Japan Aerospace
Exploration Agency

JAXA status report 2018

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Brief Summary

- Not used frequently for spacecraft or manned-structure designing by engineers
- Used for detector design/calibration and astrophysical simulations by scientists
  - Payload design/calibration: Hitomi/XRISM, Suzaku, Arase, Cubesat, …
  - Detector development
  - Astrophysical simulations

Spacecraft or Manned-Structure Designing?

- Geant4-use looks not so active:
  - Spacecraft design matured enough for near-earth mission?
  - Lunar, Martian or Venus mission can be treated as an extension of geostationary orbit—they have no magnetosphere.
- Next frontier:
  - Jovian or Saturn mission (but no active study yet)
  - Lunar manned-base? (related to post-ISS)

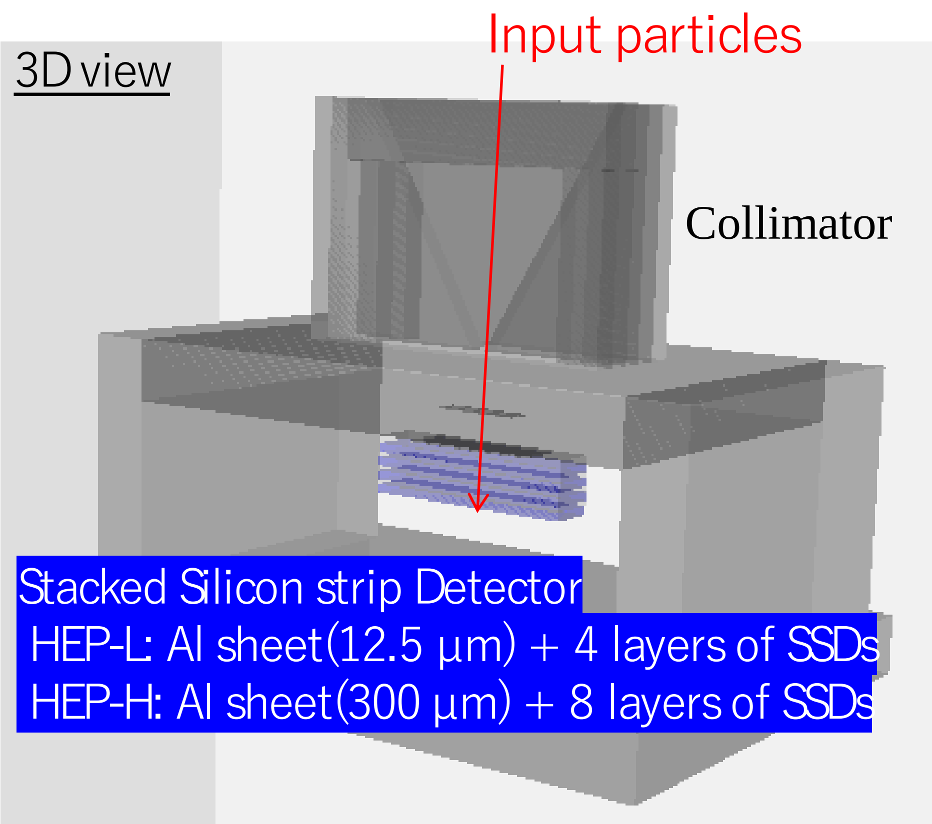
Payload design/calibration

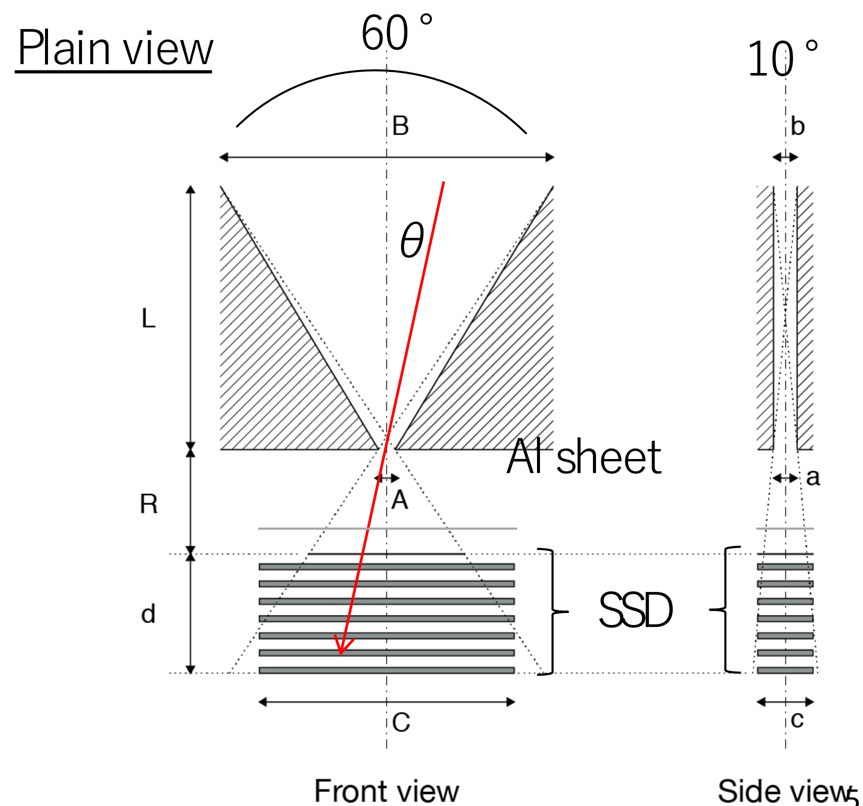
- Several Geant4-utilized missions: on-orbit or terminated
  - Hitomi (a.k.a., ASTRO-H: X-ray observatory) terminated due to on-orbit accident
    http://www.isas.jaxa.jp/en/missions/spacecraft/past/hitomi.html
  - XRISM—successor of Hitomi—(X-Ray Imaging and Spectroscopy Mission) under development
  - Arase (a.k.a., ERG: geospace probe satellite) on orbit
    http://www.isas.jaxa.jp/en/missions/spacecraft/current/erg.html
  - Suzaku terminated due to big solar flare in 2015
    http://www.isas.jaxa.jp/en/missions/spacecraft/others/suzaku.html
- Geant4 usage?
  - Detector's shielding design ← already reported in previous workshops
  - Precise detector calibration
    - Hitomi/XRISM ← will be presented 3rd day
    - Arase
    - Suzaku

