Geant4 application for X-ray astronomy satellite Astro-E2

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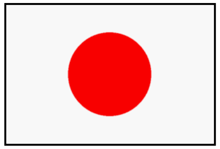
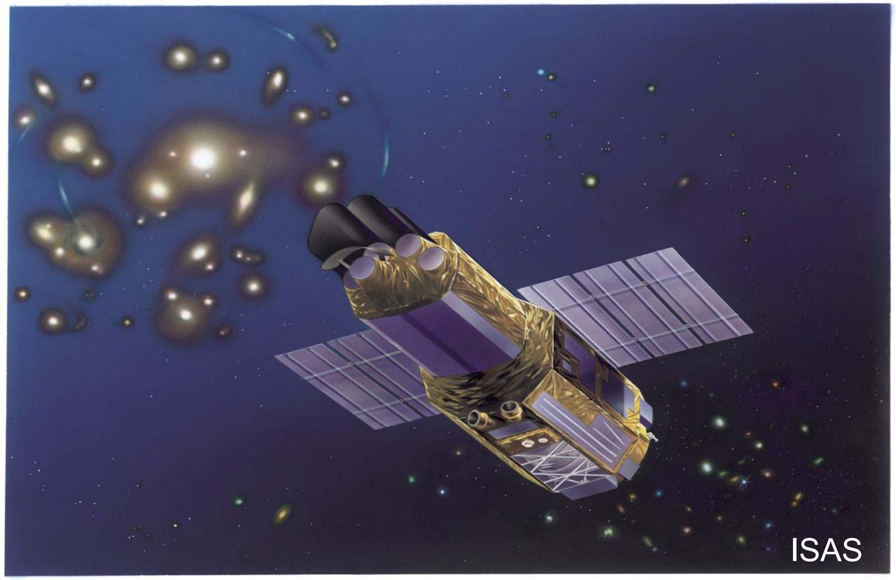
1. Astro-E2
2. MC for what?
3. The Applications



ISAS

- Japanese space development institute for academic use
- 1-2 satellite/year launch
- Scientific balloon experiments
- To be merged with NASDA and NAL (the agencies for non-academic use and aerospace) in Oct 2003

Astro-E2



- Jan 2005 launch
- Exploring the X-ray (0.4-600 keV) universe:
  a kind of **radiation measuring** mission
- High-performance spectroscopic mission
  - XRS: micro calorimeter (extreme resolution)
  - HXD: hard X-ray detector (high energy with low BGD)
  - XIS: X-ray CCD camera (with imaging)

