# Experimental set-up and measurements with a hybrid detector prototype at the Leicester University

N. Auricchio[1,2], E. Caroli[2], A. Donati[2], Filomena Schiavone[2], Leonardo Abbene[3], Stefano del Sordo[4], Richard Ambrosi[5], A. F. Abbey[5] , C. Brown[5], H. Su[5]

Internal Report INAF/IASF-Bo n. 529/2008

**Affiliation:**

[1] Dept. of Physics, University of Ferrara, Ferrara, Italy
[2]INAF/IASF-Bo, via Gobetti 101, Bologna, Italy
[3] DiFTeR, University of Palermo, Palermo, Italy
[4] INAF/IASF-Palermo, Palermo, Italy
[5] University of Leicester, Department of Physics and Astronomy, Space Research Centre, Leicester, UK

***TABLE OF CONTENTS***

1. Documents Applicable
2. Summary
3. Spectroscopic performances of the detectors
    3.1. CZT detector
    3.2. A spare CMOS CCD of EPIC/XMM
4. Experimental set-up
5. Spectra analysis
6. Performed measurements and results
7. Comparison between expected and measured transparency of a spare CMOS CCD of EPIC/XMM
8. Combined spectrum of a hybrid detector
9. Future work

References

Appendix 1 Measurement Logbook

## Aims

This document intends to provide the user with the technical informations to reliably arrange and manage the set-up of the CCD detector (Leicester) and the CZT detector (Bologna-Palermo).

## 1. Documents Applicable

1) P.J. Pool, R. Holtom, D.J. Burt, A.D. Holland.
*"Developments in MOS CCDs for X-ray astronomy"*.
NIMA, 436, (1999) 9 – 15.

2) A.D. Short, R.M. Ambrosi, M.J.L. Turner.
*"Spectral re-distribution and surface loss effects in Swift XRT (XMM-Newton EPIC) MOS CCDs"*.
NIMA, 484, (2002) 211–224.

3) T. Abbey, N. Auricchio, R. Ambrosi, E. Caroli, S. Del Sordo, A. Donati, D. Ross, F. Schiavone, G. Ventura.
*"CZT Bo/Pa Set-up for the hybrid experiment at the Leicester University"*.
Internal Report IASF/BO n. 425/2005.

4) N. Auricchio, J. B. Stephen, E. Caroli, A. Donati, G. Landini, F. Schiavone, G. Ventura, F. Frontera, A. Basili, T. Franceschini.
*"Spectroscopic characterization of two CdZnTe Multipixel Detectors in an eV Multi Pix 16 Channel ASIC Evaluation System"*
Internal Report IASF/BO n. 387

5) G. Ventura, E. Caroli, N. Auricchio, A. Donati, G. Landini, F. Schiavone, R. M. Curado da Silva.
"*POLCA2 (POLarimetry with CZT Arrays): experimental set-up, calibration procedures and results"*.
Internal Report IASF/BO n. 444/2006.

*6)* eV-Multipix 16 channel asic evaluation system by eV products /a division of II-VI incorporated User Manual

## 2. Summary

The scientific objectives of next high throughput mission in X-ray astronomy require new type of focussing telescopes able to extend the observational range at least up to 100 keV to solve crucial question concerning the nature of the high energy emission from cosmic source and the origin of the cosmic X-ray background. A challenging technology to extend the classical grazing incidence range to higher energy is today offered by the development of multilayer optics that are effective as X-ray concentrators between few keV up to 80/100 keV. A useful arrangement for this type of mission concept (e.g. HEXIT, SIMBOL-X) can foresee the soft (e.g. 0.1-10 keV) X-ray optics nested and coaxial with the hard-X mirrors. This means that the focal plane of the telescope shall operate on the overall energy range (from 0.1 to 80/100 keV) fulfilling at the best the different requirements of the two optics type in terms of detection efficiency, spatial resolution and spectroscopic performance. A solution for this kind of focal plane detector is given by an hybrid design with a soft X ray detector (e.g. CCD) in front and coaxial to an hard-X ray detector (e.g. Pixel CZT spectrometer).
In this contest our collaboration (Space Research Centre of the Leicester University and INAF/IASF-Bologna/Palermo) had the idea to assemble a hybrid detector prototype using as soft Xray detector a spare CMOS CDD of the EPIC/XMM developed at Leicester University instrument and a CZT mutipixel detector manufactured by eV-Products as hard-X ray detector.
This report describes the experimental set-up used during a second session of measurements carried out at the Leicester University, that utilizes a spare CMOS CDD of the EPIC/XMM and a multipixel detector read by a custom electronics, and presents the results obtained.
The main characteristics of the two detectors are shown in Table 1.

| **Detector** | **Type** | **Operative Range** | **Spatial resolution** | **Energy Resolution** | **Efficiency** |
|---|---|---|---|---|---|
| CZT | Pixellated (4x4) | 10 keV-1.5 MeV | 2 mm | 4.9% @ 60 keV | 99.9% at 60 keV |
| EPIC CCD22 | MOS CCD | 0.2 -10 keV | 40 μm | ~ 3% @ 3 keV<br>~ 2% @ 10 keV | ~ 80% @ 3 keV<br>~ 25% @10 keV |

Table 1. The main characteristics of the two detectors used for the Hybrid prototype.

## 3. Spectroscopic performances of the detectors

### 3.1 CZT detector

We have used an eV Multi Pix 16 channel ASIC Evaluation System paired with a 4x4 channel CdZnTe detector operating at room temperature (see Fig.1). The thickness of the detector included with this device is 5 mm, while the lateral dimensions are 10.6x10.6 mm$^2$, the pixel size is 1.8 x 1.8 mm$^2$ (2 mm pitch). The ASIC in this unit accepts an input from the CdZnTe detector and produces one unipolar shaped signal for each photon detected. The ASIC channel outputs have ~ 300 mV of DC offset and the detector bias voltage is ~520 V. The channel gain is 200 mV/fC and the peaking time is 1.2 μs. The guard ring is 0.5 mm wide to protect peripheral pixels against surface leakage current and to reduce the influence of the edge effects.
The ASIC signals are sent to a the read-out electronics Takes. Any signal is presented to a peak stretcher (**PPS**) and to a voltage comparator (minimum energy threshold $\mathbf{E_{min}}$). The peak voltage of any analog signal overcoming $\mathbf{E_{min}}$ is pre-stretched for a time of the order of the input pulse rise time. If within the coincidence window time, selectable among 1, 2, 4, 8, 16 μsec, one or two digitized outputs coming from the energy thresholds $\mathbf{E_{min}}$ occur, a post stretching action is issued

and the analog data are enabled to be converted in digital by the analog-to-digital converter (ADC). The coincidence criterion is simply based on the fact that single or double events detected within the coincidence time (selectable among 1, 2, 4, 8, 16 μsec) are accepted as valid and then post-stretched to be converted in digital by the 12 bit flash ADC. The energy of any event (single or double overcoming $\mathbf{E_{min}}$) is coded with 10 significant bits and to any channel an address code is associated depending on its physical input wiring. Takes also adds a coded field which allows to detect if a single or double event has occurred within the selected coincidence time. Furthermore, for design reasons, Takes provides output coded data in serial form.
Since the Takes internal amplification factor is set at too high values for the ASIC eV-16 output levels, it is necessary to lower the overall amplification factor by using series resistors on any measurement channel (R = 15 kΩ). Furthermore, the AC coupling of the Takes electronics' input channels ensures for the elimination of the DC offset provided by any ASIC eV output channel.
Data are acquired by the PC through a National Instrument NI DIO 6533 digital interface which is managed by a HW handshake. The PC resident SW is able to manage the experiment and to output both energy and position data, as well data storage.