By courtesy of T.Mitani (ISAS/JAXA)

High energy electron sensor onboard Arase

High-energy Electron exPeriments (HEP) instrument on board Arase observes 70 keV– 2 MeV. The HEP consists of three HEP-L modules (70 keV – 1MeV) and three HEP-H modules (700 keV - 2MeV).
A module consists of a mechanical collimator and stacked silicon strp detectors (SSDs). The Opening angle of the collimator: ~60 degree x 10 degree. To determine elevation angle, SSD has one dimensional position resolution.

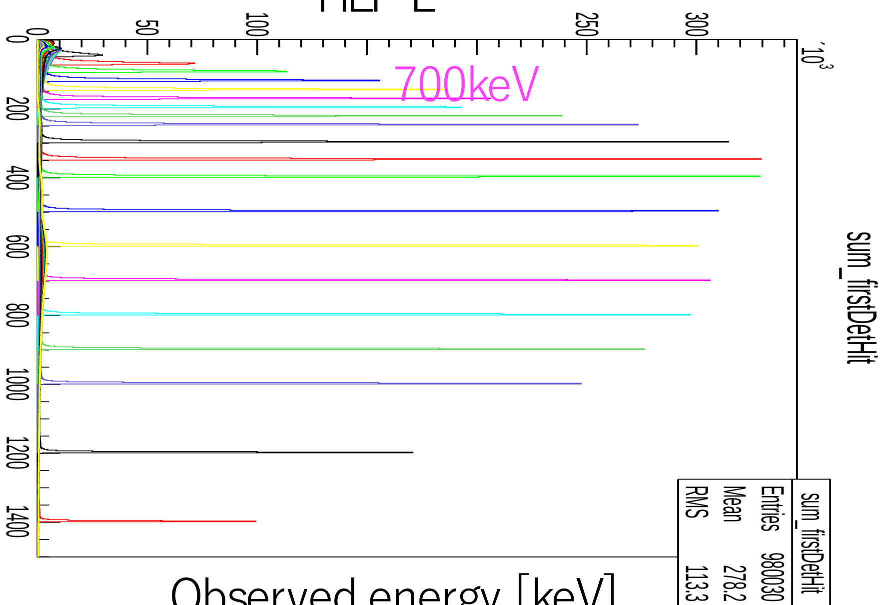




Energy response of HEP detector

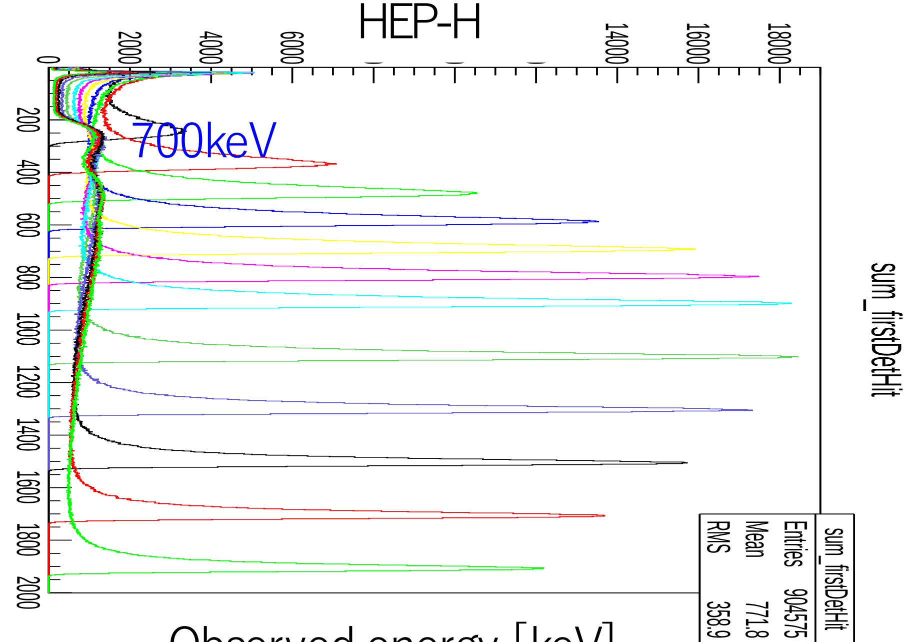
To calculate detector response to electrons, we use Geant 4 toolkit.
Figures below show detected spectra when monoenergetic electrons with various energies are irradiated to the HEP SSD module.

