Status of ASTRO-H

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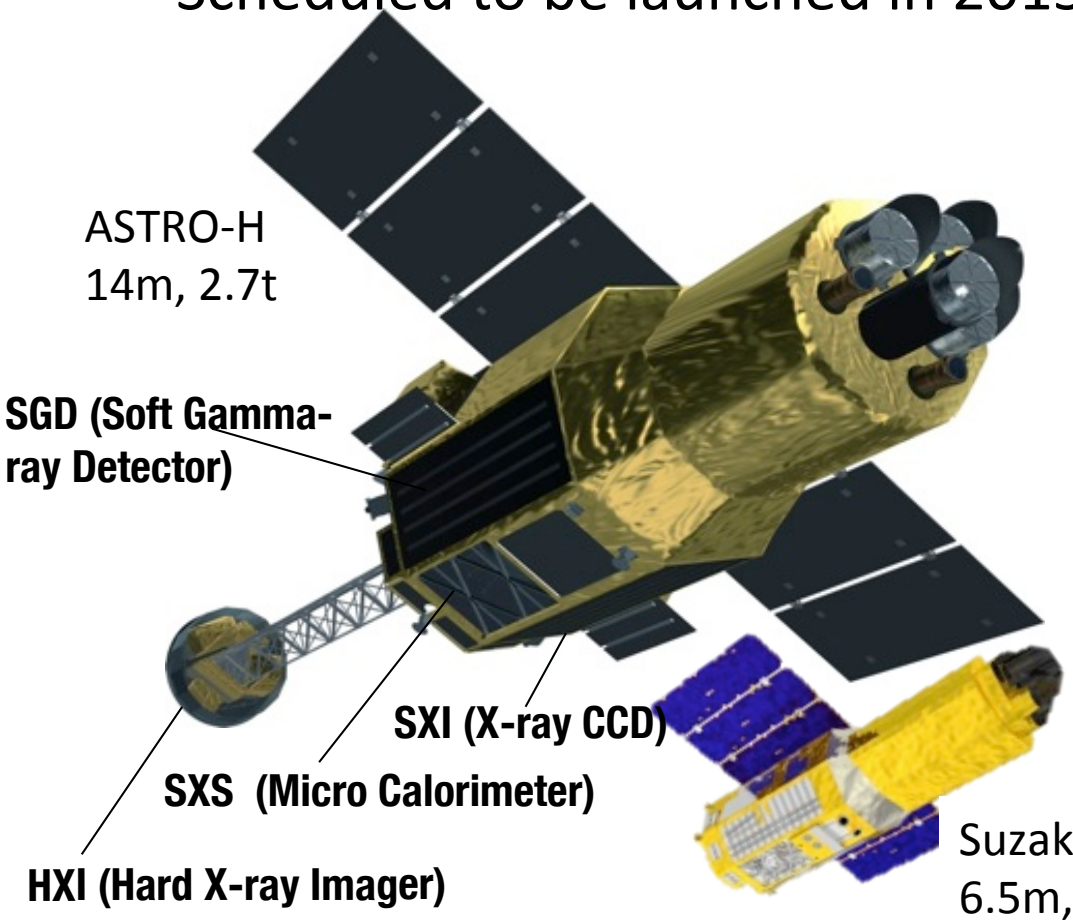
and the ASTRO-H Soft/Cal Team

Agenda

1. Status of ASTRO-H
   a. Overview
   b. Status
   c. Timeline until launch
2. ASTRO-H instruments and key requirements
   a. Instruments overview
   b. Key requirements
3. Status of each instrument
   a. SXT
   b. SXS
   c. SXI
   d. HXT
   e. HXI
   f. SGD

ASTRO-H mission

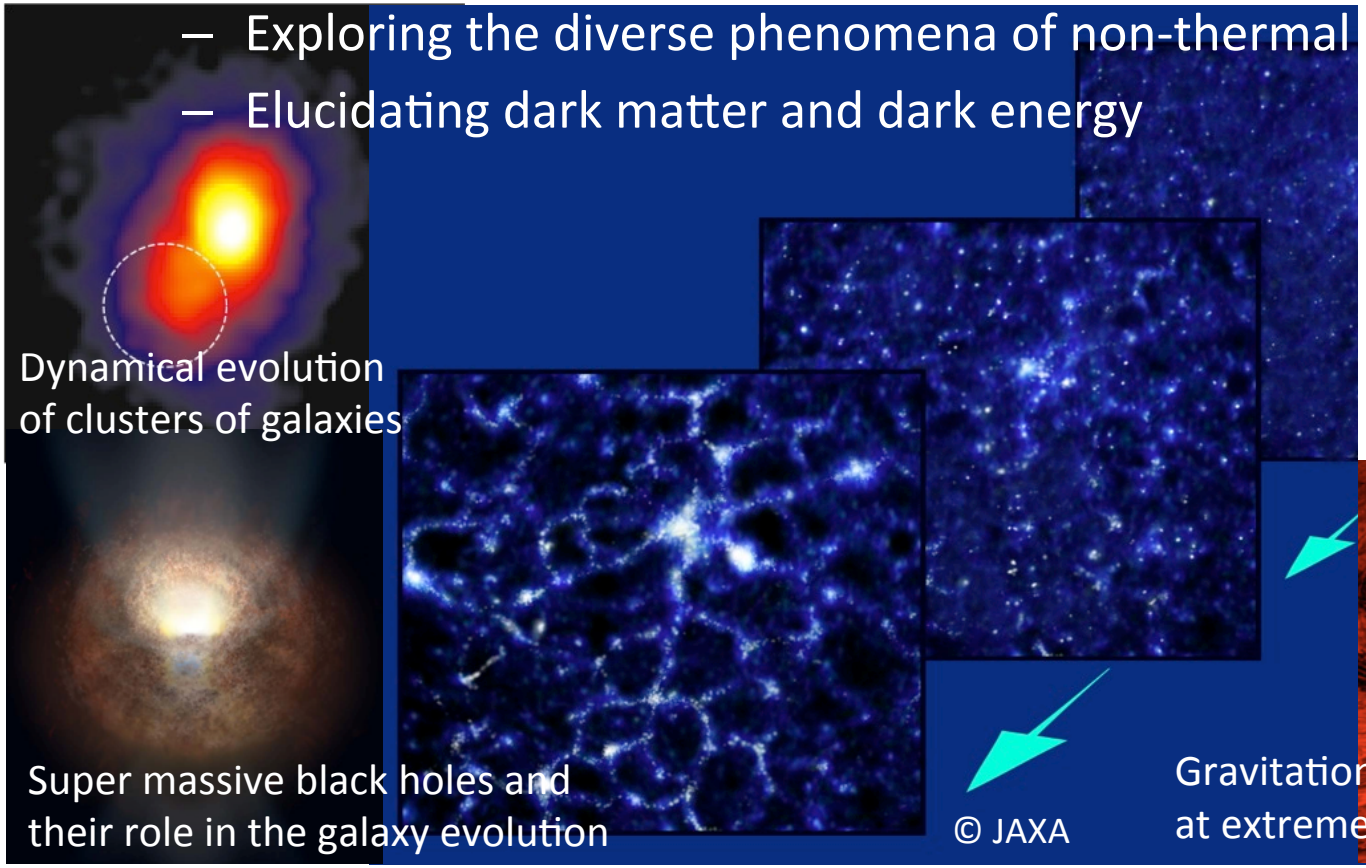
- ASTRO-H is an international X-ray observatory, which is the 6th in the series of the X-ray observatories from Japan. More than 160 scientists from Japan/US/Europe/Canada.
  - T. Takahashi et al. "The ASTRO-H X-ray Observatory", SPIE 8443 (2012)
- Scheduled to be launched in 2015

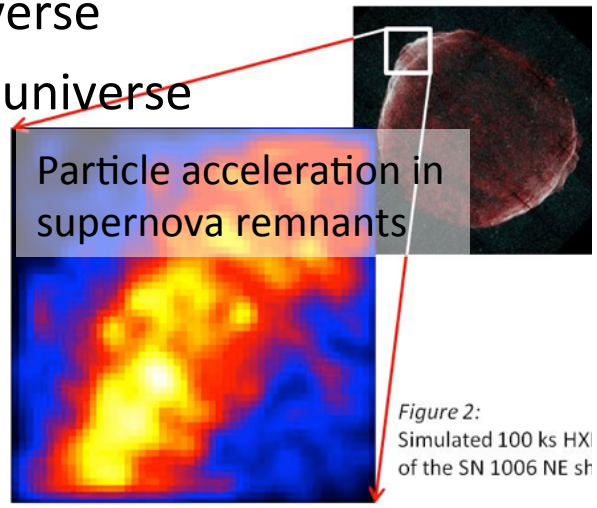


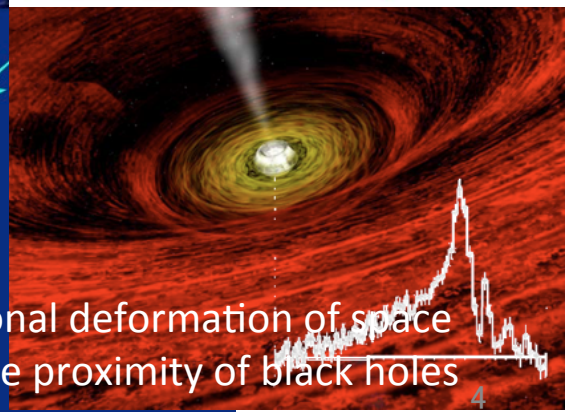
Launch site	Tanegashima Space Center
Launch vehicle	JAXA HII-A rocket
Orbit Altitude	550 km
Orbit Type	Approximate circular orbit
Orbit Inclination	~31 degrees
Orbit Period	96 minutes
Total Length	14 m
Mass	~2.7 metric ton
Mission life	> 3 years

ASTRO-H scientific objectives

- Observing the dynamic Universe and studying its history with the ultimate goal of understanding the structure and evolution of the Universe
  - Revealing the large-scale structure and its evolution of the universe
  - Understanding the extreme conditions in the Universe
  - Exploring the diverse phenomena of non-thermal universe
  - Elucidating dark matter and dark energy







ASTRO-H status

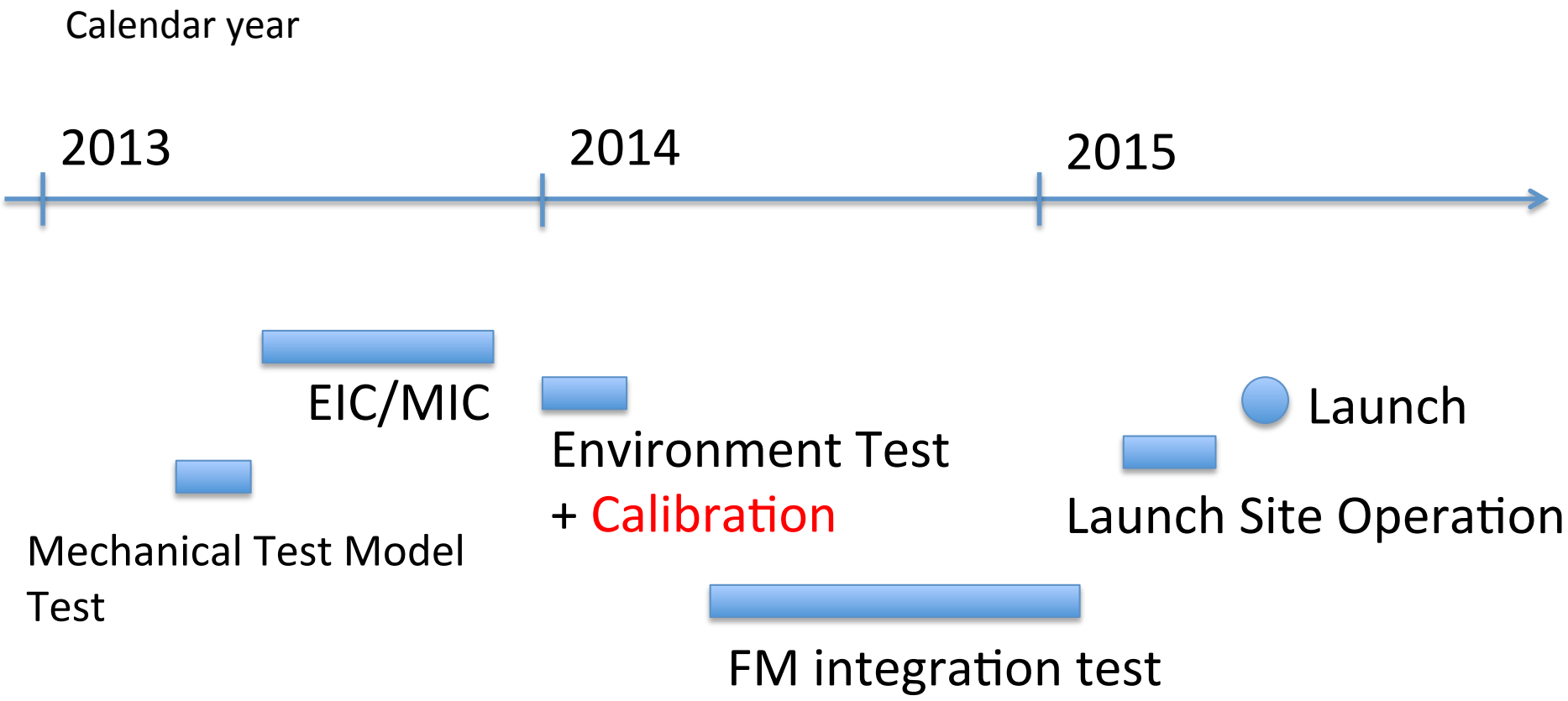
- Complete CDR1 (2012 Feb)
  - By using FM (Flight Model) of Base Plate, Fixed Optical Bench and Side Panels, we performed:
    1) Thermal Deformation Test (2012Apr-Jun)
    2) Thermal Balance Test (2012 Jun-Aug)
    3) Solar-light irradiation test (2012/Aug-Sep)
- In order to realize severe requirements of directional performance, we have verified the design by the thermal deformation test.
- We are now building FM for payloads in conjunction with testing of EM sensors
- We intend to complete our satellite by the end of 2014 JFY. The launch will be mid 2015.

