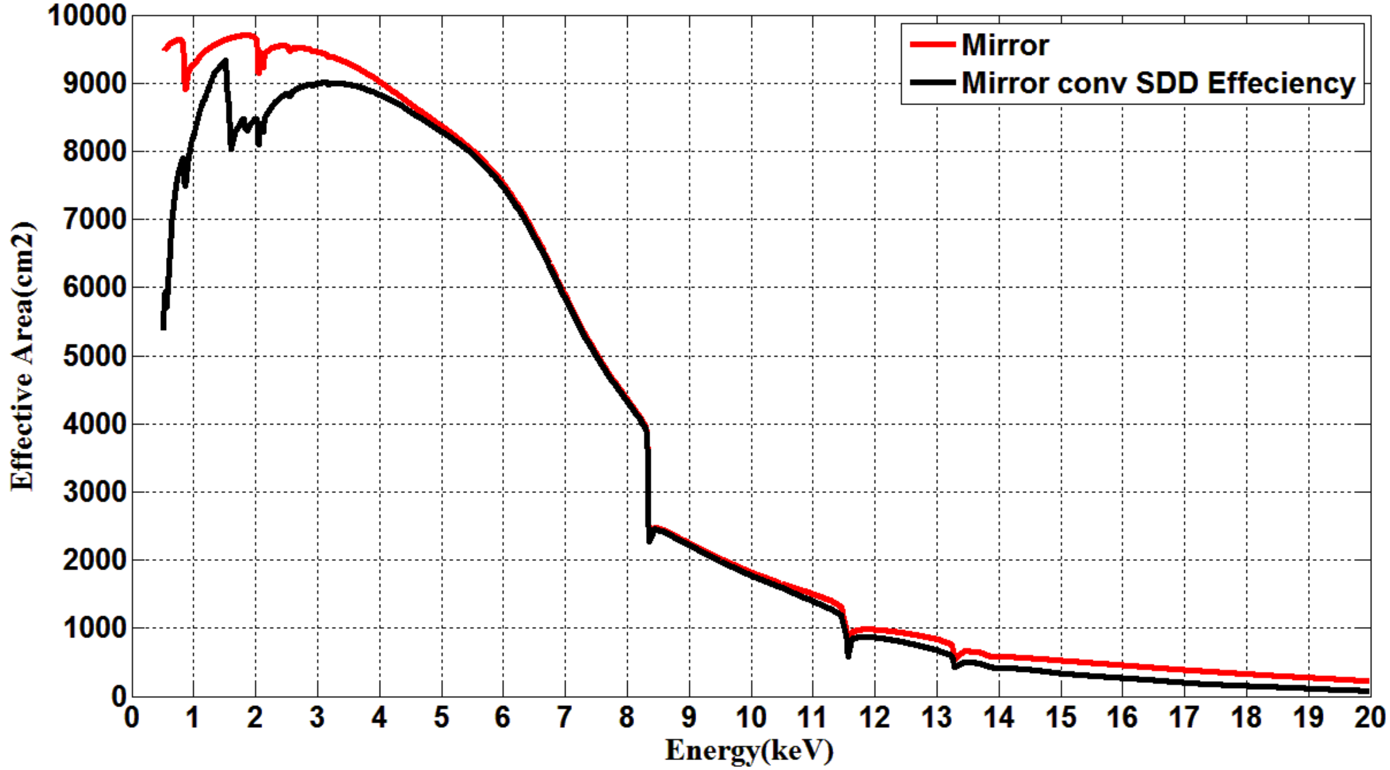




Detector	VX0033	VX0034	VX0043	VX0047	VX0049	VX0065	VX0070
FWHM(eV)	171.851	165.744	168.629	159.129	156.857	157.379	158.134

100mm^2 SDD detectors and the measured Fe-55 spectra. The typical resolution is 160eV@5.9 keV

Effective Area of SFA



Mirror effective collecting area、focal plane detector efficiency are taken into account. According to the new estimation of the sensitive area.

Background Estimation of SFA

Cosmic X-Ray Background through FOV

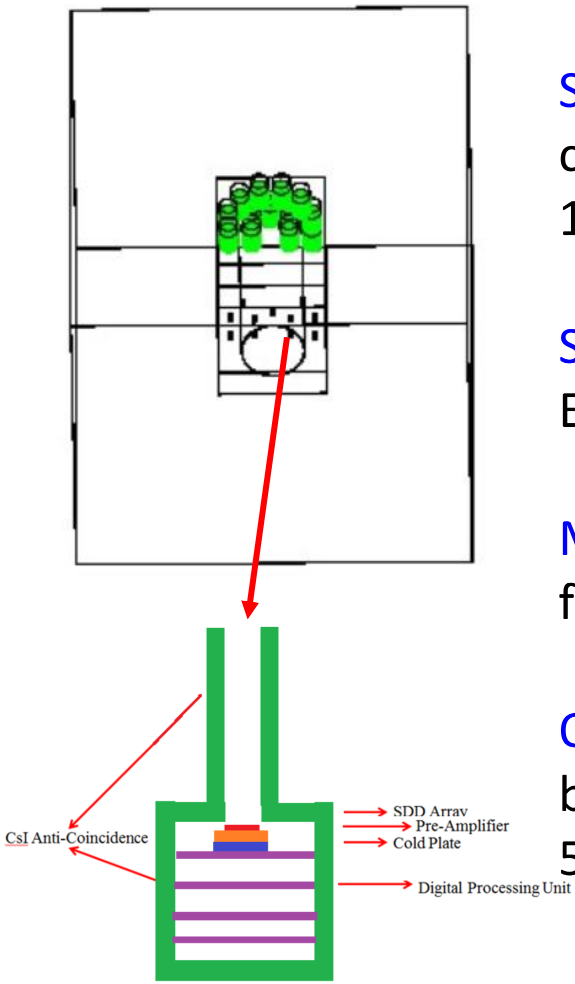
$$3\text{–}60\ \mathrm{keV}: 7.877E^{-0.29}e^{-E/41.13}\ \frac{\mathrm{keV}}{\mathrm{keV\ cm^2\ s\ sr}}$$

$$>60\ \mathrm{keV}: 0.0259\left(\frac{E}{60}\right)^{-5.5} + 0.504\left(\frac{E}{60}\right)^{-1.58}\ \frac{\mathrm{keV}}{\mathrm{keV\ cm^2\ s\ sr}} + 0.0288\left(\frac{E}{60}\right)^{-1.05}.$$

Gruber, D., et al., "*The Spectrum of Diffuse Cosmic Hard X-Rays Measured with HEAO 1*," ApJ, 520, 124 (1999)

Convolution of the CXB spectrum with mirror effective area 、solid angle of PSF and SFA efficiency gives the contribution of the CXB to the background of SFA.