HEP-L

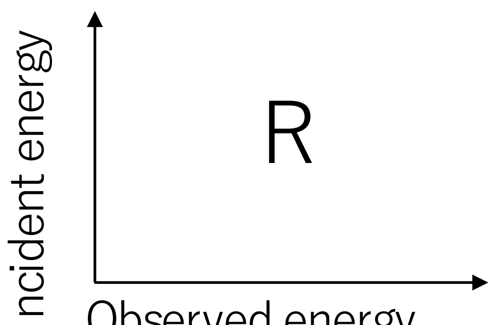


Observed energy [keV]

HEP-H



Observed energy [keV]



To deduce incident energy distribution from observed histogram, we calculate a response matrix R.

Incident flux $= R^{-1} *$ Observed count

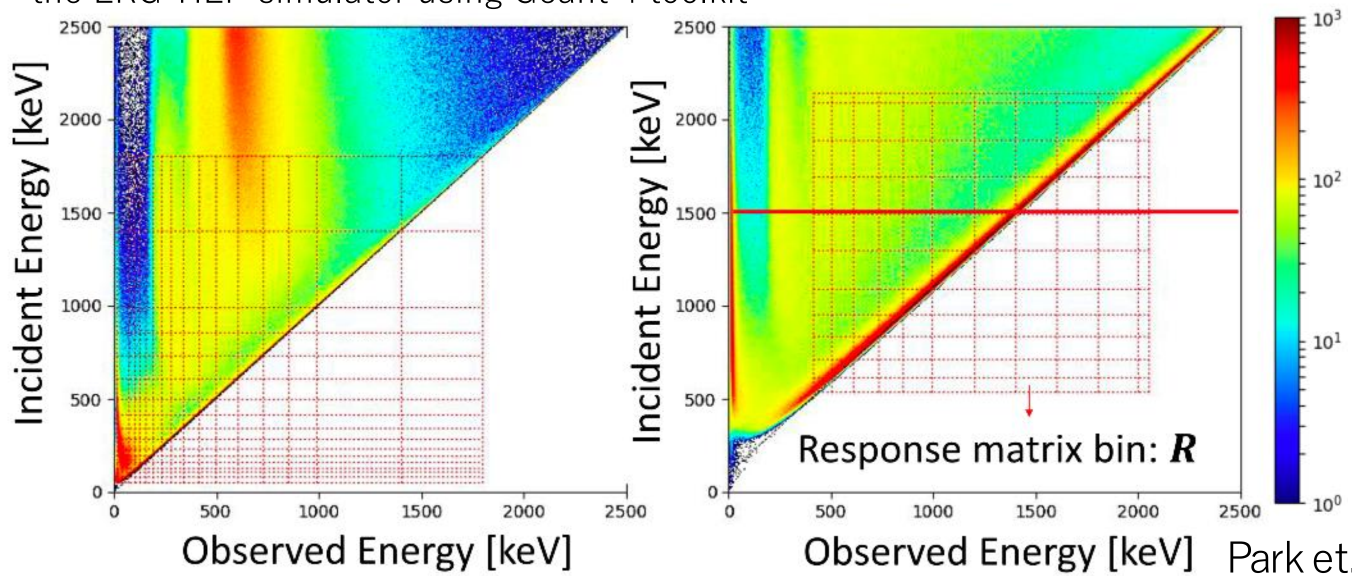
By courtesy of T.Mitani (ISAS/JAXA)

Response Matrix

- Based on Geant-4 simulations, we have constructed response matrices for HEP-L and HEP-H. By inverting the the matrices, we derive incident electron differential fluxes from an observed count histogram. The resultant flux data are open to the public as Level-2 science data product.

