Hard X-ray Imager (HXI) for the IXO mission

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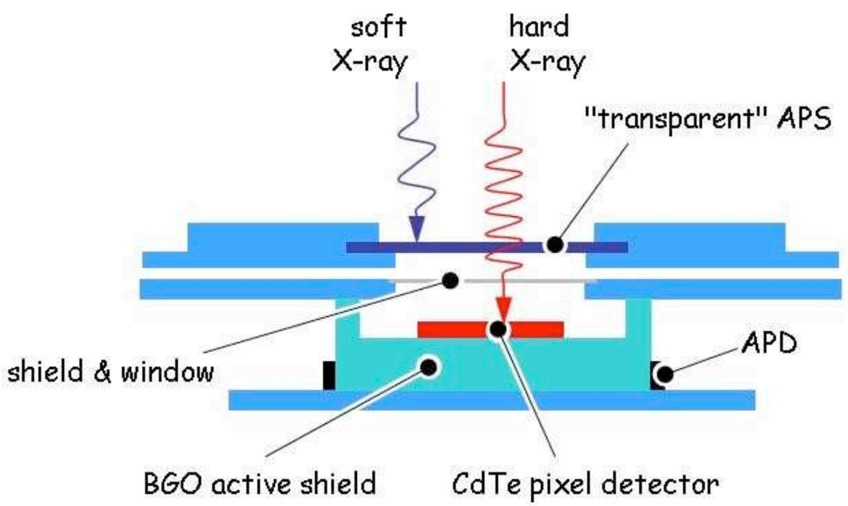
Onboard Configuration of WFI+HXI

IXO HXI

"High energy extension for the non-thermal regime science"



Requirements

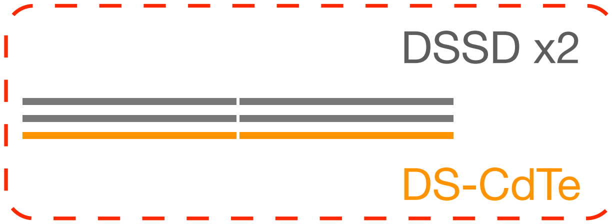
Efficiency : ~100% up to 40 keV
Energy resolution : < 1 keV (FWHM)
FOV: similar to WFI (~14')
Position resolution : 1-3 arcsec (for 10-30" HPD)
Counting rate : 1 Crab /w <10% dead-time
Background : ~5 x 10^{-4} c/s/keV/cm^2

Constraints for the I/F with WFI

Gap between the focal plane of WFI and surface of HXI should be smaller than 30 mm, which corresponds to the image defocus of ~10 arcsec.
Heat exchange onto WFI should be small (1-2W).

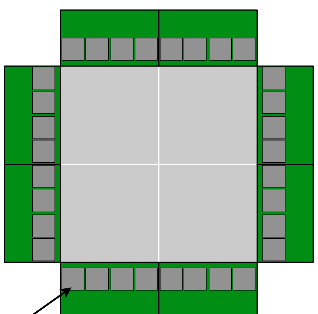
HXI detector design

Based on the latest design of Hard X-ray Imager onboard ASTRO-H.



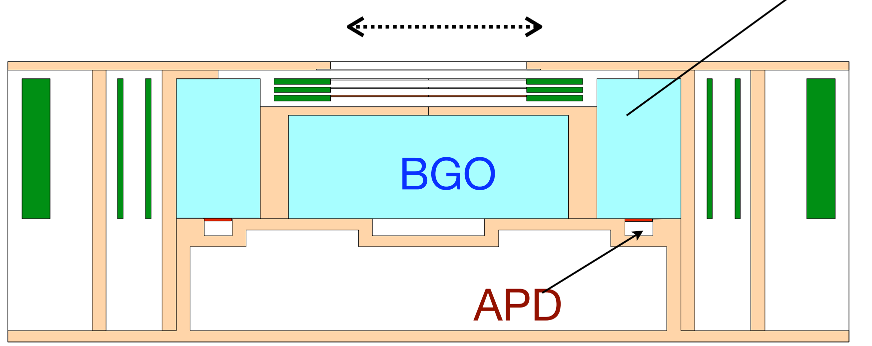
Main detection part consists of 2-layers of Double-Sided Silicon Strip (DSSD) and 1 layer of Double-sided CdTe strip (DS-CdTe). Each layer contains 2x2 devices.

Top-view
(imager part)



Readout ASICs are directly coupled with devices within the same plate.

Cross-section-view



Active shield :
2 cm thick BGO
(default)

Total Weight : 24 kg
Total Power : ~32W

(including electronics)

Heritage from
Suzaku-HXD

Current Design Parameters

IXO HXI

Characteristics	Hard X-ray Imager
Detector Type	Si and CdTe Schottky Diode double sided strip
Strip pitch	220 um (for both side) (~2.3" @ FL20m)
Number of strips/channel	320 (for both side) total 640 strips, 1280 ch for CdTe only. With 2 DSSDs and a DS-CdTe, total of 1920 strips, 3840 ch.
Array Size (mm^2)	70 × 70
Field of View	12 × 12 $arcmin^2$
Energy range	10-80 keV
Energy Resolution	< 1 keV(FWHM)
Non X-Ray Background	5×10^{-4} $counts/s/keV/cm^2$ roughly flat (based on Suzaku)
Count rate/source with 10% pile-up	20k (counts/sec) for each strip
Timing accuracy	< 10 us
Typical/ Max telemetry	11 kbps / 1 Mbps (above 10 keV)
Operating Temperature	Detector -20 ± 5 °C (Minimum temperature -40 °C)
Total Mass	24 kg
Total Power	32 W (in operation)

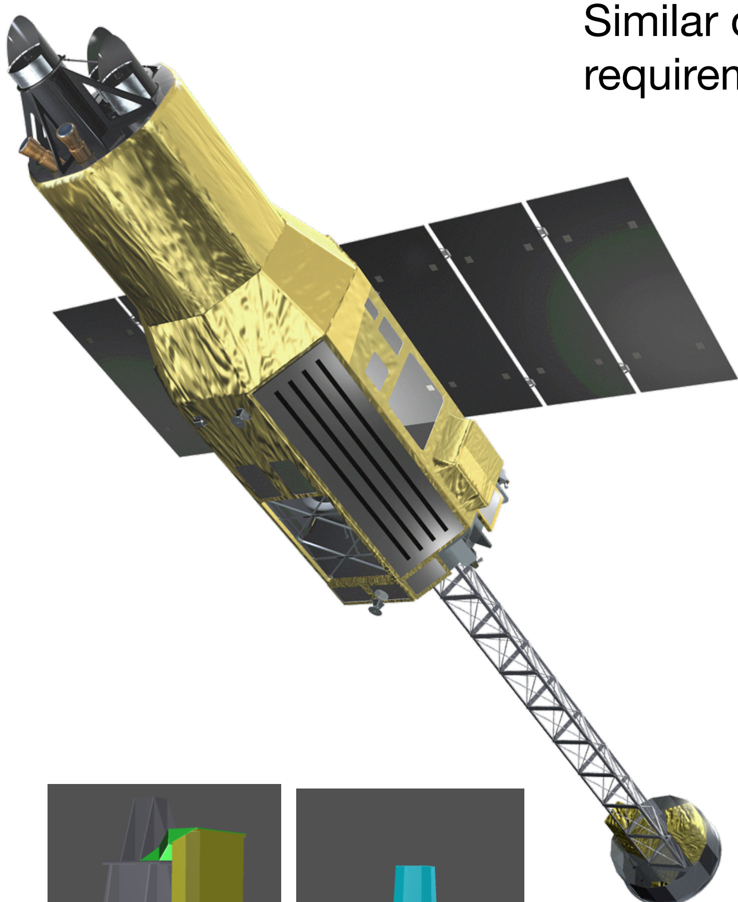
(As of 2009-01-27)

