# TRANSPARENCY OF THE ISGRI MODULE

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The Integral/IBIS/ISGRI layer transparency has been investigated. The transparency describes the ratio of transmitted to incident gamma-ray photon fluxes. Monte Carlo and experimental techniques have been used in this study. We have achieved a good agreement between these both methods, and the results confirm the well known fact that ISGRI is "opaque" for $E_\gamma < 100$ keV. Additionally, performed tests allowed for an accurate evaluation of the dependence of the transparency with energies, up to 700 keV.

## 1 The IBIS telescope

ISGRI is the upper layer of the IBIS gamma-ray telescope, which is one of two main gamma-ray instruments onboard the INTEGRAL satellite - INTErnational Gamma-RAy Laboratory, which will be launched by ESA in October 2002.

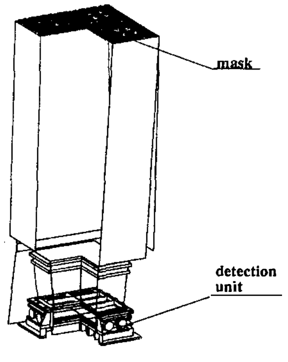


Figure 1: Perspective view of IBIS.

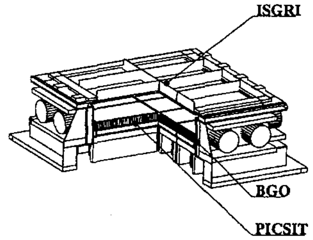


Figure 2: The detection unit of IBIS.

IBIS is a complex system composed of a coded mask and of two pixelated detectors (ISGRI and PICsIT) surrounded by a BGO anticompton shield (see Fig. 1 and 2).

### 1.1 PICsIT

PICsIT - the lower layer - consists of a system of 4096 CsI crystals with individual photodiode read-out. It is composed of scintillators 3 centimeters long which makes possible the detection of high energy photons (few MeV) with an energy resolution around dozen of percents.

### 1.2 ISGRI

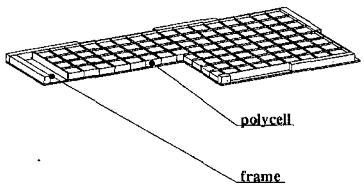


Figure 3: The ISGRI module.

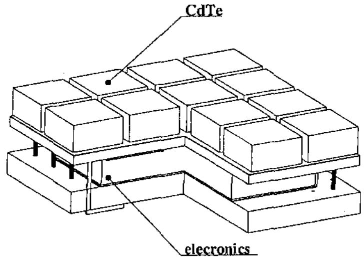


Figure 4: The polycell – 16 crystals of CdTe and its electronic unit.

The ISGRI layer consists of 16384 thin pixels of CdTe grouped into 8 modules [1]. Each module has its own analog and digital electronics and interfaces. The module consists of 128 polycells, each of them composed of 16 CdTe pixels (see Fig. 3 and 4). The pixel is the fundamental detection unit of ISGRI. It is a small (4 mm × 4 mm × 2 mm) crystal of Cadmium telluride - a semiconducting detector working at room-temperature.

## 2 Transparency measurement. Experimental setup and Monte Carlo simulations

IBIS works in several "modes" of detection: ISGRI, PiCsIT, and Compton. The Compton data result from the coincidence between the two detection planes, ISGRI and PiCsIT. The transparency of the upper detection layer (ISGRI) for gamma-rays is then an important parameter for further data analysis.

This quantity is defined as the ratio of the transmitted ($\gamma_{\rm tr}$) to incident ($\gamma_{\rm in}$) gamma fluxes:

$$T = \frac{\gamma_{\rm tr}}{\gamma_{\rm in}} \quad (1)$$

Theoretical transmission ratio $T_{th}$ of a 2 mm thick CdTe detector depends strongly on photon energies – see Fig. 5. This dependence has been computed by using the mean free path of photons in CdTe:

$$T_{th}(E_\gamma) = 1 - e^{-d/\lambda(E_\gamma)} \quad (2)$$

where: $d$ is the thickness of the CdTe block (2 mm), $\lambda(E_\gamma)$ is the mean free path of gamma-rays in CdTe. For these calculations the cross sections for interaction of gamma-rays in Tellurium and Cadmium have been used.

