The Estimation of Spatial Resolution of the Lunar Gamma-Ray Spectrometer aboard SELENE (KAGUYA) by Geant4

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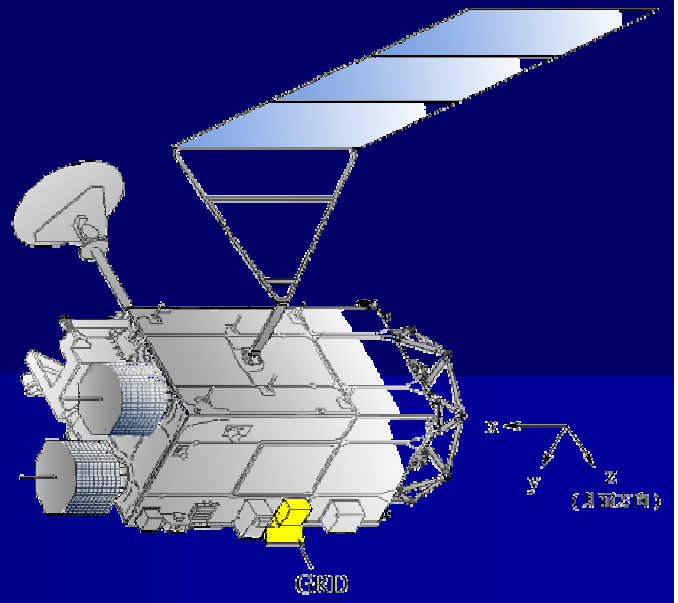
Outline

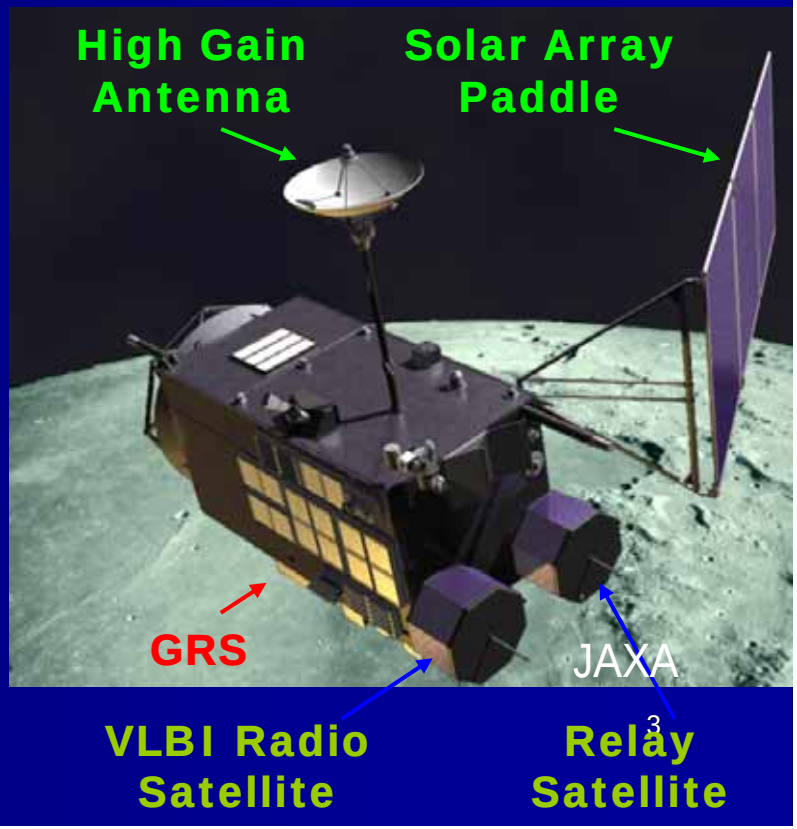
- SELENE mission & Gamma ray spectrometer (GRS) onboard SELENE (KAGUYA)

- Spatial resolution of GRS
  - Importance of the spatial response function
  - Studies by using Geant4
    1. Emission angle of gamma ray at lunar surface
    2. Spatial response function of SELENE-GRS