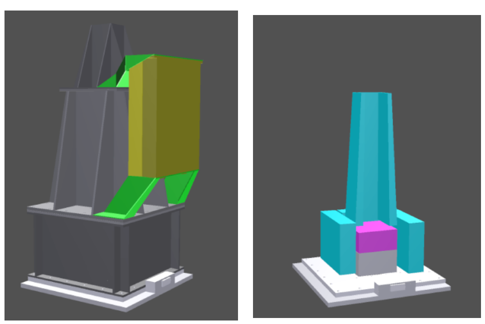
HXI onboard ASTRO-H

IXO HXI

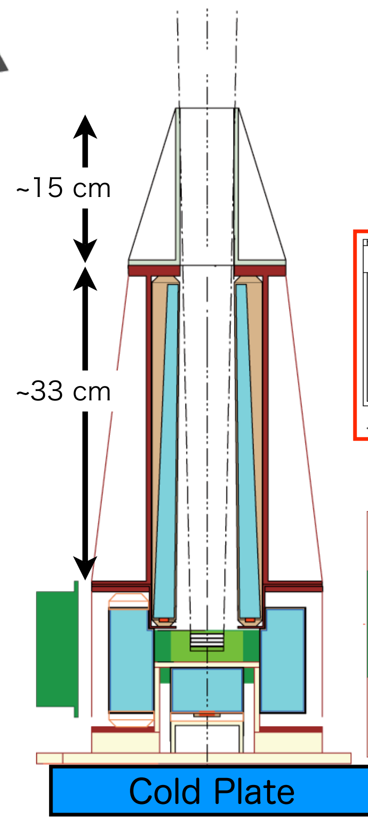
Similar design parameters derived from similar scientific requirements, except the following differences;

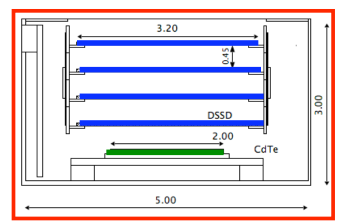
- 4 layers of DSSD + 1 layer of DS-CdTe
- Layer size 32x32 mm^2
- Fully shielded with BGO scintillators (4cm thick)

