THE NUSES MISSION

P. Savina (GSSI and INFN-LNGS)
on behalf of the NUSES Collaboration

THE **NUSES** MISSION

Italian led mission conceived as a **pathfinder** for **new observation methods and technologies** in the study of high and low energy radiations from space enabling new sensors and tools

Flagship initiative to relaunch economy of L'Aquila Area

Joint **GSSI**-Thales Alenia Space Italy (**TAS-I**) project.

ThalesAlenia Space
a Thales / Leonardo company

Funded by the italian government and the Abruzzo regional government.

Joint **GSSI-INFN** (CSN5) effort currently ongoing for the **design** and **construction** of the NUSES payloads.

The NUSES mission has been approved by ASI: funds for launch and ground segment.

Industrial Partners:

OFFICINASTELLARE OUR WORLD, YOUR SPACE

Nuclear Instruments

FONDAZIONE BRUNO KESSLER

AGE SCIENTIFIC

SOPHIA HIGH TECH

THE **NUSES COLLABORATION**

60+ persons from many institutions.

Large **expertise** (and **sinergies**) from space missions/R&D: AMS, DAMPE, eASTROGAM, Fermi, LIMADOU, GAPS, HERD, PAMELA, POEMMA, SPB2, …

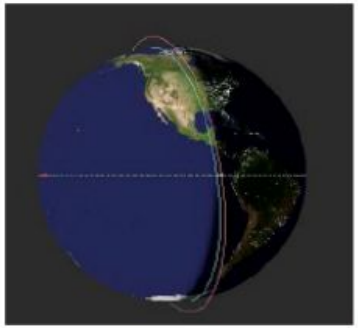
Italian Institutes:

- Gran Sasso Science Institute
- Laboratori Nazionali del Gran Sasso
- Università dell'Aquila
- Università di Roma "Tor Vergata" and INFN-Roma2
- Università di Torino and INFN Torino
- Università di Trento and INFN-TIFPA
- Università di Bari and INFN Bari
- Università di Padova and INFN Padova
- Università "Federico II" and INFN Napoli
- Università del Salento and INFN Lecce

Other Institutes:

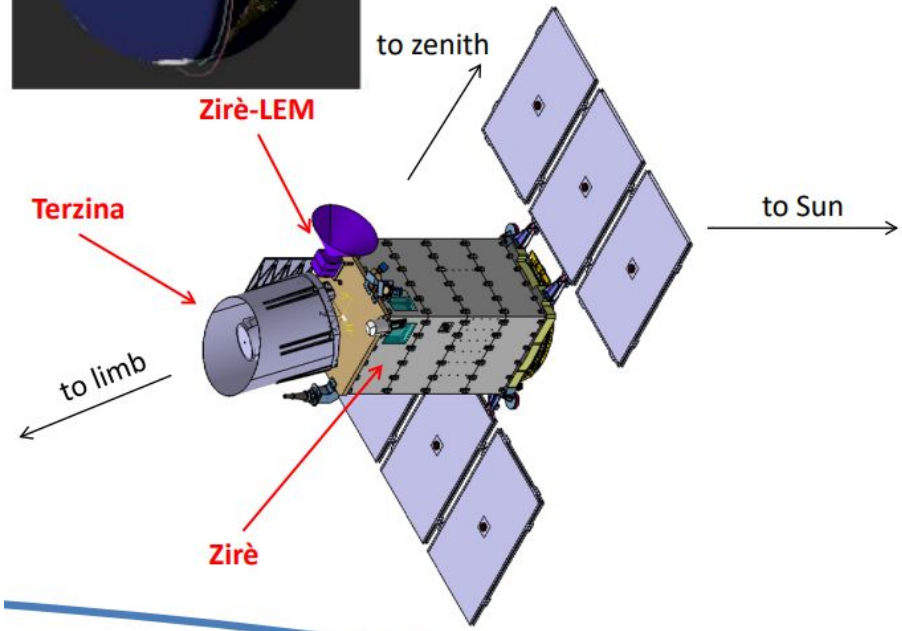
- University of Geneva
- University of Chicago
- Interests from other US institutions, …