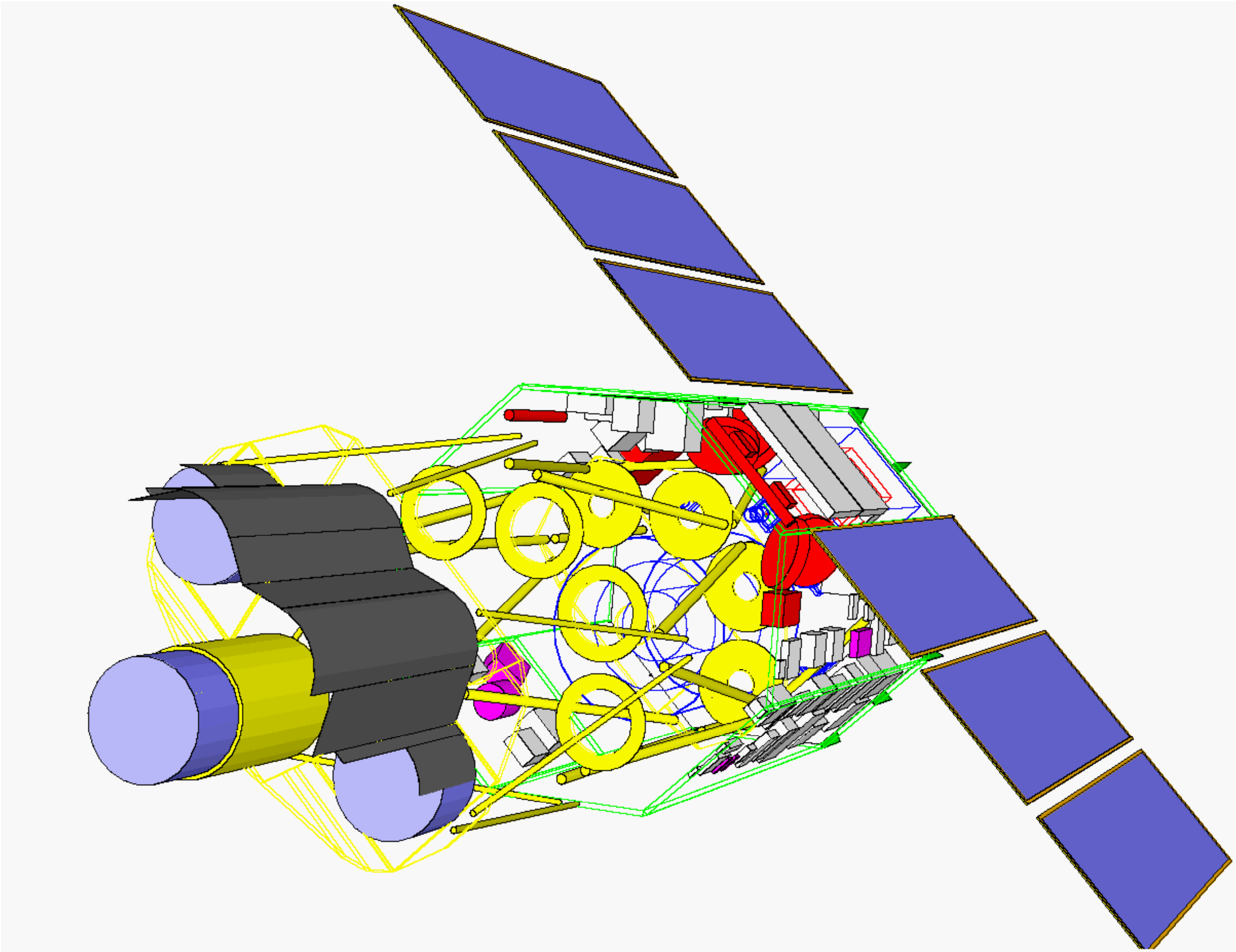
X-ray telescope

XRS
(dewar)

HXD

XIS
(x 2)

Electronics components inside all the panels



Satellite design restriction

From the launcher's ability:

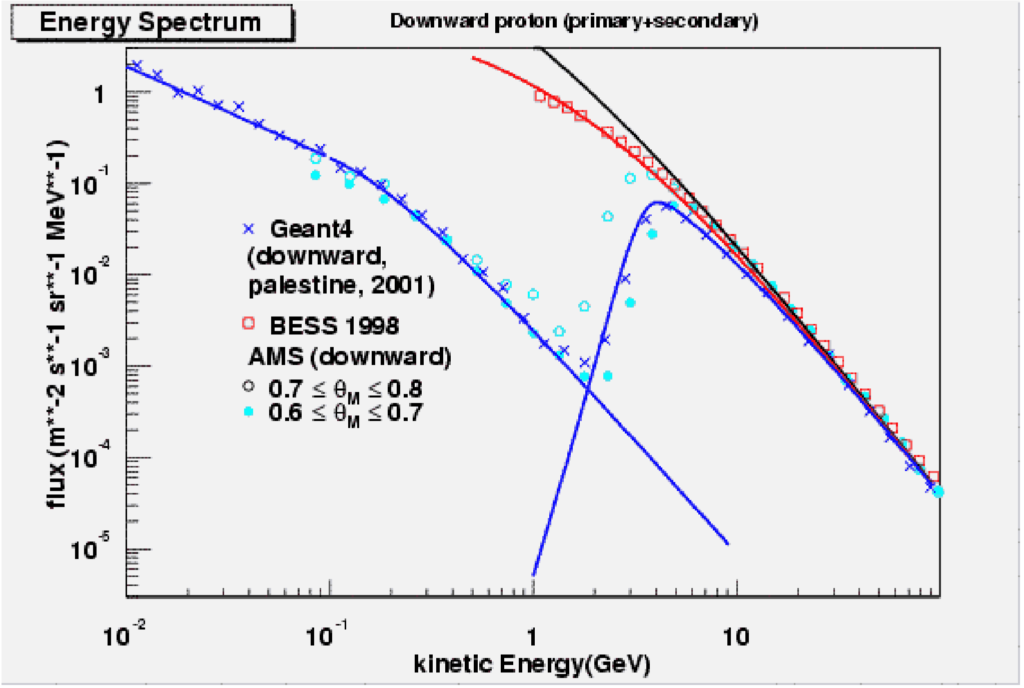
- 1600 kg (whole satellite)
  - restriction to structure and shielding
- Orbit: LEO (Alt~550 km, Inc~31 deg)
  - inside the geomagnetic shield
  - passing SAA several times/day