Figure 1. eV-MultiPIX with top cover removed (left) and in its standard housing (right).

Calibration measurements were carried out at INAF IASF/Bo with $^{241}$Am and $^{109}$Cd uncollimated sources using the same gain and peaking time of the tests performed at Leicester University. In figure 2 we report the energy spectra of all pixels acquired with these sources.

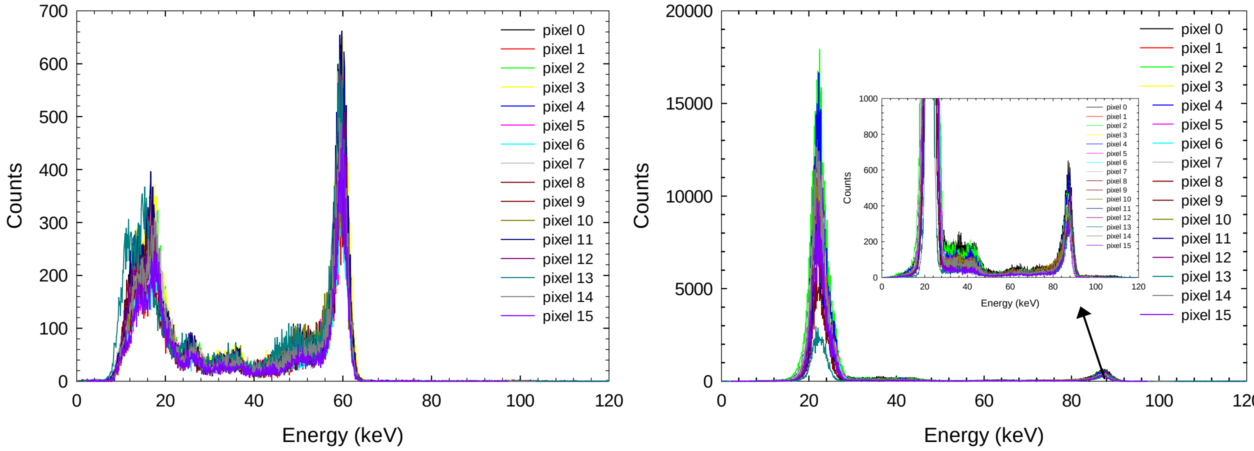


Figure 2. Energy spectra of $^{241}$Am (left) and $^{109}$Cd (right).

In figure 3 the calibration lines of all pixels, obtained fitting the experimental data at 22.1, 59.54 and 88 keV, are reported while the behaviour of energy resolution and the photopeak centroid normalized to its maximum value is shown in figure 4.

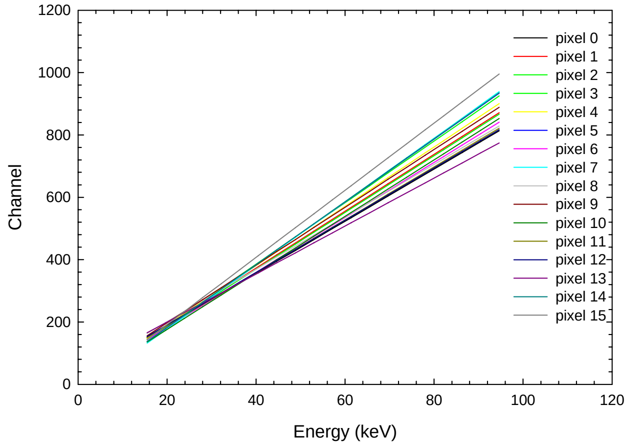


Figure 3. Calibration curves.

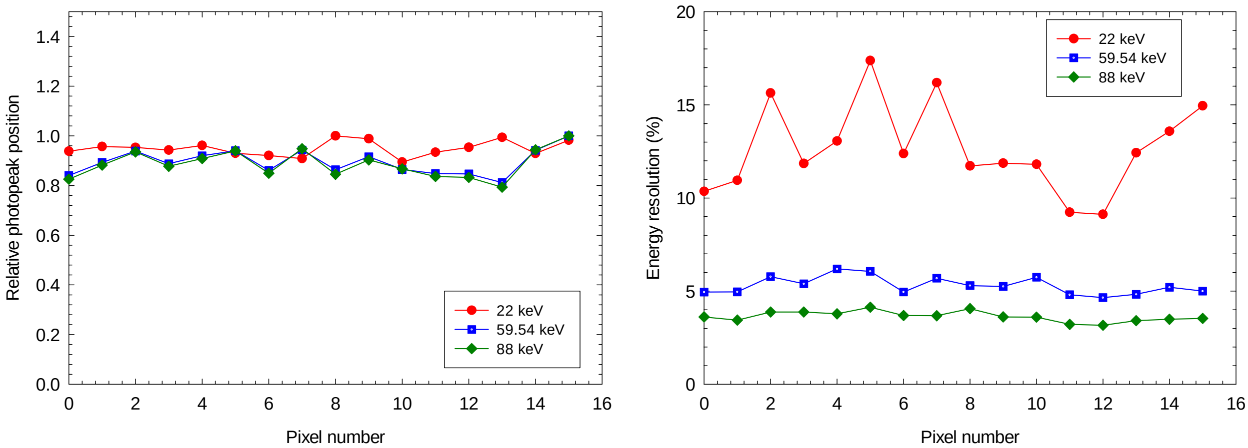


Figure 4. Behaviour of the energy resolution and photopeak centroid of all pixels.

