Silicon detectors for a Compton telescope

Nicolas de Séréville (nicolas.de-sereville@ijclab.in2p3.fr)
Laboratoire de Physique des 2 Infinis Irène Joliot Curie
Université Paris Saclay

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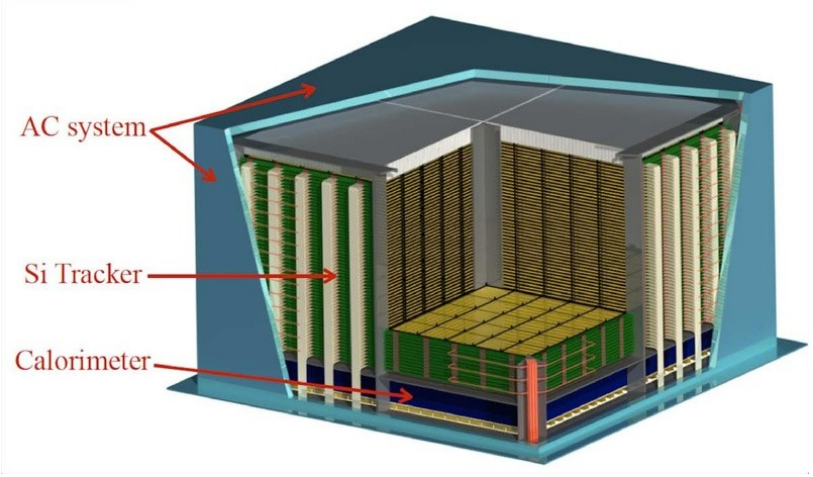
Background

All material presented comes from ongoing R&D at former IPNO, now IJCLab

- Aim is to develop a γ-ray imaging device in the MeV range based on Compton interaction

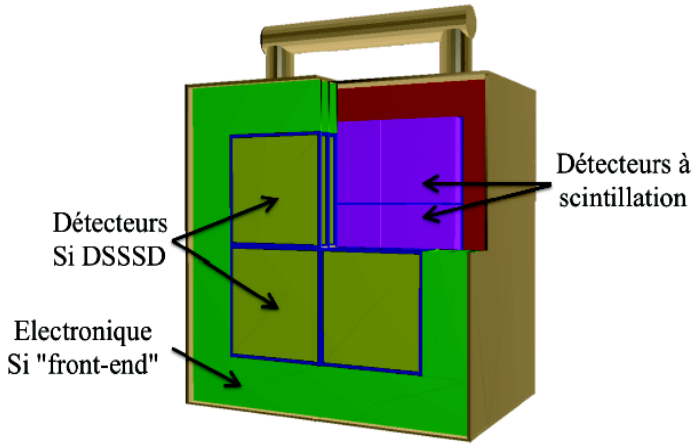
γ-rays from astrophysical sources



e-Astrogam payload

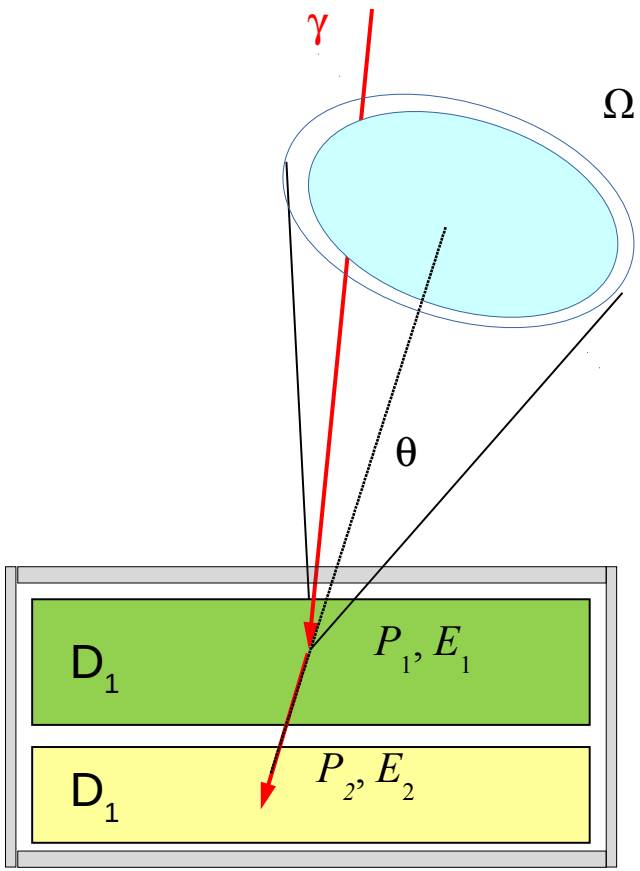
COCOTE project
(2012 – 2014; CNRS funding)

γ-rays from nuclear power plants



ComptonCAM project
(2017 – 2021+; ANDRA funding)

Compton imaging principle



Scatter plane(s)

Calorimeter

$$E_\gamma = E_1 + E_2$$

$$cos(\theta) = 1 + m_e c^2 \, [1/(E_1 + E_2) - 1/E_2 \,]$$

- Angular resolution and sensitivity depends on the precision of the energy and position measurements in the scatter and calorimeter detectors
- Several possibilities for the scattering material:

  → scintillator, germanium, silicon
- Advantages of silicon
  - Low Z materials favor Compton scattering cross-section
  - Limited Doppler broadening
  - Good energy resolution and noise performances
  - Segmentation relatively easy

The BB7 detector

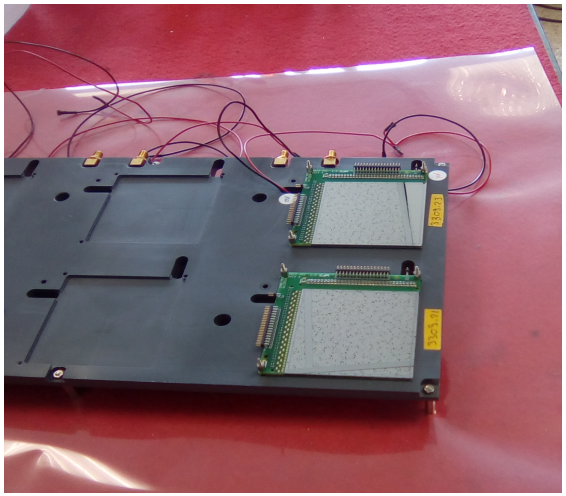
- DSSSD (BB7 model) from Micron Semiconductor Ltd.
  - Active surface: 64 x 64 mm^2
  - Thickness: 1.5 mm
  - Strip number: 32 + 32
  - Strip pitch: 2 mm
  - Bias: ~ 400 – 500 V
- Custom packaging
  - PCB on two sides of the DSSSD
  - Total size: 82 x 82 mm^2
- PCB hosts biasing resistors and DC coupling capacitance → AC coupled

