ECLAIRs instrument & scientific performances

Armelle BAJAT (3rd year PhD)

ECLAIRs : Scientific Goals

ECLAIRs is the wide-field hard X-ray imager of the SVOM mission

References

- **The Deep and Transient Universe in the SVOM Era: New Challenges and Opportunities - Scientific prospects of the SVOM mission,**J.Wei, B. Cordier et al, 2016

- **The x-/gamma-ray camera ECLAIRs for the gamma-ray burst mission SVOM,**O.Godet, G.Nasser et al, 2014

ECLAIRs : Scientific Goals

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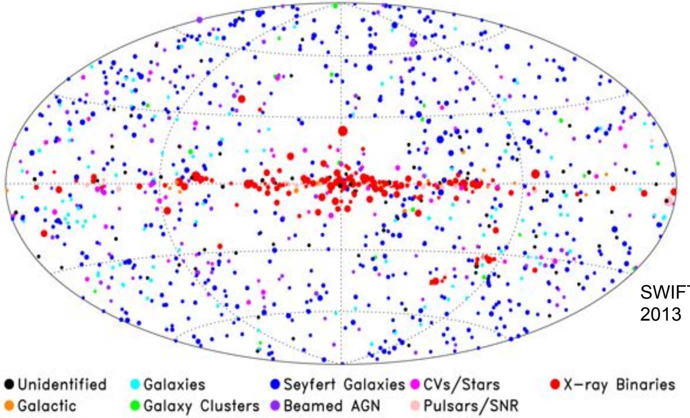
Science Goals :

- Explore the physics of the violent explosions
  - Local (TGF, Solar Flares)
  - Galactic (BH, X-rays bursts)
  - Extragalactic (Long GRBs, short GRBs)
- 70-80 GRBs/year during 3 years
- Look for the electromagnetic counterparts of GW events
- Probe the demography of stellar masses black holes
- Use GRBs to explore distant galaxies



SWIFT/BAT Baumgartner 2013

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- Detect transient X-ray sources autonomously
  - Detect hard X-ray photons
  - Measure their properties (time, energy, position, multiplicity)
  - Build images of the X-ray sky
  - Look for new sources
  - First localizations < 13 arcmin

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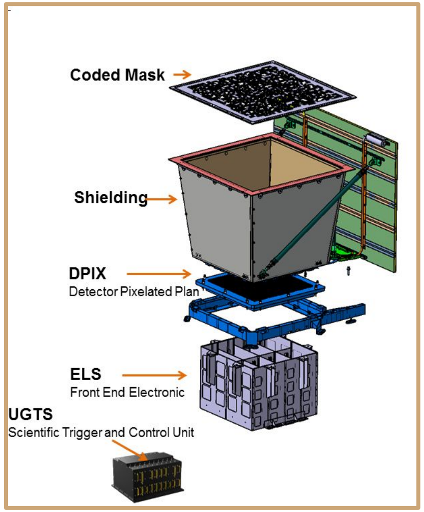
  - Look for new sources
  - First localizations < 13 arcmin
- VHF alerts messages, slew requests

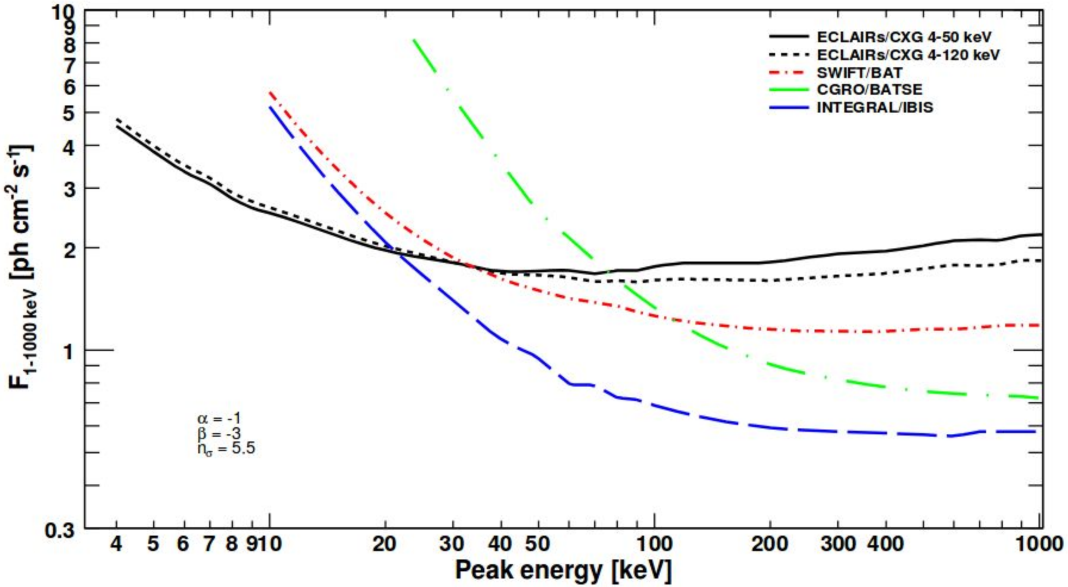
- Always operating (Photon couting mode) except inside the SAA