From the free-fall condition:

- Mass distribution of the satellite should be well balanced

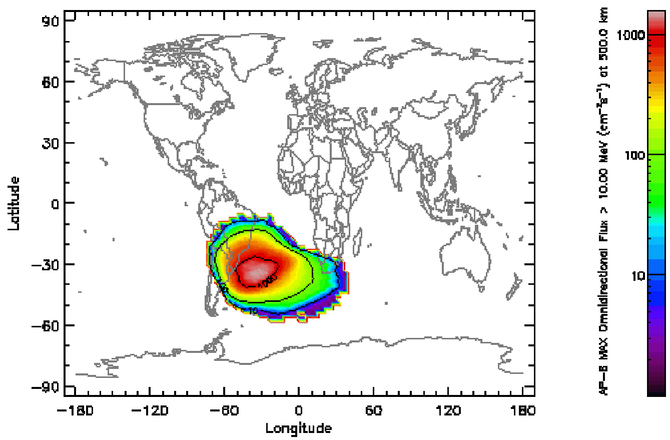
Radiation environment

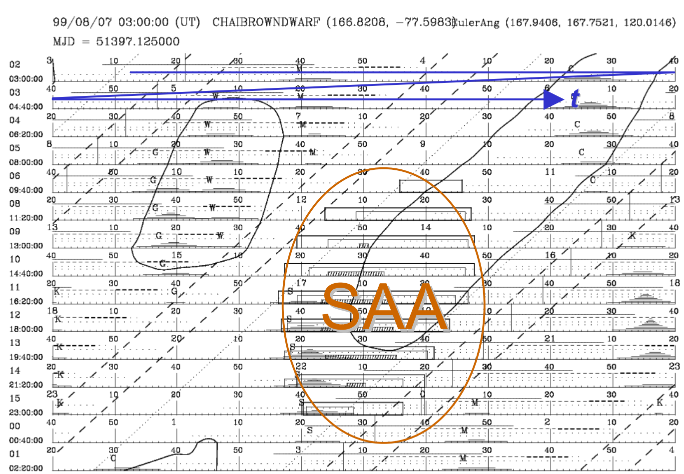
- 1 krad/yr (for LEO, Inc~30 deg)
- Many secondaries
- Omnidirectional
- SAA



