Nuclear Instruments and Methods in Physics Research A 610 (2009) 294–297

Contents lists available at ScienceDirect

Nuclear Instruments and Methods in Physics Research A

journal homepage: www.elsevier.com/locate/nima

Charge sharing in CdTe pixilated detectors

A. Meuris *, O. Limousin, C. Blondel

CEA, Irfu, Service d'Astrophysique, Bat. 709, Orme des Merisiers, F-91191 Gif-sur-Yvette, France

ARTICLE INFO

Available online 27 May 2009

Keywords:
CdTe
X-rays
Spectroscopy
Charge loss

ABSTRACT

Charge sharing was studied in Schottky CdTe detectors with segmented anode. The 1 mm-thick detector is integrated in a complete micro-camera called Caliste 64. The associated electronics gives for each event the time, the position and the energy. In case of split events, at least two neighbor pixels trigger in temporal coincidence. A model taking into account X-ray fluorescence and charge sharing correctly describes the experimental split event rates. The reconstruction of incident energy gives very good results, with a spectral resolution of 1.2 keV FWHM at 60 keV from the double events only. Charge loss in the pixel gap is estimated to be 0.5%.

1. Introduction

1.1. Scientific context

CdTe pixilated detectors will be used for hard X-ray spectroscopy and imaging in the Simbol-X mission. This space telescope to be flown in 2014 consists of two satellites flying in formation to observe high energy phenomena of the universe such as accretion near black holes, and acceleration by shocks in supernovae remnants. One satellite carries the grazing mirror to focus photons from 0.5 to 80 keV, and the other one carries the focal plane to detect the incidence, the energy and the time of arrival of the collected particles. The focal plane is an assembly of three detector units. The high energy detector, for the 4–80 keV energy range, will be a mosaic of 64 detectors of 1 cm^2 surface and 1 or 2 mm thick. The anodes of the detectors are segmented by a photolithography process, to obtain 256 pixels of 625 μm pitch, surrounded by a thin guard ring. Spectroscopic performance requirement is 1.2 keV FWHM at 60 keV over the 16 384 channels. The focusing technique requires high quality imaging with good spatial resolution and uniformity, and a minimum of dead zones. The current baseline for detection material is Schottky CdTe detectors from Acrorad (Japan) with an Al–Ti–Au contact at the anode [1].

1.2. Experimental set-up

Al Schottky CdTe detectors were studied with a segmented electrode of 64 pixels. The detectors are operated in the micro-camera called Caliste 64. This device is the hybridization of a 64-pixel CdTe detector with 4 ASICs of 16 analog channels called IDeF-X 1.1 [2].

The Caliste 64 sample is put in a thermal enclosure with a ^{241}Am source. When at least one channel detects an event, a trigger is sent by the camera to a FPGA placed outside the vessel. The board with FPGA reads the energies of the hit pixels and sends data packets to the computer through a Spacewire link. As a result, each event is tagged with a trigger time, a position (pixel number) and an energy. Among the telemetry data, some events are detected in temporal coincidence. In the less probable case, multiple hits correspond to two photons arriving in the same coincidence window (chance events). More often, they correspond to a photon whose energy is split between 2 pixels or more. The latter events can be selected using the position information of the camera. We consider patterns of multiple hits with neighbor pixels only.

1.3. Detector geometry

The 1 cm^2 anode is an array of 8×8 pixels. The side of the pixels are 900 μm, they are separated by a 100 μm gap and surrounded by a 900 μm guard ring (Fig. 1). We consider that the total detection surface is 64 mm^2, after removing the surface of the guard ring and the gap between the guard ring and the pixels. This surface is divided into two parts: a pixel surface of 51.84 mm^2 (81%) and an inter-pixel surface of 12.16 mm^2 (19%). The ratio between gap area and pixel area is 23%.

Section 2 reports experimental results with a 1 mm-thick detector. The measured split event rates are explained by a geometrical model in Section 3. Section 4 presents a method and the results of energy reconstruction with the double events.

* Corresponding author. Tel.: +33 1 69 08 12 73; fax: +33 1 69 08 65 77.
E-mail address: aline.meuris@cea.fr (A. Meuris).

0168-9002/$ - see front matter © 2009 Elsevier B.V. All rights reserved.
doi:10.1016/j.nima.2009.05.099

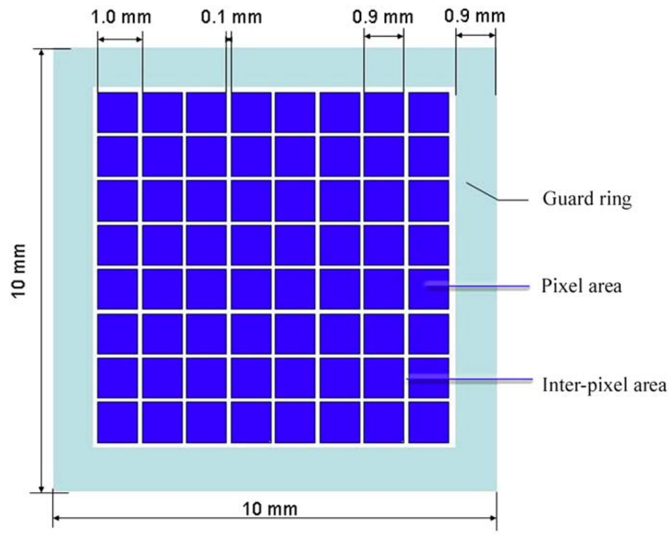

Fig. 1. Schematics of the segmented anode and dimensions of the different zones.