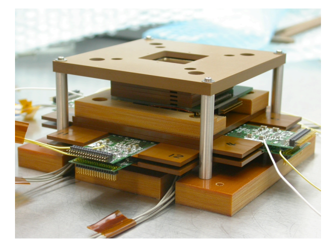


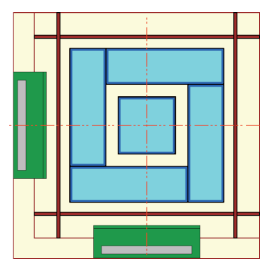


(c) MHI



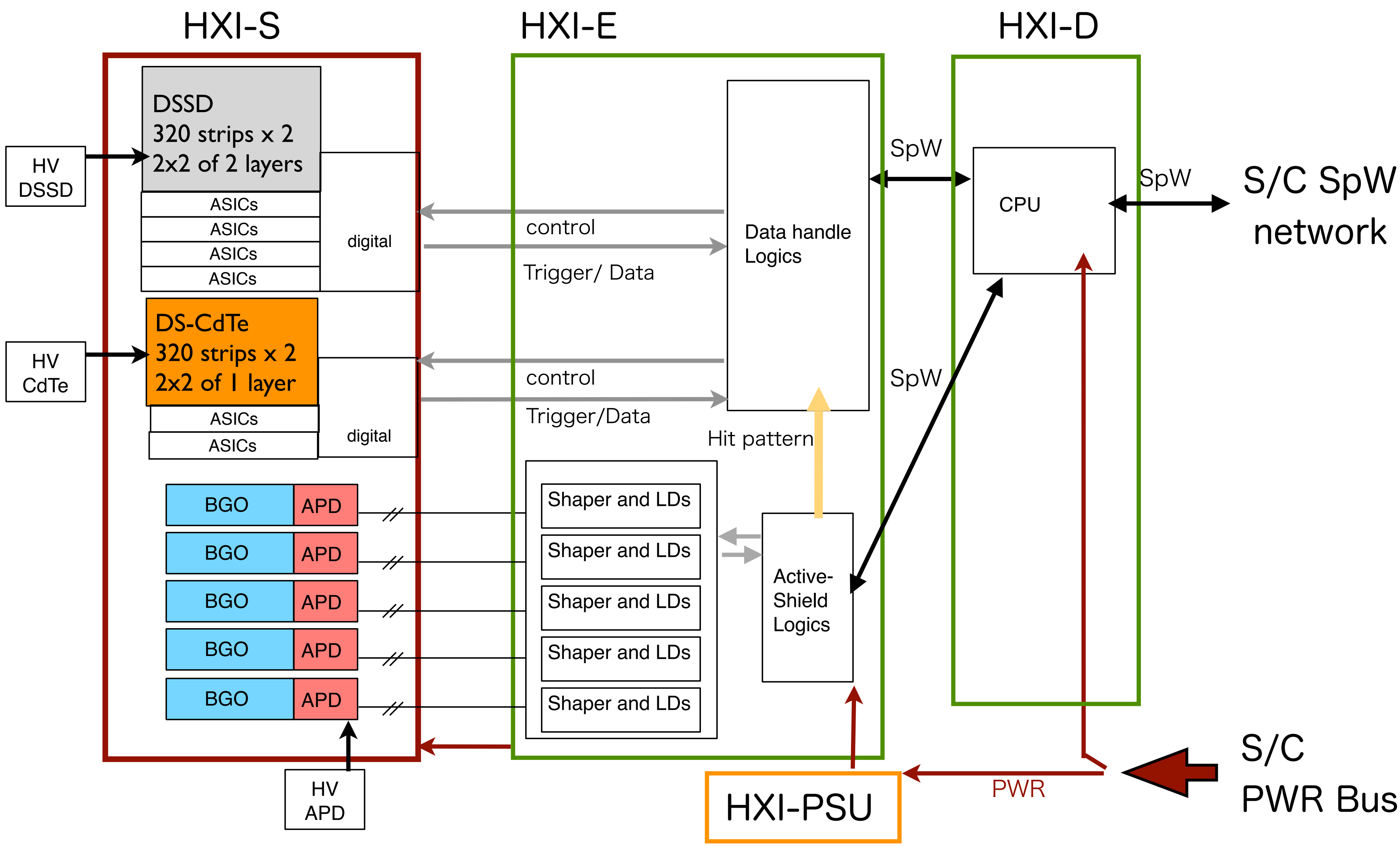




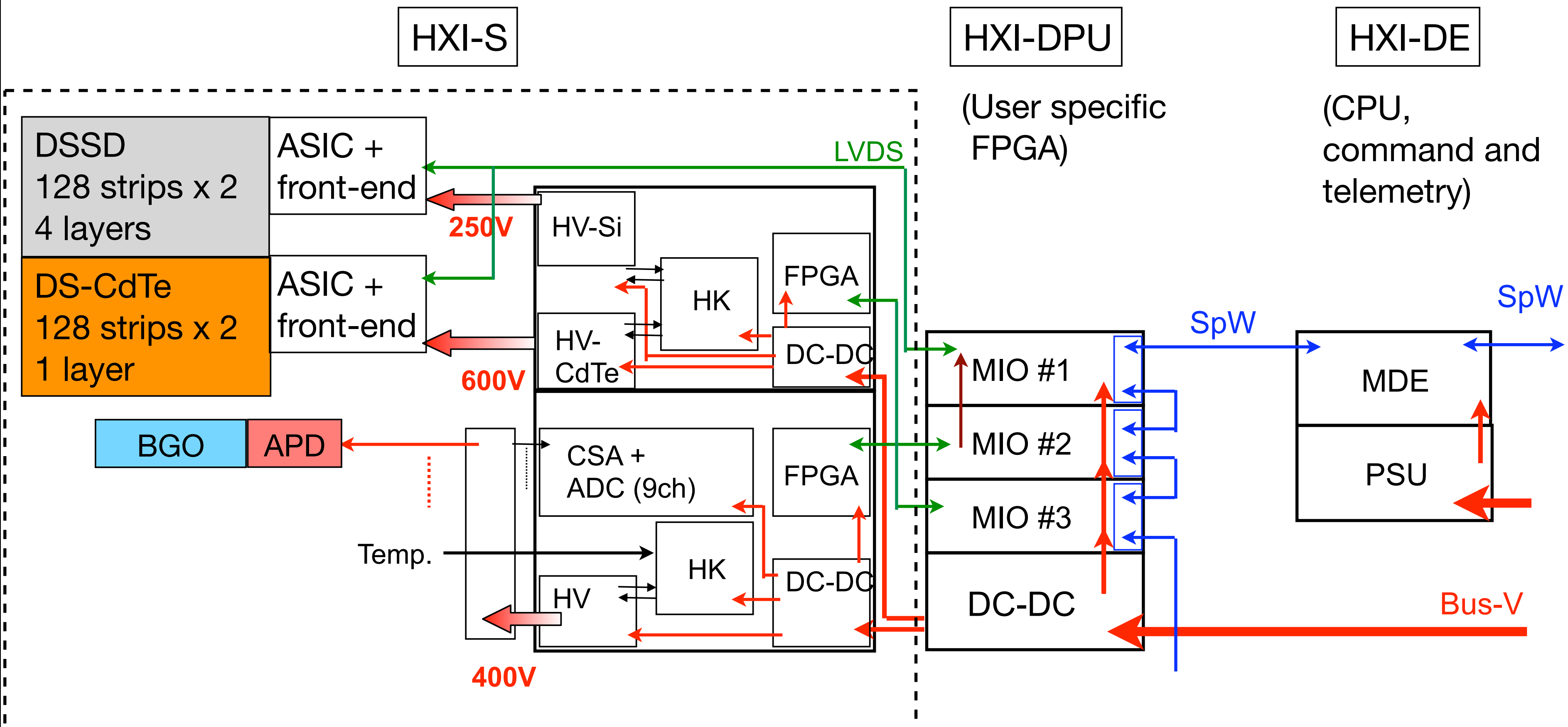


DSSD (0.5mm x 4)
+ DS-CdTe (0.5mm)

IXO-HXI block diagram (in PDD v5)



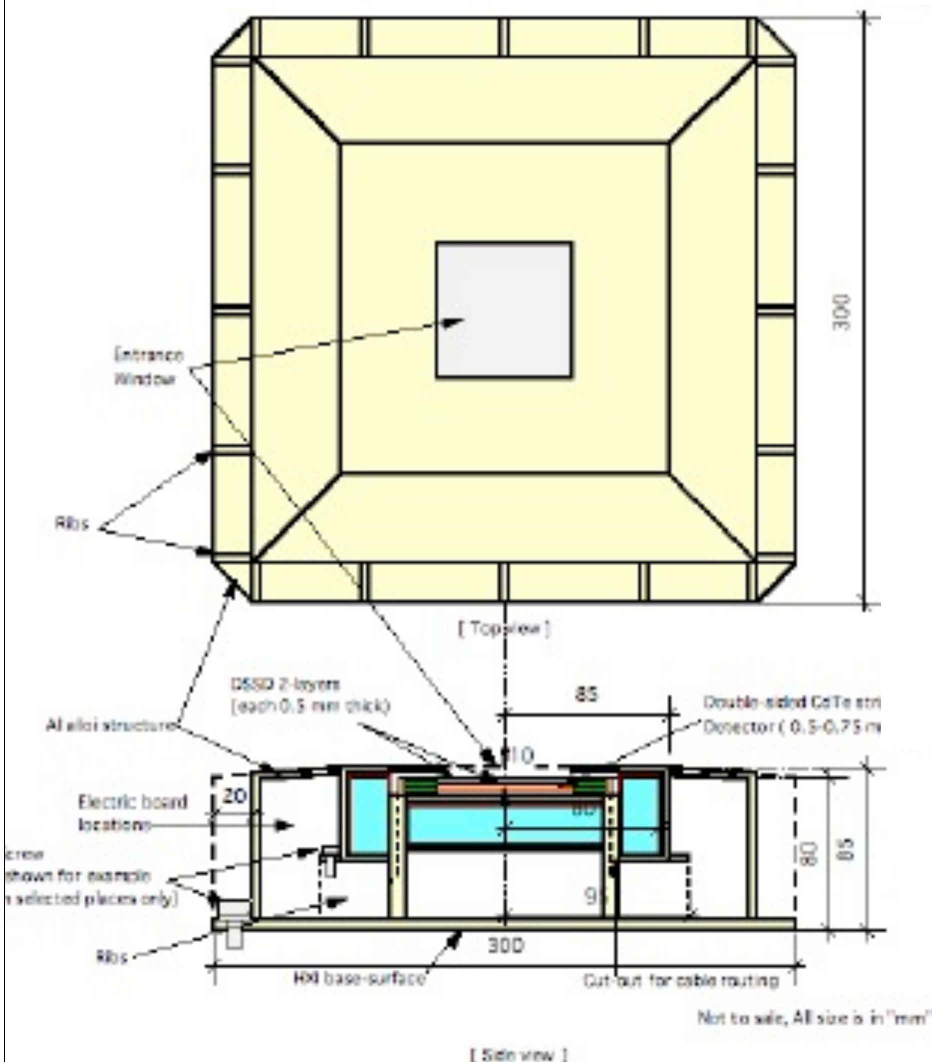
Block Diagram of ASTRO-H/HXI

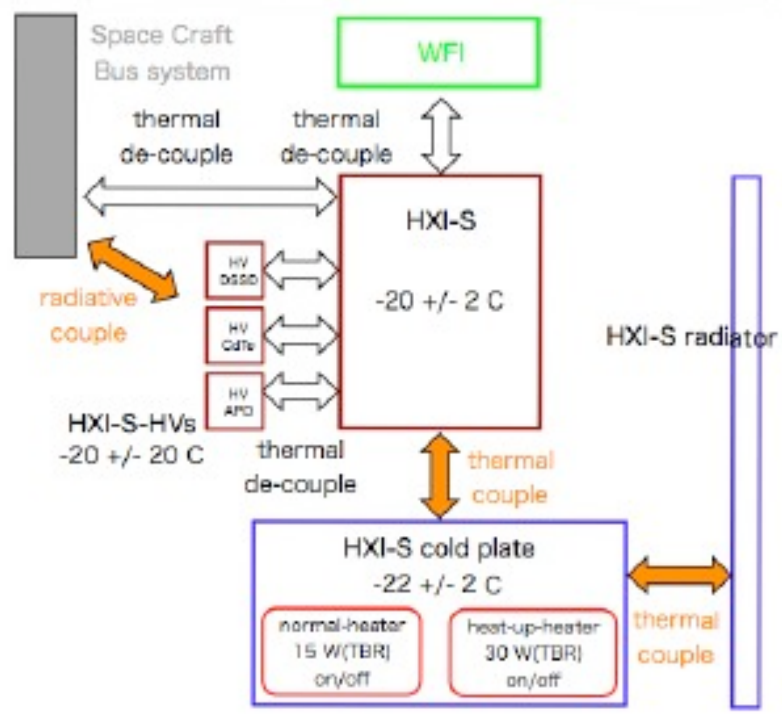


Analog part of electronics is "attached" as an extension box to HXI-S. Sensor readout is divided into two parts, main detection part (DSSD/CdTe) and shield part (APD). HK data like temperature and monitor voltage is also processed in this part.

Digital processing part consists of user-customized FPGA part using a standard I/O boards and CPU board, communicating via SpW with each other.

