The development of the MXT camera of the SVOM space mission

From the first detector tests to the flight instrument calibration

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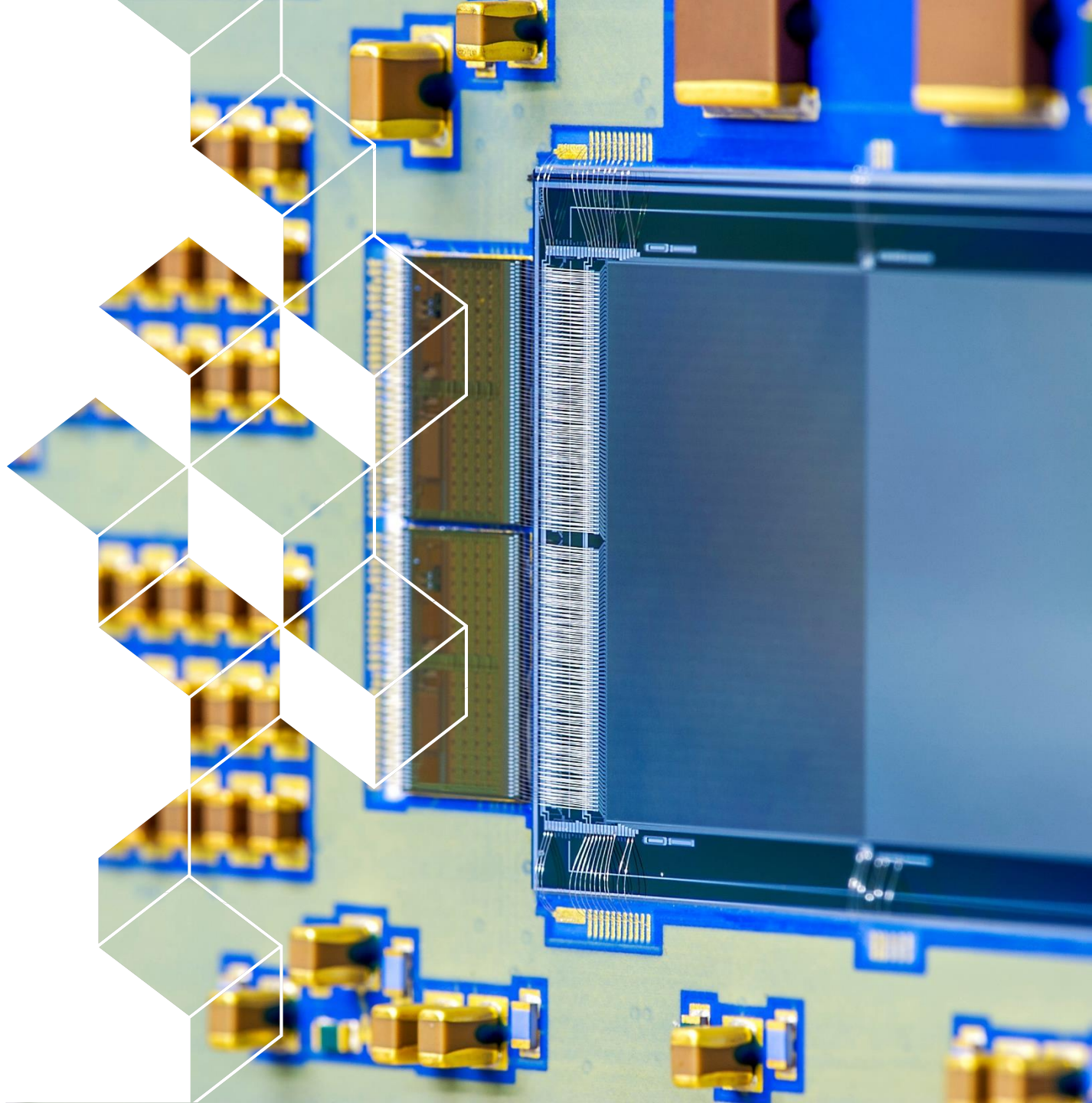
Journées thématiques IN2P3, 4 July 2023



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1. SVOM, a gamma-ray burst mission

2. Design of the MXT camera, challenges and realizations

3. Spectral performance characterization of MXT

1. The SVOM Mission

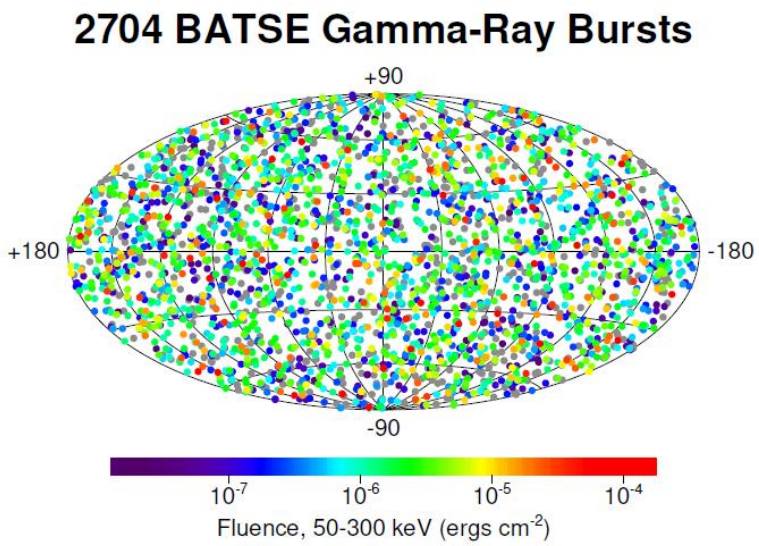
Gamma-ray bursts

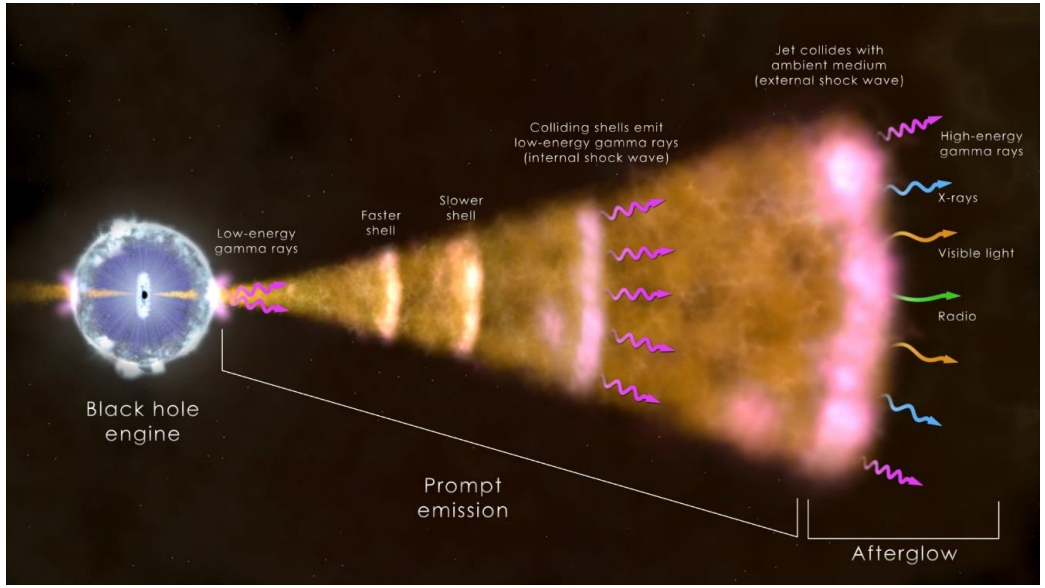
GRB are short and bright flashes of gamma-ray radiation that appear randomly over the entire sky

