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## The Motivation

PeV Cosmic Rays (CR) and Astrophysical Neutrinos ( $\nu$ ) are key to understanding: sources, acceleration mechanisms, galactic-extragalactic transitions, the nature and dynamics of multi-messenger transients...

- above  $\sim 1\text{-}10$  PeV, CRs detected via Extensive Air Showers (EAS) with ground-based detectors
- existing experiment utilize large surface arrays (for CRs) and gigaton masses (for  $\nu$ ), which are hard to scale to get larger acceptances

The **Terzina Payload** is a demonstrator of Cherenkov light detection produced by EAS:

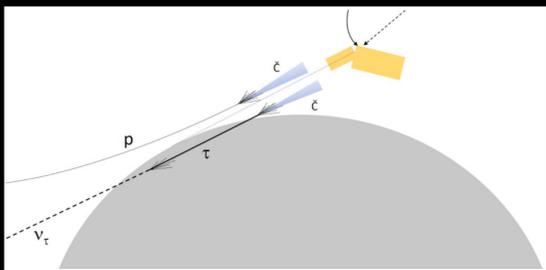
- A near-UV-optical telescope in low-Earth orbit pointing to the night side of the Earth's limb
- A technological pathfinder for future orbital and sub-orbital missions (like **POEMMA**)
- The first to test the Earth-skimming technique to detect  $\nu$ 's through their induced EAS

The **scientific goals** are:

- Measure the background conditions for the detection of UHE CRs and Earth skimming upward muon and tau neutrinos
- First measurement of showers with Cherenkov light from space for  $> 10$  PeV UHE CRs
- Develop further SiPM technology for space

The payload will orbit the Earth in LEO, looking at the Earth's limb for the observation of Cherenkov emission from secondaries (mainly  $e^-/e^+$ ) in the EAS. It will observe to kinds of events

- **Above-the-limb:** EAS induced by CRs ( $\geq 1$  PeV) entering and interacting in the atmosphere.
- **Below the limb:** EAS initiated by  $\tau$  and  $\mu$  leptons emerging from the Earth and into the atmosphere following a charged-current neutrino interaction inside the Earth's crust.



## The Payload Hardware

The payload consists of:

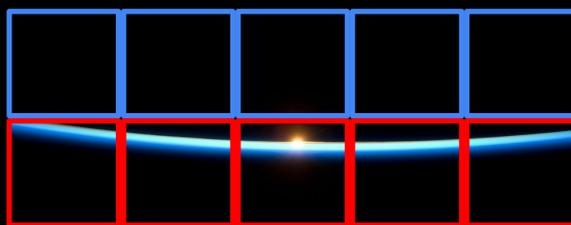
- The **thermal and mechanical support** structures (including the main baffle, radiators and supporting structure for the optics) shown **here to the right**.
- The **optics, focal plane** assembly, and front ended **electronics**, explained below.

The **Optical Head Unit** is a Schmidt-Cassegrain telescope with:

- a parabolic primary mirror (**M1**)
- a correcting-lens for the aberrations introduced by a flat focal plane,
- with one surface coated to act as a secondary mirror (**M2**),
- focusing light onto a focal plane (with  $7.2^\circ$  FOV along the limb,  $2.88^\circ$  across).

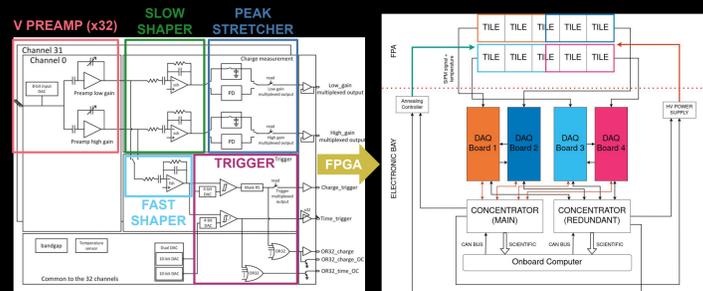
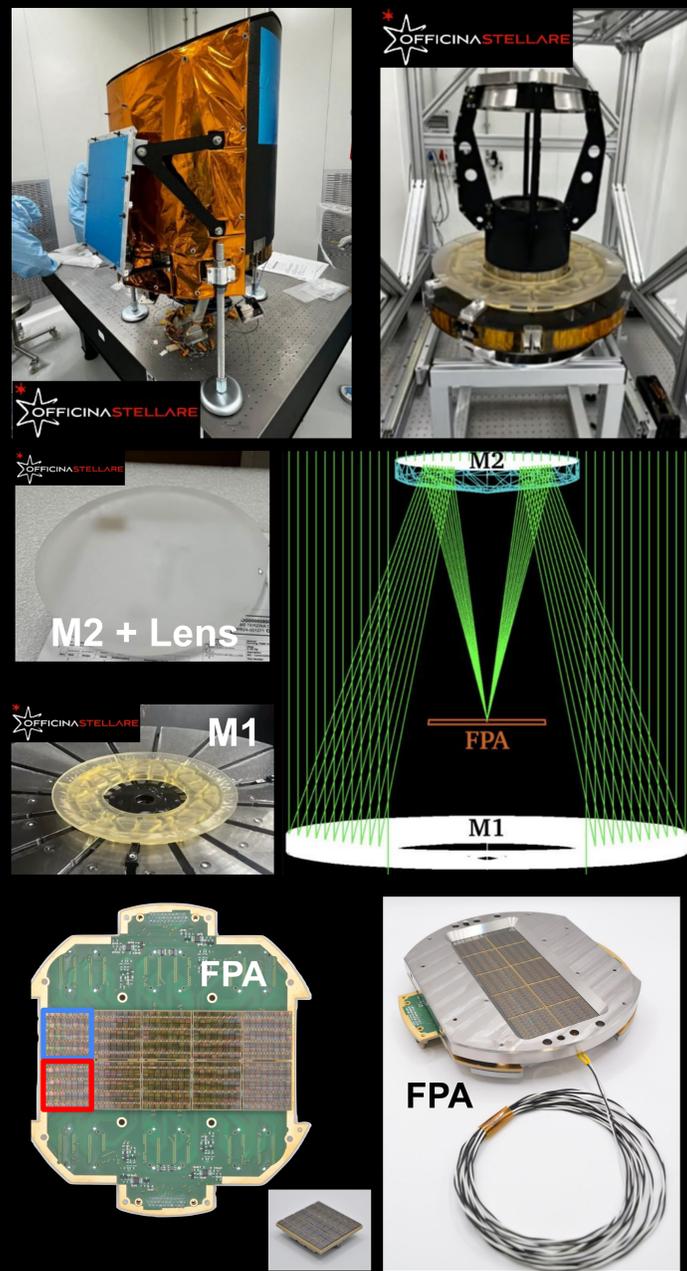
The **Focal Plane Assembly** is:

- a layout 10 silicon photomultiplier (**SiPM**) arrays (each  $8 \times 8$ ), arranged on two rows,
- for a total of 640 independently triggering channels on the camera.
- Each SiPM is  $3 \times 3$  mm<sup>2</sup>, for a total effective area of  $24 \times 24$  mm<sup>2</sup> per array.
- The top row will look for **below-the-limb** events ( $\nu$ 's), while the bottom row will observe **above-the-limb** CR events.



The **Front End Electronics:**

- The SiPM signals are routed to a set of CITIROC front-end readout-chip (ASIC).
- Each ASIC reads half tile and has 32 input channels (one per SiPM).
- A slow shaper for the charge readout, and a fast shaper for the trigger.
- A concentrator board aggregates and buffers the data.



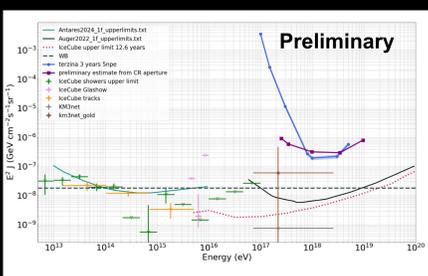
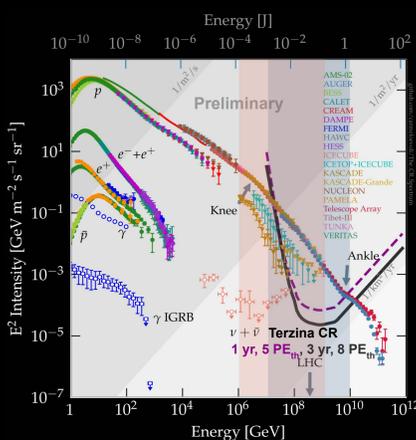
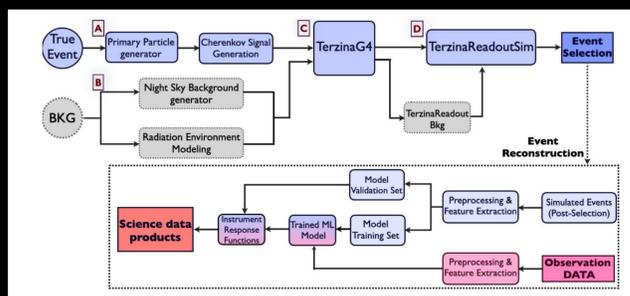
## Detector Simulation & Performance

A full detector simulation chain has been developed to:

- generate true events and background events,
- propagate their signal through detector, including both the hardware and electronics response,
- study the performances of the detector and estimate its sensitivity to both CR and  $\nu$  fluxes

Currently in development:

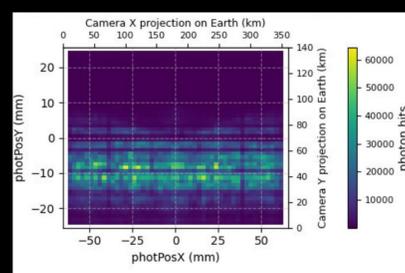
- the event reconstruction workflow, including preprocessing and feature extraction,
- model training and validation for the machine learning mode.



The simulation

incorporates results from:

- simulated EAS longitudinal development with CORSIKA
- parameterizations of the EAS electron distributions
- semi-analytical estimates of the expected photon signal
- accurate models of the telescope mechanics & optics inside GEANT4
- results from characterization campaigns of the SiPMs



Example of the (cumulative) photon hits in the SiPM camera for from 3000 PeV proton induced air showers.

Predictions of the observed number of events are made (left):

- taking into consideration the rate and other characteristics of the expected background such as city lights & the moon
- the trigger level and the electronics response
- other factors such as duty cycle, deadtime, the radiation environment and SiPM aging



More Info & References