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PICsIT - the high energy detector on-board the INTEGRAL gamma-ray satellite: results from the qualification model test campaign

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Abstract

INTEGRAL is the next γ–ray astronomy satellite mission of the European Space Agency (ESA). INTEGRAL has two main instruments: SPI, optimized for spectroscopy, and IBIS, dedicated to fine imaging. PICsIT, the high-energy detection plane of IBIS, is devoted to the study of celestial gamma-ray sources between 150 keV and 10 MeV. PICsIT Qualification Model has undergone functional and scientific tests earlier this year. The results in terms of scientific performances are presented.

1. Introduction

INTEGRAL (INTErnational Gamma-Ray Astrophysics Laboratory) was selected by the ESA Science Programme Committee in June 1993 as the next European Space Agency (ESA) medium-size scientific mission (M2) of the Horizon 2000 programme. The mission is conceived as an observatory led by ESA with contributions from Russia (PROTON launcher) and NASA (Deep Space Network ground station).

INTEGRAL (Winkler 1999) is dedicated to the fine spectroscopy ($E/\Delta E = 500$) and fine imaging (angular resolution = 12' FWHM) of celestial gamma-ray sources in the energy range 15 keV to 10 MeV with concurrent source monitoring in the X-ray (3-35 keV) and optical (V-band, 550 nm) energy ranges.

INTEGRAL will be launched by a Russian PROTON into a highly eccentric 72-hour orbit. The nominal lifetime of the observatory will be 2 years with possible extension to up to 5 years. Most of the observing time will be made available to the worldwide scientific community.

The INTEGRAL payload consists of two main gamma-ray instruments: the Spectrometer SPI (Vedrenne et al. 1999), and the Imager IBIS (Ubertini et al. 1999). Each of them has both spectral and angular resolution, but while SPI, based on Ge detectors, is optimized for fine spectroscopy, IBIS is dedicated to large field of view and fine imaging observations of the gamma-ray sky.

The Imager IBIS (Imager on Board the INTEGRAL Satellite) provides diagnostic capabilities of fine imaging (12' FWHM), source identification and spectral sensitivity to both continuum and broad lines over a broad (15 keV - 10 MeV) energy range. The Imager will exploit simultaneously with the other instruments on INTEGRAL celestial objects of all classes ranging from the most compact galactic systems to extragalactic objects. A tungsten coded-aperture mask (located at 3.2 m above the detection plane) is optimised for high angular resolution. The IBIS design takes advantage of this by utilizing a detector with a large number of spatially resolved pixels, implemented as physically distinct elements.

The detector uses two planes, one 2600 cm^2 front layer of CdTe pixels (ISGRI), each 4×4×2 mm^3 (width×depth×height), and a 3100 cm^2 layer of CsI(Tl) pixels (PICsIT), each 8.5×8.5×30 mm^3. The CdTe array and the CsI array are separated by 90 mm. The detector provides the wide energy range and high sensitivity continuum spectroscopy required for INTEGRAL. The aperture is restricted by a lead/tungsten shielding (Caroli et al. 1998) tube and shielded in all other directions by an active BGO scintillator veto system.

The qualification models of IBIS subsystems have been tested at LABEN laboratories in Vimodrone (Milan) in April 2000 before their integration in IBIS, which will be completed by the end of July 2000. The key results in terms of scientific performances of PICsIT QM are reported in this work.

2.1 PICsIT

PICsIT (Di Cocco et al. 1999) consists of 8 independent rectangular modules arranged in a 2×4 array, each one containing 512 (16×32) CsI(Tl) scintillator crystals. The total assembly is a 4096 (64×64) element matrix. The detection units are optically independent from each other and are 0.85×0.85 cm^2 in cross-section and 3 cm in thickness. The crystals are polished and wrapped with a white diffusive coating, and optically bonded to custom made low leakage silicon PIN photodiodes which convert the light pulse from a scintillation into electric charge. Each photodiode is interfaced to an analogue front-end electronic chain including a biasing filter, charge amplifier, shaping amplifier, threshold discriminator, and peak detector plus stretcher. These circuits are implemented in an analogue application specific integrated circuit (ASIC). Each ASIC serves 16 photodiodes. The scientific requirements of PICsIT are: lower energy threshold E_{TH}=150 keV (the upper energy threshold is limited by the thickness of the crystal that allows a 8% detection efficiency at 10 MeV), and energy resolution $\Delta E/E$ of 12% (FWHM) at 662 keV.

