The HERMES & SpIRIT Payload Calibrations

Riccardo Campana – INAF/OAS

On behalf of the HERMES Calibration Team:

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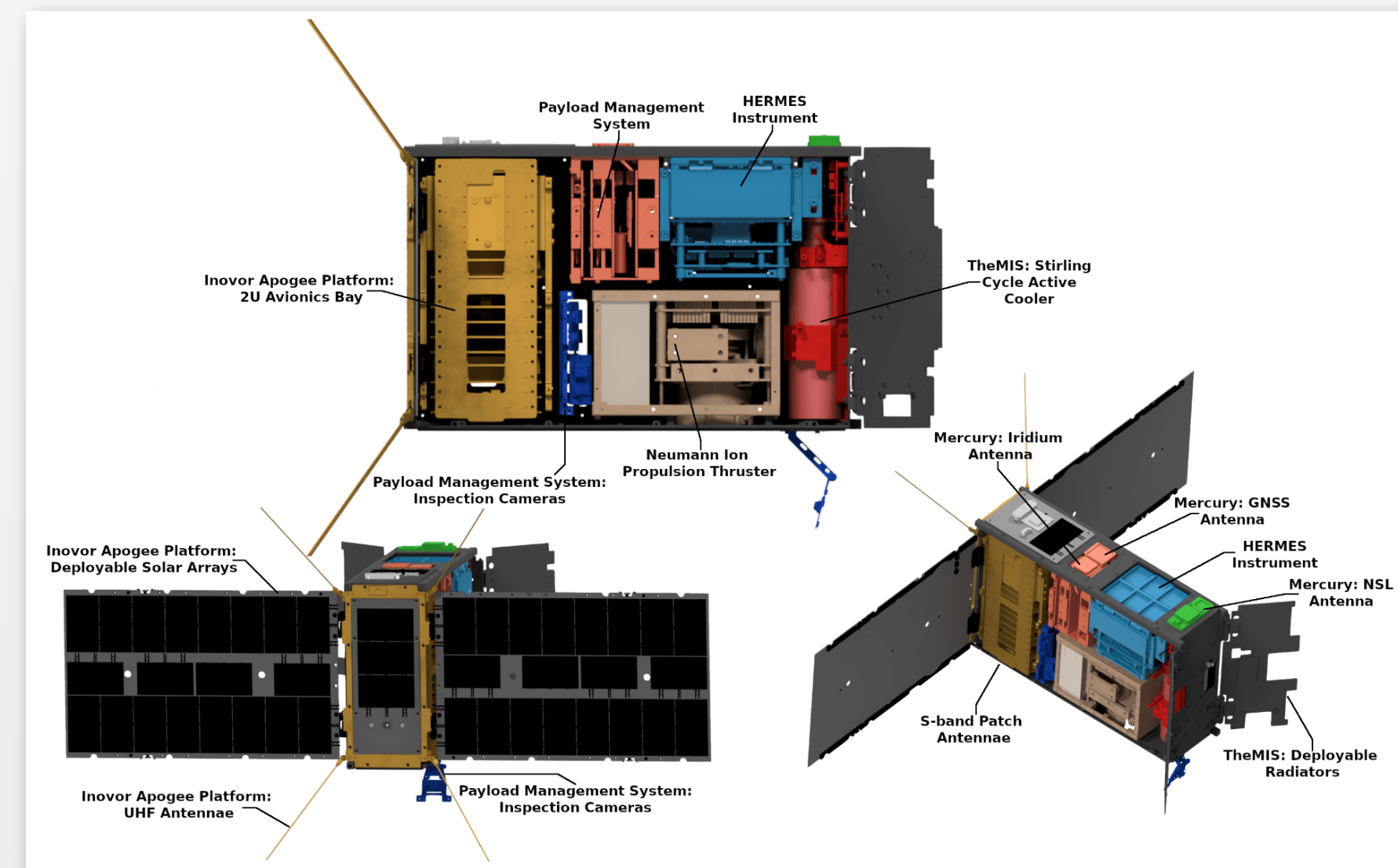
GRB V – Trieste, September 15, 2022

THE POWER OF SEVEN (PAYLOADS)

▶ **HERMES** Technological & Scientific Pathfinder (ASI+H2020 🇪🇺🇮🇹)

➡ Six 3U CubeSats, hosting one HERMES detector each

▶ **SpIRIT**: Space Industry Responsive Intelligent Thermal (UniMelbourne 🇦🇺🇮🇹)

➡ One 6U nanosatellite, the first Australian scientific mission, hosting one HERMES detector

AT THE CORE OF HERMES: TWO INSTRUMENTS IN ONE

▸ *Siswich* architecture → **huge** sensitivity band (3–2000 keV)

▸ **Silicon Drift Detector** (high sensitivity, low noise) +
scintillator crystal (GAGG:Ce, new and performing)

▸ Dual readout:

  ✓ **X-mode**: direct photon absorption in the SDD

  ✓ **S-mode**: absorption in the scintillator crystal, optical
    light readout with SDD

▸ **Different responses**!