Prompt emission: Gamma-rays (ms to min); internal of the central engine and jets

Afterglow emission: From X-rays to radio (days to months); external shocks with the environment

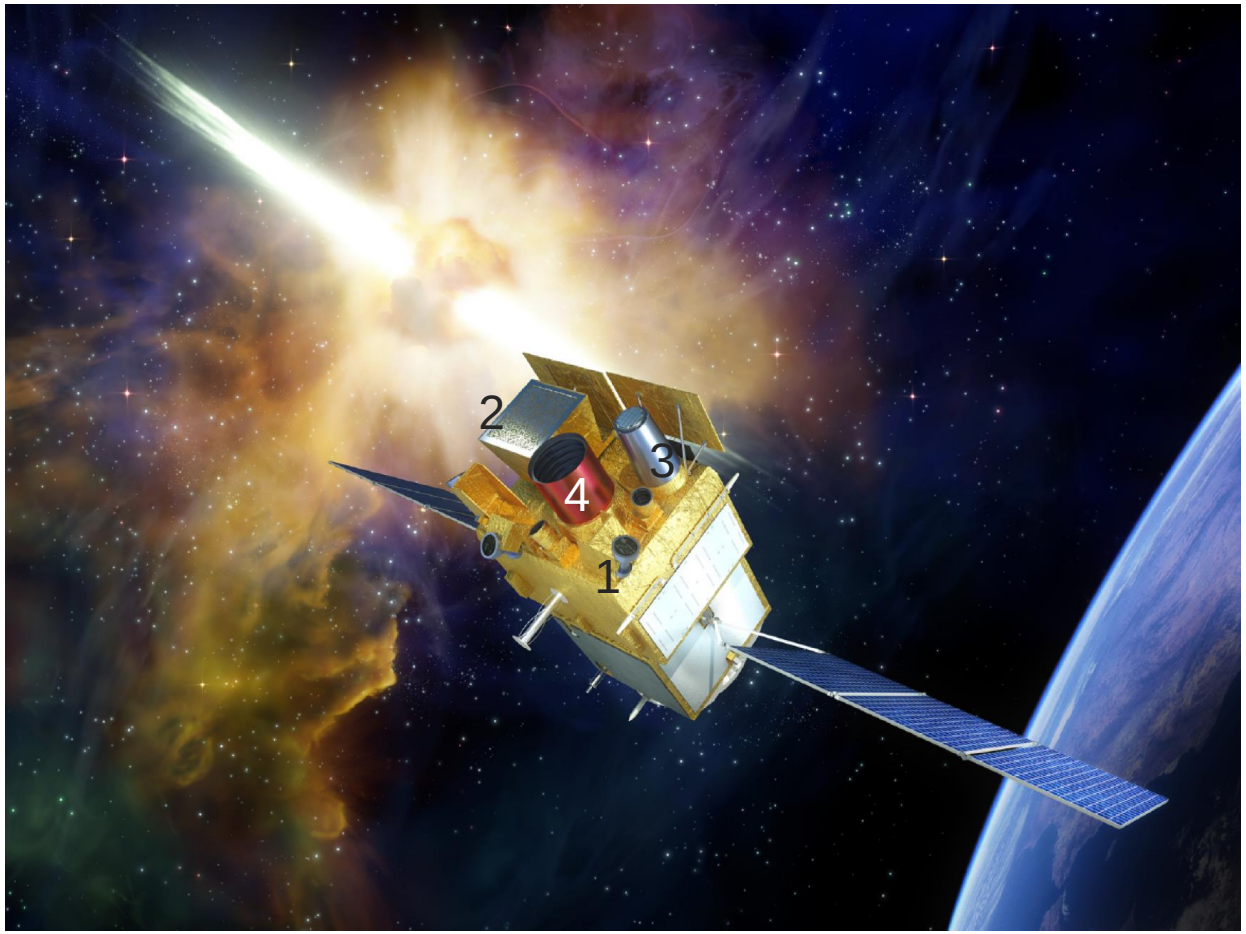
Motivations: physics in externe conditions, multi-messager astrophysics, early Universe probing





➔ **Need for a new multi-wavelength observatory with real time data management**

The SVOM mission



LEO orbit, 930 kg - Slew in 3 min

Detection

1. **GRM**, prompt γ-ray emission (15 – 5000 keV)
2. **ECLAIRs**, GRB trigger (4-150 keV)

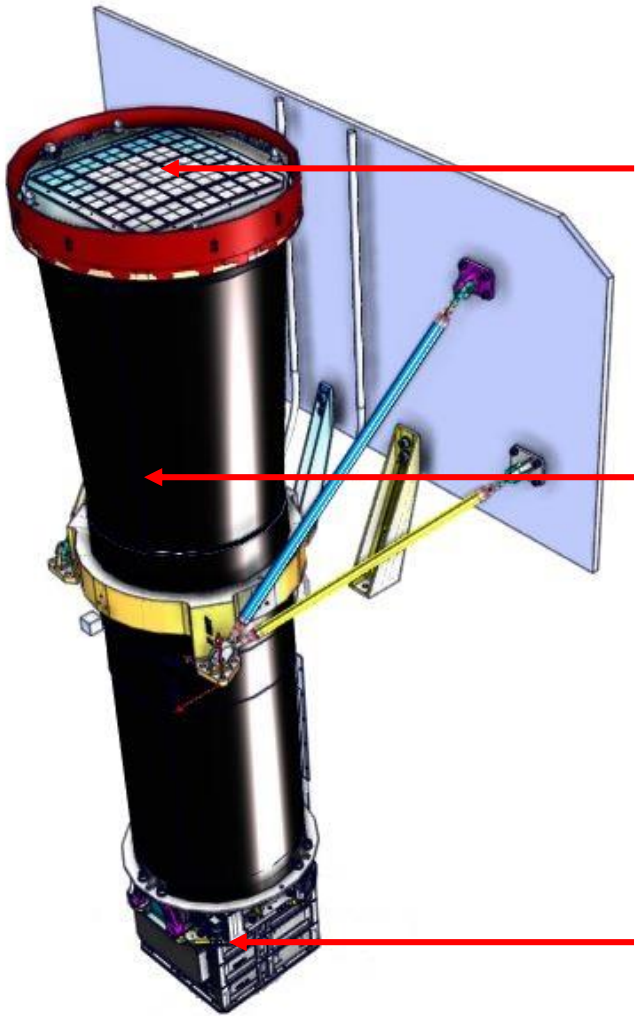
Localisation

3. **MXT**, X-ray afterglow (0,2-10 keV)
4. **VT**, Visible afterglow (400-1000 nm)

Ground follow-up

GWAC (500-850 nm)
C-GFT (400-950 nm)
F-GFT (400-1700 nm)

The Microchannel X-ray Telescope



42 kg, 60 W

Optics based on microchannel pore optics in lobster-eye configuration

UNIVERSITY OF LEICESTER

Telescope structure and radiator

cnes

Camera

cea irfu MPE

Data processing unit

IJCLab Irène Joliot-Curie

Key performance features

Localization within 2 arcmin in less than 10 min for 80 % GRB

38 cm^2 effective area at 1.5 keV

Short term sensitivity (10s)
2×10^{-10} erg cm^{-2} s^{-1} (~10 mcrab)