2.2. PICsIT Qualification Model

PICsIT Qualification Model consists of one full module (out of eight) of the PICsIT detection plane. This module consists of: one flight representative eggcrate; 512(-4)[1]CsI(Tl) pixels inserted in one semimodule; one complete DFEE; flight representative detector harness;16 ASICs flight version. A dedicated Test Equipment (TE) is used for data acquisition, archive, and quick-look analysis during

[1] Four pixels have been inserted without the crystal in order to measure the contribution of the electronic noise.

Figure 1: PICsIT QM response to ^{203}Hg photons (279 keV) obtained with a Pb mask in the shape of the word "PICsIT" placed between source and detector.

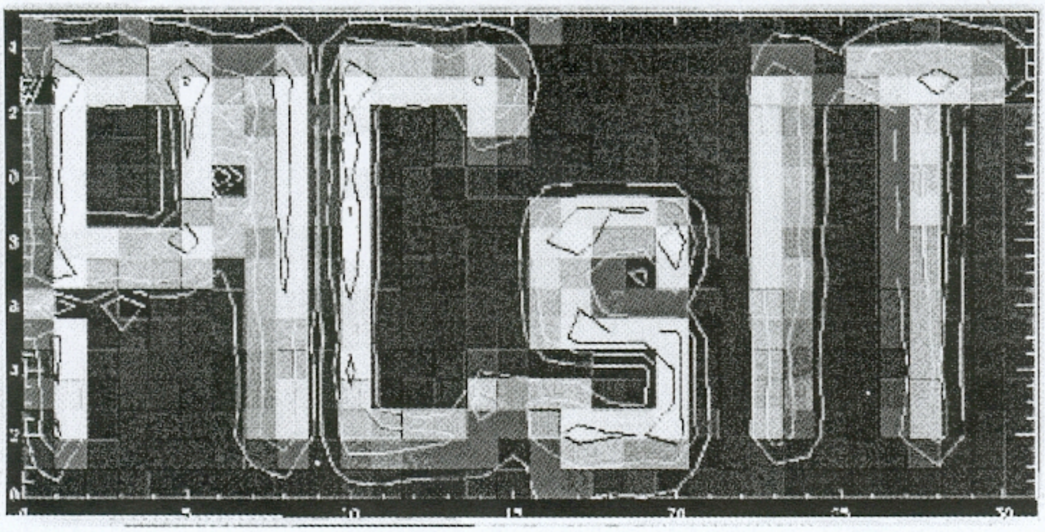


Figure 2: PICsIT QM response to ^{137}Cs photons (662 keV). The incoming spectrum is measured independently by all pixels, with an energy resolution of 12% (the four absent spectra correspond to pixels inserted without the crystal to measure the contribution of the electronic noise).