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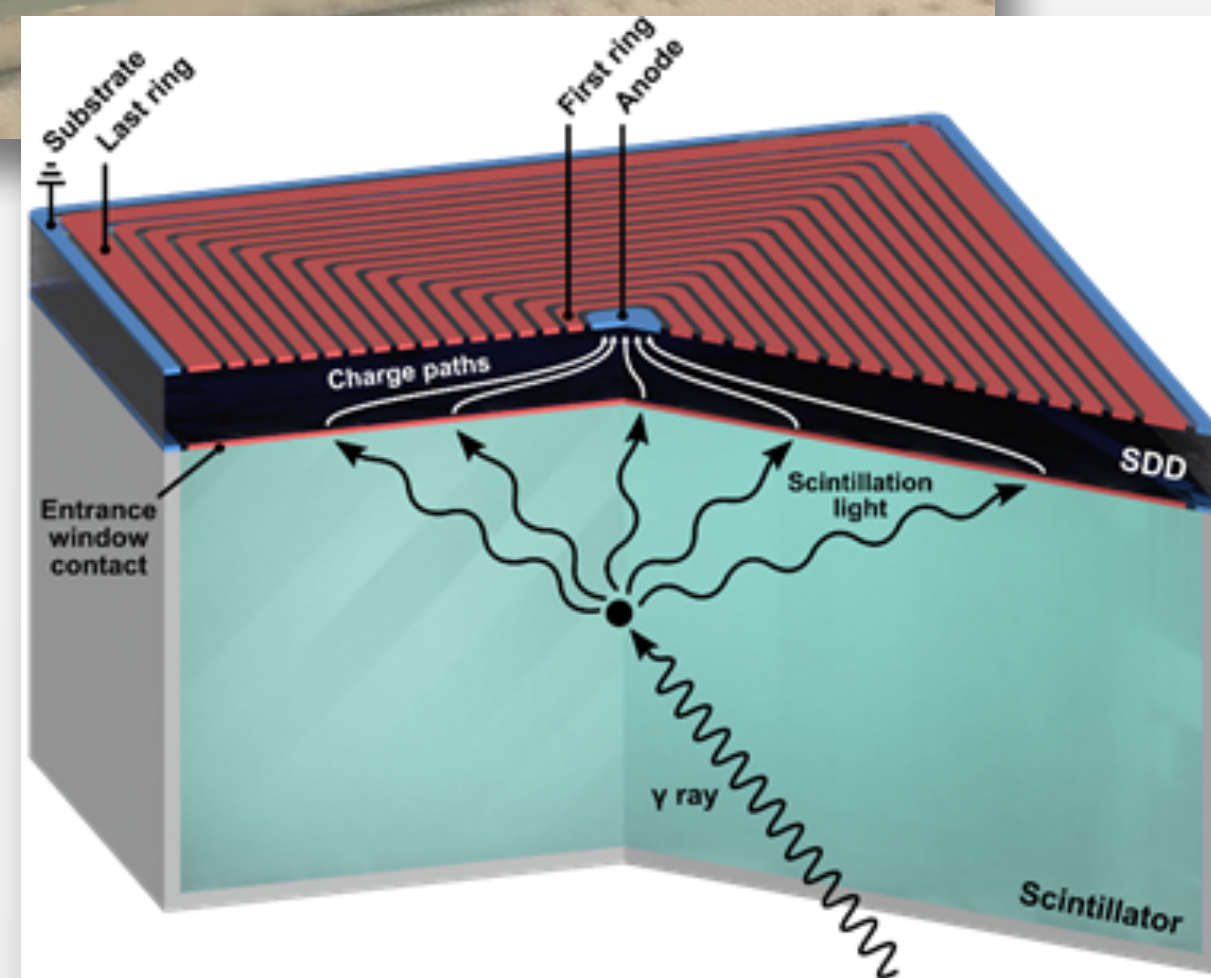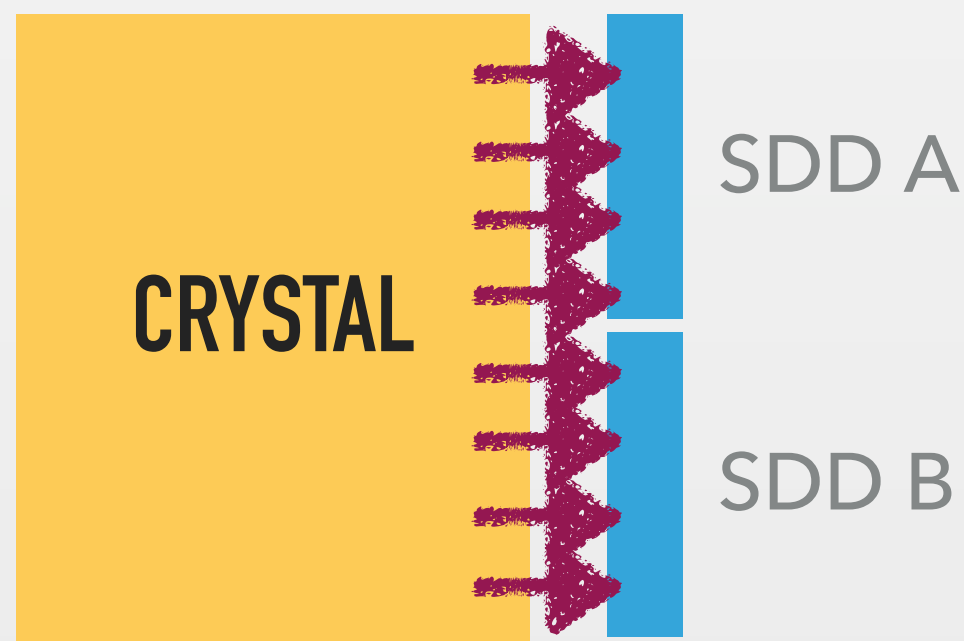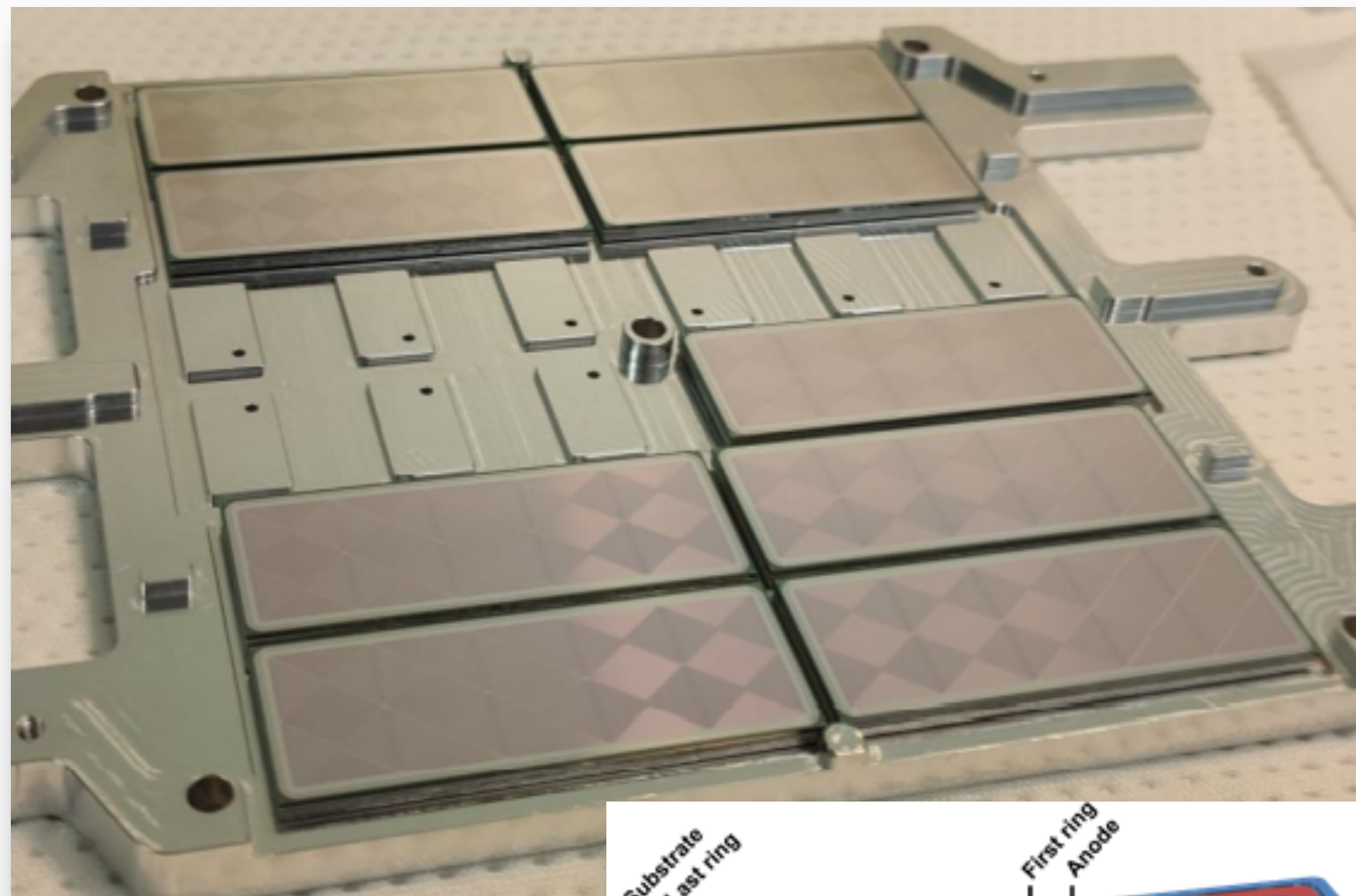   light readout with SDD
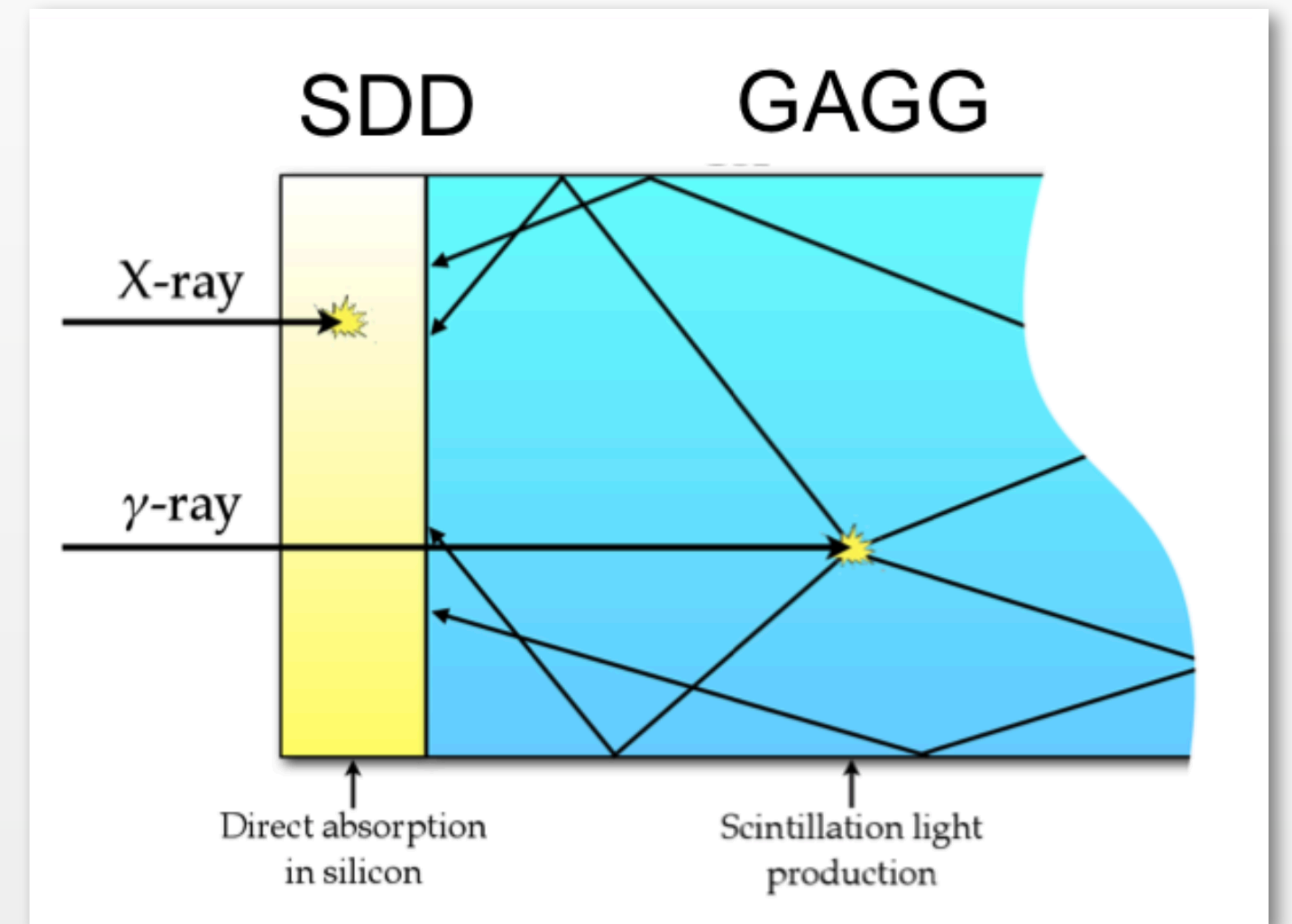
▸ **Different responses**!
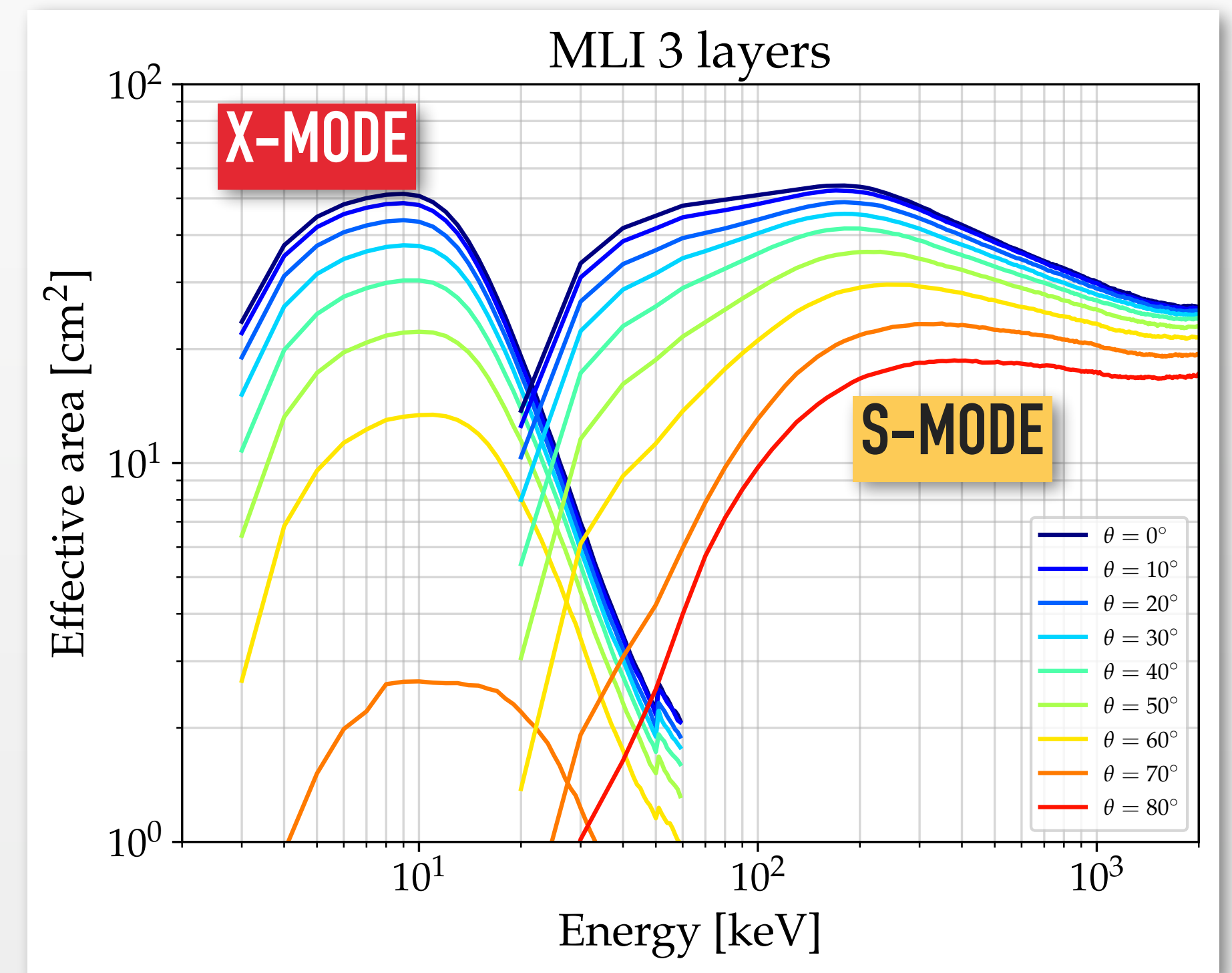
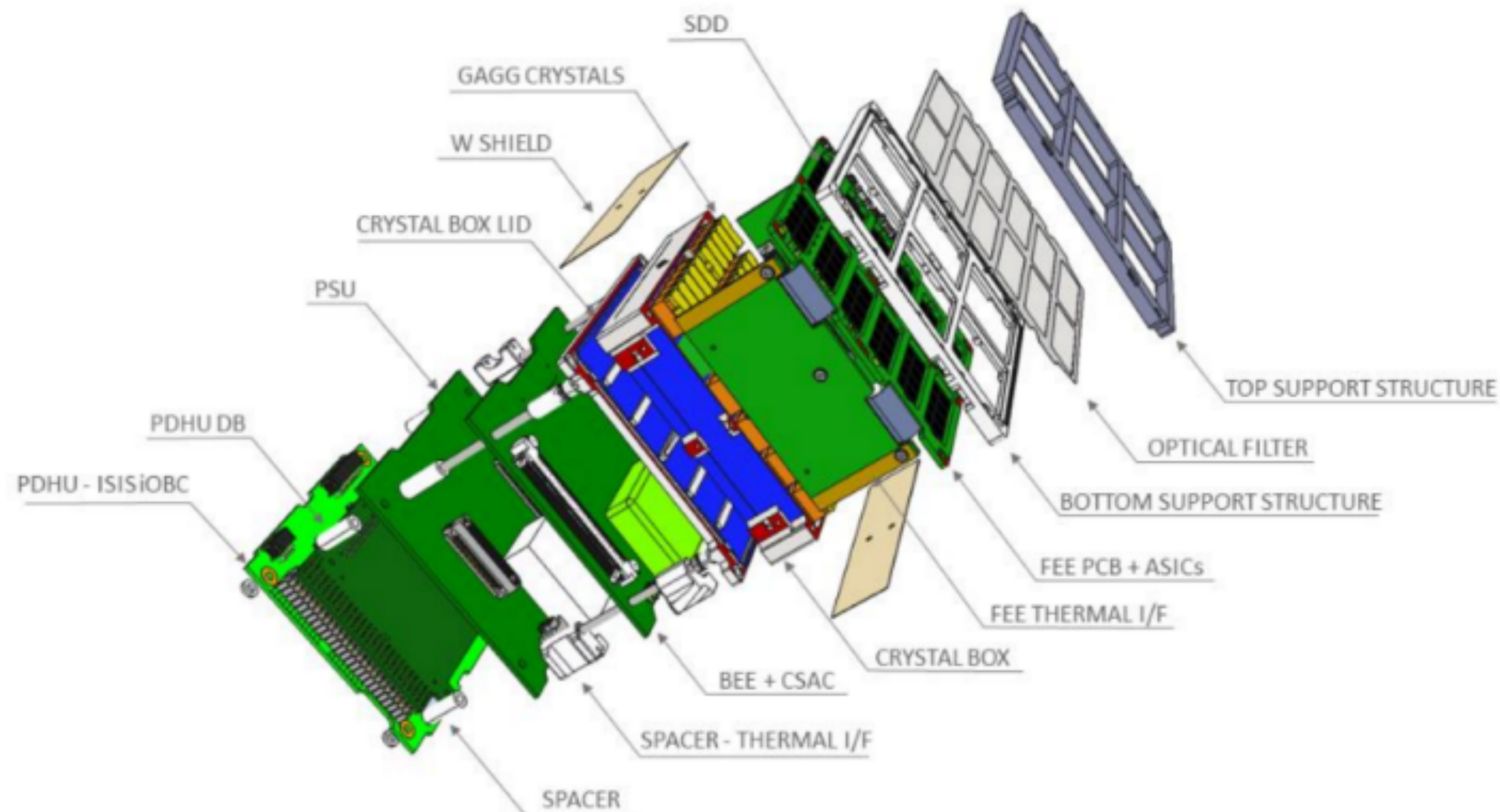# SILICON DRIFT DETECTORS AND EVENT DISCRIMINATION

