

# In-flight performance of the HEPD-02 detector onboard the CSES-02 satellite

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INFN – TIFPA

Università di Trento

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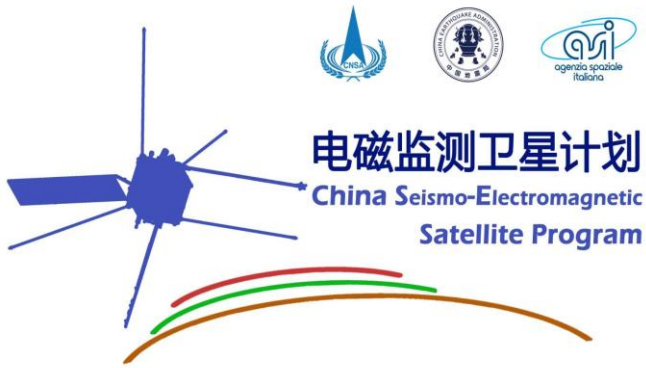
Istituto Nazionale  
di Fisica Nucleare

**TIFPA**

Trento  
Institute for  
Fundamental  
Physics and  
Applications



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# The CSES mission

- **CSES: China Seismo-Electromagnetic Satellites.**

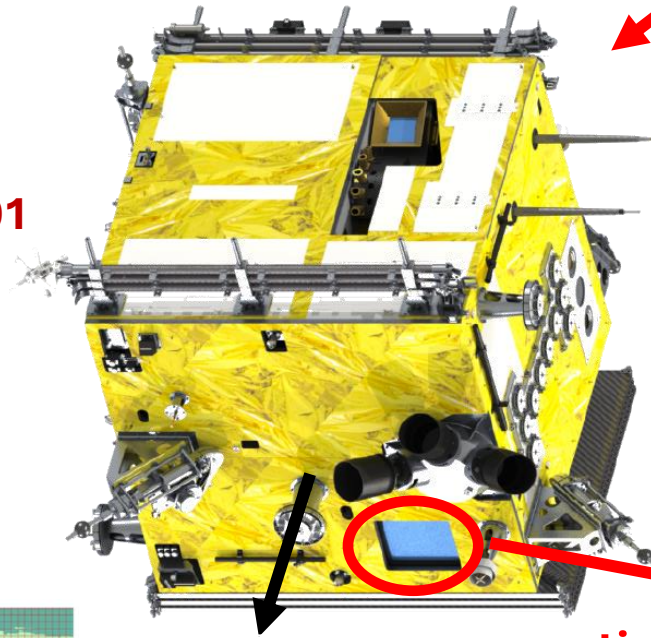
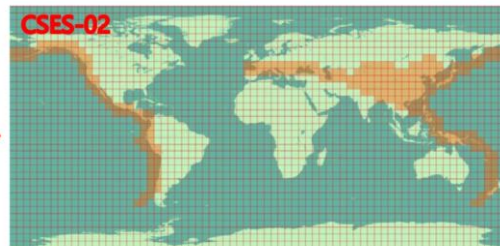
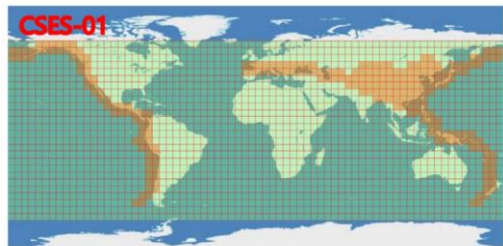
- Program developed by Chinese and Italian Space Agencies.
- CSES-01: launched on Feb 2018 and operating.
- **CSES-02: launched on June 14, 2025.**

- **Main scientific objectives.**

- Monitoring of **electromagnetic and plasma environment in near-Earth space.**
- Measurements of **ionospheric and magnetospheric perturbations** of different origins: seismic phenomena, tropospheric and anthropic transients, solar activity...
- Study of fluxes of **charged particles precipitating from the Van Allen radiation belts.**