The scientific Performances

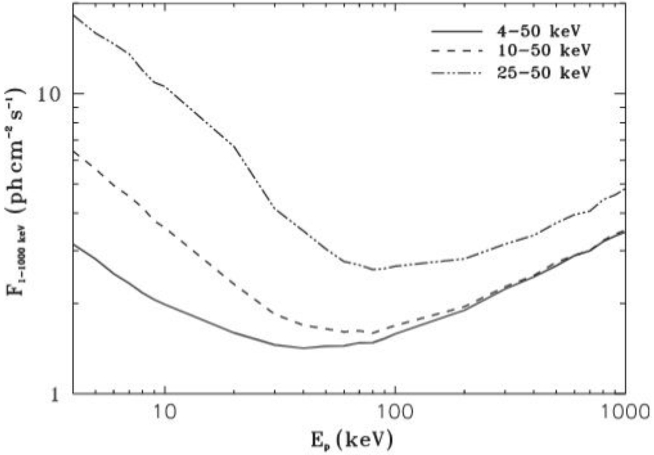


Energy Range	4 - 150 keV	Defines the level of detector leakage current and electronic noise
Effective area	> 340 cm^2 @ 10-70 keV > 200 cm^2 @ 6 keV	Defines the level of absorbers above the detector
Energy resolution @ 60 keV	< 1.5 keV	Defines the performances of the detectors and the electronic noise
Dead Time	< 5%	For the brightest sources
Field of view	2.05 sr total	Defines the number of detectors in the plane and the design of the shielding
localization error box	< 13 arcmin (90% confidence level)	Impact on the field of views of MXT & VT

The scientific Performances : the Low Threshold



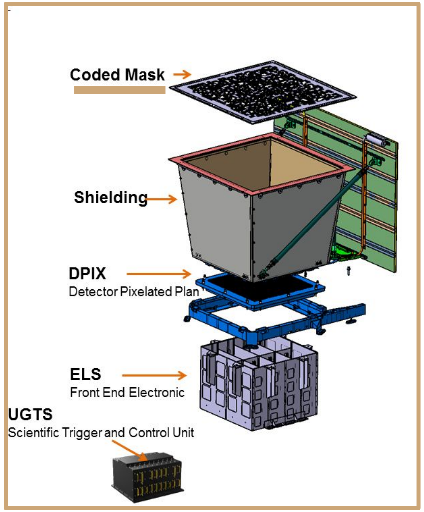
S.Schanne on behalf of the ECLAIRs collaboration, 2008



O.Godet et al, 2009

- Small detective area
- 4 keV threshold
- Detect softer GRB

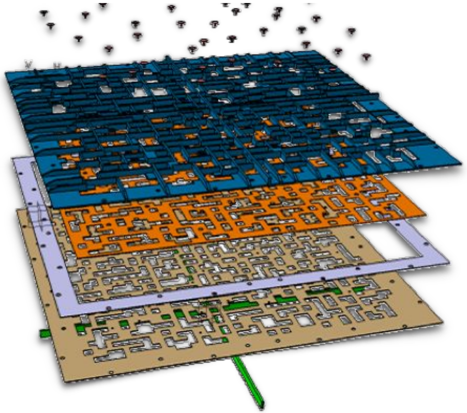
Instrument : The mask



- 4 x 23 x 23 elements
- 54 x 54 cm^2
- Ti(1 mm), Ta (0.6 mm), Ti (1mm)
- Total aperture : 40%
- Distance Mask-plane : 46 cm
- Opacity Energy < 80 keV

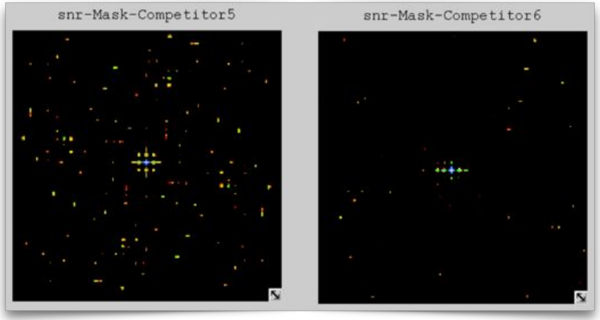
Mechanical studies

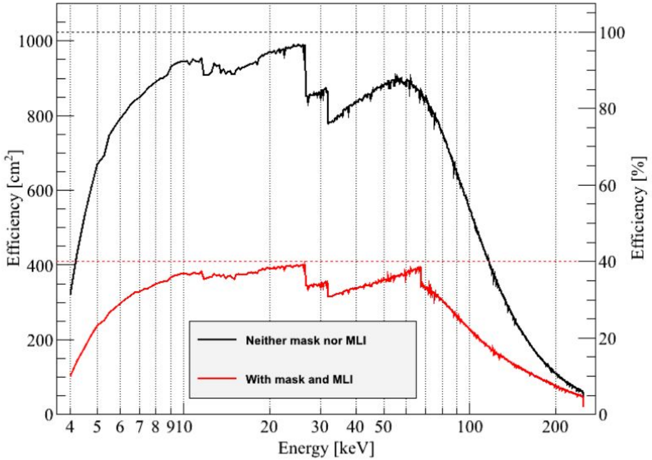
- Mechanical resistance simulations
- Cross (Ti, height : 15 mm)
- Design
- Manufacturing