Particle Background Level Estimate using Geant4



Mass Model

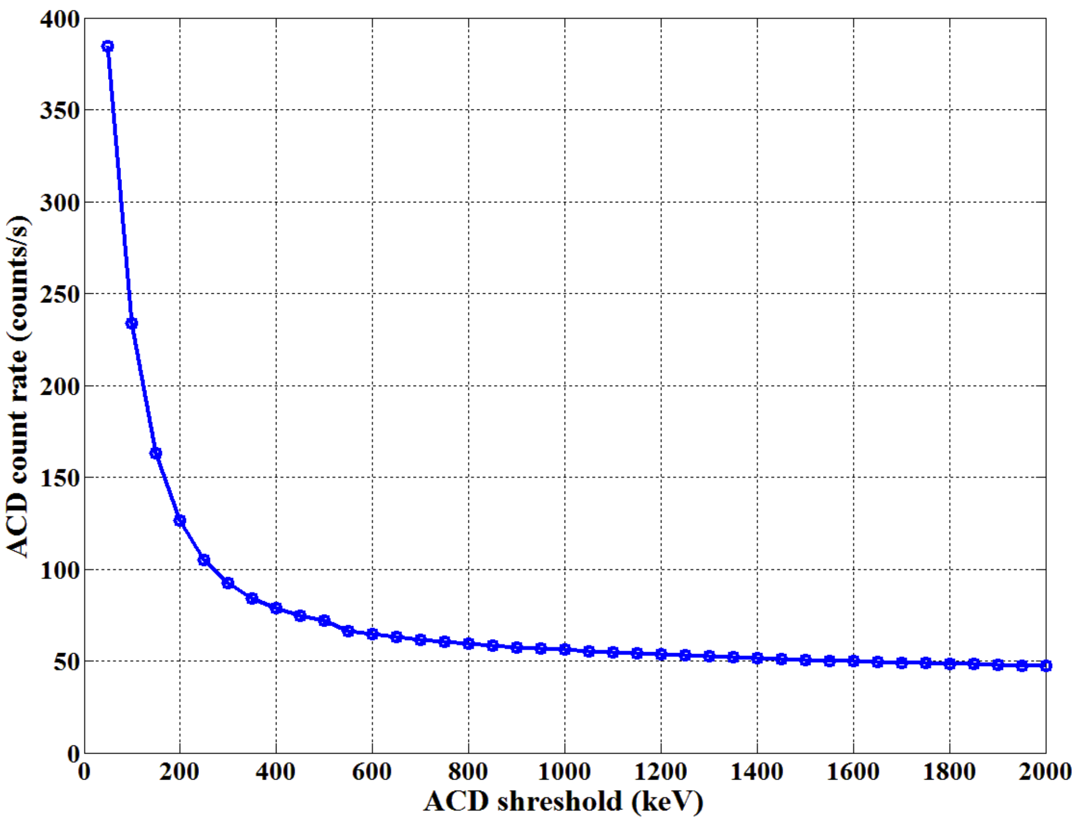
Satellite deck: Aluminum skin + Aluminum honeycomb core + Aluminum skin, Equivalent aluminum thickness 1mm

Satellite central support column: carbon fiber plate Equivalent thickness 5mm

Mirror and focal plane detectors support plate: carbon fiber plate Equivalent thickness 5cm

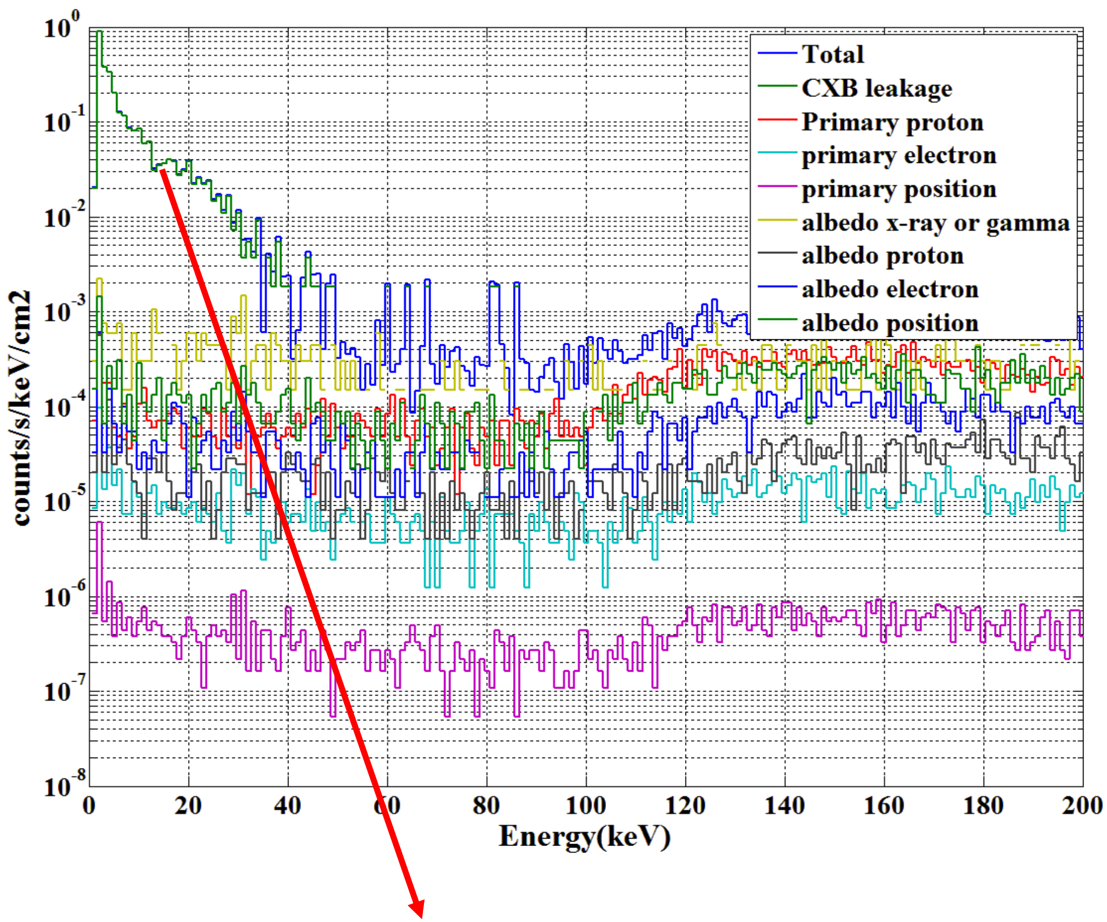
Others: Using 3m*3m*2cm Aluminum plane in the bottom to represent the platform components, about 500kg.

Particle Background Level Estimate using Geant4
(veto count rate versus threshold)



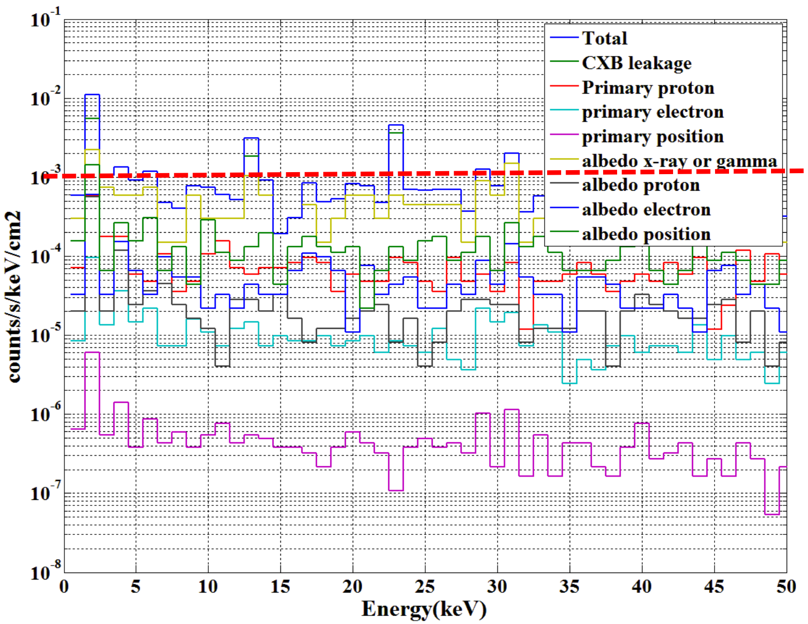
We choose a low energy threshold of 50 keV in the simulation