Design allow easy combination to form a plane with 2 x 2 DSSSD (~ 4U like)

Detector testing

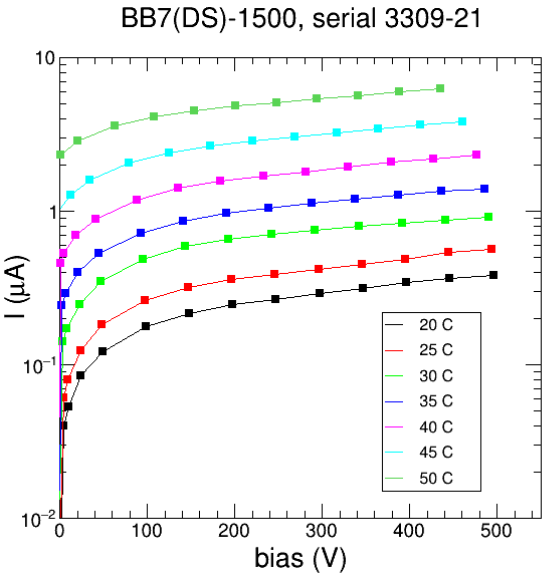
Testbench for leakage current measurement in climatic chamber

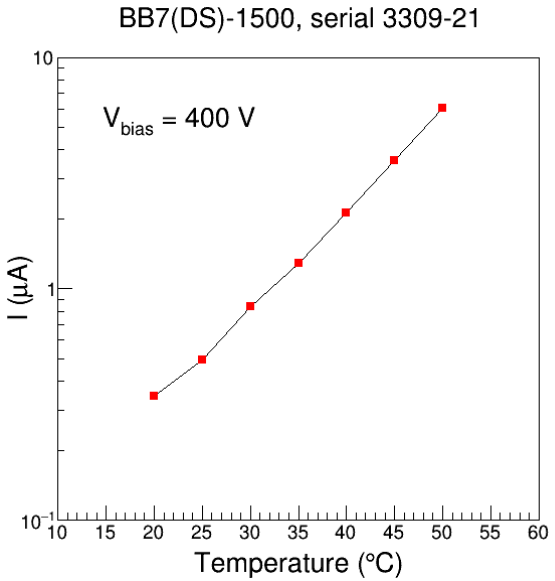
Temperature range:
-45°C – +180°C



Possiblity to perform measurement for up to 6 DSSSDs at the same time

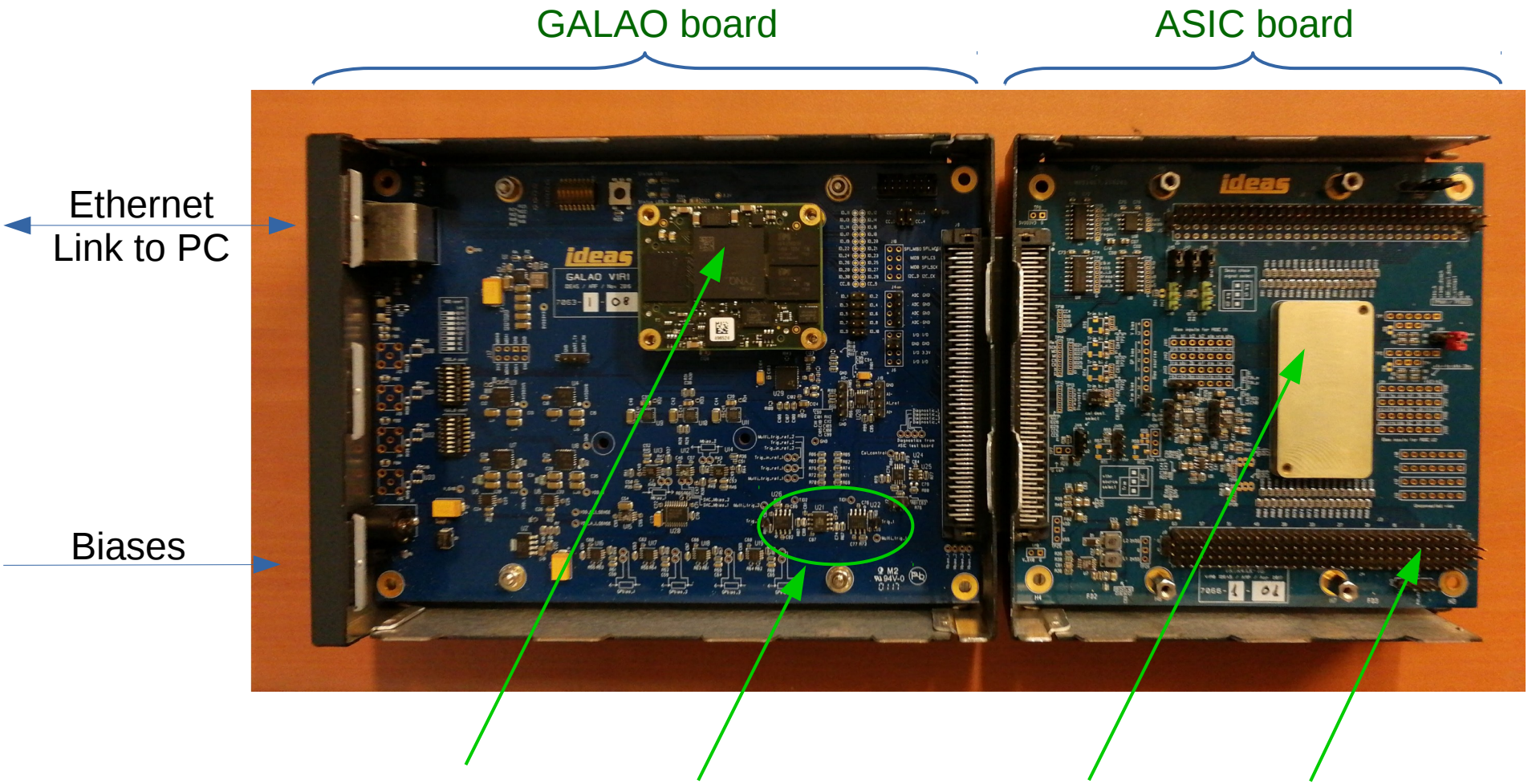
Results





Readout electronics

GALAO system from IDEAS company hosting a VATA 460.3 ASIC

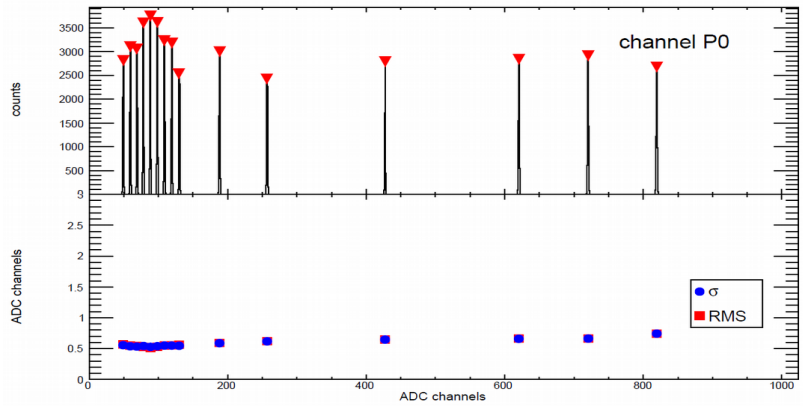


ASIC performances

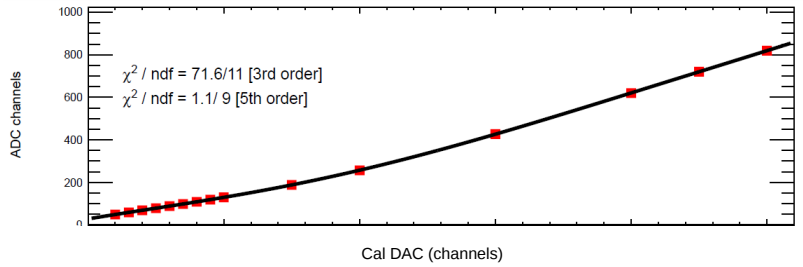
VATA460.3 characteristics

- 32 charge preamplifiers
  - Bipolar, dynamic range ± 90 fC
  - Shaping: 2 μs (spectro), 0.6 μs (trigger)
- 32 ADCs (10 bits)
- Selective data readout
- 1 test input

