

# Calorimeter Prototype Based on Silicon Drift Detectors Coupled to Scintillators for Compton Telescopes Application

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## The Context

**Compton telescopes** are suitable instruments to observe the gamma-ray sky in the MeV energy range, where Compton effect is the most probable interaction process for gamma rays with matter.

- Compton telescopes are made of two coupled detectors: the first (D1) should be based on low-Z materials to maximize the Compton interaction probability, while the second (D2) is usually based on high-Z materials to maximize the absorption probability for the scattered gamma and thus to allow a good total energy reconstruction. Moreover, D1 and D2 must be position sensitive to reconstruct the scattered photon direction.

- A state of the art choice for detector D2 could be the use of CsI(Tl) scintillating crystals coupled to PIN photodiodes. CsI(Tl) is a high-Z scintillator with a high light yield (60000 photons/MeV) and PIN photodiodes are well known reliable and robust solid state devices suitable for densely packed pixelated arrays. This approach was chosen for the MEGA Compton Telescope prototype [1].

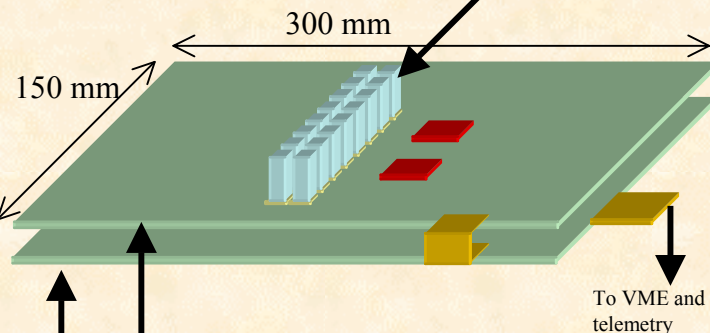
- Energy resolution** in detector D2 is an important feature, together with the energy resolution of detector D1, as it determines the error on the scattering angle of the incidence photon. Typical CsI(Tl)/PIN photodiodes detectors have about 10% energy resolution at 661 keV.

- An improvement in energy resolution can be obtained using **Silicon Drift Detectors (SDD)** [2]. These devices allow better noise performances than PIN photodiodes because of a careful modulation of the electric field inside the active area that concentrates the charge in a spot smaller than the entrance window of the device, thus reducing its output capacitance. Moreover SDDs can be realized with the first amplifying FET integrated on the device, further reducing the noise. SDDs have been developed as X-ray detectors, but have also been tested as photodetectors coupled to CsI(Tl) scintillators [3]. The drawbacks are higher costs, if compared to photodiodes, and the need for a more complex polarization circuit (up to 6 different tension values are needed for the integrated FET SDDs)

## Calorimeter Main Elements:

- 16 independent gamma ray detectors (pixels)
- each pixel is composed of a 10 mm<sup>2</sup> active area SDD optically coupled to a 2 cm long CsI(Tl) scintillating crystal.
- pixel read-out by means of custom built ASICs
- digital front-end electronics
- VME bus interface

## Scheme of the Calorimeter Prototype



### AFEE: Analog Front End Electronic board

- supply SDD polarization
- detectors read-out by means of ICARUS-SDD ASIC [5]

### ASIC main features:

- derived from ICARUS ASIC used in the IBIS/PICsIT instrument on board the INTEGRAL satellite[6]
- first amplifying stage external to the ASIC, to be coupled to SDDs with on-chip FET
- noise 14  $\mu$ V rms, power/channel 6.25 mW

### DFEE: Digital Front End Electronic board

- takes care of handshaking sequences for ASICs read-out on AFEE board
- A/D conversion and data formatting
- handle communication with VME / telemetry
- same design as the DFEE board used in the IBIS/PICsIT instrument. For this reason the dimensions of the board are not optimized for the number of detectors used
- already designed and tested by LABEN spa, Milano, Italy

## The Calorimeter Prototype

- To exploit the possibilities offered by SDDs, a calorimeter prototype based on such devices coupled to a CsI(Tl) scintillators is under development at CNR-IASF, Bologna. The chosen approach is a pixelated array of independent gamma-ray detectors. This is the same approach used in the PICsIT instrument (4096 CsI(Tl)/PIN-PD detectors) developed by this team and currently perfectly operative on board the INTEGRAL satellite [4].

- Because of the expertise gained during the realization of PICsIT, it has been decided to re-use the instrument concept and as much hardware as possible in order to:

- focus on the feasibility of the SDD based detectors
- have a reliable read-out and data handling hardware, already tested and working properly
- speed up the prototype realization

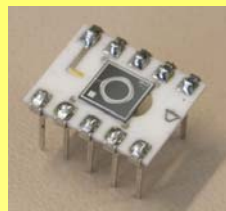
- A small number of detectors will be realized as this instrument is meant as a technological demonstrator to study the feasibility and the performances of the chosen approach.

- The instrument expected energy resolution is better than 5% at 661 keV.

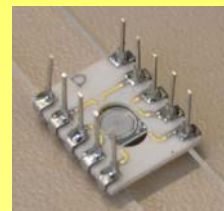
- It is expected to test the performances of the instrument in conjunction with the MEGA prototype with radioactive sources and possibly in a balloon flight (MEGABALL mission).

## The SDD Detectors

- 33 mm<sup>2</sup> chips with 10 mm<sup>2</sup> active area and integrated FET supplied by PNSensors gmbh
- 1 contact on the backside (entrance window) (a) and 8 contacts on the electronic side (b) need a custom built ceramic housing. The ceramic housing is for prototype use only, as it does not allow a dense packaging of the detectors

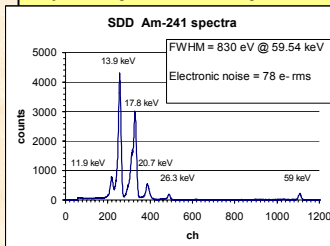


(a) Backside (light entrance window)

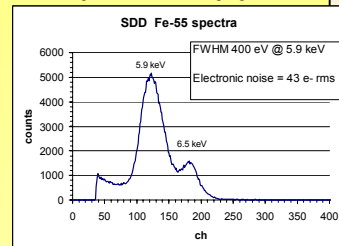


(b) Electronic side

- the detector was tested, without a scintillator coupled, with <sup>241</sup>Am (c) and <sup>55</sup>Fe (d) sources
- gain and noise are strongly dependent on the 6 polarization values that must be carefully adjusted to optimize the detector performances. Parameters optimization is still in progress



(c) Am-241 spectra



(d) Fe-55 spectra

- the SDD passivation and optical coupling to scintillator processes have already been developed and tested on dummy devices and will be applied to working SDDs as soon as the electrical tests will be completed

## Current Status

- Detectors:** SDD procurement OK; SDD bonding OK; SDD passivation and coupling to scintillator in progress; SDD electrical tests and polarization optimization in progress
- AFEE:** ASICs procurement and test OK; board design in progress
- DFEE:** in production
- VME interface:** to be defined

## References

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