NUSES: **THE SATELLITE**



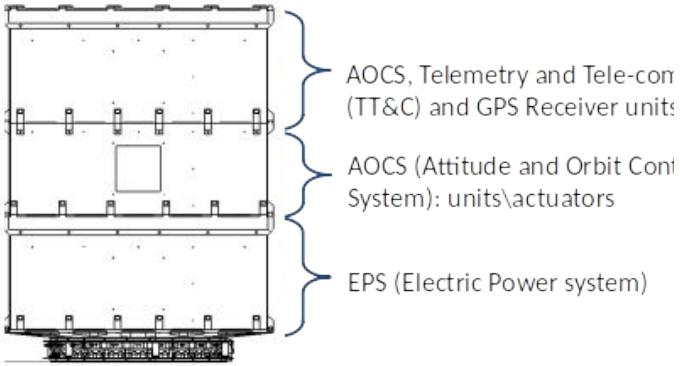
Low Earth Orbit (LEO) with high inclination, **sun synchronous orbit on the day-night border**
(altitude ~550 km, inclination = 97.8 deg, LTAN = 18:00)

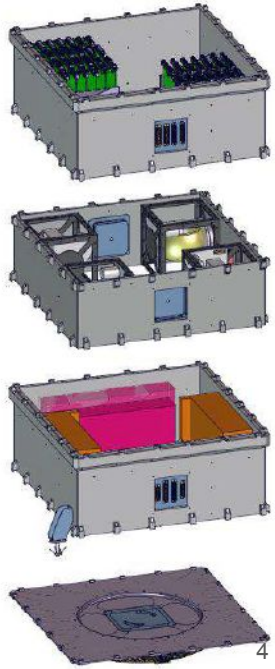
ThalesAlenia Space
A Thales / Finmeccanica Company



New **I**talian **M**icro **BUS**

New platform concept which foresees a modular approach relying on standard trays.

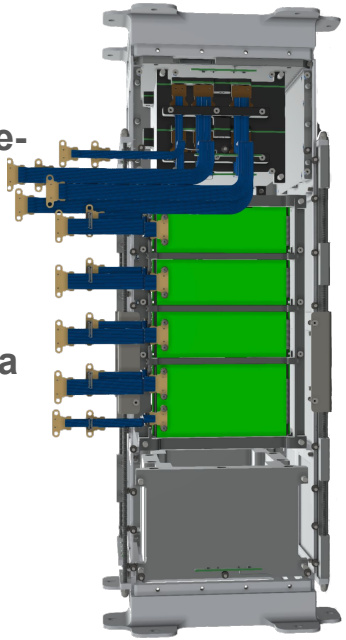




NUSES: **TWO PAYLOADS**

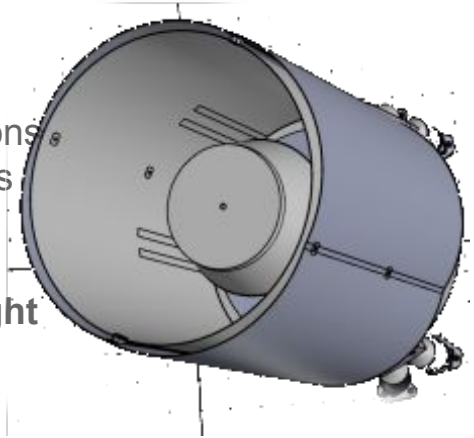
Zirè

- Measure the flux (E<300 MeV) of cosmic e^-, p and light nuclei of solar/galactic origin;
- **Study of the cosmic radiation variability** (Van Allen belt system);
- Possible correlation with seismic activity due to **Magnetosphere-Ionosphere-Lithosphere Coupling** (MILC);
- Detection of 0.1 - 30 MeV photons for **study of transient and stable gamma sources**;
- Paving the way for future **applications of new technology** (SiPM, …);



Terzina

Pathfinder for future missions devoted to UHE cosmic rays and neutrino astronomy through **space-based** atmospheric **Cherenkov light** detection.



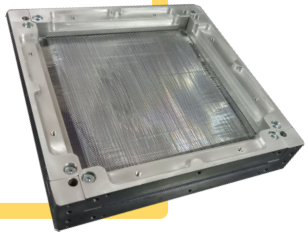
New Technologies and approaches

Development of new observational techniques, testing new sensors (e.g. **SiPM**) and related electronics/DAQ for space missions. New solutions for the satellite platform.

