Gamma Assay Using CMOS

Xavier Bertou
Centro Atómico Bariloche

What we do in Bariloche

Tourism




People interested

- Miguel Sofo Haro
  - (Skipper) CCD expert
- José Lipovetzky
  - CMOS expert
- Darío Balmaceda
  - Master student (up to 2019)
- Xavier Bertou
  - The lucky traveler and speaker

There could be more…

X-ray Spectroscopy with Commercial CMOS Image Sensors

Miguel Sofo Haro, F. Alcalde Bessia, M. Pérez, D. Balmaceda
X. Bertou, JJ. Blostein, M. Berisso, J. Lipovetzky

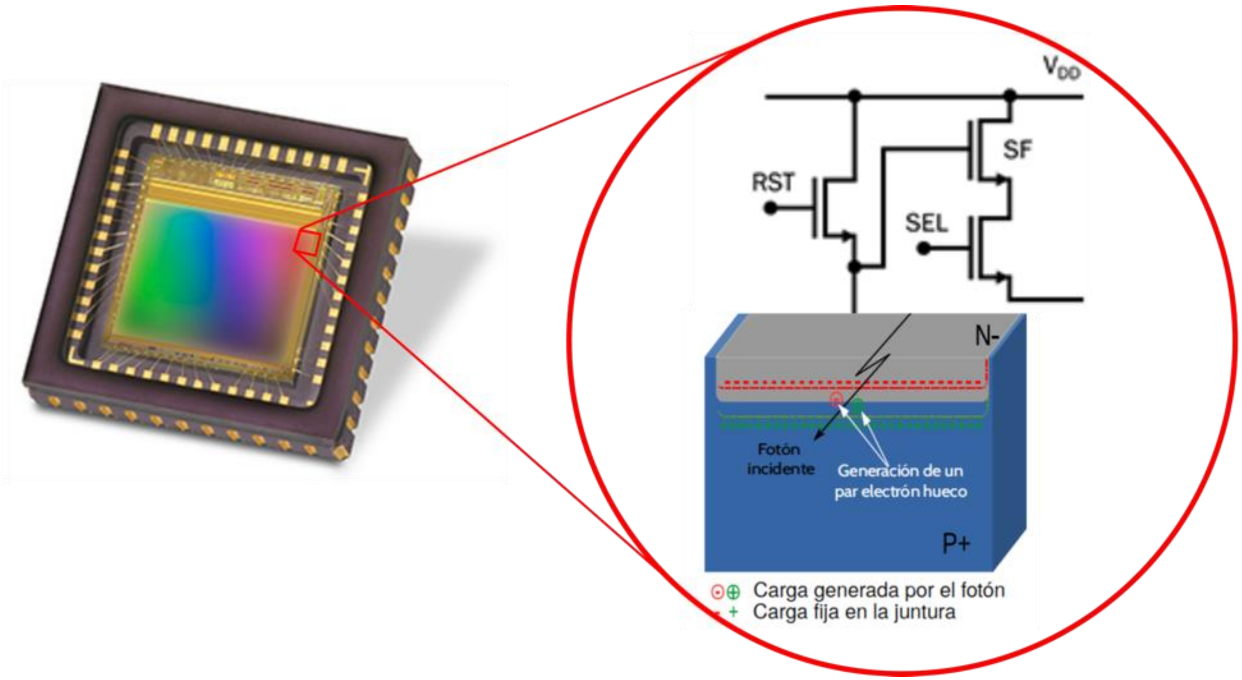
[1]Centro Atómico Bariloche, Comisión Nacional de Energía Atómica (CNEA).
[2]Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET), Argentina.
[3]Instituto Balseiro, Universidad Nacional de Cuyo.

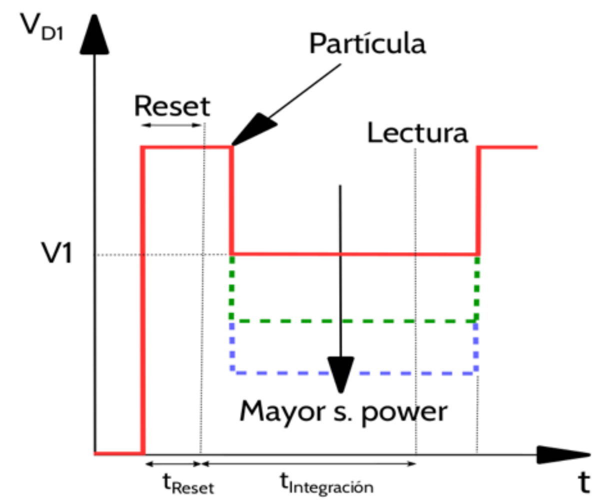
14th International Symposium on Radiation Physics
October 7-11 of 2018, Córdoba, Argentina

CONICET

Instituto Balseiro

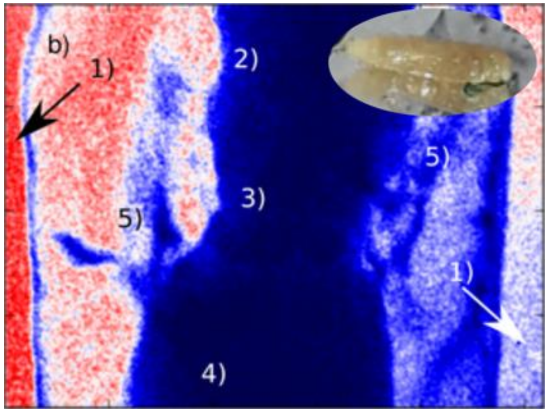
CMOS Image Sensors (CIS)



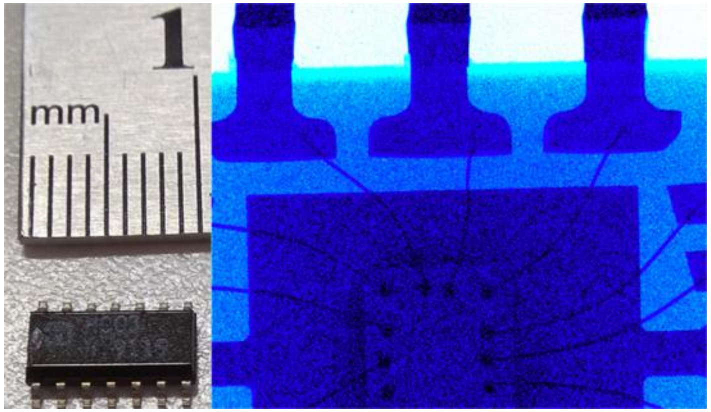


Consumer electronics applications:

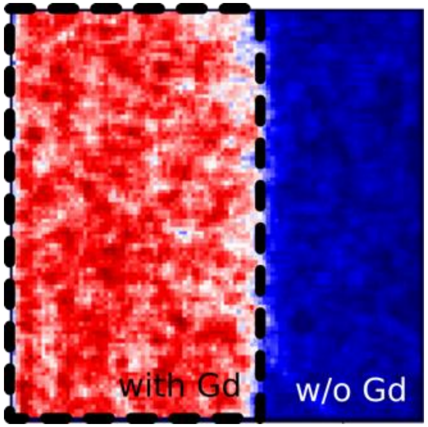
CMOS Image Sensors (CIS), other applications:



X-ray image of a pupae of a fly



X-ray image of a electronic chip



Neutron detection

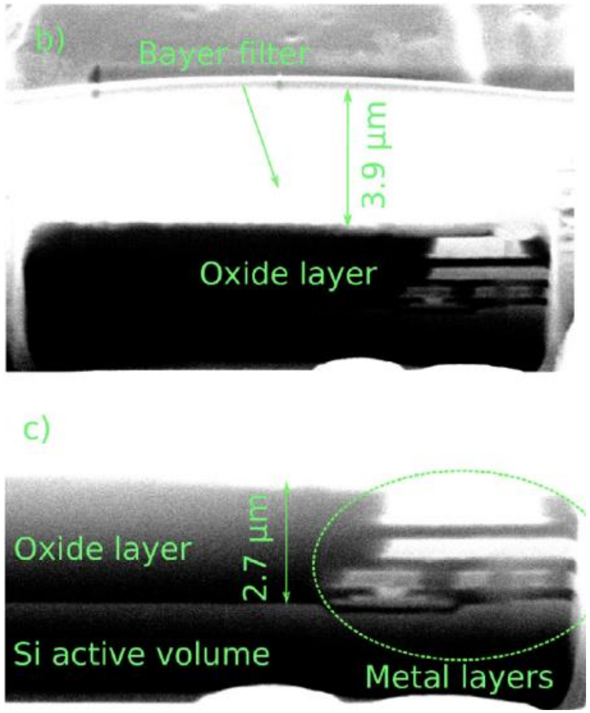
Objetive of this work:

To study the capability of this sensors to measure an x-ray energy spectrum

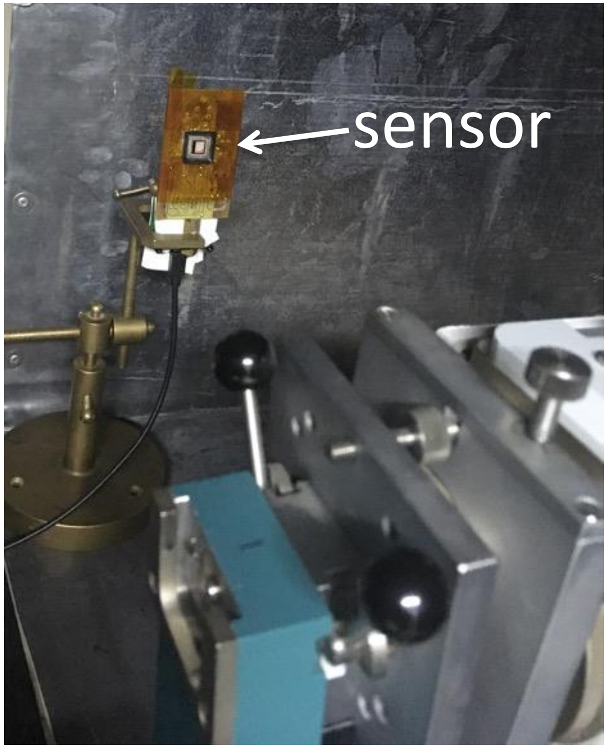
- Pérez, Martín, et al. "*Thermal neutron detector based on COTS CMOS imagers and a conversion layer containing Gadolinium.*" NIM-A 893 (2018): 157-163.
- Alcalde Bessia, Fabricio, et al. "X-ray micrographic imaging system based on COTS CMOS sensors." International Journal of Circuit Theory and Applications (2018).
- Pérez, Martín, et al. "Particle detection and classification using commercial off the shelf CMOS image sensors." NIM-A 827 (2016): 171-180.