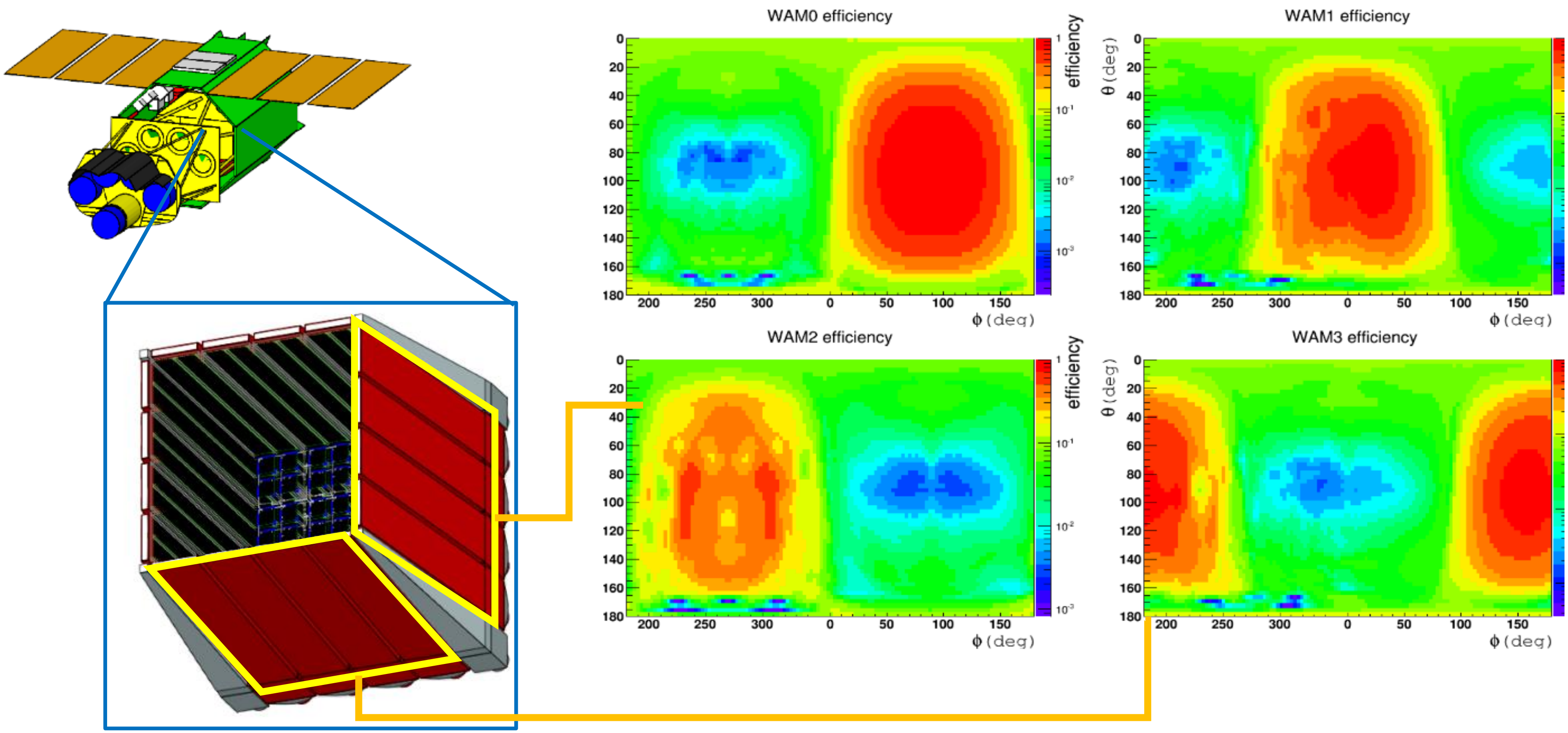
[Observed histogram] (1D) = [Response Matrix] (2D) x [Differential flux] (1D)
→ [Differential flux] = [Response Matrix]$^{-1}$ x [Observed histogram]

Electron count histograms over the incident-observed energy space simulated by the ERG-HEP simulator using Geant 4 toolkit



Park et. al, in prep.

Suzaku HXD detector precise calibration



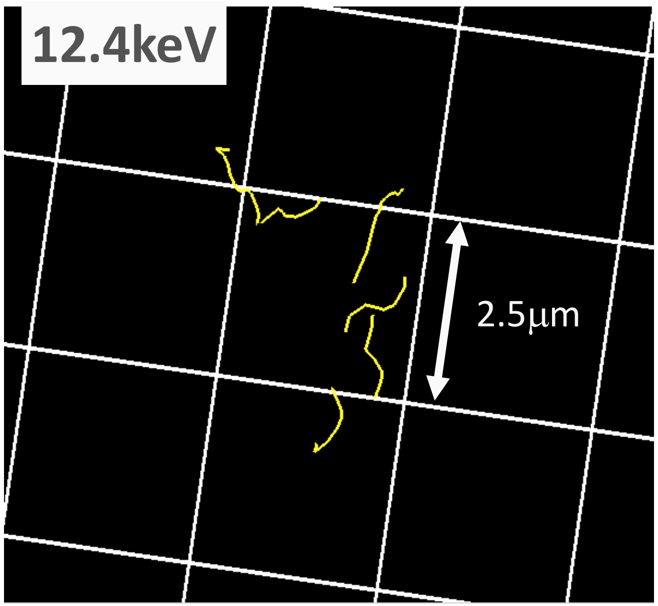
Geant4 mass models

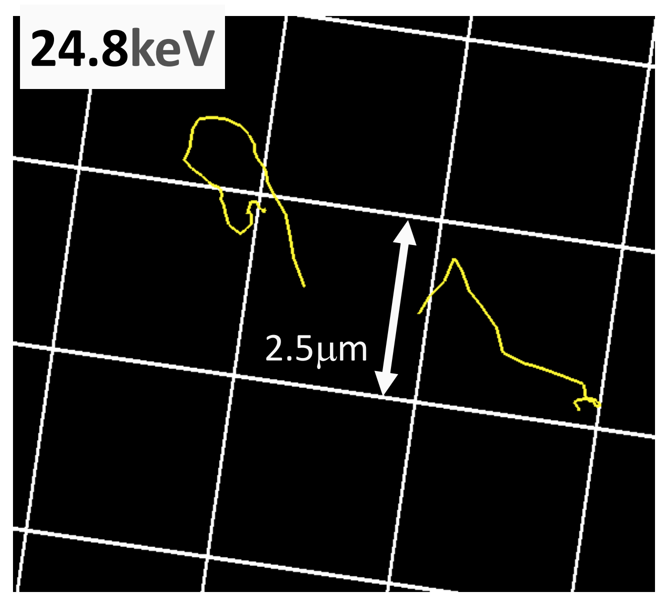
Gamma-ray detection efficiency for each panel