Mechanical/Thermal Design

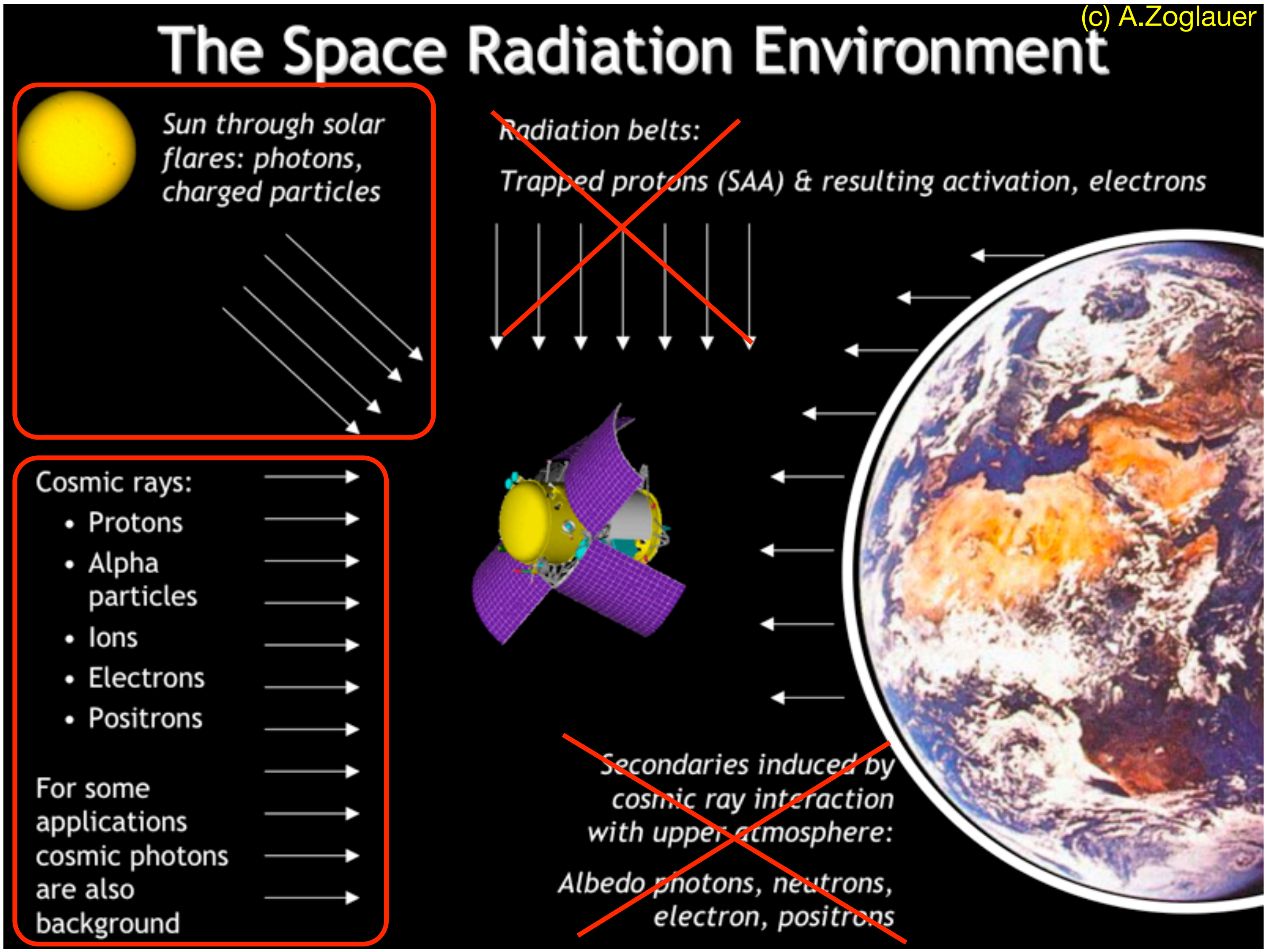




A housing structure made of CFRP will provide a sufficient mechanical strength. Temperature is controlled by a “cold plate” which is thermally coupled to the radiator and can be warmed with built-in heaters.

Radiation Environment at L2

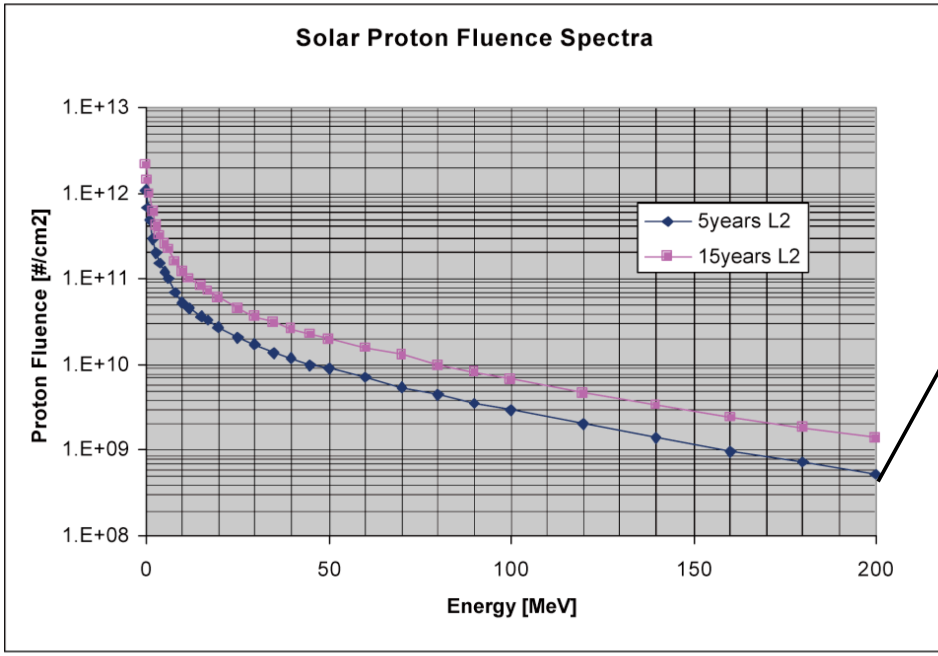
IXO HXI



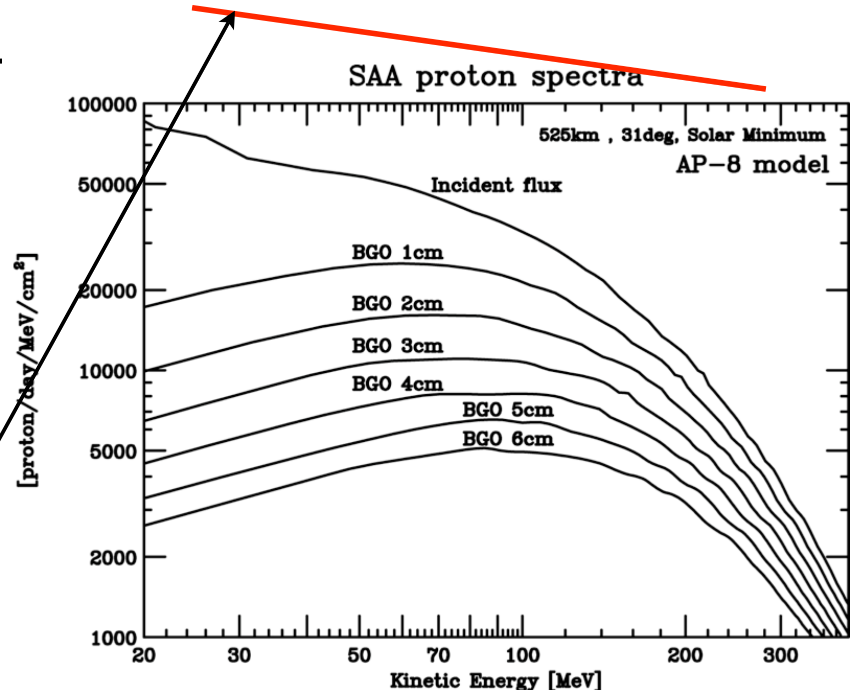
Radiation Environment at L2

IXO HXI

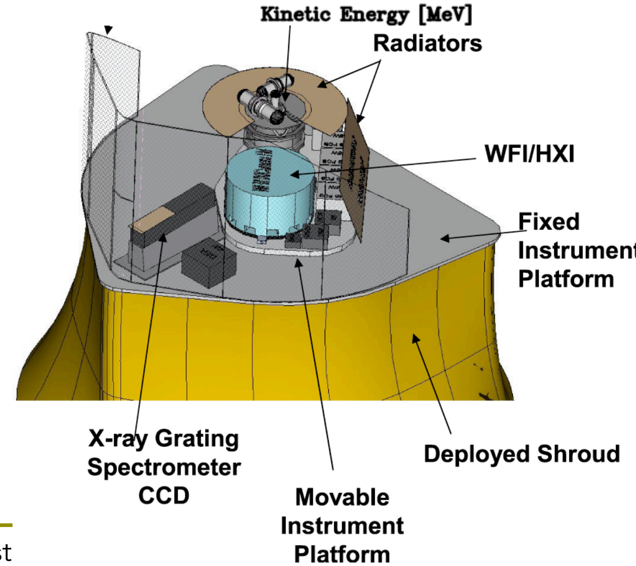
Solar Proton becomes the dominant component.