Long term sensibility (10 ks)
4×10^{-12} erg cm^{-2} s^{-1} (150 µCrab)

The camera at a glance

Technical specifications

9 kg, 7 W, 20 cm x 20 cm x H27 cm
Fits in the ∅ 240 mm telescope tube

z

Functions:

- X-ray detection and event pre-processing
- Detector active cooling
- Energy calibration
- Proton shielding

Performance requirements

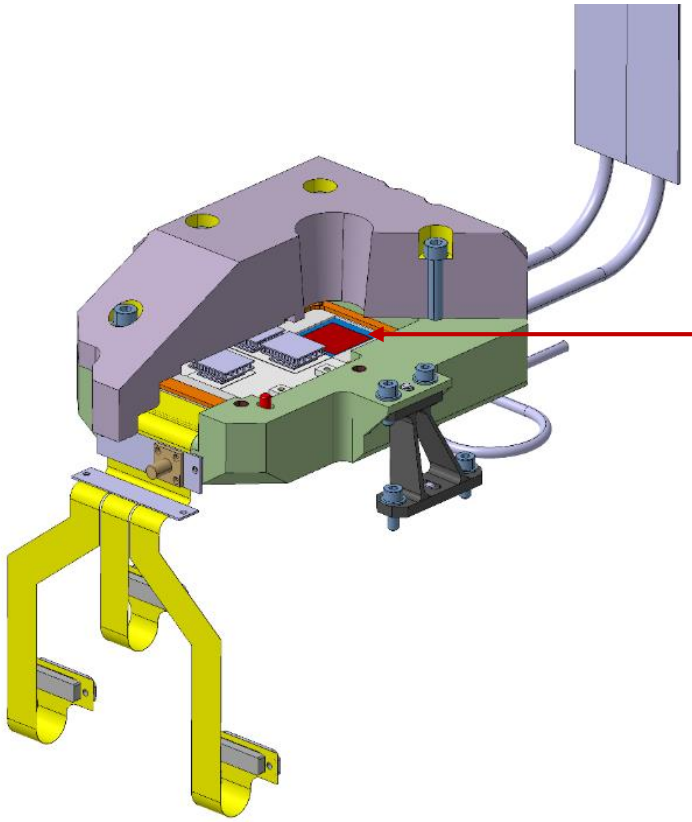
0.2-10 keV dynamic range
80 eV at 1.5 keV beginning of life
100 ms event time resolution

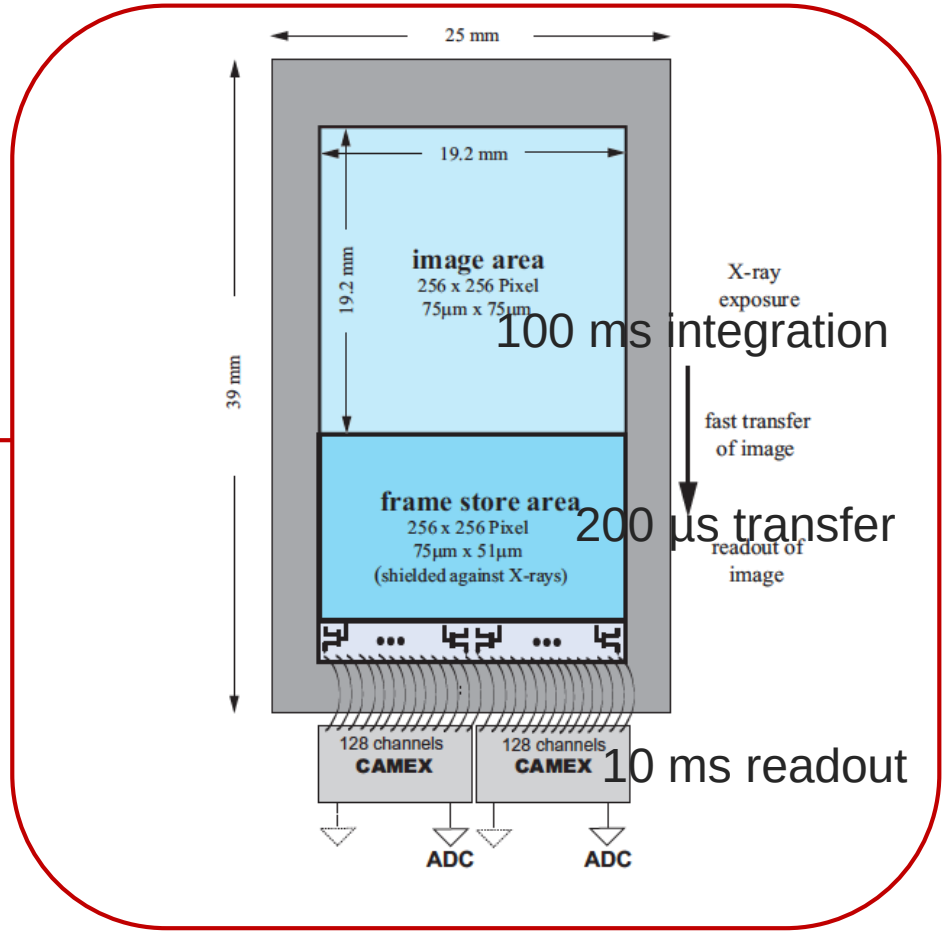
A. Meuris, NIM-A

2. The Camera design and integration

Focal plane assembly: detector assembly

- **Goal**: imaging spectroscopy from 0.2 to 10 keV with pnCCD and CAMEX ASIC provided by MPE.
- **Challenges**: space qualification