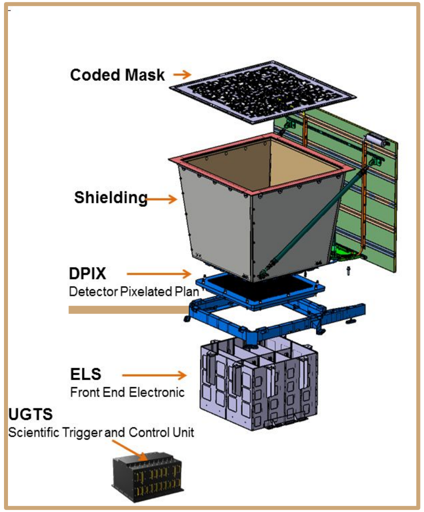
Scientific studies

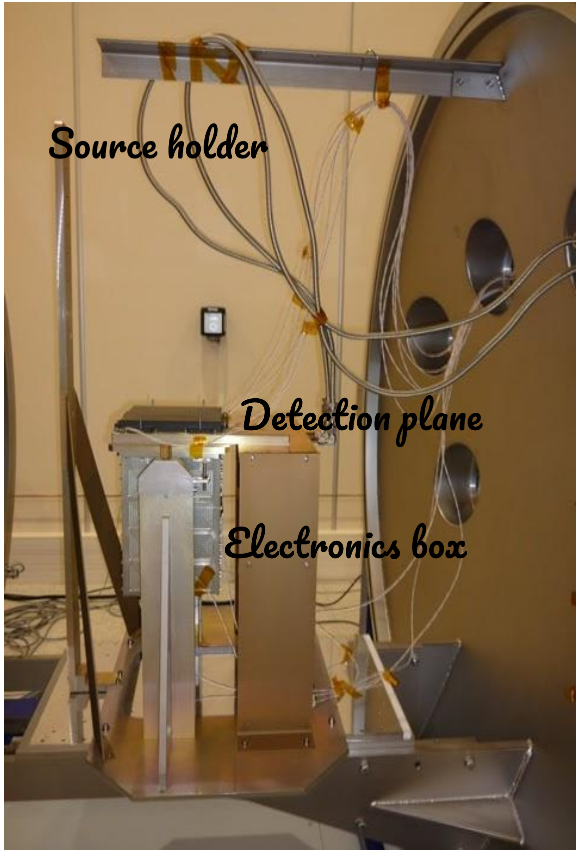
- New mask pattern
- Burst losses simulations
- Best performances selection
- Ghosts studies



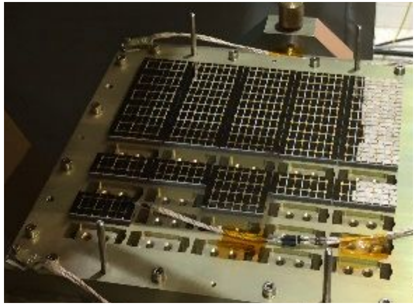


Instrument : The detection plane

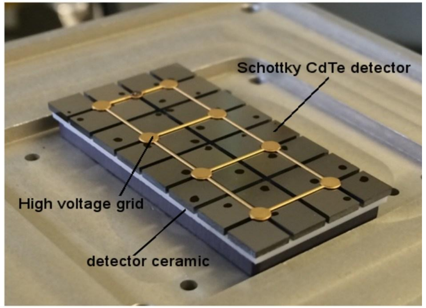




Prototype



1 complete Sector + 7 modules



1 module

The detection plane

- 6400 pixels (80 x 80)
- 8 independent sectors

A sector

- 25 modules per sector
- Drived by an ELS

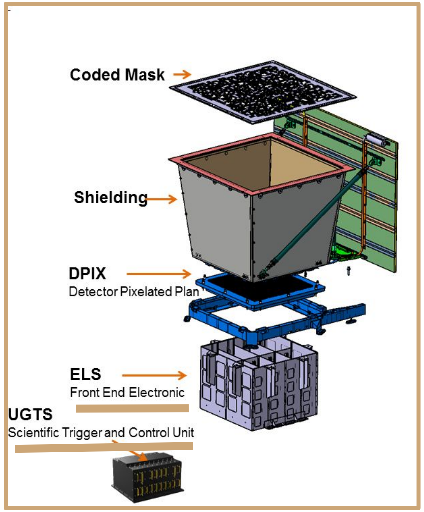
A module

- 32 pixels
- 4 x 4 x 1 mm^3
- CdTe Schottky detectors
- Asic low noise

Prototype

- 1 complete sector + 7 modules
- vacuum chamber + thermic regulation
- source holder
- radioactive sources (^{241}Am, ^{55}Fe or ^{57}Co)