### 3.2 A spare CMOS CCD of EPIC/XMM

The CCD22 is a three-phase frame transfer device, which utilises high resistivity silicon and an 'open' electrode structure in order to achieve useful quantum efficiency in the energy range 0.2–10 keV. Each CCD is three sides buttable and has an imaging area of 2.5×2.5 $cm^2$.
The CCD image section is a 600×600 pixel array of 40×40 $\mu m^2$ pixels. The storage region is a 600 × 602 $pixel^2$ array of 39×12 $\mu m^2$ pixels. The readout register is split into two sections, each of 300+5 elements, ending in a readout node. The full CCD image may be read out using either node, or may be split and read out using both nodes simultaneously. The CCDs may also be operated in fast timing mode (spectroscopy but no imaging), and window mode (rapid readout of a central imaging area only). These modes allow spectroscopy to be conducted over a wide range of source flux. This capability is important for observing sources as bright as several times the intensity of the Crab. A simplified CCD schematic is given in figure 5.
The low-energy response of a 'conventional' front illuminated CCD is restricted to energies greater than 700 eV due to X-ray absorption in the electrode structure. This may be improved by thinning one of the electrodes, as demonstrated for the JET-X CCDs developed by the University of Leicester and e2v Technologies for the Russian Spectrum-X-Gamma observatory [1]. For XMM a further improvement was required in order to increase the quantum efficiency below 300 eV. In

order to achieve this, one of the three phases is enlarged to occupy a greater fraction of each pixel, and comprises electrode fingers, leaving 'holes' to the gate oxide [2 and 3]. This gives an 'open' fraction of 40%. In the open areas, the surface potential is pinned to the substrate potential by means of a 'pinning implant'. Details of this electrode structure are still the subject of commercial confidentiality, so a greatly simplified schematic is given in figure 6. High-energy efficiency is maximised by using epitaxial silicon of the highest available resistivity (typically 4000 Ω cm). The depletion depth is about 30 µm thick, the epitaxial layer is 80 µm thick (p-type) and the substrate is 200 µm thick.

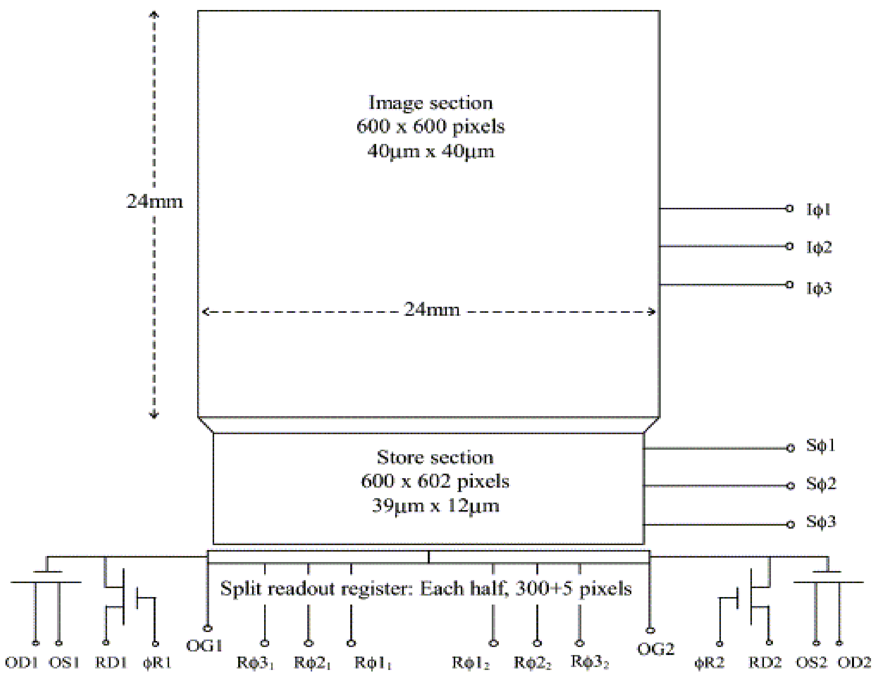


Figure 5. CCD22 simplified schematic.

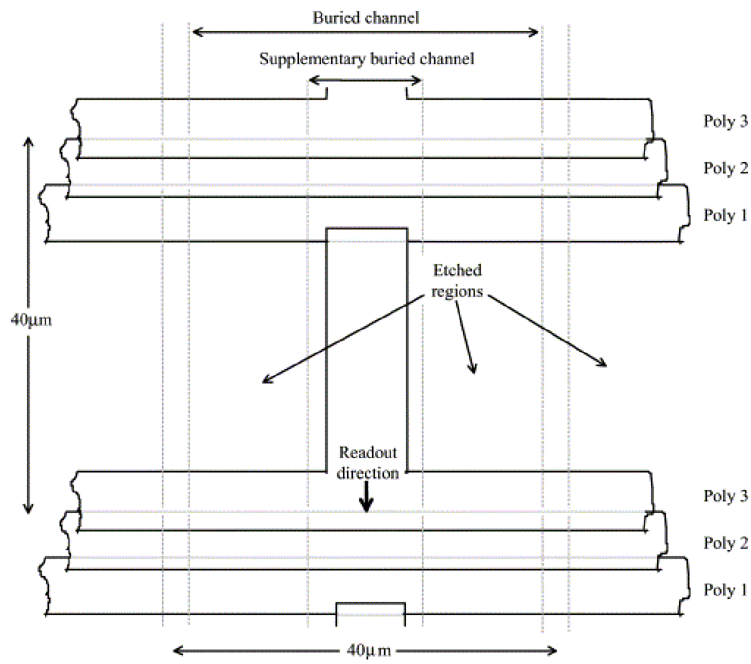


Figure 6. Simplified CCD22 electrode structure.

In the following figure we present the energy spectra acquired with a single pixel and with 4 pixels. We have used an attenuating Al filter placed in front of the $^{109}$Cd source thick 288 μm.