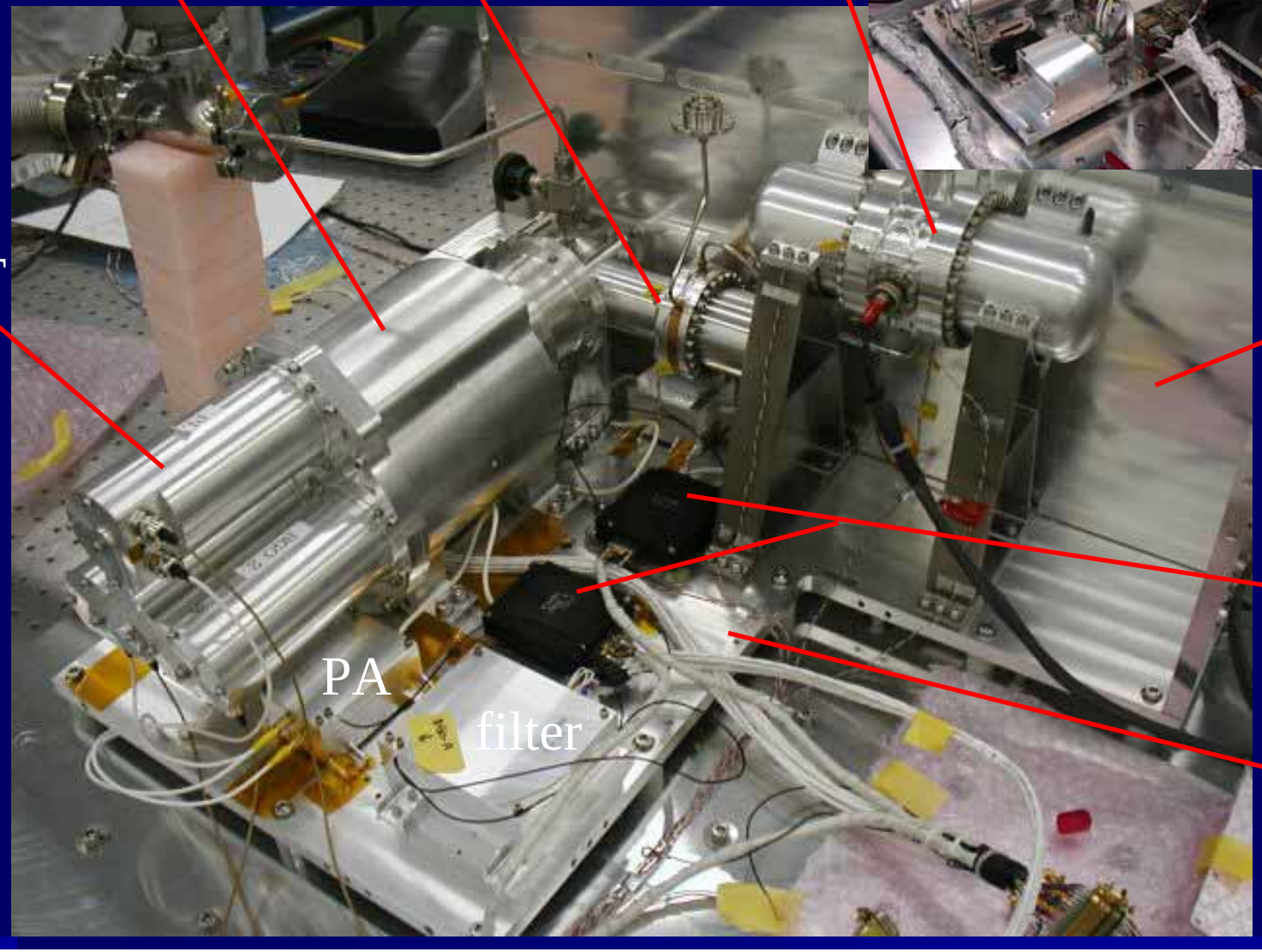
SELENE (KAGUYA)

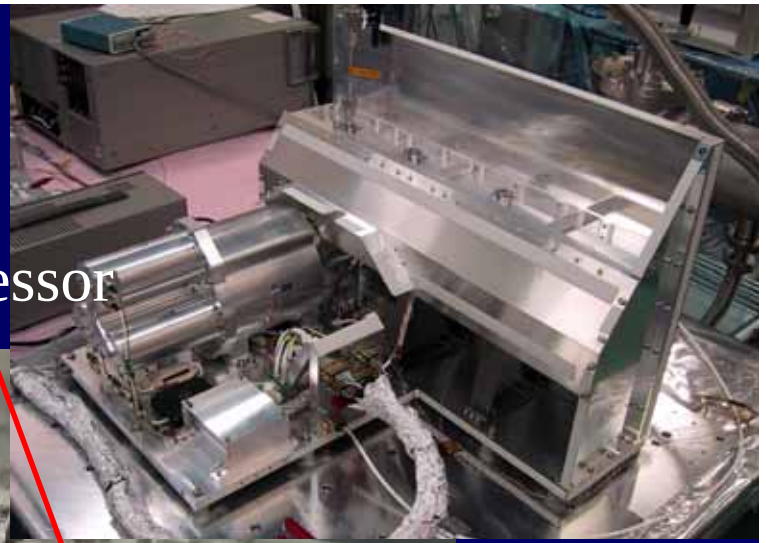
- Lunar explorer
- SELENE was launched by H-IIA rocket on Sep. 14, 2007.
- 14 scientific instruments
- Moon's origin and evolution
- Altitude: 100 km
- Polar orbit (~90 deg.)
- Attitude: 3 axes stabilized



