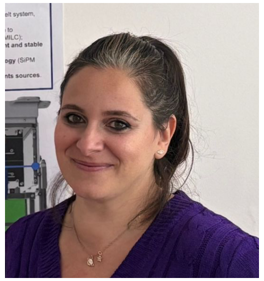
11th Astroparticle Physics Science Fair 2024/2025

Felicia Barbato on behalf of HE-experimental group

Who we are

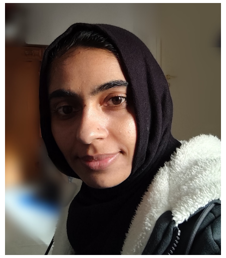

Ivan De Mitri
Full professor


Adriano Di Giovanni
Associate professor


Felicia Barbato
Assistant Professor


Pierpaolo Savina
Assistant Researcher


Sara Fogliacco
PhD student


Iqra Siddique
PhD student


Herman Lima
Assistant researcher


Sindor Ashurov
PhD student


Diptiranjan Pattanaik
Postdoc


Abhijit Roy
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Dimitrios Kyratzis
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Irene Cagnoli
PhD student


Giulio Fontanella
PhD student


Rodrigo Alberto Torres Saavedra
PhD student

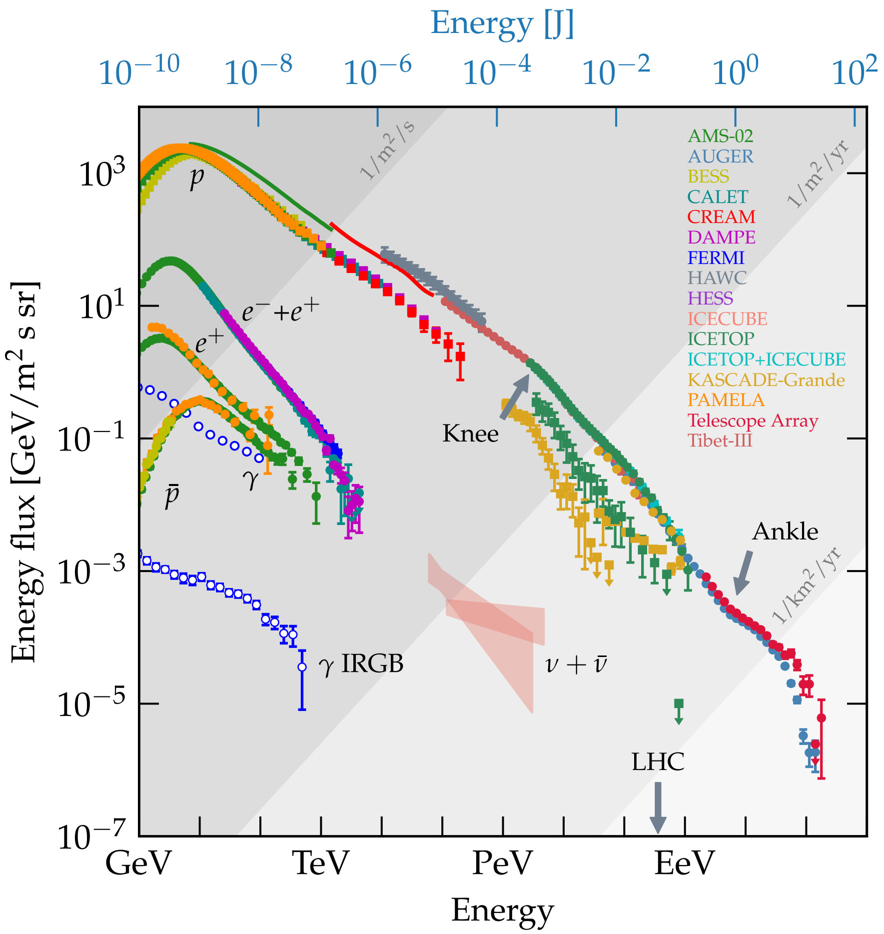

Uygar Atalay
PhD student


Ritabrata Sarkar
Assistant Researcher

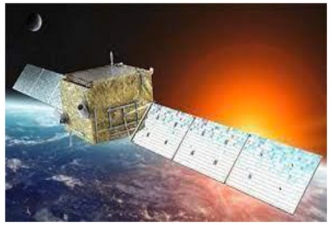

Aleksei Smirnov
PhD student


Zheng Xiong
Postdoc

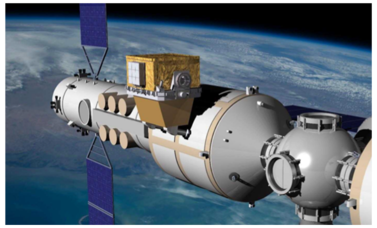
What we do



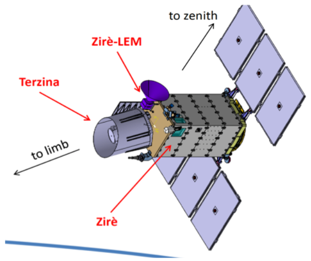
Direct



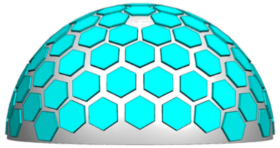
Dampe



HERD



NUSES