NUSES: **ZIRÈ LAYOUT**

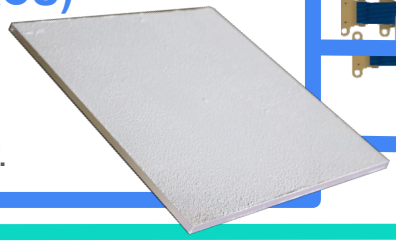
Fiber TracKer (FTK)

3 double layer XY modules of fibers to be used for track identification.



Anti-Coincidence System (ACS)

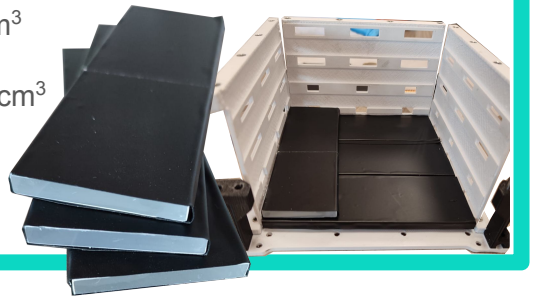
9 PS layers surrounding the detector.



Plastic Scintillator Tower (PST)

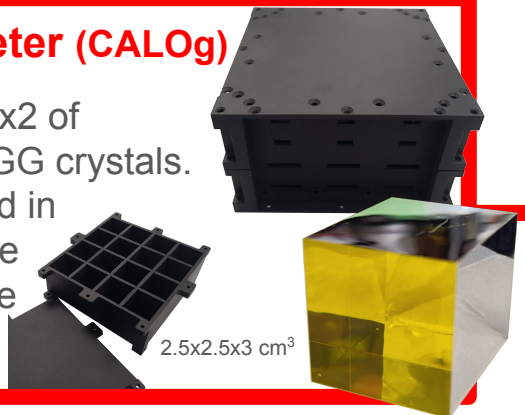
Tower of 32 Plastic Scintillator layers. Each layer is composed by 3 bars.

6 layers:
4x12x1 cm^3
26 layers:
4x12x0.5 cm^3

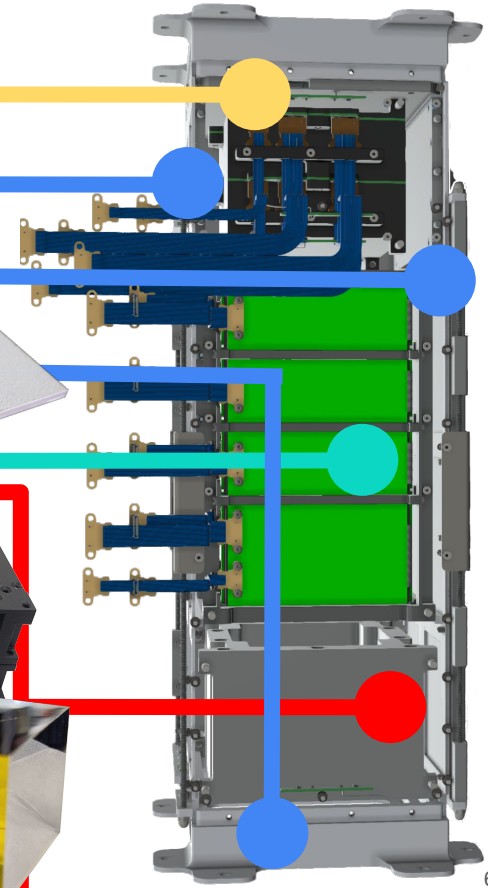


Calorimeter (CALOg)

Matrix 4x4x2 of LYSO/GAGG crystals. Segmented in cubes to be Crystal Eye pathfinder.