Detector Development

- Geant4 is used to simulate the detector behavior
  - X-ray polarization detection with precise CMOS image sensor
  - Optimal scintillator design using G4 optical photon simu

By courtesy of K.Asakura (Osaka-U)





$$MF = \frac{C_{max} - C_{min}}{C_{max} + C_{min}}$$

MF=16.6±1.2%@12.4keV

MF=18.7±0.7%@24.8keV

- Simulation of photoelectron tracks.
- 100% polarized incident X-rays are irradiated.
- Diffusion of the charge inside the detector is NOT taken into account.

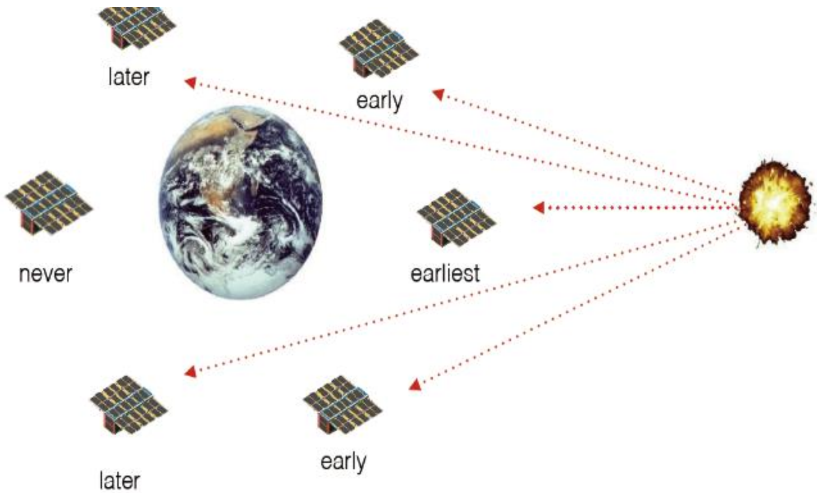
Detector Development

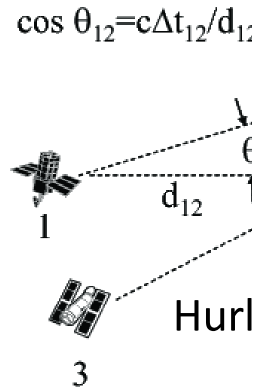
Japan Aerospace Exploration Agency

- Geant4 is used to simulate the detector behavior
  - X-ray polarization detection with precise CMOS image sensor
  - Optimal scintillator design using G4 optical photon simulation for GRB detection fleet

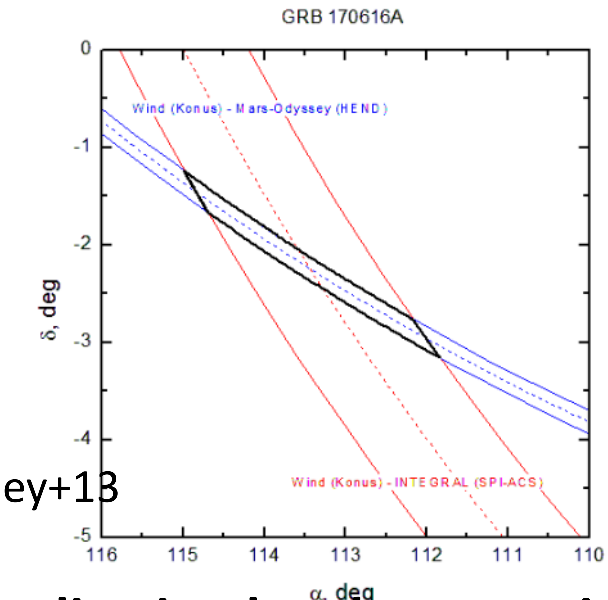
By courtesy of M.Ohno (Hiroshima-U)

fleet of cube-satellite w/ triangulation





Hurley+13



- **dozen cube satellite constellation**

➔ all-sky coverage
(no earth shadow)
huge effective area

- **localization by photon arrival time**

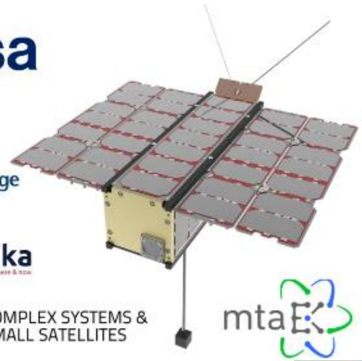
High timing synchronization by GPS
➔ <100 μ-sec timing accuracy results several arcmin localization accuracy (Pal+18 SPIE)

CAMELOT (Cubesat Applied for MEasuring and Localising Transients) (Werner+18 SPIE)