▸ HERMES uses **multi-cell SDD matrices**: 10 independent cells each

▸ Event discrimination: coupling of one crystal with 2 SDD cells

▸ Trigger in:

  ✓ **one** individual channel: **X-mode** event

  ✓ **two adjacent** channels: **S-mode** event

▸ Fine segmentation of the detector:

  ➡ Redundancy

  ➡ Particle background rejection

HERMES AT A GLANCE

- **12 SDD MATRICES (120 CHANNELS)**
- **60 GAGG:CE SCINTILLATORS**
- **FRONT-END ELECTRONICS (FEE)**
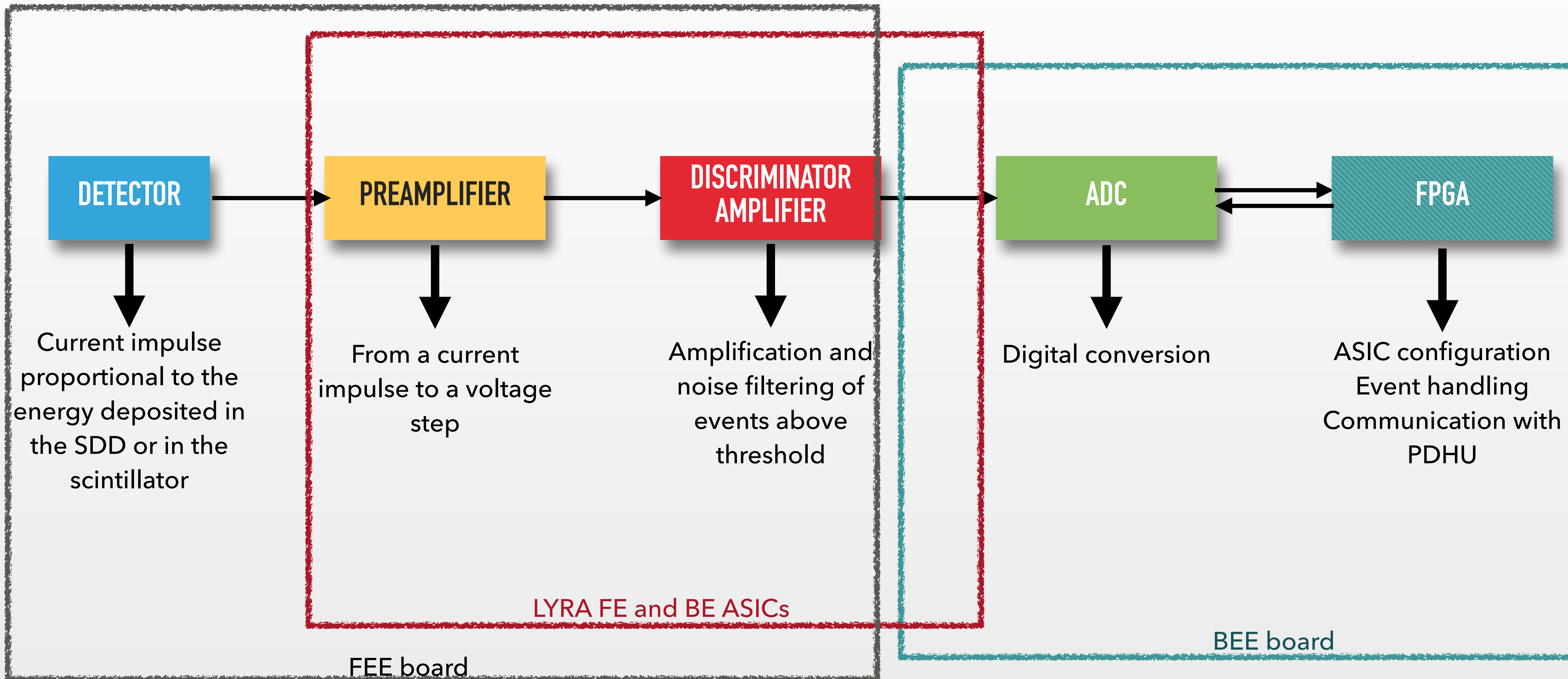- **BACK-END ELECTRONICS (BEE)**
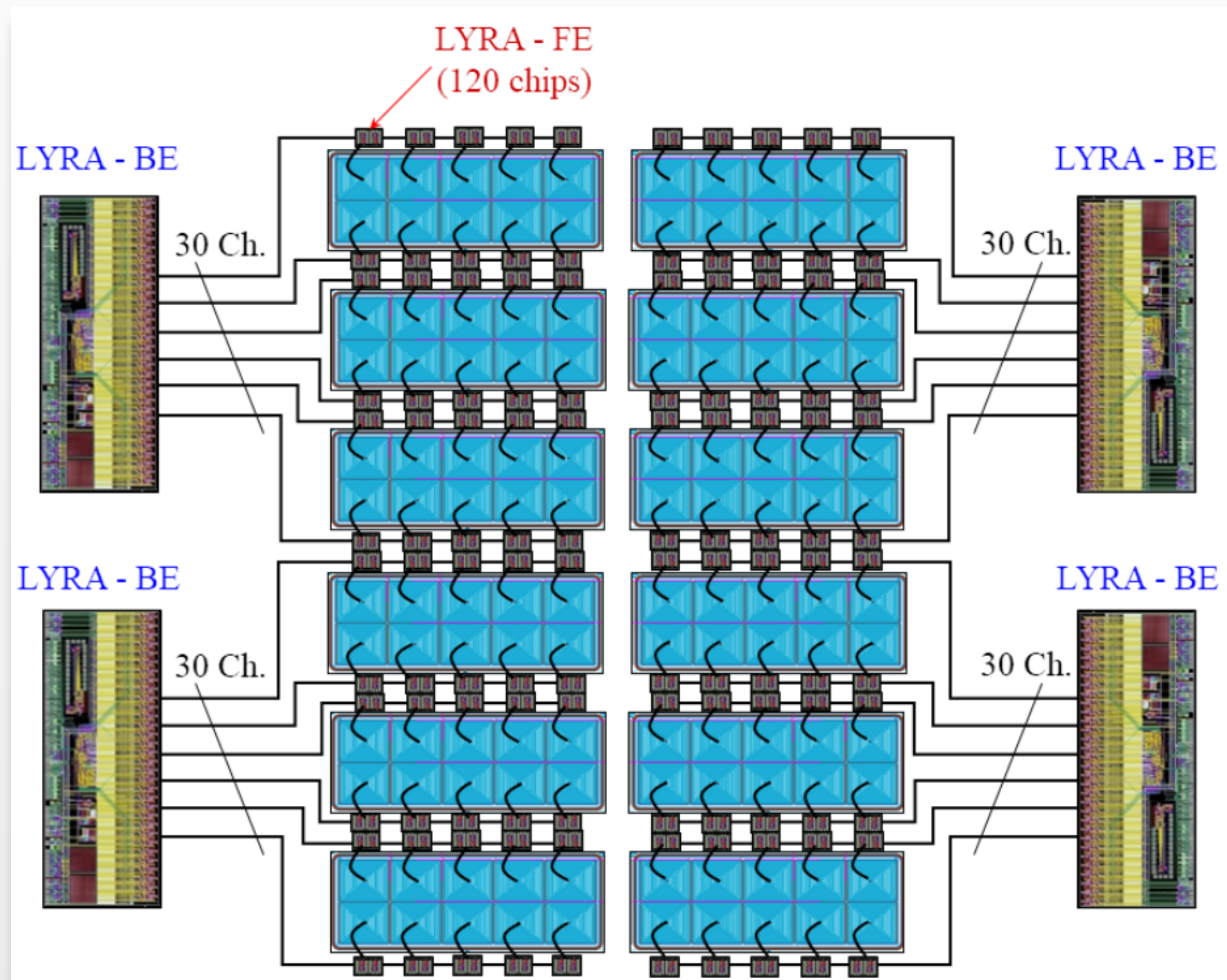- **POWER SUPPLY UNIT (PSU)**
- **PAYLOAD DATA HANDLING UNIT (PDHU)**