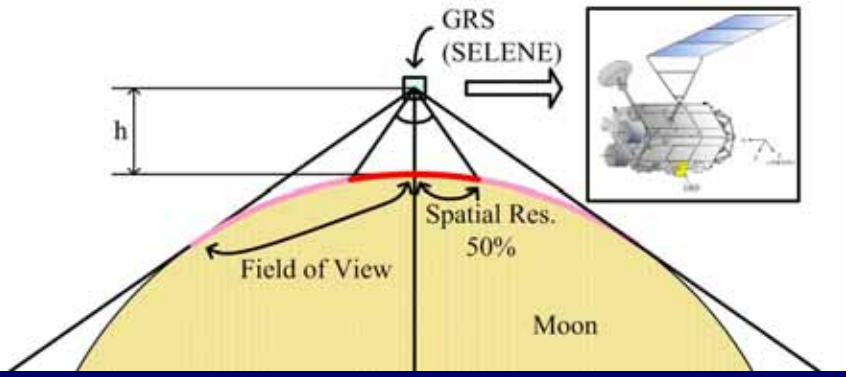


SELENE-GRS


Detector vessel
Cold head
Compressor
PMT
Radiator
HV
PA
filter
Base plate



Question



Q. How large is the field of view of the GRS?

A. GRS views the region from the nadir to the horizon, i.e. any place on the lunar surface. The detector is basically omni-directional!

→ But, an effective area observed by GRS (spatial resolution) is defined.

– The key is a Spatial Response Function (SRF)

What is a spatial response function?

- SRF is a set of probabilities to detect gamma rays as a function of positions (x, y) on the Lunar surface from which the detected gamma rays are emitted

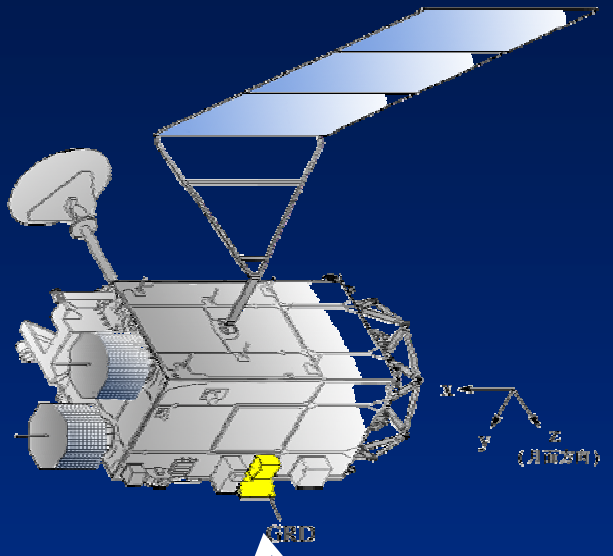
$$\Pi(\theta_1, \varphi_1) = \frac{1}{C_{\text{rate}}} \cdot \epsilon_{\text{int}}(\theta_3, \varphi_3) \cdot \omega(\theta_1, \varphi_1) \cdot f(\theta_2, \varphi_2, \theta_1, \varphi_1)$$

- **SRF is important.**
  - Spatial resolution of GRS
  - Incident direction dependences of the sensitivity
  - Deconvolution to make images