The sensor: ARDUCAM MT9M001

- Area: 6.66mm x 5.32mm
- Pixel size: 5.2um x 5.2um
- Frame-rate: 30fps
- 10bits of resolution (8bits with the current RO electronics)
- Front-side illuminated (6.6um of Bayer filter + SiO2 before reach the Si active volume)
- Cost of <u$s50
- **Room temperature**



The experiment:



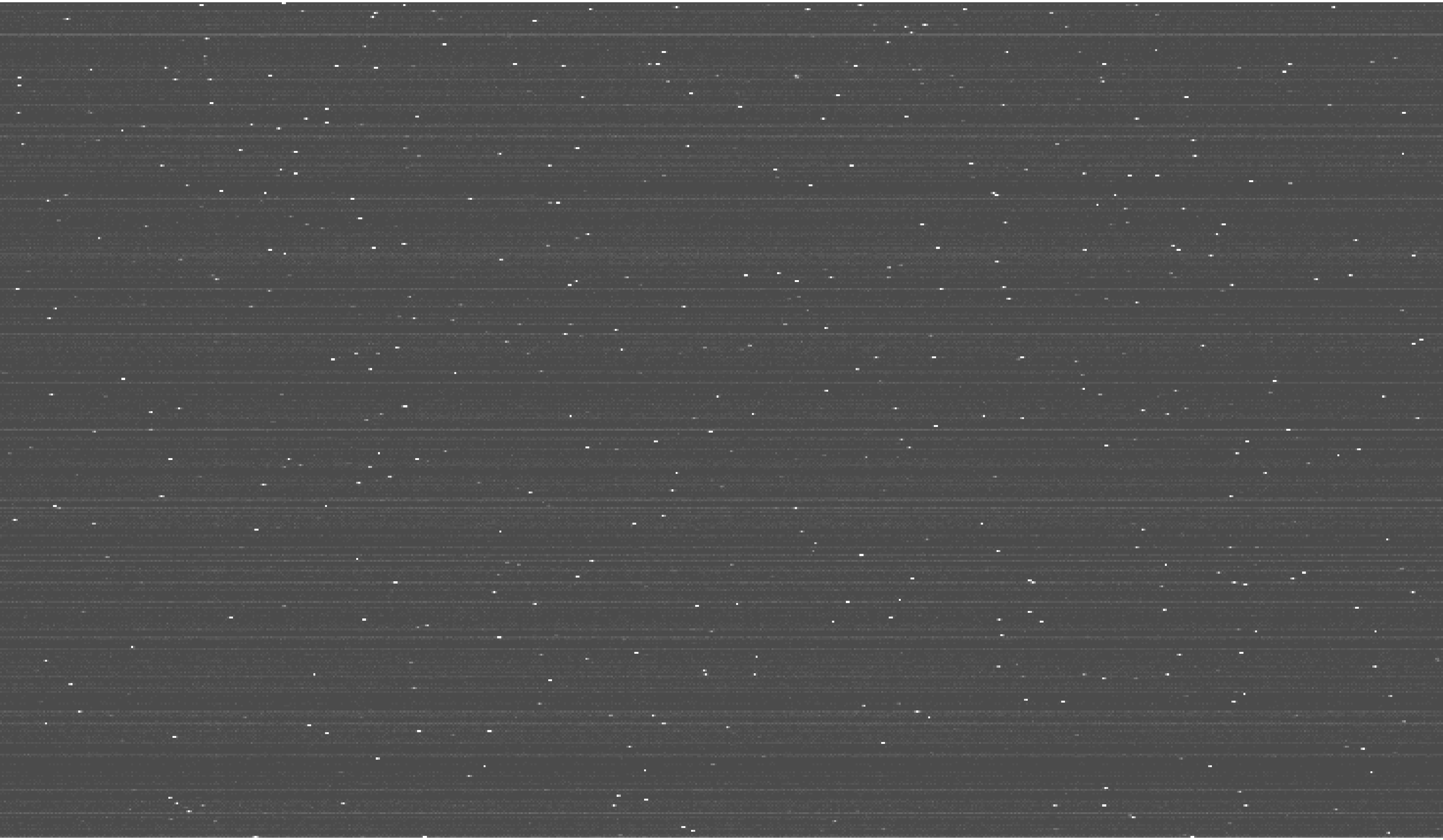
Cu K_α K_β
from X-ray tube

Fe fluorescence

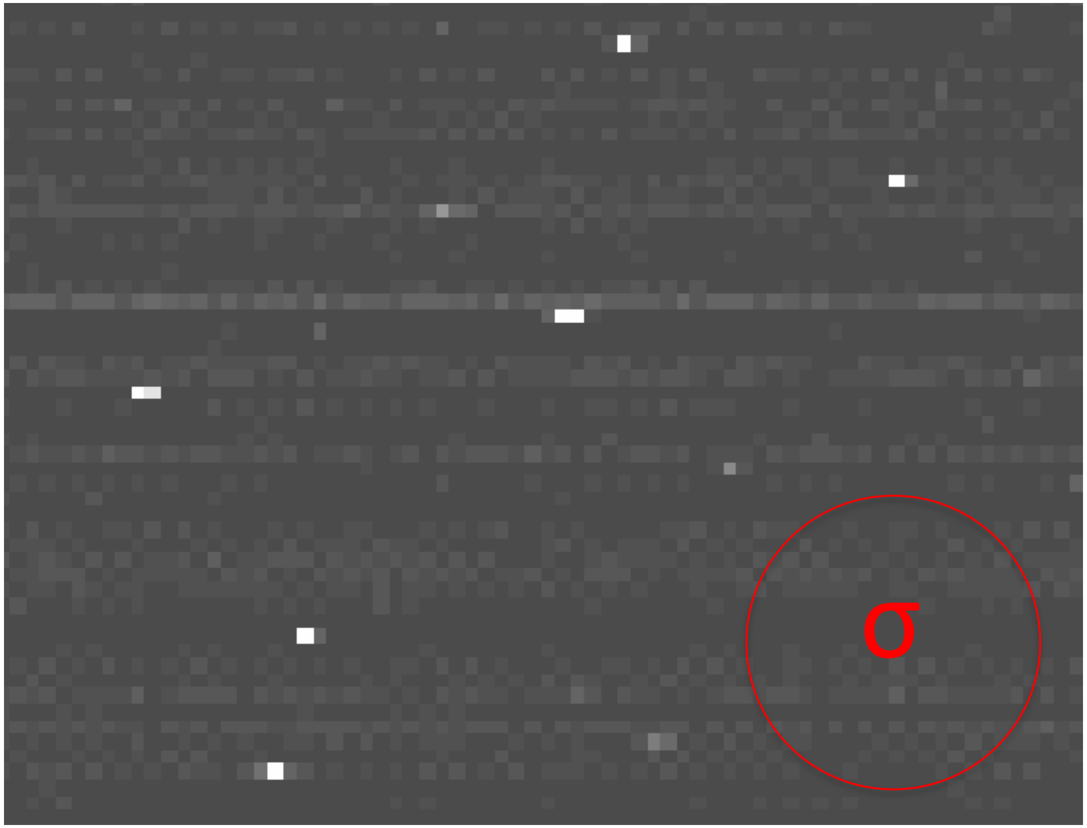
Calcium
fluorescence

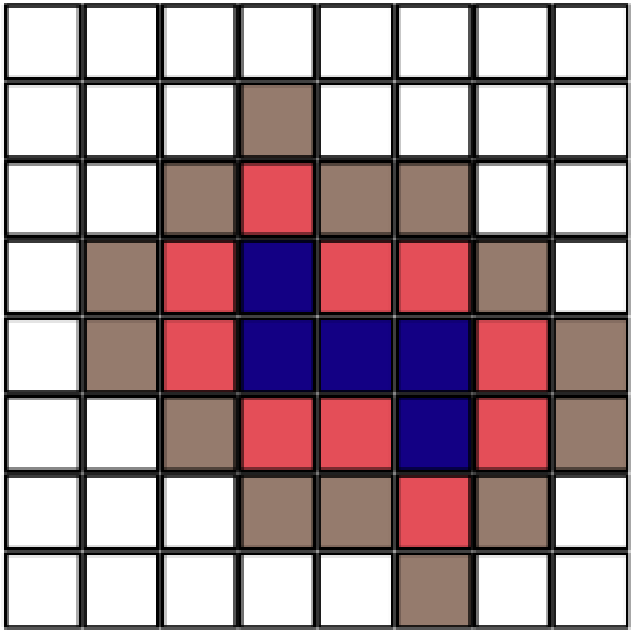
Pixel integration time of 4µs

Image:



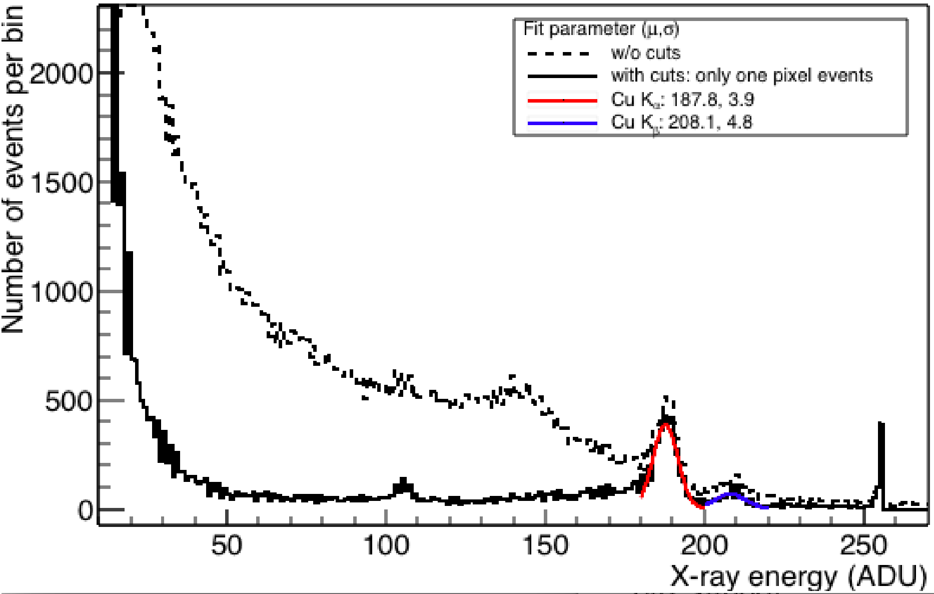
Extraction of the events:

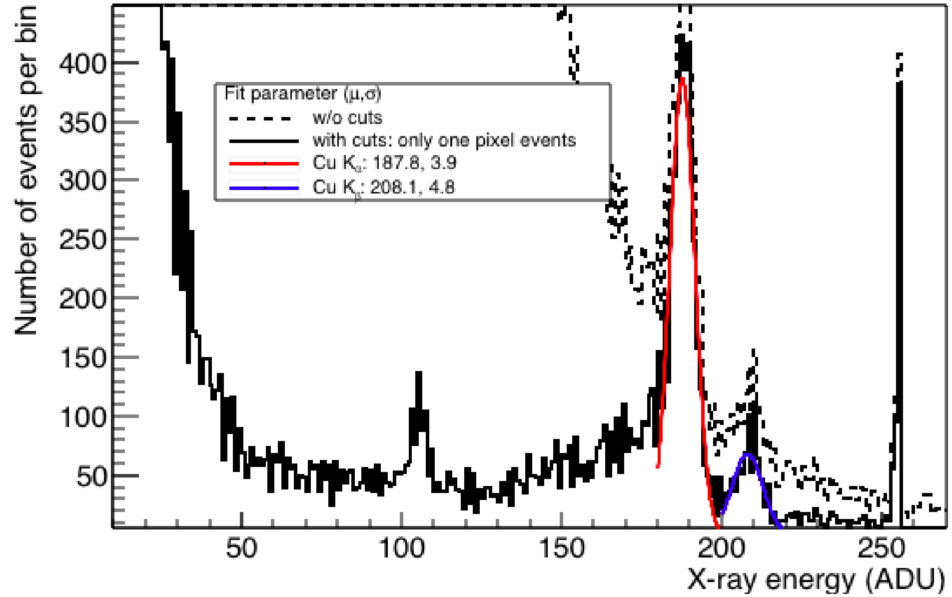


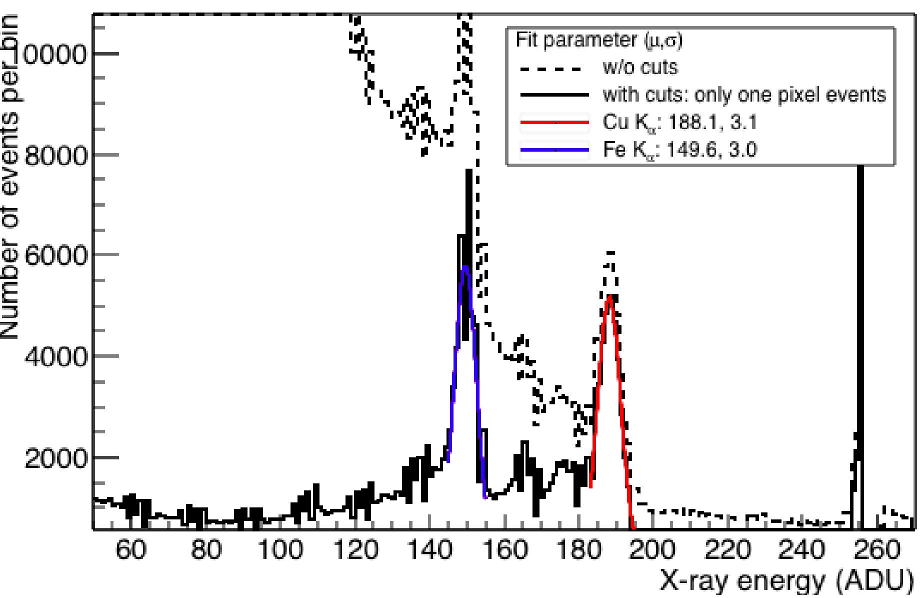


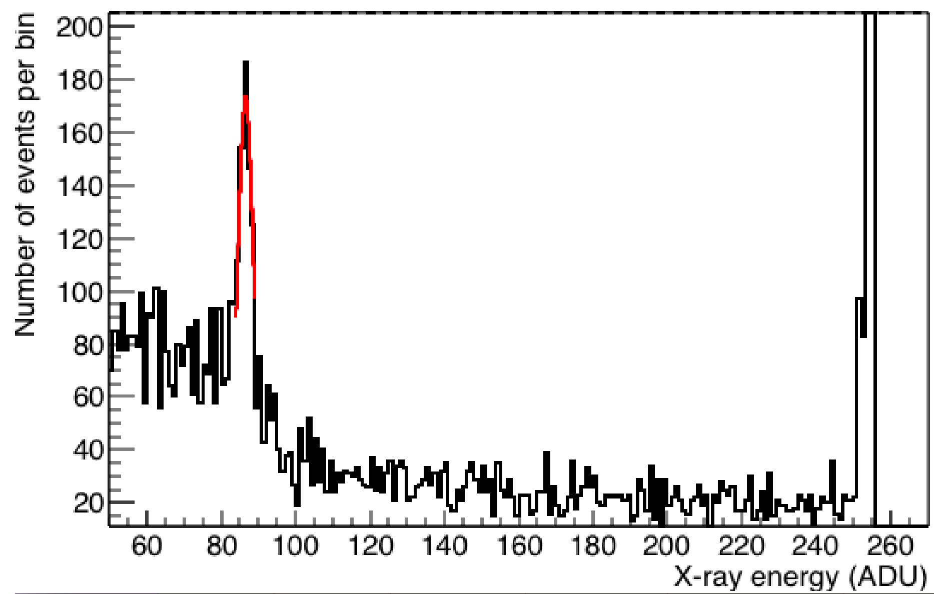
All the pixels that have more than 4 times the noise (σ)

Resulting spectrum:

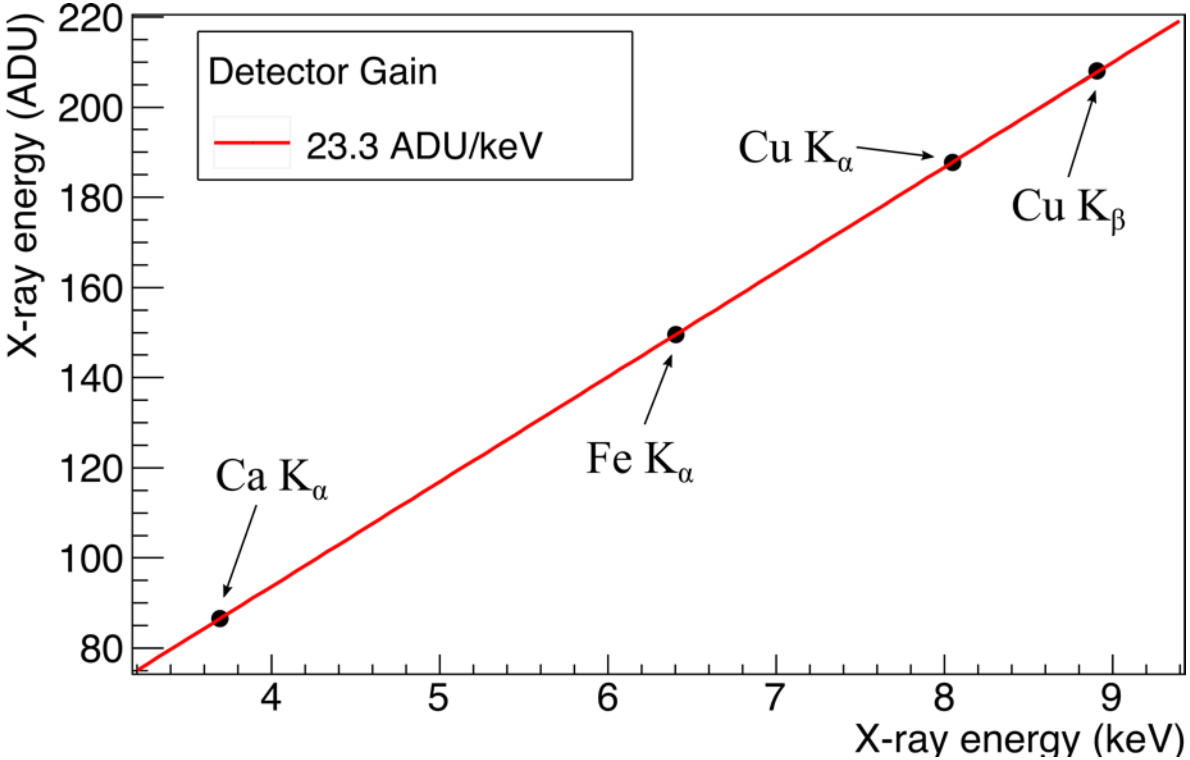








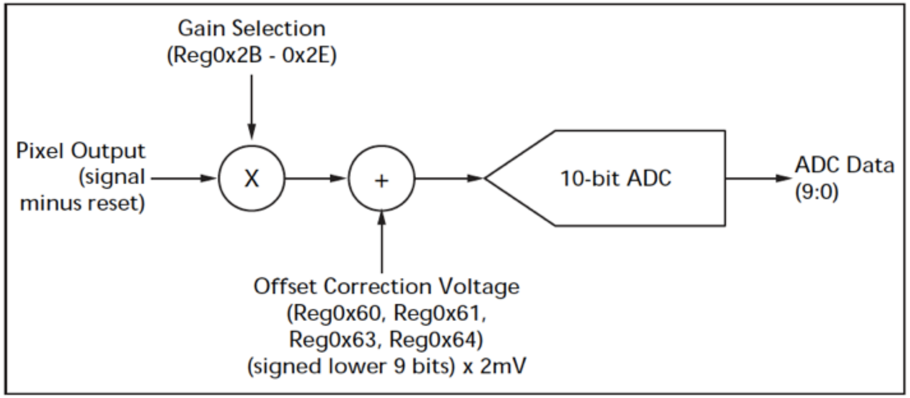
Linearity and gain:



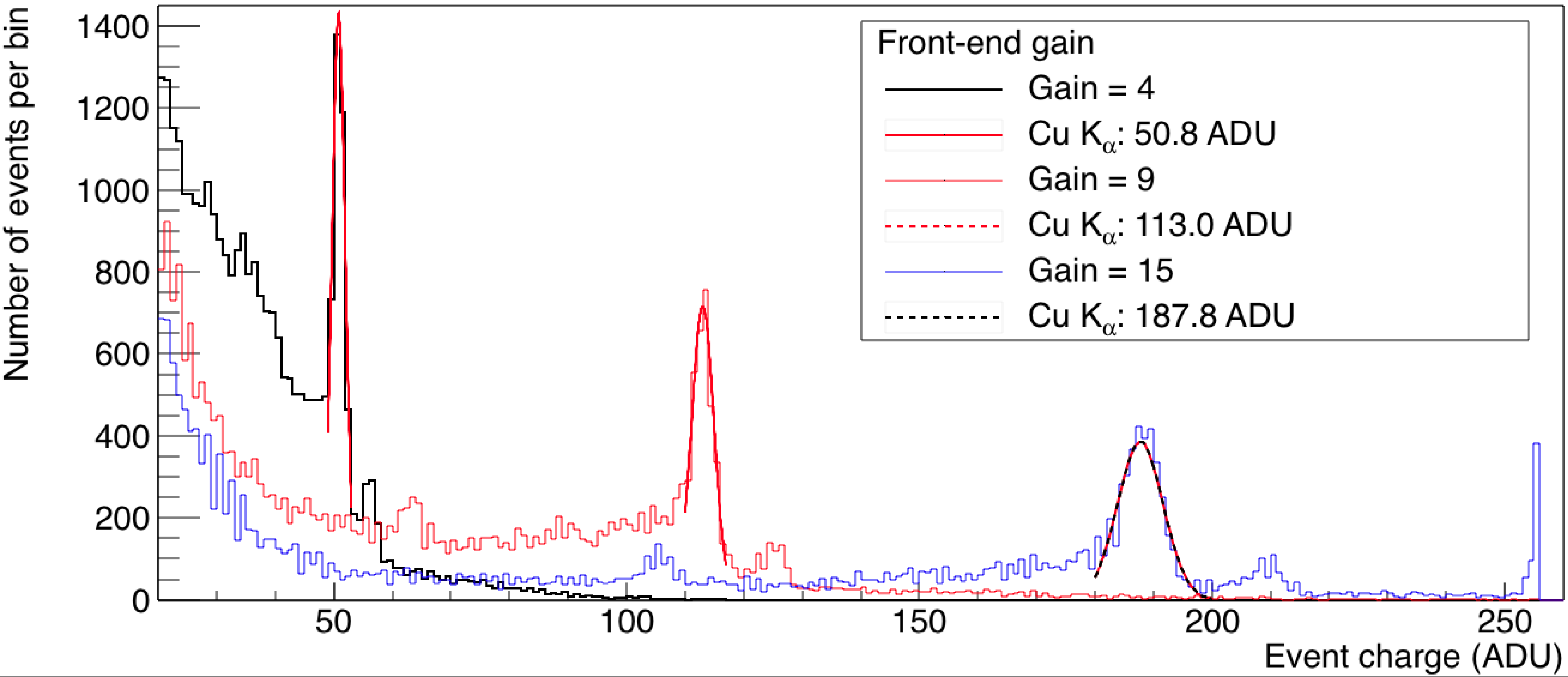
X-ray	Energy (keV)	FWHM (eV)
Cu K_β	8.905	485
Cu K_α	8.047	394
Fe K_α	6.403	303
Ca K_α	3.691	224

Amtek SDD
122eV @ 5.9keV

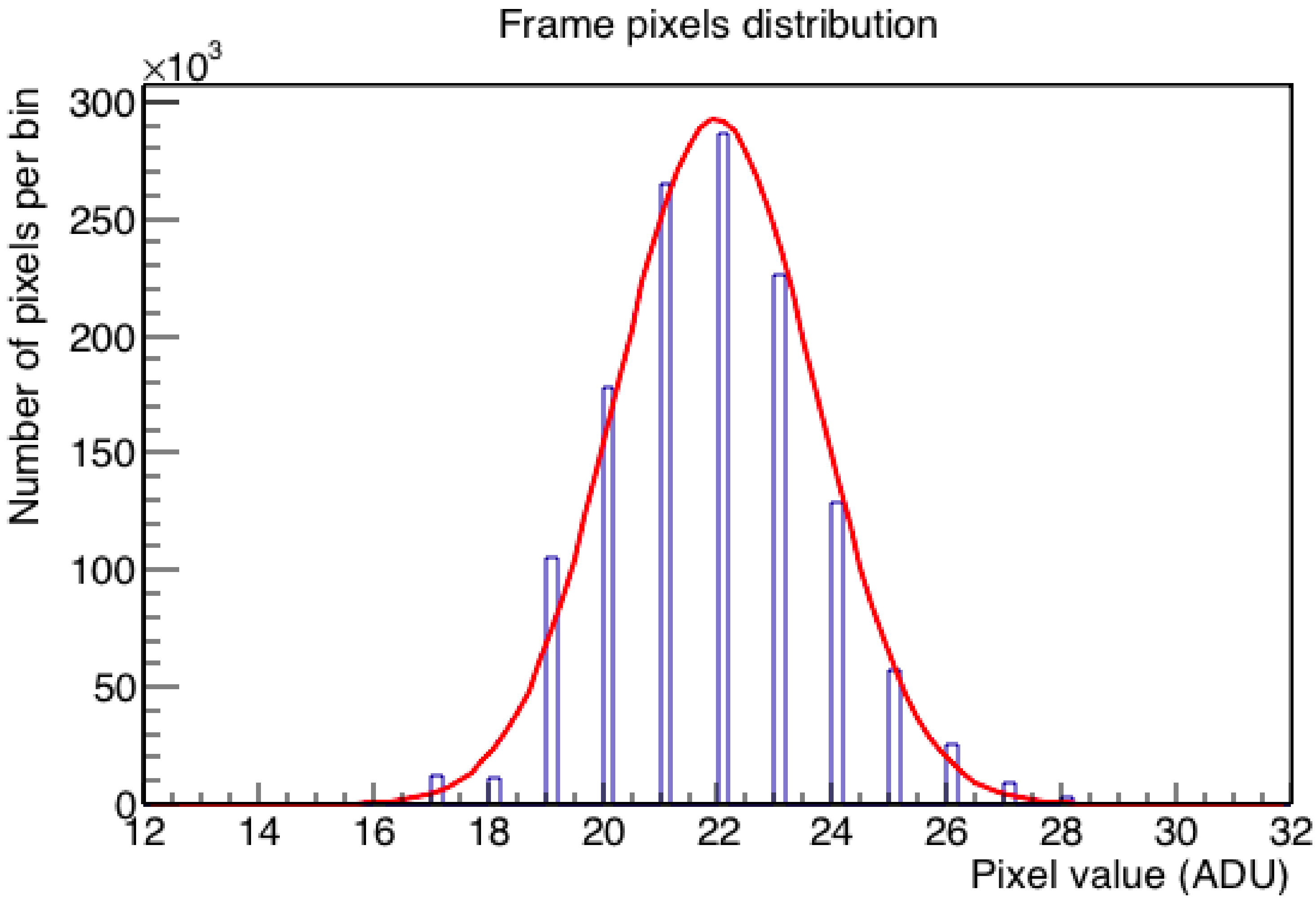
Dynamic range:



FE Gain	DR (keV)
4	39 keV
9	17.8 keV
15	10 keV



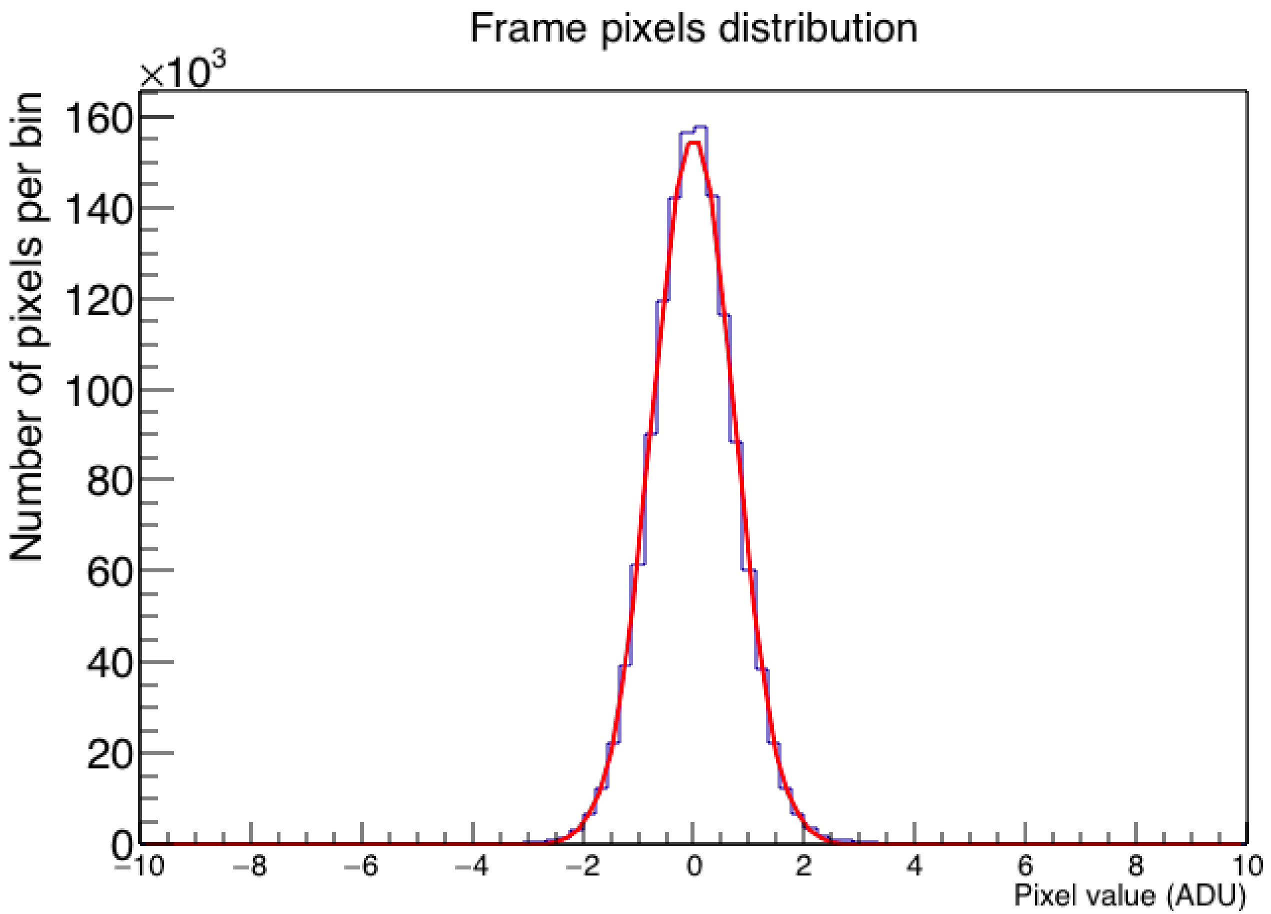
Calibrated measurement of the frame noise:



	ADU	eV	e^- (3.64eV/e-)
Noise (σ)	1.73	74 eV	20 e^-/pix

Noise after image processing:

Adding information from previous acquired pixels allows to reduce the noise



	ADU	eV	e^- (3.64eV/e-)
σ	0.74	31 eV	8.51 e^-/pix

Conclusions from Miguel's talk

- It was possible to obtain the energy spectrum of incoming X-rays.
- High resolution X-ray imaging and spectroscopy can be obtained by a single device.
- Can be used as a low cost and easy access X-ray detector for educational proposes.
- With further R&D, CIS could be competitive to commercial and dedicated X-ray detectors.
- Upgrade of the readout electronics to be able to acquire with 10bits and improve the image processing to increase the energy resolutions under way.
- Need to measure the detection efficiency.

Detection efficiency of X-ray and gamma photons using a BSI CMOS image Sensor (PiCAM) and aplication to X-ray imaging.