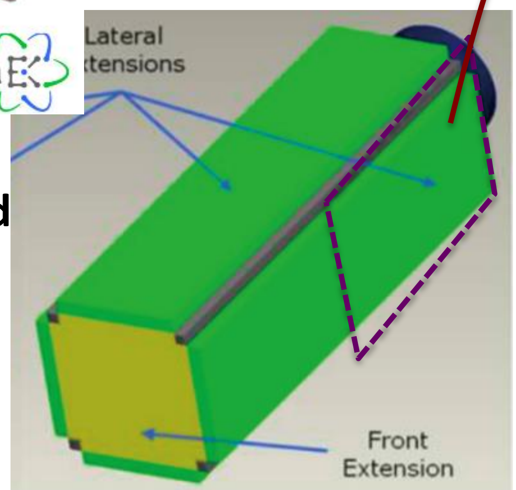
Detector design

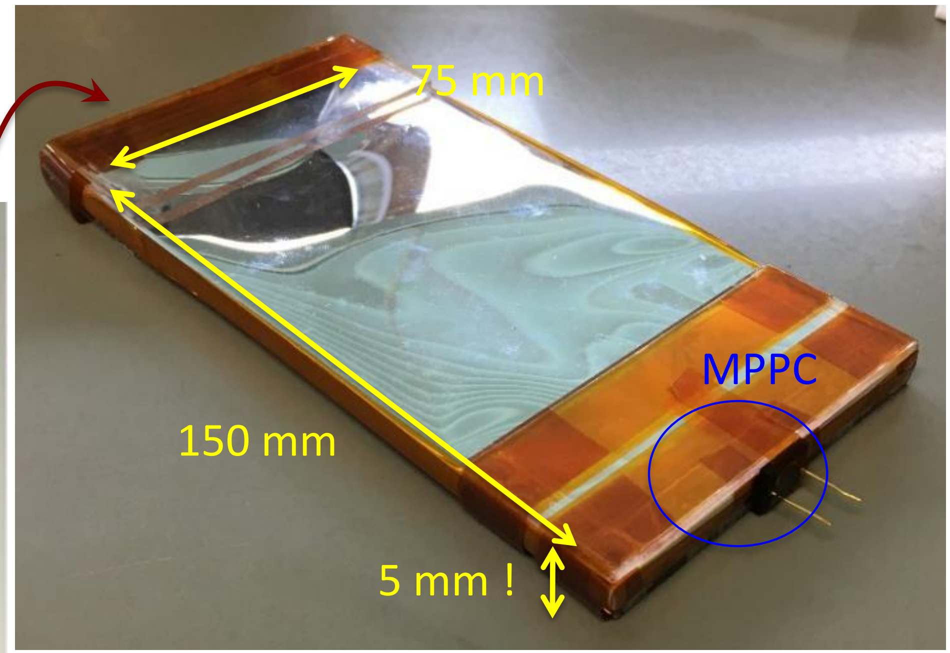
By courtesy of M.Ohno (Hiroshima-U)

広島大学



Satellite platform : 3U Cubusat designed for “RADCUBE” mission. Hungarian 3CS company + ESA consortium



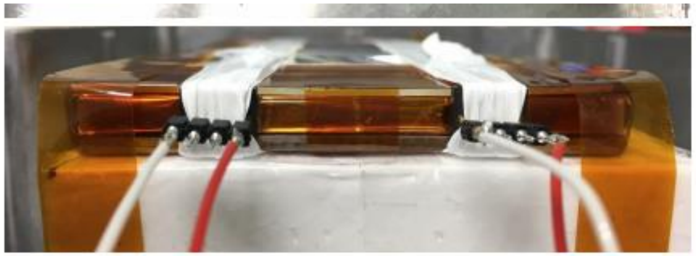


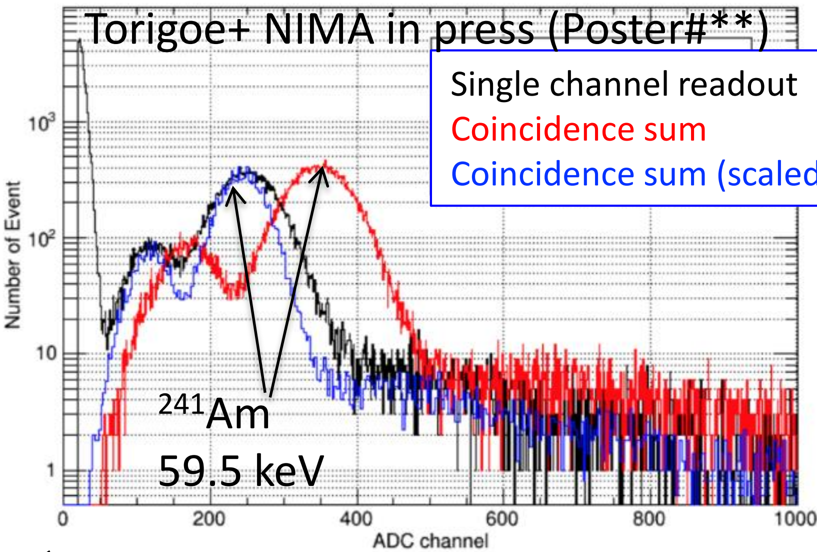
- two sides of lateral extension : ~268 cm^2 x 9mmt is a basic idea to maximize geometrical area
- challenging for such “large and thin” detector with small readout area

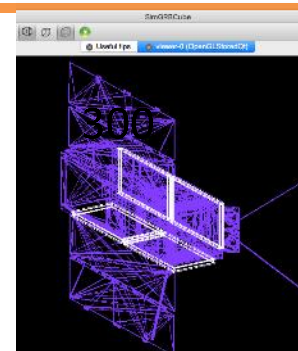
CsI scintillator readout by multi pixel photon counter (MPPC) is now being evaluated as the first feasibility study for their large light yield, compact readout area and low power consumption.