Focal plane assembly: detector assembly

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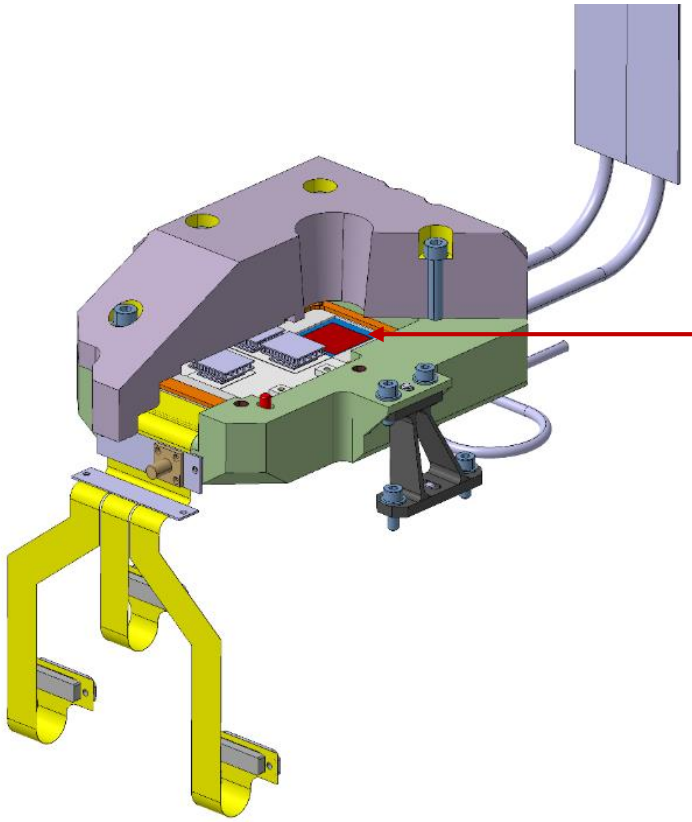
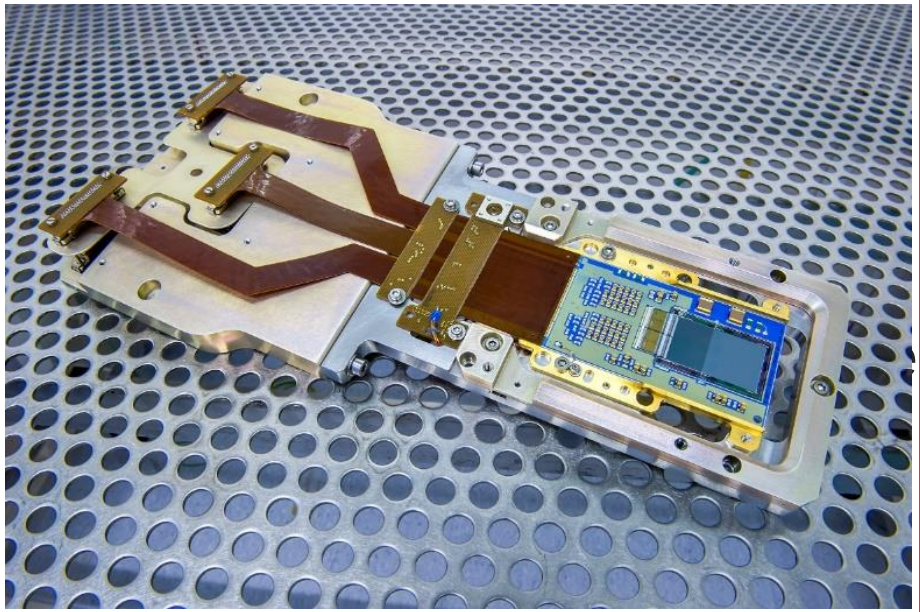
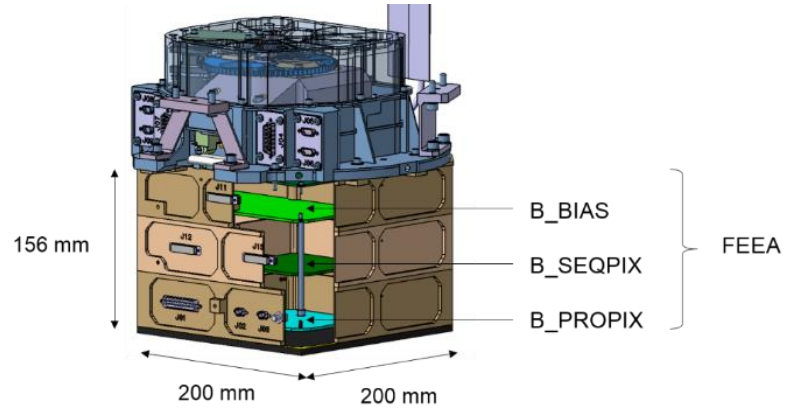




Front-end electronics: hardware



Challenges of the US free design:

- Charge transfer with high voltages
- Atmel FPGA performance

BIAS Board

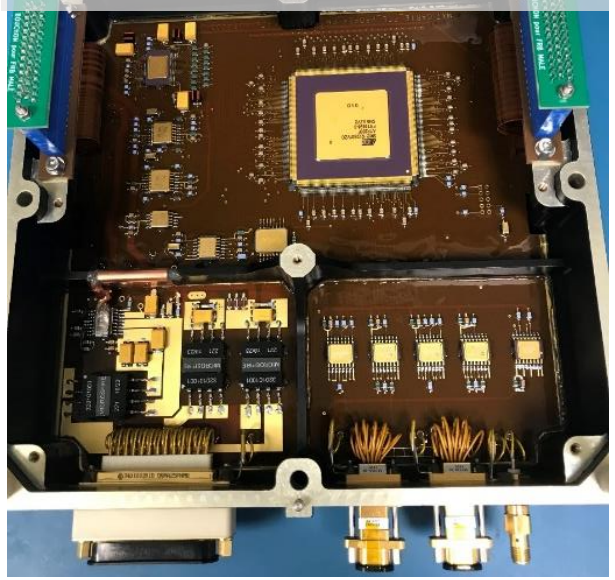
Acquisition channels (ADC)
CCD/CAMEX bias voltages

SEQPIX Board

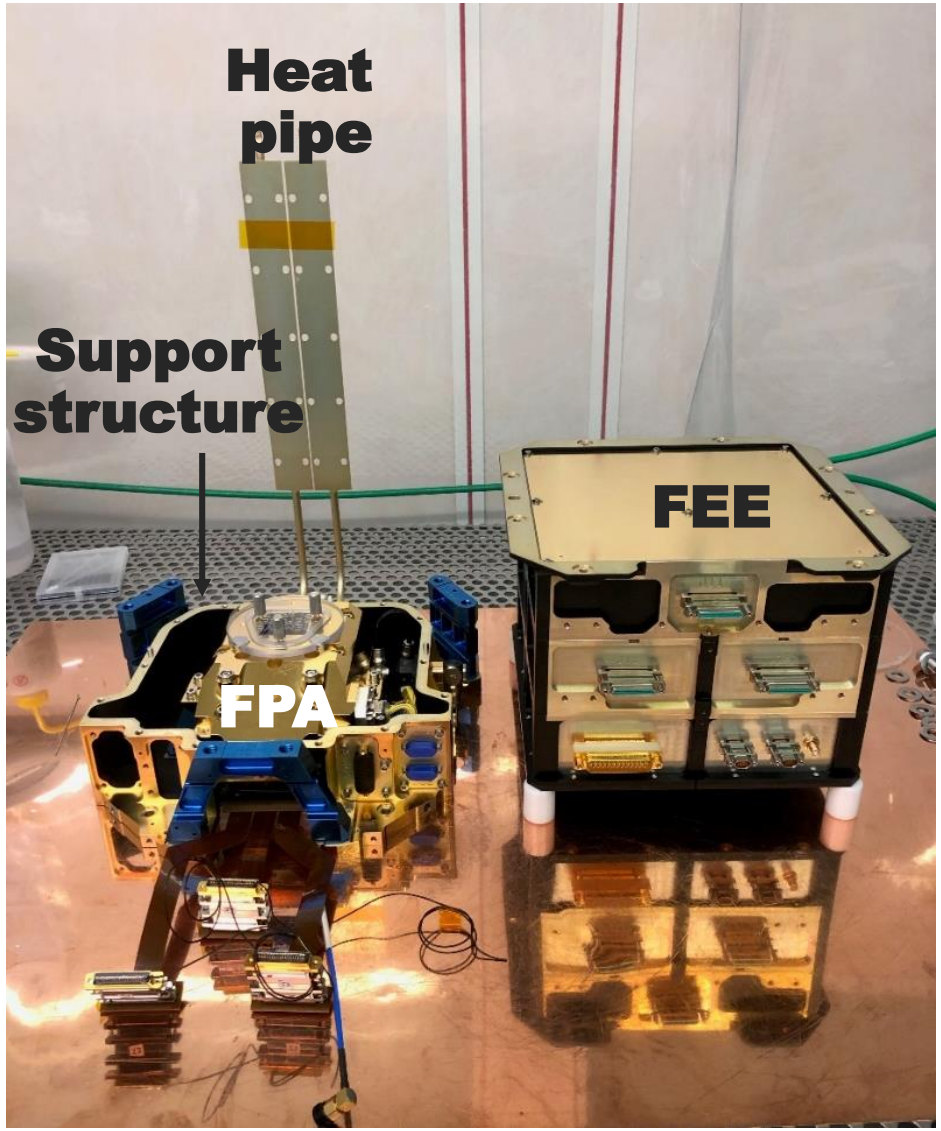
Readout sequencing
Clocks for fast transfer