ASTRO-H under construction

System TTM test
(Aug-Sep 2012)

13m thermal vacuum chamber
JAXA Tsukuba Space Center

Timeline until launch



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ASTRO-H instruments

Sunshades

X-rays

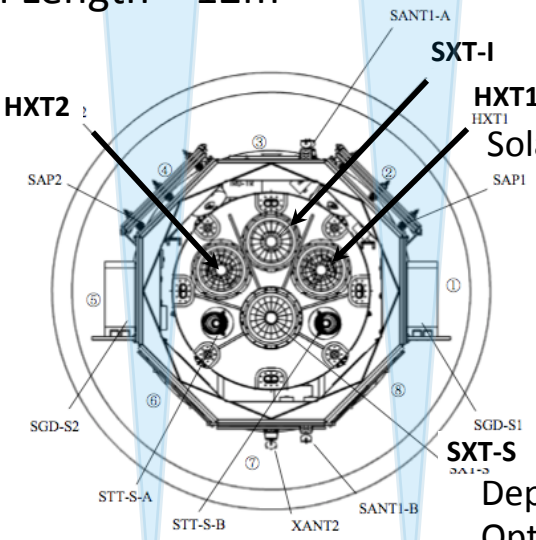
Hard X-ray Telescopes
(*HXT*)

Fixed
Optical
Bench

Soft X-ray Telescopes
(*SXT-S*, *SXT-I*)

Focal Length = 12m

Focal Length = 5.6 m

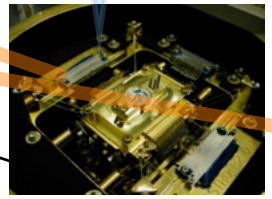


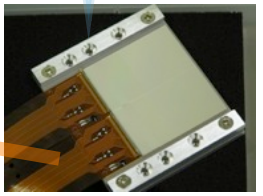
Solar power

Microcalorimater
(*SXS*)

Radiator

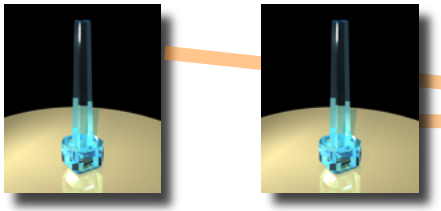
X-ray CCD
(*SXI*)

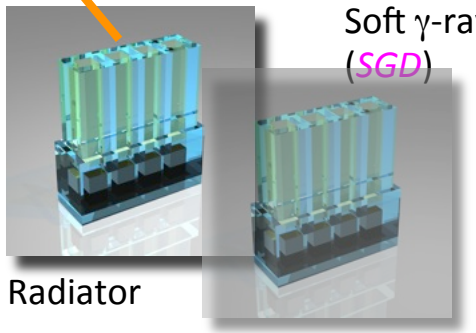




Deployable
Optical Bench

Hard X-ray Imagers
(*HXI*)



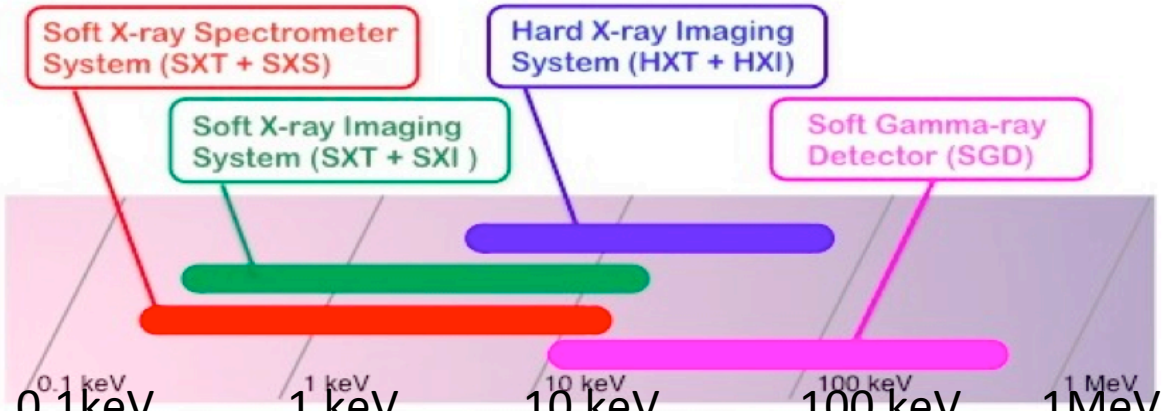


Soft γ-ray detectors
(*SGD*)

Radiator

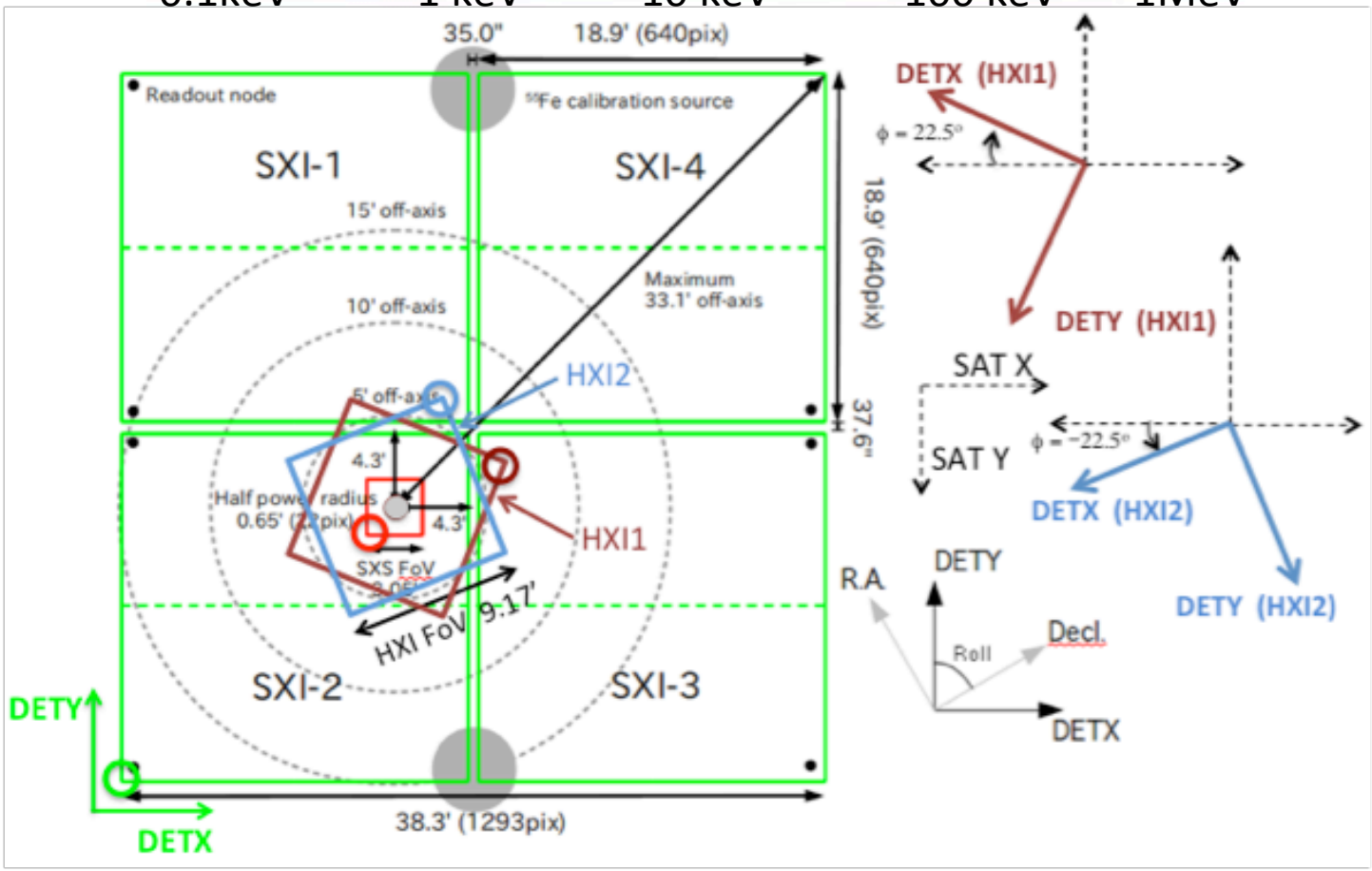
ASTRO-H instruments

Energy coverage



0.1keV 1 keV 10 keV 100 keV 1MeV

FOV coverage



Calibration requirements

Table 2. Key parameters of the ASTRO-H payload — Takahashi et al. 2012

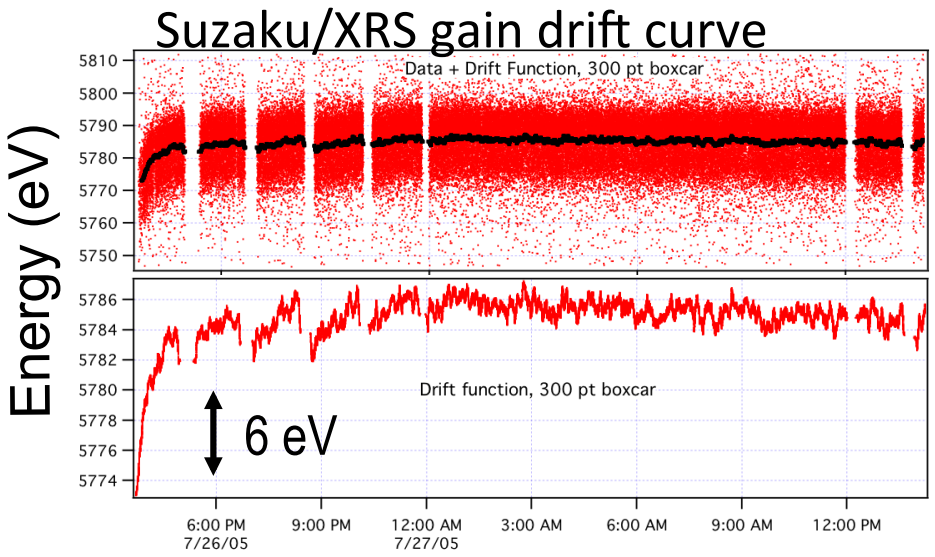
Calibration requirement

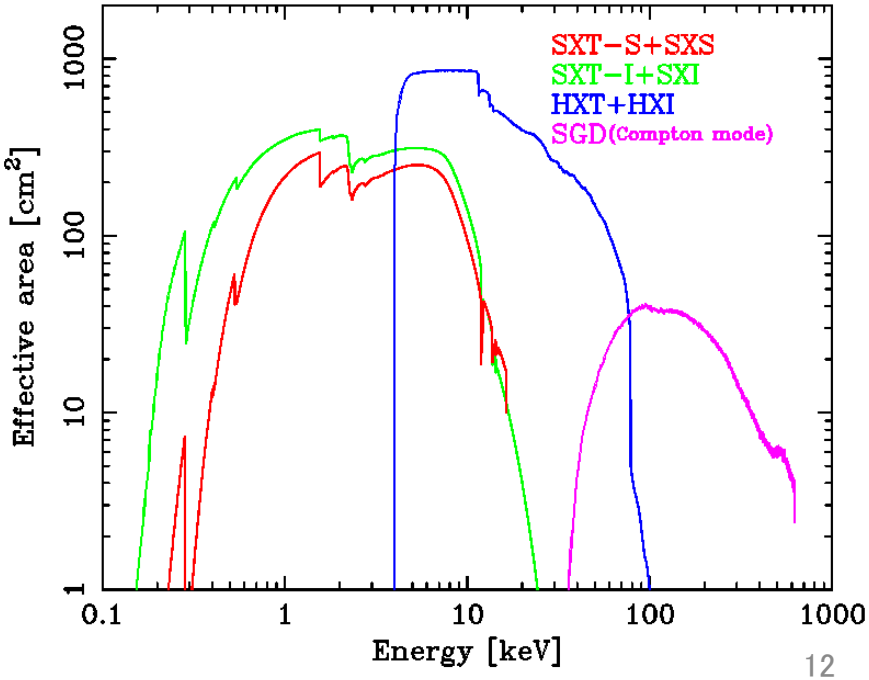
Parameter	Hard X-ray Imager (HXI)	Soft X-ray Spectrometer (SXS)	Soft X-ray Imager (SXI)	Soft γ-ray Detector (SGD)
Detector technology	Si/CdTe cross-strips	micro calorimeter	X-ray CCD	Si/CdTe Compton Camera
Focal length	12 m 1mm	5.6 m 1mm	5.6 m 1mm	–
Effective area	300 cm^2@30 keV 5%	210 cm^2@6 keV 160 cm^2 @ 1 keV 5%	360 cm^2@6 keV 5%	>20 cm^2@100 keV Compton Mode 15%
Energy range	5 –80 keV	0.3 – 12 keV	0.5 – 12 keV	40 – 600 keV
Energy resolution (FWHM)	2 keV (@60 keV) 5%	< 7 eV (@6 keV) 2eV	< 200 eV (@6 keV) 3%	< 4 keV (@60 keV) 5%
Angular resolution	<1.7 arcmin HPD 20%	<1.3 arcmin HPD 20%	<1.3 arcmin HPD 20%	–
Effective Field of View	$\sim 9 \times 9$ $arcmin^2$	$\sim 3 \times 3$ $arcmin^2$	$\sim 38 \times 38$ $arcmin^2$	0.6×0.6 deg^2 (< 150 keV)
Time resolution	25.6 μs	5 μs	4 sec/0.1 sec	25.6 μs
Operating temperature	−20°C	50 mK	−120°C	−20°C