Count rates at the altitude of spacecraft

SRF deconvolution

The flux of gamma ray at the surface



3. Detection efficiency, ε

2. Solid Angle, ω

1. Distribution of Emission angle of gamma ray, f(θ)

Lunar surface

Calculation by using Geant4 library

Objectives

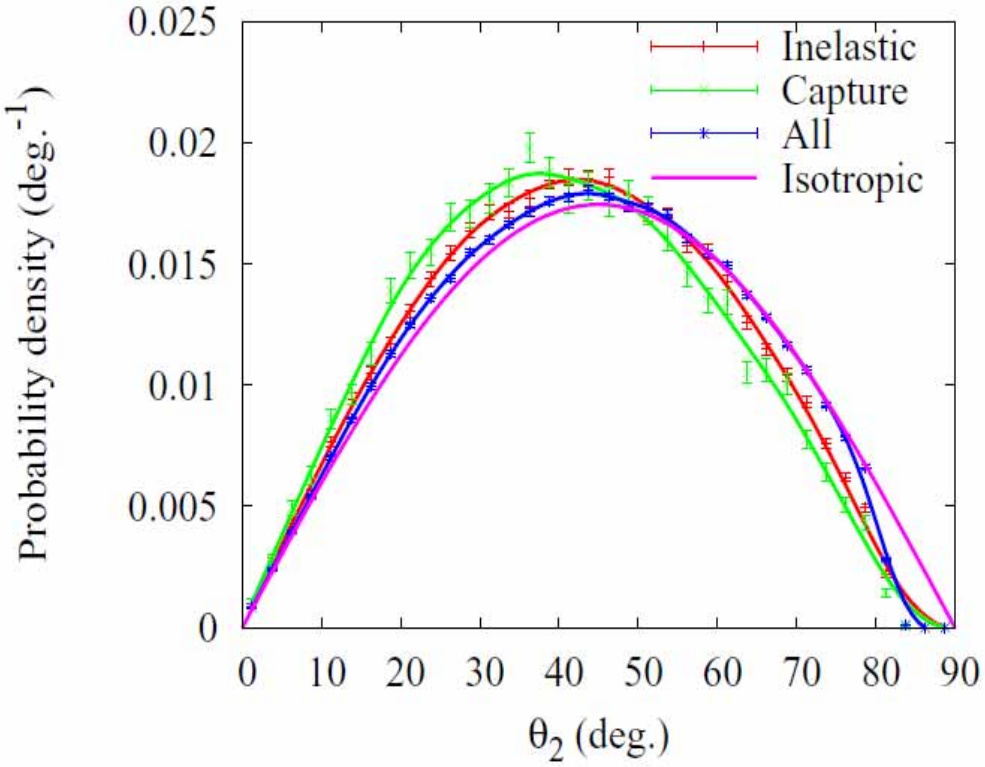
To understand the characteristics of the spatial response function ($f\varepsilon\omega$) of SELENE-GRS

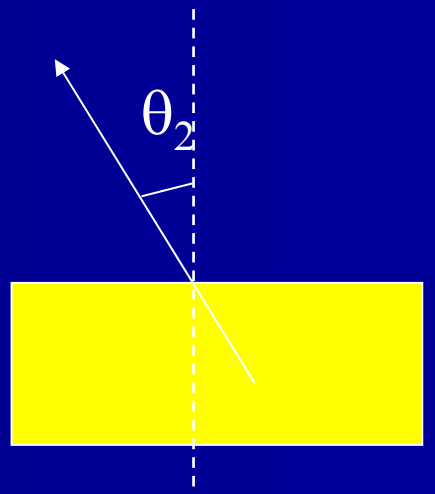
1. $f(\theta)$: Emission angle distribution of lunar gamma-ray
   - Does the lunar surface emit gamma ray isotropically?
   - Emission angle will affect the SRF.

2. Calculation of the SRF of SELENE-GRS, $f\varepsilon\omega$
   - Incident direction dependence of the sensitivity?
   - Spatial resolution of SELENE-GRS?

1. Is the gamma-ray emission isotropic or not?, f(θ)?

- The gamma rays are not emitted isotropically.
  - The gamma-rays tend to go upward.