Lipovetzky José [1,2,3,4]
Cicuttin Andrés [1]
Crespo María Liz [1]
Sofo Haro Miguel [3,4]
Alcalde Bessia Fabricio [2,3]
Pérez Martín [3,4]
Gomez Berisso Mariano [2,3]

(1) The Abdus Salam International Centre for Theoretical Physics (ICTP)
(2) Consejo Nacional de Investigaciones Cientificas y Tecnicas (CONICET)
(3) Instituto Balseiro, Universidad Nacional de Cuyo.
(4) Comision Nacional de Energia Atómica, Centro Atómico Bariloche.

Motivation and objectives.

Motivation:

- Low cost CMOS Image Sensors (CIS), designed for consumer electronics, also can acquire µm-resolution X-ray images.

Objectives

- To study the detection efficiency of the CIS as a function of photon energy.
- Compare the results with the well-established MediPix2 sensor.
- To study the ability to obtain multi-energy high resolution images.

Devices: BSI CIS and Medipix2

OmniVission 5647 BSI CIS:

5M 1.4 x 1.4 μm^2 pixels

3.6 x 2.7 mm^2 area

2µm thick Si sensitive Volume

low dark current at T_{amb}

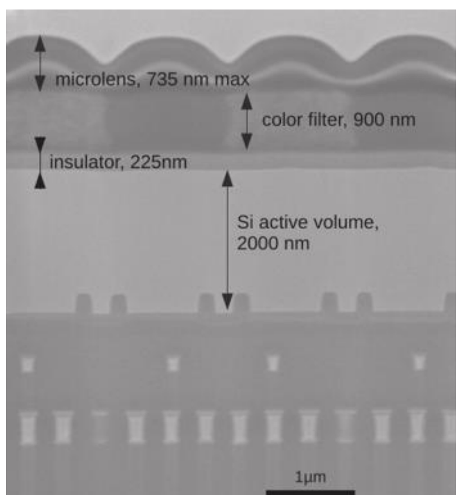
Medipix2/TimePix ASIC:

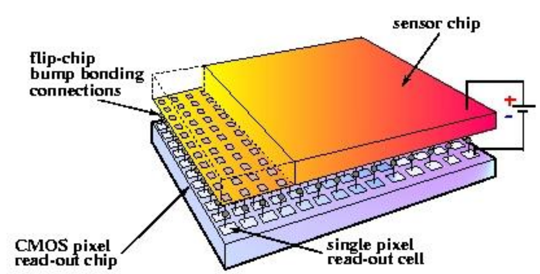
64K 55 x 55 μm^2 pixels

14 x 14 mm^2 area

300µm thick Si sensitive volume

zero dark current with proper threshold

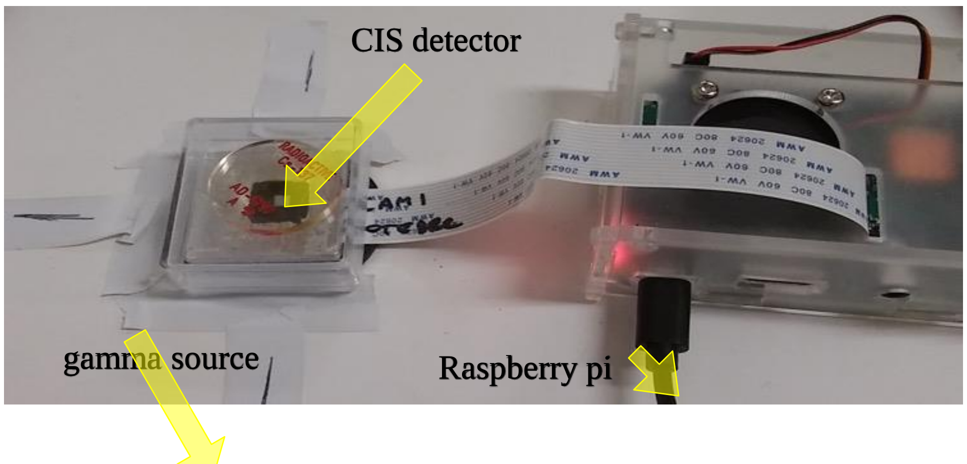


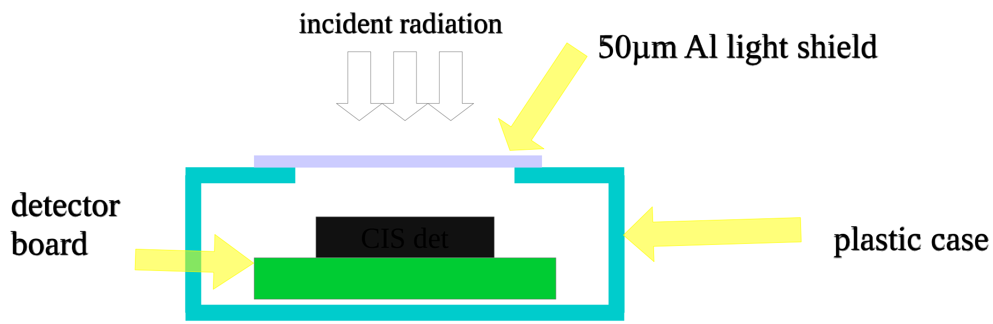


CIS photon detection efficiency.

Calibrated sources:

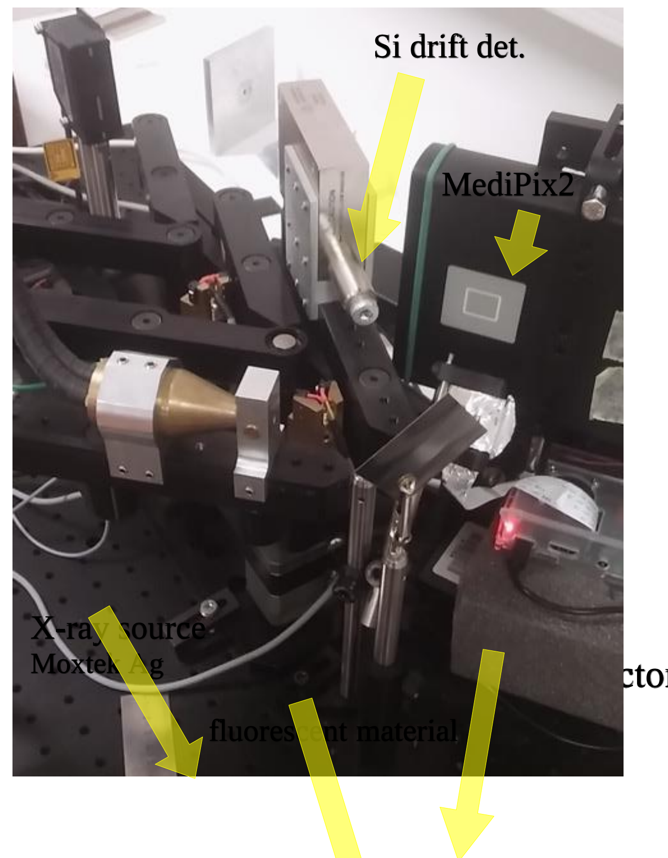
^{133}Ba, ^{109}Cd, ^{137}Cs, ^{60}Co, ^{22}Na,





X-ray Fluorescence

Ti, V, Zr, Pd, Ag

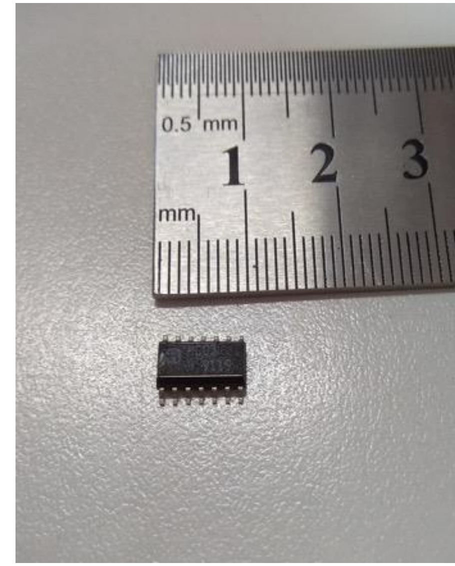


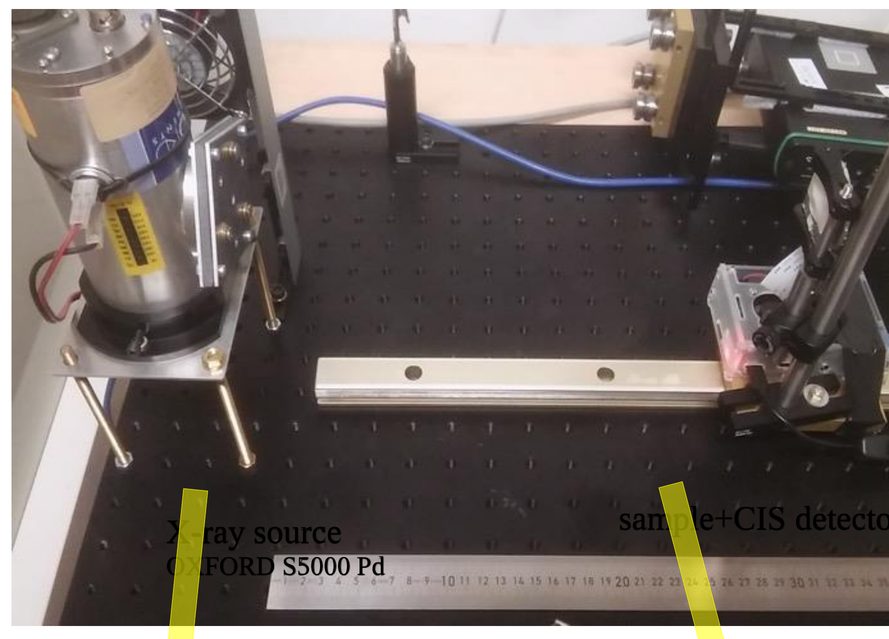
Radiographic images of an integrated circuit.

As a case study, an SMD integrated circuit was used to obtain rX images.

Using diferent RX tube voltages (7.5keV--50keV) different RX spectrums were obtained.