resolution

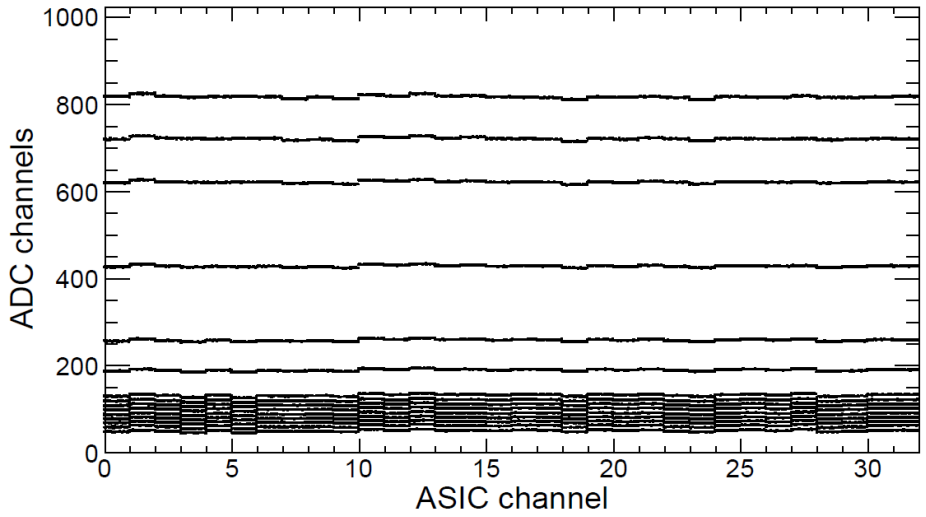


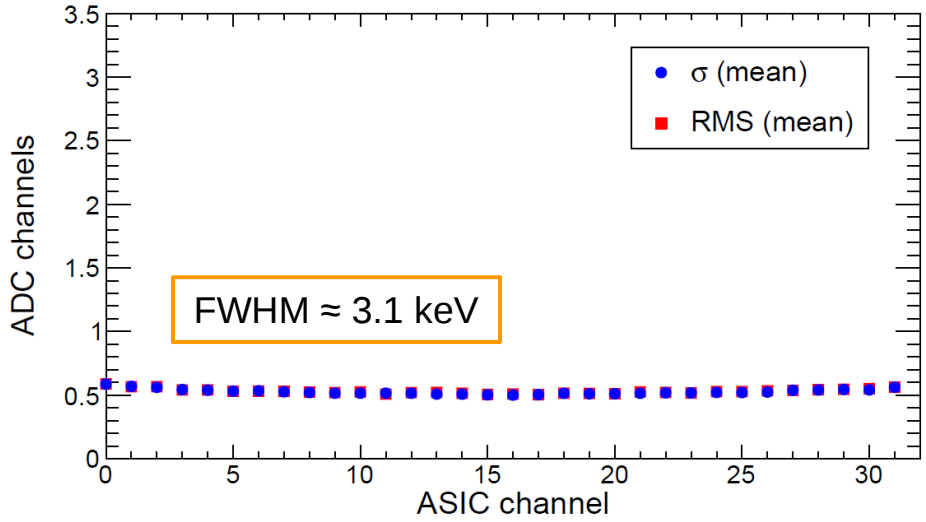
linearity



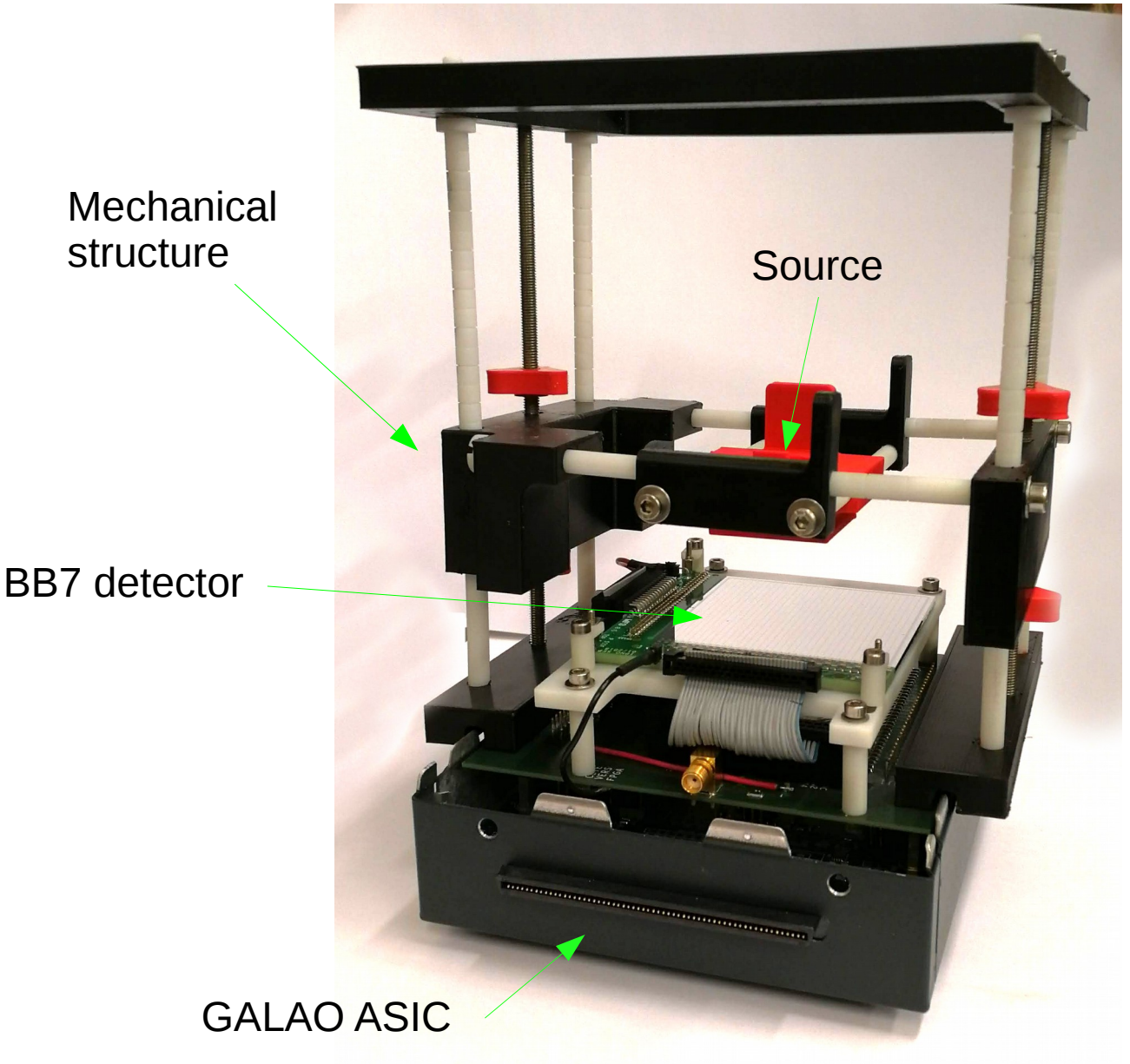
In line with IDEAS specifications

p-side