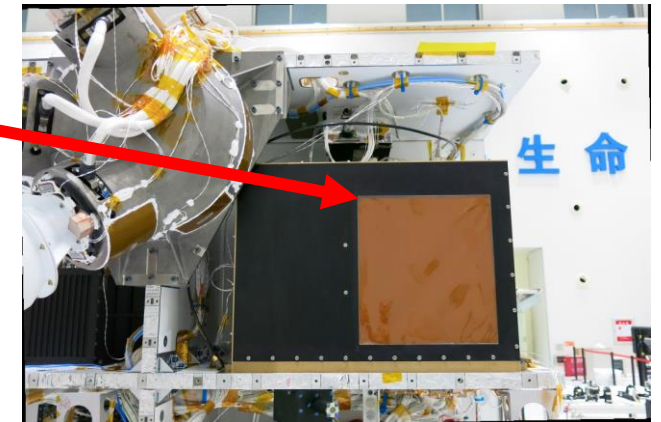
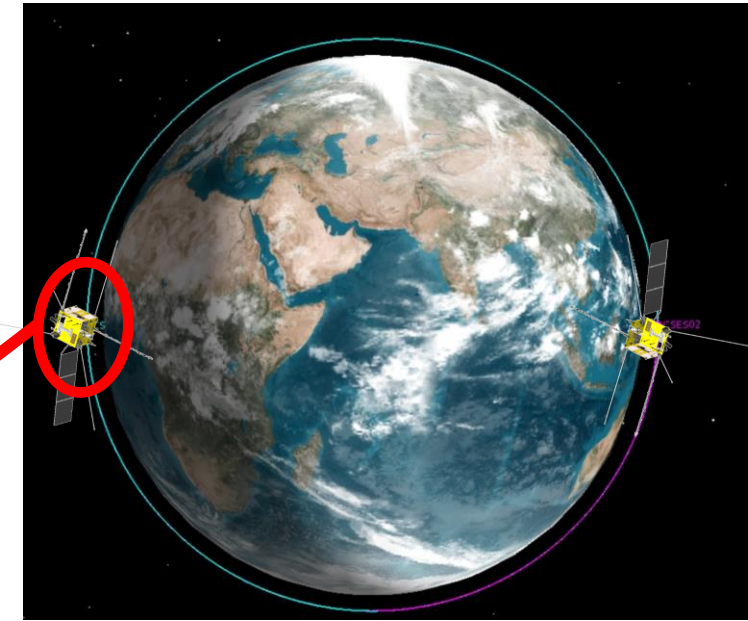
# CSES-02

- **Same DFH CAST-2000 platform of CSES-01 with some upgrades**
  - Earth oriented 3-axis stabilization system with orbit manoeuvre capability
  - X-Band Data Transmission 120Mbps → 150Mbps
  - Storage 160Gb → 512Gb
  - Total Mass: 730kg → 900kg
  - Peak Power Consumption: ~900W
  - Design Life-span: 5 years → 6 years
- **Complementary Ground Track wrt CSES-01**
  - Identical Orbit Plane
  - 180° Phase Difference
  - Track interval: 5° → 2.5°
  - Return cycle: 5 days → 2.5 days
- **Operation mode: Full time operational**

