Wide-band soft gamma-ray all-sky monitor by the large-area BGO active shield of the ASTRO-H Soft Gamma-ray Detector (SGD)

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Abstract

The SGD (Soft Gamma-ray Detector) is one of scientific instruments onboard the ASTRO-H. The main part of the SGD is Compton camera with a narrow field of view, surrounded by BGO active shileds. By this combination, SGD can achieve more than ten times as good a sensitivity as the Suzaku HXD (Hard X-ray Detecor). As well as the Suzaku HXD-WAM, BGO active shield can be operated as Wide-band All-sky Monitor (WAM) with a large effective area in 30keV - 10MeV energy band, to observe transient phenomena such as gamma-ray bursts (GRBs), soft gamma-ray repeaters (SGR), terrestrial gamma-ray flash (TGFs), and solar flares, and monitor bright soft gamma-ray sources with the earth occultation technique. Here, we present a design plan of soft gamma-ray monitor by SGD BGO active shiled and a current staus of development.

Key words: Detector: Soft gamma-ray, Gamma-ray bursts

1. SGD BGO Active Shield

The main part of SGD is Compton camera with a narrow field of view, surrounded by large BGO active shields. By this combination, SGD can achieve more than ten times as good a sensitivity as Suzaku/HXD. BGO active shields (SGD-BGO) will work as Wide-band all sky monitor (WAM), as well as HXD-WAM. SGD-BGO will have the largest effective area around the MeV band at the time of Astro-H launch and have a big potential to explore important sciences.

SGD-BGO will have about 1900 cm^2 effecive area which is twice as large as that of the HXD-WAM (see Fig. 1); $\sim$ 400 cm^2 even at 10 MeV, with a very wide energy band from 100 keV to 10MeV. These will be very effective to observe objects with a hard spectrum and a rapid time variability, since photon statistics in the high energy band increases. Moreover, SGD-BGO will also have a large field of view of 4π in comparison with 2π of HXD-WAM. This will lead to a higher GRB detection rate than about 140 per year of HXD-WAM.

2. Expected Sciences

So far, there has been not enough observations for short duration phenomena such as short GRBs and TGFs, because of restriction by small photon statistics. Therefore, observations by SGD-BGO with a good time resolution and a large effective area are highly expected.

Main scientific target of SGD-BGO is short GRB.Past observations reported that short GRBs show a harder spectra than long GRBs (e.g Ohno et al. 2008). But, for many GRBs, we could not determine spectral parameters such as the peak energy (Ep) and the photon index above Ep (β). SGD-BGO enables us to do it and resolve a rapid time variability. So we will be able to discuss the difference of distribution between short and long GRBs by using Yonetoku's relation (Yonetoku et al. 2004), and study the differences of progenitors. In addition, we can clarify the relation between soft gamma-ray repeaters (SGRs) and short GRBs. In these days, some GRBs are

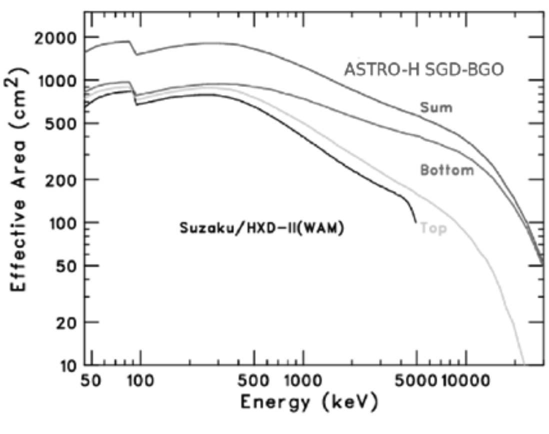

Fig. 1. Comparison of effective area between SGD-BGO and HXD-WAM.

found to be near galaxies. Their energy and luminosity are estimated to be very similar to those of SGRs. If we detect the pulsation from the light curves of short GRBs, we can study the association between short GRBs and SGRs.

Other science of interest is Terrestrial Gamma-ray Flash (TGFs) which have a very short duration of a few milliseconds and a hard spectrum up to 20 MeV. The origin of radiation is thought to be due to bremsstrahlung by accelerated electrons. Beam structure should be resolved with a finer time resolution and thus we will be able to study the acceleration mechanism. In addition, we can detect 2.2MeV line of nuclear decay and 511keV line of pair annihilation from solar flares. Monitoring the bright soft gamma-ray sources to study the long term variability by earth occultaion technique is also expected.

3. Design plan of all-sky gamma-ray monitor

We are now considering a design plan of functionality of all-sky gamma-ray monitor with SGD-BGO, within the limited resources.

For energy range, we will optimize the energy bins against the HXD-WAM and extend the energy band up to 10 MeV to constrain the hard spectra of short GRBs and TGFs better. For time resolution, we are considering a finer resoultion of the pulse height history than HXD-WAM to study the time valiability of short GRBs and so on (see Table 1). Alternatively, monitor data every one second are reduced by optimizing so that the data size does not become large.

Table 1. Data format plan of SGD-BGO (below). For reference, that of HXD-WAM is also shown (above).

Data Type	Format	energy bins	Time resolution	Output (duration)
Monitor	PH[a]	55	1 s	Any time output
Trigger	TH[b]	4	1/64 s	64 s duration
	PH	55	0.5 s	64 s duration
Monitor	PH	16	4 s	Any time output
Trigger	TH	4	1/64 s	64 s duration
	PH	64	244 μs	2 s duration
	PH	64	0.5 s	64 s duration

a: Time History data, b: Pulse Height data

4. Current status of BGO shield development

SGD employs APD (Avalanche Photo-Diode) for BGO readout. The advantage of APD against photo-multiolier is a small size, a lower bias voltage, and a small affection by the magnetic field. However, the scintillation light accumulation is one of concerns because of its small light detection window. By experiment, we confirmed that readout with a combination of a large BGO and a small APD can achieve the threshold down to 50 keV (see Fig. 2), which is enough for the anti-coincidence background rejection for the main sensor (Compton camera).

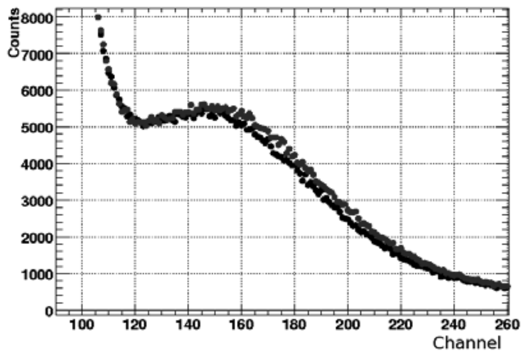

Fig. 2. ^{241}Am (59.5 keV) spectrum with a large BGO plut a small APD. Colors of data indicate the difference among the readout positions of APD to BGO.

To reduce the BGO weight, we consider the optimal shape of BGO blocks. We are studying with both experiments as above and ray-tracing simulations, so that the BGO light output is not reduced so much.

5. Summary

We are planning a design of the Wide-band All-sky monitor by using SGD BGO active shields. This will have a big potential to study the phenomena of a rapid time valiability and a hard spectrum, since the high energy phothon statistics of the data increases. We are now considering some improvements from HXD-WAM and performing some experiments to evaluate basic capabilities and optimze the BGO shape.

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