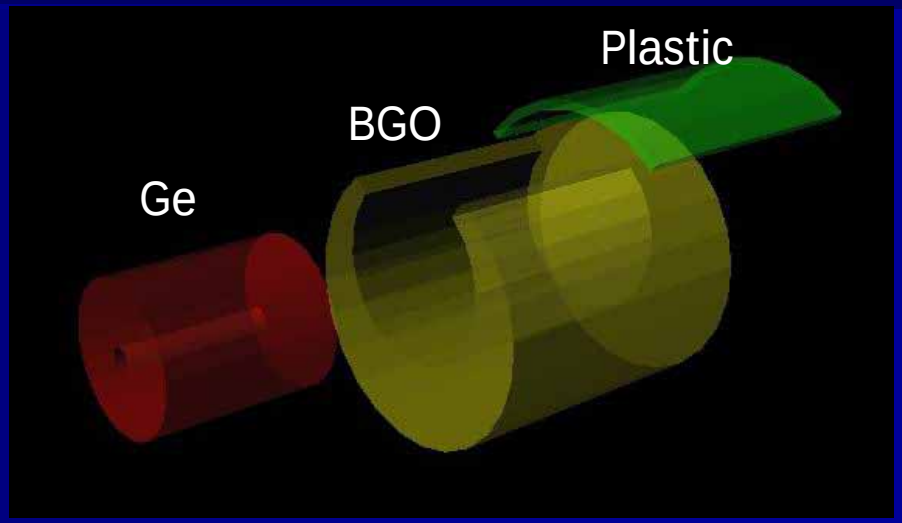


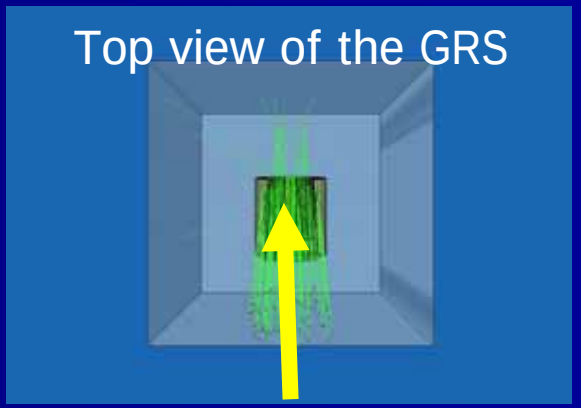


2. Calculation of spatial response function, $f \cdot \varepsilon \cdot \omega$

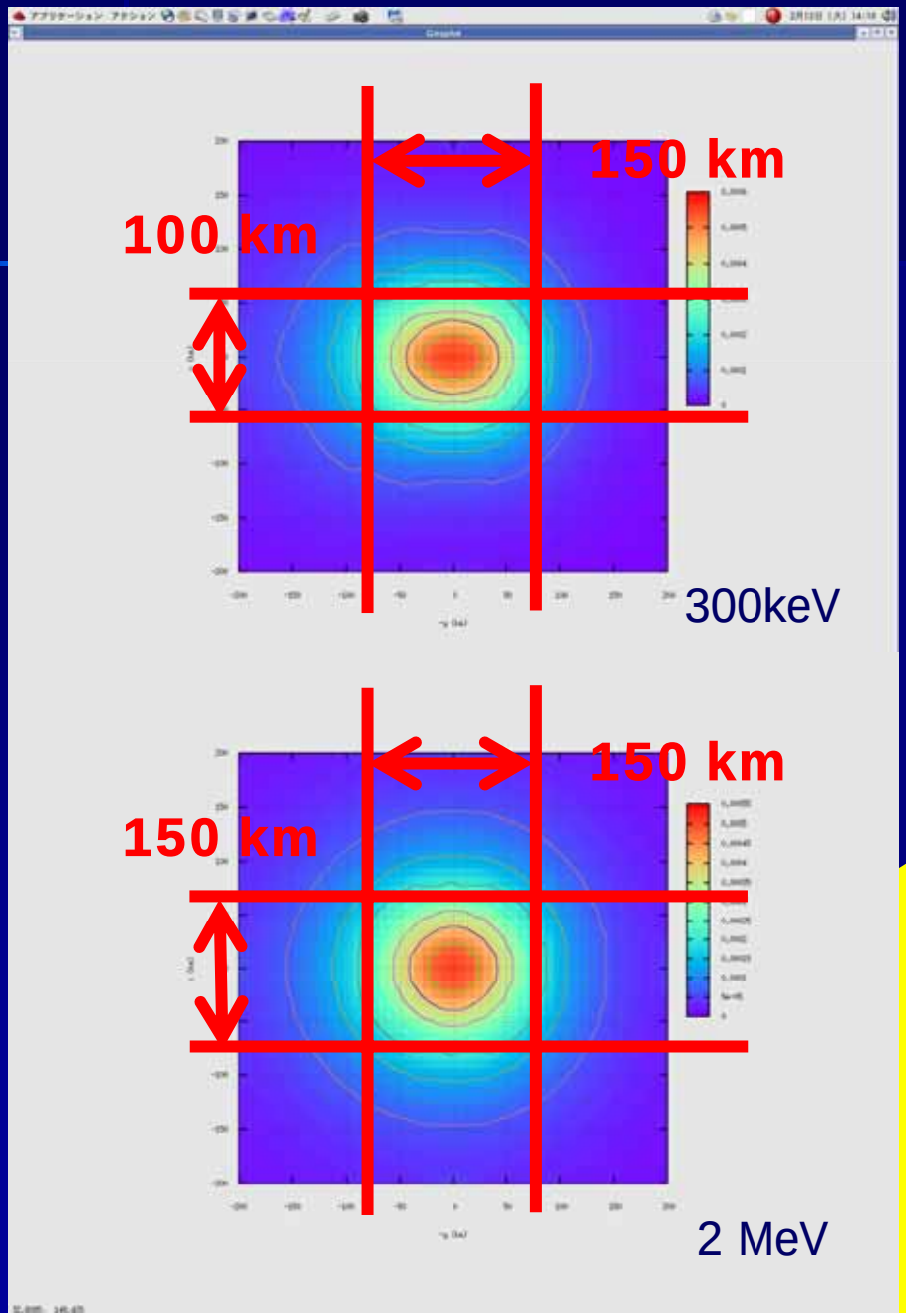
- $f(\theta)$ <- isotropic
- $\varepsilon \cdot \omega$ <- Geant4.8.0.p01
  - Detector