From "Xeus Environmental Specification" (Issue 1.0)



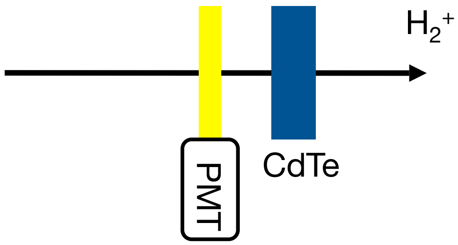
Since the coming direction of solar particles is known, a thick passive shield on the Sun direction would efficiently act as an absorber.

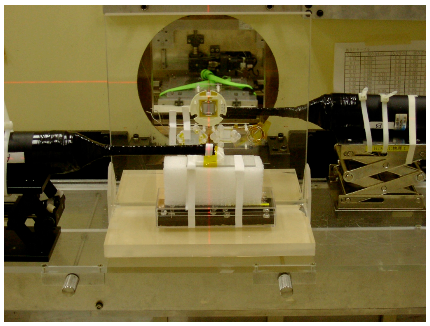


Background Simulation

IXO HXI

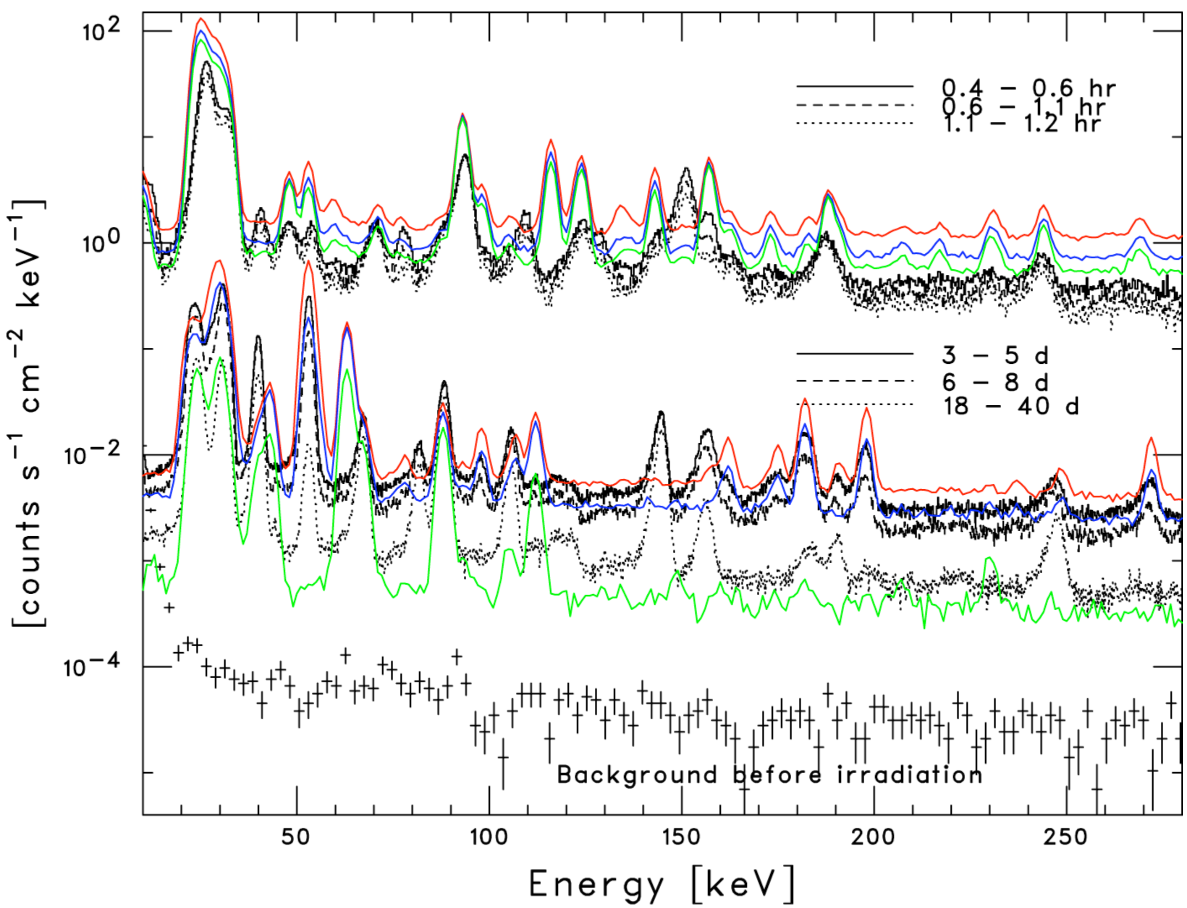
Beam irradiation experiment



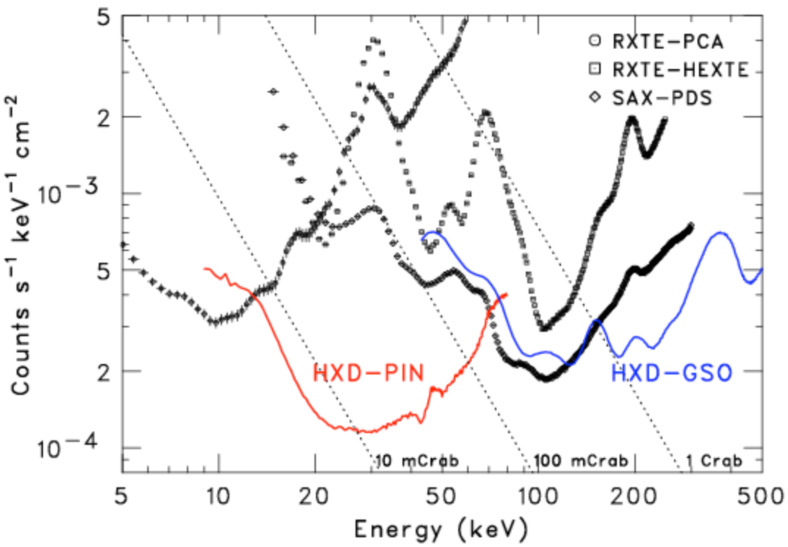


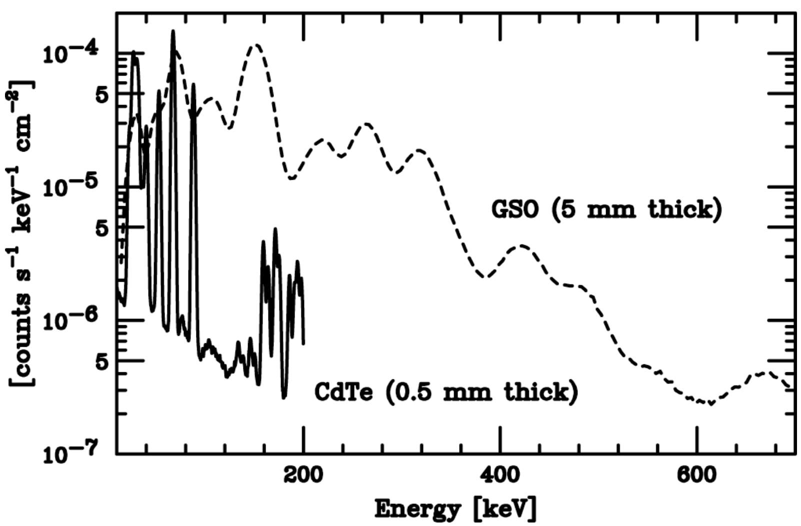
- Beam
  p150MeV (RCNP)
  1.7×10^{10} proton / 87min
- Target :
  CdTe
  10x10x0.5 mm^3
- Measurement :
  CdTe(ΔE~3keV)
  Cu+Pb cave

Comparison between the measurement and simulation of induced activations shows a reliable agreement except several peaks. We are now investigating the detail.