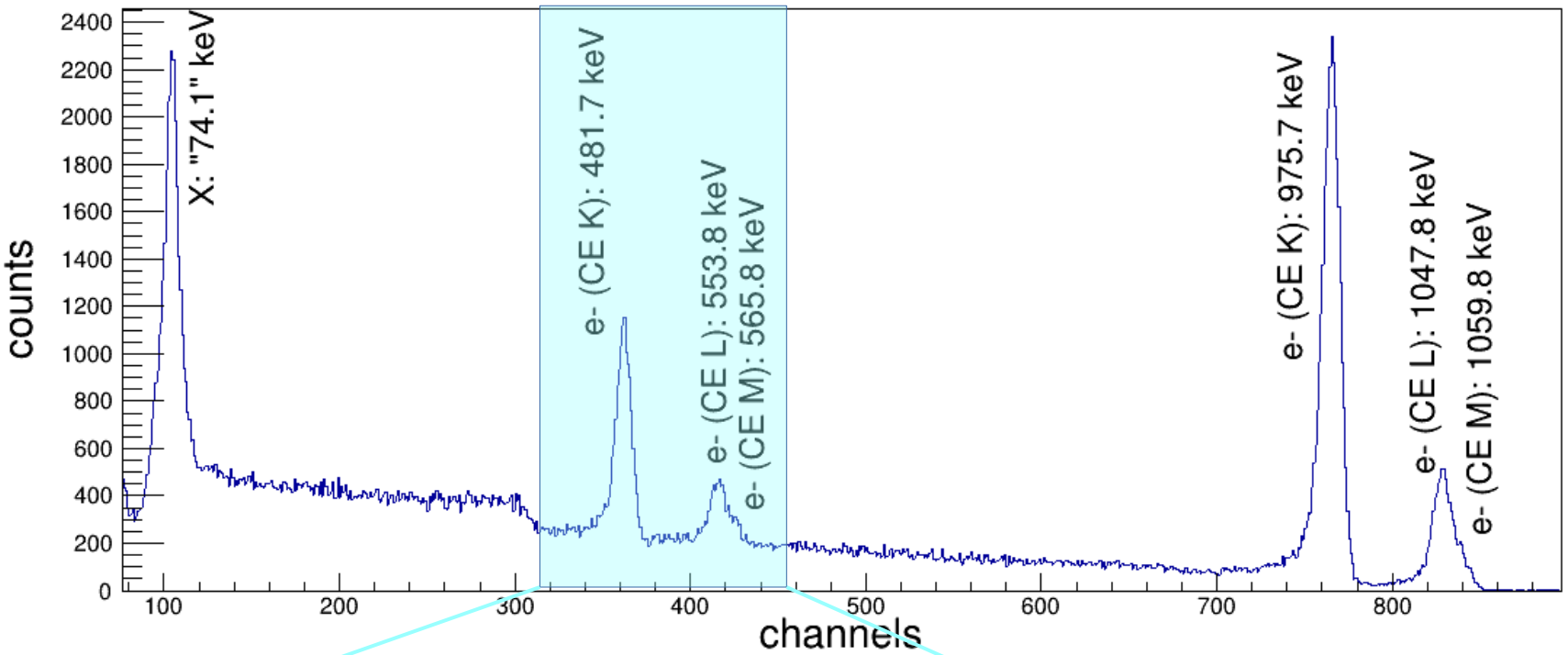


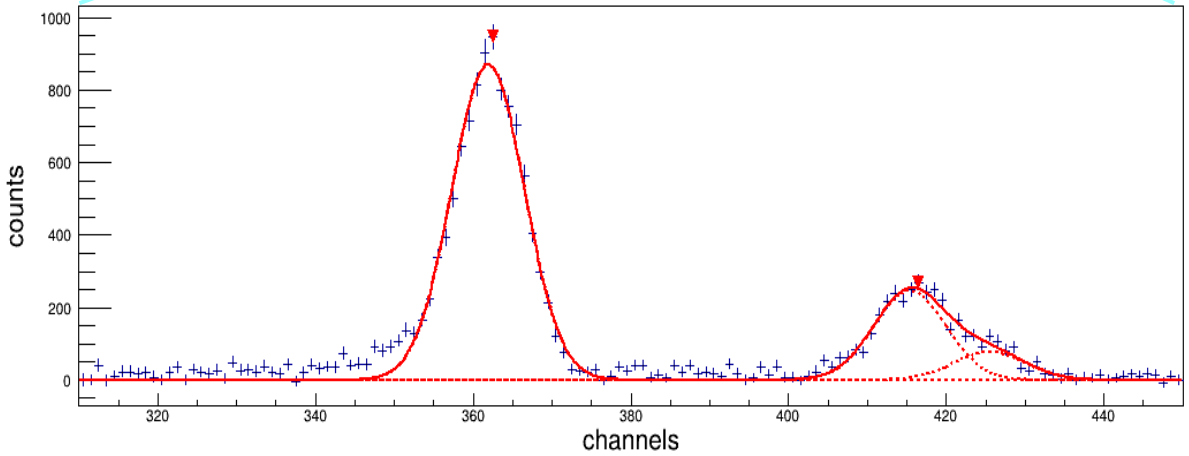


BB7 + GALAO system



Results with ^{207}Bi source

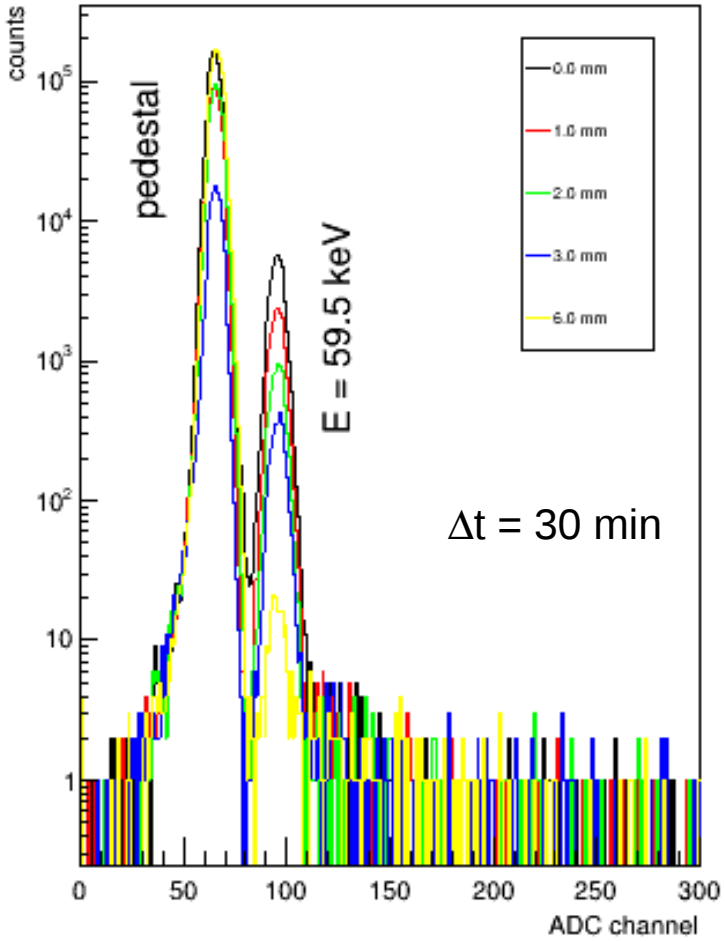


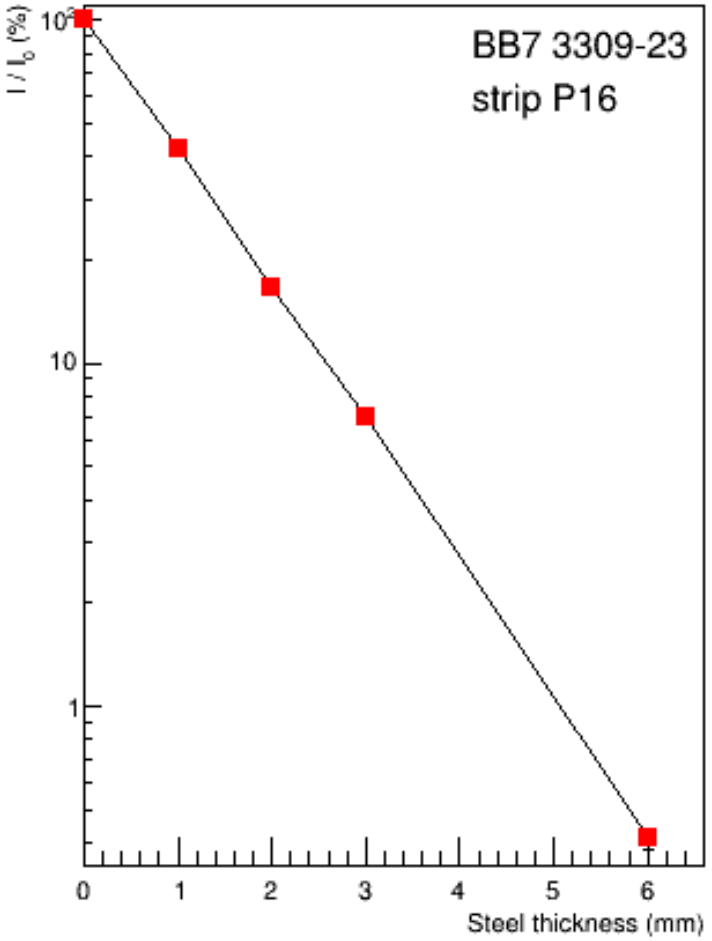


Temperature : 22.3 °C
Leakage current : 361 nA

Resolution (FWHM) :
≈ 14.6 keV

Results with ^{241}Am source





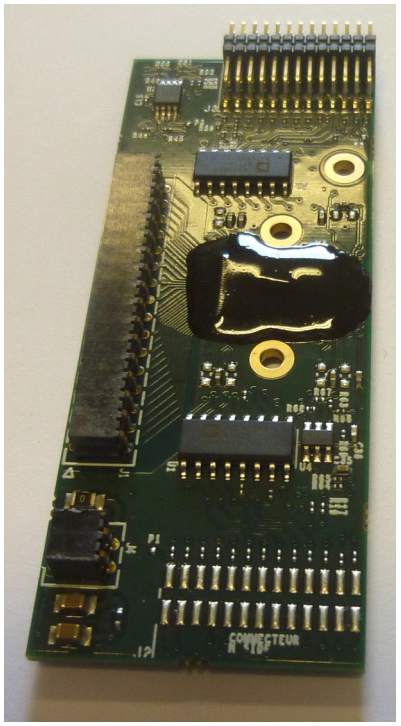
Temperature : 23.4 °C
Leakage current : 411 nA