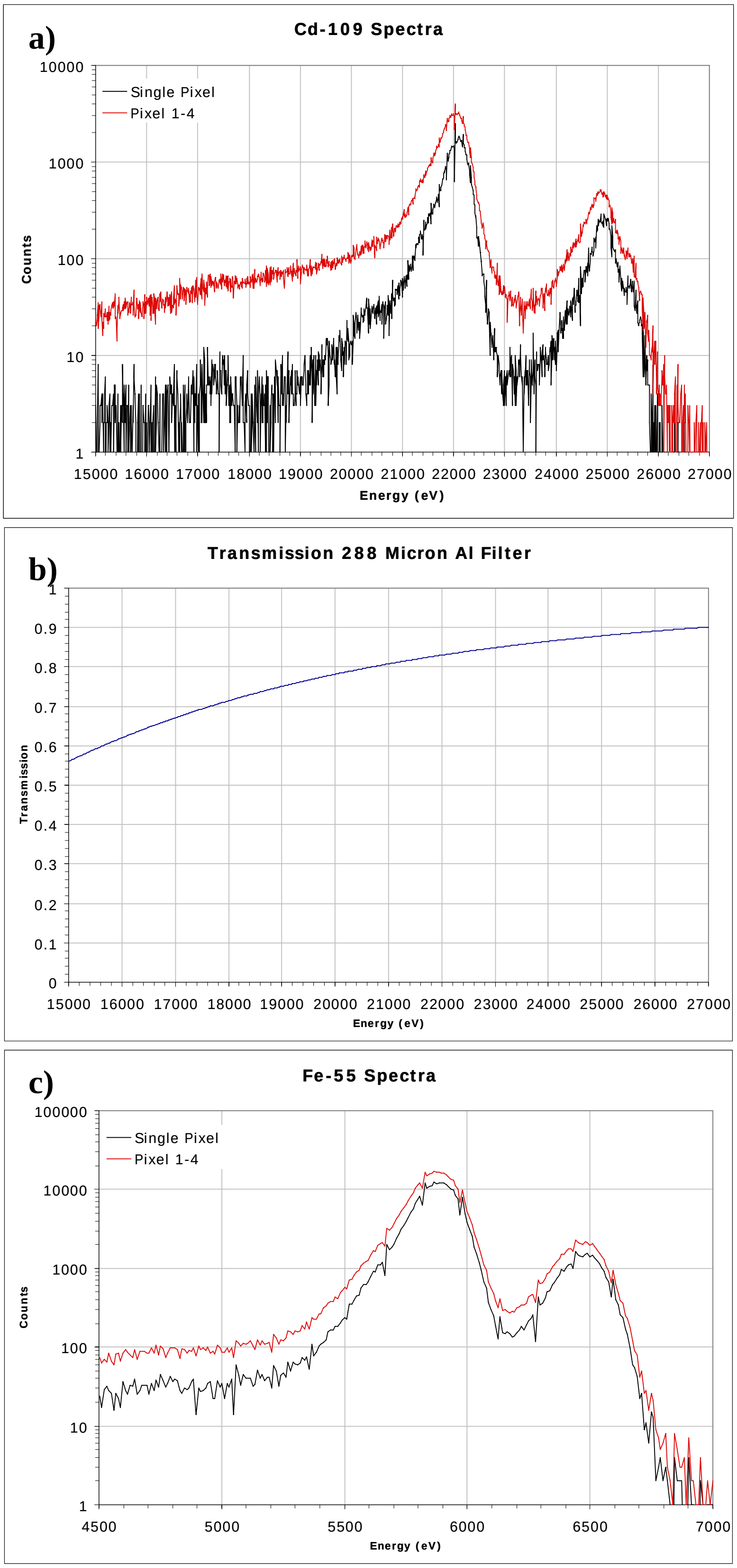


Figure 7. a) Pulse height spectrum recorded with $^{109}$Cd source; b) transmission calculated for the 288 micron Al filter; c) spectrum acquired with $^{55}$Fe without attenuating filter.

## 4. Experimental set-up

The IASF Bologna and Palermo groups in Italy together with the University of Leicester, Space Research Centre, have initiated a collaborative instrument development program to build a hybrid position sensitive detector consisting of a Cadmium Zinc Telluride (4x4 pixel array) and a thinned EPIC CCD22. This detector would be sensitive over the 0.2 to 100 keV energy range. The aim of the collaboration is to produce a breadboard model that could be exploited in a future X-ray astronomy mission opportunity.

An experimental program has been defined to integrate the two detectors in a specifically designed facility at the University of Leicester and carry out a series of live X-ray tests over the sensitive range of the detector. The CZT multipixel detector is mounted on a plexiglass support outside of the vacuum chamber (see photo 8) and irradiated with radioactive sources and with a X-ray flux through a window of 10x10 $mm^2$ size, composed of a Al layer 25 $\mu$m thick and a kapton layer 500 $\mu$m thick. The use of such materials allows the transmission of 76% at 11.4 keV, 95% at 22.5 keV and 99% at 88 keV.

In figure 8 the vacuum chamber containing the CCD and in figure 9 the overall view of the system are shown. The multipixel detector is mounted in place of the detector contained in the brown box.

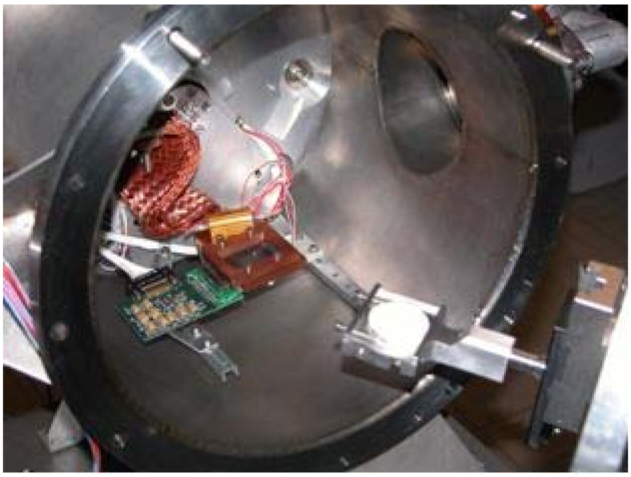

Figure 8. Vacuum chamber containing the CCD.

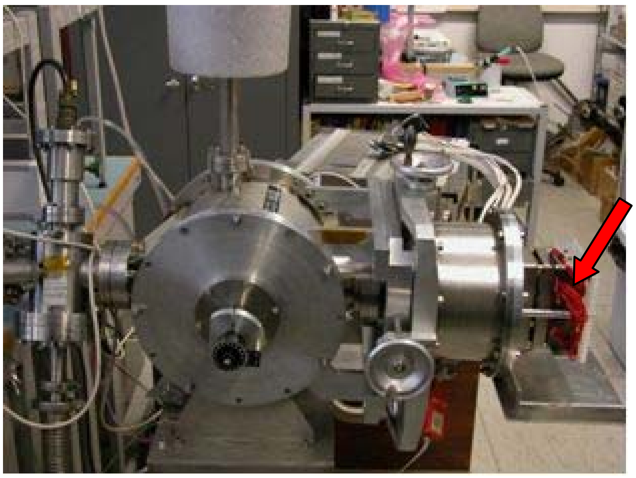

Figure 9. Overall view of the used system. The multipixel detector is mounted in place of the brown box (indicated by the arrow).

## 5. Spectra analysis

Calibration measurements were repeated at Leicester University with $^{241}$Am and $^{109}$Cd uncollimated sources and the energy spectra are displayed in figure 10.

The spectra have been analysed using the PeakFit software package (PeakFit v4.0. Peak separation and Analysis Software: User's Manual, Jandel Scientific Software, 1995) in order to obtain several parameters as thephotopeak pulse amplitude and the energy resolution. The main characteristics of the spectra are: a Gaussian photopeak component corresponding to the energy of the incident photons and an asymmetric component caused by trapping effects. The first component has been modelled using a Gaussian distribution and the second was fitted using a typical chromatographic asymmetric function known as a Half-Gaussian Modified Gaussian.

In figure 11 the calibration lines of all pixels, obtained fitting the experimental data at 22.1, 59.54 and 88 keV, are reported and in figure 12 the energy resolution and the photopeak centroid normalized to its maximum value are shown.