Energy scale	5%	2eV	0.1%	5%
Timing accuracy	60μs	80μs	TBD	60μs

Key requirements

- SXS energy scale (gain stability) 2eV
- SXT+SXS effective area 5%
- SXS, SXI + HXI cross calibration 10%
- Background reproducibility of HXI 5%
- Accuracy of PSF shape knowledge 20%





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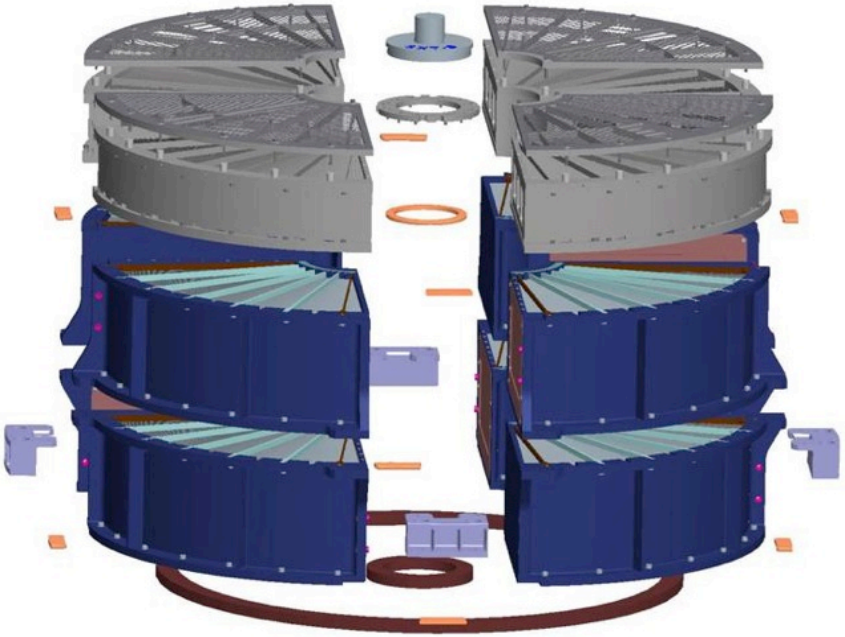
SXT: basic design



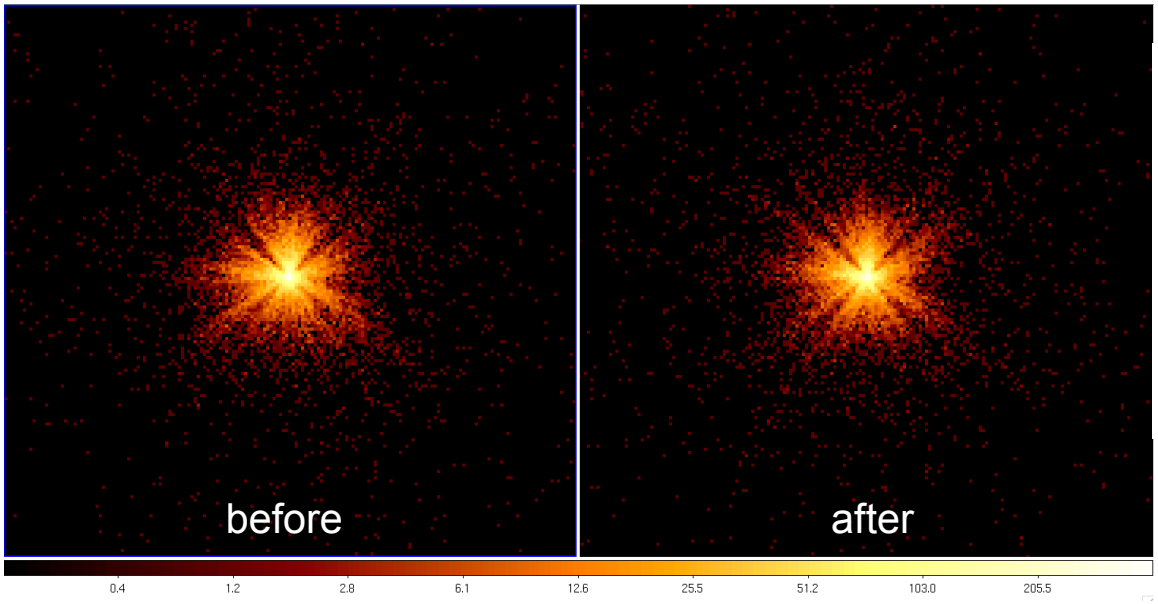
ASTRO-H requirement vs Suzaku

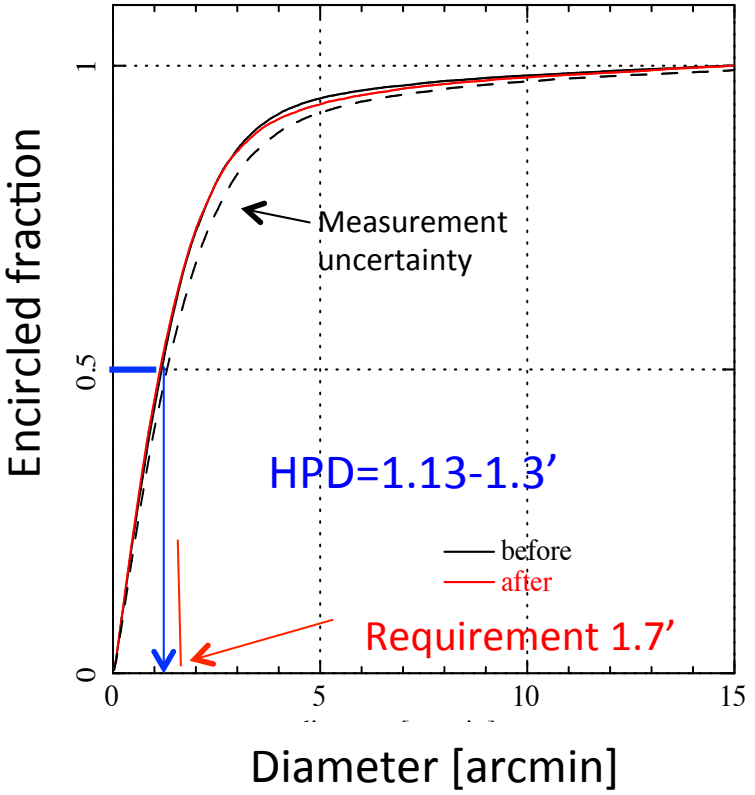
	ASTRO-H SXT	**Suzaku**
Focal length (m)	5.6	4.5/4.75
Diameter (cm)	45	40
Mass (kg)	44	20
Aeff (cm2@6keV)	390/mirror	270/mirror
HPD (arcmin)	<1.7	1.7–2.1

- Soft X-ray Telescope for SXS and SXI will be an upgraded version of the Suzaku X-ray telescope.
  - The diameter and focal length are larger, thus number of the nesting shells are increased.
  - Angular resolution is improved from Suzaku.
- The first of these mirrors (FM1) completed and tested

SXT: status

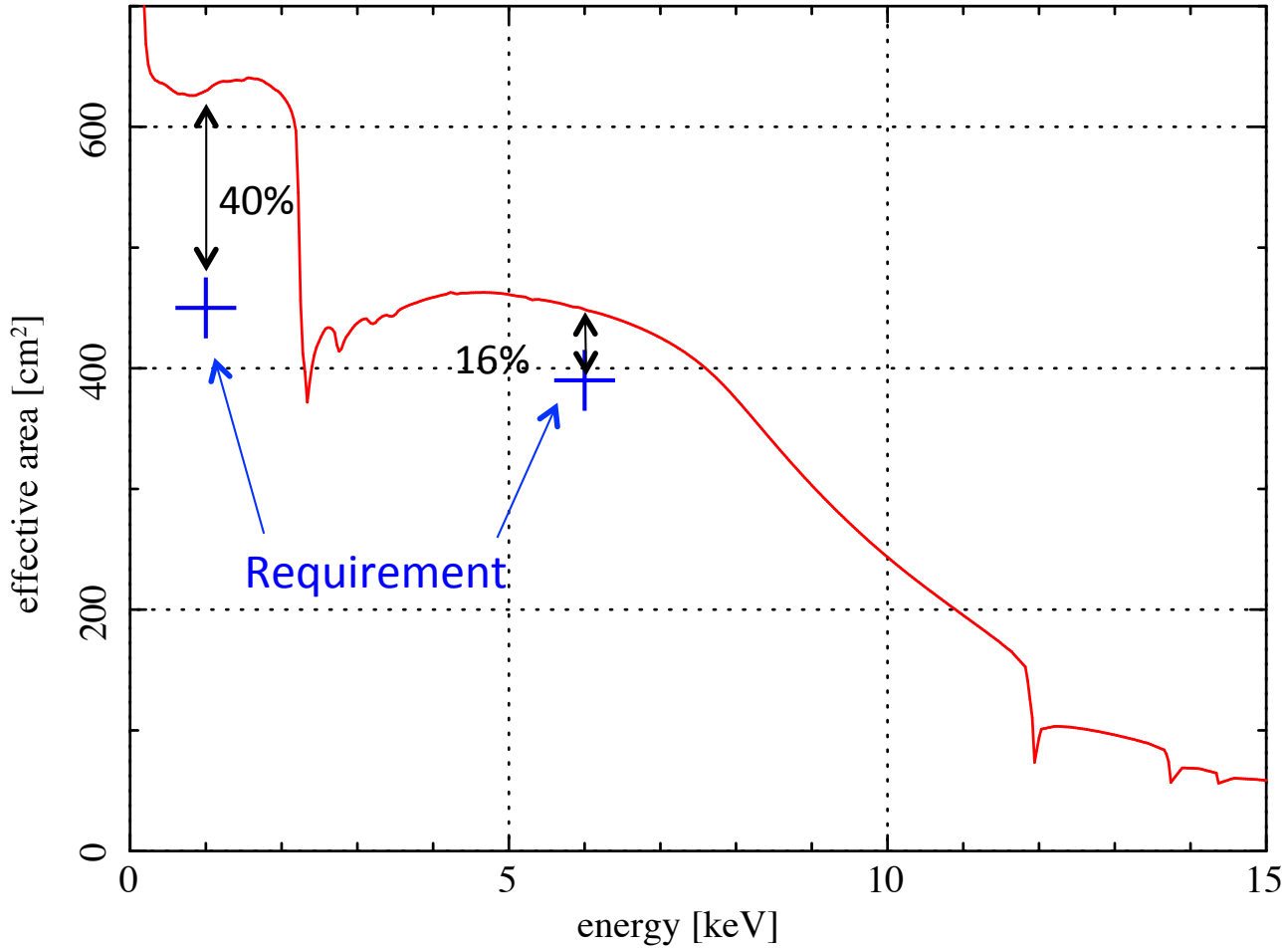
- FM1 performance test
  - SXT was illuminated by diverging X-ray beam and on-axis image was obtained
  - HDP = 1’.13–1’.3. No significant change after the vibration test
  - Effective area will be measured at ISAS





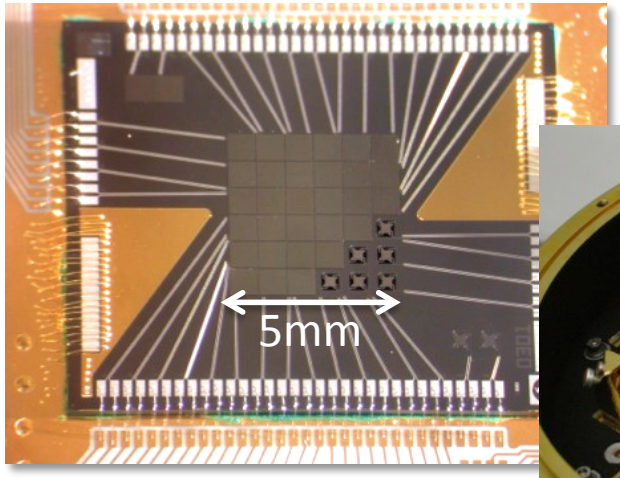
SXT: status

- SXT effective area (EM)