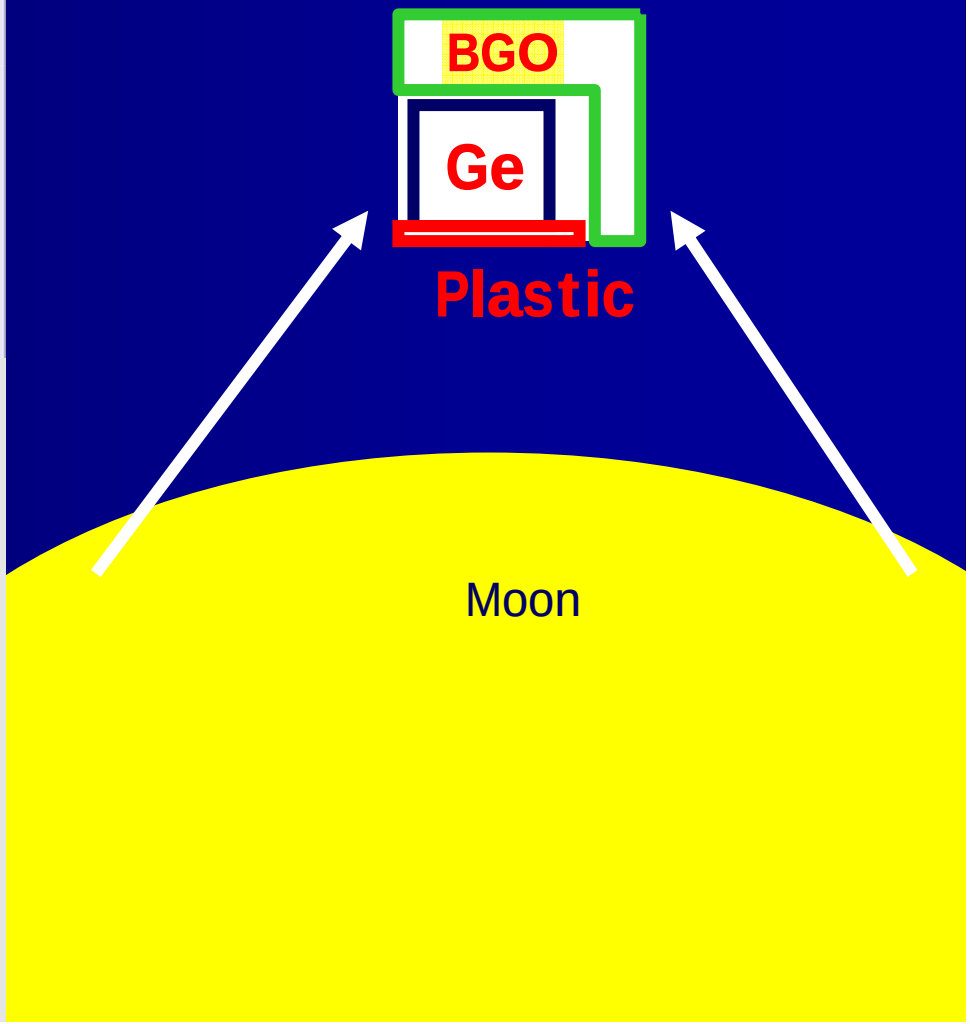
    Ge+BGO+Plastic
  - Beam
    - gamma (0.1~10 MeV)
    - Beam dia. (~ 50 cm)
    - Incident directions (~3600)
      - polar angle, 0 ~ 72°
      - azmuthal angle, 0 ~ 180°