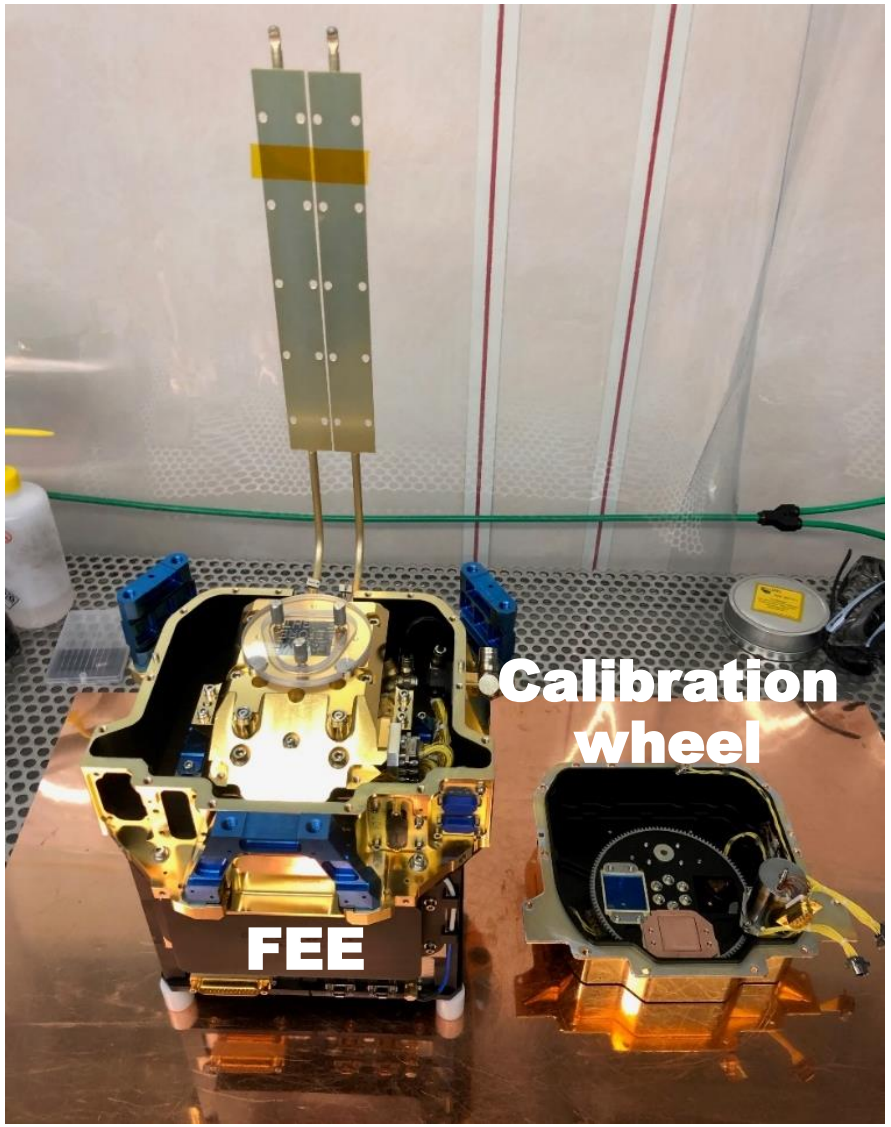
PROPIX Board

Interface with MDPU,
Event pre-processing

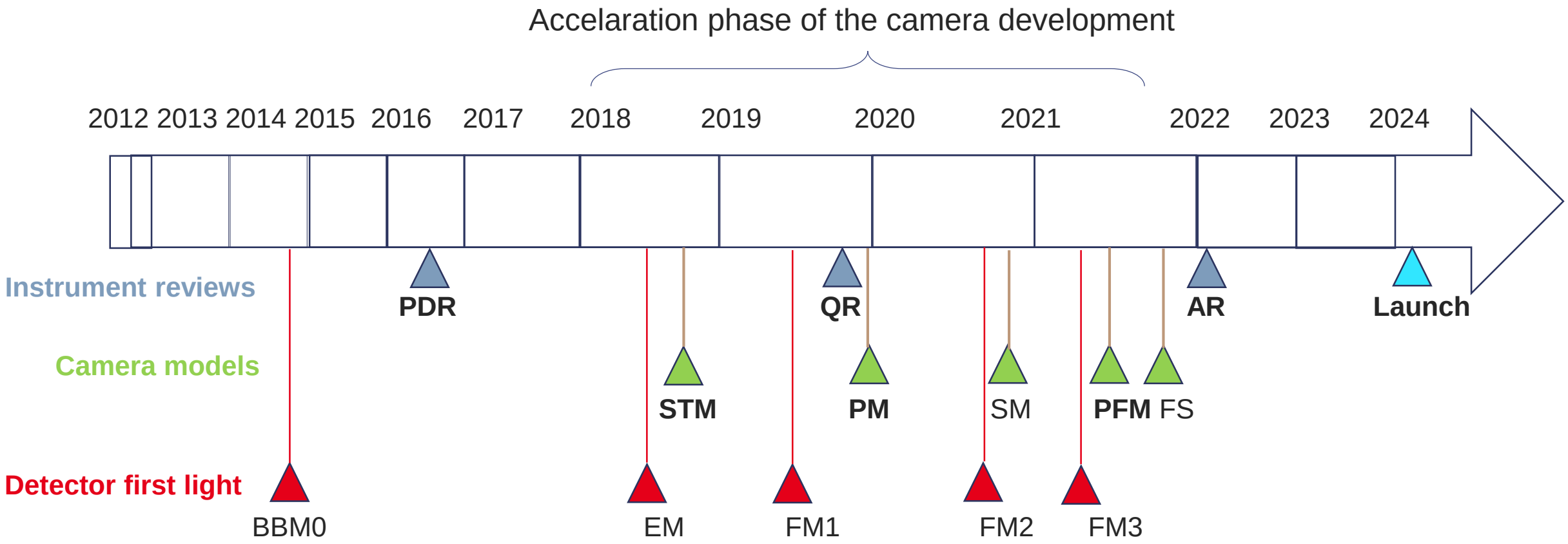


Camera integration





Project development



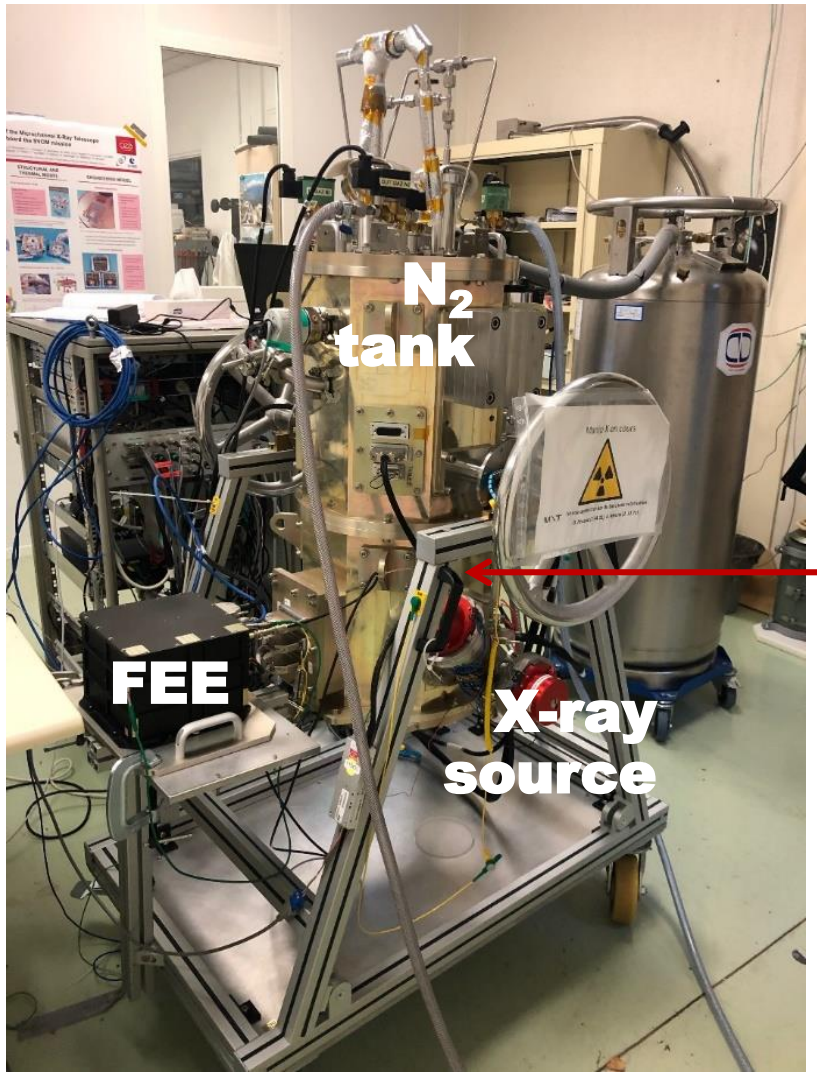
PDR: Preliminary Design Review; QR: Qualification Review; AR: Acceptance Review

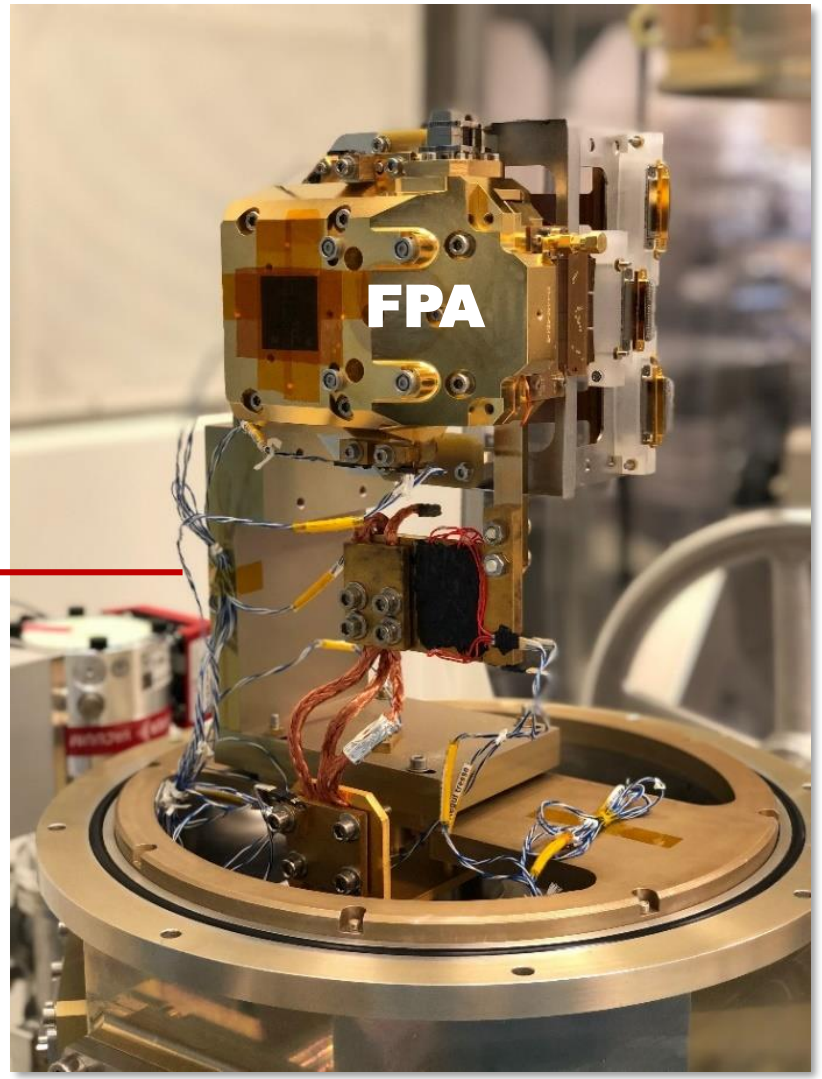