Crystal Eye

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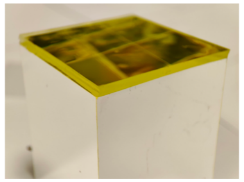
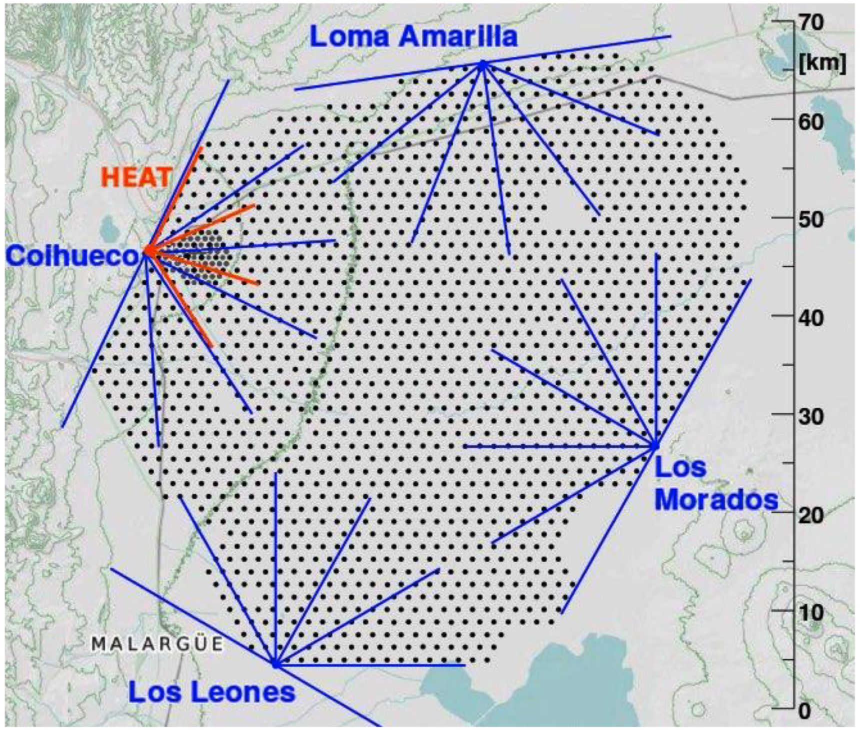


Space it up

Indirect

AUGER

The Pierre Auger observatory



Southern hemisphere: Malargue, Province Mendoza, Argentina

Surface detector (SD)

- 1600 stations in 1.5 km grid, 3000 km^2 E > $10^{18.5}$ eV
- 61 stations in 750 m grid, 23.5 km^2, E > $10^{17.5}$ eV
- 19 stations in 433 m grid, E > 6 10^{16} eV

Fluorescence detector (FD)

- 24 telescopes in 4 sites, FoV: 0-30^o, E>10^{18} eV
- HEAT (3 telescopes), FoV: 30 - 60^o, E>10^{17} eV

Auger Engineering Radio Array (AERA)

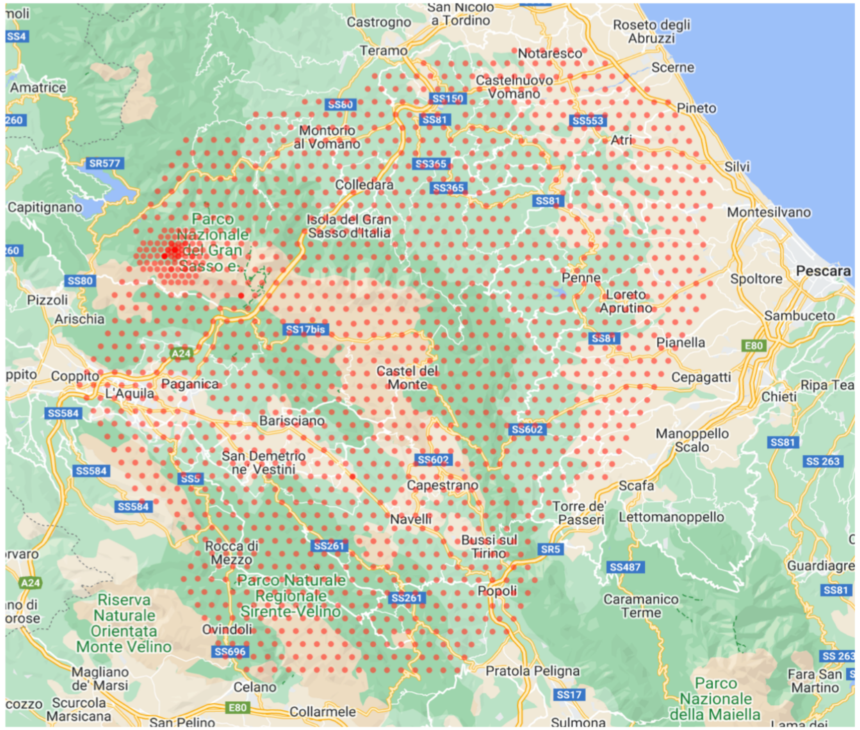
- 153 antennas in 17 km^2 array, E> 4 10^{18}eV

Underground muon detector

- 19(61) stations in 433(750)m array $10^{16.5}$<E< 10^{19} eV

- *Energy spectra (new features, deviations from a purely power law)*
- *Mass Composition: new hints in the determination of CR species*
- *Arrival Direction: determination of large-scale anisotropy of arrival directions*
- *Neutral searches and Multi-messenger physics*
- *Hadronic interactions and more…*