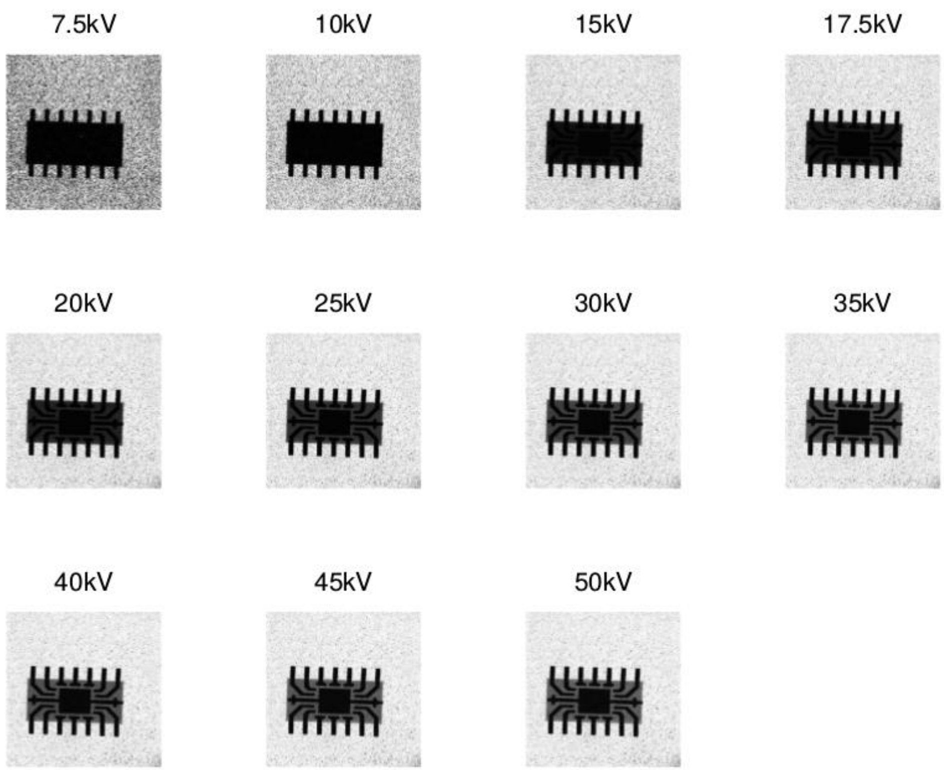
We compared CIS detector with the MEDIPIX2 detector.

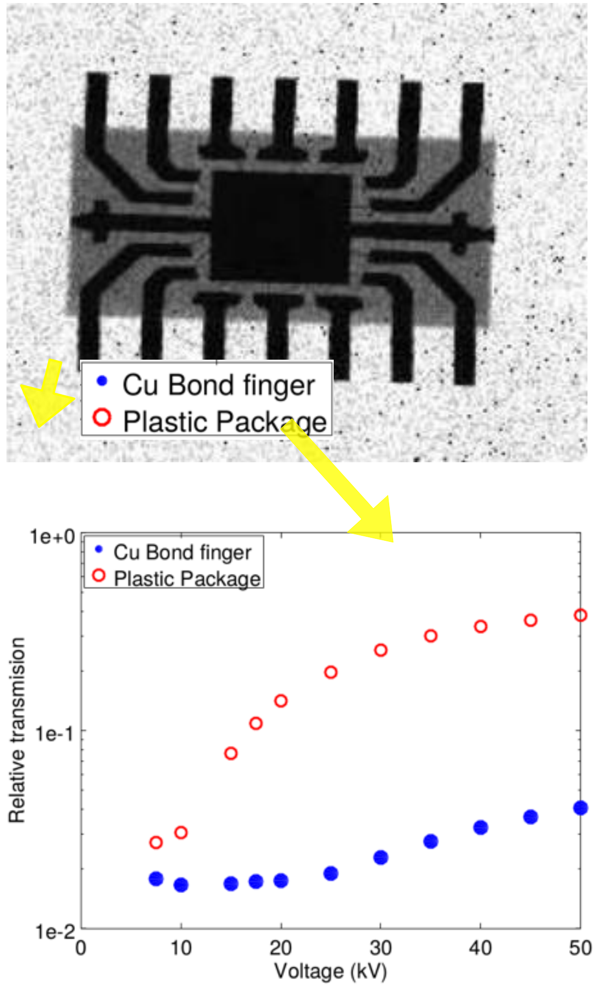




Medipix2 images at different RX tube voltages

The different regions show different transmissions at different RX V (and different RX spectum), allowing the identification of different structures and materials and not only thicknesses. Intensities are normalized to max outside the chip (transmission=1)





Fusion of information in false color image

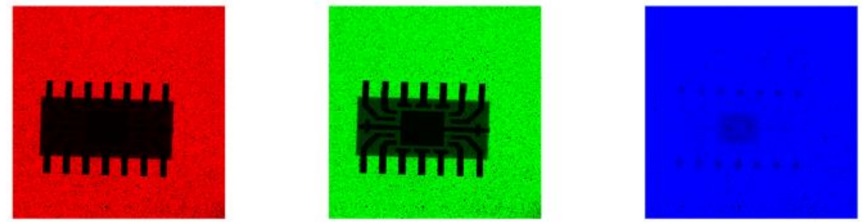
To allow the visualization of more information in a single image, a false color picture is created merging for example:

RED → 15kV image

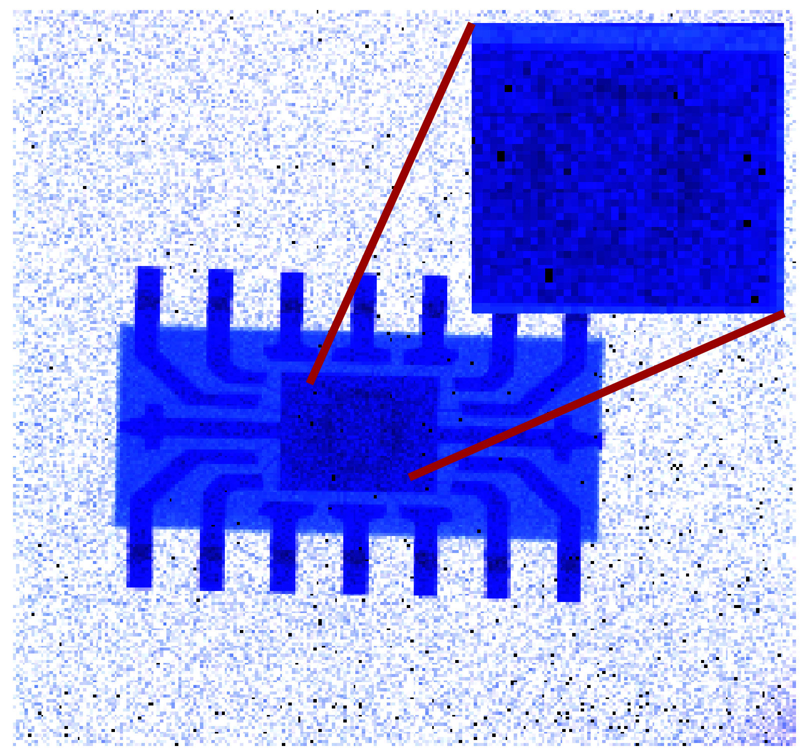
GREEN → 25kV image

BLUE → 50kV magnified 20 times to allow more detail in low contrast regions

It is possible to identify different structures, but limited to the MEDIPIX 50µm pixel size.



R:V=15KV G:25kV BV=50kV (x20)



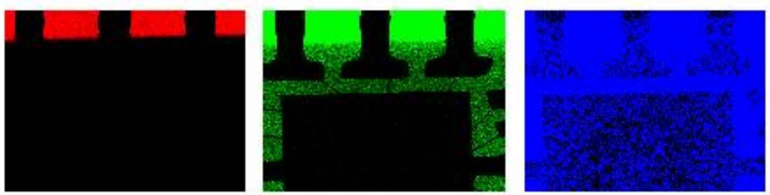
CIS performance as RX imager

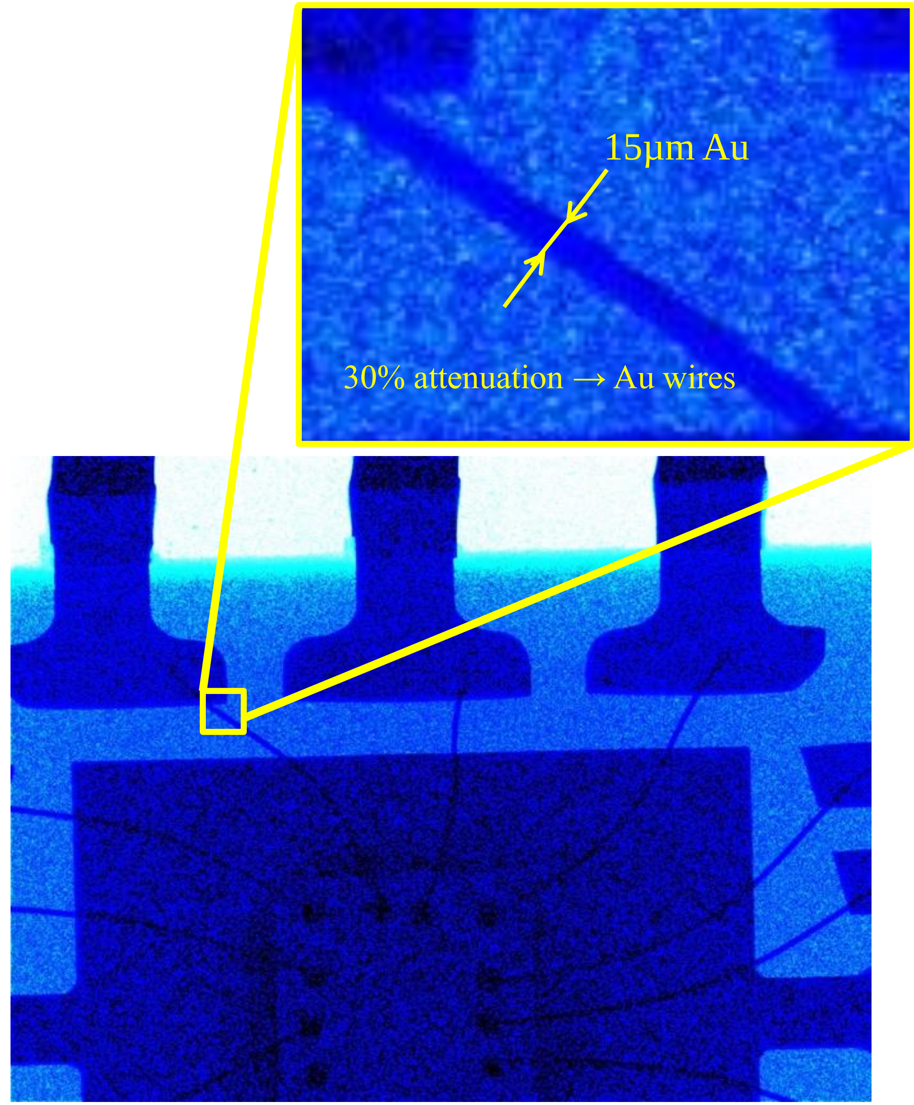
The sample was radiographed with the same method:

RED → 15kV image

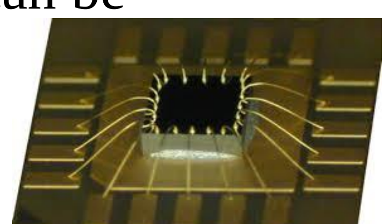
GREEN → 25kV image mag x 5

BLUE → 50kV mag x 1000





The bonding wires, wire bonds, excess of epotec, die dimensions, can be observed e.g.:



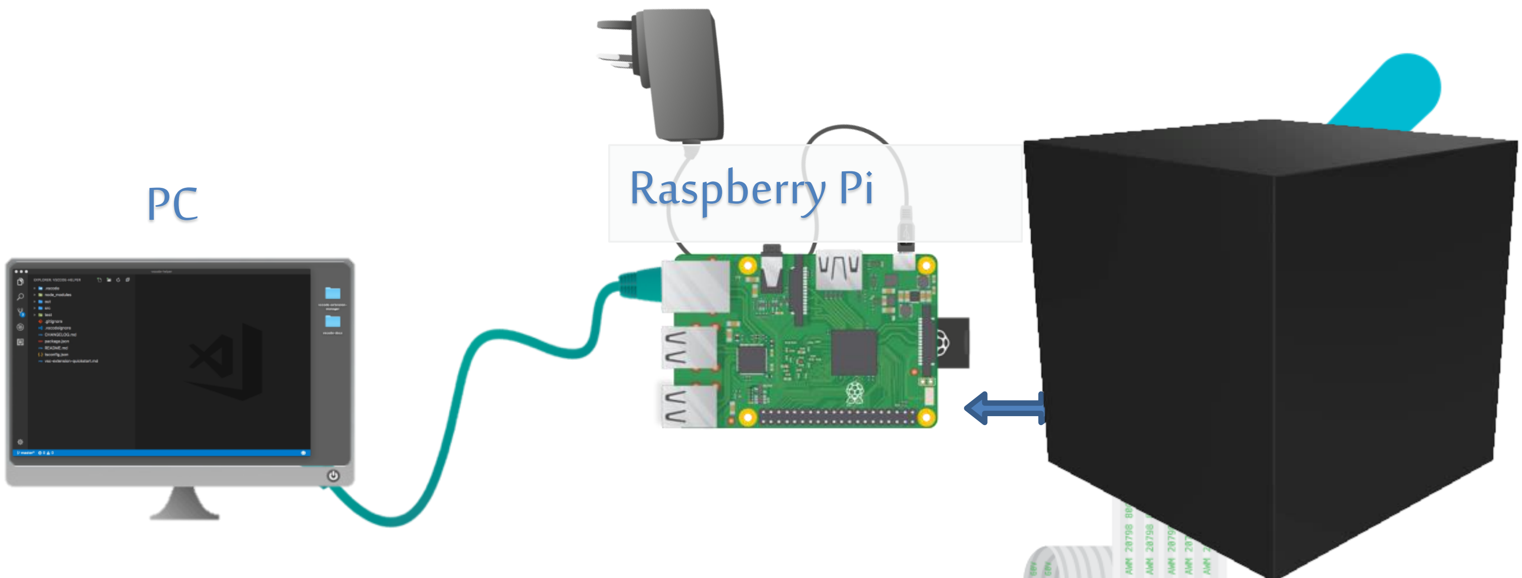
Conclusions from José's talk

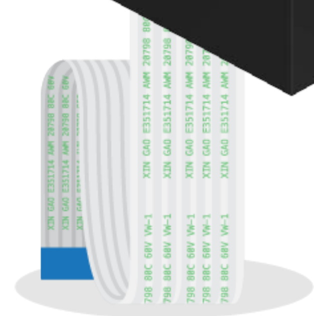
- The quantum efficiency of the thin BSI detectors was measured, in the range of 10^{-4}–10^{-3} in the range from 26keV to 1.3MeV, much lower than the MediPix2 (up to 85%).
- X-ray images could be obtained with the CIS BSI detector. The higher resolution allows identification of structures and materials which cannot be observed with the MediPix2 chip.
- Fusioning images obtained at different RX voltages and different ranges can provide pictures with more information.

Detección de interacciones de partículas con sensores CMOS

Laboratorios Avanzados @ Licenciatura en Física
Balmaceda, Darío Federico. leschatten@gmail.com