STM: Structural and Thermal Model; PM: Performance Model; SM: Schock Model; PFM: Proto-flight model; FS: Flight Spare

3. The performance characterization

Spectral performance of the detection chain

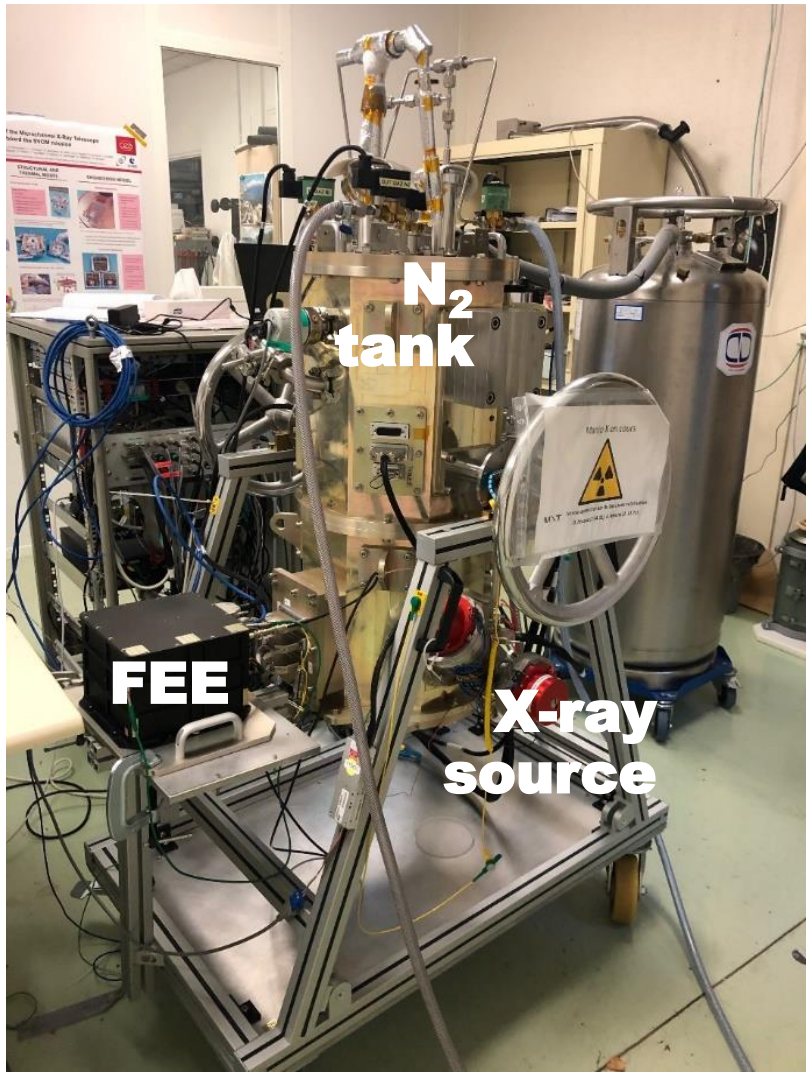
Full-custom cryostat for design validation and initial detector characterizations