The Pierre Auger observatory

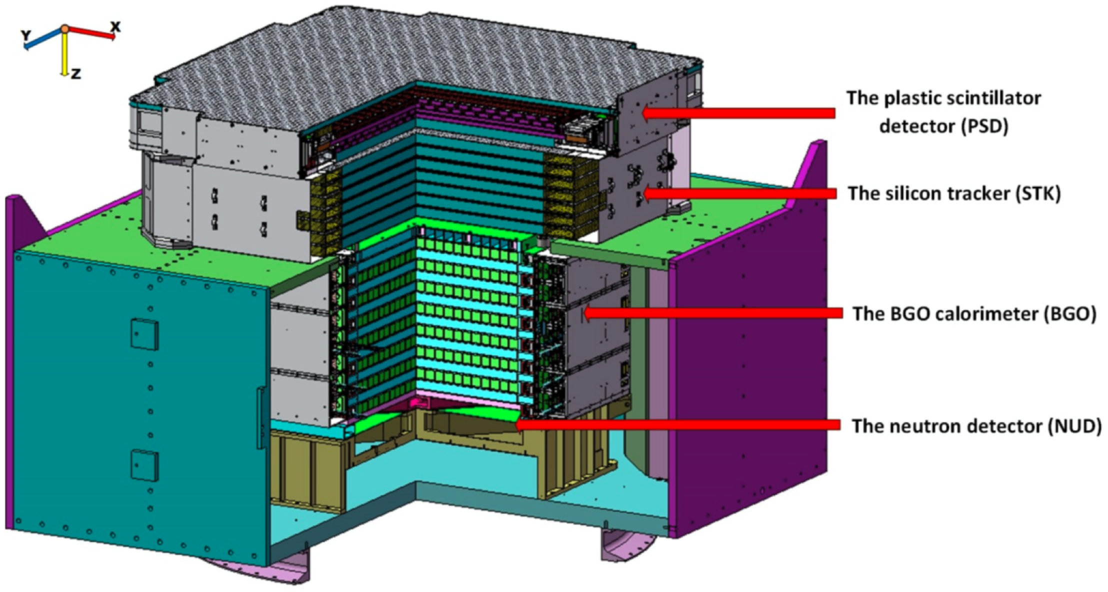


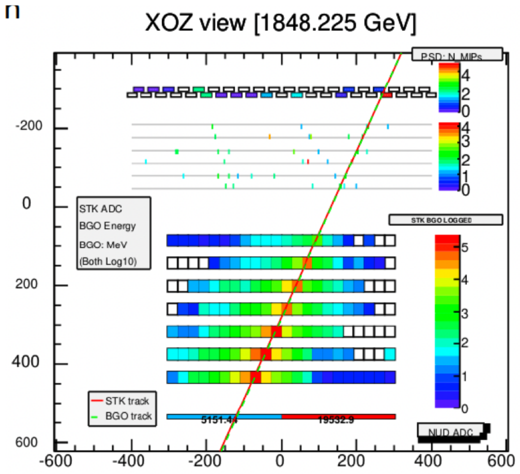
L'Aquila group experimental activities

- Commissioning of the AugerPrime electronics
- Atmospheric Characterization Activities with the Raman Lidar
- Spectrum Measurement with Hybrid Events i.e., Fluorescence Detector + Surface
- Analysis of Spectrum + Composition Measurements in Terms of Astrophysical Scenarios
- Mass Measurement Analysis
- High-Energy Neutrinos and photon searches in the Context of Multimessenger Astronomy
- Study of Limits on Lorentz Invariance Violation with UHECRs
- Limits on Dark Matter
- Properties of UHECR Fluxes Exiting Galaxies
- Outreach activities: Auger Masterclass, Street Science

DArk Matter Particle Explorer

The DAMPE Space Mission





PSD

Charge measurement + anti-coincidence for γ ID
2 planes (X/Y) of plastic scintillator bars

STK

Track reconstruction + additional charge measurement
6 planes of Si microstrip detectors + 3 W layers

BGO

Energy measurement + em/had showers discrimination
14 layers of BGO crystal bars
32 X_0 and 1.6 λ_I