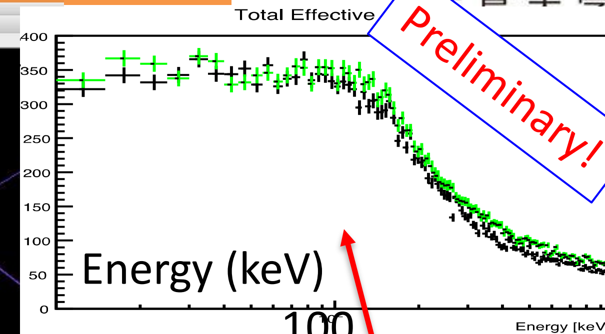
Detector feasibility

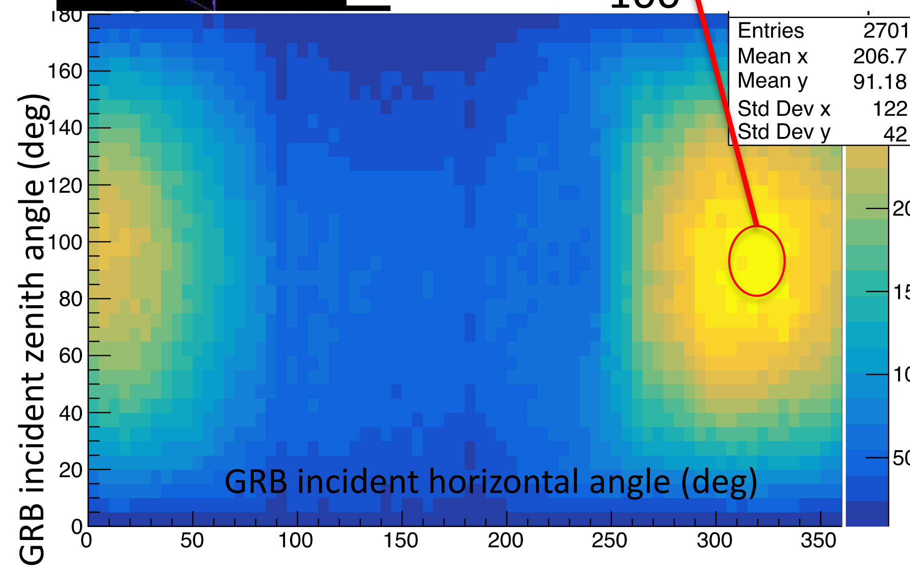
By courtesy of M.Ohno (Hiroshima-U)











- ✓ **Developed a multi-readout system for high light yield and redundancy**
- ✓ **Effective area simulation including ... absorption**
- ✓ **... from GRBs**

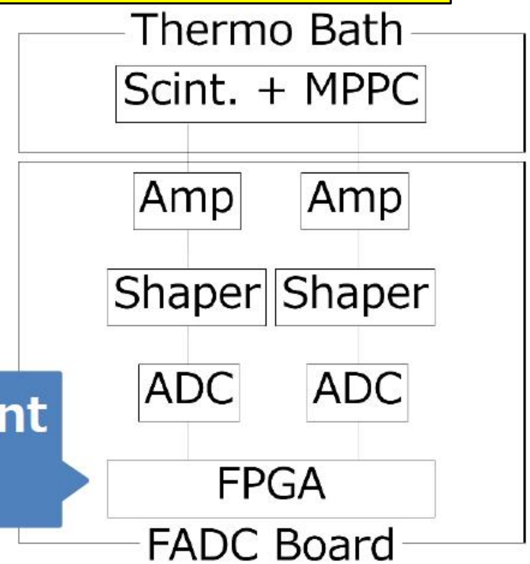
Comparable observational capability to the one detector of Fermi-GBM with our single unit of Cubesat

By courtesy of K.Torigoe (Hiroshima-U)

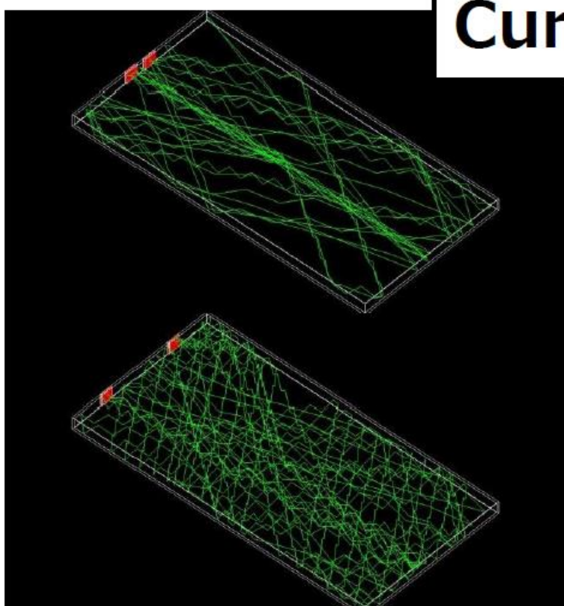
In order to improve the light yield, we dev[…] readout system with MPPCs