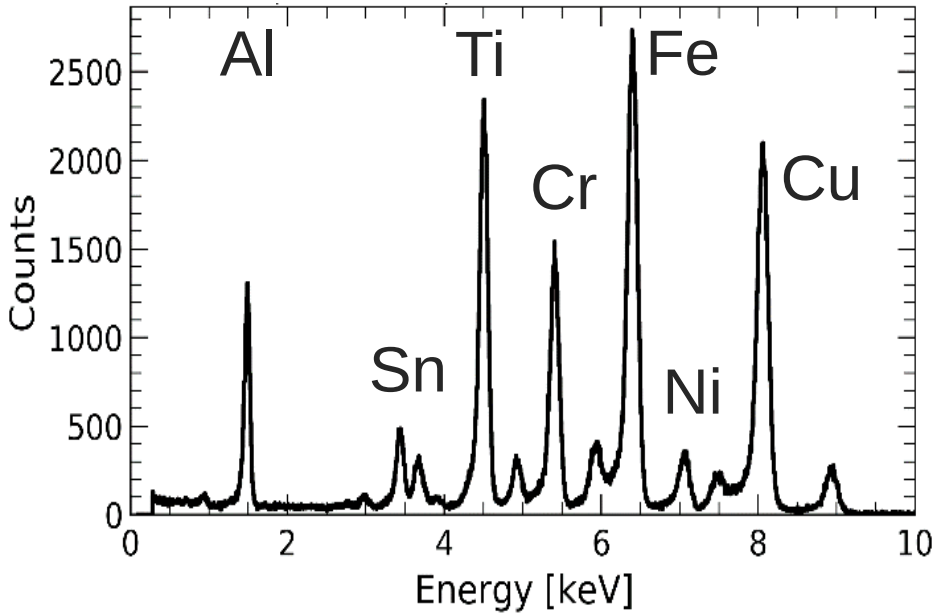


Spectral performance of the FPA

Full-custom cryostat for design validation and initial detector characterizations



Calibration source based on composite fluorescence targets.



+ Complementary spectral data with SOLEIL synchrotron (see Poster P02-13)

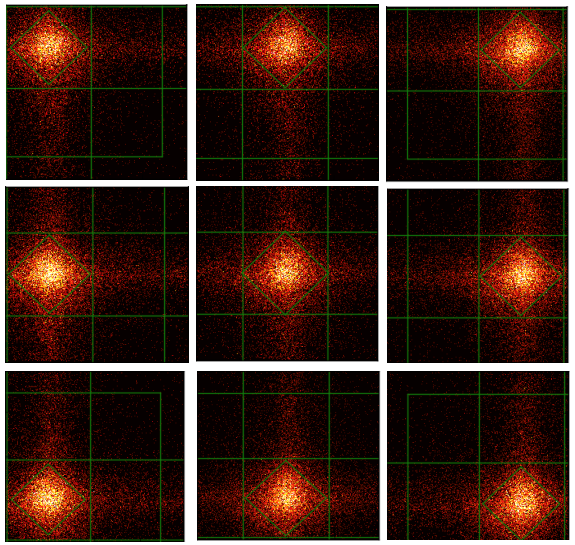
➔ **3 defect-free flight model detector assemblies**

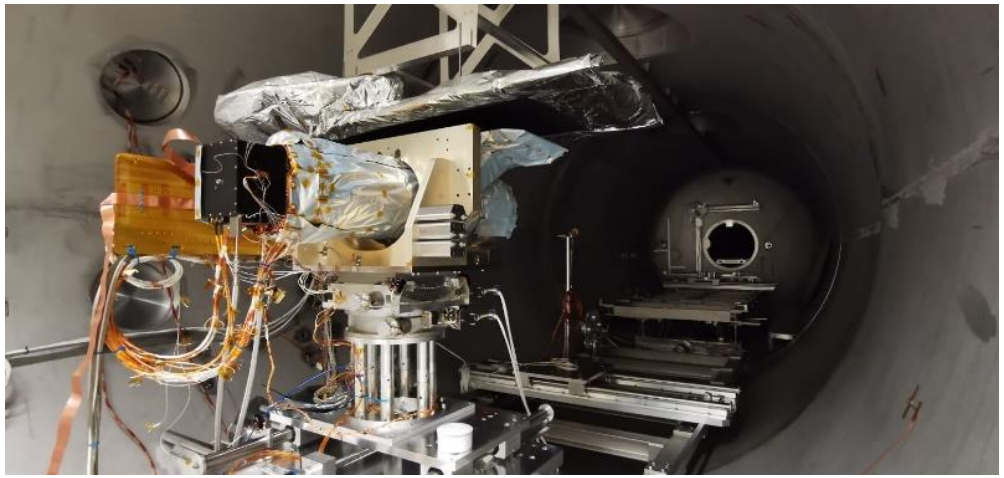
Instrument calibration in panter test facility

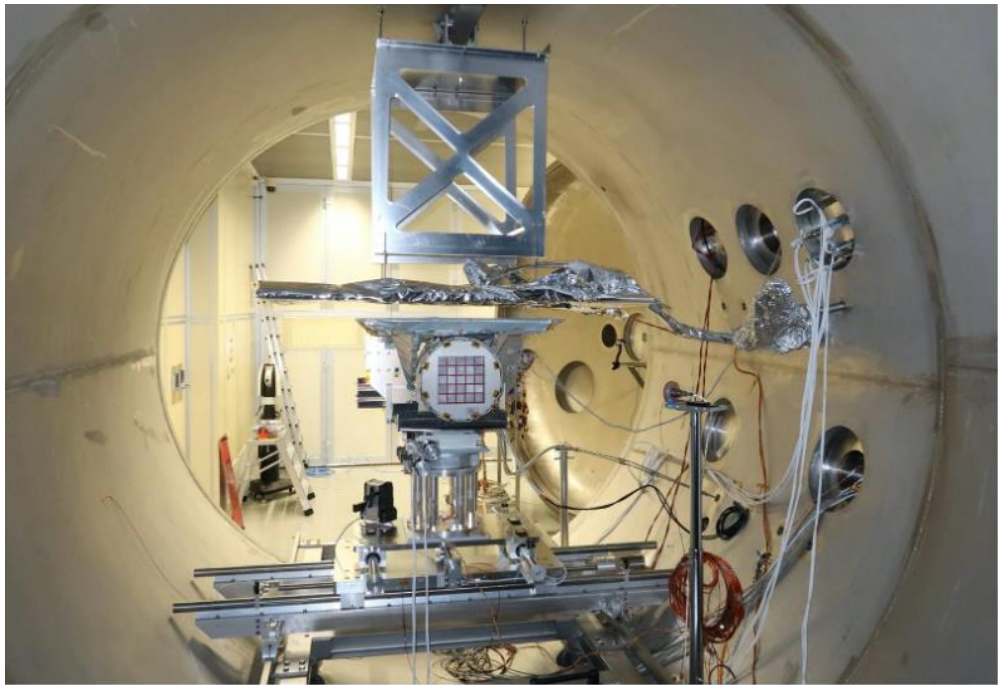
X-ray facility in
Neuried (Germany)