Instrument : The Electronics



Front End Electronic

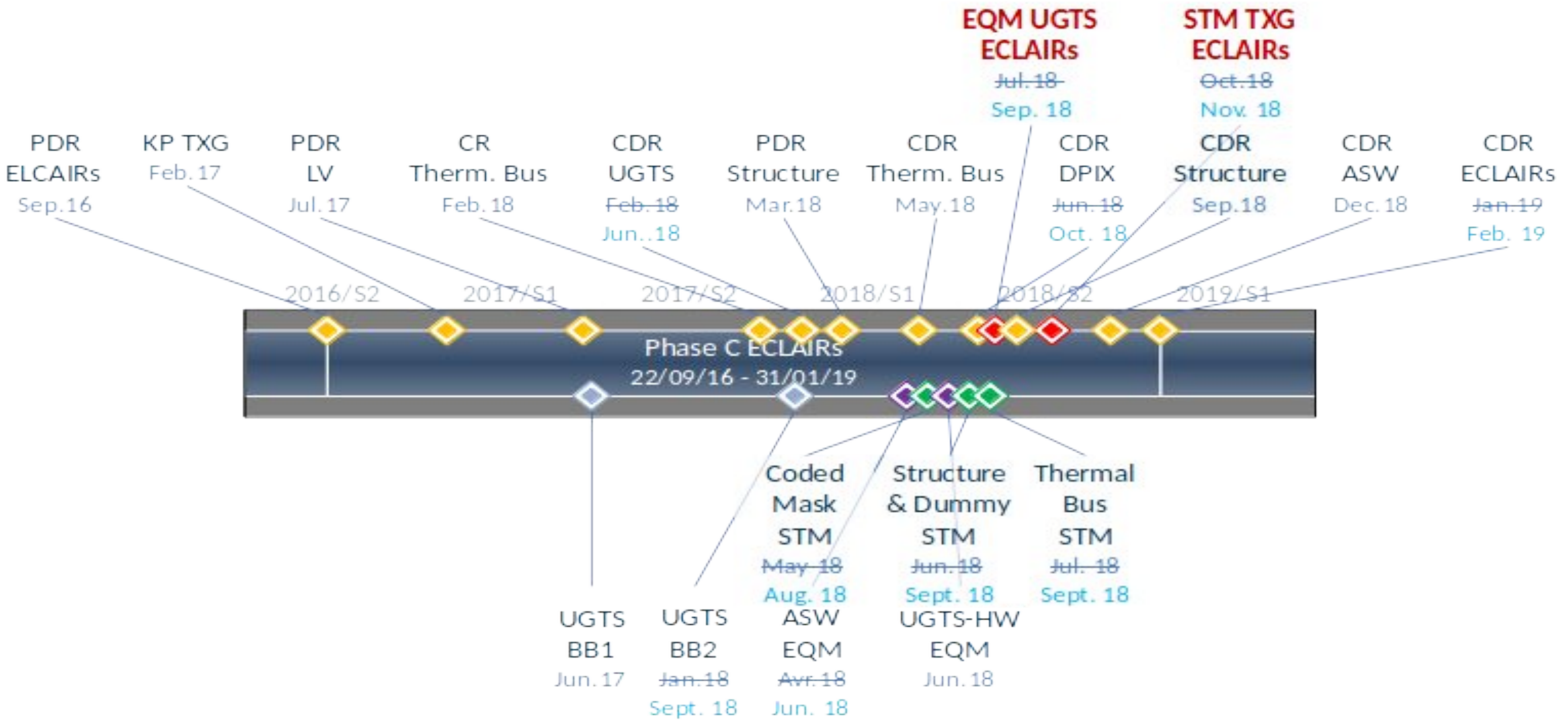
- Encode the energies of detected events
- Order and exchanges signal
- Supply the High Voltage
- Recover configurations
- Transmit events frame to UGTS

Scientific Trigger and Control Unit

2 algorithms to autonomously search for transient events

- Image trigger (image reconstruction on different time scale, energy bands…)
- Count rate trigger (couting rate excess)
  - sky image recontruction for the best excess
- search for new point sources

Instrument : Agenda

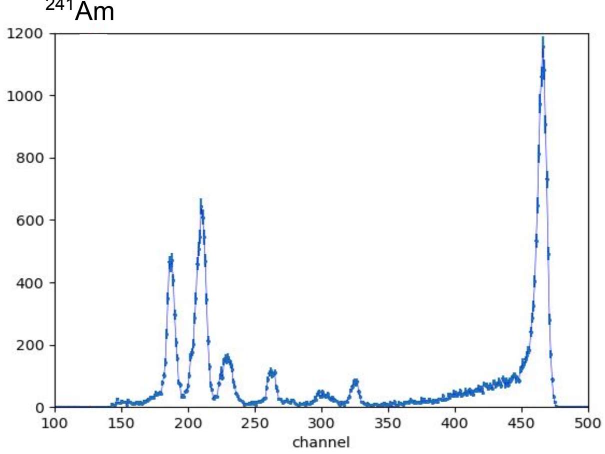


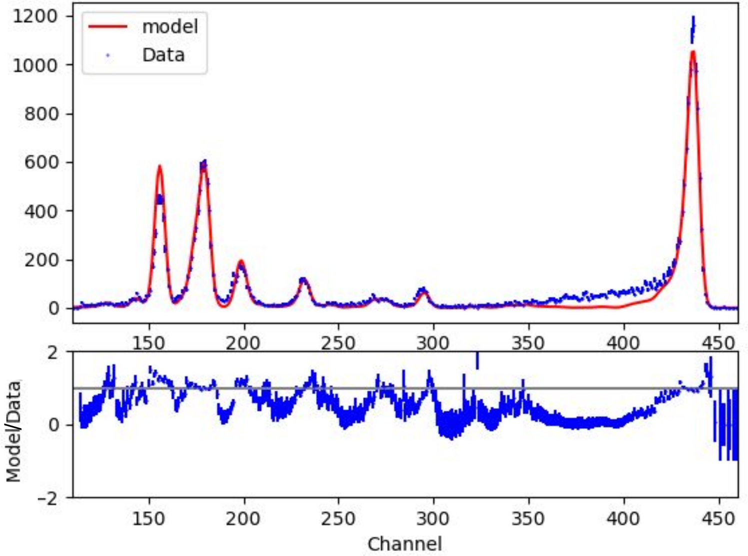
The scientific Performances

Methods

- BUILD A SPECTRAL RESPONSE MODEL
  - Monte Carlo Simulations (Geant4)
    - Spectrum simulation
    - energies: radiation matter interaction
    - physical process
  - Charges losses corrections
  - Electronic contribution