Particle+Leakage Background Level Estimate using Geant4

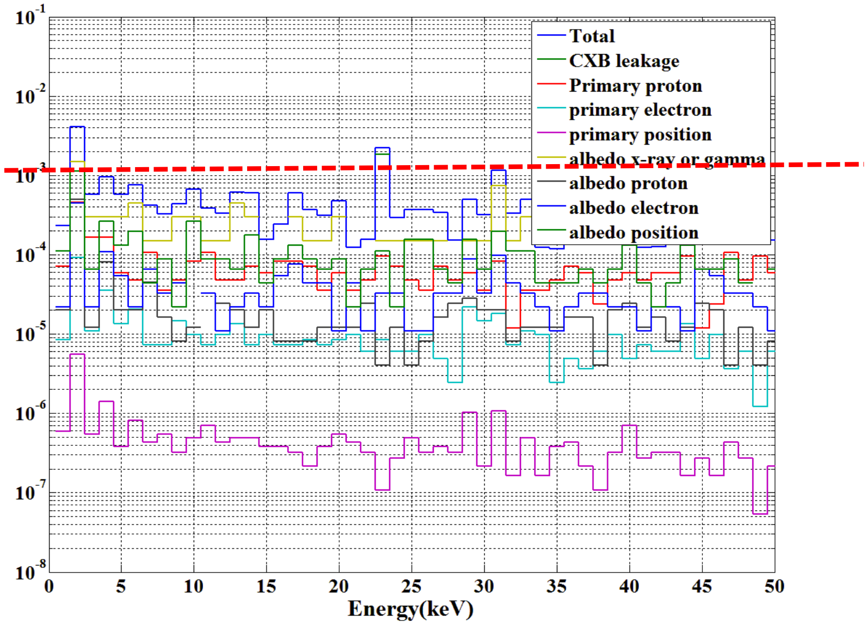


CXB leakage account for a larger proportion because of thin Satellite deck (1mm Al)。

Particle+Leakage Background Level Estimate using Geant4



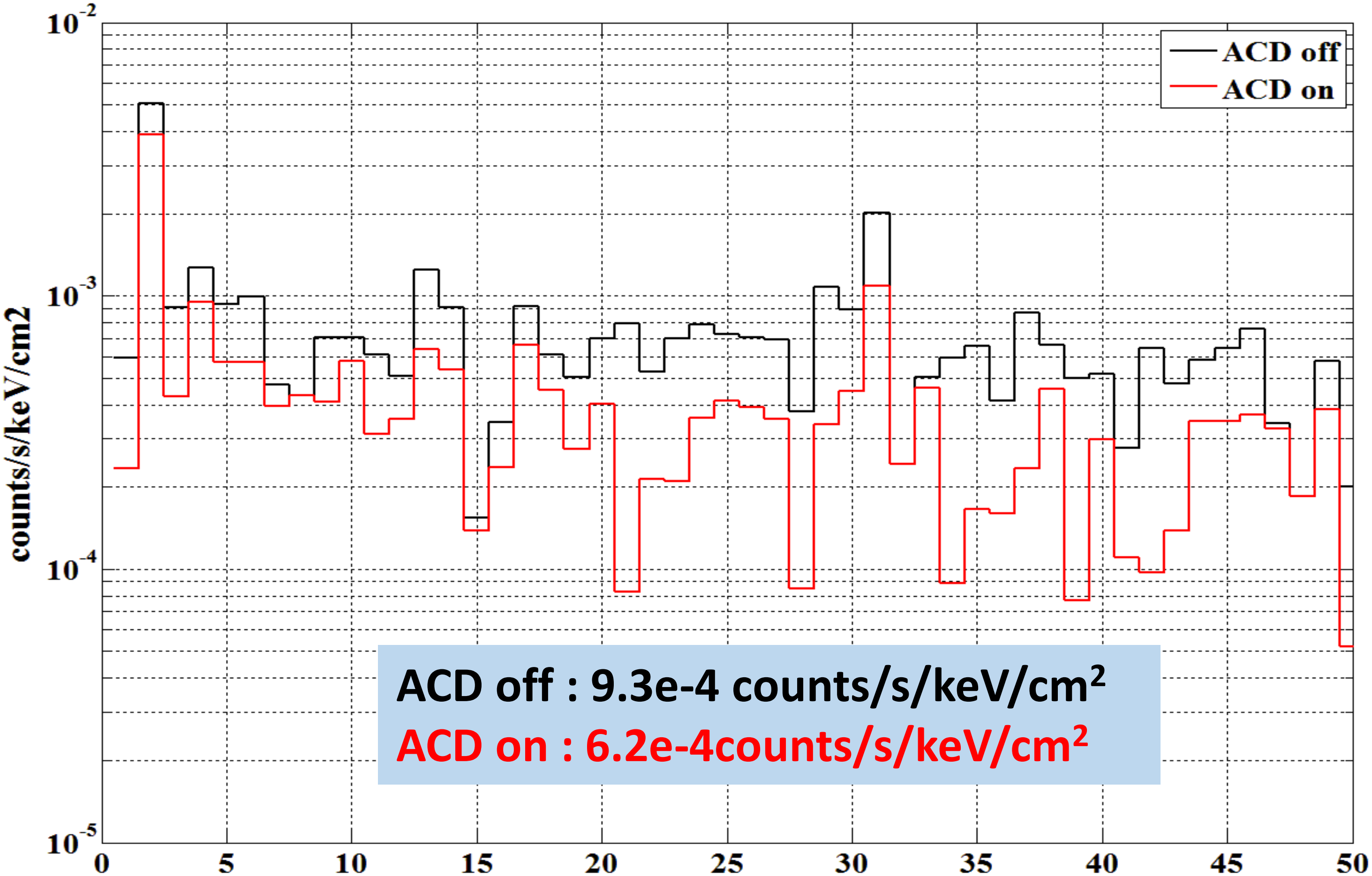
ACD off



ACD on (threshold 50keV)

If we set the thickness of the satellite deck as 2 cm, the contribution of the CXB leakage will be reduce to 2.0e-4coutns/s/keV/cm^2. So, if we put some passive shielding materials surrounding the focal plane detector, ACD may be not needed.

Particle Background Level Estimate using Geant4



Charged particle background level

Table 1. Background levels in CCDs, silicon drift detectors and microcalorimeters in different orbits.