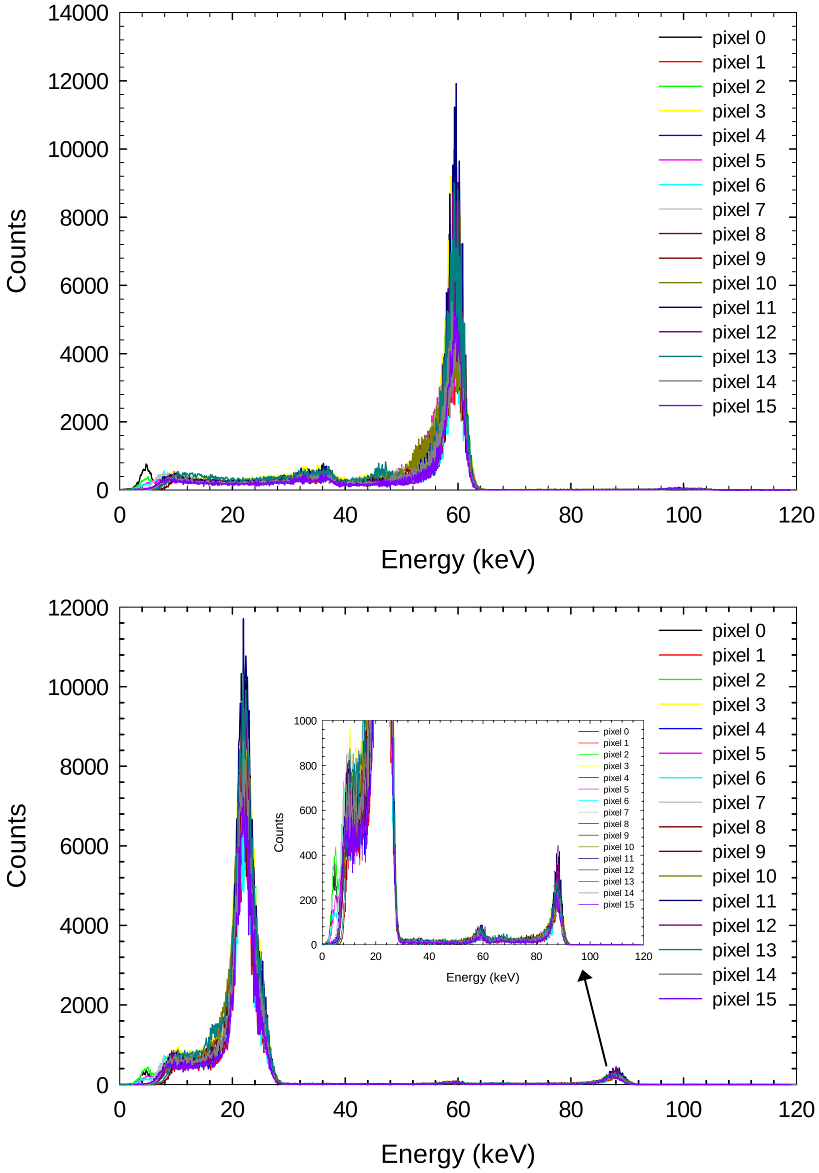


Figure 10. Energy spectra of $^{241}$Am (top) and $^{109}$Cd (bottom).

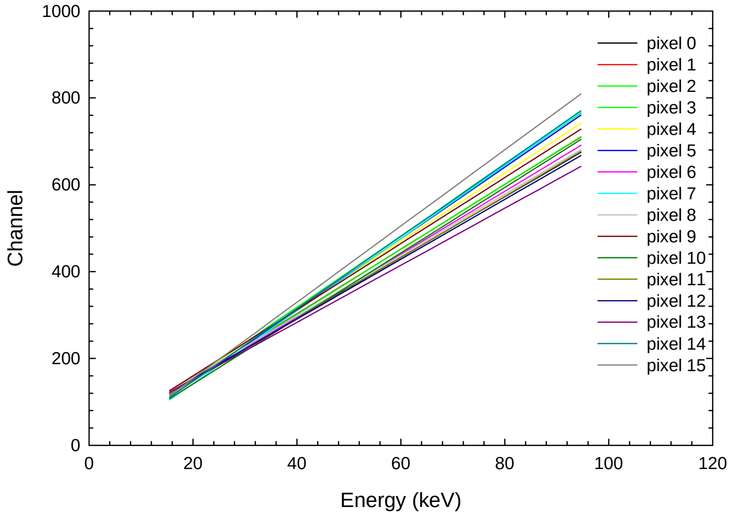


Figure 11. Calibration lines of all pixels.

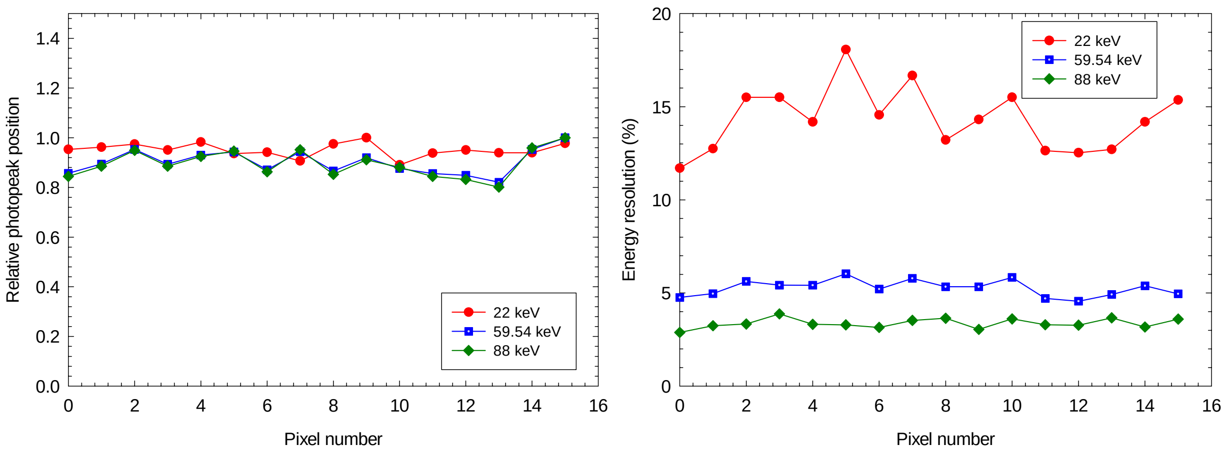


Figure 12. Behaviour of the energy resolution and photopeak centroid.

## 6. Performed measurements and results

The aim of the recorded measuments is to verify the coupling of a hybrid detector prototype using as soft Xray detector the spare CMOS CDD of the EPIC/XMM and the CZT mutipixel detector as hard-X ray detector.

After calibrating the CZT detector and adjusting the low energy threshold we have performed some measurements as follows:

1) a source of $^{55}$Fe was placed immediately behind the source of $^{109}$Cd; in this way the two sources irradiated both the CCD and the multipixel. The low energy photons of $^{55}$Fe (~ 6 keV) interacted within the CCD but their energy was below the value of the CZT threshold, instead the $^{109}$Cd lines was measured both by the CZT multipixel and by the CCD.
   We have carried out two tests:
   a. the first without CCD in front of the multipixel,
   b. the second with CCD in front of the CZT detector;
2) the two detectors were illuminated with an X-ray tube having a Pb target, that generates characteristic X-rays whose energy is 10.55 and 12.61 keV. We have performed the measurement without CCD and with CCD in front of the CZT detector.
3) background spectrum was acquired in order to subtract it from each pixel.