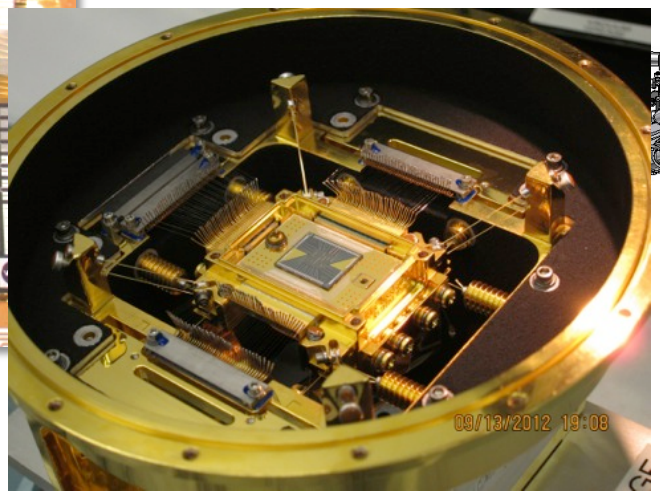
SXS: basic design

- X-ray micro-calorimeter spectrometer with energy resolution better than 7 eV (FWHM)
- 6 x 6 array with 3’ x 3’ field of view
- Operated at 50 mK
  - Nominal expected liquid He lifetime 3.3 years

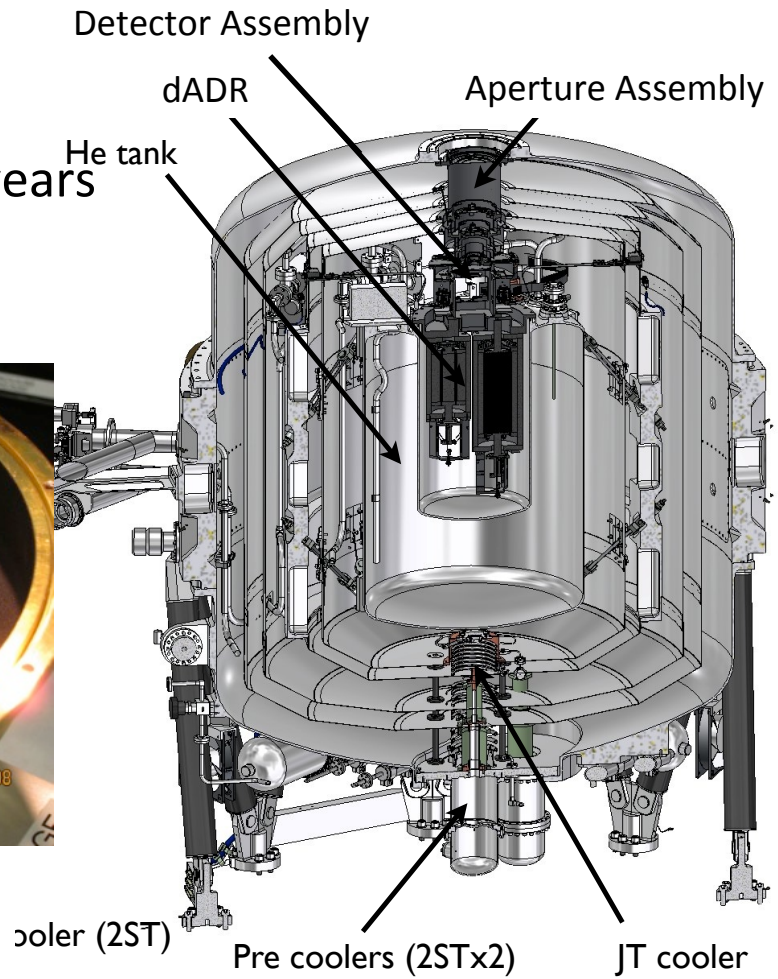


Microcalorimeter array

NASA/GSFC



SXS detector assembly



SXS dewar

SXS: calibration items

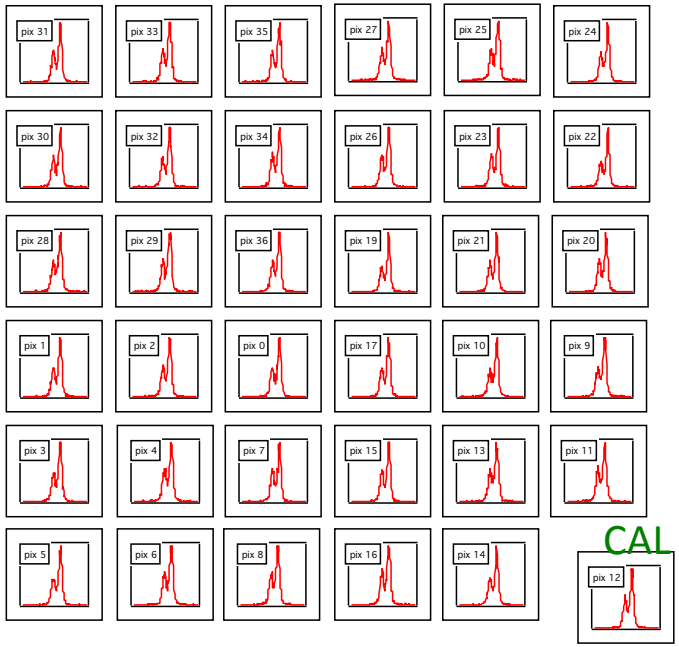
1. Energy Redistribution
   - Gain drift correction
   - Linearity correction
   - Energy scale
   - Energy resolution
   - Line spread function

	Requirement	Goal
Energy resolution	<7 eV	5 eV
Energy scale	2 eV	1 eV
Line width	2 eV	1 eV

2. Effective Area
   - Blocking filters, Filter Wheel, contamination
   - QE
   - PSF & Event branching ratio
3. Background
   – Cosmic-rays, crosstalk, electron escape from other pix
4. Time Assignment