- SPECTRAL FITTING
  - χ^2 minimization
  - extraction 6 parameters
  - characterization of each detector





Bajat et al proceeding + POSTER, SPIE, Austin ,Tx, USA

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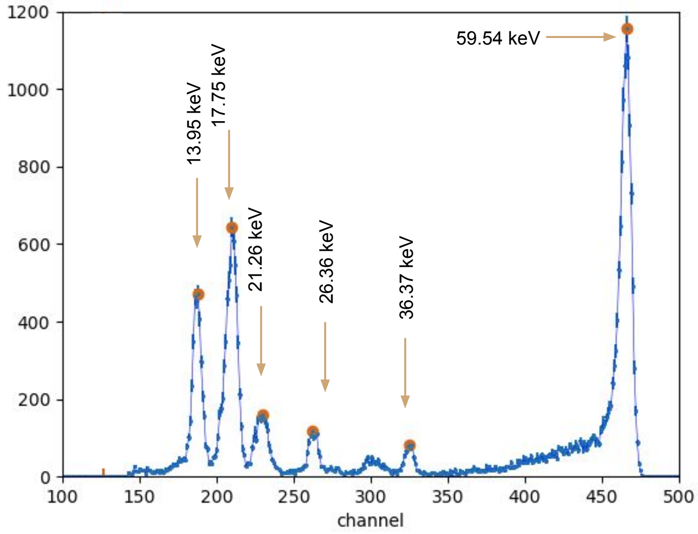
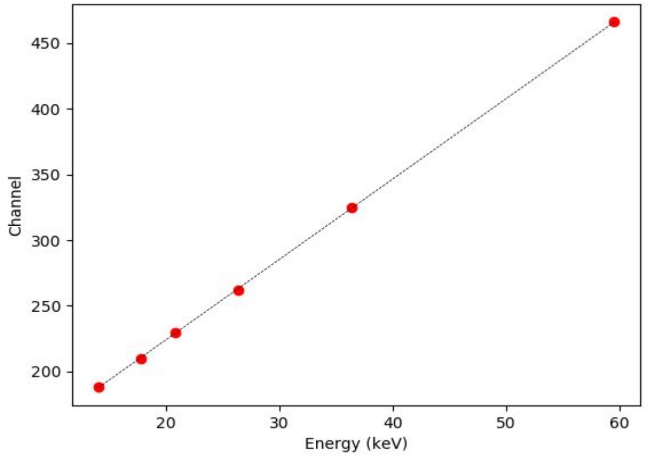
Parameters

➔ Gain + Offset





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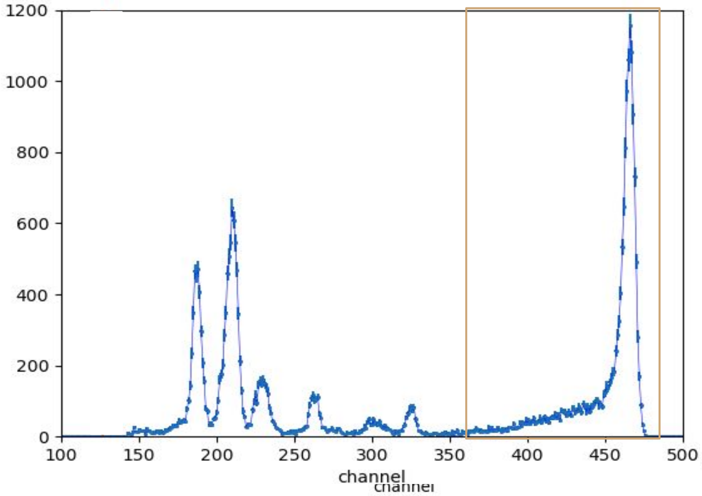
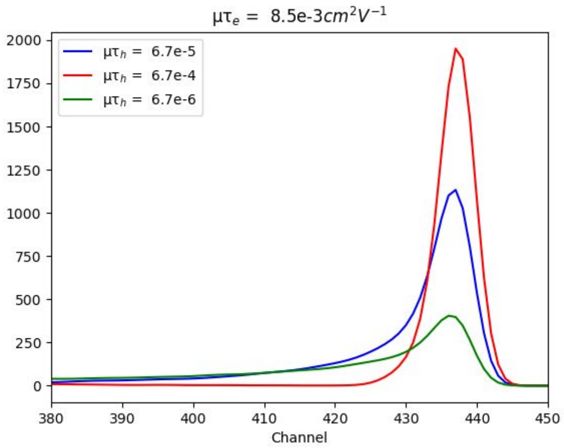
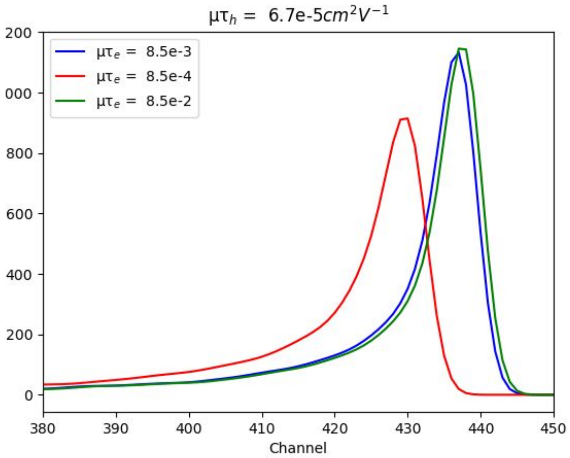


