SENSITIVITY AND EFFICIENCY OF THE INTEGRAL IMAGER

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Abstract. A detailed simulation program of the INTEGRAL Imager has been written and implemented using the GEANT-3 Monte Carlo code. The expected detection efficiency and continuum sensitivity have been evaluated. The results obtained for the CsI configuration of the Imager are compared with those obtained with the new configuration which foresees a top plane made of CdTe solid state detector elements.

Key words: artificial satellites - instrumentation:γ-ray detectors - Monte Carlo simulation.

1. Introduction

INTEGRAL [1] is a satellite mission for γ-ray astronomy recently selected by ESA within the Horizon 2000 program. The payload consists of two main instruments, one optimised for spectroscopy (Spectrometer) and the other for fine imaging (Imager). Both detectors are coupled with a coded mask. The INTEGRAL payload is completed by two monitors, one operating in the X-ray band (XRM) and the other in the optical window (OTC).

The Imager detector consists of three planes and each plane is made out of 24 triangular modules. Each module contains 120 CsI hexagonal shaped detection unit each viewed by a silicon photodiode. The top plane is 1 cm thick, while the other two are 3 cm thick. At the end of the Phase-A Study this configuration has been changed, and the top CsI plane has been substituted with a 2 mm layer of CdTe elements in order to achieve a lower energy threshold and improve the energy resolution at low energy.

In this work, the detection efficiency and sensitivity of the Imager obtained by Monte Carlo simulation for both configurations are presented.

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TABLE I
Operational modes in the Imager detector.

Mode	number of interaction(s)/layer			Mode	number of interaction(s)/layer		
	1st layer	2nd layer	3rd layer		1st layer	2nd layer	3rd layer
1a	1	-	-	4a	1	1	-
1b	2	-	-	4b	1	>1	-
1c	>2	-	-	4c	>1	≥1	-
2a	-	1	-	5a	1	-	1
2b	-	2	-	5b	1	-	>1
2c	-	>2	-	5c	>1	-	≥1
3a	-	-	1	6a	-	1	1
3b	-	-	2	6b	-	1	>1
3c	-	-	>2	6c	-	>1	≥1
7a	1	1	1	7b	≥1	≥1	≥1

2. The INTEGRAL Imager

The Imager detector operates between 50 keV and 10 MeV, while with the CdTe option the lower energy threshold goes down to 20 keV. The total active area in both configurations is $\simeq$3000 cm^2. However, only the inner 2500 cm^2 are used, due to background reasons [2]. The cross-sectional dimension of the detector pixel is $\simeq$1 cm^2. In the case of CdTe the detection units of the top layer are further subdivided into six triangular sections so that the intrinsic spatial resolution is improved. The main detector is then shielded on six sides and the bottom by a 2 cm thick BGO crystal shield. The multi-layer discrete elements geometrical assembly provides the possibility for the Imager to work in different interaction modes (Table I), which are defined by the number and location of the interaction(s) caused by the primary incident γ-ray.

3. Simulation and results

The Monte Carlo simulation of the Imager was performed using a program based on the GEANT-3 software package [3]. In order to reproduce as closely as possible the real operational conditions, the whole detector, including all the passive materials, was considered in the simulation.

The energy thresholds for individual signals used in the simulation correspond to those under consideration for the Imager: 50 and 3000 keV (lower and upper) for the top layer in the CsI option, being such values 15 and 1000 keV in the CdTe option. For the second and third layer the values