SXS: status

All 36 channels by location

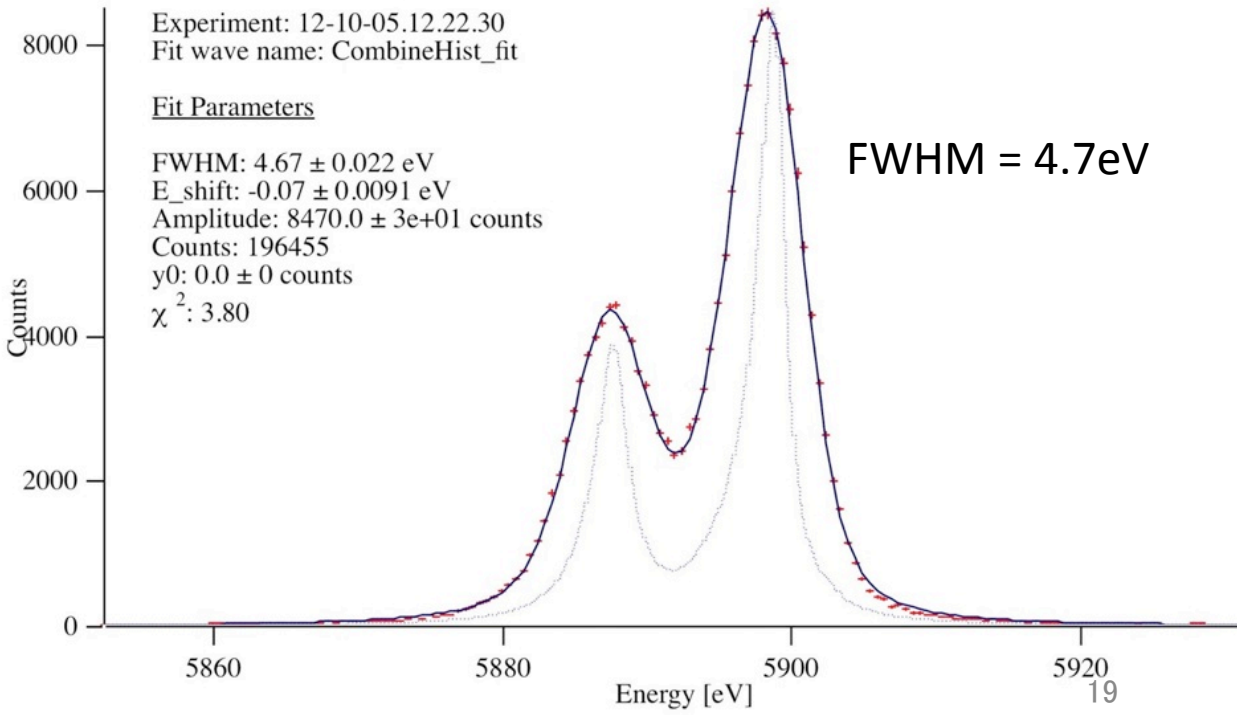


- FM detector system calibration campaign

Oct 2012 – Feb 2013, GSFC/NASA

All pixels meet requirement < 7eV

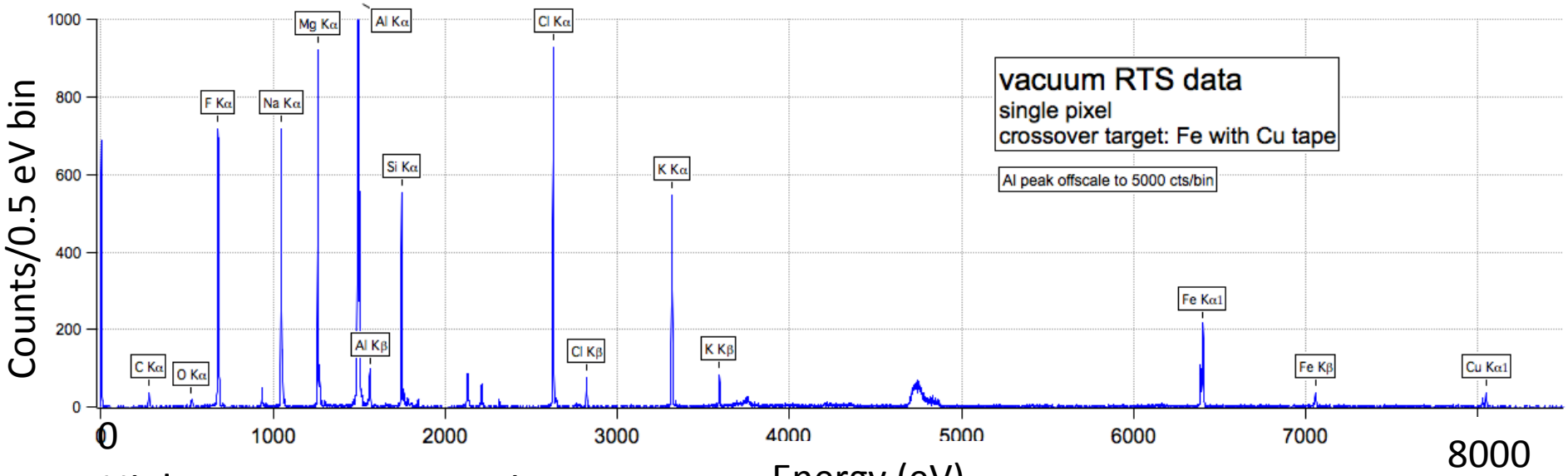
Composite fit to all 36 channels



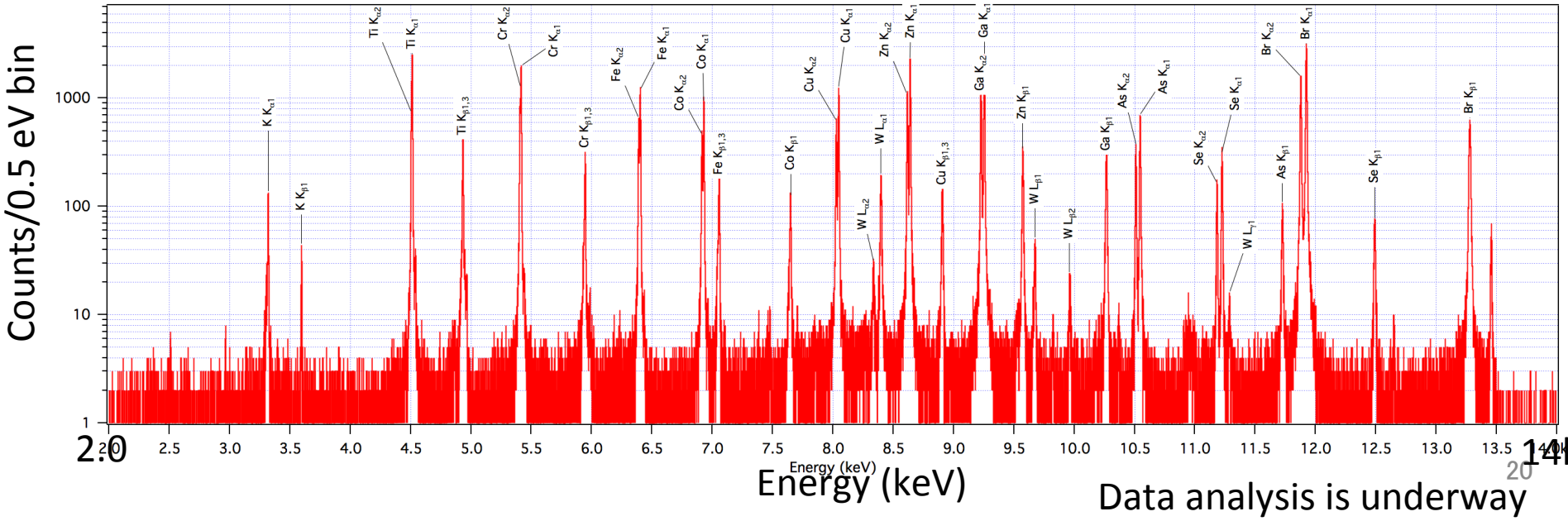
FWHM = 4.7eV

SXS: status

- Gain scale experiment



- High count-rate experiment

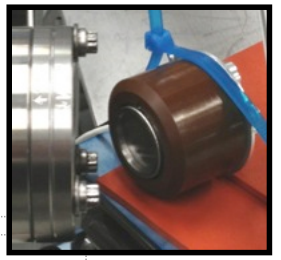


2.0 14keV

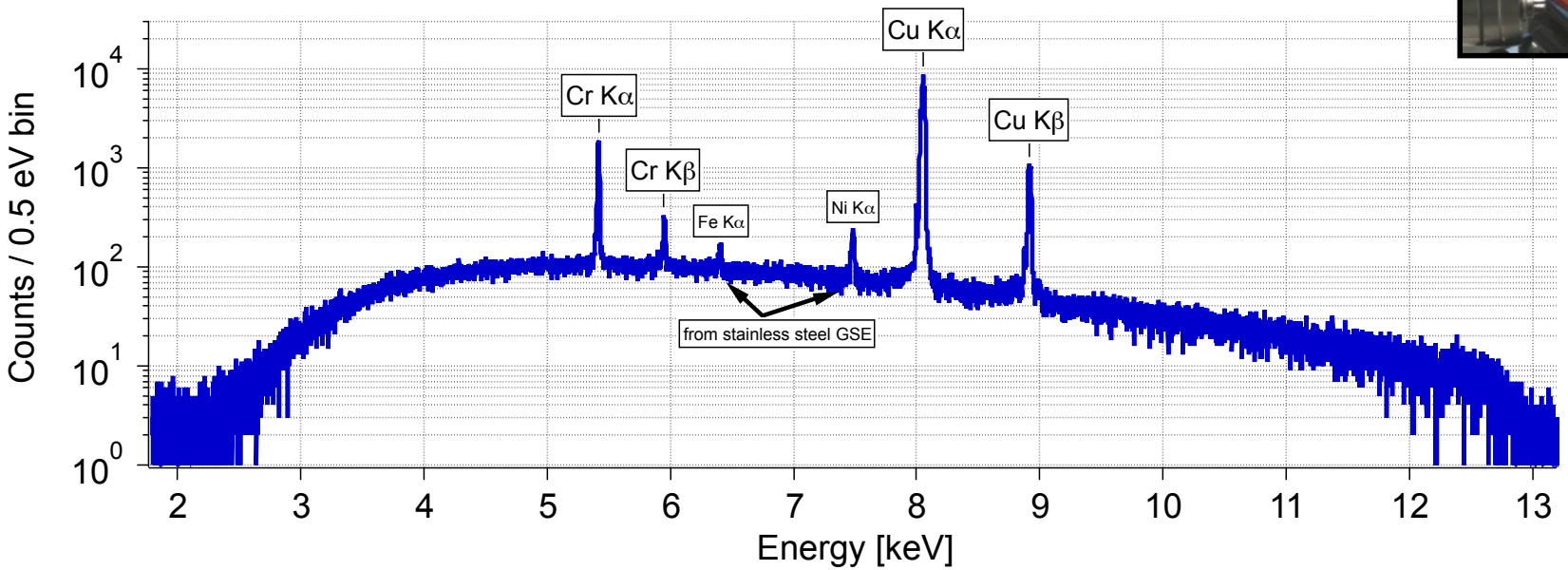
Data analysis is underway

SXS: status

- MXS (Modulated X-ray Source)
  - MXS is mounted on the Filter Wheel and enables self-calibration of energy scale at a 10 min timescale
  - Cu-Cr for direct source, operated in pulsed mode→ gain calibration
  - Al-Mg for fluorescent source → gain curve (non-linearity)



MXS from SRON (direct source)

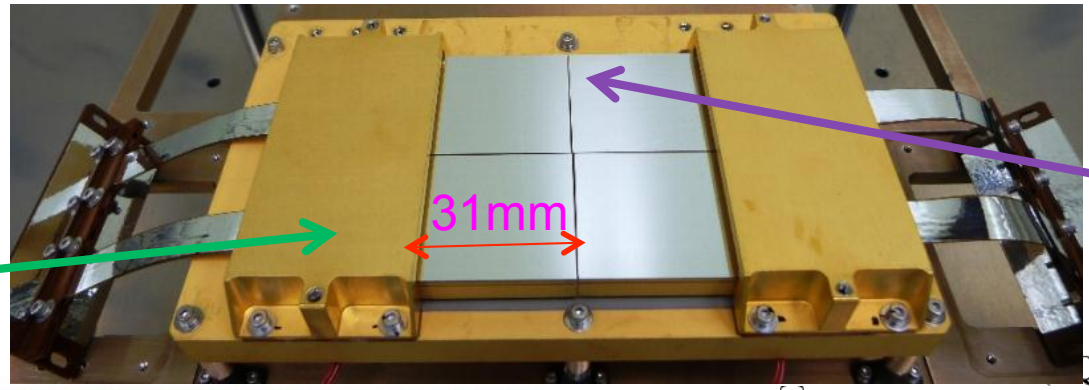


MXS performs as expected.

SXI: basic design

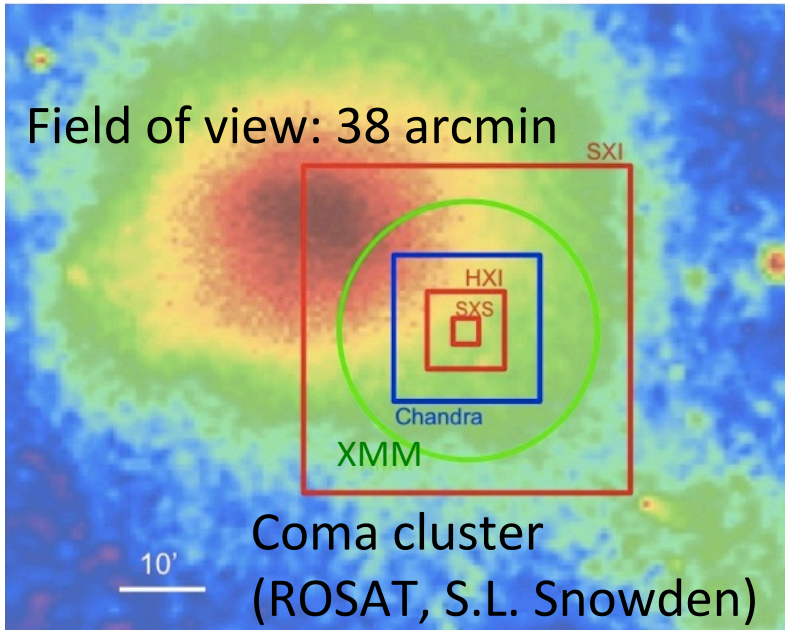
- Wide FOV X-ray CCD 38'x38'
- Backside illuminated, P-channel CCDs
- Energy resolution < 200 eV (requirement)

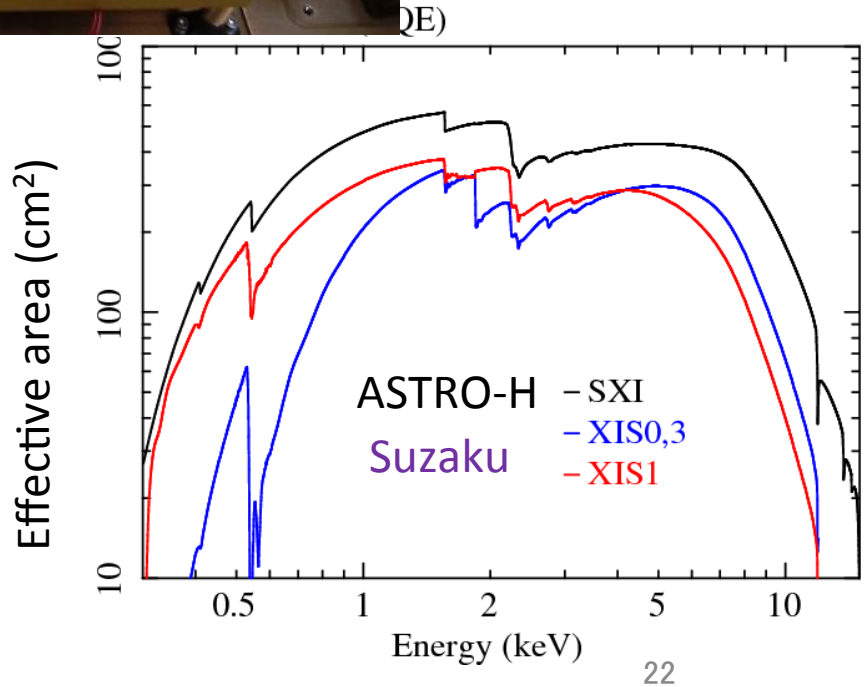
4CCD chips/62x62mm^2
Depletion layer ~200 micron



Frame Store Area is covered

Al Coating on the surface as Optical Blocking Layer

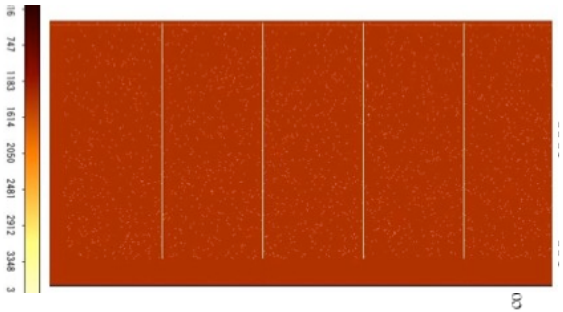


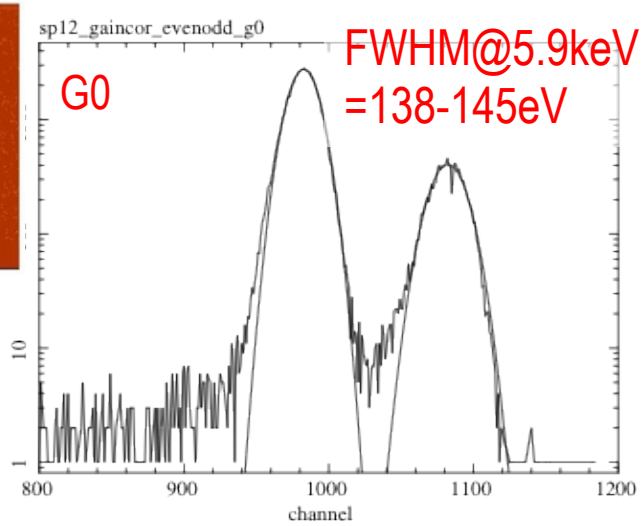


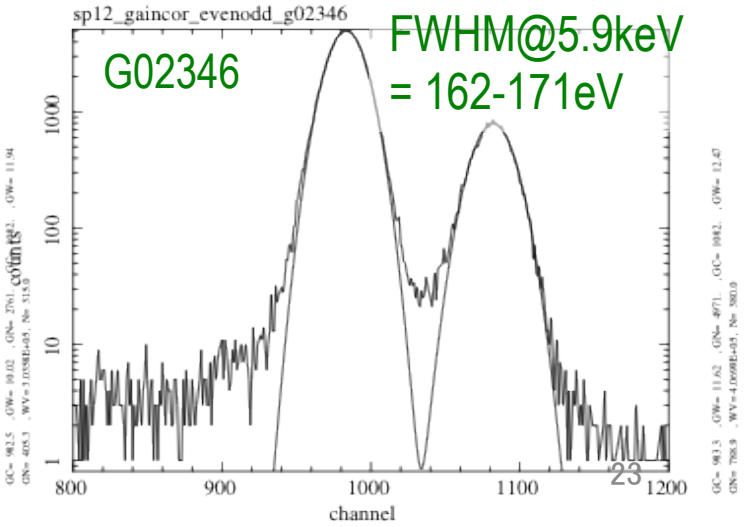
SXI: status

- SXI EM was build and function & environment tests have been performed
- Hardware/Software design fixed. FM production is going on.
- FM calibration is prepared.