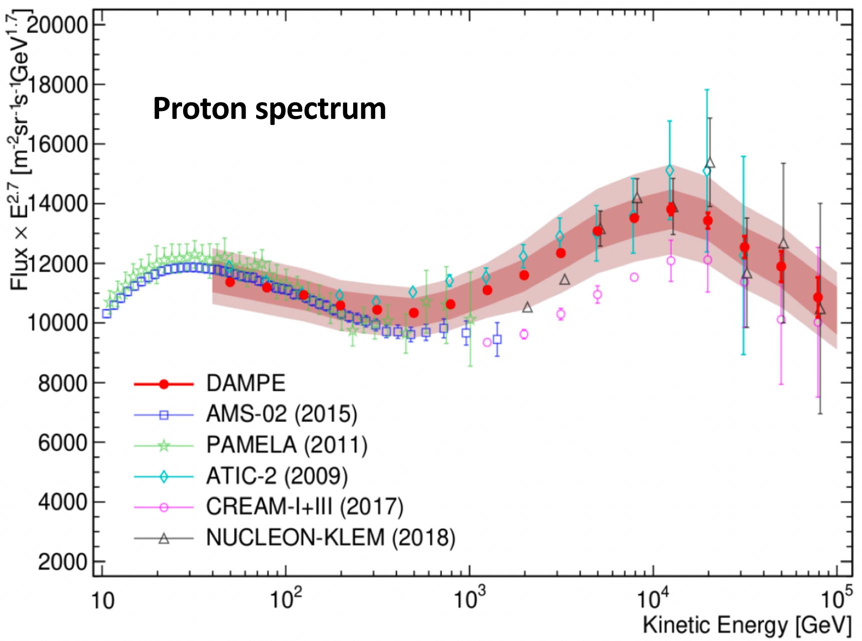
NUD

Further em/had showers separation
4 boron-doped scintillator tiles

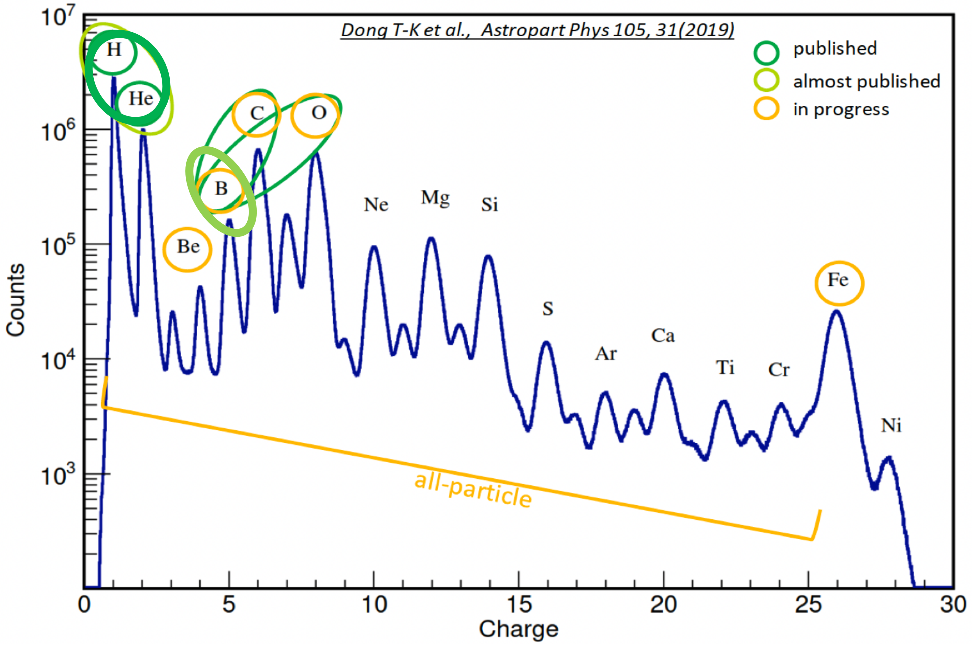
The DAMPE Space Mission

Primary scientific goals

- **Study of CR protons and nuclei**
- Study of cosmic ($e^- + e^+$) spectrum
- Indirect search for dark matter signatures in lepton spectra
- High energy gamma ray astronomy

