Charge sharing in CdTe pixilated detectors

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Technological context

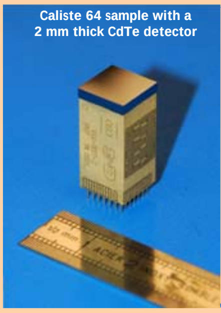
Detector: CdTe with 64 pixels

- CdTe detectors from Acrorad (Japan)
- 1 cm^2 detectors with 8 x 8 pixels
- 1 or 2 mm-thick
- 900 µm pixels, 100 µm gap
- 900 µm guard ring
- Anode, with Schottky Al-Ti-Au contact, processed by photolithography
- Planar Pt cathode negatively biased

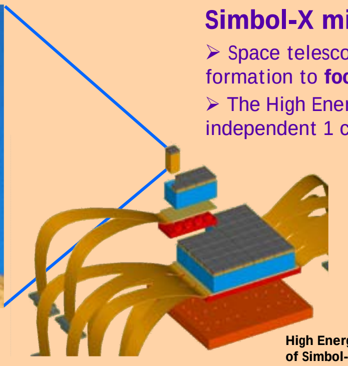
Device: Caliste 64

Hybridization of front-end electronics IDeF-X 1.1 and Cd(Zn)Te detector.

Caliste 64 sample with a 2 mm thick CdTe detector



ACRORAD 3D plus



High Energy Detector (HED) of Simbol-X focal plane

Scientific context

Simbol-X mission

- Space telescope of 20 m focal length with two satellites flying in formation to **focus photons from 0.5 keV to 80 keV** (flight in 2014).
- The High Energy Detector of the focal plane is a mosaic of 64 independent 1 cm^2 micro-cameras.

Instrument specifications

- Energy resolution better than 1.3 keV fwhm at 60 keV over all the channels (at -35°C).
- Dead zones inferior to 10 %.
- 625 µm pixel pitch

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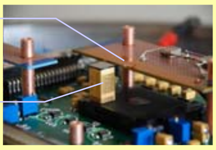
Experimental set-up



① At least one channel detects a photon from the ^{241}Am source.

② Caliste 64 sends a trigger signal outside the thermal enclosure.

③ The external board with FPGA performs the readout sequences and sends data packets to the computer.

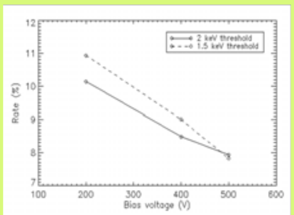
④ In the telemetry, each event is tagged with:

- A time (Caliste trigger),
- A position (pixel number),
- An energy.

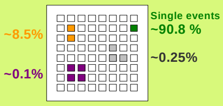
⑤ **To study split events, we extract from global telemetry the events in temporal coincidence between neighbor pixels.**

Split events statistics

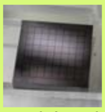
Probability of split events



Rate of split events into two neighbor pixels, as function of the bias voltage, for a 1 mm-thick detector.



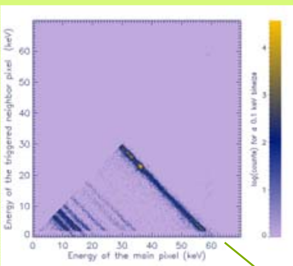
Pattern of triggered pixels (2 keV-threshold, 400V)



Segmented electrode on a CdTe detector sample.

The split event rate is all the more important as the voltage is low. The **effect of the diffusion** of the charge cloud towards the electrodes can't be neglected, even with this pixel size (1mm pitch). A high voltage accelerates charge and limits diffusion.

Correlation graph



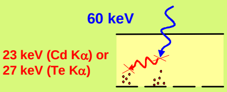
For any couple of triggered pixels, energy of the neighbor pixel versus energy of the main pixel with ^{241}Am source.

We select couple of events whose sum of the energies is greater than 50 keV, in order to isolate events corresponding to 59.54 keV photons of the source.

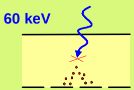
The maxima at 32 and 36 keV correspond to **Te and Cd K$_\alpha$ fluorescence escape lines**. The other events are due to **charge sharing**.

The sum of the two energies gives only singular constants, which correspond to the energies of the Americium photons.

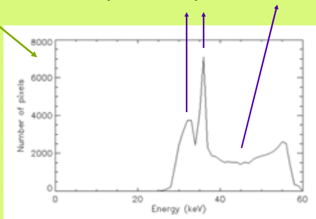
The straight lines of the correlation graph prove that **charge loss is almost negligible in this detector**.



X-fluorescence photon escape



Charge sharing

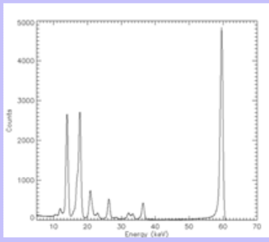


Energy distribution of the main pixel in case of multiple hits with only two neighbor pixels (200V, 2 keV threshold).

Spectrum reconstruction from double events

Method

- Precise individual energy calibration (2-order polynomial),
- Use of tables of calibration to know the amount of energy detected by each pixel of the double events,
- First spectrum by adding the two energies,
- Extra calibration to compensate charge loss.

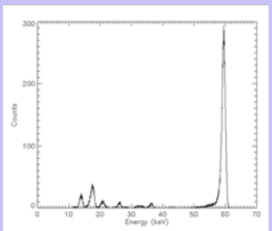


Spectrum of a typical pixel of Caliste 64, at 400V, -10°C. Energy resolution is 722 eV @ 13.94 keV and 918 eV @ 59.54 keV.

Results

- Without extra calibration, the 59.54 keV line is centered on 59.23 keV
→ **0.5% charge loss**
- Single events: mean resolution of 764 eV @ 13.94 keV and 875 eV @ 59.54 keV.
- Double events: **1.23 keV @ 59.54 keV**

$$\Delta E^{double} \approx \sqrt{2}\,\Delta E^{single}$$



Spectrum with only the split events between two pixels. Energy resolution is 1.23 keV fwhm at 59.54 keV.

Degradation of resolution for split events is only due to the quadratic sum of electronic noise of two independent channels.

Conclusions

1. Charge loss is only ~0.5 % in CdTe pixilated detectors.

- The detector is sensitive in pixel zones as well as inter-pixel zones.
- The dead zones in Simbol-X HED plane are only between the crystals.

2. Possibility to reconstruct spectrum with split events.

- Energy resolution with Caliste 64 meets Simbol-X requirements, even with double hits.