Parameters

- ➔ Gain + Offset
- ➔ $\mu\tau_e + \mu\tau_h$ (lifetime, mobility)





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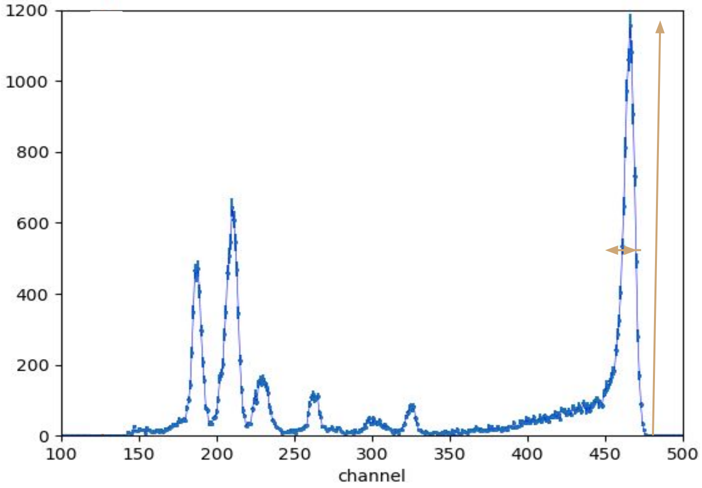
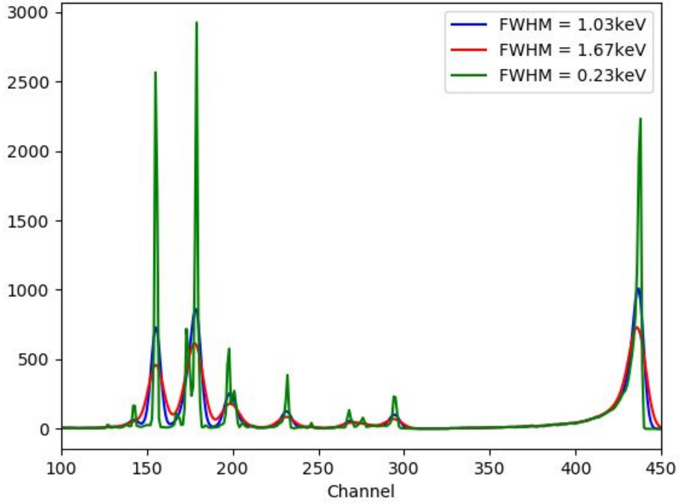
Parameters

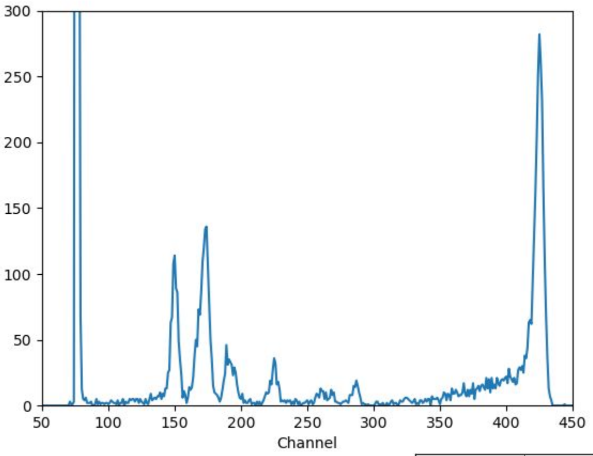
- ➔ Gain + Offset
- ➔ $\mu\tau_e + \mu\tau_h$ (lifetime, mobility)
- ➔ electronic Noise (FWHM)
- ➔ Amplitude