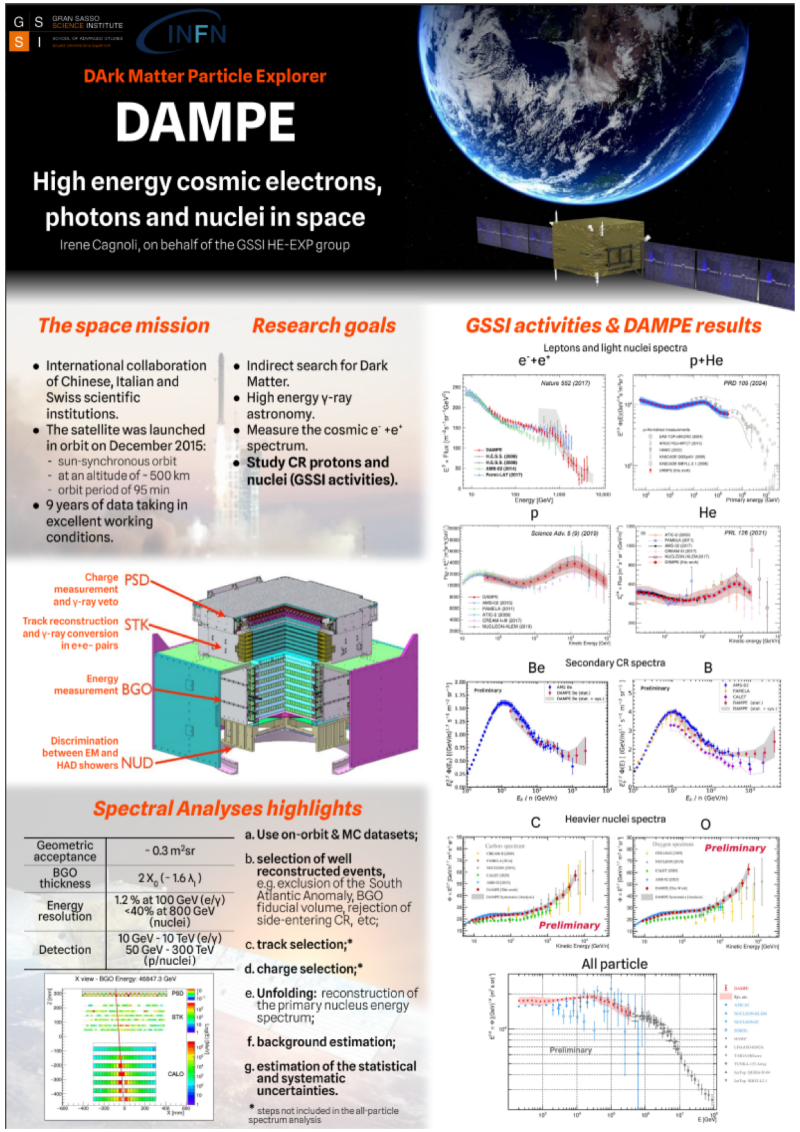


1st strong evidence of the softening at 10TeV

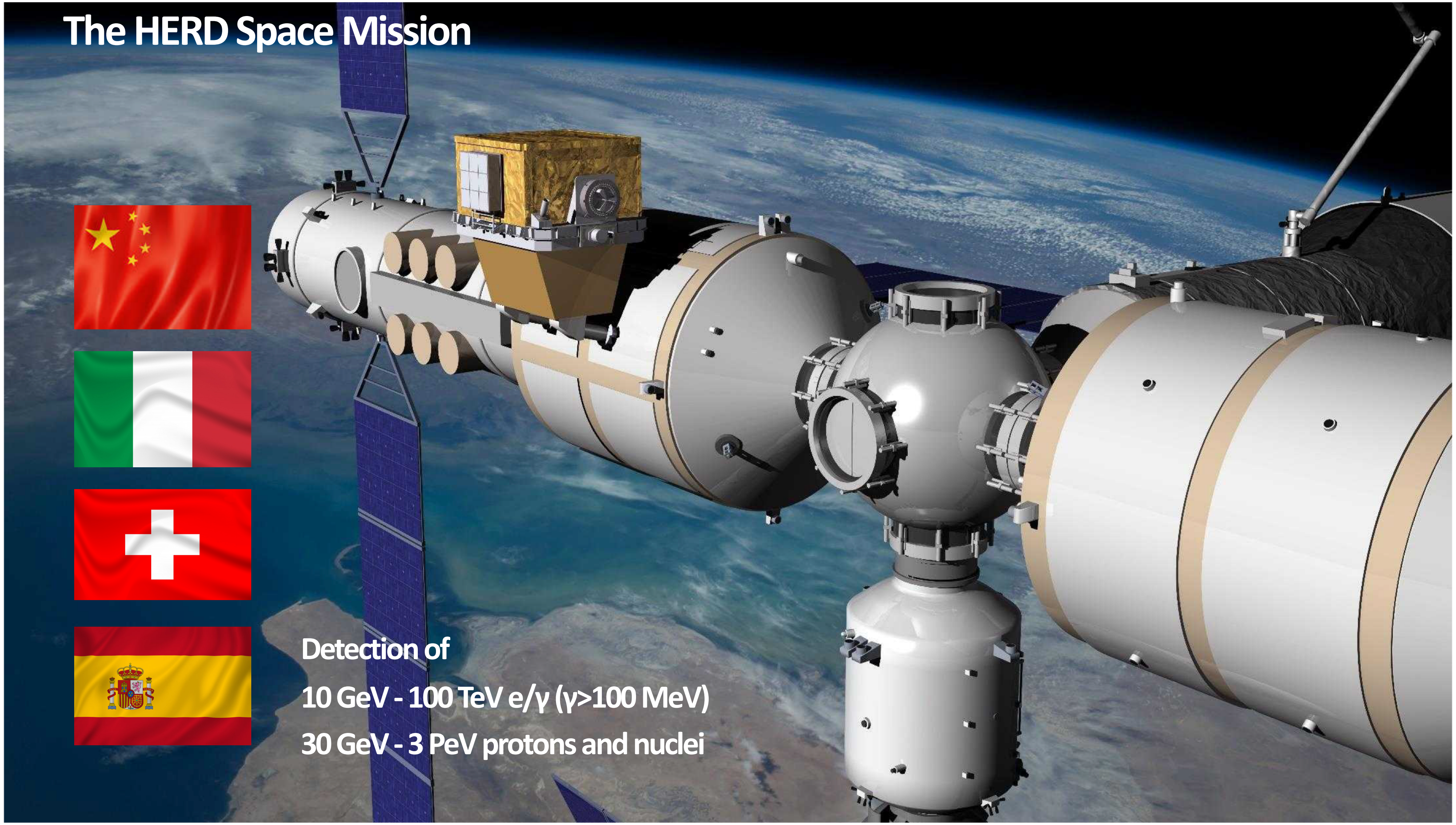


The DAMPE Space Mission

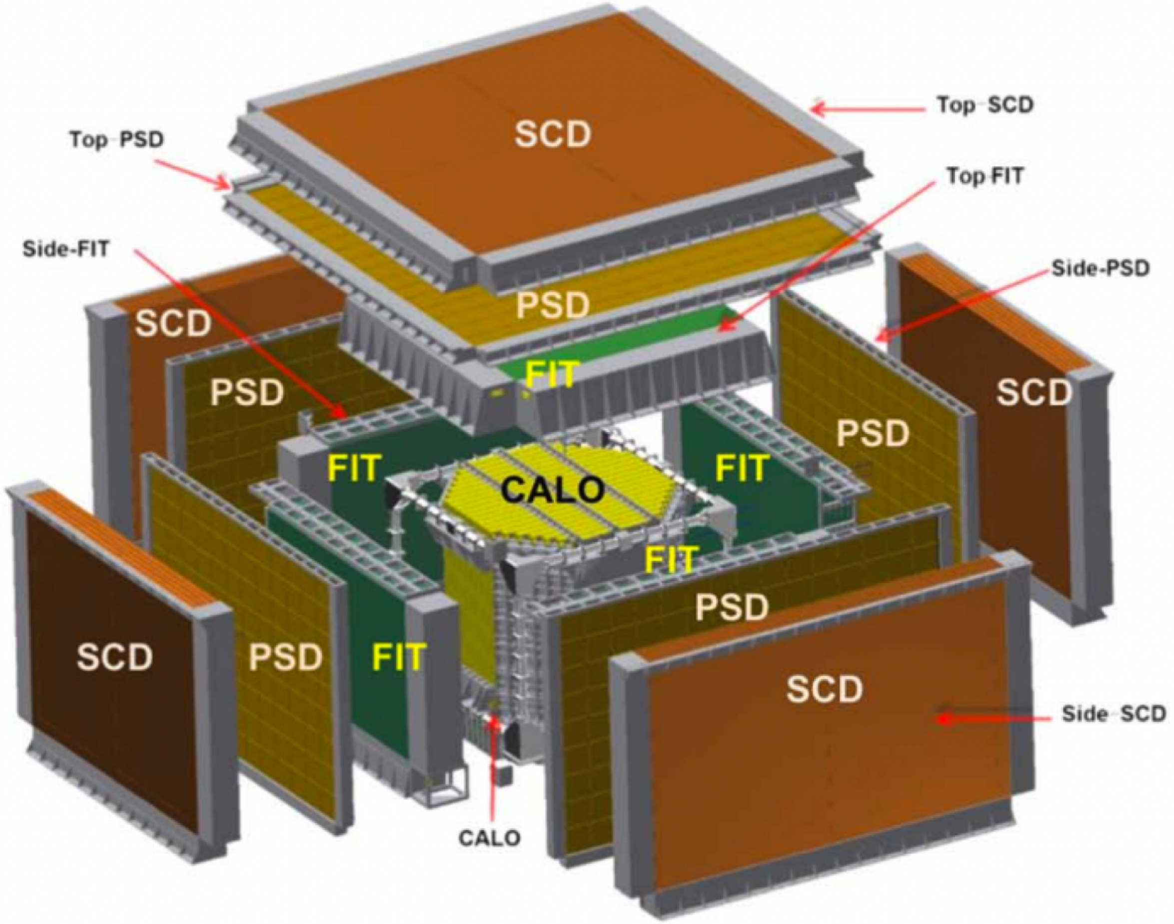
The DAMPE experiment: for a more detailed overview see Irene Cagnoli's poster