FRONT-END AND BACK-END ELECTRONICS

FEE ELECTRONICS

For each payload:

➡ 120 LYRA-FE (single-channel, preamplifier)

➡ 4 LYRA-BE (multichannel, shaper, discriminator, peak&hold)

➡ 4 fully independent quadrants

Each payload has **120** channels to be individually calibrated!

PAYLOAD CALIBRATIONS

SIGNAL
AMPLITUDE
(ADC UNITS)

PAYLOAD CALIBRATIONS

SIGNAL AMPLITUDE (ADC UNITS)

Parameters of each electronic chain

GAIN [ADC/keV]

X-MODE CALIBRATION

OFFSET [ADC]

Radioactive sources: ^{55}Fe, ^{109}Cd, …

PAYLOAD CALIBRATIONS

SIGNAL AMPLITUDE (ADC UNITS)

X-MODE ENERGY UNITS (keV)

Parameters of each electronic chain

GAIN [ADC/keV]

X-MODE CALIBRATION

OFFSET [ADC]

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PAYLOAD CALIBRATIONS

X-ray events in SDD:
1 e− every 3.65 eV deposited

SIGNAL AMPLITUDE (ADC UNITS) → **X-MODE ENERGY UNITS (keV)** → **ABSOLUTE ELECTRIC CHARGE AT DETECTOR ANODE (electrons)**

Parameters of each electronic chain

X-MODE CALIBRATION

GAIN [ADC/keV]

OFFSET [ADC]

Radioactive sources: ^{55}Fe, ^{109}Cd, …

PAYLOAD CALIBRATIONS

X-ray events in SDD:
1 e– every 3.65 eV deposited

SIGNAL AMPLITUDE (ADC UNITS) → **X-MODE ENERGY UNITS (keV)** → **ABSOLUTE ELECTRIC CHARGE AT DETECTOR ANODE (electrons)** →

Parameters of each electronic chain

Optical contact efficiency

GAIN [ADC/keV]

LIGHT OUTPUT [e–/keV]

X-MODE CALIBRATION

OFFSET [ADC]

S-MODE CALIBRATION

Radioactive sources: ^{55}Fe, ^{109}Cd, …

Radioactive sources: ^{137}Cs

PAYLOAD CALIBRATIONS

X-ray events in SDD:
1 e– every 3.65 eV deposited

| SIGNAL AMPLITUDE (ADC UNITS) | → | X-MODE ENERGY UNITS (keV) | → | ABSOLUTE ELECTRIC CHARGE AT DETECTOR ANODE (electrons) | → | S-MODE ENERGY UNITS (keV) |

Parameters of each electronic chain

Optical contact efficiency

GAIN [ADC/keV]

LIGHT OUTPUT [e–/keV]

X-MODE CALIBRATION

OFFSET [ADC]

S-MODE CALIBRATION

Radioactive sources: ^{55}Fe, ^{109}Cd, …

Radioactive sources: ^{137}Cs

PAYLOAD CALIBRATIONS

SIGNAL AMPLITUDE (ADC UNITS) → **X-MODE ENERGY UNITS (keV)** →

X-ray events in SDD:
1 e– every 3.65 eV deposited

ABSOLUTE ELECTRIC CHARGE AT DETECTOR ANODE (electrons) → **S-MODE ENERGY UNITS (keV)**

Parameters of each electronic chain

Optical contact efficiency

GAIN [ADC/keV]

LIGHT OUTPUT [e–/keV]

X-MODE CALIBRATION

OFFSET [ADC]

S-MODE CALIBRATION

Radioactive sources: ^{55}Fe, ^{109}Cd, ...

Radioactive sources: ^{137}Cs

All the parameters are temperature dependent!

EGSE FOR CALIBRATIONS
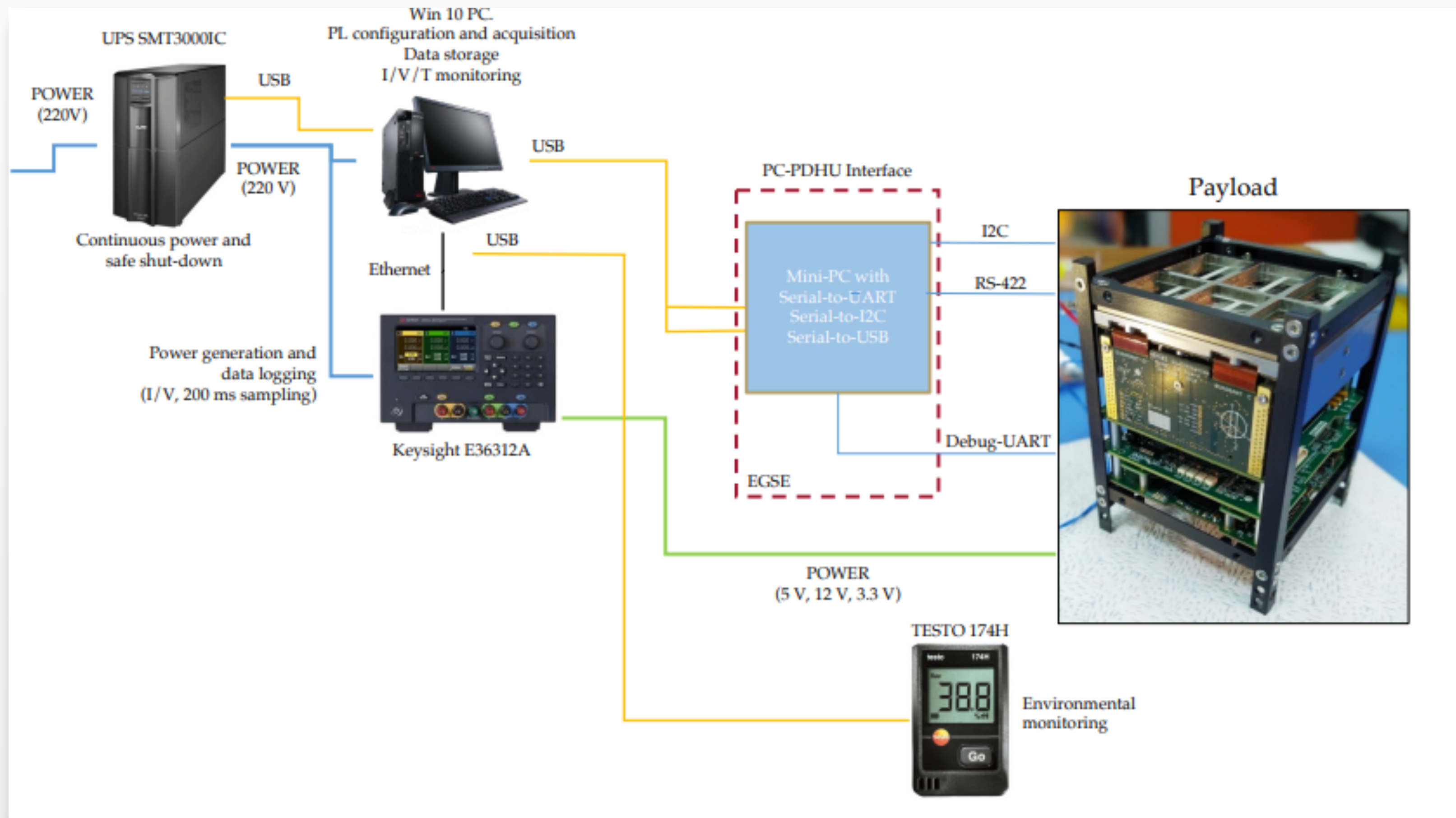
Calibrations performed at INAF/IAPS Clean Room in a temperature-controlled climatic chamber