- Mn-K Irradiation with Spaced Row Charge Injection (SCI) on

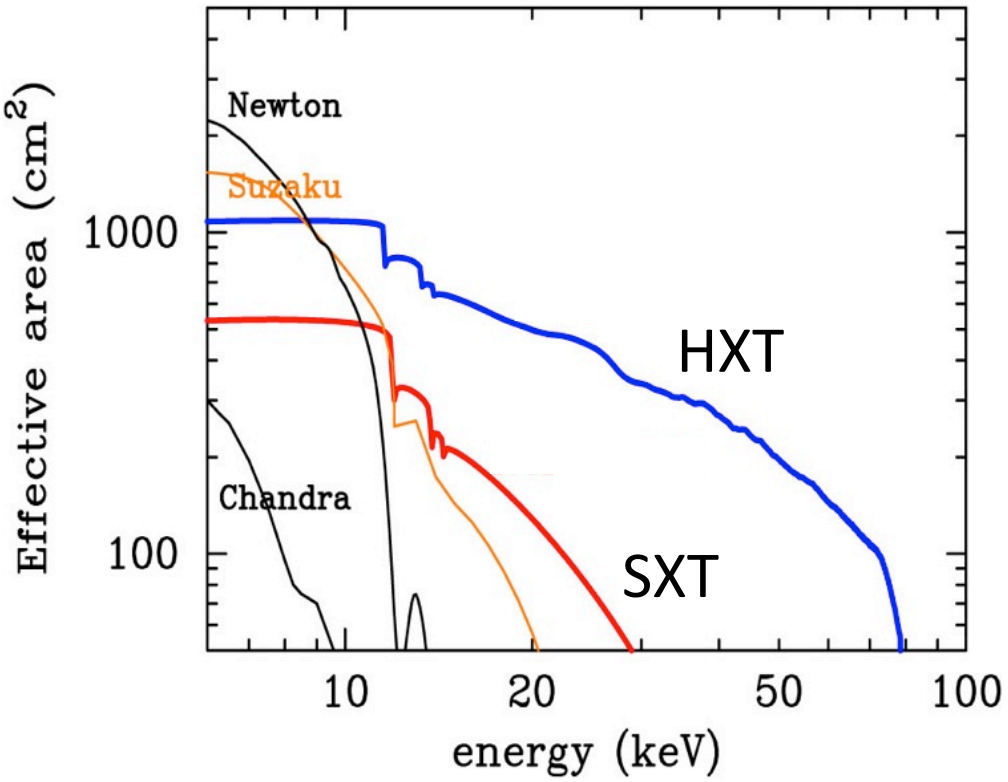




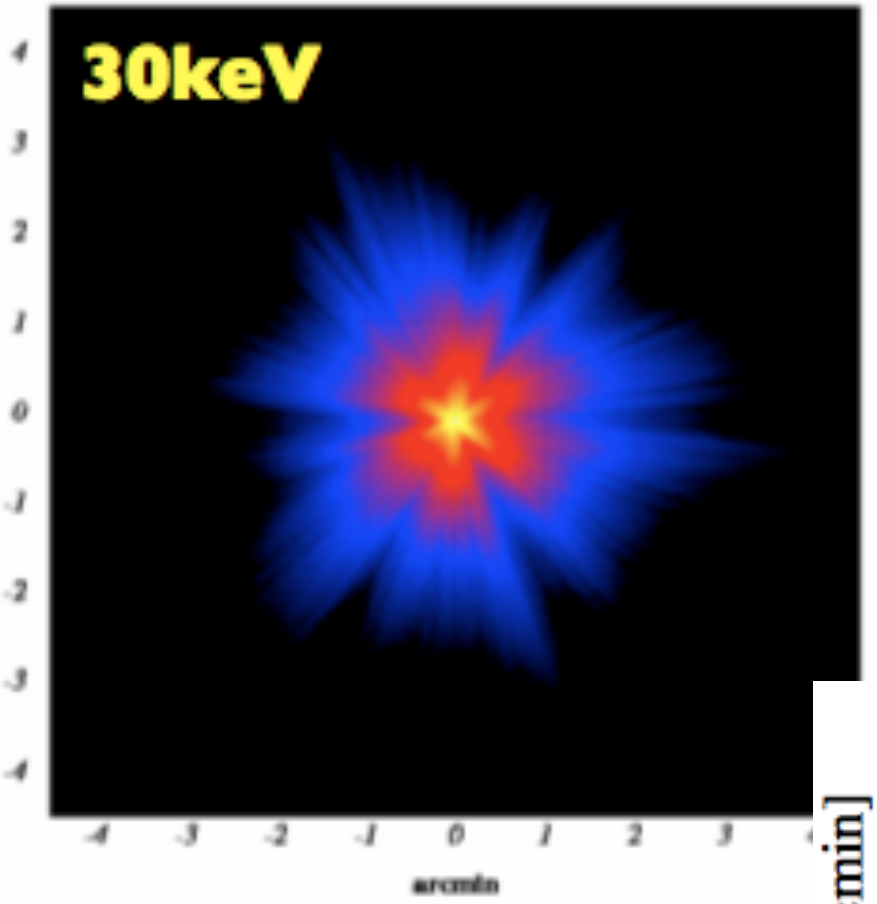


HXT: basic design

- Pt/C multi-layer mirror using Bragg reflection
- Large effective area above 10 keV
  - 150 cm^2/telescope @30keV, 55cm^2/telescope@50keV
- HPD < 1.7 arcmin is the requirement