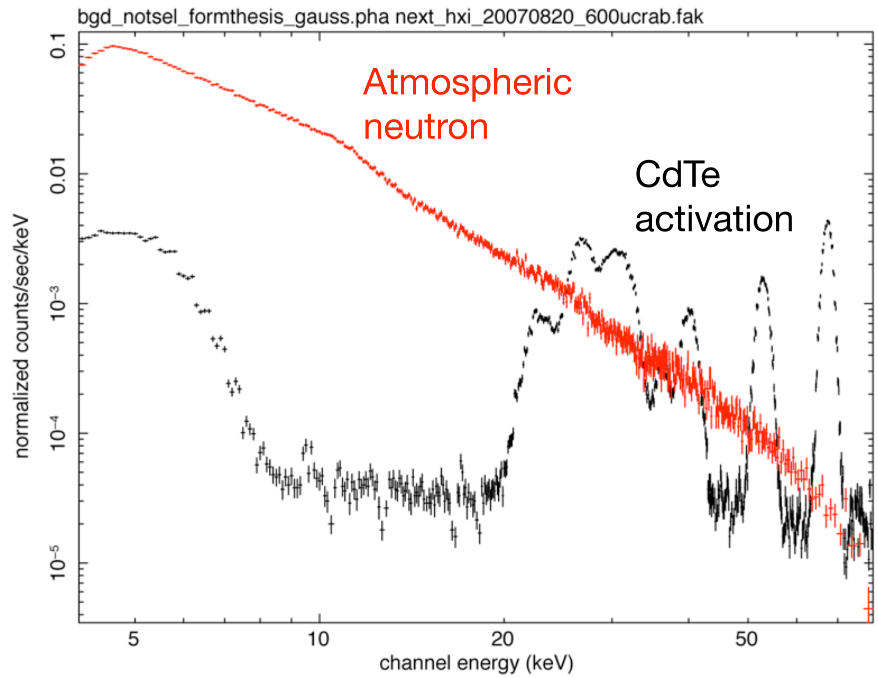


Current Estimation





Estimated background spectrum with the MC simulation for ASTRO-H/HXI.



The neutron component will be negligible in case of L2 environment, but we need further detailed study with a mass model of S/C to take into account the secondary emissions.

Double-sided Si Strip Detector

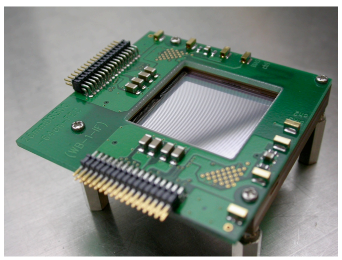
IXO HXI

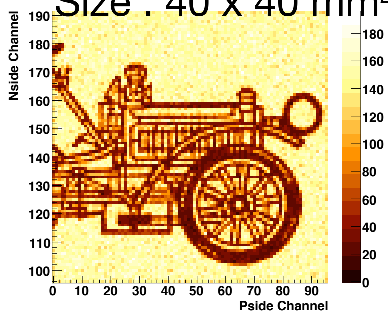
Lower intrinsic background can be achieved than CdTe thanks to its small atomic number. Also act as a “fluorescent X-ray shield” for WFI located between CdTe and WFI. Background reduction with anti-coincidence can be also utilized.

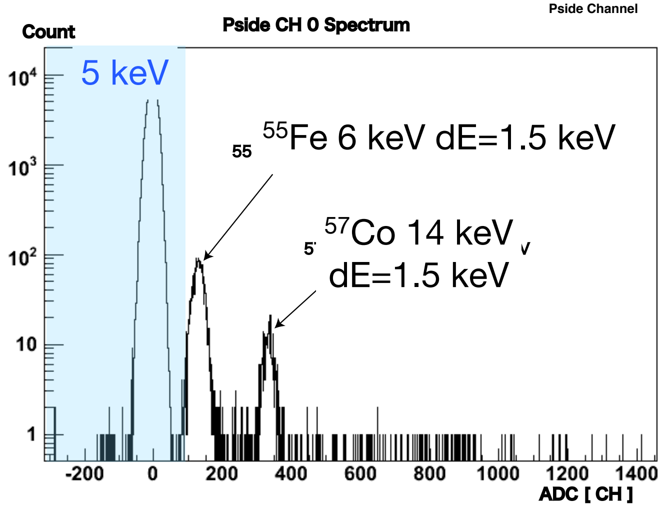
Engineering model

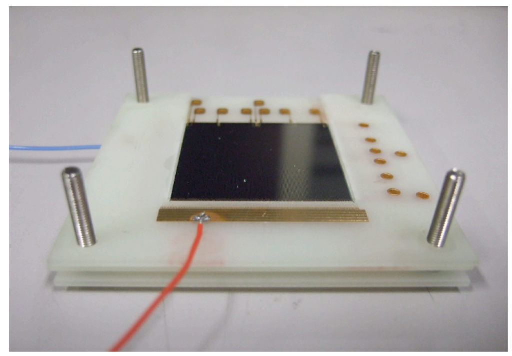
Strip pitch: 400um

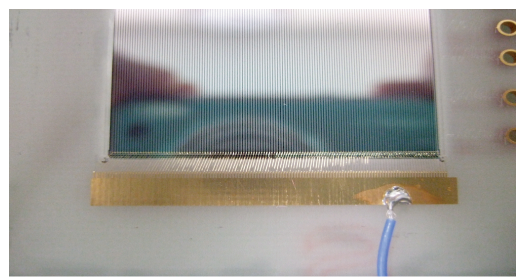
Size : 40 x 40 mm^2











ASTRO-H fight model

Strip Pitch : 250μm
Thickness: 500μm
Area: 32 mm × 32 mm
(128 ch for both sides)

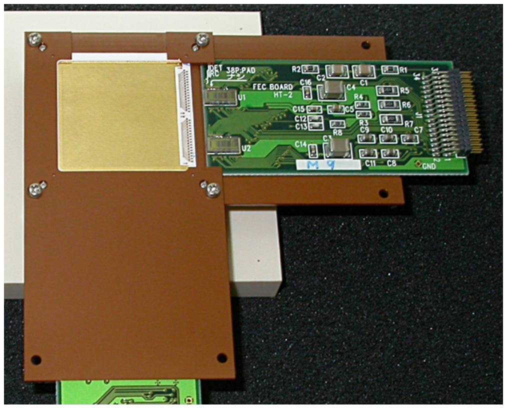
Low noise performance has been verified with a lower energy threshold of ~5 keV.

Status of CdTe imager

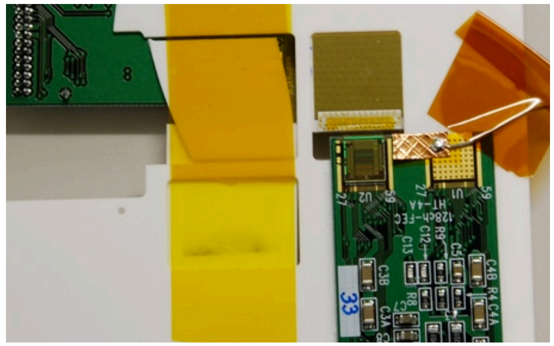
IXO HXI

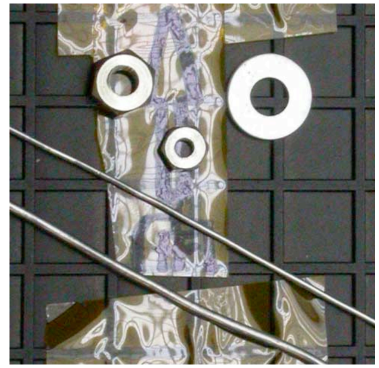
Double-sided strip detector based on CdTe diode devices from ACRORAD