In following figures the measurements described above are reported.

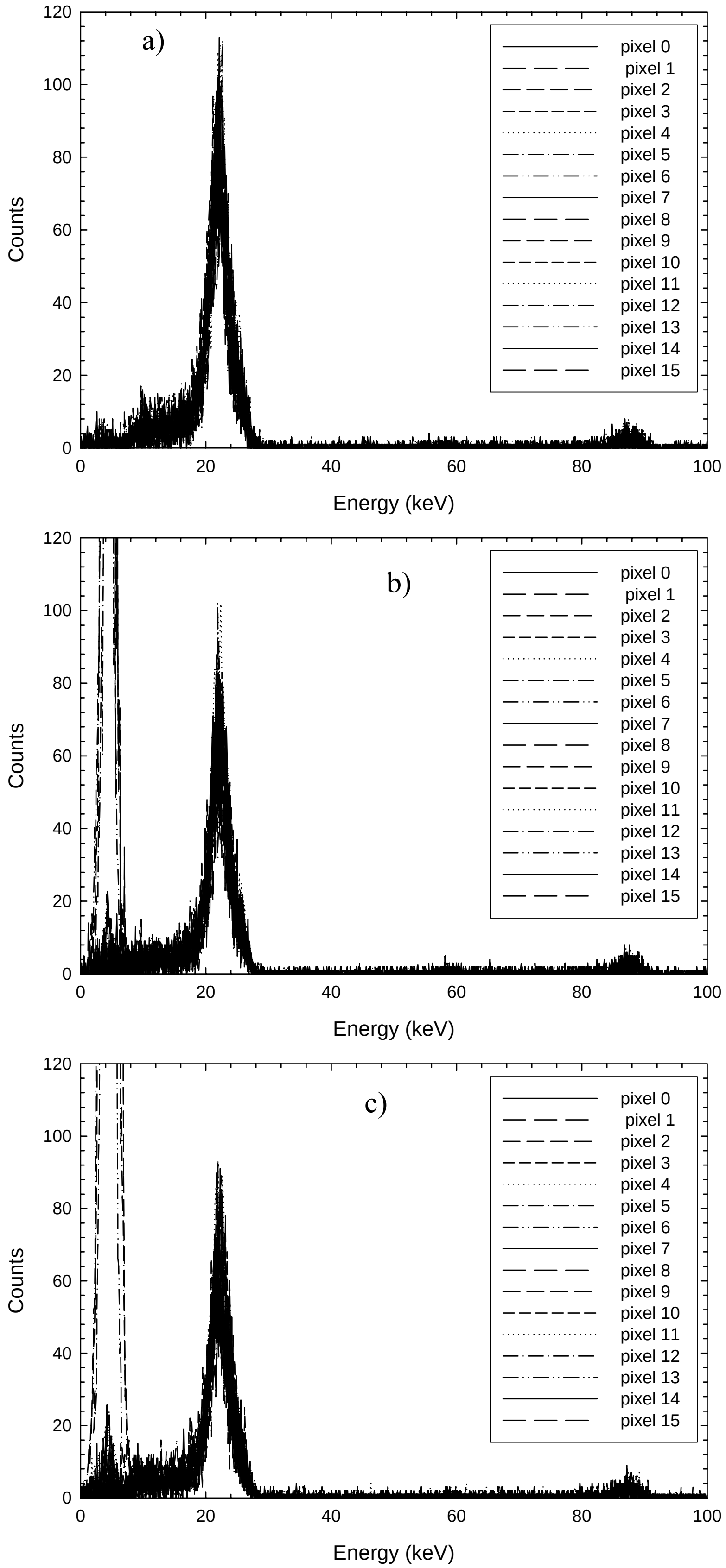


Figure 13. a) Measurement recorded without CCD in front of the CZT multipixel; b) with CCD turned off in front of the CZT and c) with CCD switched on using the sources of $^{55}Fe$ and $^{109}Cd$.

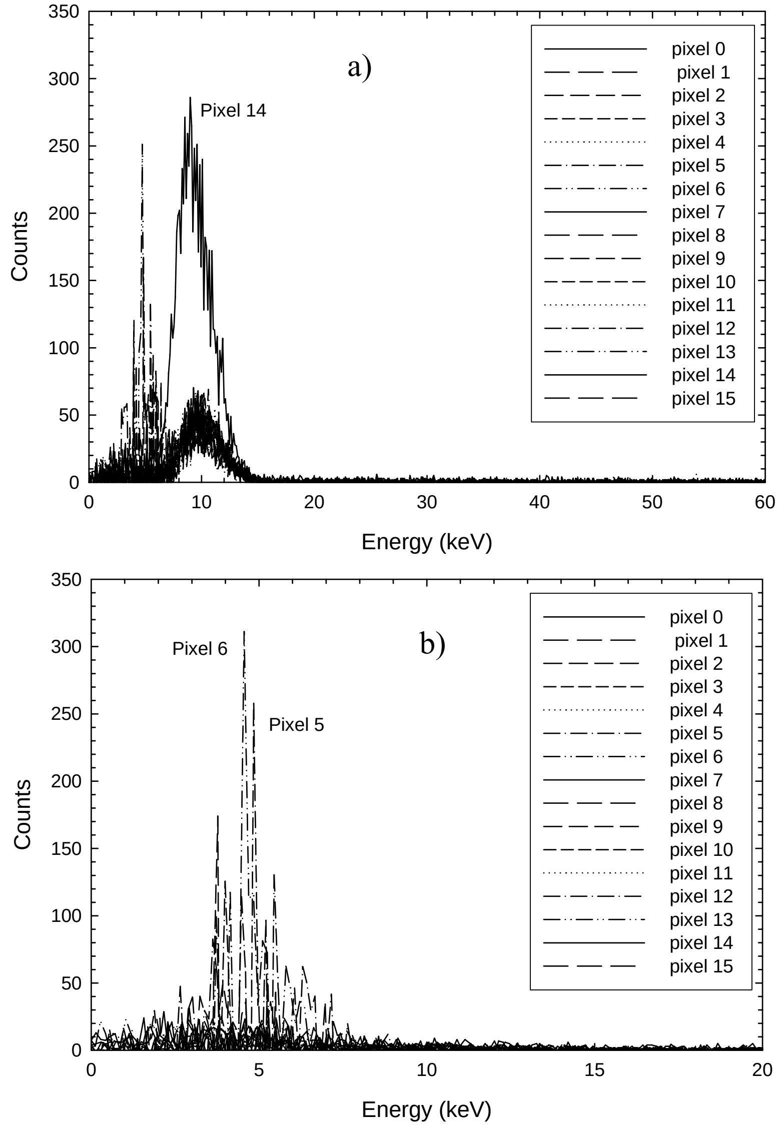


Figure 14. a) Measurement recorded without CCD in front of the CZT multipixel; b) with CCD turned on in front of the CZT using the X-ray tube.