Temperature range −20 °C to +20 °C

Different FEE operating parameters

CALIBRATIONS

RADIOACTIVE SOURCE

X-ray or γ-ray photons
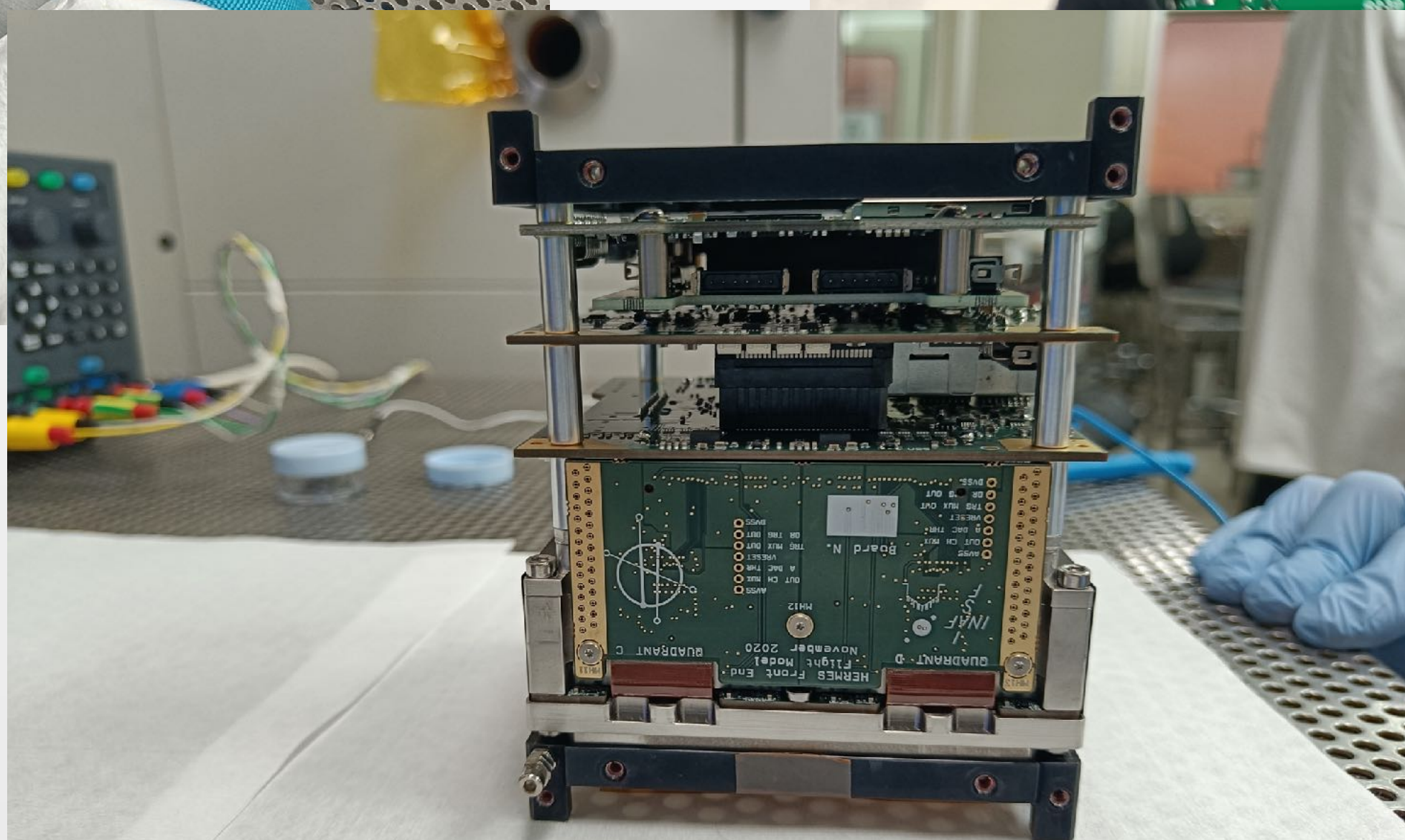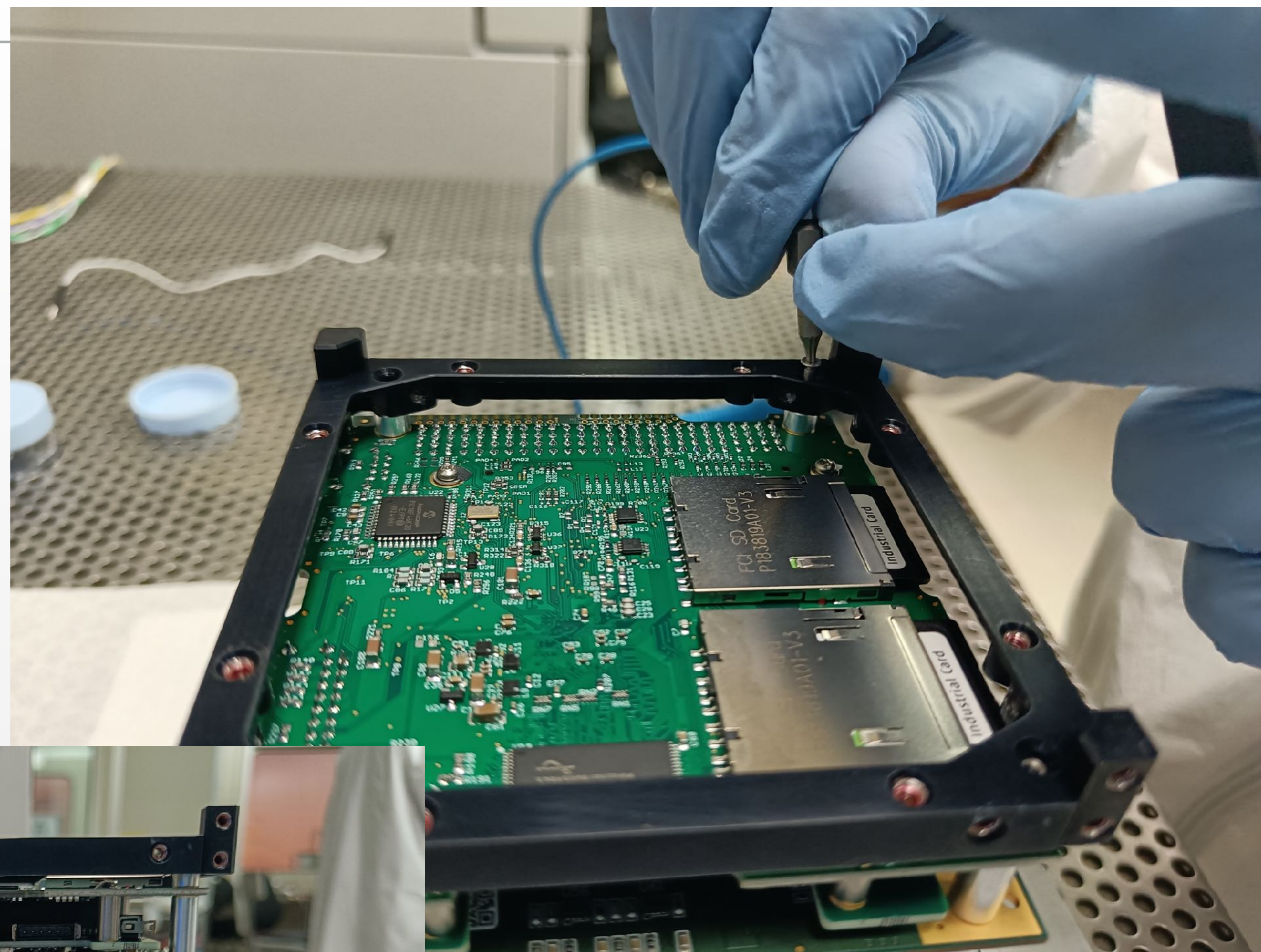
PAYLOAD