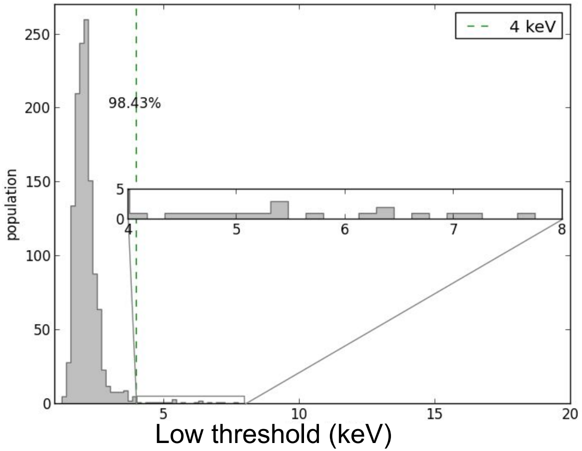
Other parameter : Low-Energy Threshold





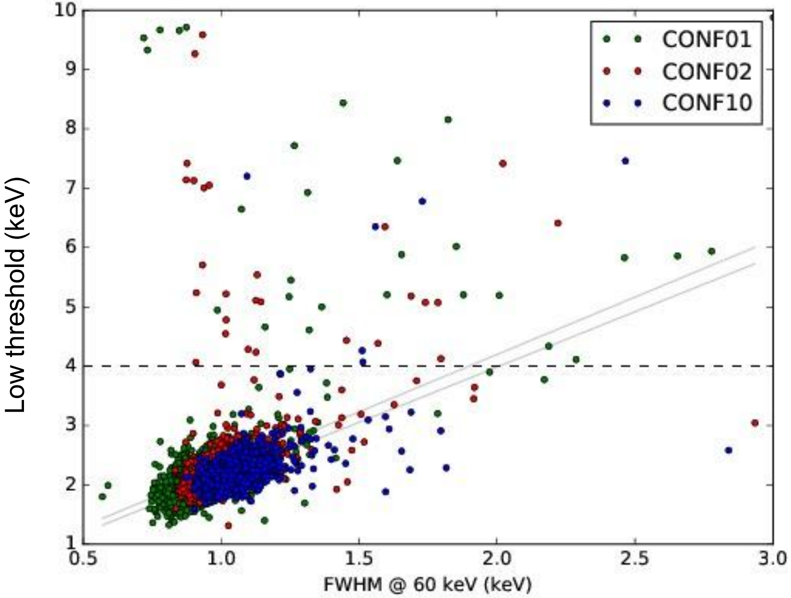
The scientific Performances : Low energy threshold





Nominal configuration (CONF10)
1312 pixels

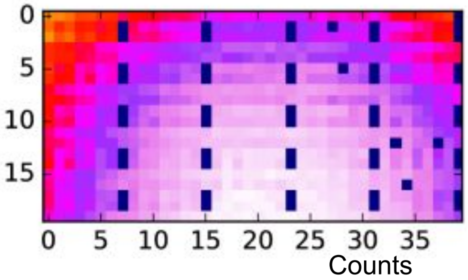
1024 pixels

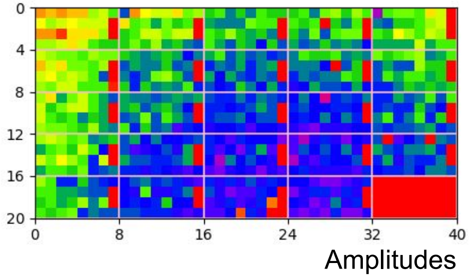


CONF01: HT = -400 V, Tp = 4.4 µs (~2.5% pixels > 4keV)
CONF02: HT = -400 V, Tp = 2.6 µs (~1.5% pixels > 4keV)
CONF10 : HT = -300V, Tp = 2.6 µs (< 1% pixels > 4keV)

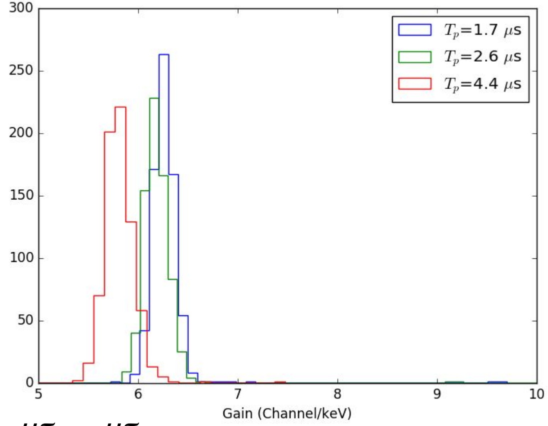
The scientific Performances : Calibration