2.5 cm DS-CdTe



1.3 cm DS-CdTe

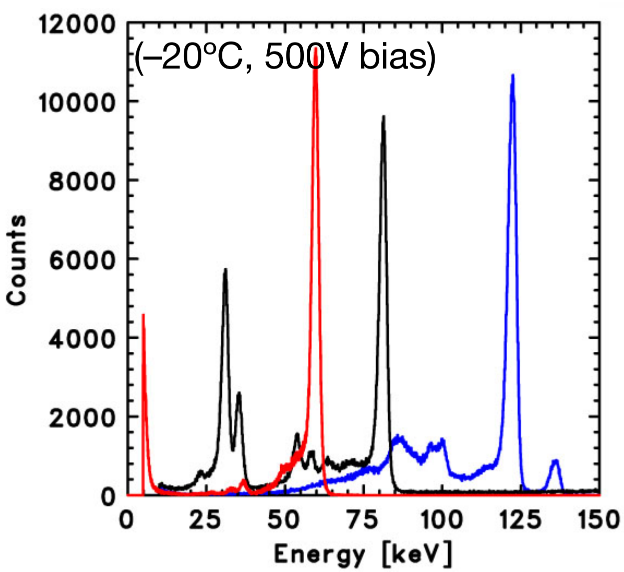


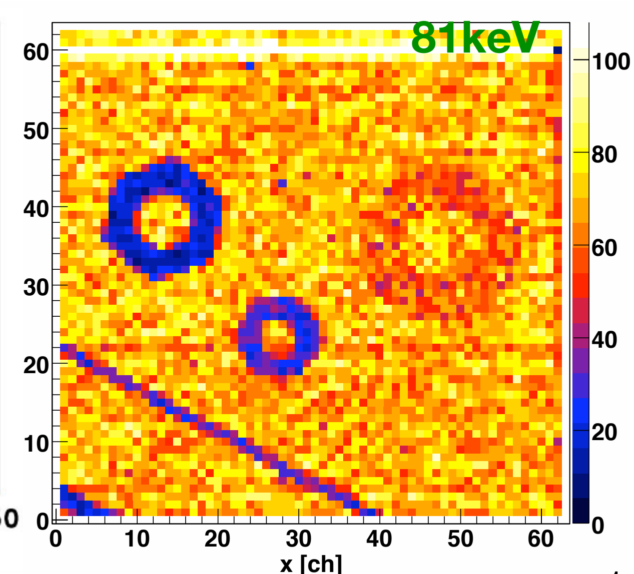


Shadow Image with various RIs (^{241}Am, ^{133}Ba, ^{57}Co)

<u>Comparisons of strip with Pixel</u>

- smaller read-out channels (2n instead of n^2)
- 1-dimensional ASIC
- relatively large leak and C



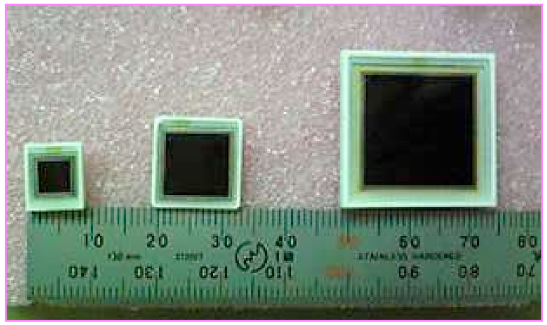


APD for BGO read-out

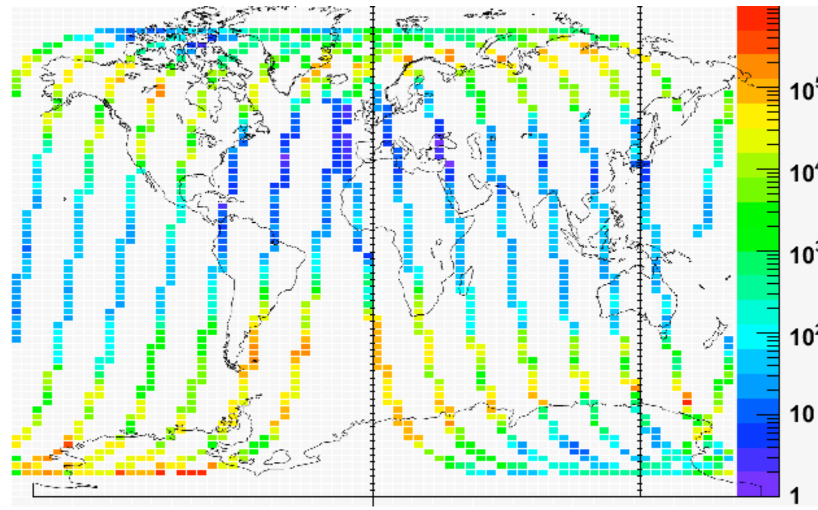
IXO HXI

Reverse-type APD development (with HPK)

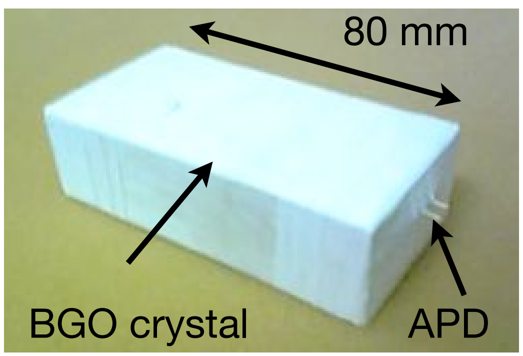
Ikagawa, et al. 2003, 2005 NIM-A
Nakamoto et al. 2005 NIM-A,
Sato R. et al., 2005 NIM-A,
Kotoku et al. 2005 SPIE, 2006 NIM-A,
Kataoka et al. 2006 NIM-A etc...

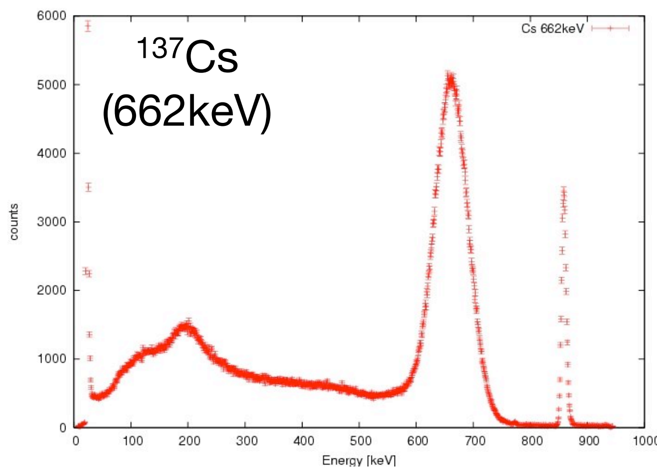


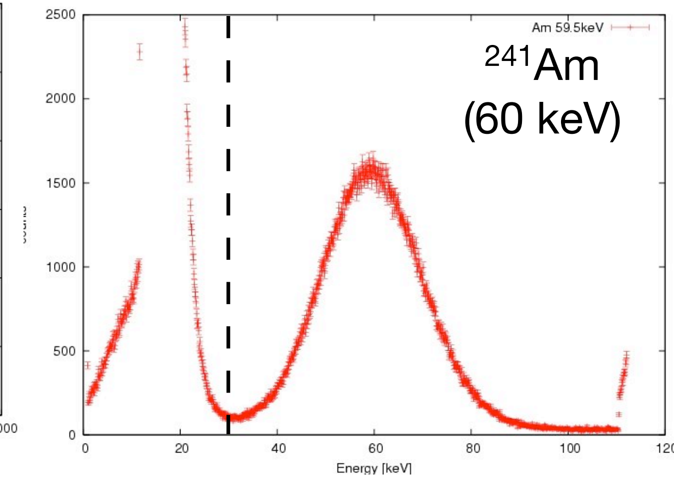
APD demonstration in-orbit (Cute-1.7)



Direct attachment







Energy threshold of ~30 keV will be achieved.