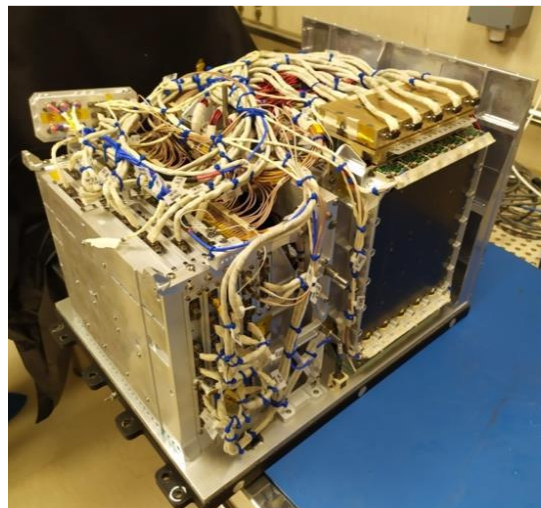
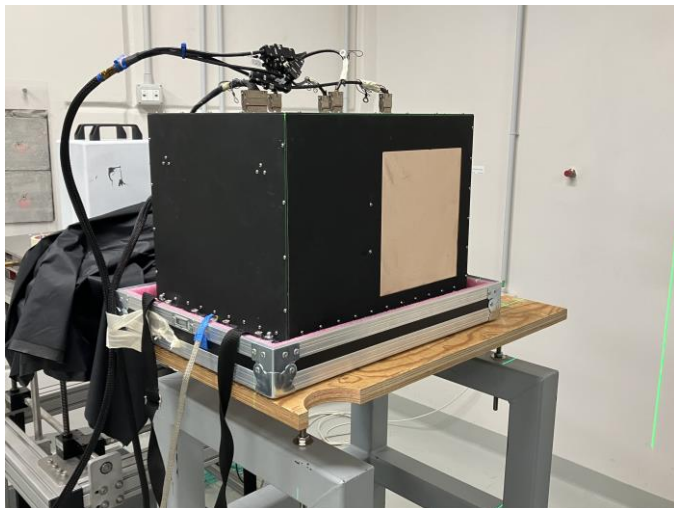
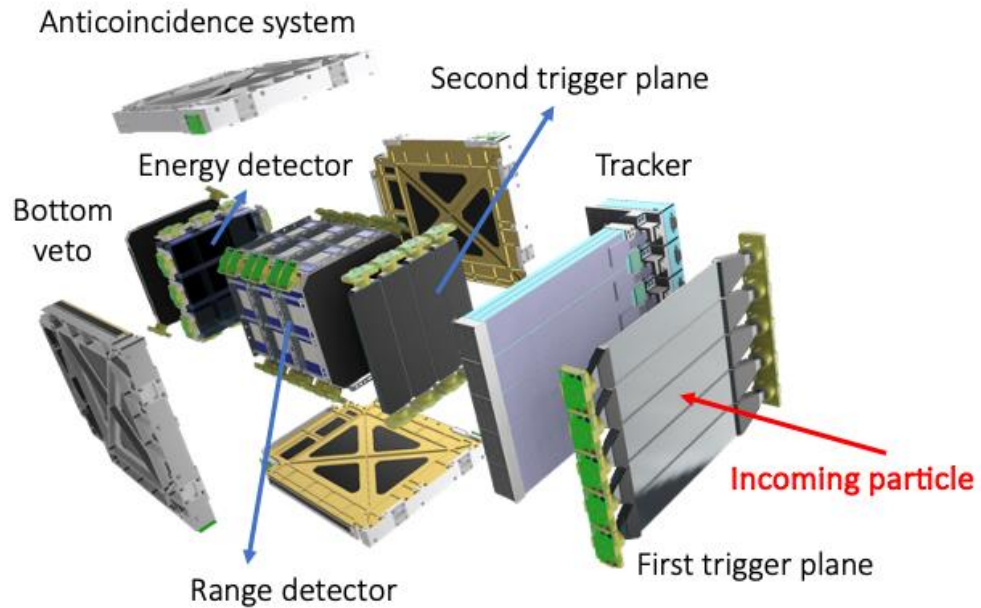


zenith

particle  
entrance  
window

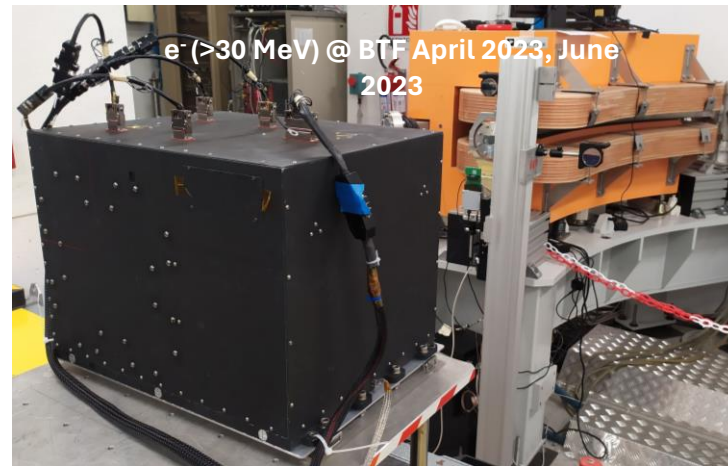
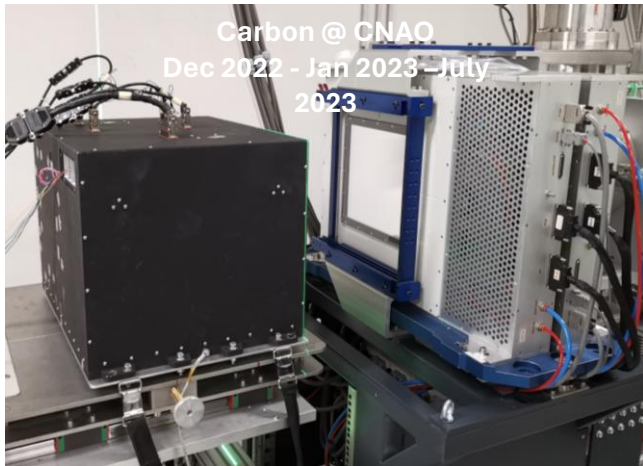