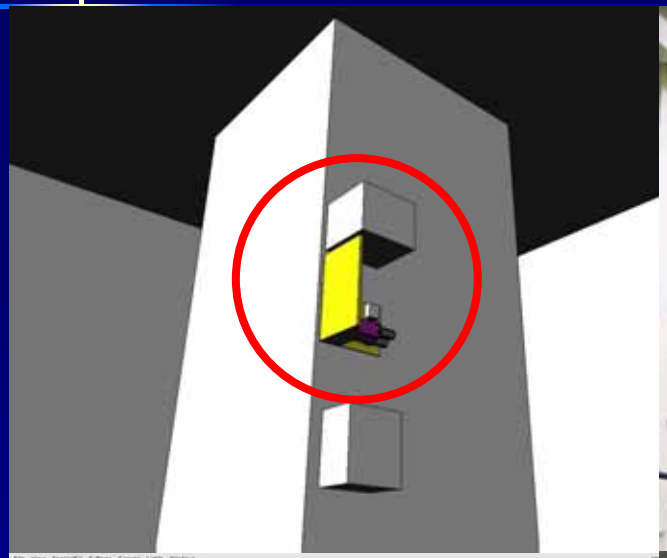


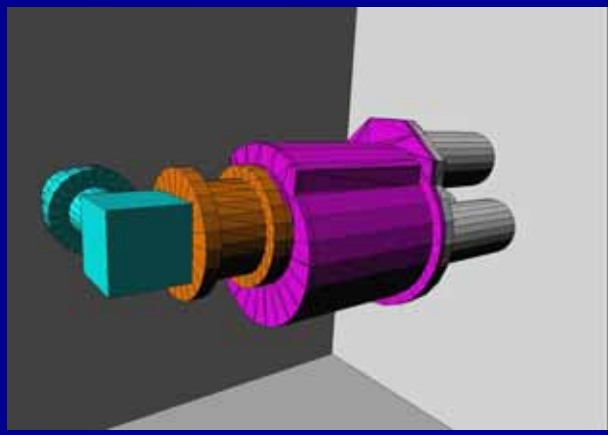
Contour plot of spatial response function (f･ε･ω)