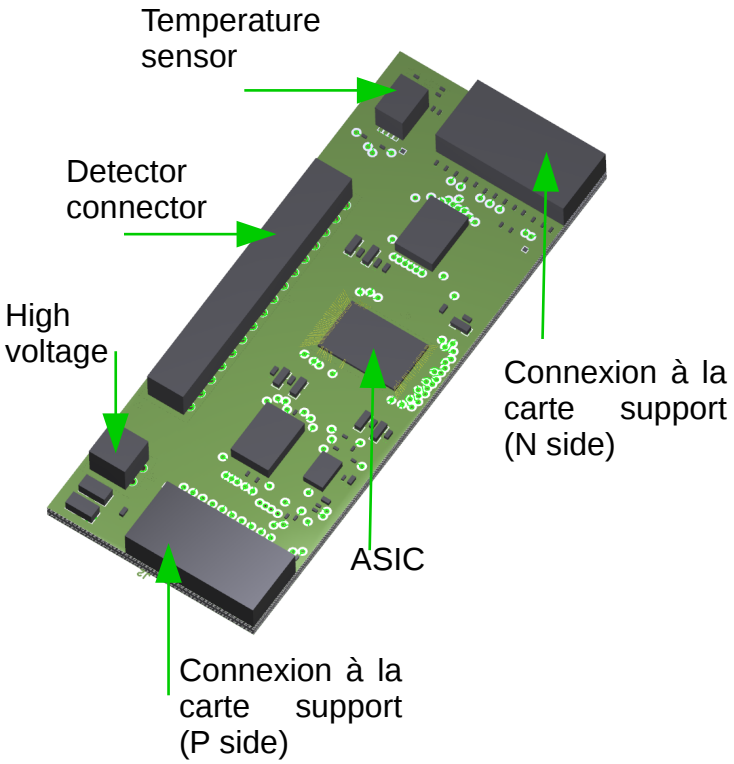
γ-ray transition at 59.5 keV successfully detected