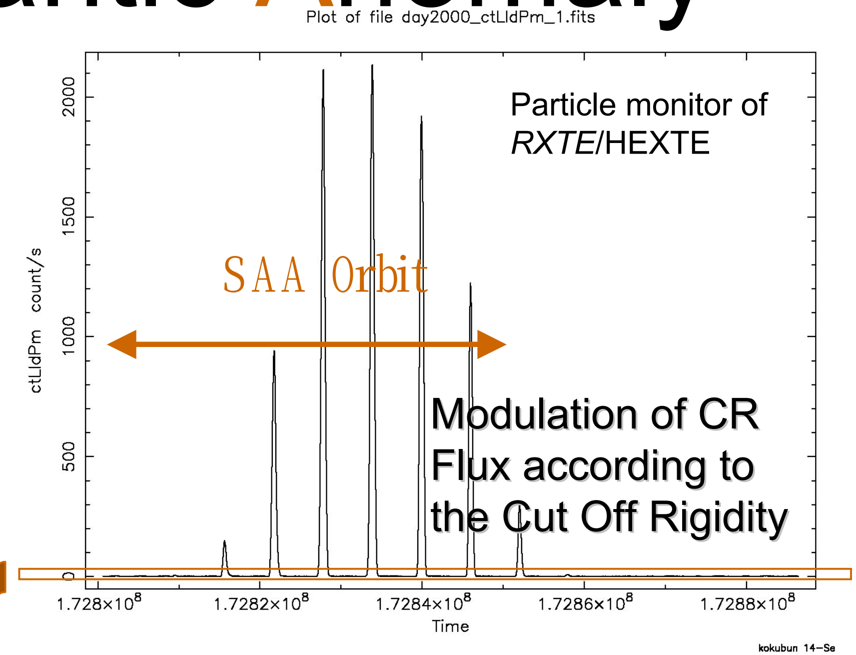
(from GLAST balloon experiment simulation)

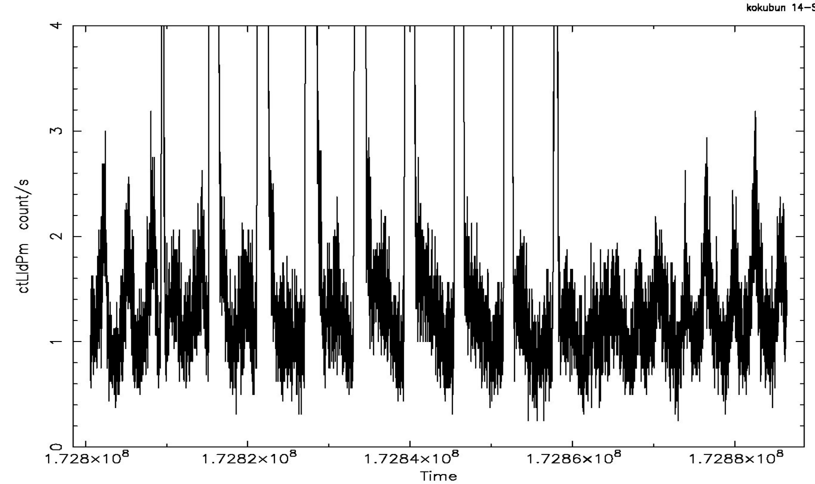
SAA: South Atlantic Anomaly





ASCA satellite orbital environment plot
(one day)





MC for what?

- Design trade-off under limited resources
  - radiation shielding v.s. mass
  - shielding v.s. activation
- Performance estimation
  - Detector response matrix
  - Background estimation

so, what is required for MC is...

MC quality requirement

Rough energy deposition (i.e. ionizing loss):

- shielding

Accurate spectrum of secondaries:

- activation
- response matrix of the detector
- BGD in the spectroscopy

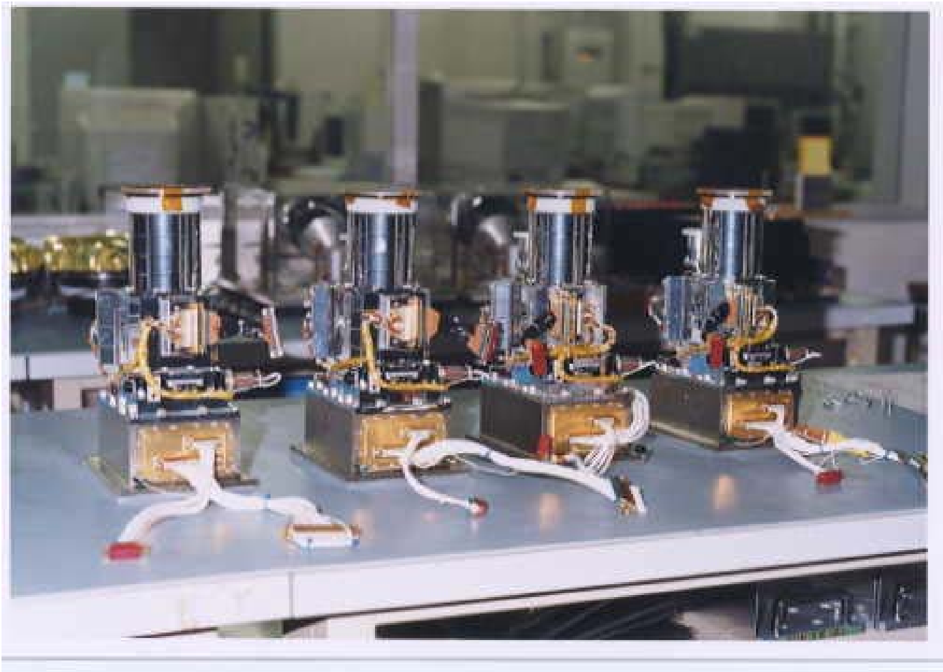
Mainly < 1 GeV process

X-ray detectors

- non-dispersion type spectrometers (detect energy deposition)
- cannot distinguish particle type
  - shielding and BGD estimation are essential

G4-applied detectors

HXD

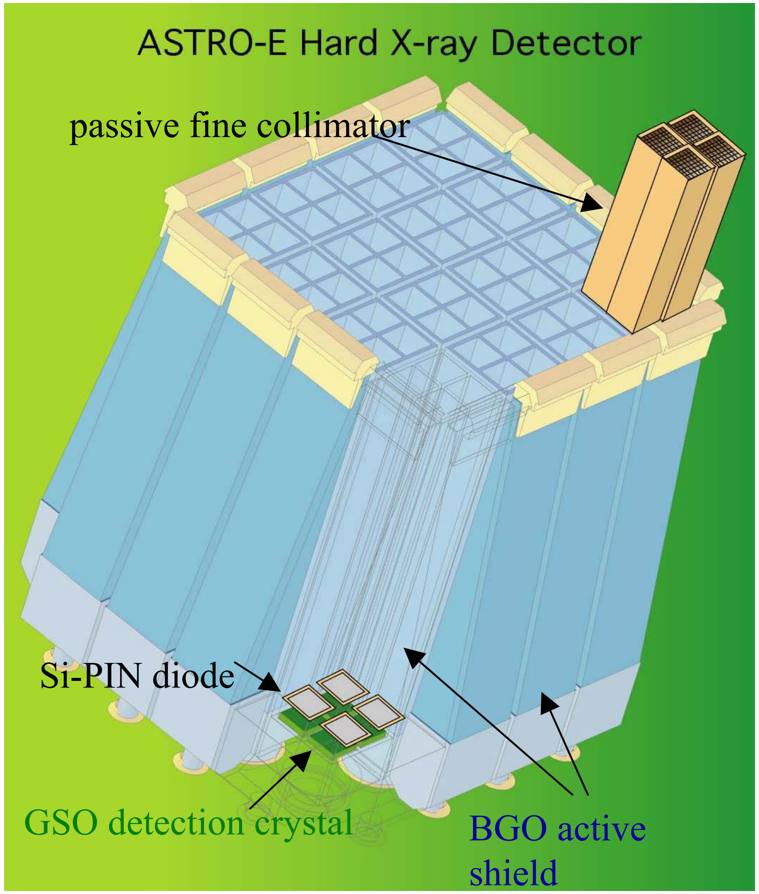


XIS

HXD

- Well-type phoswich (GSO/BGO)
  - ➢ Active narrow FOV
- Hybrid devices (Si+GSO)
  - ➢ Wide energy range
- Compound-Eye configuration
  - ➢ Large area
  - ➢ anti-coincidence