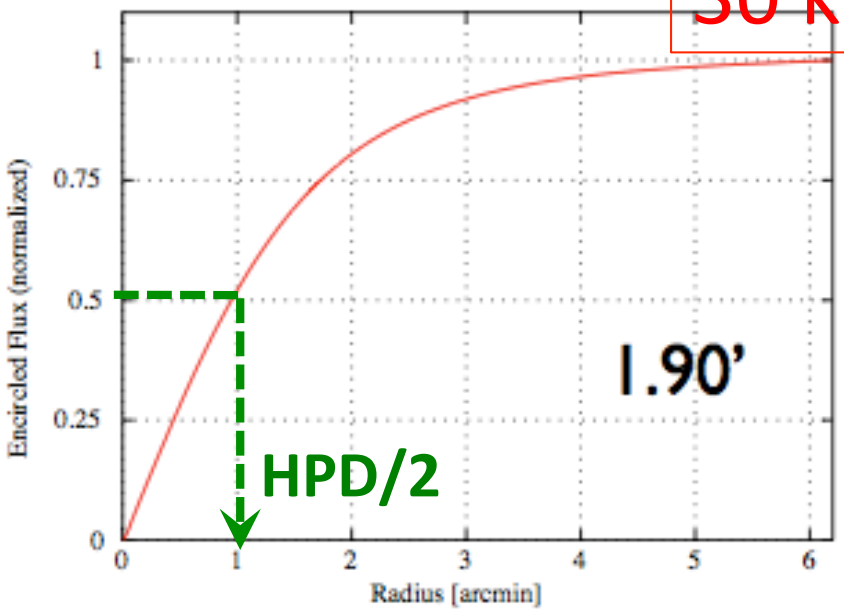
HXT: status

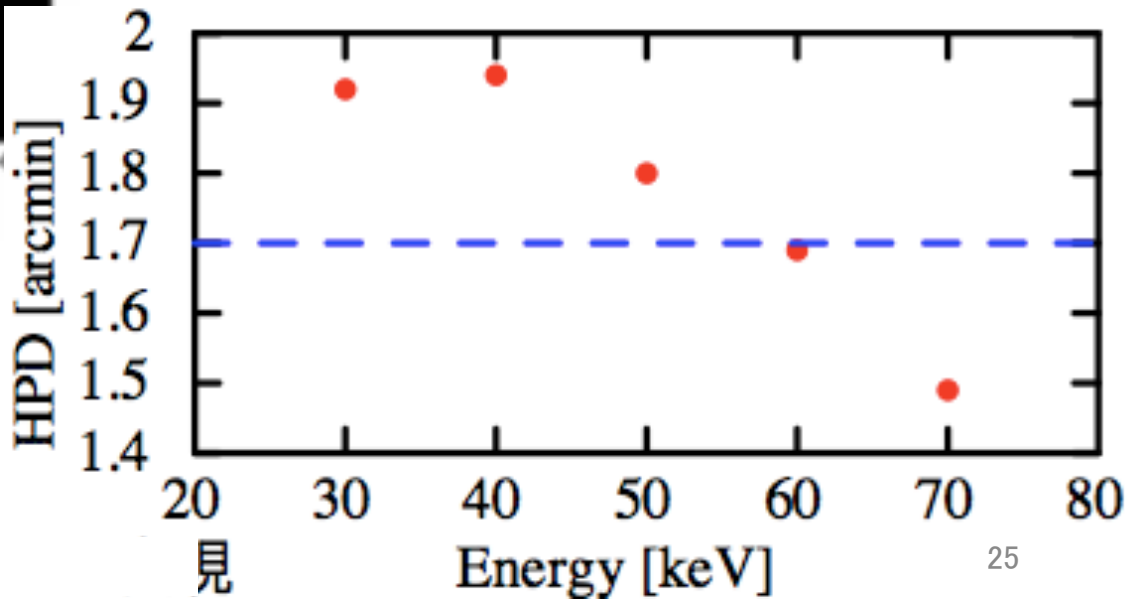


X-ray measurement of the first flight telescope, HXT-1

Encircled Energy

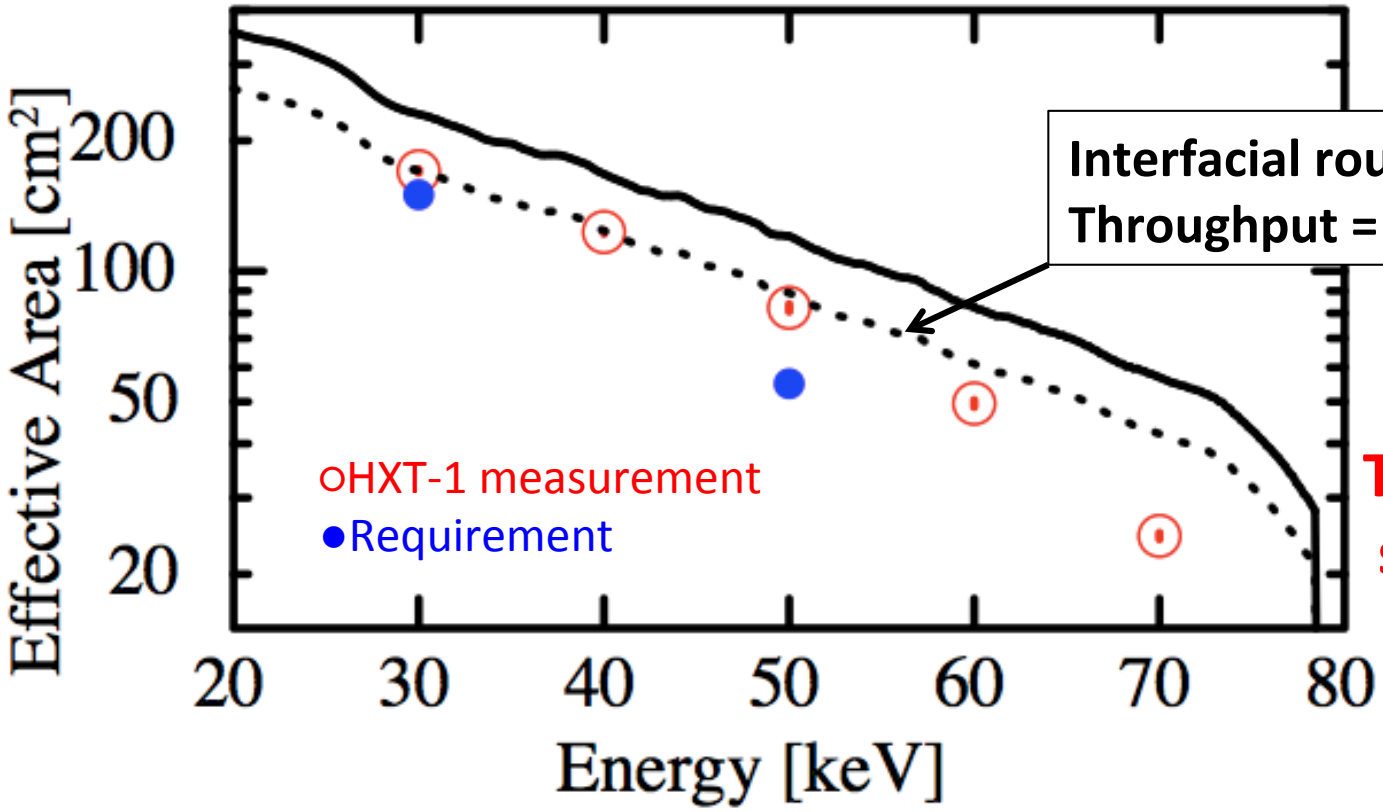
30 keV





HXT: status

- Effective area

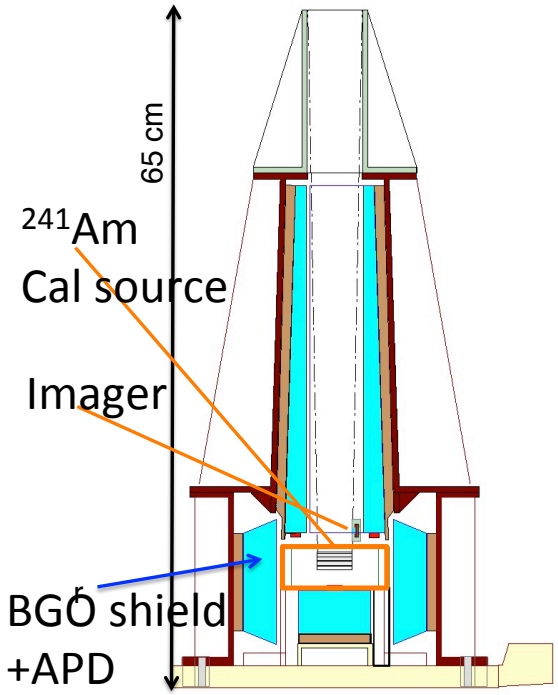


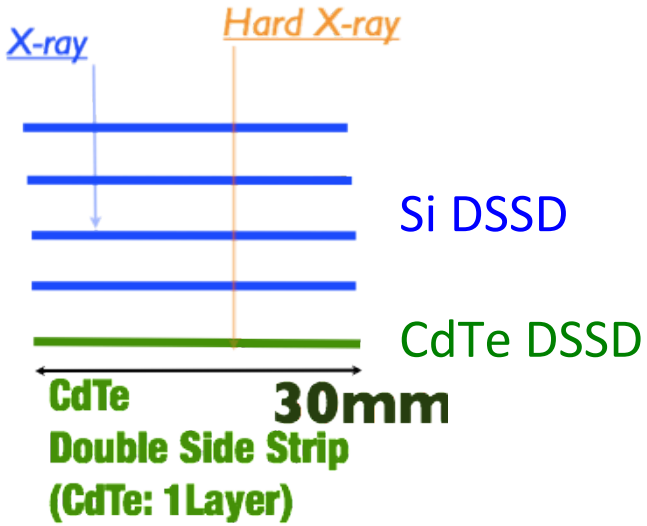
There is ~10 % systematic error

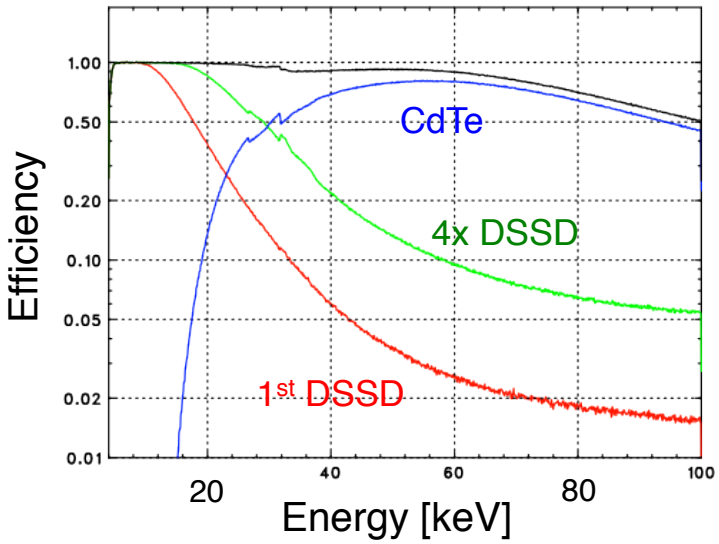
Measured roughness of 124 foils 4.1 +/- 1.0 Å

HXI: basic design

- Si + CdTe hybrid imager sensitive in 5–80 keV
  - Soft X-ray photons below 20 keV are absorbed in the Si part, while hard X-ray photons go through the Si part and are detected by the newly developed CdTe double sided cross-strip detector
- 9'.2 x 9'.2 field of view
- Well-type BGO shield is used to reduce background
- HXT+HXI makes the detection limit of point sources ~ x100 better than Suzaku



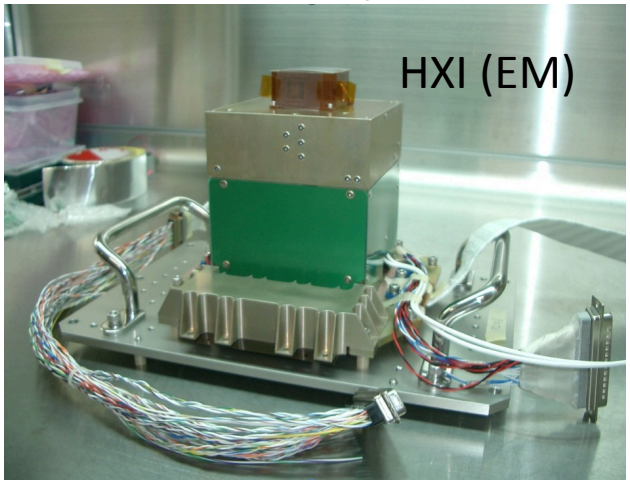




Detection efficiency of 1xDSSD, 4xDSSD, CdTe and all of the HXI

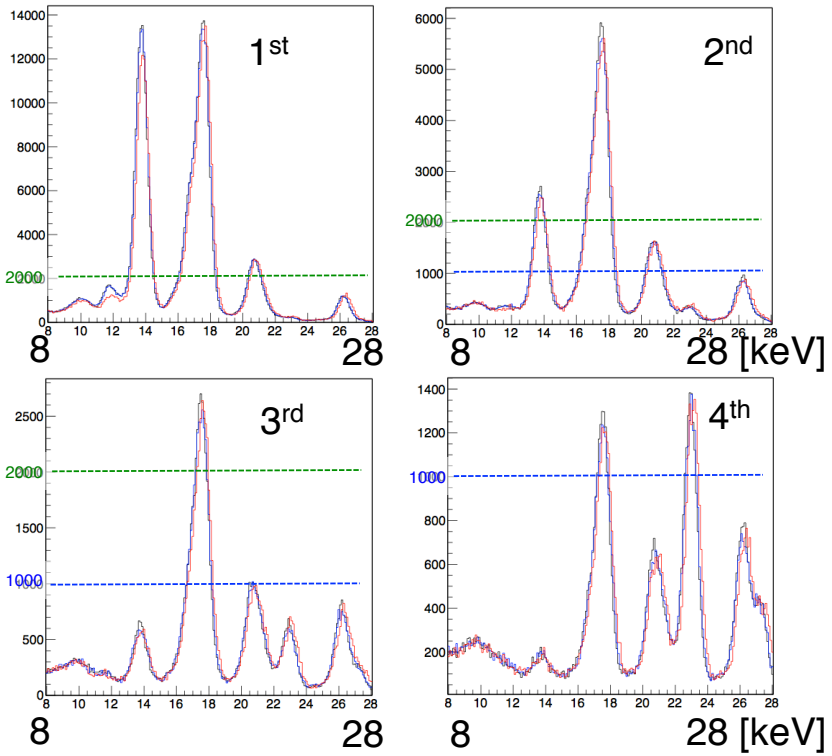
HXI: status

- Thermal Vacuum Test 2012-Oct
  - Operated at -25℃ in vacuum
  - ✓ no discharge, thermal design OK
  - ✓ Good spectral performance as in lab

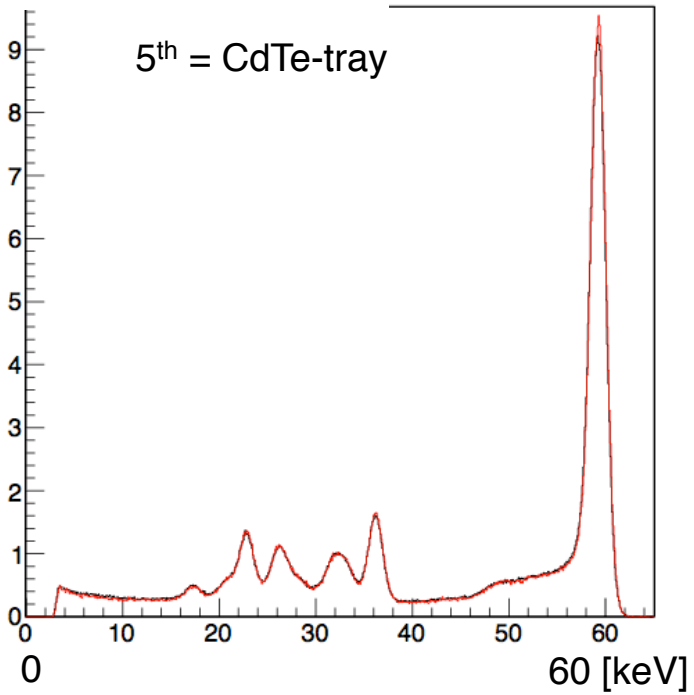


DSSD

^{241}Am spectra



CdTe

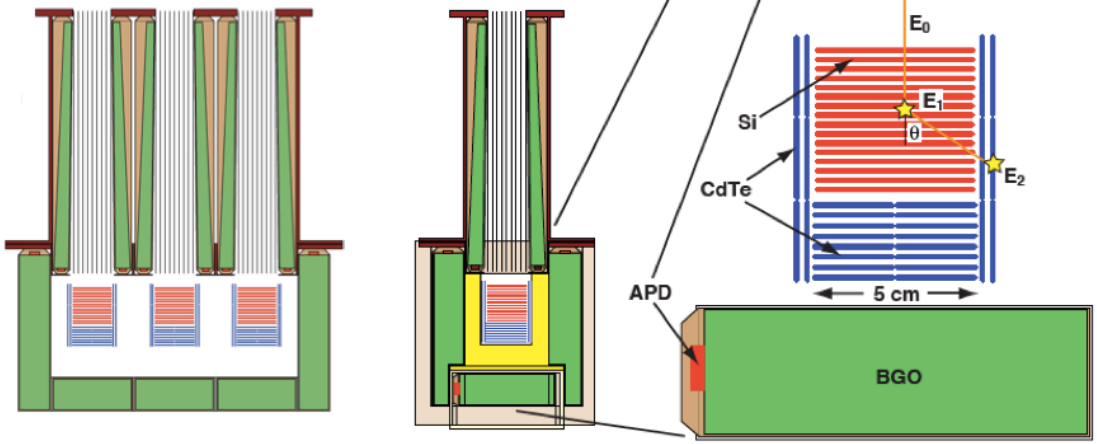


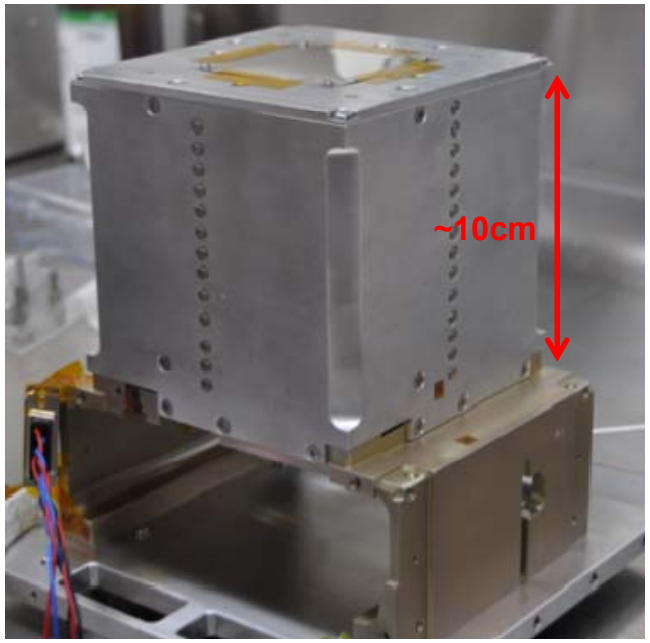
SGD: basic design

- Si/CdTe Compton Gamma Camera and Well-type shield to achieve ultimately low background (40–600 keV)
- Fine collimator
  - Narrow field of view ~ 0.55 deg
- GRB monitoring using BGO shield

Full EM constructed!