FINAL PAYLOAD INTEGRATION
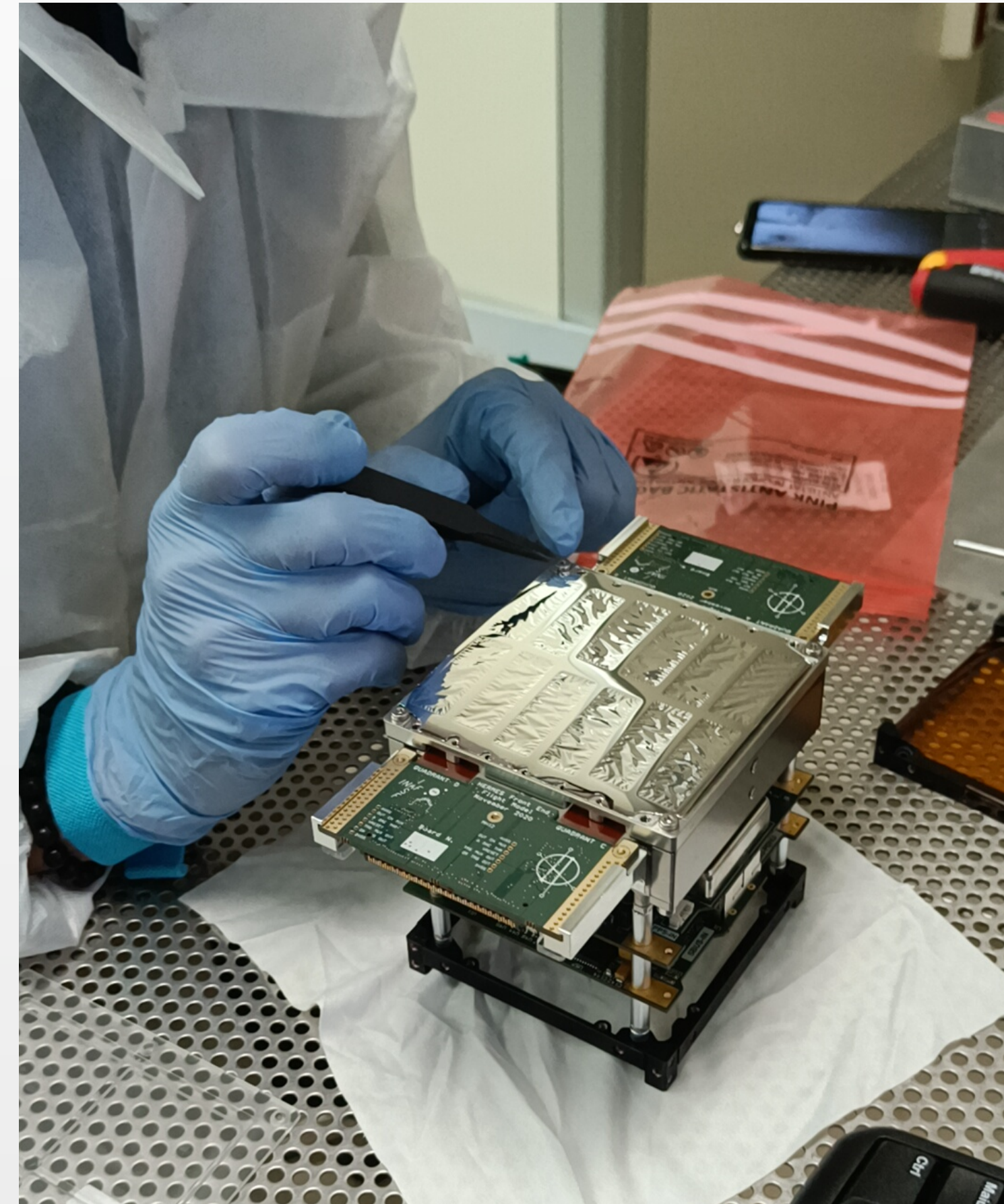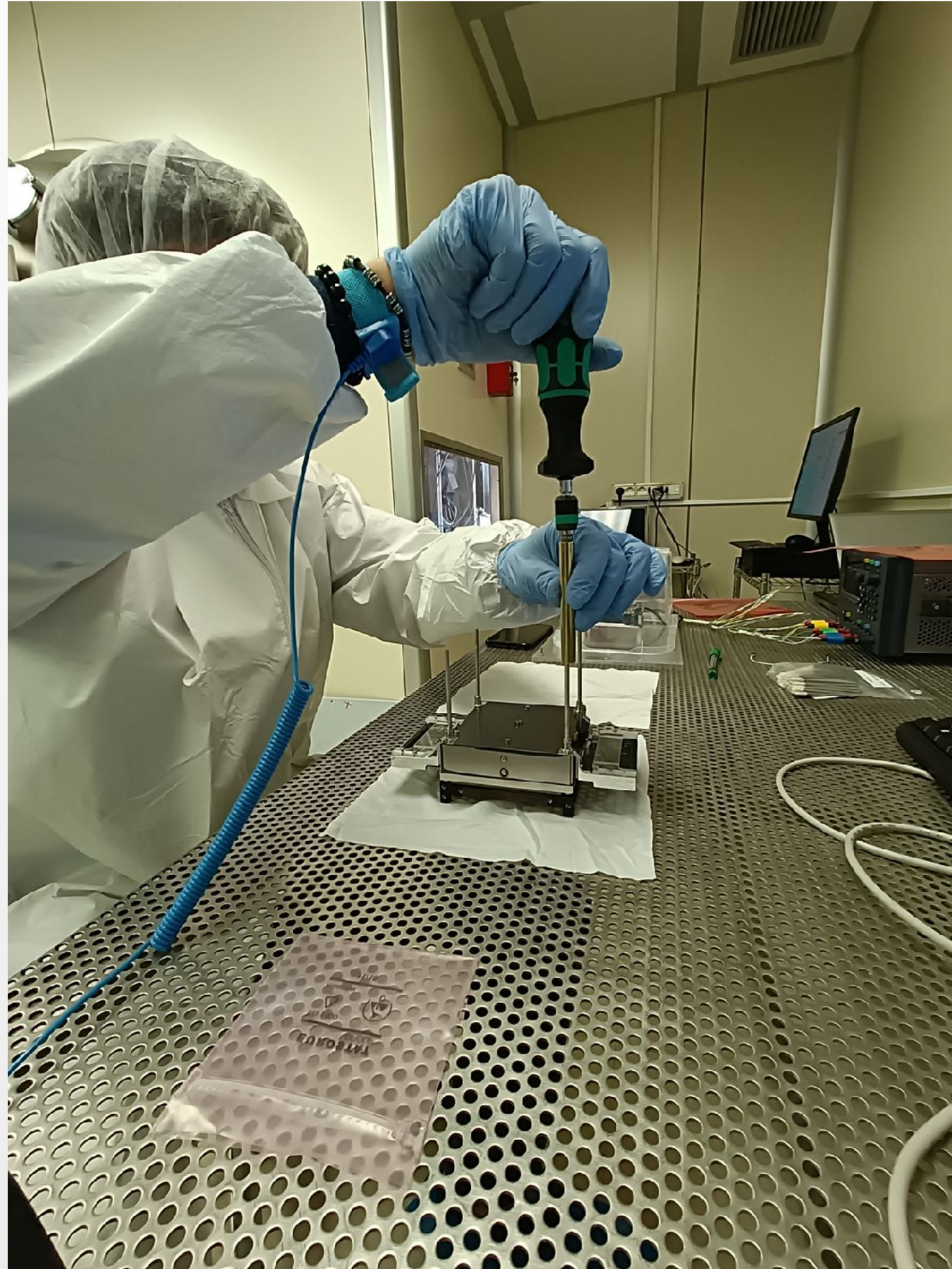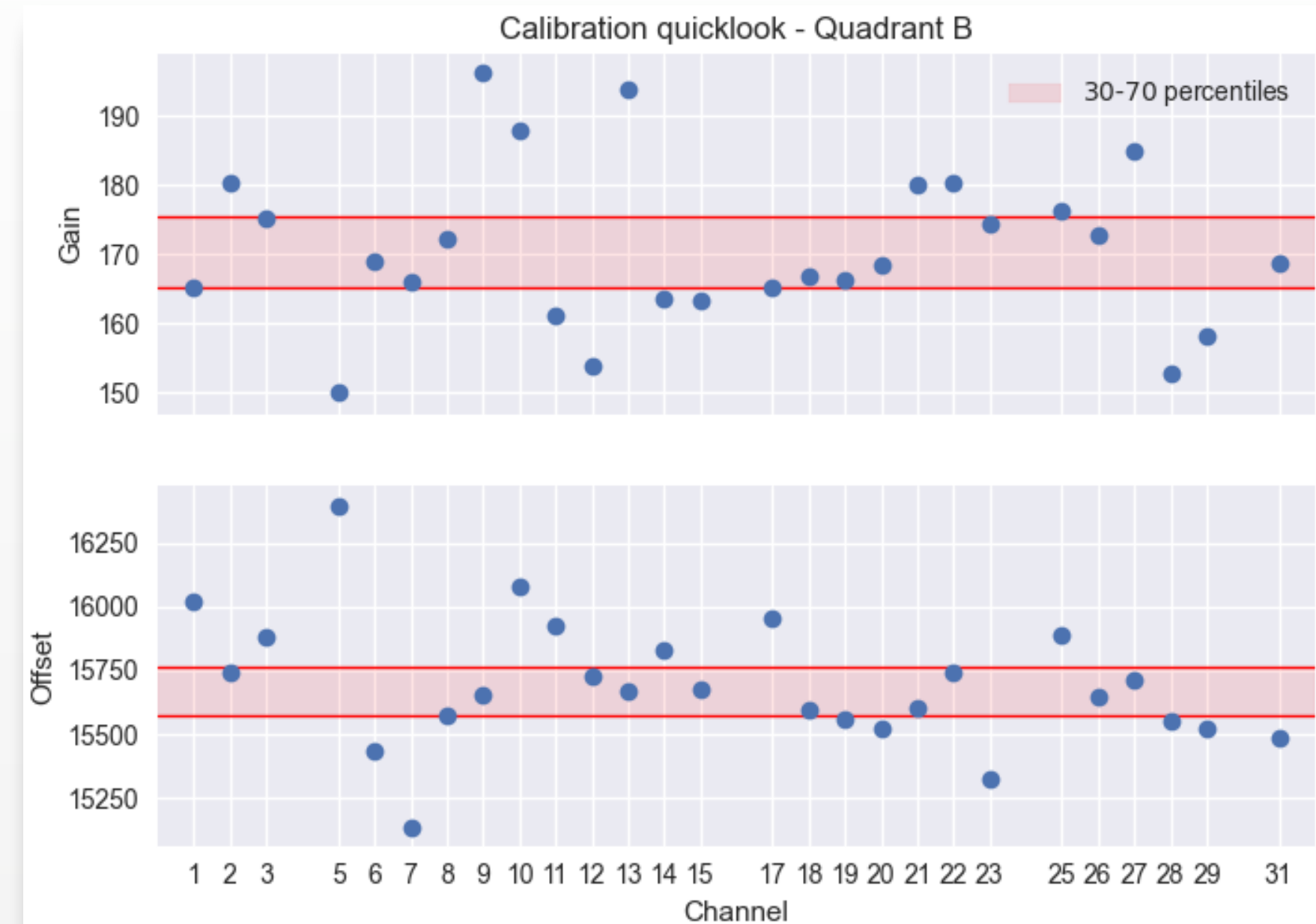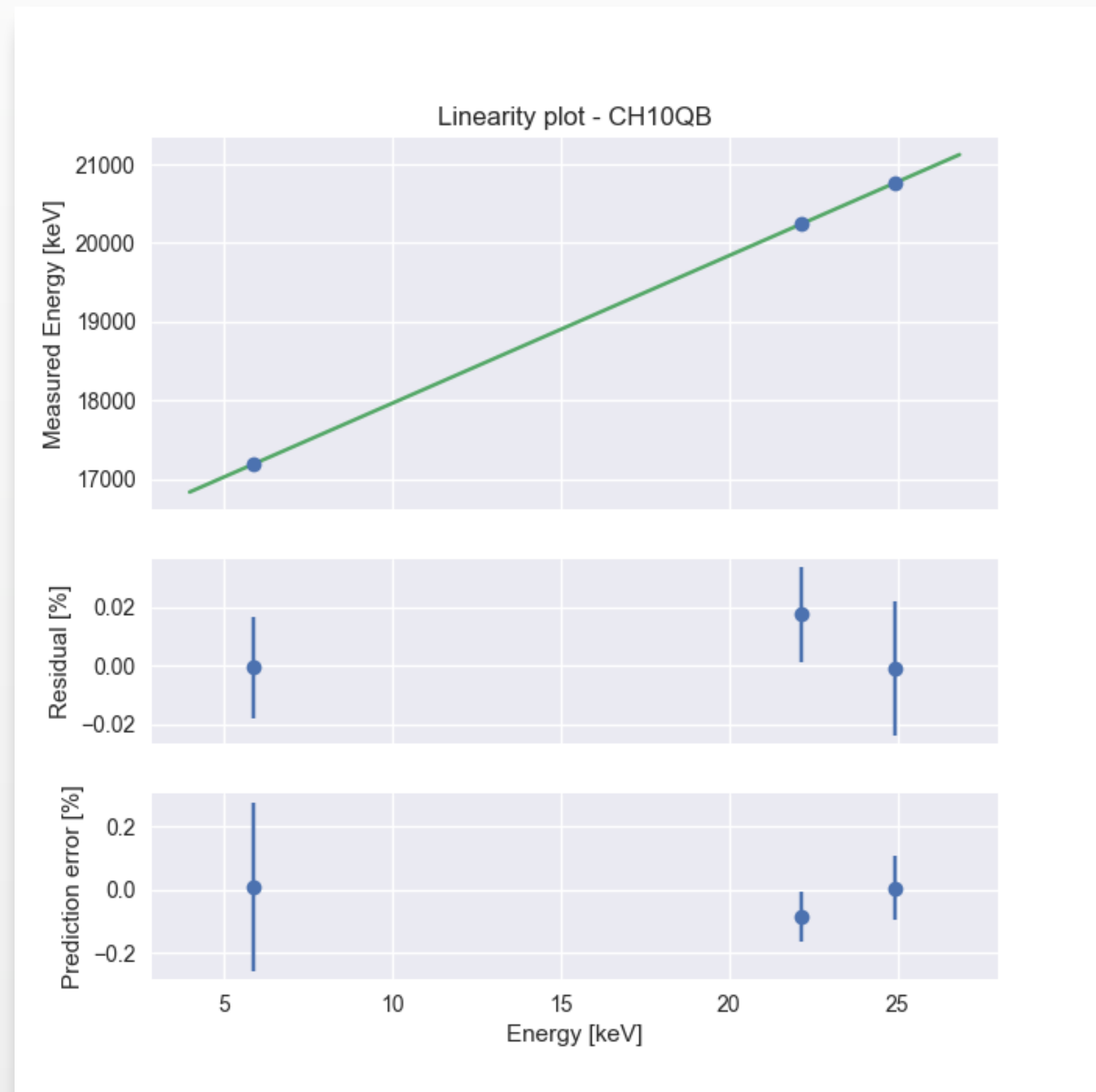
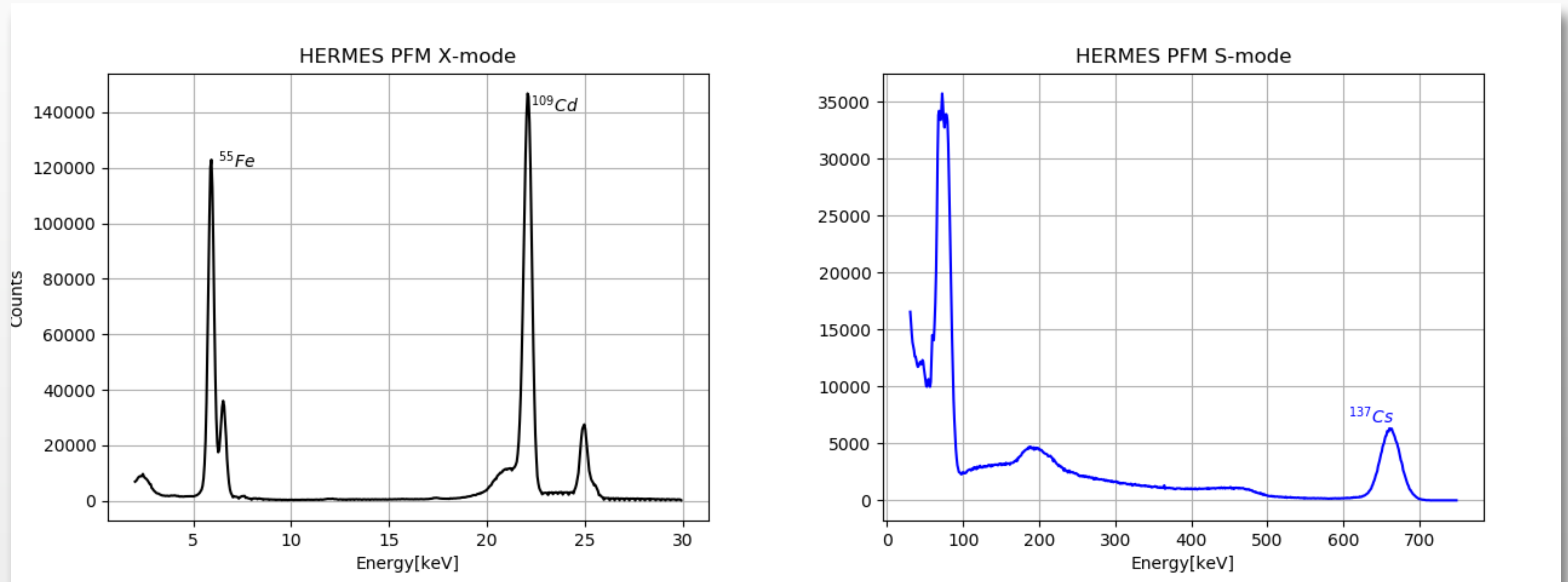# FINAL PAYLOAD INTEGRATION