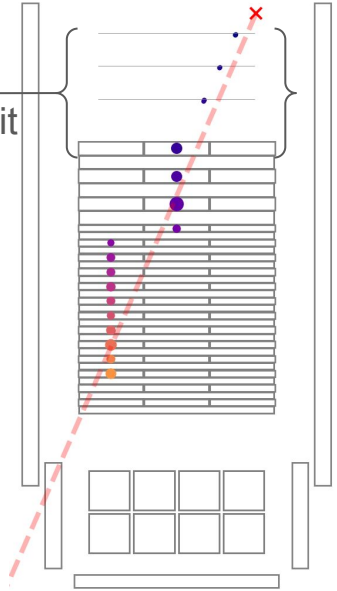


2.5x2.5x3 cm^3



NUSES: **ZIRÈ SIMULATIONS**

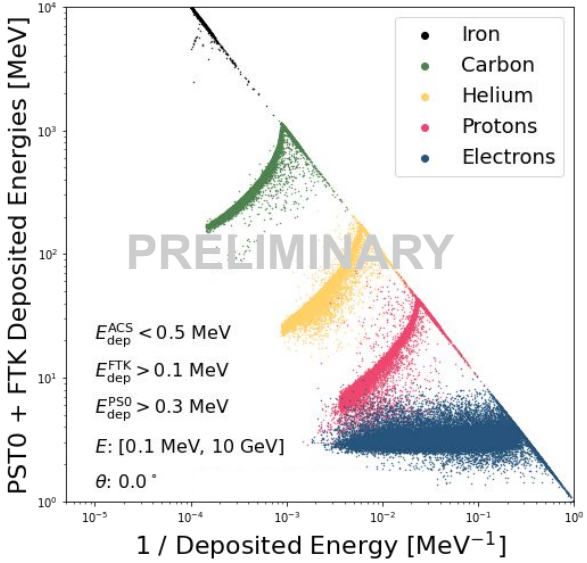
FTK + PS0
Energy deposit



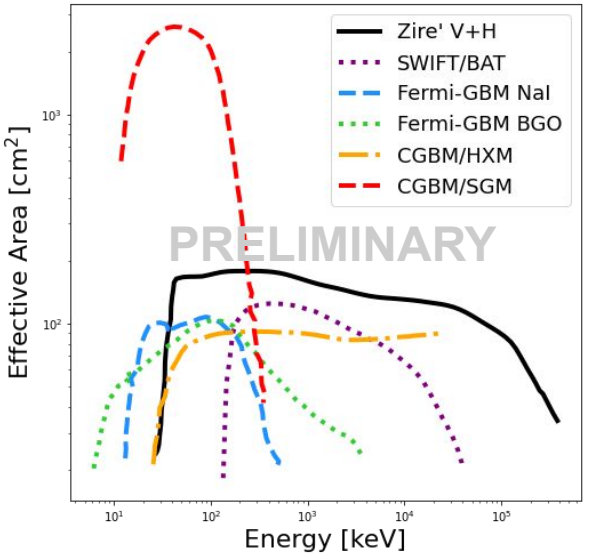
$$\Delta_0 = \Delta E_{\mathrm{FTK+PS0}} \simeq \frac{dE}{dX} \propto \frac{z^2}{\beta^2} F(\gamma\beta)$$

$$E_{\mathrm{dep}} \simeq E_k \propto \beta^2$$

$$\Delta_0 \propto \frac{z^2 F(\gamma\beta)}{E_{\mathrm{dep}}}$$



Particle Identification by studying the correlation between the energy deposit inside FTK+PS0 and the inverse of the total energy deposition in the whole detector.

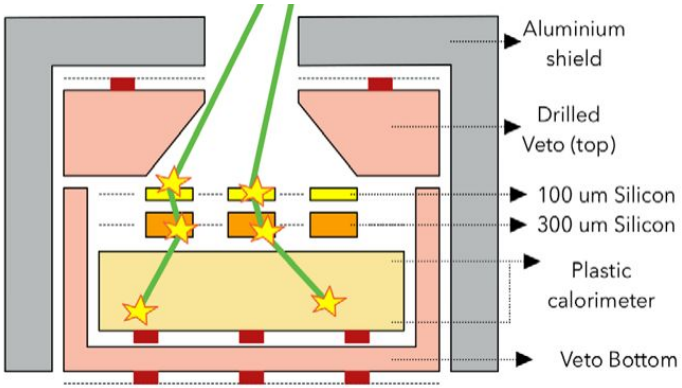


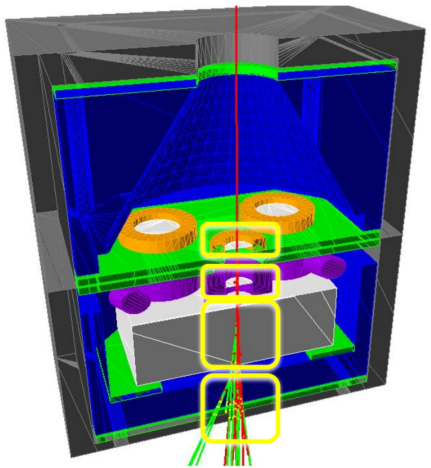
CALOg will be also used for the study of **low energy γ-rays** between 10 keV and 50 MeV.