Amplitude

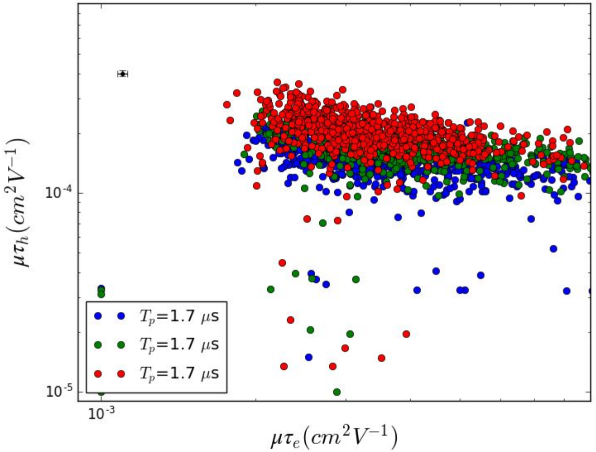




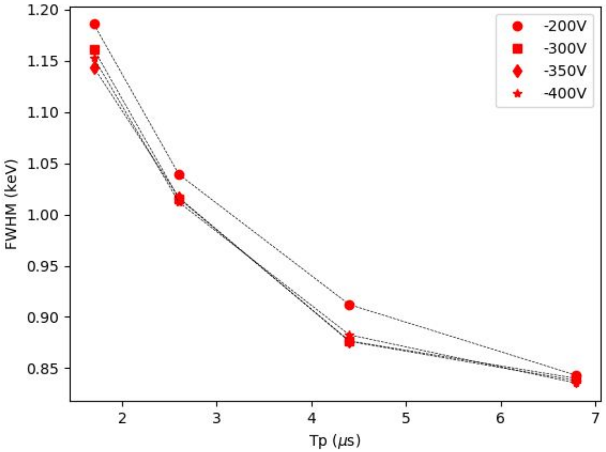
Gain

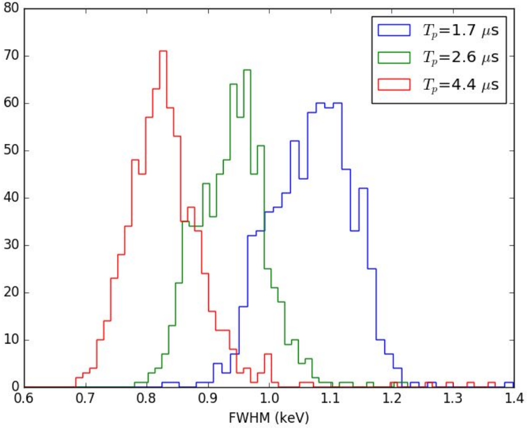


$\mu\tau_e$, $\mu\tau_h$



Related to the electronic noise





750 channels
HT = -300V

The scientific Performances : Dead Time
Bajat et al. (submitted 2018)

Tools :

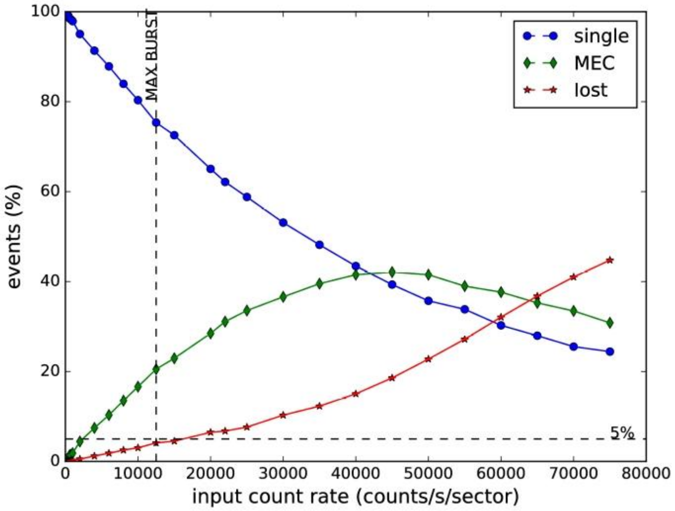
- Test Bench
- Simulator

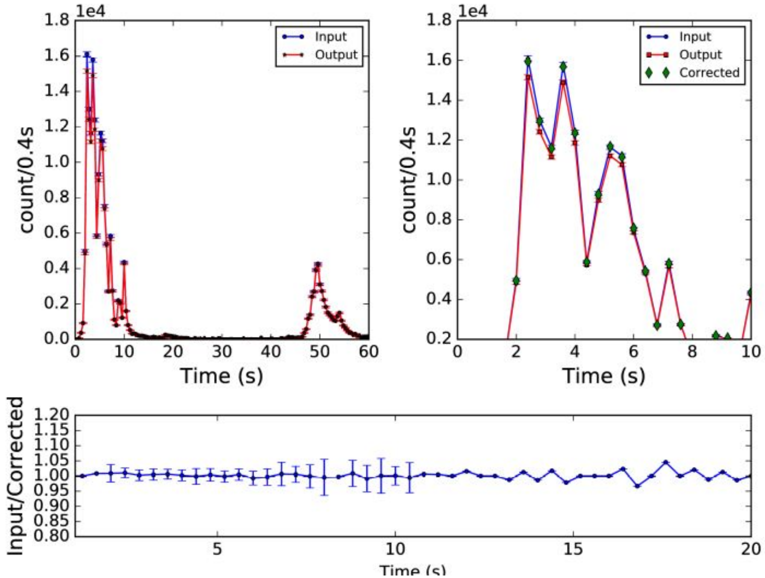
Goals :

- Validate the readout and encoding process of data
- Building an analytical model of dead time
- Application to a burst light curve

Scientific requirements: DT < 5% for 12500 counts/s/sector
Results : DT = 3.6% (±0.1%) for 12500 counts/s/sector

$$\ln(p) = \begin{cases} -0.05 \times N_{illu} + 3.95 - 0.97\ln(\frac{ACD}{10\mu s}r) : N_{illu} > 12 \\ -0.12 \times N_{illu} + 4.75 - 0.97\ln(\frac{ACD}{10\mu s}r) : N_{illu} \leq 12 \end{cases}$$





ECLAIRs: CONCLUSION

ECLAIRs performances

- Prototype gives very promising results
- Homogeneous detection plane
- Respects the scientific requirements
  - FWHM < 1.5 % @ 60 keV
  - Low threshold < 4keV
  - Dead Time < 5%

ECLAIRs advances

- Design stabilization
- Well filled agenda
- Many work to finish and deliver the FM
- Science : calibration on ground

- Development of tools for analysis
  - To characterize each detectors of the detection plane
  - To analyse the temporal and the spectral response
  - To study every part of the instrument
  - To estimate the best performances of the instrument

Thank you for your attention