Extreme low background and high sensitivity



Geant4 for HXD

- 10-600 keV wide-band spectrometer
- No imaging capability

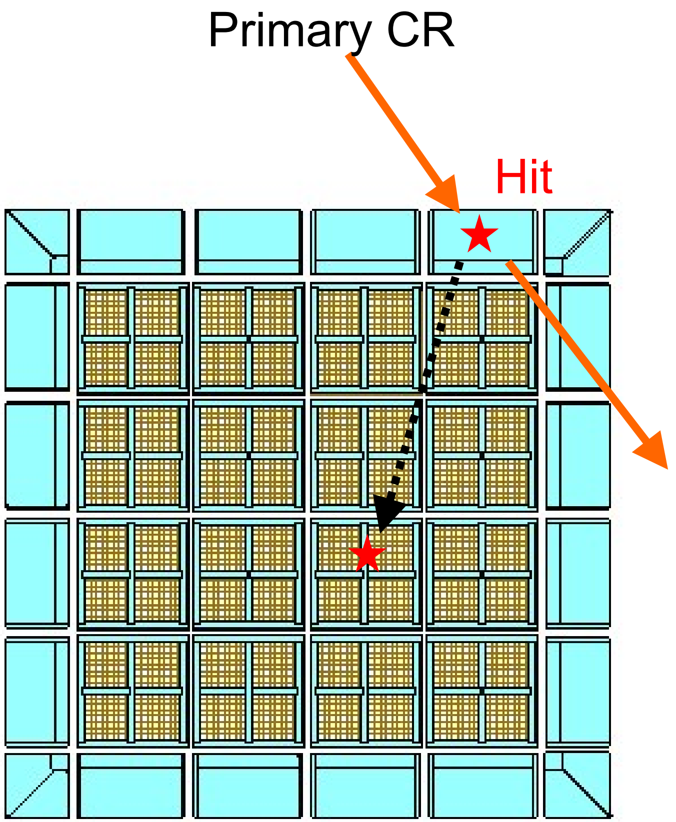
Most of MC-sim has been done with EGS4, but now considering Geant4

1. BGD1: fake event by CR
2. BGD2: activation
3. Detector response matrix

BGD1: Fake event by CR

Irradiation of high energy CRs
during the normal operation
(except SAA)

"Fake" event generation by secondaries



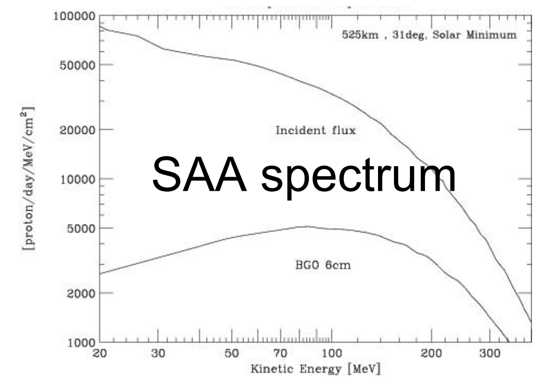
So, we need to estimate...
- Secondary particle generation (n,p,γ, …)
- Accurate energy deposit (pulse height)
- Optimization of anti-coincidence selection

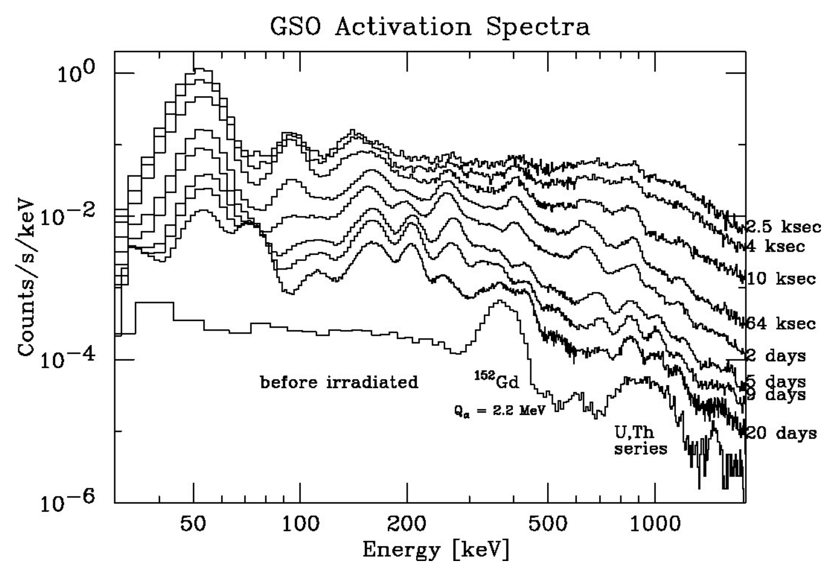
BGD2: Activation

Source energy ~ 100 MeV
(inside thick BGO shield)
Flux ~ several x 10^7 c/day/unit