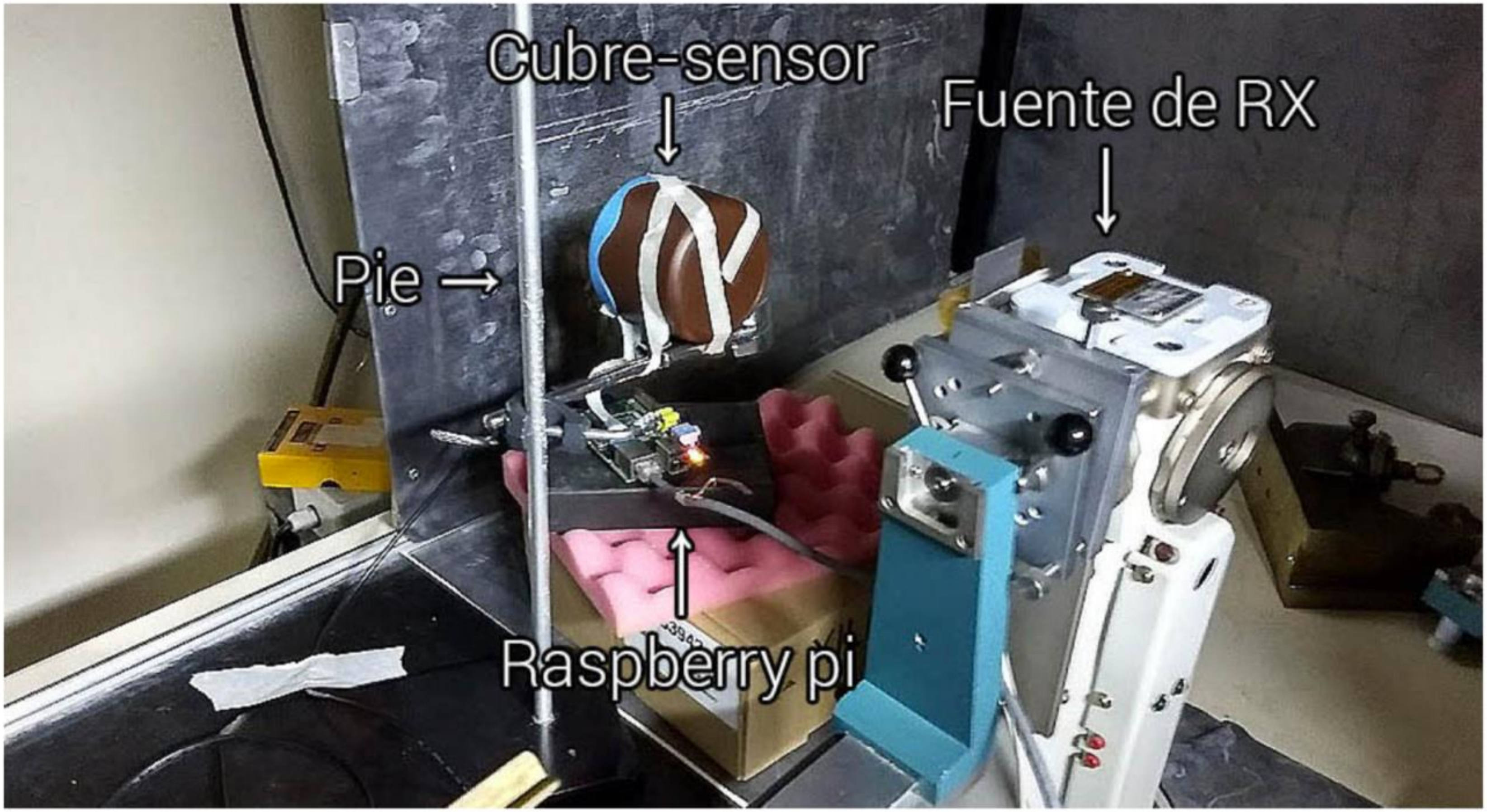
Esquema Experimental



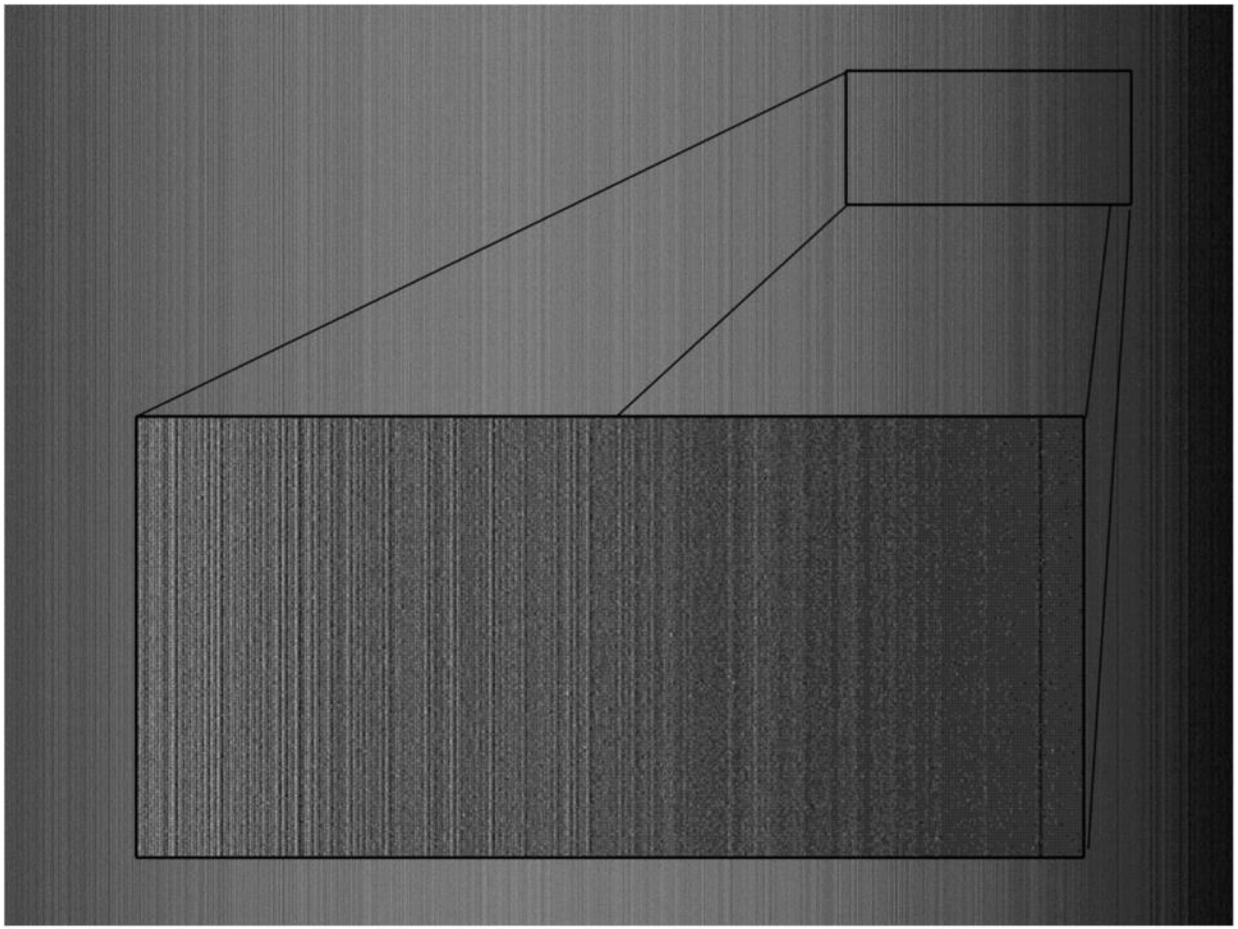


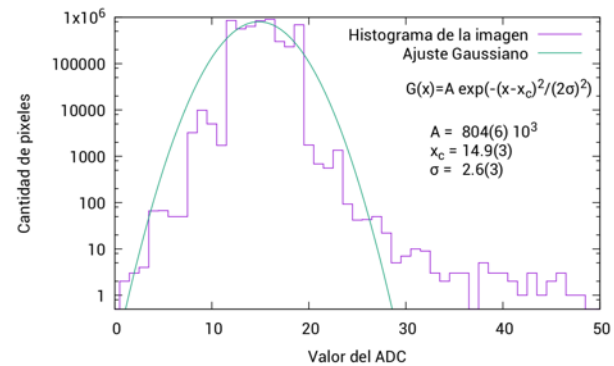
- Resolución máx.: 2592x1944
- Sensor *OmniVision OV5647* BI
- Tamaño del pixel 1.4 µm × 1.4 µm

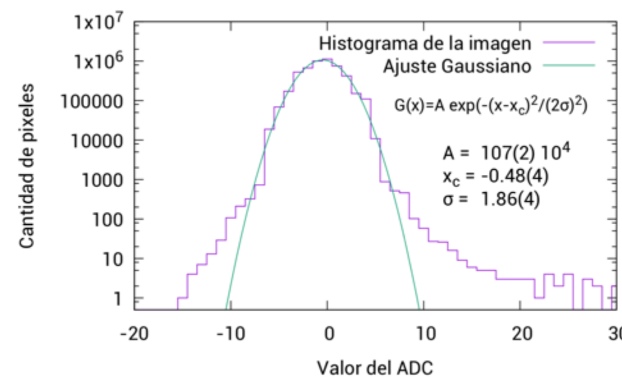
Experimental setup



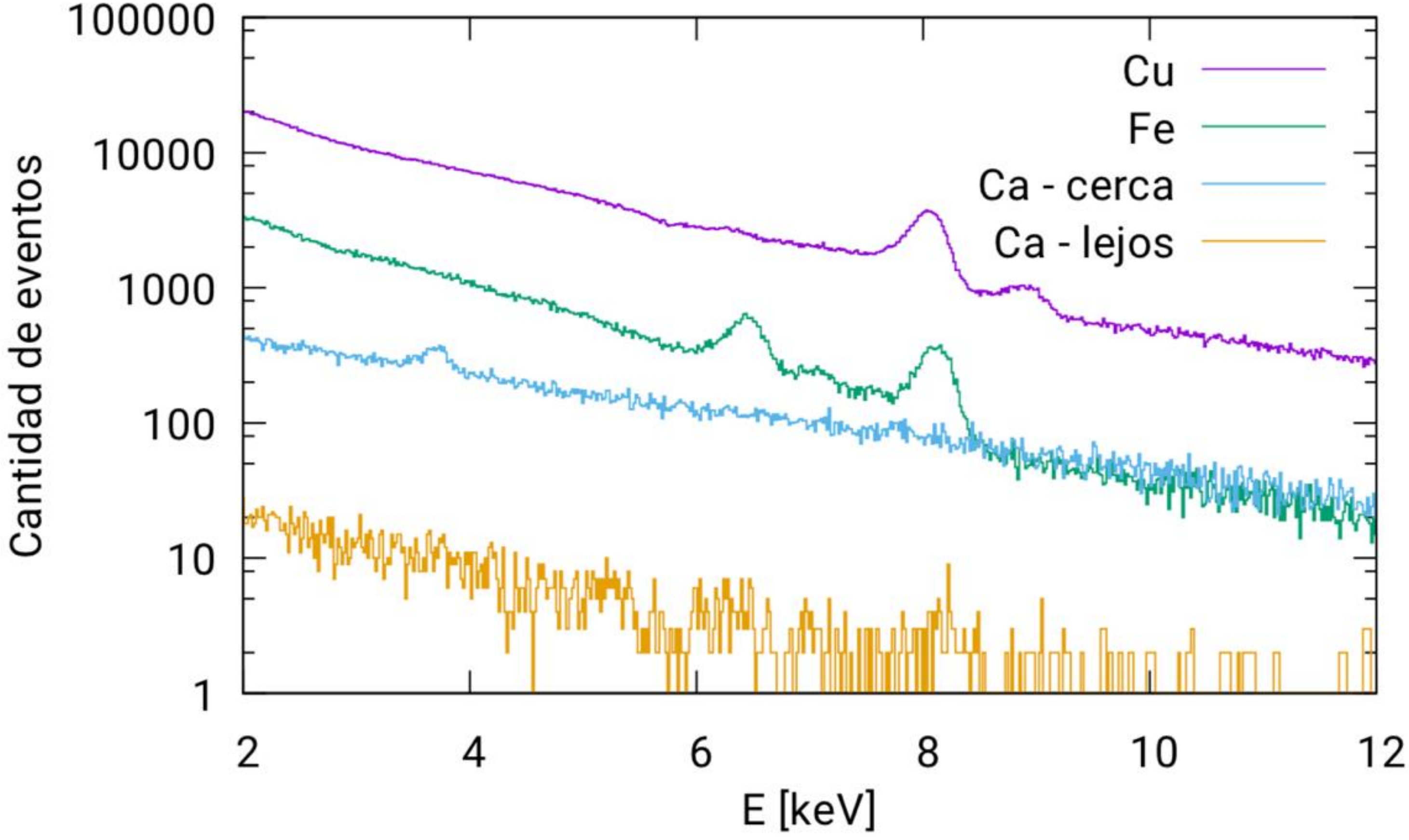
Pattern noise subtraction



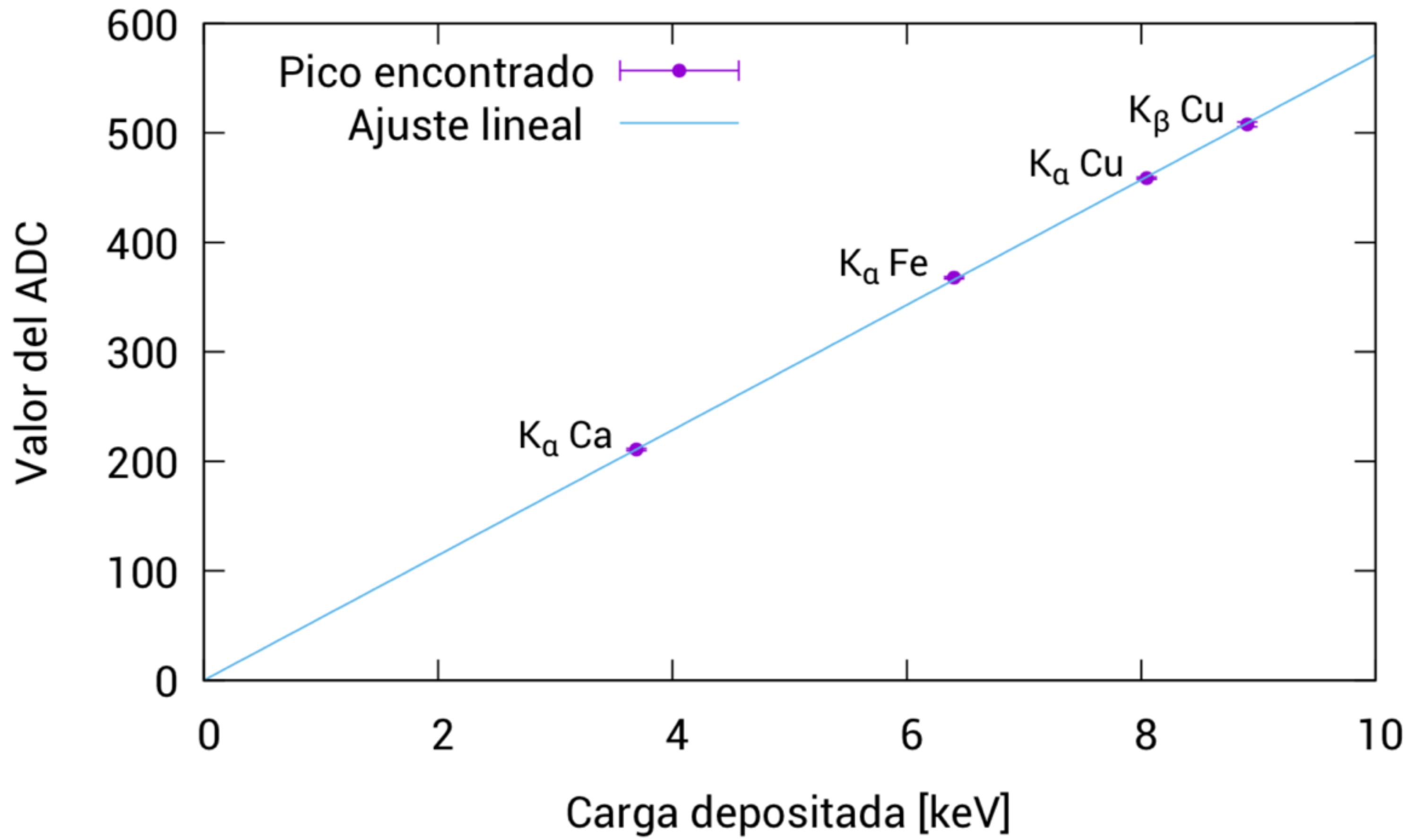




Spectra obtained



Conclusion: Final calibration



Conclusions

- COTS CMOS are great as X-ray detectors
  - Excellent linearity
  - Very low ro noise even at room temperature (<70 eV)
  - Low cost, easy to operate
- BUT
  - Full well capacity has to be enough
  - All measurements were done with lens removed
  - Detection efficiency is extremely low (<1%)
  - Sensors are very small
- Solution could be to design our own low cost sensor
  - Photodiode
  - CMOS…