Calibration campaign with the flight instrument in October-November 2021

PSF, Effective area, vignetting characterisation



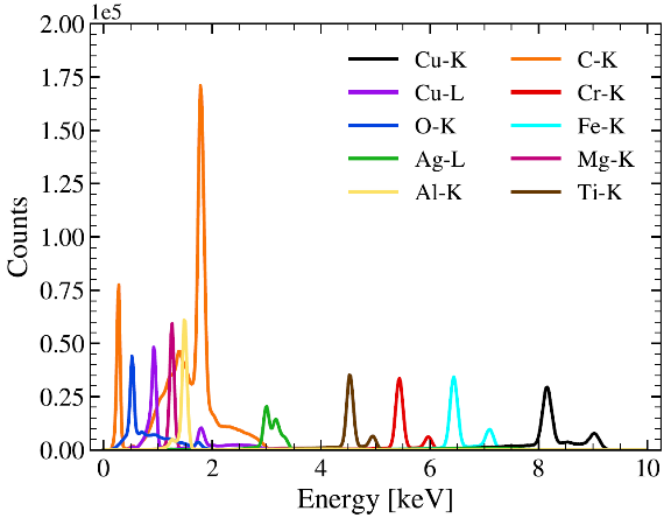


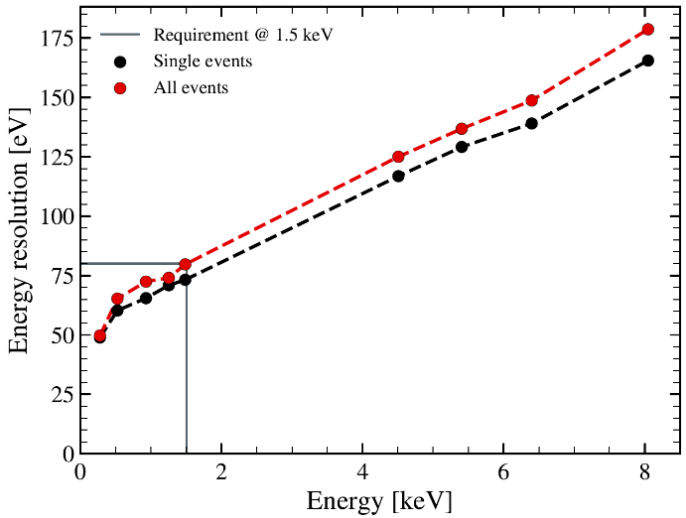


Spectral calibration of the camera

Performance at -65°C (flight operating temperature)

- Gain uniformity within 1 %
- Uniform dark noise map, 45 eV low energy threshold
- 80 eV FWHM @ 1.5 keV with all events





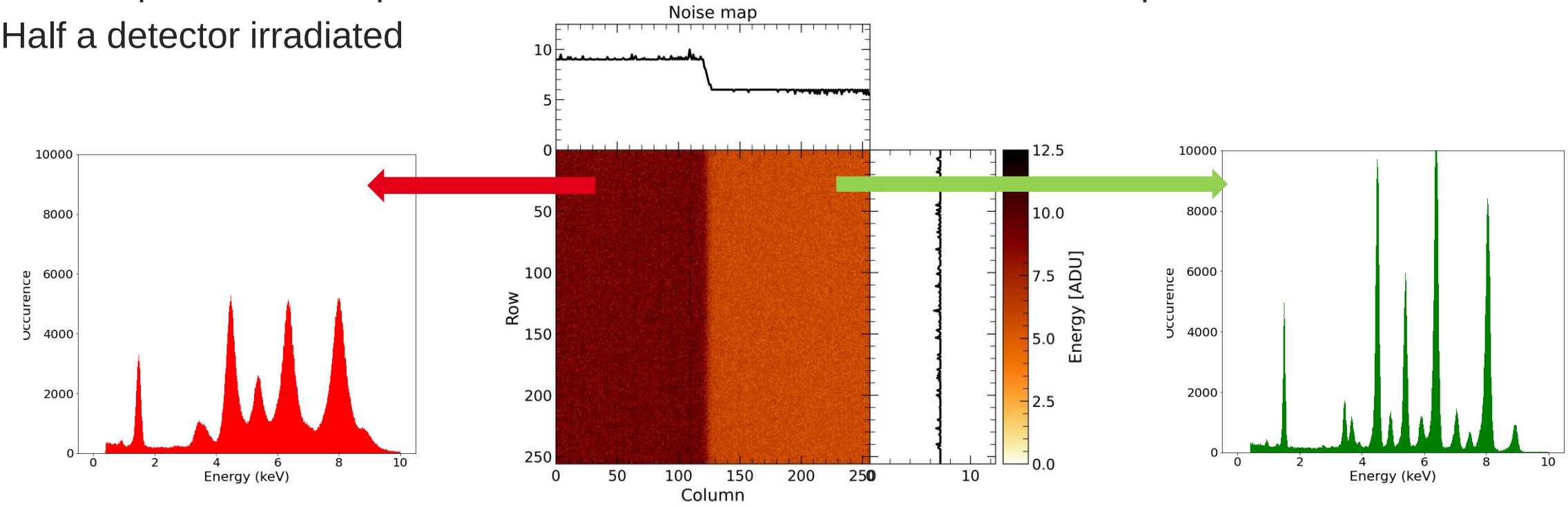
Calibration

- Model of multiple events statistics and spectral calibration method

End-of-life performance

Proton irradiation at Arronax cyclotron in June 2022 to simulate 3 years in orbit with margins

- 50 MeV protons, 6.10^9 protons/cm2 fluence, 2.10^5 protons/cm2/s flux, passive irradiation @RT
- Half a detector irradiated



- On-going caracterization of FWHM, CTI on-going: See Poster C. Plasse

Conclusions

The MXT camera is a compact system that includes all functions for the optimal performance of the detector.

Its development and validation represent:

- 7 detector assemblies (2 with dummy detector for qualification)
- 3 complete camera models (STM, PM, PFM)
- One full custom cryostat and the adaptation of 3 vacuum chambers
- 3 calibration test campaigns (2 in PANTER, 1 in SOLEIL)

The MXT camera fulfills all mission requirements, with spectral performance at the state of the art.

The MXT instrument is ready to fly: right now integrated in the satellite platform for final acceptance tests. Launch planned for beginning 2024.

THANK YOU FOR YOUR ATTENTION