Generates radioactive isotopes via (p,xn) reaction

Generate background from delayed γ/β-rays





Results from irradiation experiment (135MeV H^+)

Activation modeling

Information of primary particles, orbital variation (CR,SAA,COR)

Mass Model (GEANT4)

Hadron - nucleon (secondary, activation)

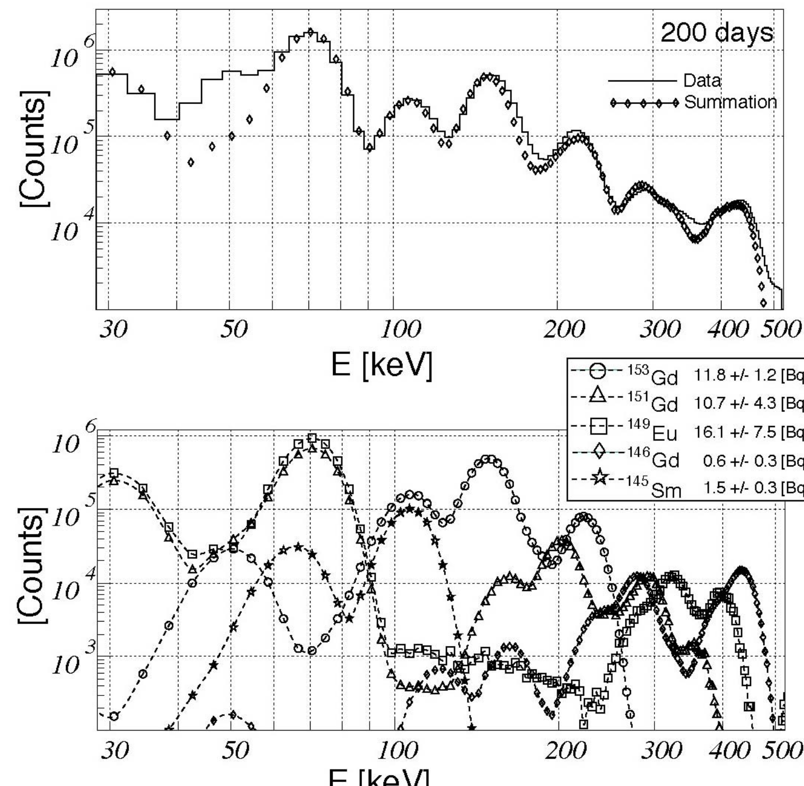
Nuclear/Atomic de-excitation (Database files)

EM transport (GEANT4)

Detector Response

Background Model

Comprehensive treatment with GEANT4 !



Example of modeling with EGS4
(Kokubun *et.al.*, IEEE 1999)