# The HEPD-02 detector



<b>Kin. energy range (electron)</b>	<b>3 MeV to 100 MeV</b>
<b>Kin. energy range (proton)</b>	<b>30 MeV to 200 MeV</b>
<b>Angular resolution</b>	<b><math>\leq 10^\circ</math> for <math>E_{\text{kin}} &gt; 3</math> MeV electrons</b>
<b>Energy resolution</b>	<b><math>\leq 10\%</math> for <math>E_{\text{kin}} &gt; 5</math> MeV electrons</b>
<b>Particle selection efficiency</b>	<b>&gt; 90%</b>
<b>Detectable flux</b>	<b>up to <math>10^7 \text{ m}^{-2}\text{s}^{-1}\text{sr}^{-1}</math></b>
<b>Operating temperature</b>	<b>-10 °C to +35 °C</b>
<b>Operating pressure</b>	<b><math>\leq 6.65 \cdot 10^{-3}</math> Pa ("vacuum")</b>
<b>Mass budget</b>	<b>50 kg</b>
<b>Power Budget</b>	<b>45 W</b>
<b>Data budget</b>	<b><math>\leq 100</math> Gb/day</b>

# HEPD-02 characterisation campaign



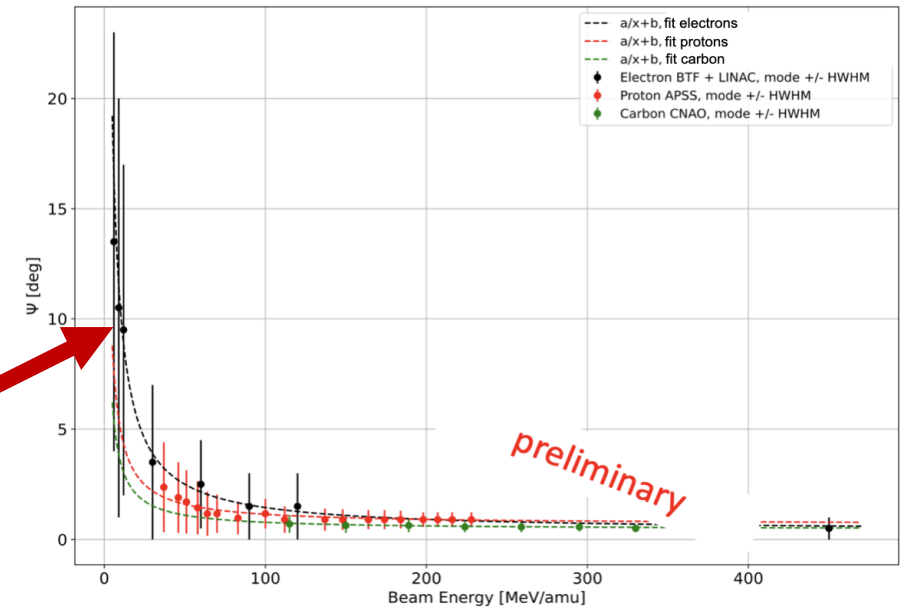
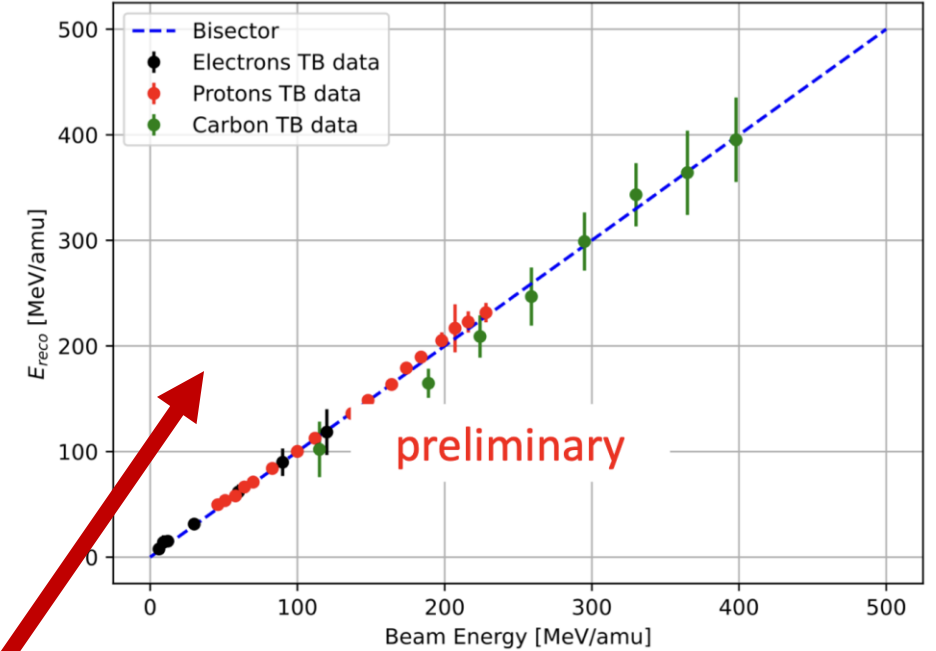
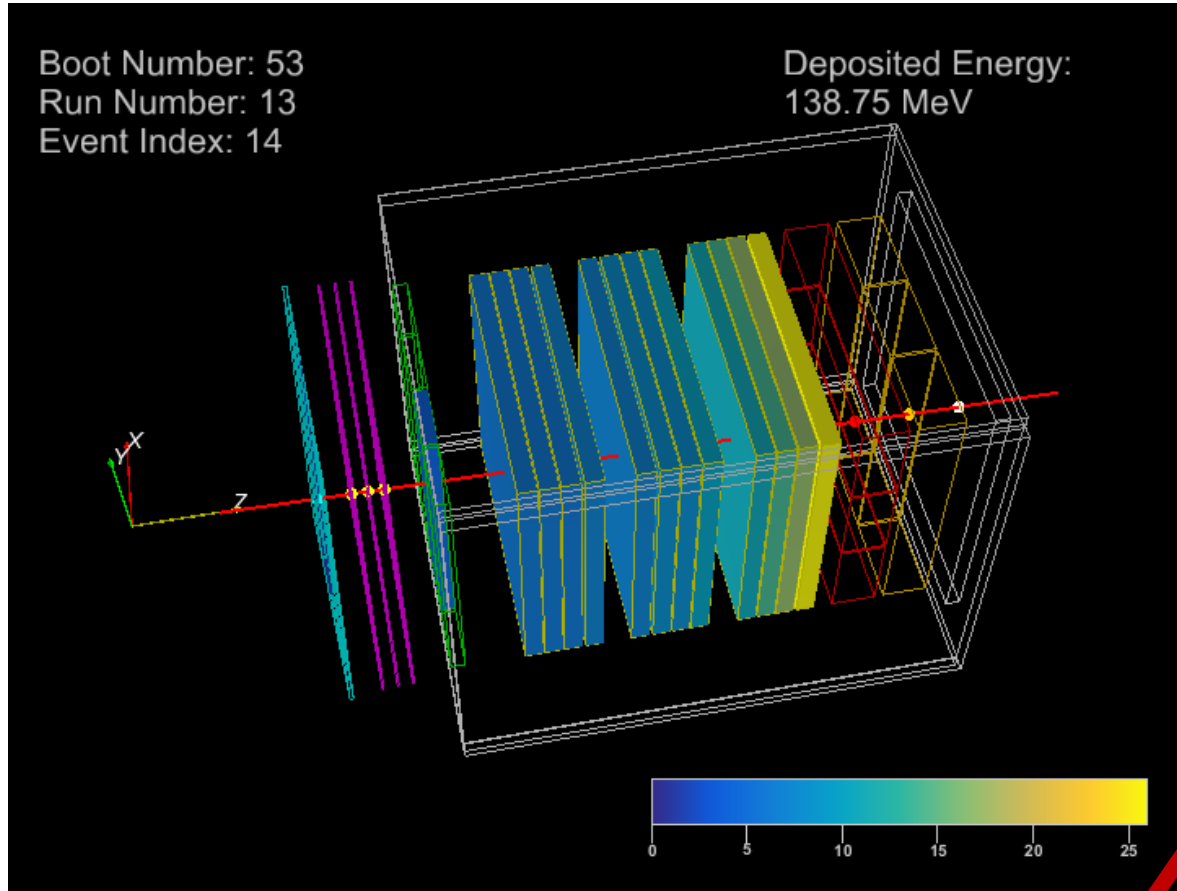
## Calibration tests:

- **Carbon @ CNAO** (Pavia, Italy) in December 2022 and January 2023
- **Electrons (30-450 MeV) @ BTF** (Frascati, Italy) April 2023

## Full characterisation:

- **Protons @ Proton Therapy Center** (Trento, Italy) June 2023
- **Electrons (6-12 MeV) and photons (4-10 MV) @ S. Chiara Hospital** (Trento, Italy) June 2023
- **Electrons (30-450 MeV) @ BTF** (Frascati, Italy) June 2023
- **Carbon @ CNAO** (Pavia, Italy) July 2023

# HEPD-02 performance: energy measurement

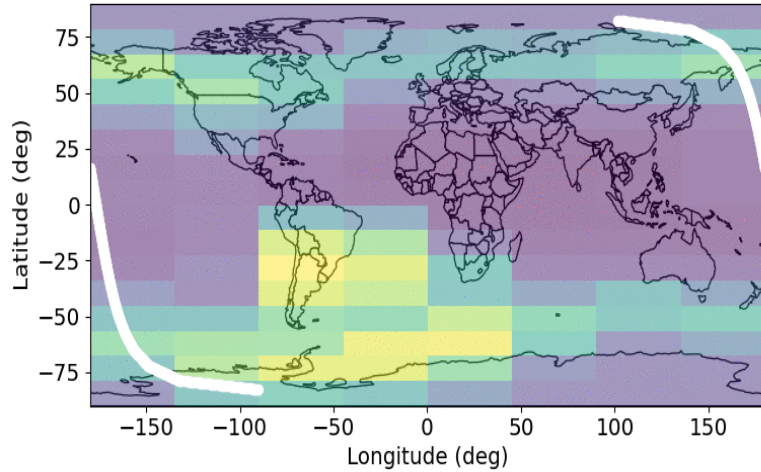


**Reconstructed energy for contained events vs. nominal energy** (various beam particles).

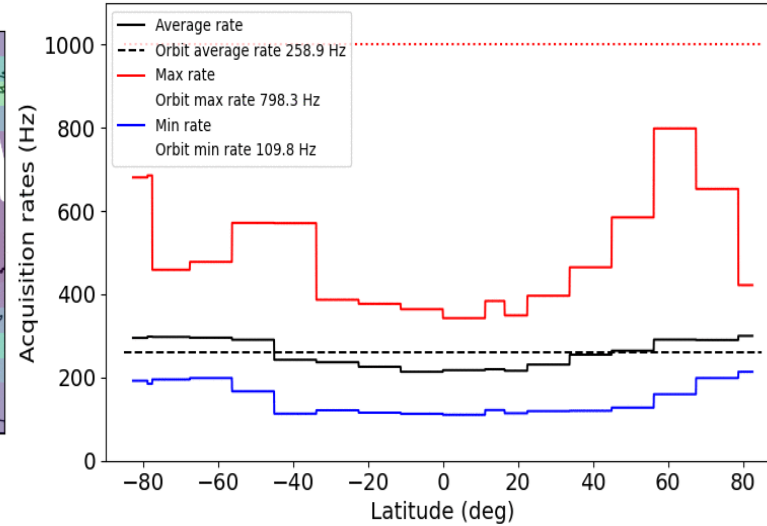
**Uncertainty on angle reconstruction** with the tracker data