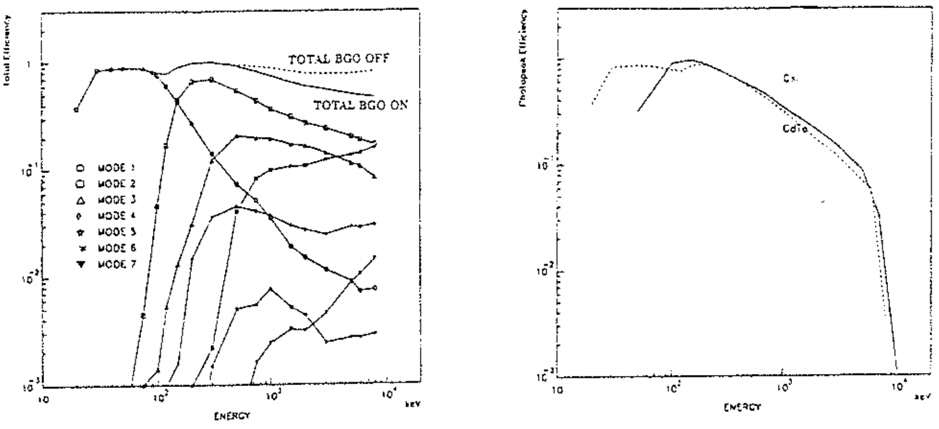

Fig. 1. Left: Total efficiency of the Imager for the CdTe option. The effect of the BGO veto shield (BGO "on", BGO "off") is displayed.Right:Comparison between photopeak efficiencies of the Imager for the CdTe option (dashed line) and CsI option (full line).

considered are 120 and 5450 keV. The low energy threshold for the BGO veto is 100 keV.

3.1 Detection Efficiency

The calculated total and full-peak efficiency profiles are shown in Figure 1. The effect of the BGO veto shield (BGO A/C "ON") is negligible below 500 keV, increasing its importance as energy increases. On the other hand we have found that single events (only one detection unit triggered) dominate at incident energies below 1 MeV whereas the multiple events (more than one unit triggered) dominate above that energy.

In Fig. 1 (right panel) the photopeak efficiency obtained with the CdTe configuration is compared with those obtained with the CsI option (CsI for the three layers of the Imager). As it can be expected there is a significant improvement in the photopeak efficiency for energies below 60 keV when the CdTe option is considered, being similar for both options the efficiencies in the rest of the energy interval considered.

3.2 Sensitivity

The continuum sensitivity is one of the key scientific parameters of the Imager. The background spectrum has been taken from Monte-Carlo results obtained using the same code [4]. The model for background cal-

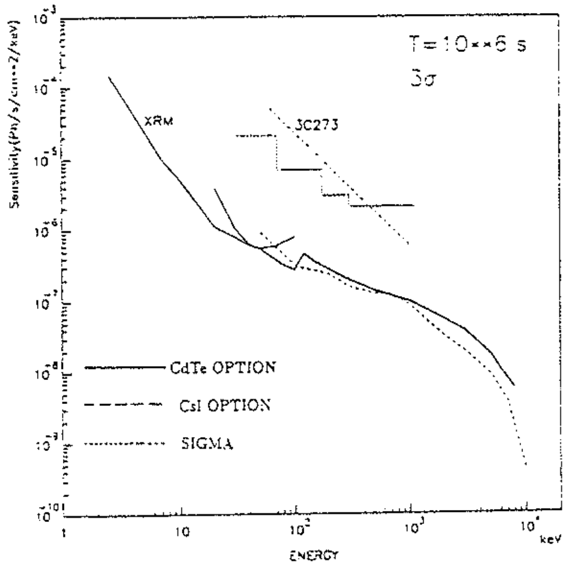

Fig. 2. Imager continuum sensitivity for a significance level of 3σ for the two options considered in this work. The X-Ray Monitor (XRM) and SIGMA sensitivities are also shown (see text).

culations takes into account the contributions from cosmic diffuse background, gamma-rays produced in the material spacecraft, cosmic ray induced radioactive spallation products within the material of the gamma-ray detector itself and events derived from protons trapped within the earth's radiation belts.

In Fig. 2 we compare the expected continuum on-axis sensitivity for the Imager CdTe option with that obtained for the CsI option. A statistical significance of 3σ (σ=standard deviation) was considered in these calculations. Ojo intentar ver lo que hay de Pino y Cocco sobre esto. In both cases there is a significant improvement with respect to previous γ-ray missions (SIGMA sensitivity is showed for comparison together with the 3C273 spectrum). As it can be seen in Fig. 2, in the CdTe option the sensitivity shows an improvement of a factor $\sim$1.5$-$2 at energies less than 100 keV with respect to the CsI configuration. Furthermore, at low energy the overlap between the sensitivity curve of the Imager with the X-Ray Monitor one ensures a coverage of the critical energy band comprised between 10 and 80$-$100 keV. Nevertheless, further studies are under development in order to increase the sensitivity of the Imager at low energies, mainly related to the suppression and/or minimization of passive materials that interfere in the field of view of the Imager.

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