High Energy cosmic-Radiation Detector



The HERD Space Mission



A deep (~55 X_0, 3 λ_I) 3D cubic **calorimeter (CALO)**, forming an octagonal prism, to accurately measure the deposited energy and separate electron & proton induced showers.

A **Fiber Tracker (FIT)**, situated on all active sides, determining tracks of impinging particles.

A **Plastic Scintillator Detector (PSD)**, covering the calorimeter and tracker, providing gamma–ray and charged particle triggers, with an additional level of charge measurement.

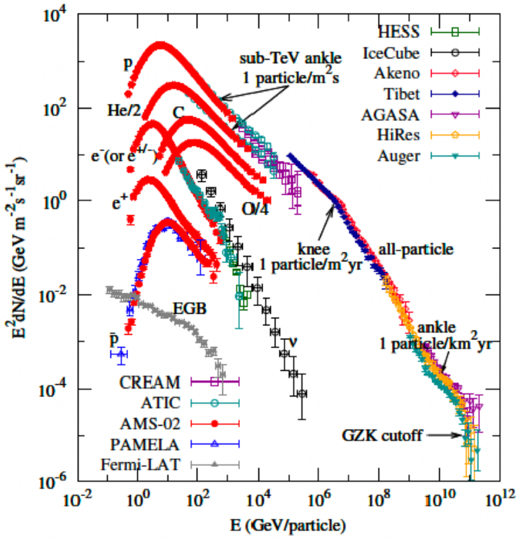
A **Silicon Charge Detector (SCD)**, that envelops all sub-detectors, ensuring an additional determination of the charge.

A **Transition Radiation Detector (TRD)**, placed on one of the lateral faces, providing energy calibration of nuclei (TeV region). (Not Visible)

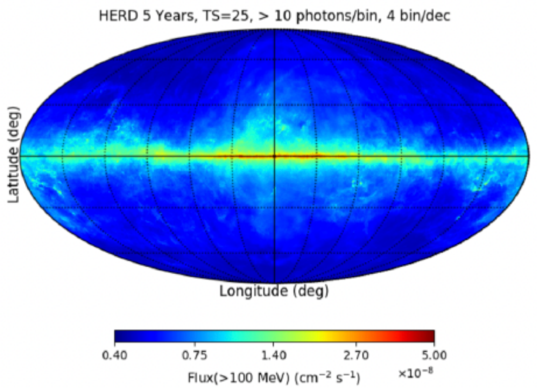
The HERD Space Mission

HERD primary scientific goals include

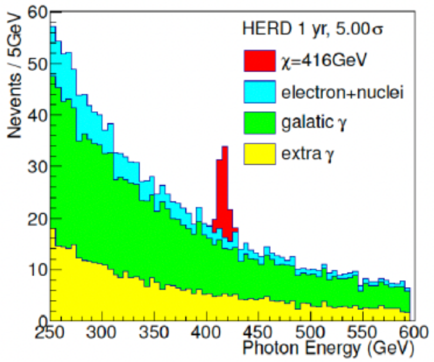
- precise measurements of the energy spectra of CR individual species up to few PeV



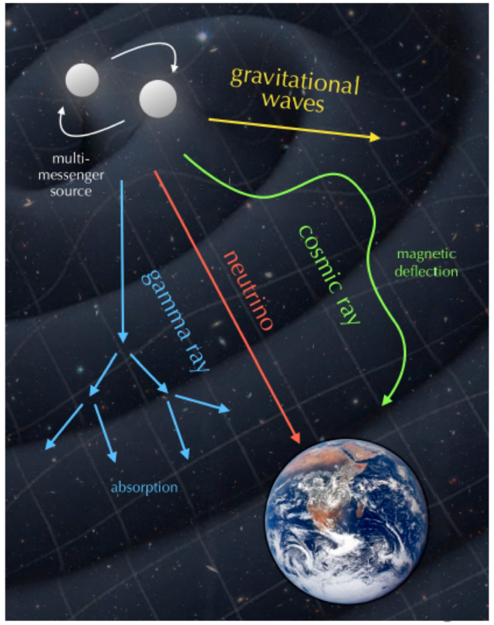
- study electrons and photon of spectra from GeV up to tens of TeV