# First in-flight performance: particle rates

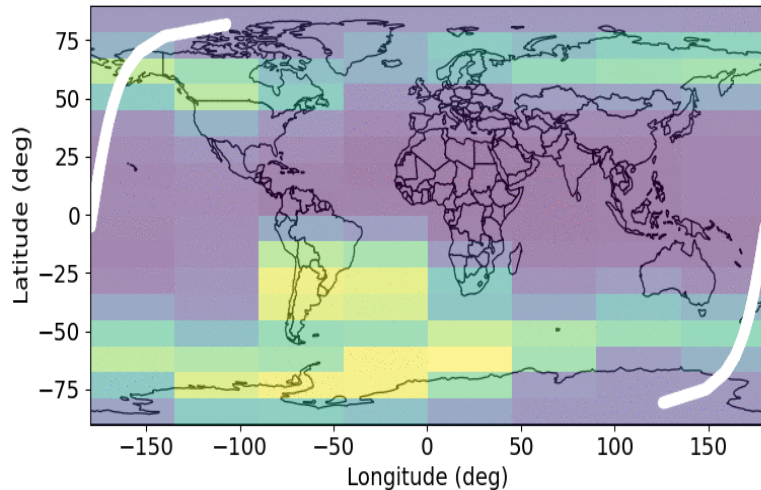
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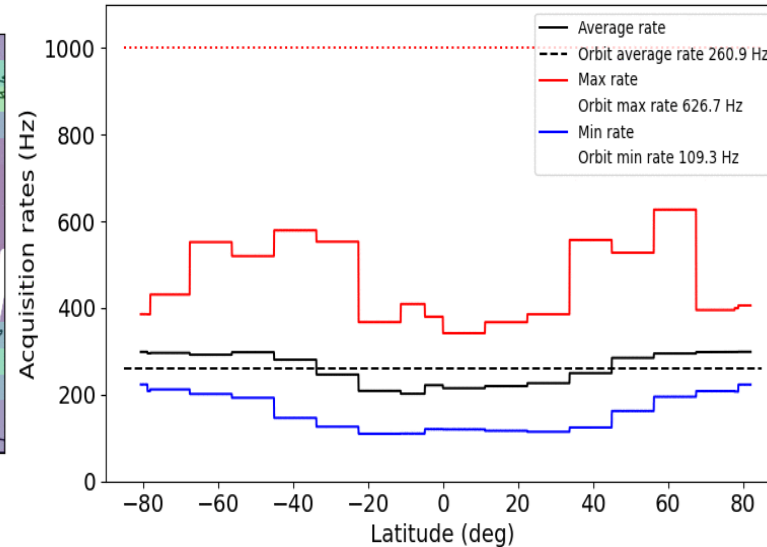
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DESCENDING ORBIT template nr. 00010