Resolution (FWHM) : ≈ 12.3 keV

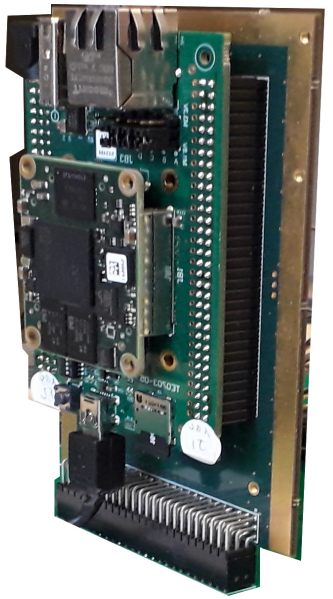
Custom electronic boards

Front-end Electronic Board





Back-end Electronic Board

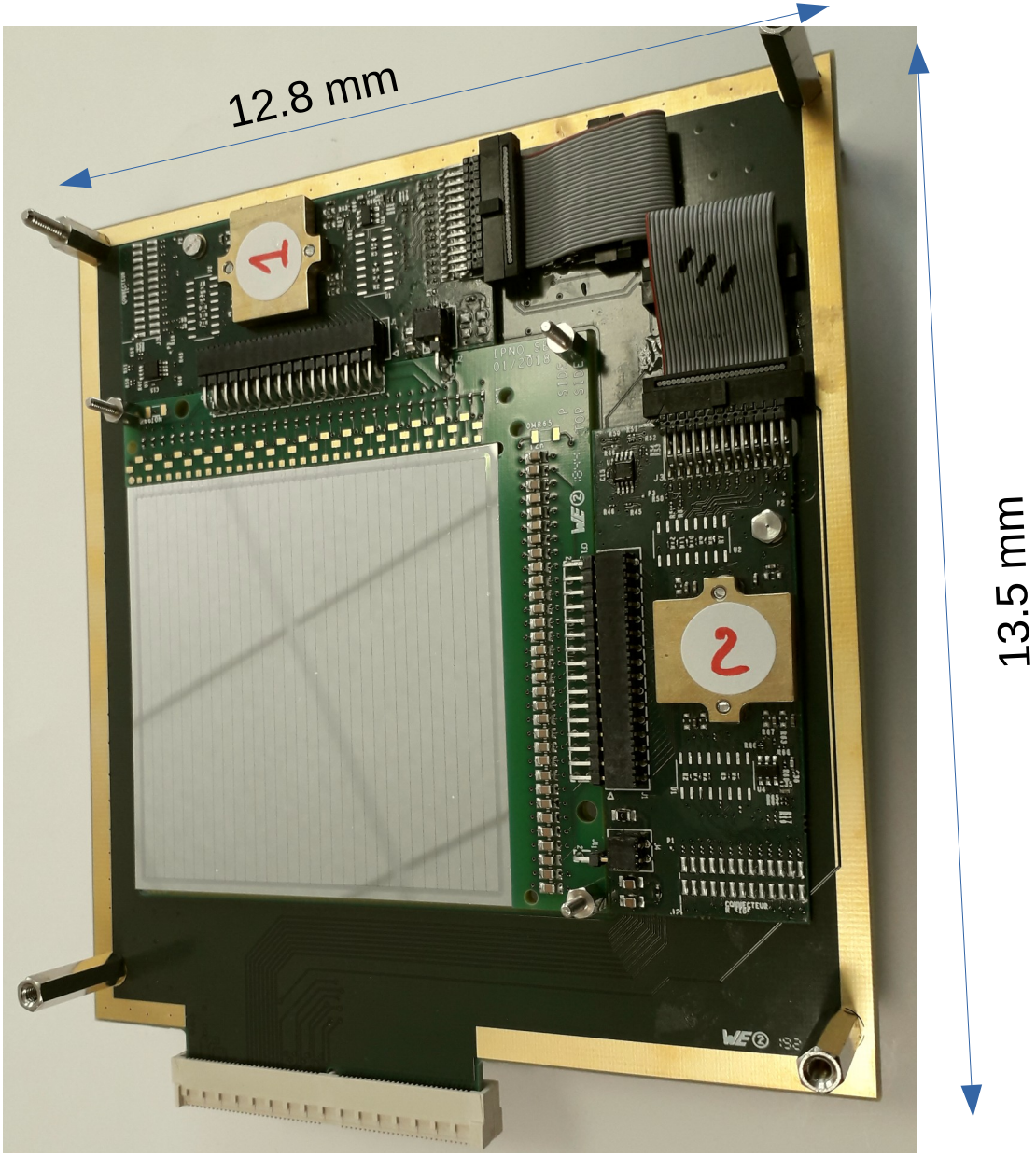


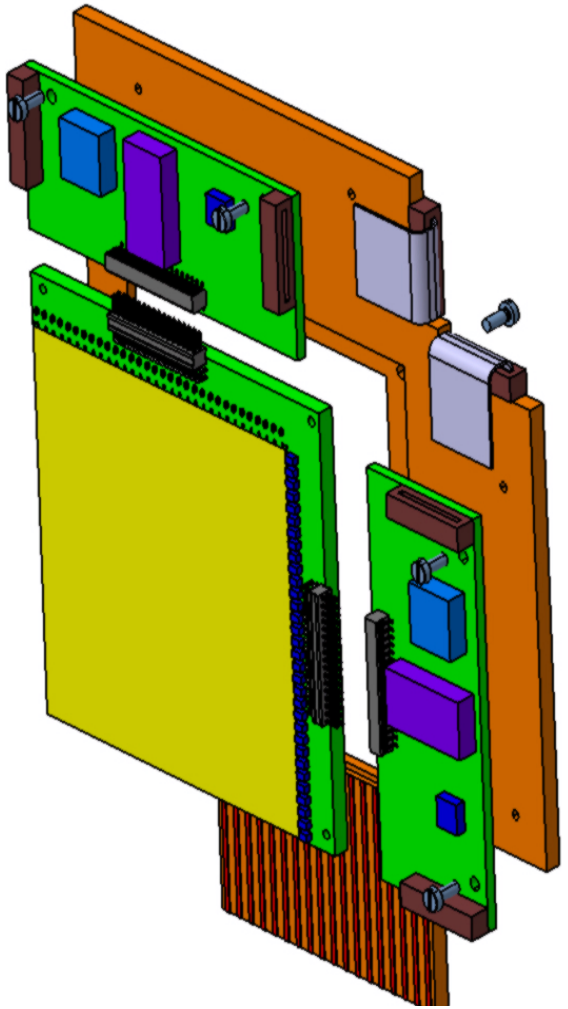
Zynq module:

- Processor (linux)
- FPGA Xilinx
- Ethernet interface...