- indirect dark matter search

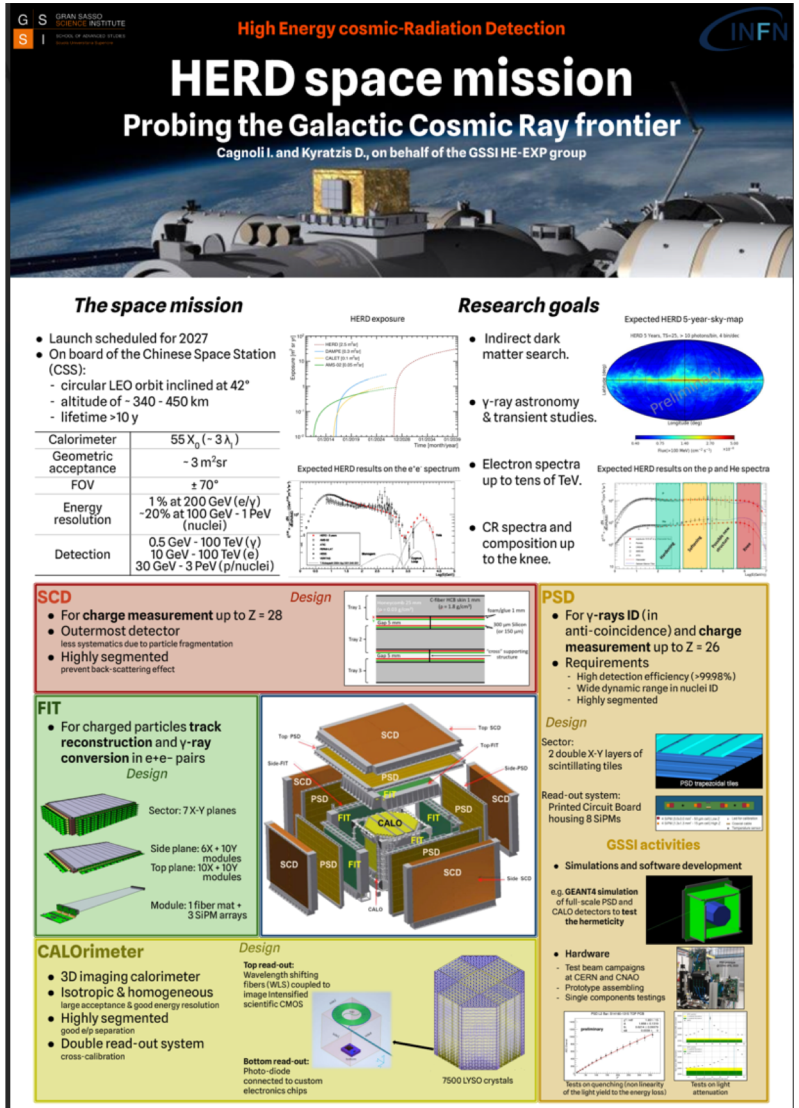


- contributing to multi-messenger observations together with other satellites and ground-based experiments

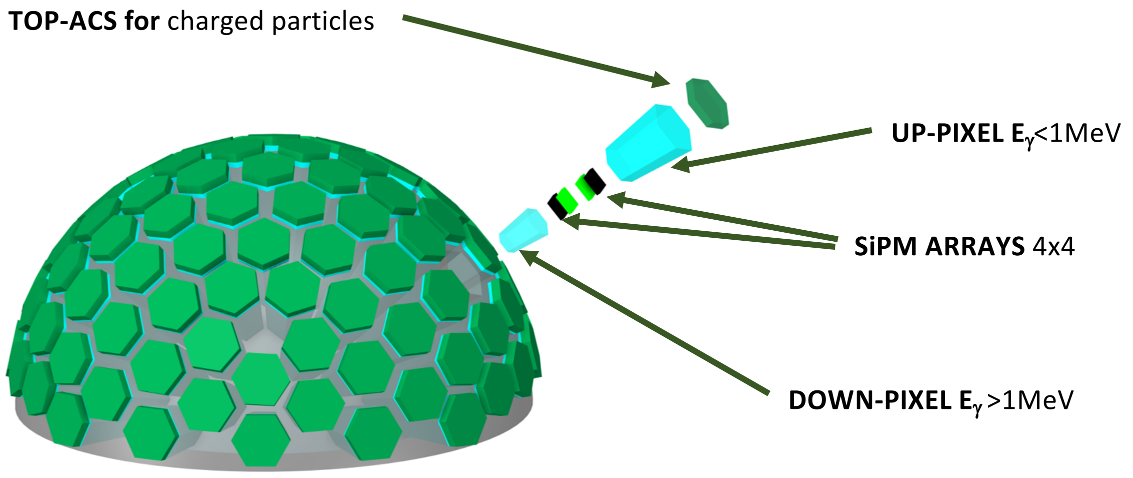


The HERD Space Mission

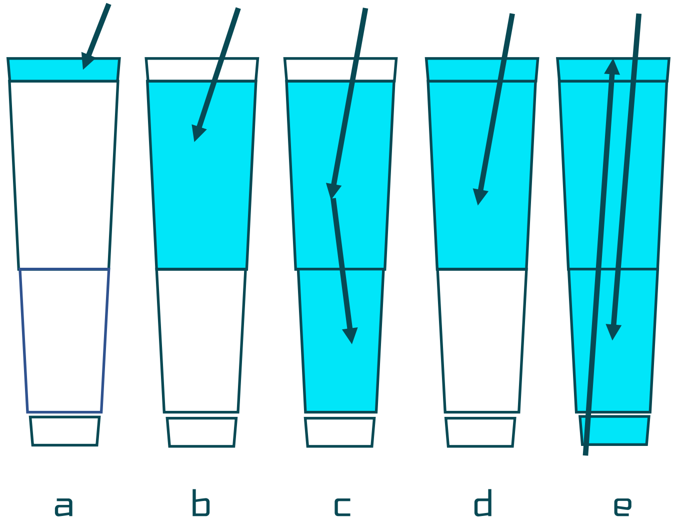
The HERD experiment: for a more detailed overview see Irene and Dimitris's poster