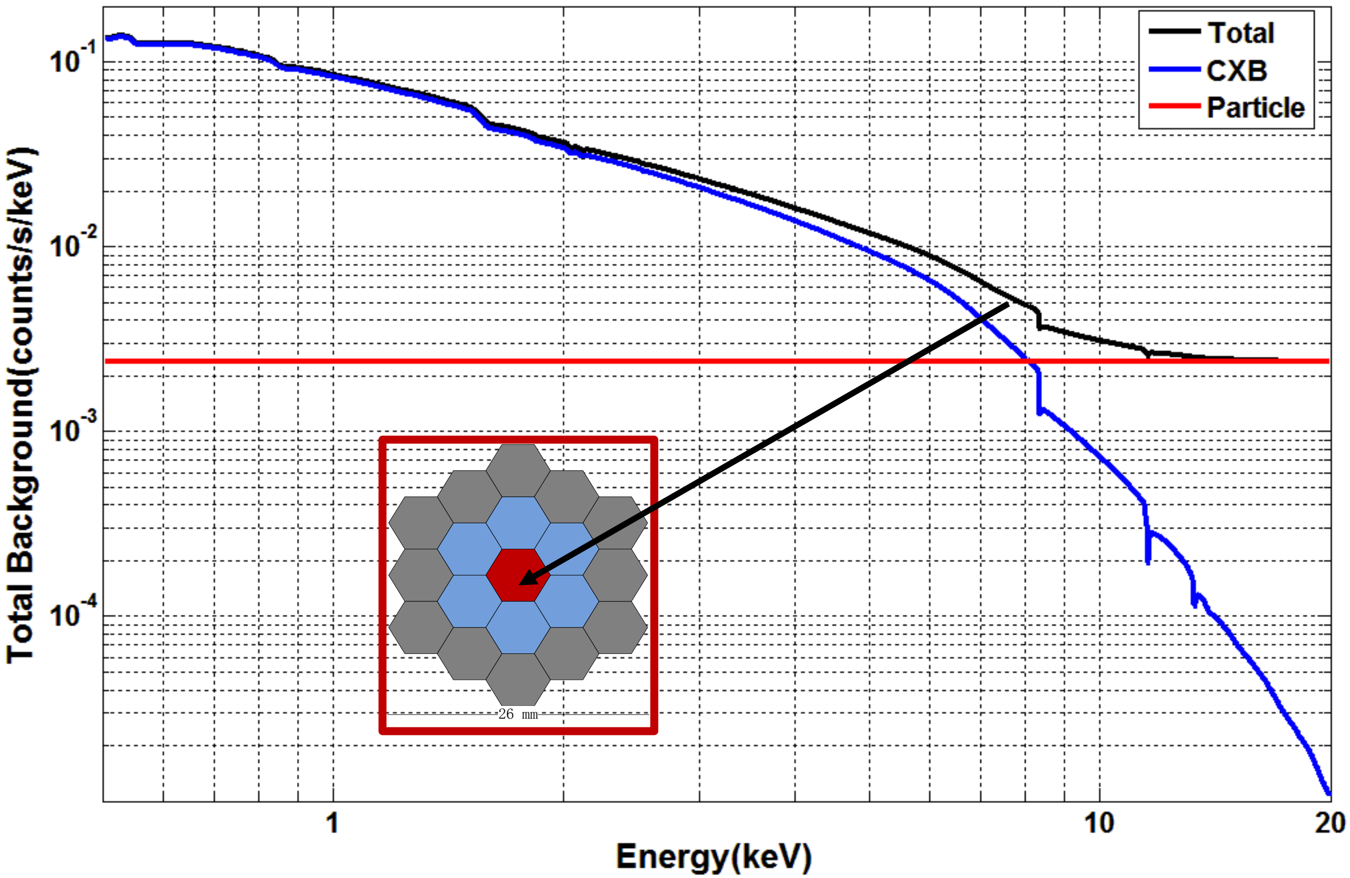
Total background in the energy range

Mission	Detector name	Detector type	Orbit	Background [cts cm^{-2} s^{-1}]
Suzaku	XIS	CCD (BI)	LEO	0.048
Suzaku	XIS	CCD (FI)	LEO	0.016
Suzaku	XRS	Microcalorimeters	LEO	0.05
Origin	X-IFU	Microcalorimeters	LEO	**0.043**
Simbol-X	LED*	Silicon drift	LEO	**0.002**
XMM	EPIC	pn-CCD (BI)	HEO	0.078
XMM	EPIC	MOS-CCD (FI)	HEO	0.026
SRG	eRosita*	CCD (BI)**	L2	**0.07**
ATHENA	X-IFU	Microcalorimeters	L2	**0.31**
ATHENA best	X-IFU*	Microcalorimeters	L2	**0.05**
IXO	WFI*	Silicon drift	L2	**0.01**

Notes. Data in bold are simulated. (*) Detector surrounded by an electron-shielding material. (**) Value obtained without pattern analysis.

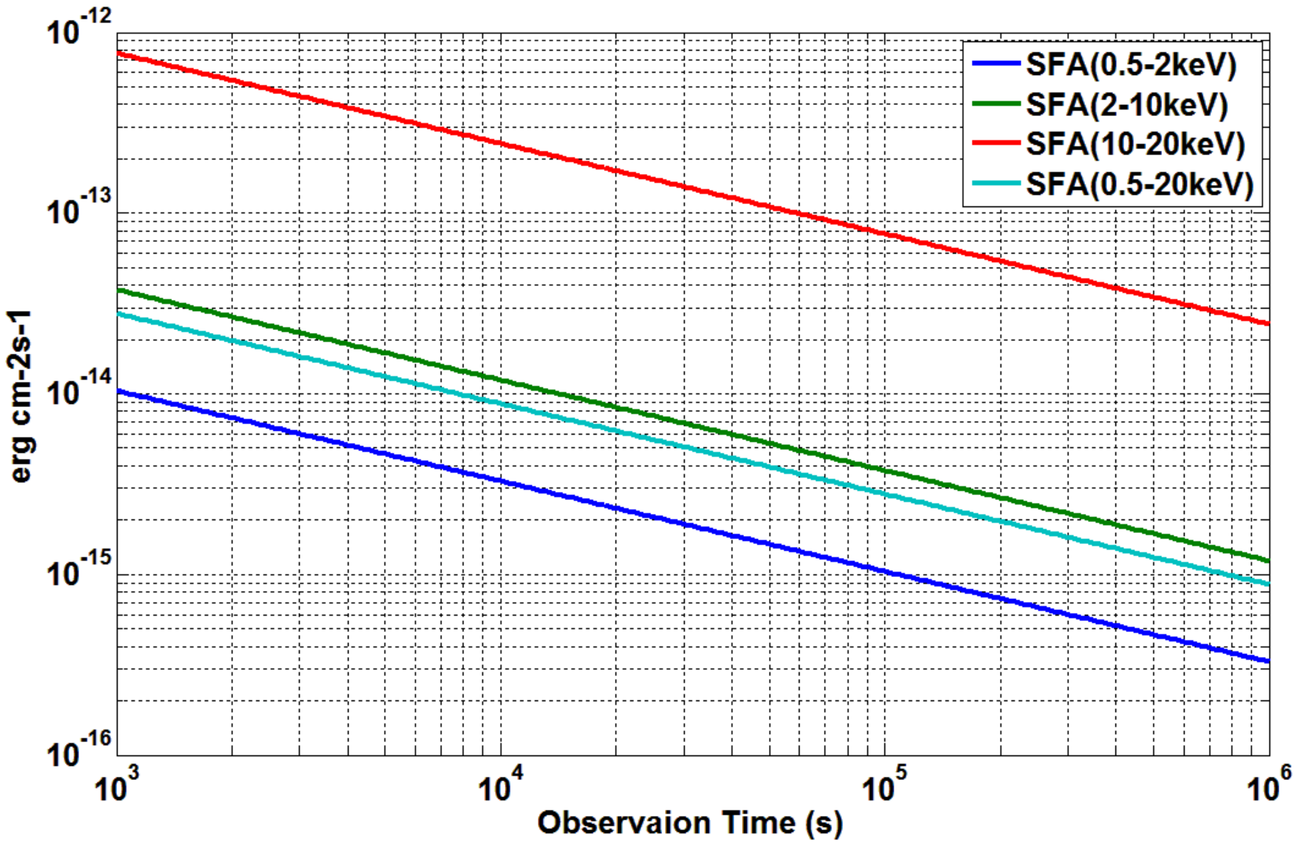
References. Lotti et al. (2012); Perinati et al. (2011); Lumb et al. (2002); Hauf et al. (2009); Kuntz et al. (2008).