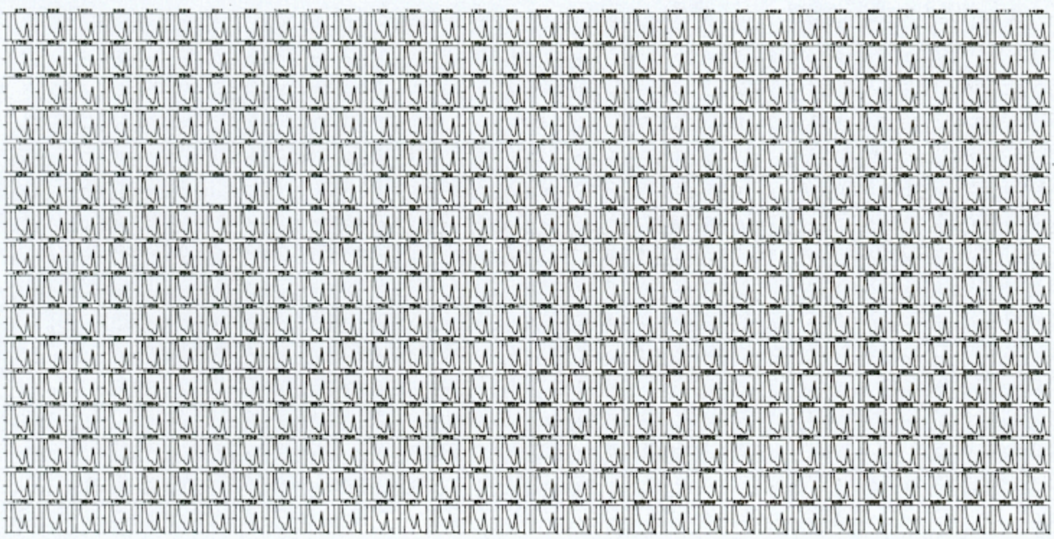
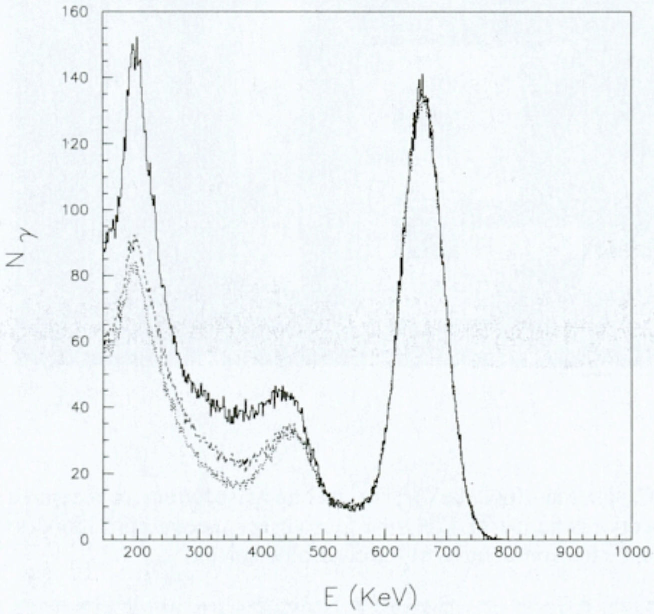


Figure 3: Simulated ^{137}Cs spectra. Dotted, dashed, and continuous lines refer to central, intermediate and external pixels respectively. The figure shows that backscattering peaks are higher in external pixels, which have a higher probability of an interaction with source photons scattered off by the surrounding material.



measurements. Associating lower gain pixels with higher gain ASIC channels has optimized the coupling between each individual pixel and channel gain.
PICsIT QM integration has taken place in February-March 2000, while the first part of the campaign for performance verification and test has taken place April 5th - 7th 2000 c/o LABEN Laboratories in Vimodrone (Milan).

2.3. PICsIT QM Test Results

PICsIT QM has been irradiated with several radioactive sources (^{203}Hg, ^{137}Cs, ^{88}Y), which span a broad energy range between 279 keV and 1.8 MeV in order to evaluate the key scientific performances of each pixel independently.

Figure 1 shows the imaging capability of PICsIT. For this measurement, PICsIT QM has been covered with a lead mask with a hole pattern in the shape of the word "PICsIT", and illuminated with a ^{203}Hg (279 keV) source.

The spectroscopy capability of PICsIT has also been checked. Figure 2 shows the single pixel spectra detected after the irradiation of PQM with a ^{137}Cs source (662 keV). The incoming spectrum is measured independently by all pixels, with an energy resolution of ~12%.

A detailed Monte-Carlo simulation program of PICsIT has been developed. Figure 3 shows simulated ^{137}Cs spectra. Dotted, dashed, and continuous lines refer to central, intermediate and external pixels respectively. The figure shows that backscattering peaks are higher in external pixels, which have a higher probability of an interaction with source photons scattered off by the surrounding material.

References

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