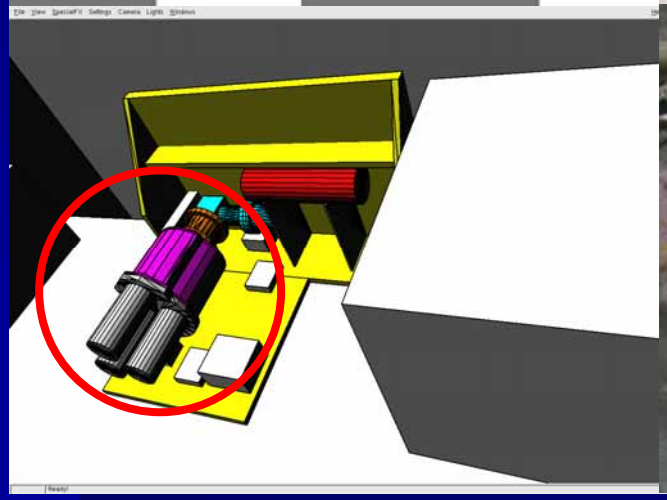


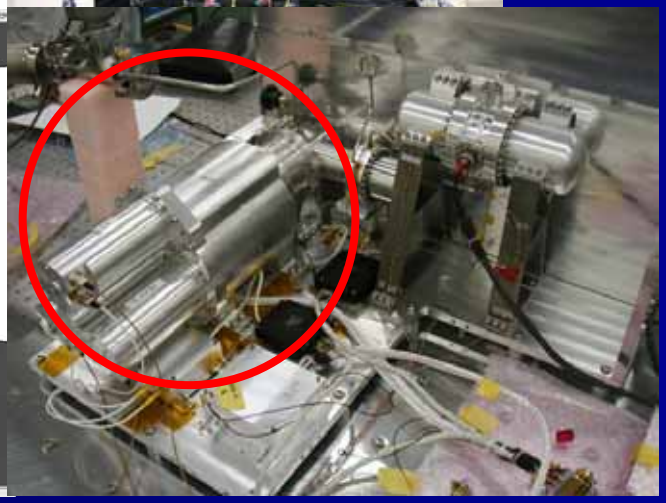


Modeling of KAGUYA-GRS by Geant4



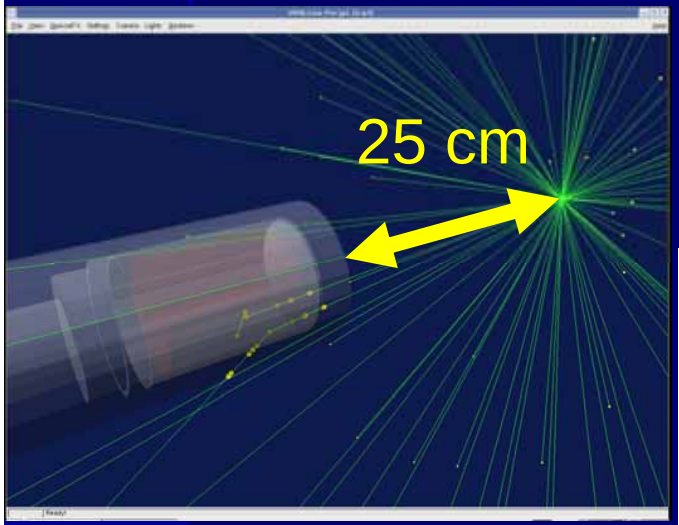




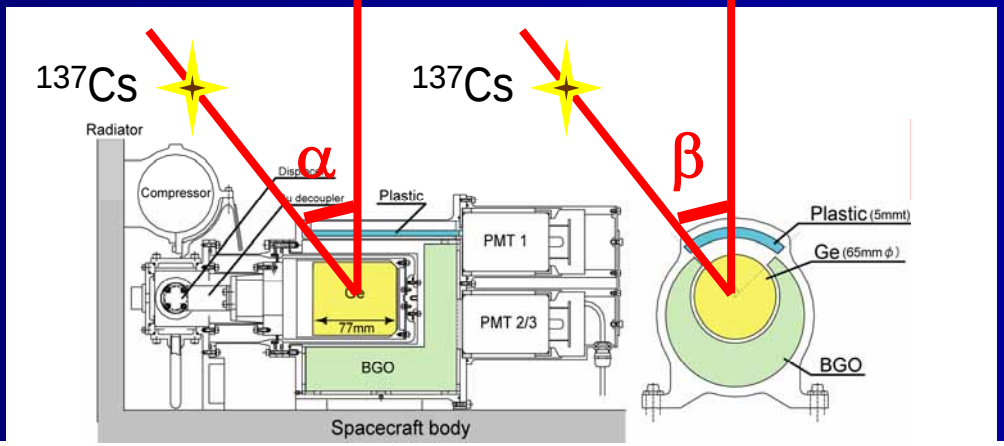


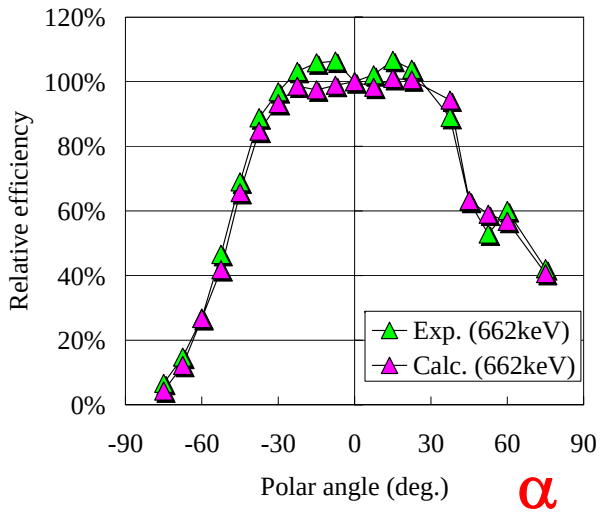
Model checking (exp. vs. calc.)

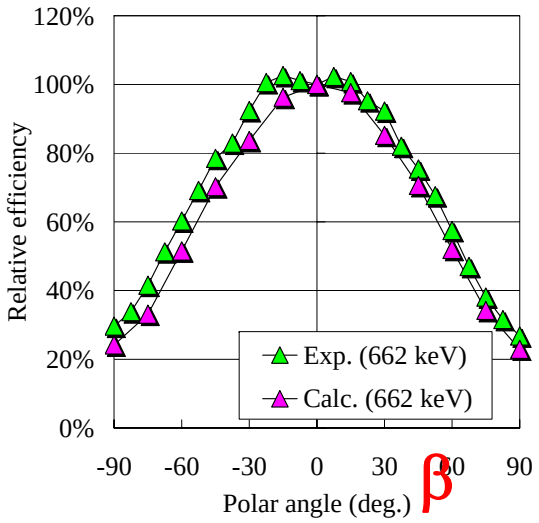
- Detection efficiency (IEEE standard method)
  - Exp. = 59.3 %
  - Calc. = 59 %
  - O.K.



- Detection efficiency (Pre-flight test)







Summary

- Gamma-ray remote sensing is a powerful method
  - Global mapping of various elements (K, Th, U, Si, Fe…)
- The spatial response function is very important for GRS.
  - Spatial resolution
  - Incident direction dependences of the sensitivity
  - Deconvolution
- Calculation of SRF of SELENE-GRS was made by using Geant4 library
- It calculates well
  - the anisotropy of sensitivity (SRF) of the SELENE-GRS,
  - energy dependence of SRF, and
  - the spatial resolution (150 km for 2 MeV)
- Current status
  - Checking the detailed model of SELENE-GRS made by Geant4 library