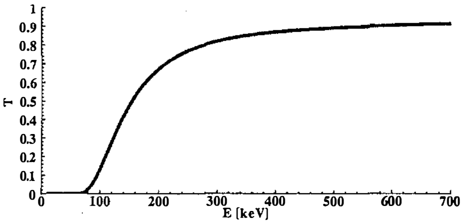


Figure 5: Theoretical transparency of a thin block of CdTe (2 mm) as a function of energy.

The complex structure of ISGRI makes practically impossible the analytical calculation of its transparency so numerical simulation remains the only tool for such computation. Verification of the applied Monte Carlo code has been performed experimentally. Gamma-rays from several

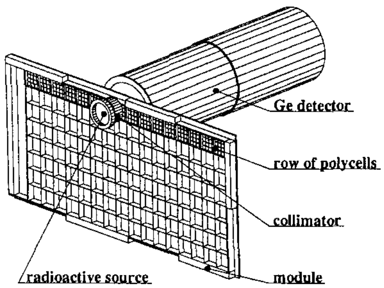


Figure 6: Experimental setup. During the $\gamma_{\rm in}$ measurement the ISGRI module was removed.

standard calibration sources have been collimated using a 3 mm thick Tungsten collimator. We have collected the transmitted photons with a HPGe detector. All experiments were done on an "early" version of the ISGRI module with one row of polycells. The small size of the beam (3 mm) compared with the dimension of polycell (~20 mm) justify this approach, and results for the full module geometry should be equivalent. Axes of the coaxial Ge detector and of the collimator were parallel but shifted by 23 mm to get an higher detection efficiency. To measure the unperturbed incident flux ($\gamma_{\rm in}$ in Eq. 1) the ISGRI module has been removed from the beam.

We have then compared these results with Monte Carlo simulations performed with the IBIS Mass Model[2], which has been modified to take into account the real geometry of the experiment including the Germanium detector and the collimator (see Fig. 6).

## 3 Results

To confirm the applicability of the Monte Carlo model, the experimental and simulated transparencies were compared for various regions of the polycell. Two examples: first – the center of the polycell, and second – the pixel in the upper row, are shown on Fig. 7.

The correspondence between experimental points and results of the numerical simulations shows a very good agreement.

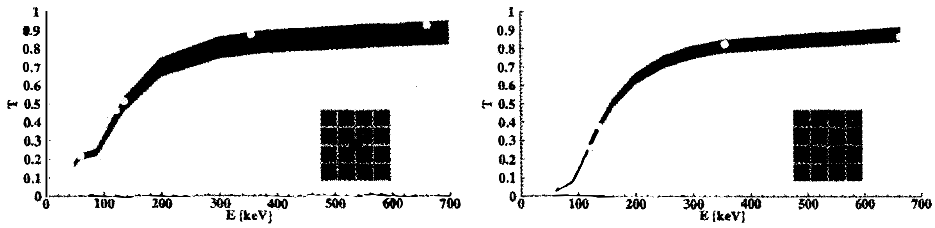


Figure 7: Comparison of experimental (bright dots) and Monte Carlo (dark area) results for two position of the gamma-ray beam. Places and sizes of beams in each case are schematically represented as dark circles on polycell profiles.

## Acknowledgments

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## References

1. F. Lebrun, J. P. Leray, O. Limousin et al. *Proc. of the* $4^{th}$ *Integral Workshop*, ESA **SP-459**, 591 (2001).
2. P. Laurent, O. Limousin, G. Malaguti et al. *Proc. of the* $4^{th}$ *Integral Workshop*, ESA **SP-459**, 587 (2001).