S. Lotti, et al. In-orbit background of X-ray microcalorimeters and its effects on observations， A&A 569, A54 (2014)



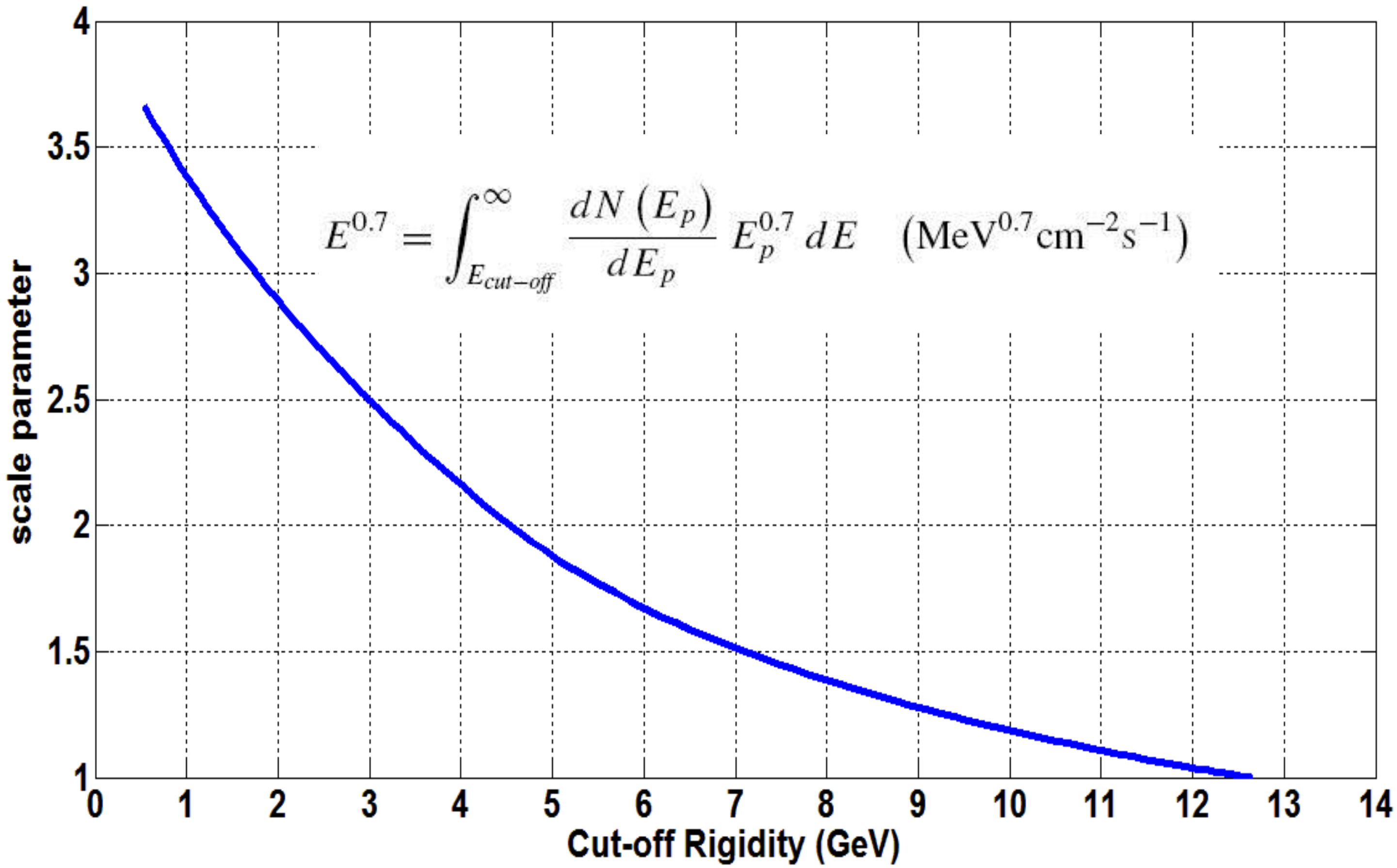
Total background of SFA observations of point-like sources.

(Detector pixel size (26.6mm^2) is comparable with the size of PSF (W90), if HPD is 1')



SFA point source sensitivities（5σ， HPD=1′, pixel area= 26.6mm2 ） versus observation time in different energy bands.

Impact of orbit inclination on particle background



$$E^{0.7} = \int_{E_{cut-off}}^{\infty} \frac{dN(E_p)}{dE_p} E_p^{0.7}\, dE \quad (\mathrm{MeV}^{0.7}\mathrm{cm}^{-2}\mathrm{s}^{-1})$$

Empirical formula from DEAN et al. SSR, 105, 285 (2003)