→ **Light yield and uniformity was improved**

→ **Energy threshold is ~10 keV at 25 ℃**



Current study

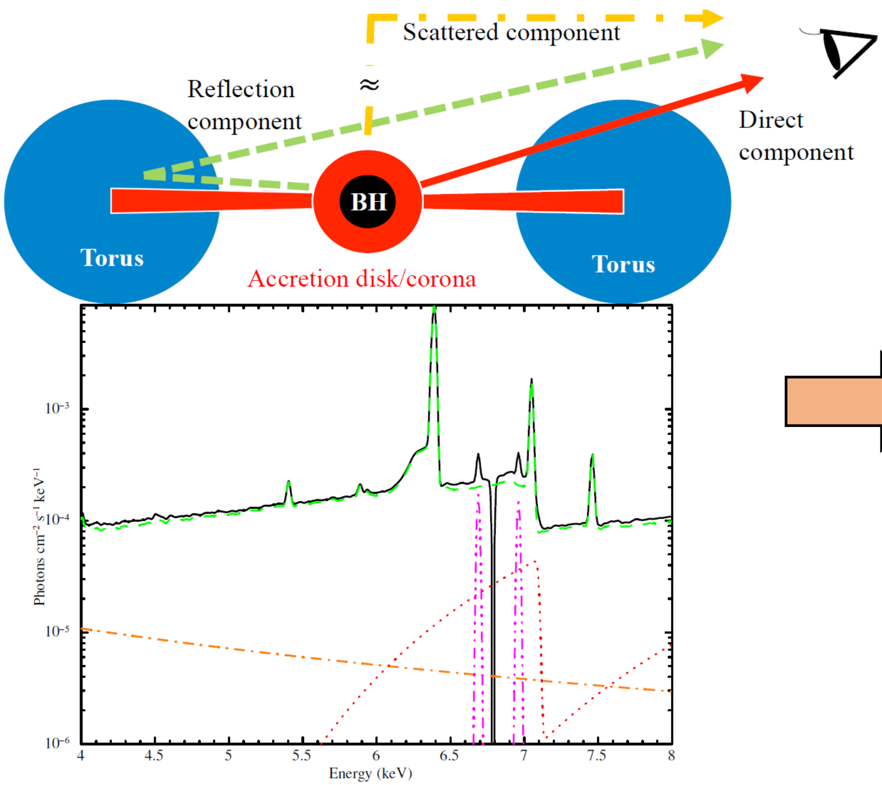


Optimum position of two MPPCs based on Geant4 simulation

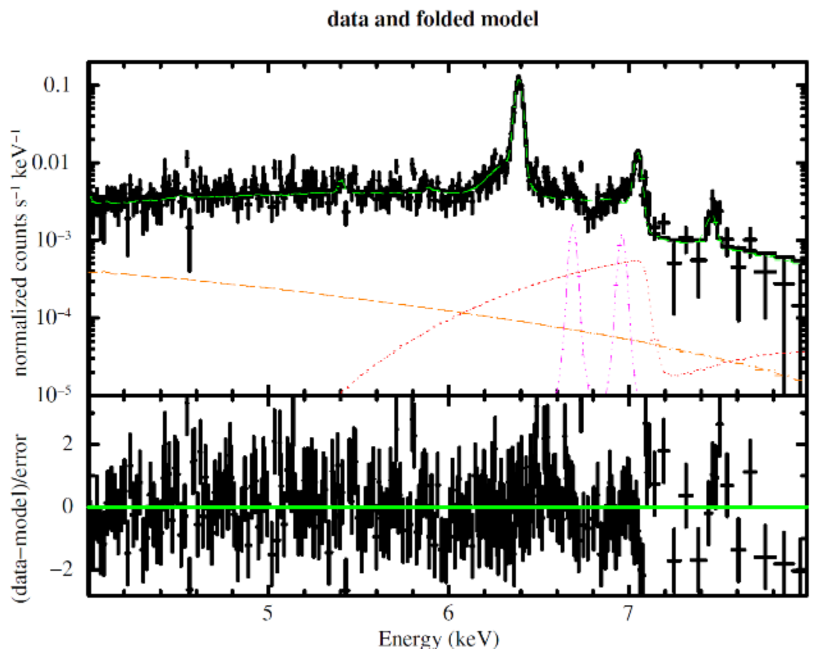
Effect of radiation damage to MPPCs in orbit by the proton beam test

Astrophysical Simulations

- Geant4 simulation in astrophysical scale (e.g., pc to Mpc) to represent observations
  - Hitomi results ← will be presented 3rd day
  - Chandra spectrum of active galactic nuclei



M.Hikitani+ 2018 (doi: 10.3847/1538-4357/aae1fe)



Summary

- Geant4 not used frequently for spacecraft or manned-structure designing by engineers
  - Maybe some use PHITS
- Used for detector design/calibration and astrophysical simulations by scientists
  - Payload design/calibration: Hitomi/XRISM, Suzaku, Arase, Cubesat
  - Detector development: Scintillator design, CMOS X-ray polarimeter
  - Astrophysical simulations: photon simulations observed by Chandra, Hitomi