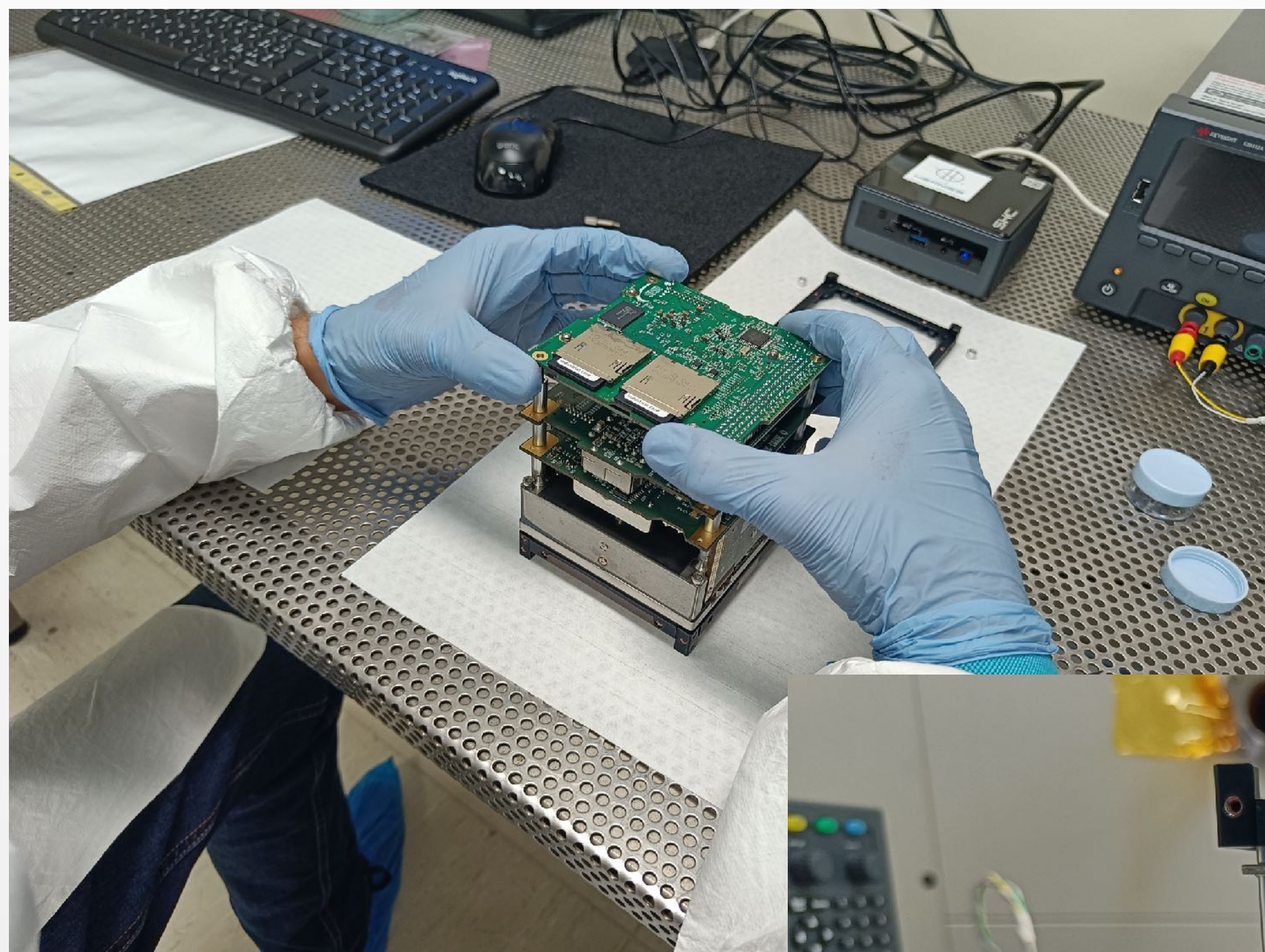
PREPARATION FOR CALIBRATIONS
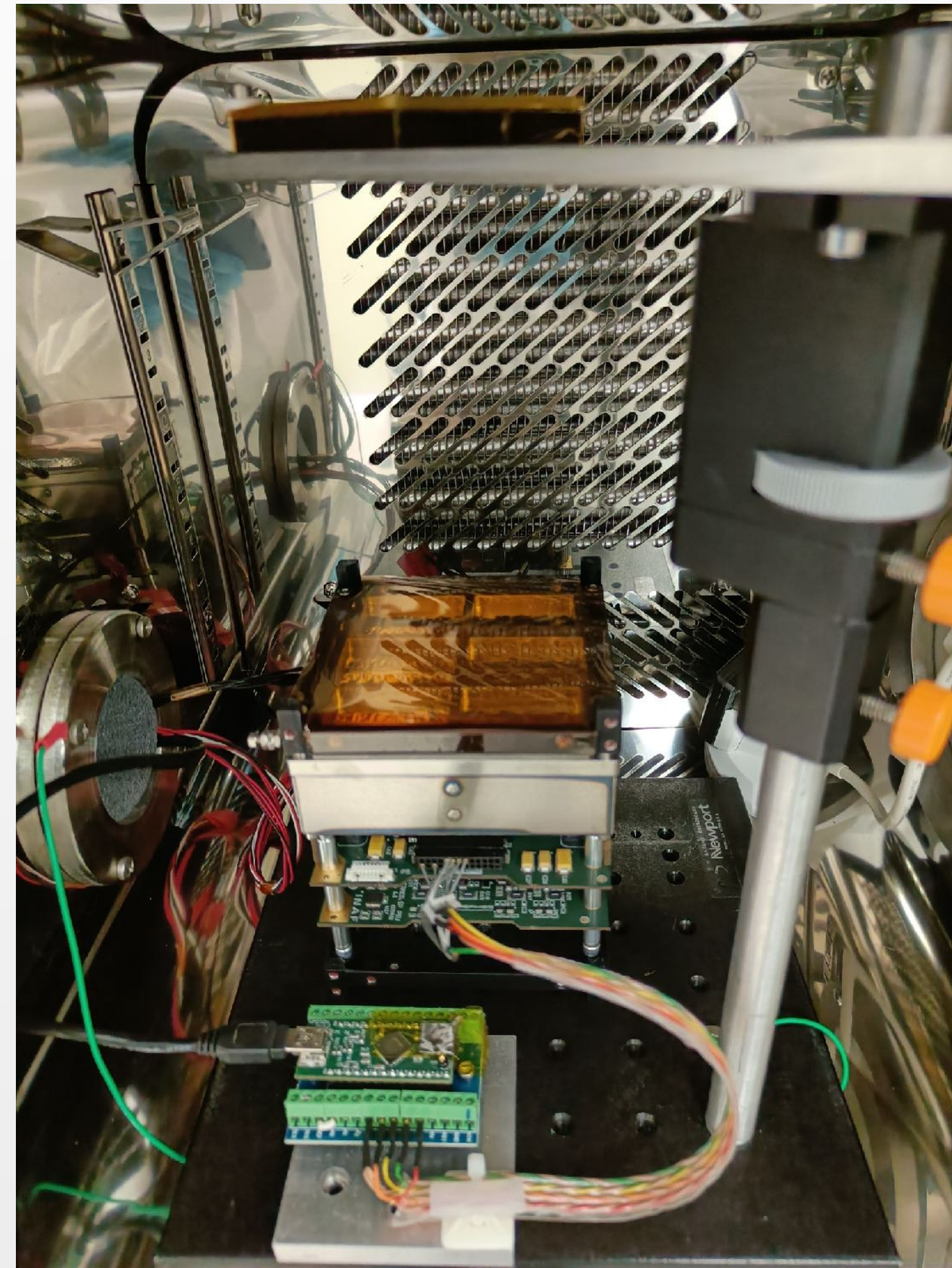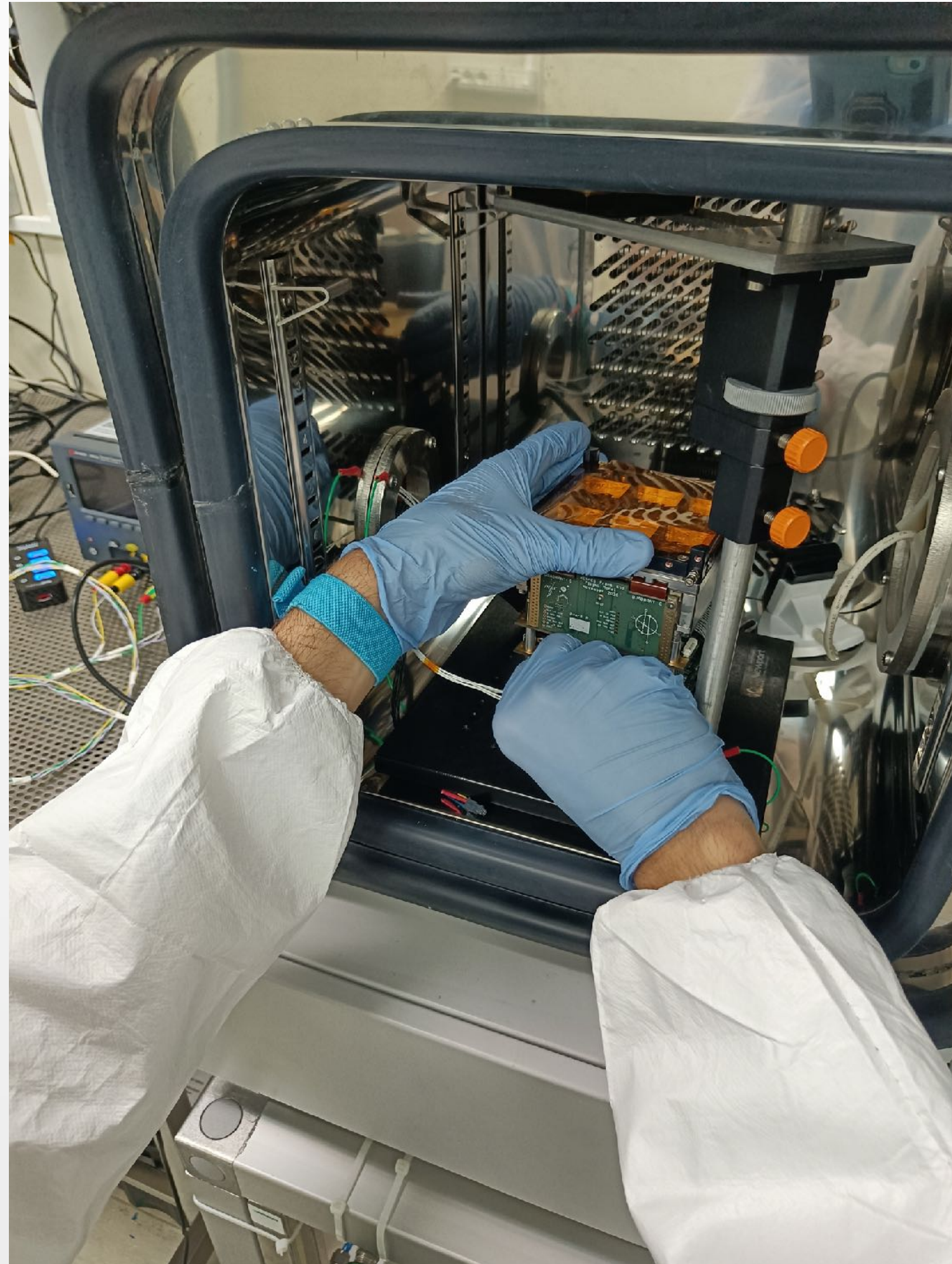
RESULTS
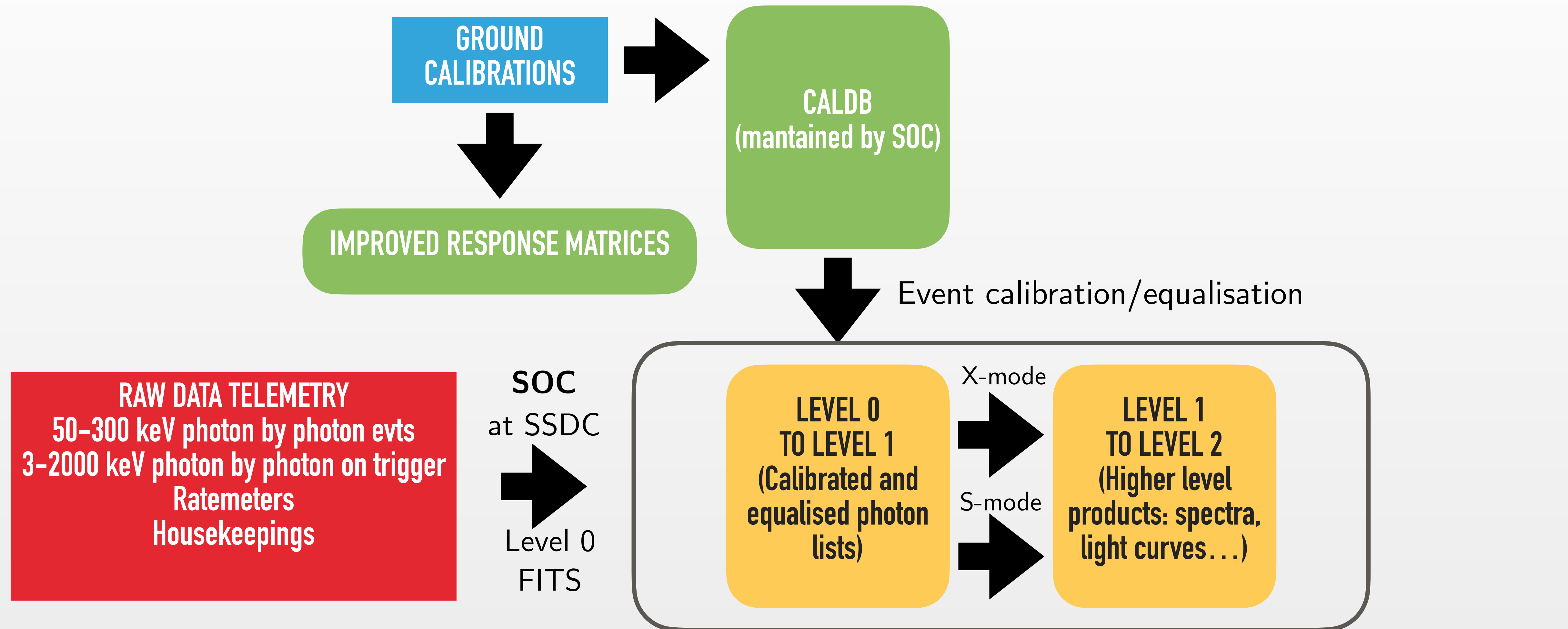