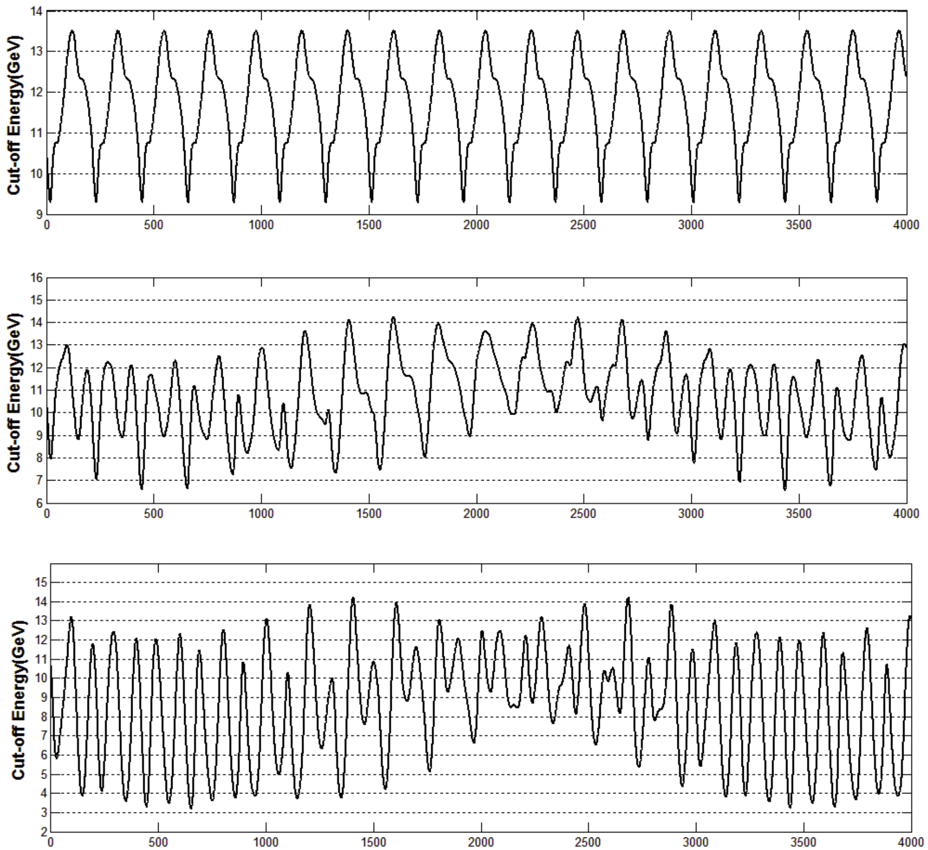
Inclination

Particle background scale parameter

0 deg — 1~1.2

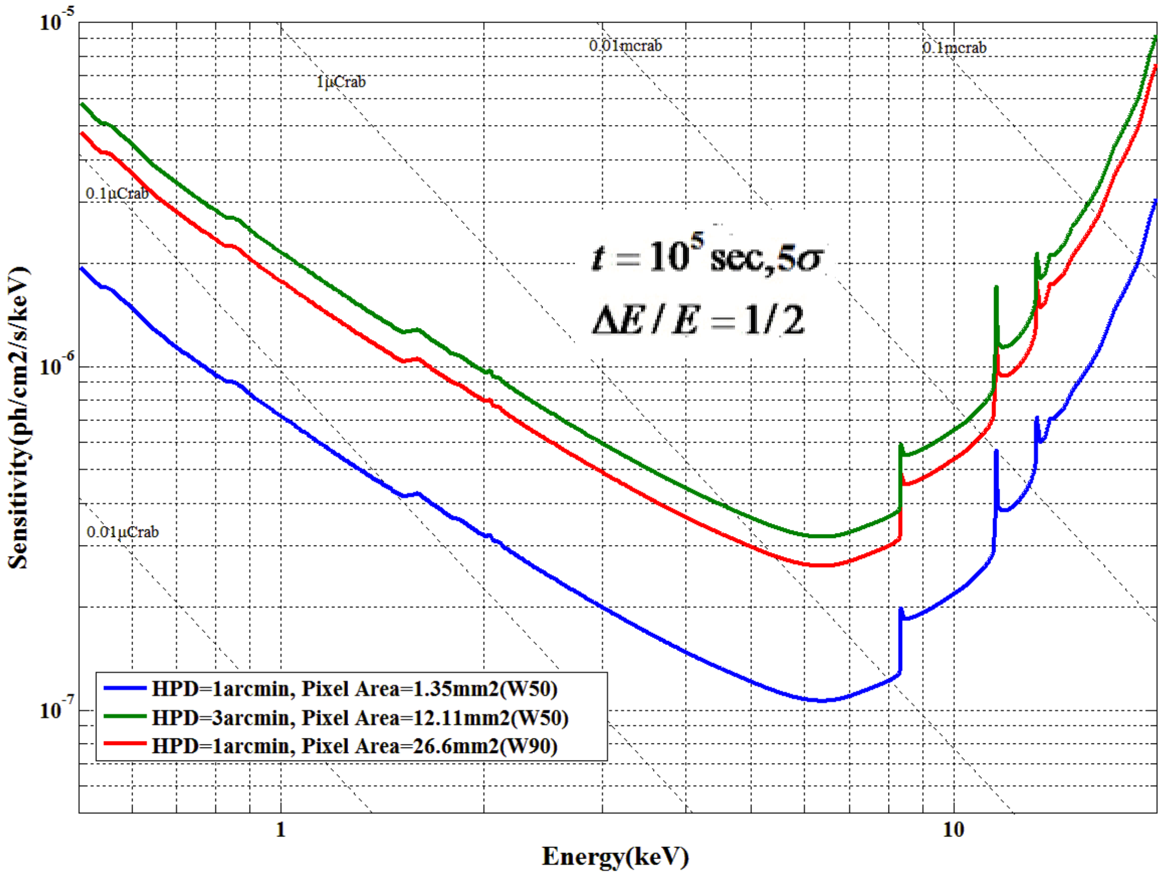
15deg — 1~1.5

30deg — 1~2.5



Cut-off Rigidity Energy In Orbit

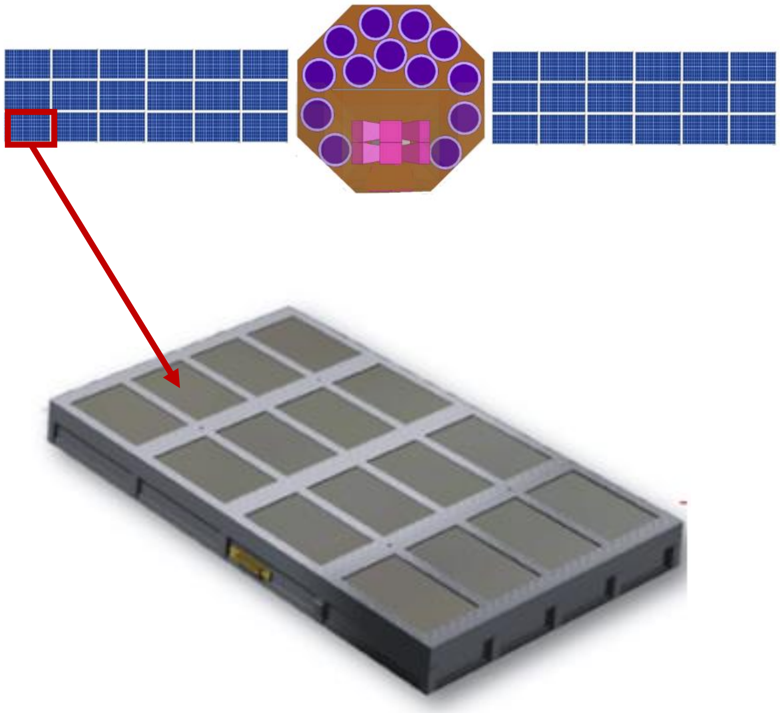
The higher the inclination angle the larger the background variation amplitude and the higher the mean particle background. When the inclination angle changes from 0 to 15 degrees, the mean particle background increases by 10%; and from 0 to 30 degrees, the particle background increases by 30%.

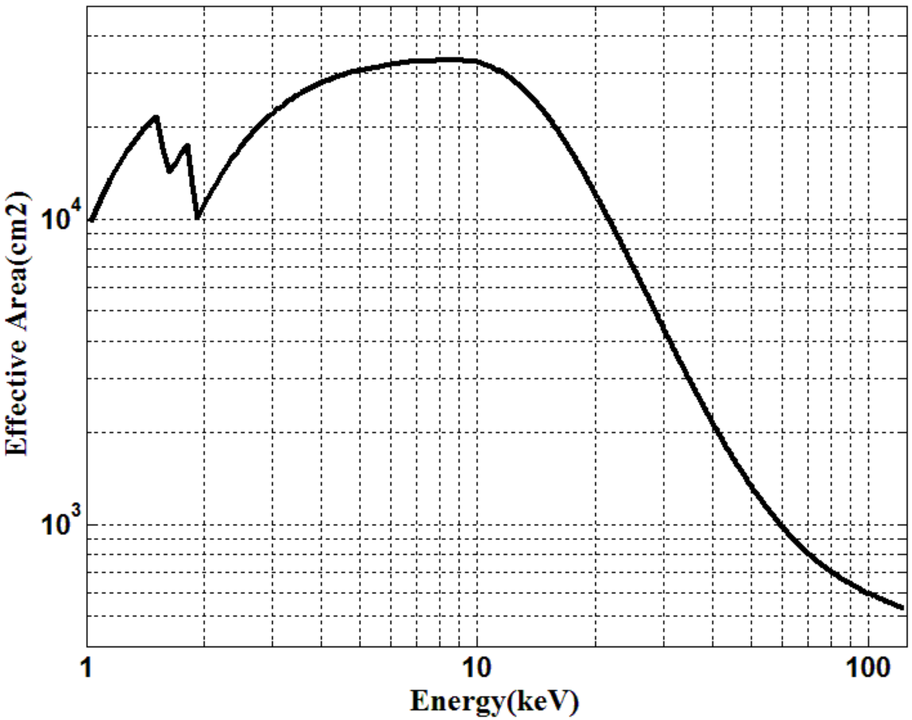


Continuum sensitivities of SFA with different PSF widths and pixel sizes, using the events in the central 50% only.