Rate of DESCENDING ORBIT template nr. 00010

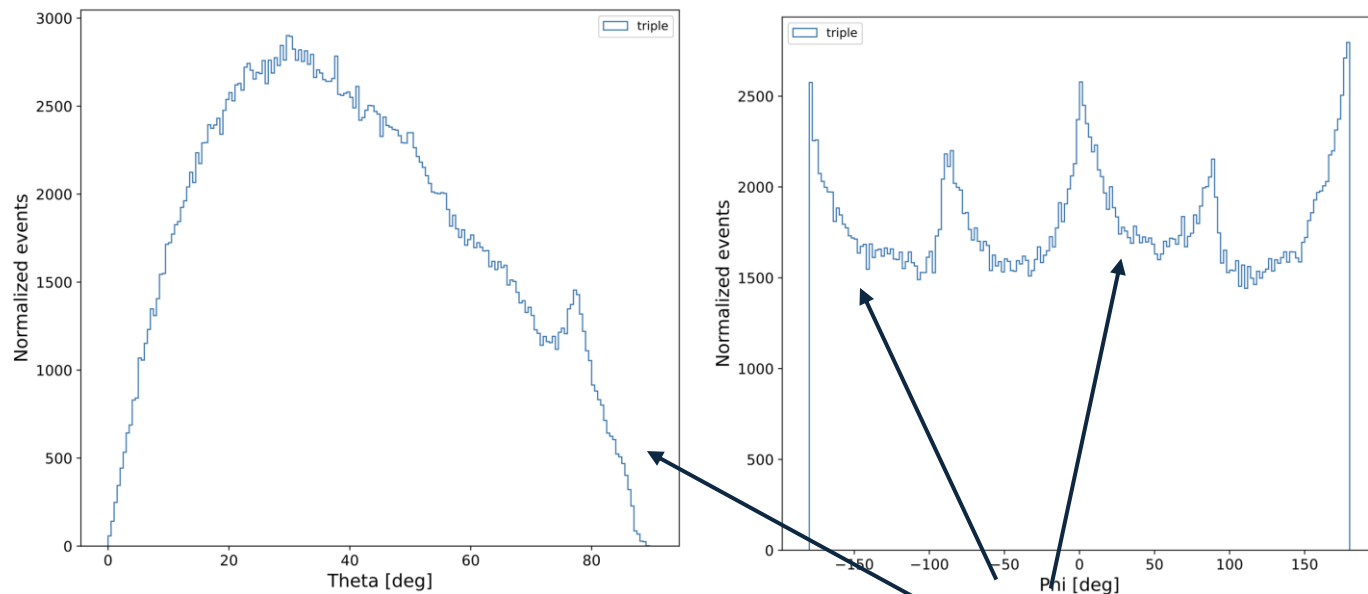


CSES-02 launch,  
June 14, 2025

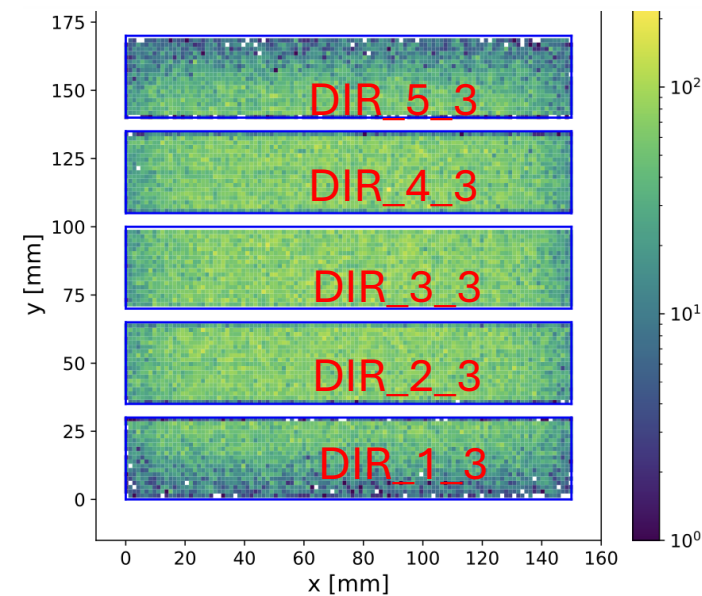
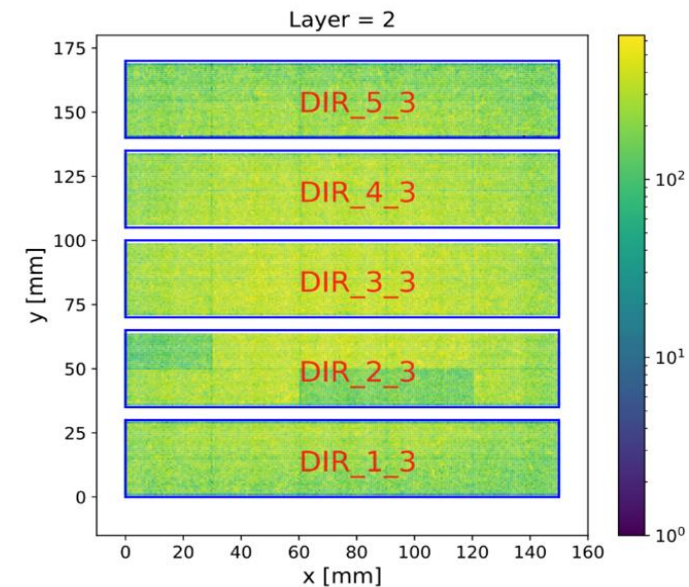
- **Rate** measured along the orbit after the **data acquisition optimisation**
- The data **never exceed** the limits of data budget assigned to the payload
- It is at the same time **maximised** to ensure the best scientific outcome

# First in-flight performance: tracking performance

- **Reconstructed angles** follow the expectations and the constraints given by the detector geometry
- **Two independent methods** are currently used for **tracking**, allowing for a more accurate analysis of the data
- **Automatic in-flight calibration** corrected the minor differences on chip thresholds shown during the first days of data acquisition
- The status of the tracker is **carefully monitored**, the response is in line and exceeding the expectation, as the surrounding environment is slightly colder than the expectations.



All structures as expected



# Conclusions

- The **High-Energy Particle Detector HEPD-02** is a state-of-the-art instrument on-board CSES-02 satellite. It was launched in **June 14, 2025**.
- **Aimed at studying Van Allen belts and galactic particles** in the kinetic energy range from few MeV to hundreds MeV.
- Preliminary analysis of beam test data demonstrates **more than satisfying scientific performances**.
- **Energy reconstruction, particle identification and angle measurements** are within the requirements for the scientific success of the mission.
- The **commissioning** of the instrument was **completed at the end of 2025**. Data taking is now stable and the data will be available soon for the community
- The performance recorded in flight are compatible with the measurements on ground and are the best premises for a **stable and reliable data taking** for the mission lifespan.