For each measurement the energy spectra of all pixels are summed in order to obtain the total response of the detector and calculate the CCD transparency. The obtained results are:

- at 11.4 keV (average between 10.55 and 12.61 keV) the upper limit is (12.4±3)%;
- at 22.1 keV the CCD transparency is ~(78.1±0.6)%;
- at 88 keV it is (99.6±4.7)%.

## 7. Comparison between expected and measured transparency of a spare CMOS CCD of EPIC/XMM

In figure 15 the expected transparency of a CCD22 (calculated considering the materials placed in front of the source) is reported as a function of the energy.

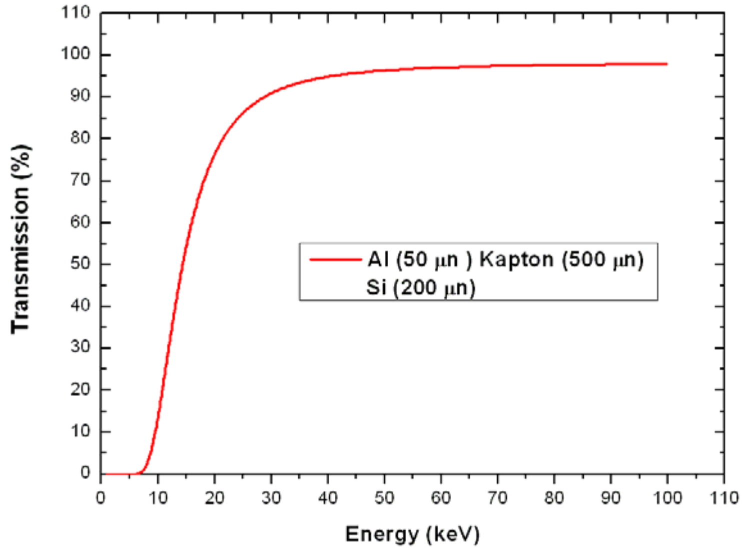


Figure 15. Expected transparency.

It is worth noticing that the measured values of transmission are in good agreement with the theory.

## 8. Combined spectrum of a hybrid detector

In figure 16 we present the spectrum of the hybrid position sensitive detector, composed of a EPIC CCD22 and the CZT multipixel, irradiated with $^{55}$Fe and $^{109}$Cd. We report the data of a CCD22 single pixel.

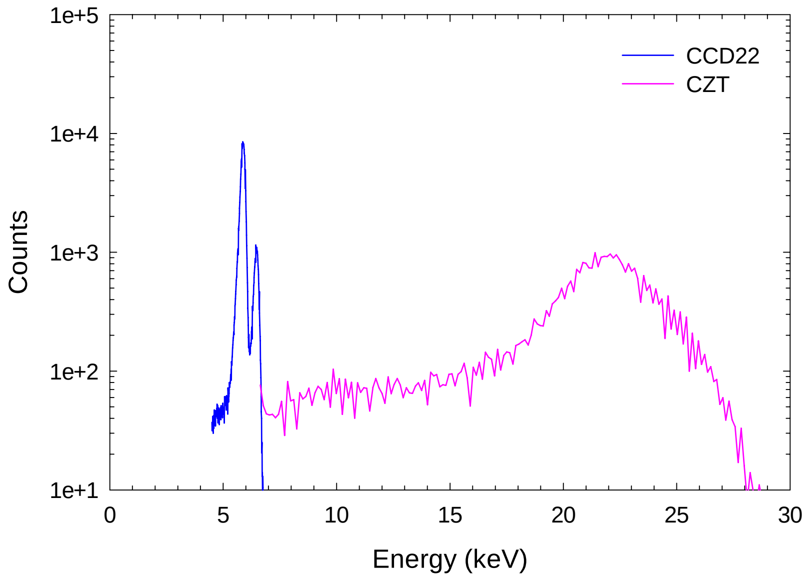


Figure 16. Spectrum of the hybrid detector.

## 9. Future work

We foresee to use a  custom CZT 256 pixel detector with a lower energy threshold to better overlap the CCD and CZT energy ranges.
We plan to perform simultaneous measurements on imaging properties of both detectors.

**References**

1. A. Owens, et al., A comprehensive study of the intrinsic radiation properties of CCDs, collection of papers ref: JET-X (94), 1994 UL–230.
2. H. Tsunemi, K. Yoshita, A.D.T. Short, P. Bennie and M.J.L. Turner Nucl. Instr. and Meth. A 437 (1999), pp. 359–366.
3. J. Hiraga, H. Tsunemi, A.D. Short, A.F. Abbey, P.J. Bennie and M.J.L. Turner , Measurement of the sub-pixel structure of the EPIC MOS CCD on-board the XMM Newton satellite. Nucl. Instr. and Meth. A 465 (2001), p. 384.

**Appendix 1 Measurement Logbook**

In the following pages the list of the measurements taken during the Campaign (05/07/2007-10/07/2007) is reported.
The data log is shown day by day as a table. The measurements are classified for type: e.g. background (bkg), with monochromatic sources and X-ray tube. Filename, detector set-up, source type and notes are reported for each measurement. Below the table there is the list of the corresponding measurements taken directly from the quick look data log.

| **File name** | **Detector** | **Sources** | **Note** |
|---|---|---|---|
| Multipix_bgk050707_00.bin | CZT | | bkg |
| Multipix_bgk_1_7_01.bin | | | vthr = 1.7 |
| | | | |
| Multipix_Am_00.bin | | $^{241}$Am | Relative efficiency whit energy lines |
| Multipix_Am_01.bin | | | collimated source |
| PIXCd-Fe-CCD+Frame_01.bin | CZT/ EPIC CCD22 | $^{109}$Cd - $^{55}$Fe | only CZT |
| PIXCd-Fe+CCD+Frame_00.bin | | | CCD off |
| PIXCd-Fe+CCDon+Frame_00.bin | | | CCD on |
| PIXPb+Xray+CCDon+Frame_00.bin | | X-ray tube/Pb target | |
| PIXPb+Xray+CCDon+Frame_00.bin | | | CCD off |
| PIXCd1h_00.bin | CZT | $^{109}$Cd | Multipixel calibration measurements |
| PIXCd1h_1mm_00.bin | | | collimated source |
| PIXAm1h_01.bin | | $^{241}$Am | |
| PIXAm1h_coll_00.bin | | | collimated source |
| PIX_bgk_00.bin | | | bkg 06/07/07 |
| bkg_070707_00.bin | | | |
| PIX_Pb_00.bin | | Pb, Fe, Titanio, Al, Cu/target | only CZT |
| PIX_Pb2_00.bin | | $^{109}$Cd | |
| PIX_PbCCdon_00.bin | CZT/ EPIC CCD22 | Pb target | CCD on |
| PIX_Pb-CCD-frame_00.bin | | | only CZT |
| PIX_Pb-CCD-frame_01.bin | | | |
| PIX_Pb-CCD-frameMax_00.bin | | | |
| PIX_Fondo_00.bin | CZT | | bkg |
| PIX_Pb_No_CCD_00.bin | | | only CZT |
| PIX_Pb_CCD_01.bin | CZT/ EPIC CCD22 | Pb target | |