Electronics with SpaceWire

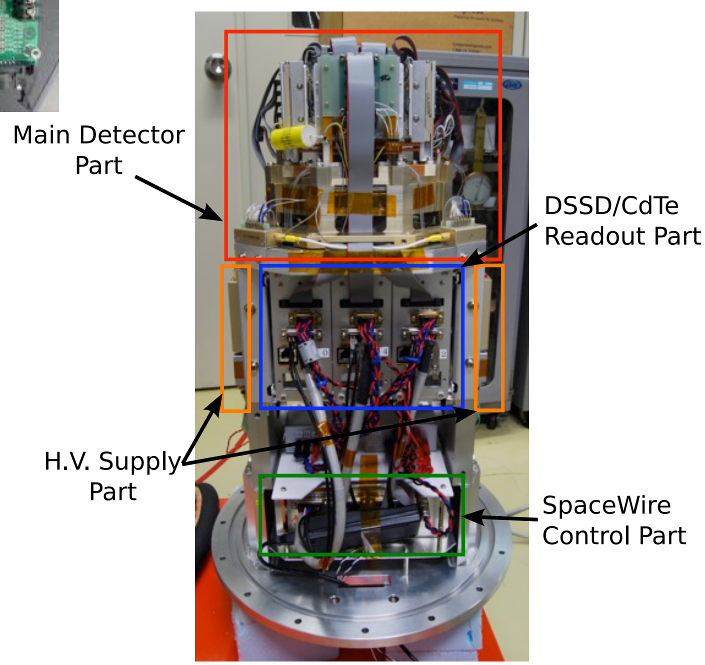
IXO HXI

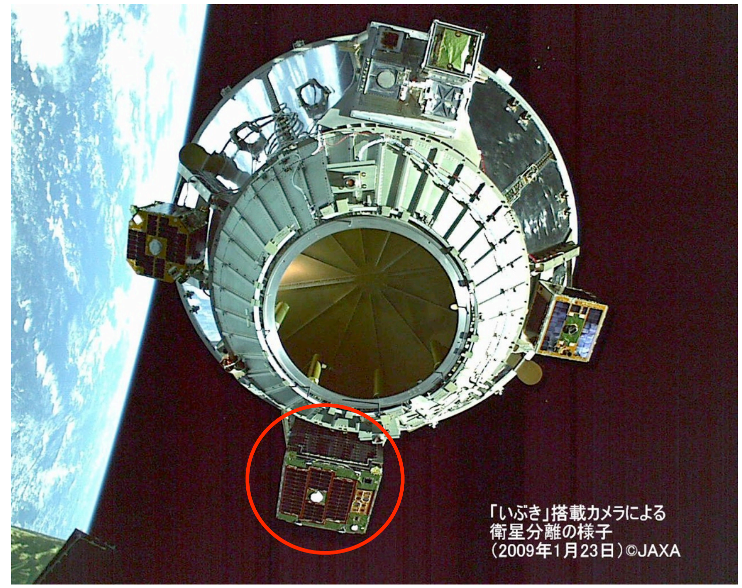
SpaceWire based readout system are almost established with BBM for ASTRO-H.

Universal I/O board
with SpW I/F

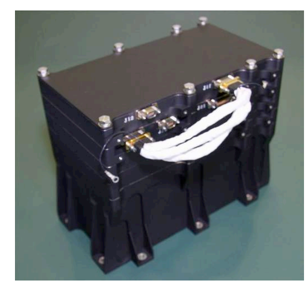
SpaceCube-I

Sensor(DSSD/CdTe) and read-out system based on the SpW, developed for the balloon experiment



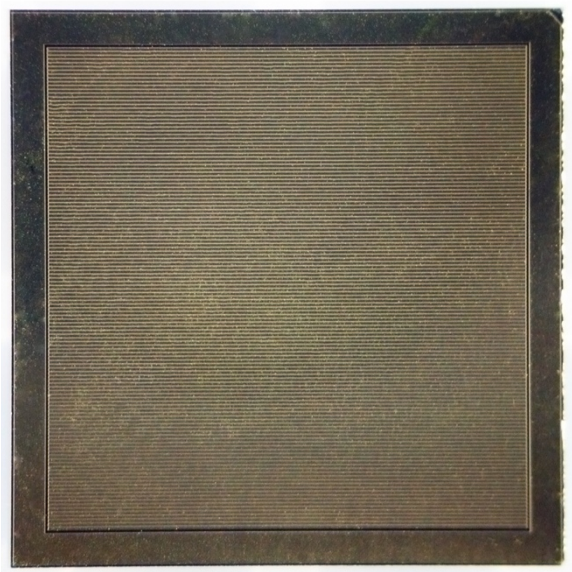


Technology demonstration satellite SDS-I of JAXA, launched as a piggy-bag of “Ibuki (GOSAT)”, 4 days ago. A SpaceWire experimental module is onboard.



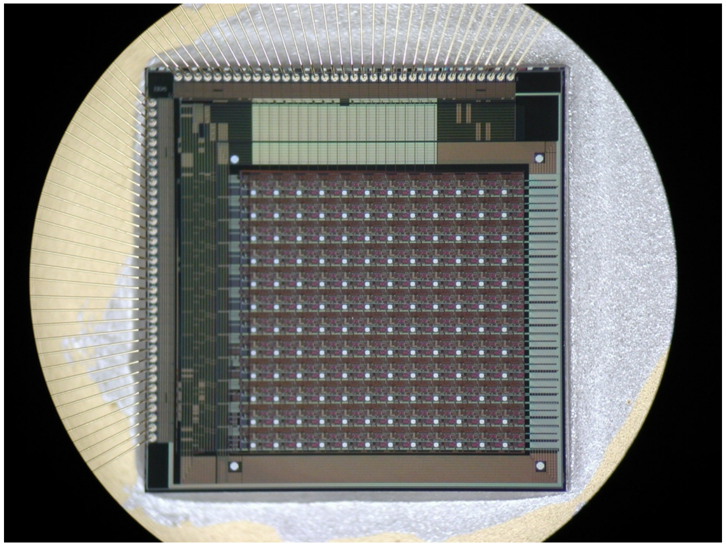
Future Options

In the time-frame of IXO launch (2020's), we can expect further advanced technologies will be available.
Two examples are shown below. Also refer to Olivier's talk.



<u>Fine pitch double-sided strip (60 um)</u>

We are trying to make the position resolution finer than 100 um. Though a smaller HPD is required for HXT, 60 um pitch corresponds to an angular resolution of sub-arcsec.



<u>2D low-noise ASIC (H04)</u>

Next generation analog ASICs (H04; 12 x 12 channels with 270 um pitch) developed in JAXA (G.Sato et al. IEEE 2008).
A low noise performance of 50 e- (@ 0 pF) is achieved.

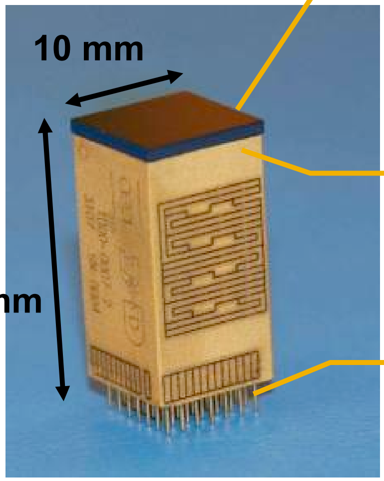
Another possibility

IXO HXI

CALISTE 64 DESIGN

Irfu cea saclay cnes CENTRE NATIONAL D'ÉTUDES SPATIALES 3D plus

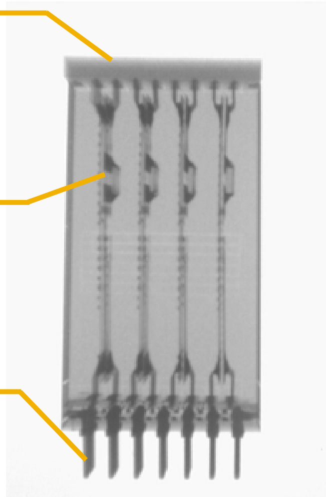
- A hybrid component based on a 3D Plus space proof technology.



CdTe detector
(64 pixels, 1mm pitch, 1mm thick, guard ring)

Front-end electronics
(4 IDeF-X 1.1 ASIC of 16 analogue channels)

Rear interface
(7x7 pin grid array, 1.27 mm pitch)



X radiography

- Four micro PCB perpendicular to detection plan.
- Four ASICs to read out 2 rows of eight pixels each.
- Lateral routing to share signals between ASICs.

Summary

IXO HXI

Hard X-ray imaging option will realize a large effective area with a fine resolution (10”), will provide a crucial capability to the IXO mission.

As for the HXI detector for IXO, the ASTRO-H/HXI based detector can be a default with a moderate TRL.

There are several things to be studied with more detail;

- Detailed interface definition (mech., elec., thermal)
- Detailed mechanical designing
- Calibration and Alignment plan (on ground and in orbit)
- Ground test requirements (EMC and verification @ RT etc ...)
- WFI-HXI interference (thermal, mechanical, shielding etc..)
- BGD estimation with L2 environment (Geant-4 based)