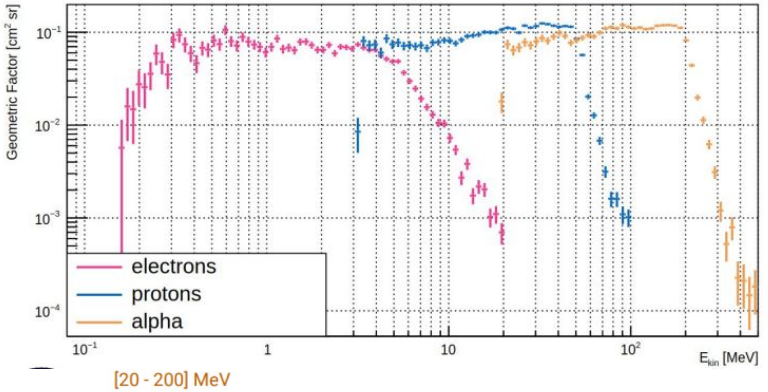
Two windows surrounding the CALOg are included for this purpose.

NUSES: **ZIRÈ Low Energy Module**

Contained Event: **Selected**

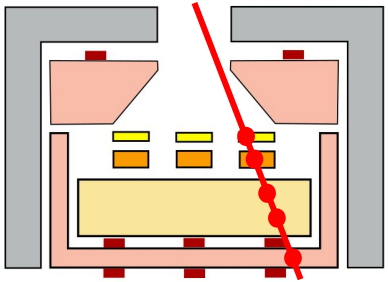




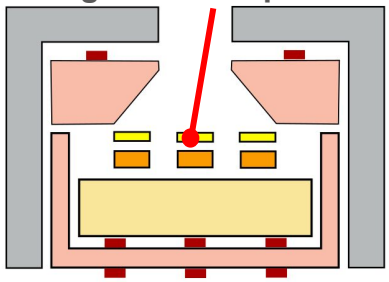


[20 - 200] MeV

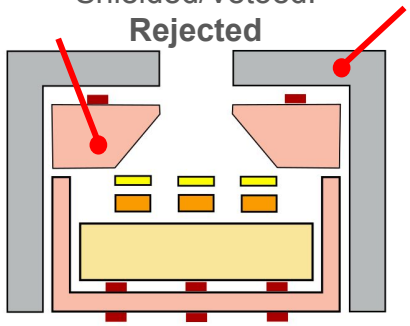
Through-going:
MIP - Calibrations

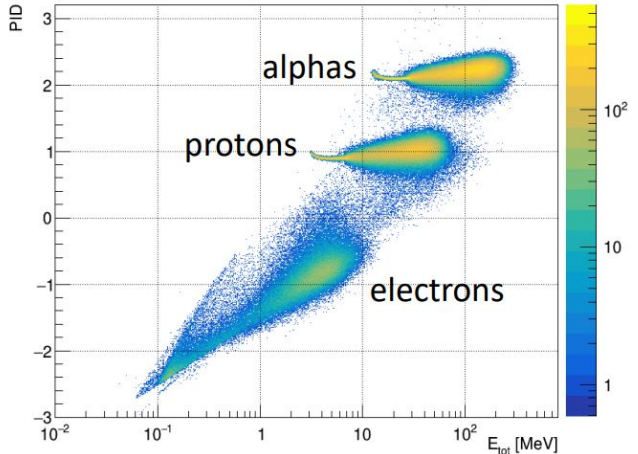


Low-energy:
Single silicon spectra

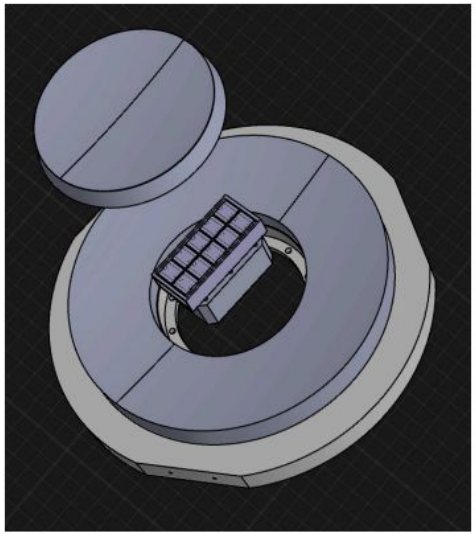


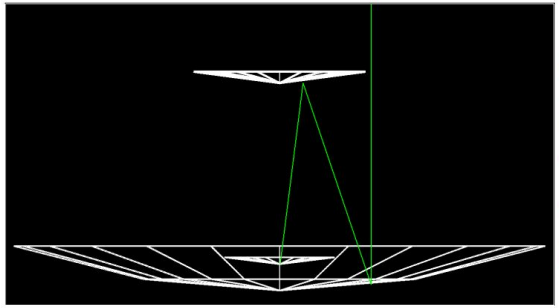
Shielded/Vetoed:
Rejected



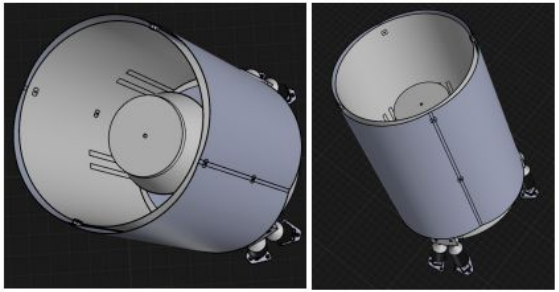


NUSES: **TERZINA LAYOUT**



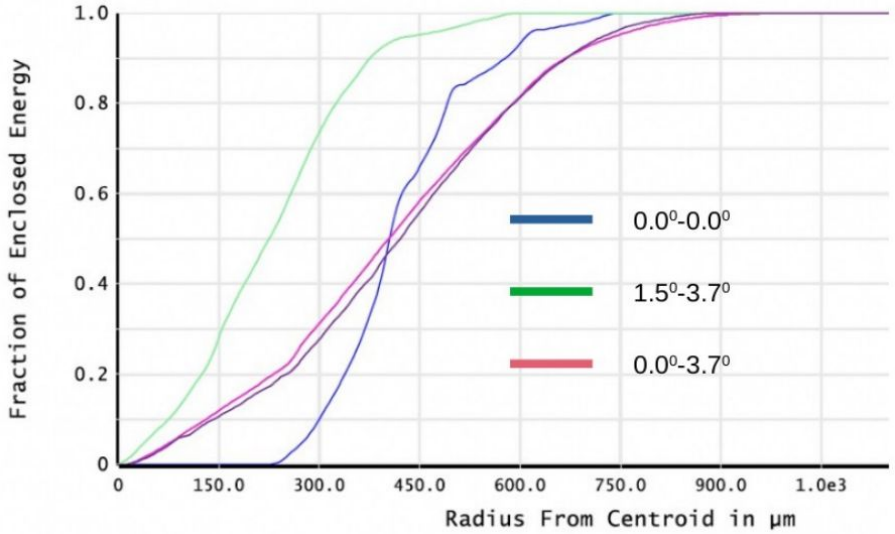


- ✓ Equivalent focal length 925 mm
- ✓ Field of View (FoV) : 7.2º
- ✓ Point spread function (PSF) : <1.0 mm
- ✓ Effective area of the telescope : 0.1 m²
- ✓ M1 paraboloid, M2 hyperbole

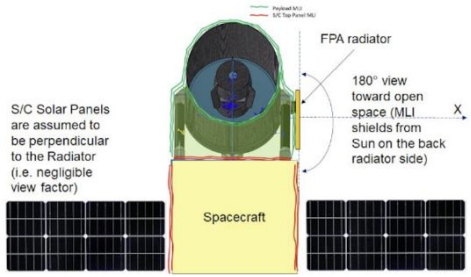


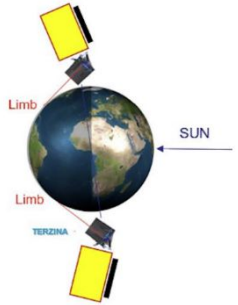
Terzina total weight ~35 kg

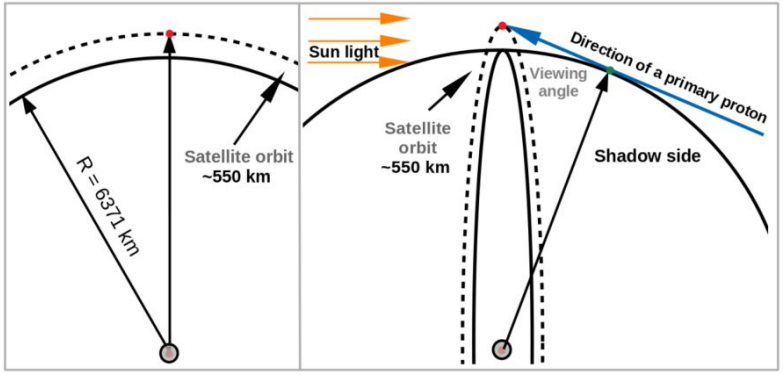
Point spread function for different inclination angles