→ slow control, digital readout

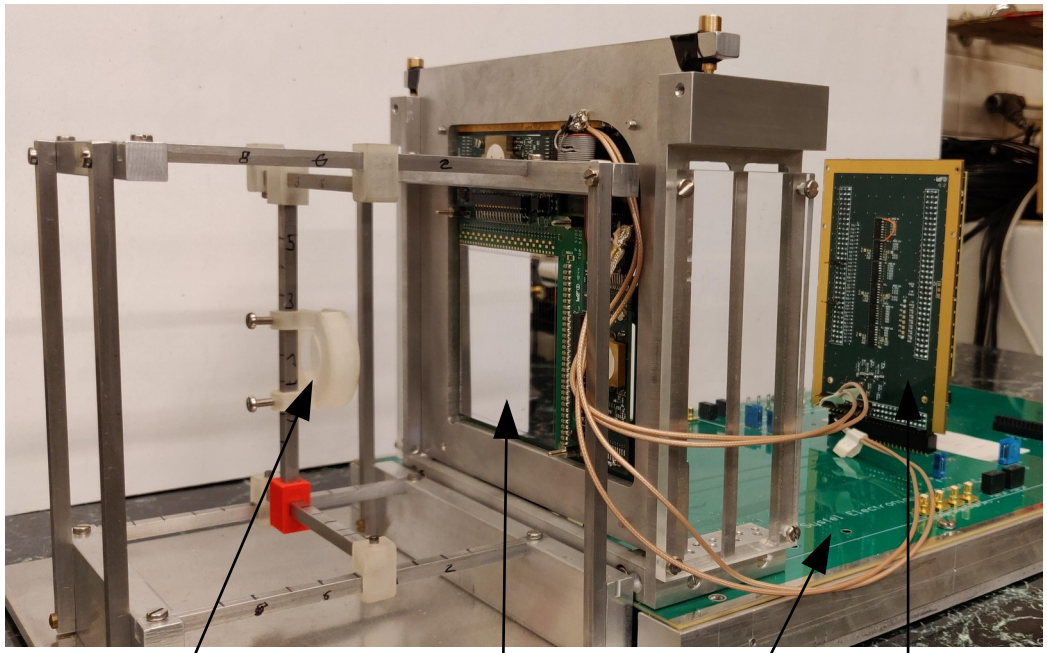
DSSSD + Front-end electronic board





First results

Testbench for the ComptonCAM camera



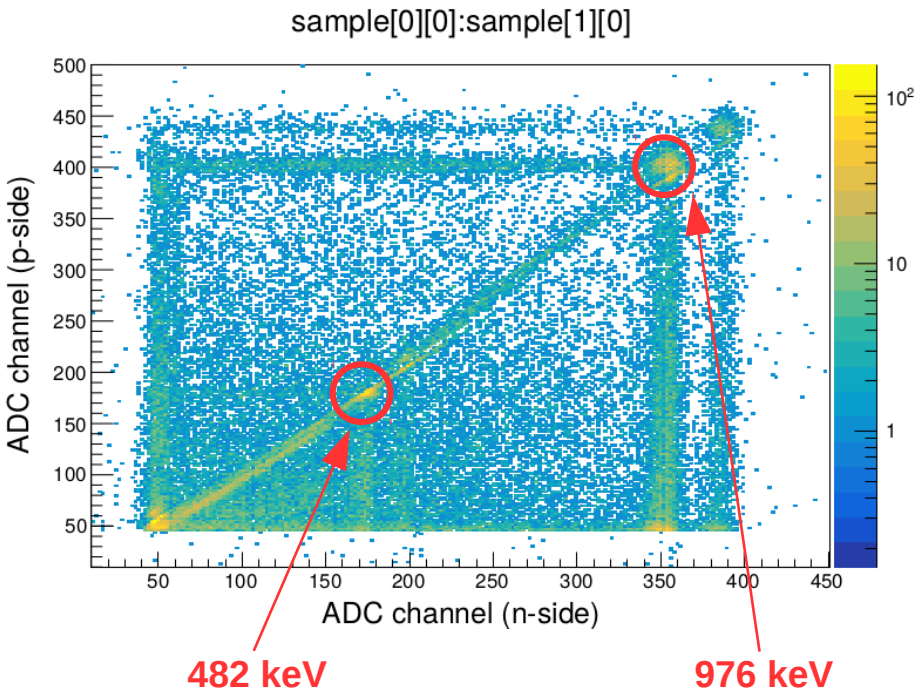
Radioactive source

DSSSD + FEB

Back-end

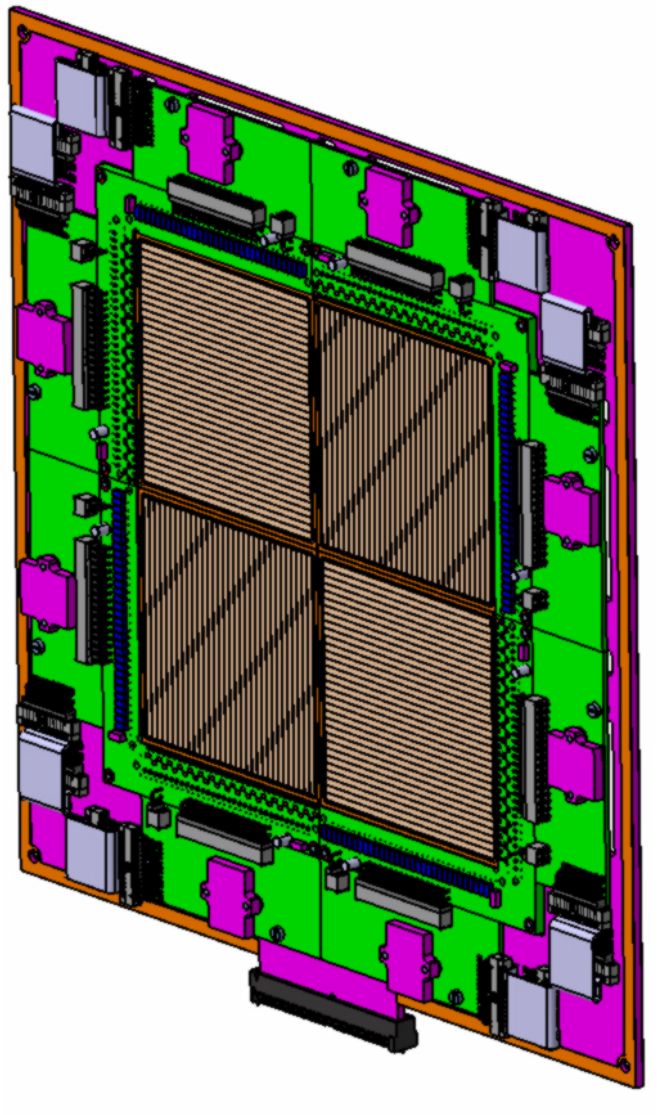
Backplane

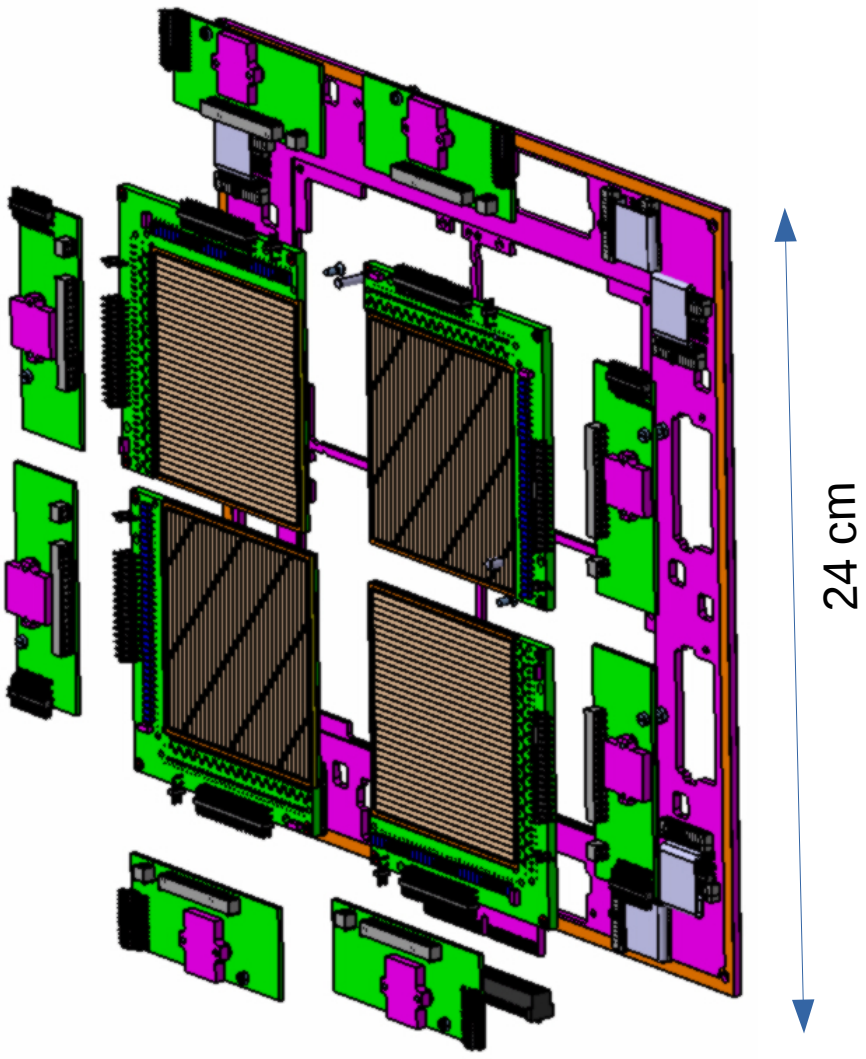
Data obtained with ^{207}Bi source



- Coincidence data between the p- and n-side
- Raw data, all strips
- On-going analysis...

Toward a 4U design





Thank you for your attention