Si/CdTe Compton Camera
only select gamma-rays from the FOV

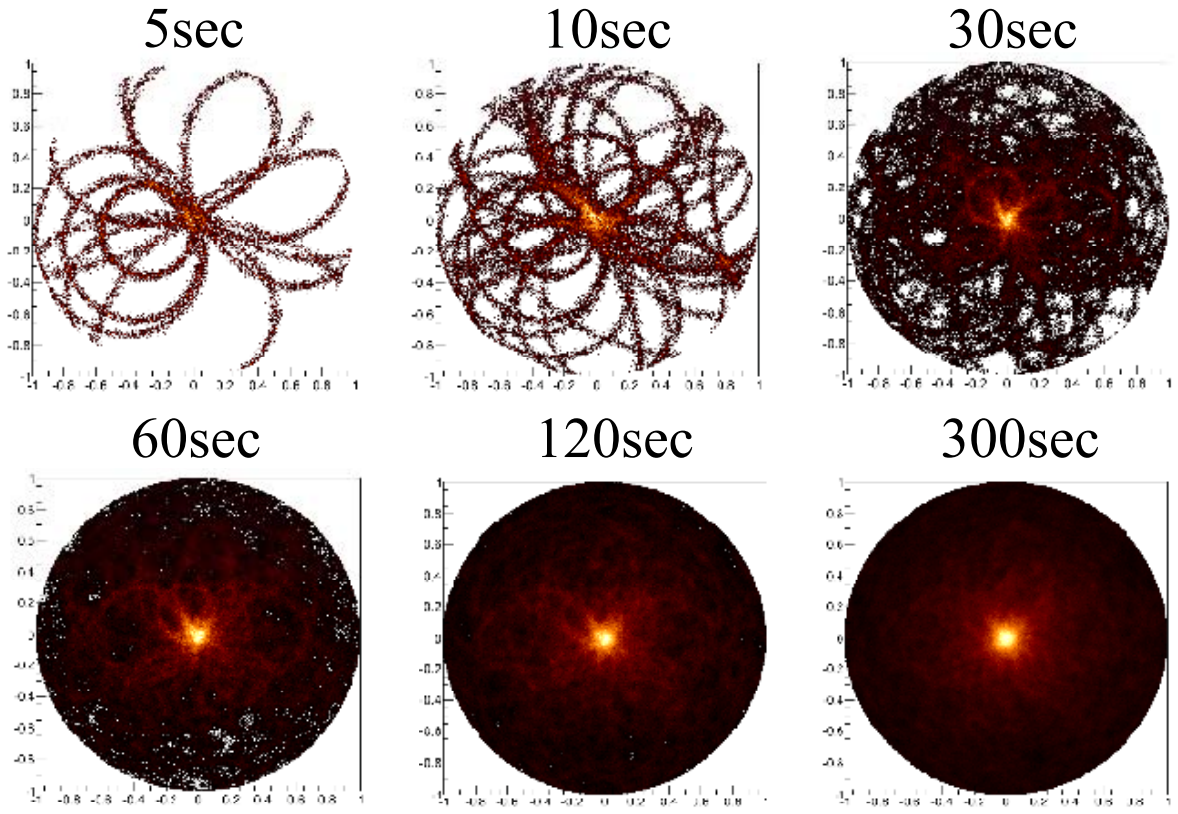


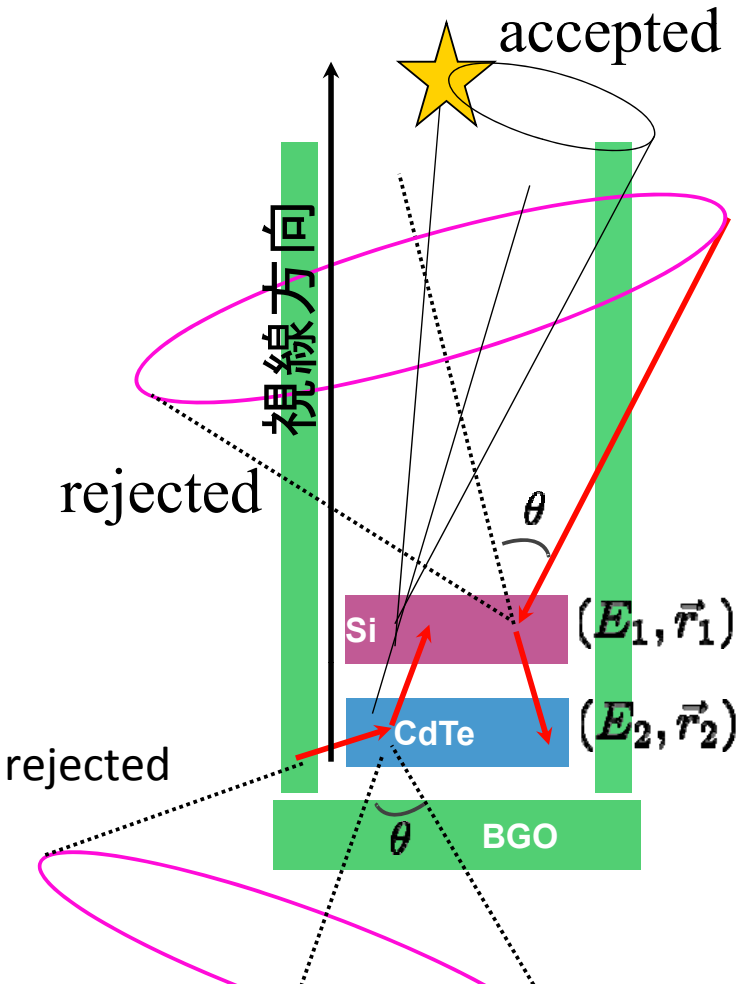


SGD: status

- Image reconstruction using RI gamma-rays

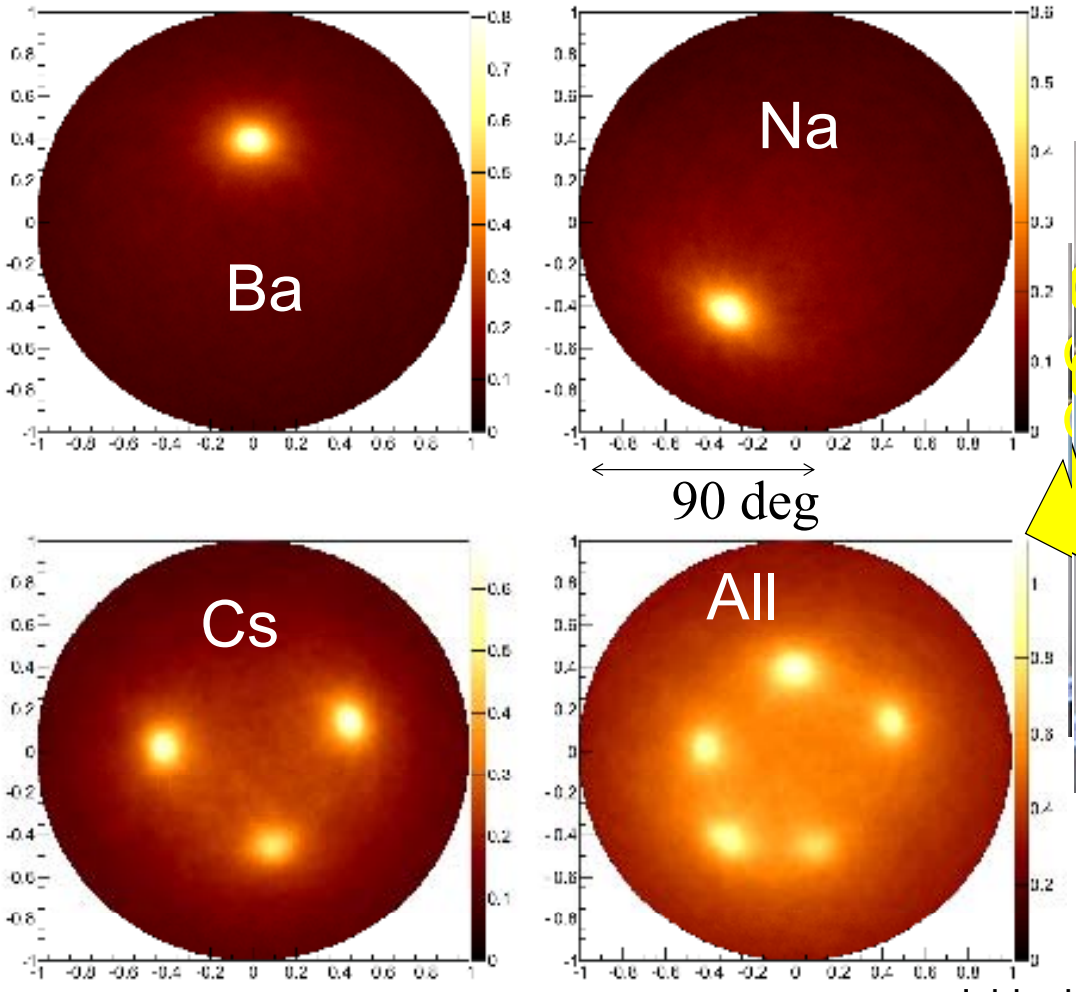
$$\cos\theta = 1 + \frac{m_e c^2}{E_1 + E_2} - \frac{m_e c^2}{E_2}$$

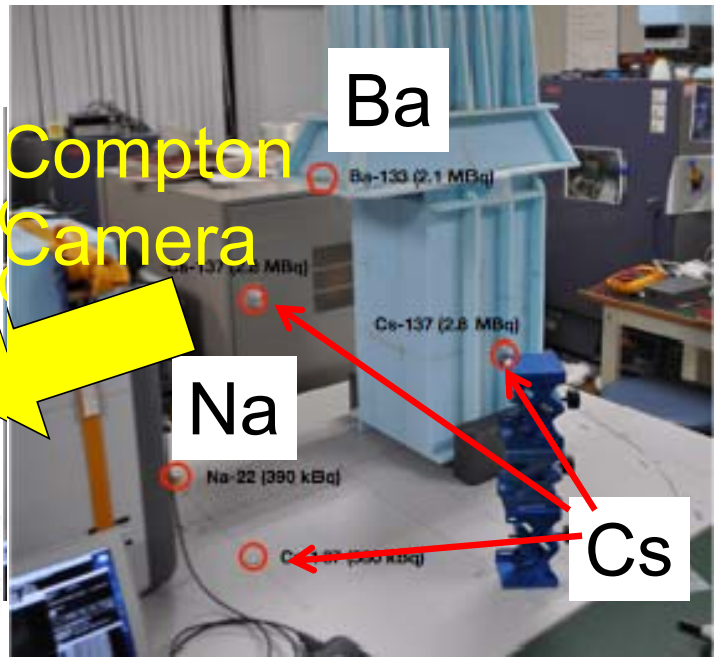




SGD: status

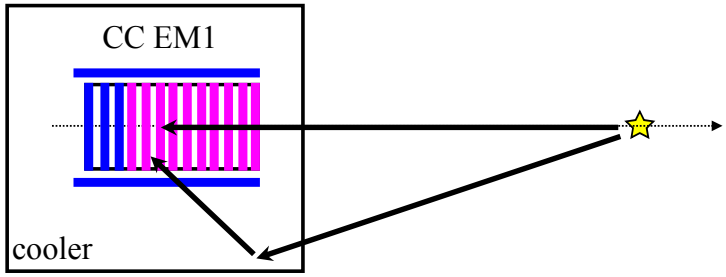
- Image reconstruction of RI gamma-rays

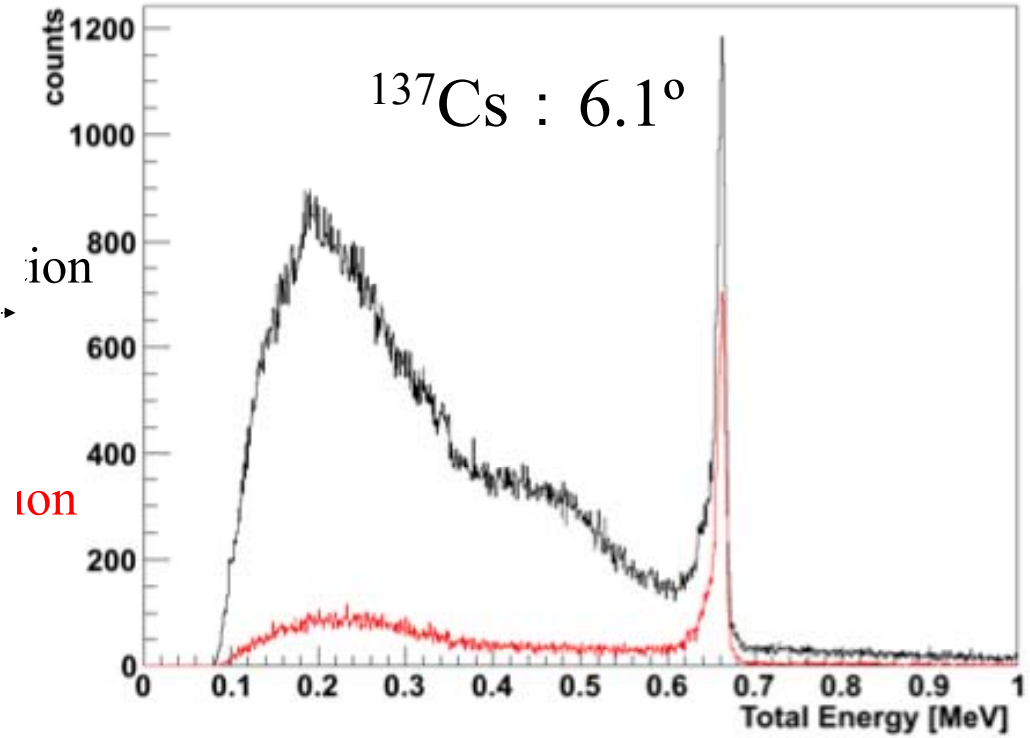




SGD: status

- Reconstructed spectra and background rejection





+Before background rejection
+After background rejection

Summary

- ASTRO-H is scheduled to fly in mid-2015
  - Wide-band and high-resolution observations will provide exciting data sets for many science fields
  - Synergy with X-ray (NuSTAR, eROSITA, ..) and other-λ observatories
- We are now building FM for payloads in conjunction with testing of EM sensors
- The ASTRO-H SCT will be formulating the in-orbit calibration plan over the next year.
  - Suggestions are welcome!