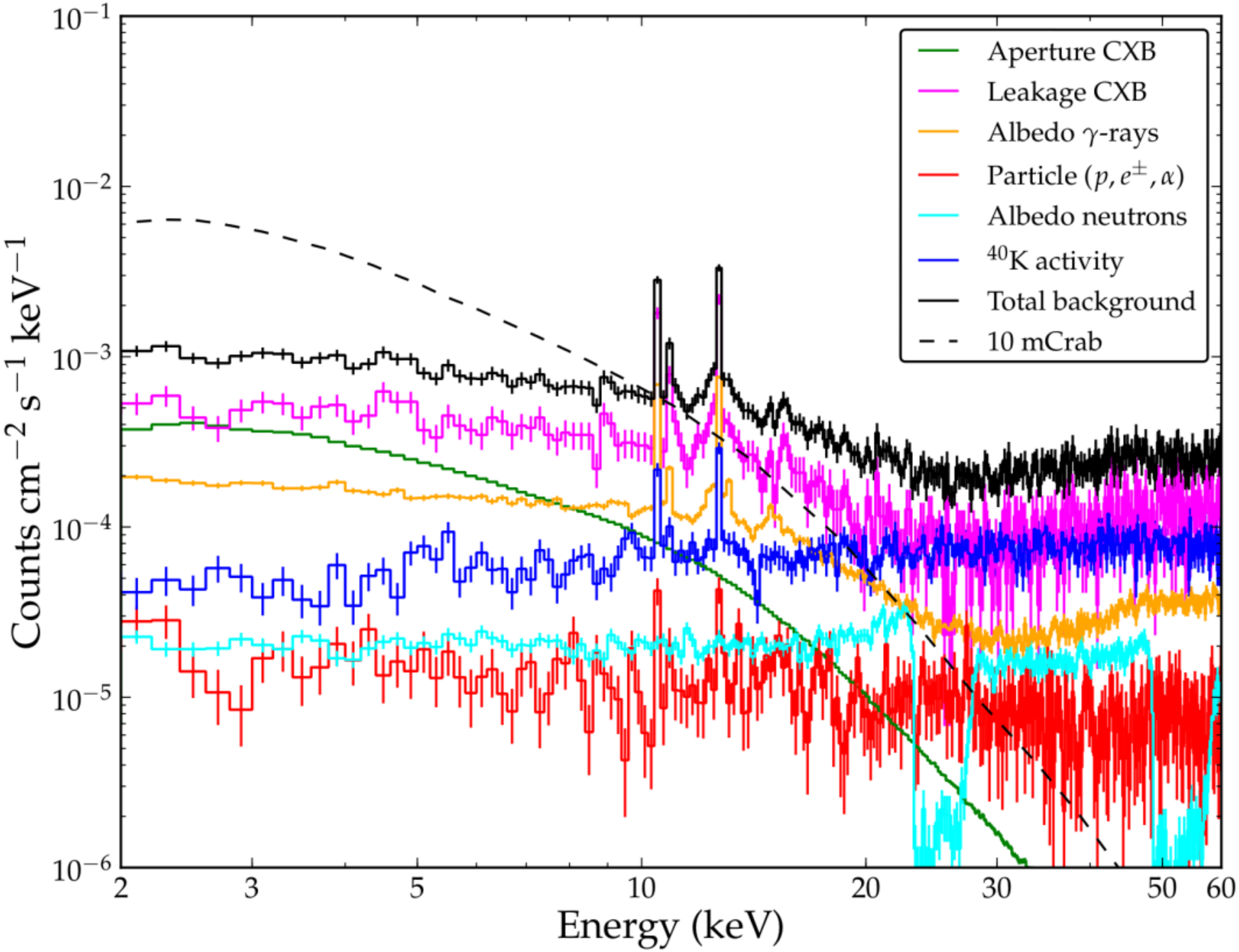
The W90 area of PSF with HPD=1' is comparable to 26.6mm^2. Therefore, with this PSF width, the sensitivity will be almost the same even with much smaller pixel size, if all the events within W90 are used.

Configuration of LAD





LAD will have an effective area of about 33800 cm^2.



Simulated in-orbit background of LOFT/LAD(inclination 5deg)

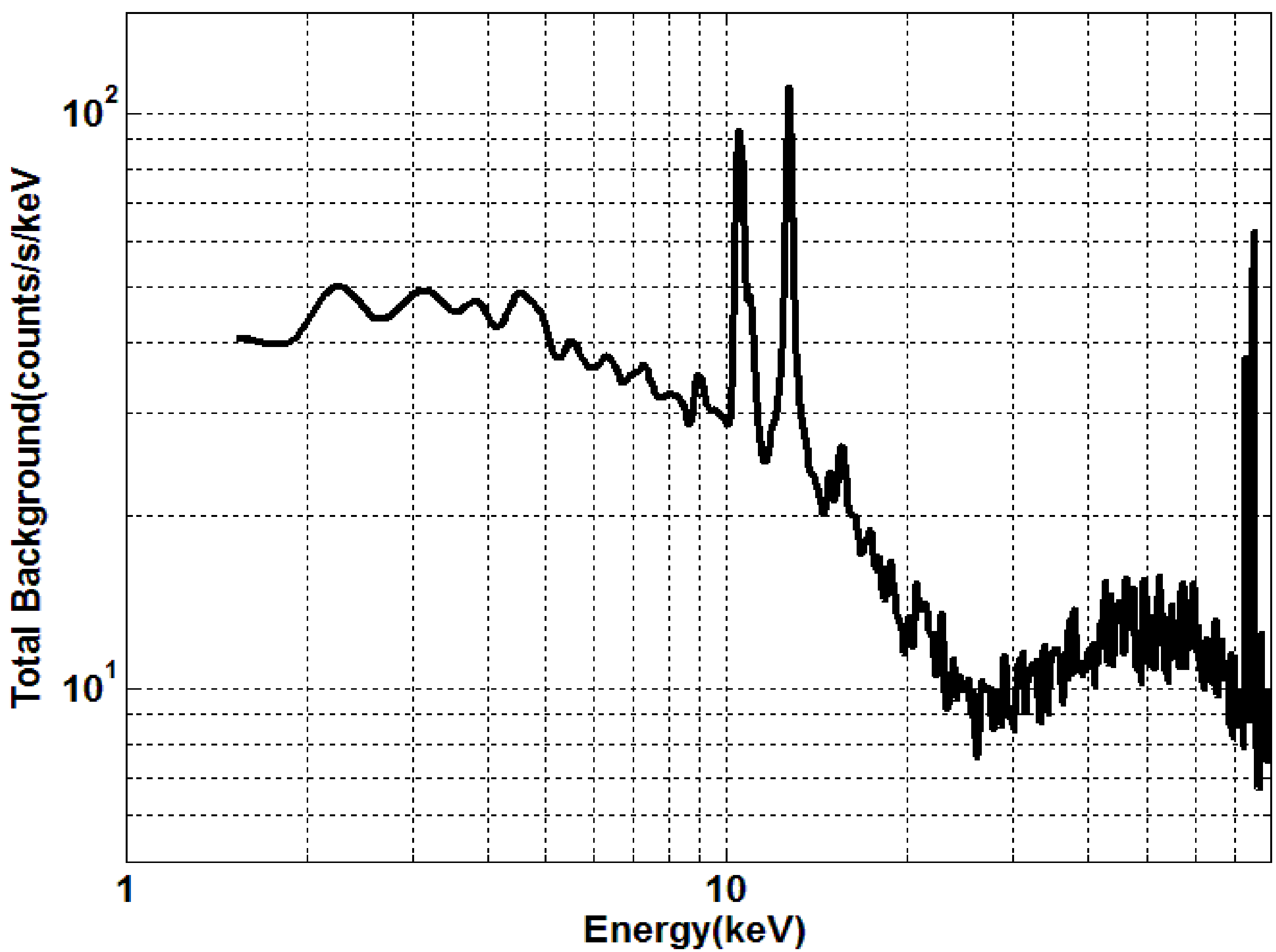
Campana, R. Exp Astron (2013) 36:451–477