C:\CCD-CZT\Misure\Multipix_bgk050707_00.bin El-Multiparametrico
Number Read.:  5496 --  Date and Time: 05/07/2007 18:18:30 --  Elapsed Time (s): 280
Background

C:\CCD-CZT\Misure\Multipix_Am_00.bin El-Multiparametrico
Number Read.:1543704 --  Date and Time: 05/07/2007 18:02:24 --  Elapsed Time (s): 119

C:\CCD-CZT\Misure\Multipix_Am_01.bin El-Multiparametrico
Number Read.:3284992 --  Date and Time: 05/07/2007 18:04:34 --  Elapsed Time (s): 98
Source collimated Am

C:\CCD-CZT\Misure\Multipix_bgk_1_7_01.bin     El-Multiparametrico
Number Read.:  6916 --  Date and Time: 05/07/2007 18:27:30 --  Elapsed Time (s): 1602
Background
1.7

C:\CCD-CZT\Misure\PIXCd-Fe-CCD+Frame_01.bin        El-Multiparametrico
Number Read.: 62526 --  Date and Time: 06/07/2007 10:15:11 --  Elapsed Time (s): 3601
montato in linea con la finestra
asic 1
con Frame
senza CCD
Cd e Fe

C:\CCD-CZT\Misure\PIXCd-Fe+CCD+Frame_00.bin       El-Multiparametrico
Number Read.: 85500 --  Date and Time: 06/07/2007 11:41:06 --  Elapsed Time (s): 3601
montato in linea con la finestra
asic 1
con Frame
Cd e Fe

C:\CCD-CZT\Misure\PIXCd-Fe+CCDon+Frame_00.bin   El-Multiparametrico
Number Read.: 94413 --  Date and Time: 06/07/2007 13:15:45 --  Elapsed Time (s): 3602
montato in linea con la finestra
asic 1
con Frame
con CCD on
Cd e Fe, vuoto e raffreddamento
Multipixel

C:\CCD-CZT\Misure\PIXPb+Xray+CCDon+Frame_00.bin          El-Multiparametrico
Number Read.: 32475 --  Date and Time: 06/07/2007 16:41:34 --  Elapsed Time (s): 2158
montato in linea con la finestra
asic 1
senza frame
Multipixel
X-ray +target di Pb

C:\CCD-CZT\Misure\PIXCd1h_00.bin       El-Multiparametrico

Number Read.:5097472 -- Date and Time: 06/07/2007 17:18:58 -- Elapsed Time (s): 1101
asic 1
Multipixel, Cd, vthr= 1.7

C:\CCD-CZT\Misure\PIXCd1h_1mm_00.bin El-Multiparametrico
Number Read.:503808 -- Date and Time: 06/07/2007 17:39:15 -- Elapsed Time (s): 302
asic 1
Multipixel, Cd fenditura 1 mm
vthr= 1.7

C:\CCD-CZT\Misure\PIXAm1h_01.bin El-Multiparametrico
Number Read.:4604928 -- Date and Time: 06/07/2007 17:47:46 -- Elapsed Time (s): 795
asic 1
Multipixel, Am
vthr= 1.7

C:\CCD-CZT\Misure\PIXAm1h_coll_00.bin El-Multiparametrico
Number Read.:8931328 -- Date and Time: 06/07/2007 18:03:27 -- Elapsed Time (s): 1101
asic 1
Multipixel, Am
vthr= 1.7
collimata

C:\CCD-CZT\Misure\PIX_bgk_00.bin El-Multiparametrico
Number Read.: 9341 -- Date and Time: 06/07/2007 18:46:28 -- Elapsed Time (s): 1102
asic 1
Multipixel
vthr= 1.7
background 060707

C:\CCD-CZT\Misure\bkg_070707_00.bin El-Multiparametrico
Number Read.: 20496 -- Date and Time: 07/07/2007 09:22:28 -- Elapsed Time (s): 2403

C:\CCD-CZT\Misure\PIX_Pb_00.bin El-Multiparametrico
Number Read.: 45081 -- Date and Time: 07/07/2007 10:51:57 -- Elapsed Time (s): 3602
vuoto
senza CCD, no frame
Source: Pb, Fe, Titanio, Al, Cu

C:\CCD-CZT\Misure\PIX_Pb2_00.bin El-Multiparametrico
Number Read.: 60844 -- Date and Time: 07/07/2007 16:19:37 -- Elapsed Time (s): 3427
vuoto, senza CCd, no frame
Source: Cd

C:\CCD-CZT\Misure\PIX_PbCCdon_00.bin El-Multiparametrico
Number Read.: 62656 -- Date and Time: 07/07/2007 17:36:00 -- Elapsed Time (s): 3680
vuoto, senza CCd, no frame
Source: Pb

C:\CCD-CZT\Misure\PIX_Pb-CCD-frame_00.bin El-Multiparametrico
Number Read.: 1136 -- Date and Time: 07/07/2007 19:19:34 -- Elapsed Time (s): 166
vuoto,senza CCd, no frame
Source: Pb
flusso X ray: 0.1 mA, 13.8 kV - senza titanio, senza Fe
C:\CCD-CZT\Misure\PIX_Pb-CCD-frame_01.bin El-Multiparametrico
Number Read.: 3542 -- Date and Time: 07/07/2007 19:22:22 -- Elapsed Time (s): 472
vuoto,senza CCd, no frame
Source: Pb
flusso X ray: 0.1 mA, 13.8 kV
senza titanio, senza Fe

C:\CCD-CZT\Misure\PIX_Pb-CCD-frameMax_00.bin El-Multiparametrico
Number Read.: 17225 -- Date and Time: 07/07/2007 19:38:57 -- Elapsed Time (s): 1548
vuoto,senza CCd, no frame
Source: Pb
flusso X ray: 0.2 mA, 14.4 kV
senza titanio, senza Fe

C:\CCD-CZT\Misure\PIX_Fondo_00.bin El-Multiparametrico
Number Read.: 87205 -- Date and Time: 09/07/2007 15:35:30 -- Elapsed Time (s): 6362
Fondo

C:\CCD-CZT\Misure\PIX_Pb_No_CCD_00.bin El-Multiparametrico
Number Read.:271330 -- Date and Time: 10/07/2007 10:24:26 -- Elapsed Time (s): 18002
Pb senza CCD 18000 s

C:\CCD-CZT\Misure\PIX_Pb_CCD_01.binEl-Multiparametrico
Number Read.:232421 -- Date and Time: 11/07/2007 10:55:26 -- Elapsed Time (s): 16925
Pb con CCD 18000 s
13.2 kV
0.165 mA
Correzione: file senza CCD 13.2 kV e 0.165 mA