Detector response matrix

Scientific analysis

Observational dataset from celestial objects

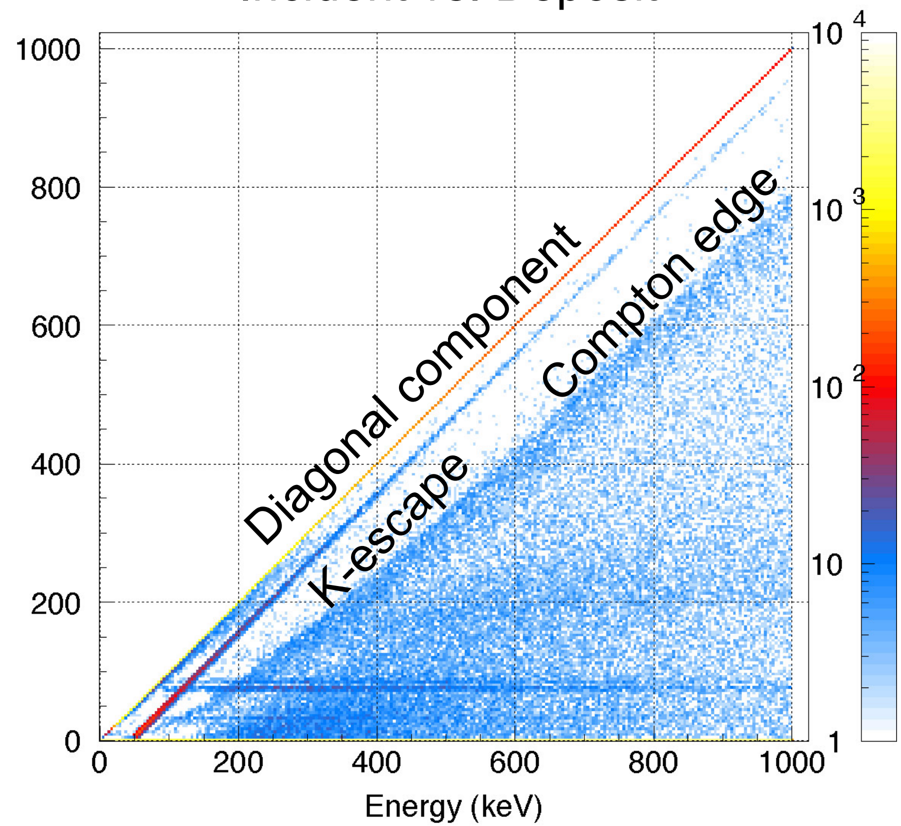
Convolution/reconstruction with detector response matrix

Theoretical emission models

With GEANT4…

- Complicated geometry
- Precise treatment of low-energy EM

Incident vs. Deposit



Example of response matrix (with EGS4)

XIS

- X-ray CCD camera
  - similar to *XMM-Newton*

    `examples`

    `-> advanced`

    `-> xray_telescope`
  - easily damaged by radiation

camera body

Geant4 for XIS

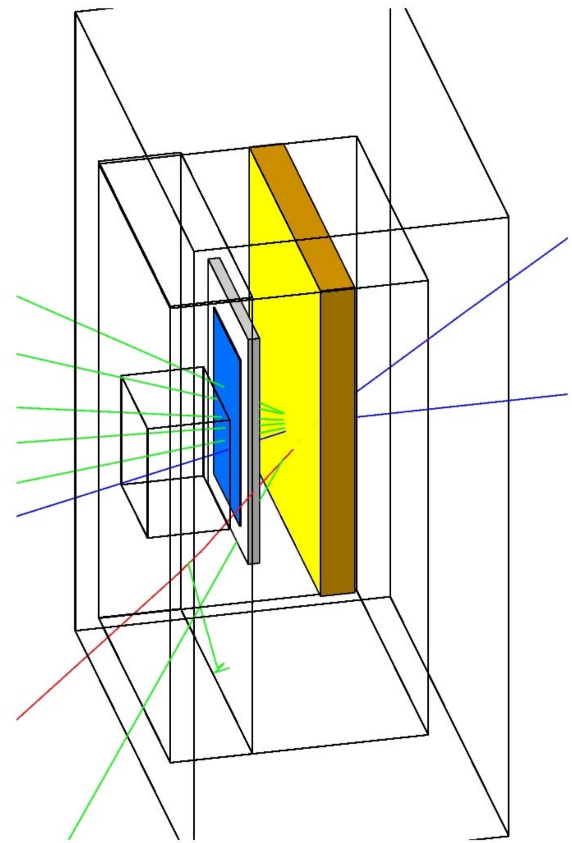
- 0.4-10 keV imaging spectrometer
  - good for large diffuse objects
  - low BGD is essential for diffuse source analysis
- Operated at -90 degC by Peltiert cooler
  - to keep low BGD
  - heatsink should be stiff

mechanical parameters v.s. shielding/activation

Secondaries by heatsink

- *Cu* or *W* for Stiffness
- Concern: secondaries and activation

planning G4 simulation with lowEnergy EM processes



Summary

- For Astro-E2 development, we are using Geant4 to evaluate the design trade-off.
- For data quality evaluation, we are evaluating Geant4.
  - Accurate-in-energy MC is important.