Pb *L*-shell lines at 10.55 and 12.61 keV of the collimator glass

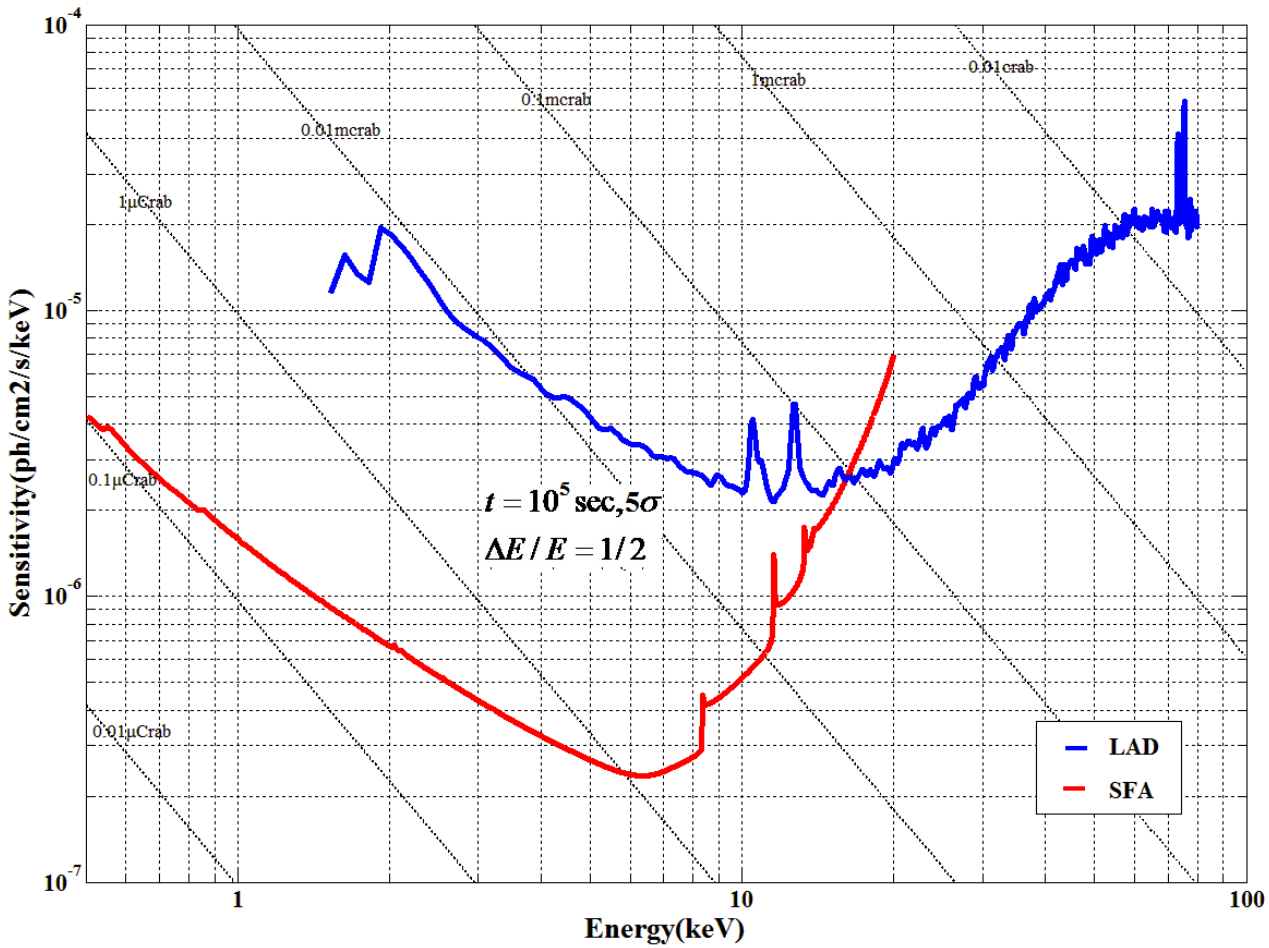
Tabel The LAD background contributions. The last line shows the LAD requirement for the total background level in the 2–30 keV band

Contribution	counts cm^{-2} s^{-1}	Percentage
	2–30 keV	2–30 keV
Aperture CXB	1.9×10^{-3}	13 %
CXB-induced	7.4×10^{-3}	51 %
Earth albedo γ-rays	2.8×10^{-3}	19 %
Earth albedo neutrons	5.0×10^{-4}	2.5 %
Cosmic-ray particles	3.6×10^{-4}	3.5 %
^{40}K activity	2.0×10^{-3}	14 %
Total background	1.4×10^{-2}	100 %
Requirement	1.6×10^{-2}	–

The inclination only impacts on albedo and cosmic-ray particle components, their total percentage is 25%。 For inclination from 5deg to 30deg, even if these components doubled, total background increase less than 25%.



Total background of eXTP/LAD scaled from LOFT/LAD



$$F_{\min} = n_\sigma \cdot \frac{\sqrt{B \cdot A_{\det}}}{\varepsilon \cdot \eta \cdot A_{eff} \cdot \sqrt{T_{\text{int}} \cdot \Delta E}}$$

Continuum sensitivity curves of SFA（26.6mm^2 SDD pixel） and LAD.

Conclusion and suggestions

- The pixel size($26.6 mm^2$) of the SFA detector is comparable with the size of the optics focal spot (W90), if HPD is 1'. We suggest such a pixel size to reduce the complexity of the readout electronics for smaller pixel sizes.
- The simulation results show that , the charged particle induced background is about 9.0e-4 count/s/keV/cm^2 in energy range 0.5~20keV, and the ACD detector can reduce the charged particle induced background by ~30%. If the focal plane detector is shielded with materials equivalent to 2cm thick Al, the CXB leakage can be reduced to 2.0e-4 count/s/keV/cm^2 .
- If the orbit inclination angle changes from 0 to 30 degree, the mean particle background will increase by 30%, and the total background will increase by 7%. However, considering that a lower inclination angle gives a more stable particle background, and the satellite will not pass the SAA region, a low inclination angle is desired.
- The continuum sensitivity of SFA is about 1 uCrab (@6keV) and that for LAD is about 0.02 mCrab.