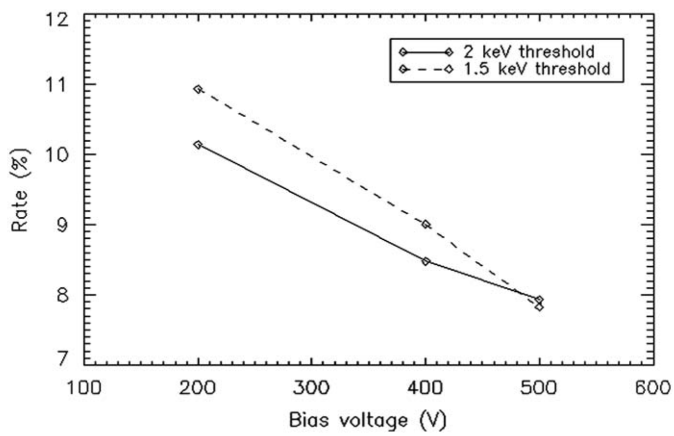

Fig. 2. Rate of events split into two neighbor pixels, as function of the bias voltage of the 1 mm-thick detector, for low thresholds set to 1.5 and 2 keV, at −10 °C.

2. Experimental results

2.1. Hit pixel patterns and occurrence probability

From one million events obtained with a ^{241}Am source at −10 °C, we extract multiple hits between neighbor pixels. We mostly obtain patterns of 2 pixels, but also 3 or 4 pixels. With a 2 keV low-threshold and a bias voltage of 400 V, patterns of 2–4 neighbor pixels represent, respectively, 8.5%, 0.2% and 0.1% of all the patterns of hit pixels.

The split event rate is studied versus the bias voltage, in particular for couples of hit pixels, which are the large majority of split events. Fig. 2 reveals that the split event rate is all the more important as the bias voltage is low. With 200 V/mm, charges are less accelerated and drift times are a bit longer. As a consequence, diffusion of the charge cloud is more important and the electron cloud at the anode is statistically larger than the diffused electron cloud at 500 V. Charge sharing between 2 pixels becomes more probable. The bias voltage dependency implies that we cannot neglect diffusion even with this pixel size (1 mm pitch).

The absolute value of the split event rate depends on the low-level threshold. Since there are no Am or Np lines below 3 keV, the events between 1.5 and 3 keV are only due to dissymmetrical charge sharing. The lower the threshold, the more shared events should be detected. Our experimental results certainly underestimate by several ‰ the rate at 500 V with a 1.5 keV threshold, probably because of a lack of statistics.

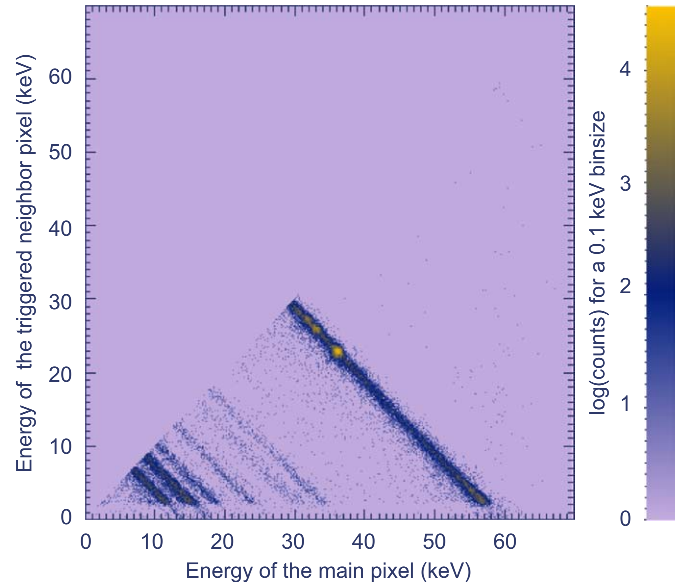

Fig. 3. For any couple of triggered pixels, energy of the neighbor pixel versus energy of the main pixel with a ^{241}Am source.

2.2. Energies in two neighbor pixels

Energies of the pixels were studied in case of multiple hits with only two neighbor pixels. In the following paragraph, the pixel that records the greater energy is called the main pixel.

2.2.1. Correlation graph

Fig. 3 shows a strong correlation between the energies of the pixel couples. The sum of the two energies only gives singular constants, which correspond to the energies of the Am photons. Contrary to CZT detectors studied by Kuvvetli et al. [3] with 2.5 mm pixel pitch instead of 1 mm, we do not observe a curvature of the correlation graph due to charge loss in the 100 μm-gap. Charge loss occurs when drift time is not negligible with respect to trapping time. According to Bolotnikov [4], electric field lines towards the pixel electrodes, in a non-ideal material with small contacts (or large gaps), can be distorted such that they are much longer for electrons generated in the gap; that is why those electrons are more likely to be trapped before inducing their whole signal. In our Schottky CdTe detectors, electric field is high enough (400 V/mm) and the ratio between gap size and pixel size is small enough (1/9) so that this effect is almost negligible. Estimation of charge loss will be given in Section 4.

2.2.2. Energy distribution

On the line corresponding to the 59.5 keV photons, we notice several spots (Fig. 3). Energies of the main pixels in case of two hit pixel events are not equally probable. To obtain the energy distribution due to the interactions of 59.5 keV photons, we select couple of events whose sum of the energies is greater than 50 keV. We notice on this distribution two maxima at 32 and 36 keV (Fig. 4). Those events occur when the 59.5 keV photons first interact with Cd (resp. Te) atoms to create a 23.2 keV (resp. 27.5 keV) K_α fluorescence photons that escape in the neighbor pixels. The main pixels record the Cd and Te fluorescence escape lines. The other couples of events are due to charge sharing when the charge cloud