- ▶ Gain and offset dispersion as expected (30% variation channel-by-channel)

- ▶ A few percent variation w.r.t temperature in the −20 °C to +20 °C range

- ▶ Low-energy range and energy resolution as expected

RESULTS

FROM CALIBRATIONS TO CALDB

GROUND CALIBRATIONS

CALDB (mantained by SOC)

IMPROVED RESPONSE MATRICES

Event calibration/equalisation

RAW DATA TELEMETRY
50–300 keV photon by photon evts
3–2000 keV photon by photon on trigger
Ratemeters
Housekeepings

SOC
at SSDC

Level 0
FITS

LEVEL 0 TO LEVEL 1
(Calibrated and equalised photon lists)

X-mode

S-mode

LEVEL 1 TO LEVEL 2
(Higher level products: spectra, light curves…)

HEASARC-compliant scientific software pipeline, being developed by ASI-SSDC

PRESENT (AND FUTURE) STATUS

▸ **PFM** (first Proto Flight Model HERMES payload) → Fully integrated and calibrated, integration with S/C in progress

▸ **FM1** (SpIRIT payload) → Fully integrated and calibrated, delivered to Australia in July 2022

▸ **FM2** (HERMES payload) → Detector assembly integrated, test & calibration in progress

▸ **FM3** (HERMES payload) → Detector assembly integrated, test & calibration in progress

▸ **FM4** (HERMES payload) → Detector assembly integration in progress

▸ **FM5** (HERMES payload) → Detector assembly integration in progress

▸ **FM6** (HERMES payload) → Detector assembly integration in progress

In the next months:

▸ Verification and benchmark of Monte Carlo simulations (new, improved **response matrices**)

▸ Integration of calibration correction factors accounting for **crystal non-linearity** (measured in the past months with a dedicated experiment at the **LARIX-A** University of Ferrara facility, with monochromatic 20–200 keV photon beam. Paper in preparation)

▸ Dedicated measurements with later flight model(s): benchmarking of on-axis/off-axis **effective area** (LARIX-A)

Thank you!

SILICON DRIFT DETECTORS AND EVENT DISCRIMINATION

▸ Low noise (sensitive area ≠ anode area)

▸ Sensitive to X-rays and optical light

▸ Standard photolithographic process ➔ extreme design flexibility

▸ Large Italian heritage (ReDSoX project, INFN, FBK, INAF)