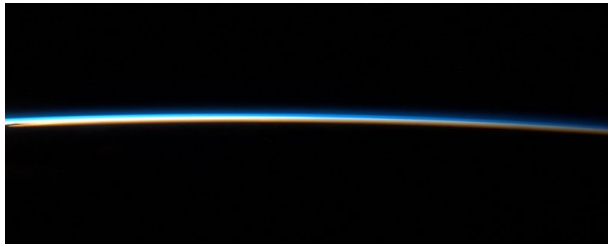


NUSES: **Signal in the Terzina Telescope**

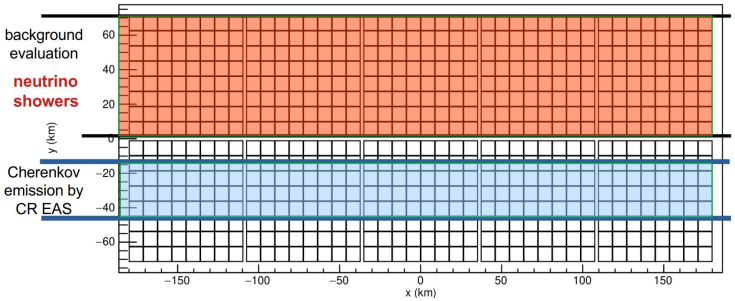




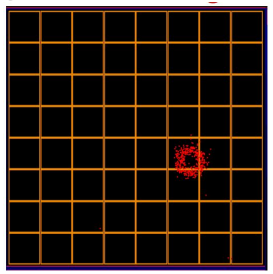




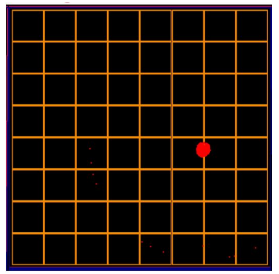
Camera plane with projection on the Earth (total area 360x140 km²)



Single Shower



Point Source



SiPM arrays: **8 x 8 channels**

Pixel: **3 x 3 mm²**

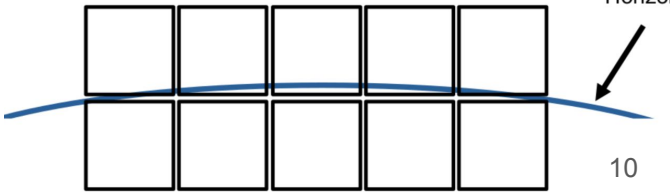
Pixel FoV: **0.18°**

5 x 2 = 10 SiPM arrays In total

(8 x 8) x 10 = 640 pixels (channels)

Array dim. : 25.3 x 25.3 mm²

Array Eff. area : 24 x 24 mm²



Looking at the atmosphere limb (above) for CR detection and (below) for neutrinos detection.

CONCLUSIONS

Science Goals:

- Measure electrons, protons and nuclei up to hundreds MeV;
- Study particle flux correlation with seismic activity and space weather phenomena;
- Monitor very low energy (0.5-5 MeV) electron flux;
- Cross correlations among low-energy-electrons, protons-alpha, photons in coincidence with (high-intensity) GRBs;
- Measure photons in the 0.1-30 MeV for transient and steady gamma source detection;
- Interdisciplinary applications (TGF, Earth Observation, etc);

New Technologies:

- Use of SiPM in space;
- Use a scintillating fiber tracker (~300μm) readout by SiPM arrays;
- Optimize a LYSO crystal array to act as a (astrophysical) γ detector (0.1-30 MeV);
- Design/use low power electronics (try to go down to ~few mW/ch);
- Test / Optimize onboard (Standard and/or Machine Learning) techniques for data reduction;
- Test new approaches for the satellite platform ;