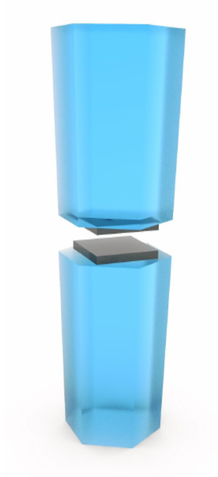
Crystal Eye



Detection of
10 keV - 30 MeV γ
All-sky Monitor



a – Down-going hard X-ray
b – Down-going LE g-ray
c – Down-going ME g-ray
d – Down-going LE charged particle
e – HE charged particle

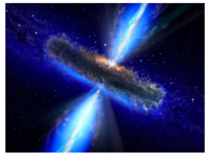


- **Pixel FOV:** 2.5°x2.5°.
- **LYSO+GAGG crystals**
- **Photodetectors:** 4x4 MPPC array
- **VETO** for charged cosmic-ray rejection.

Crystal Eye

1) Monitoring the electromagnetic counterpart of gravitational waves

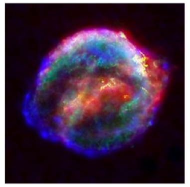
2) Multimessenger observations



Progress in understanding mechanism that power jets (like GRBs, AGNs)

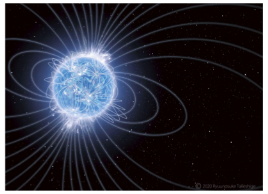
3) Observation of gamma ray lines from supernovae??? (still under study)

Progress in understanding the mechanism of element formation in extreme environment



4) Searching for magnetars

Understanding possible correlation with FRB

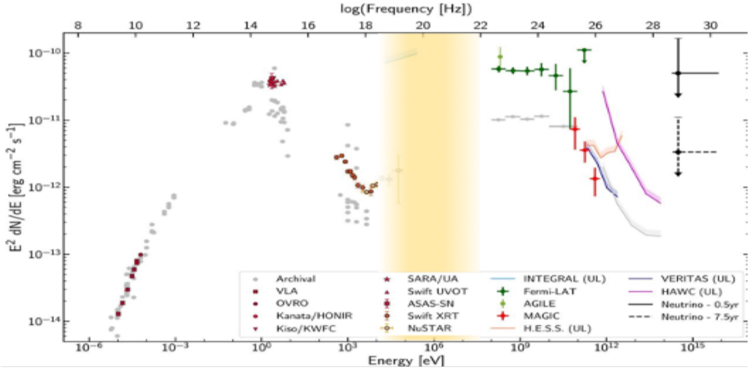


5) Study of X-ray binaries in MeV region

6) TGF, space weather

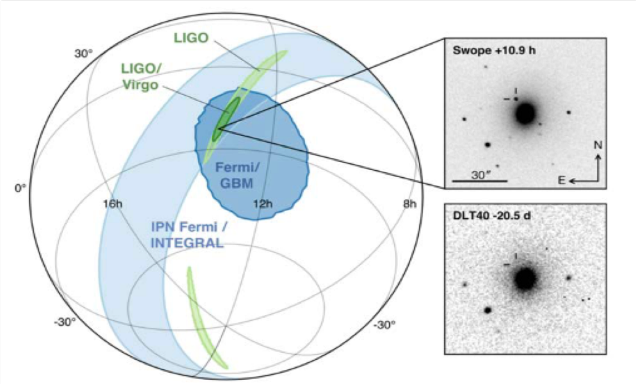
Possible joint thesis with Gor and Felicia to study Crystal Eye science case

TXS 0506+056



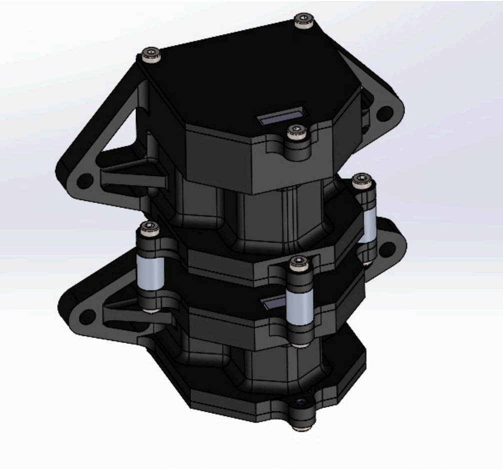
Medium energies still under-explored (E ~ MeV)

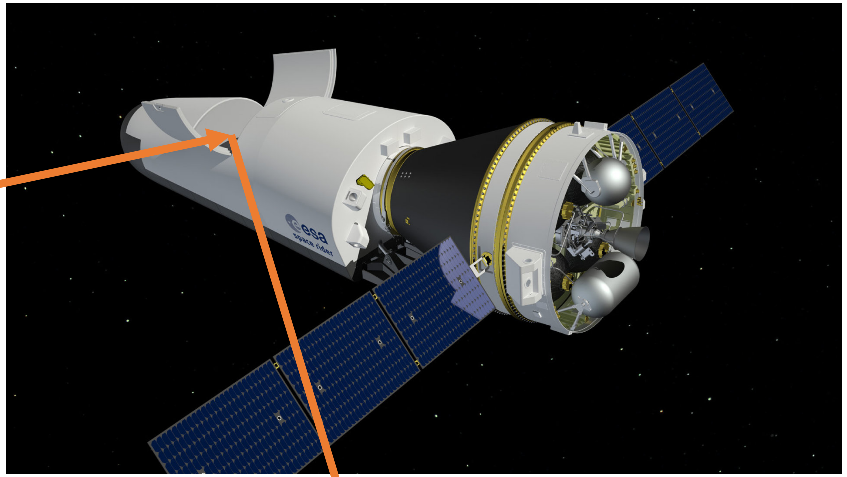
GW170817



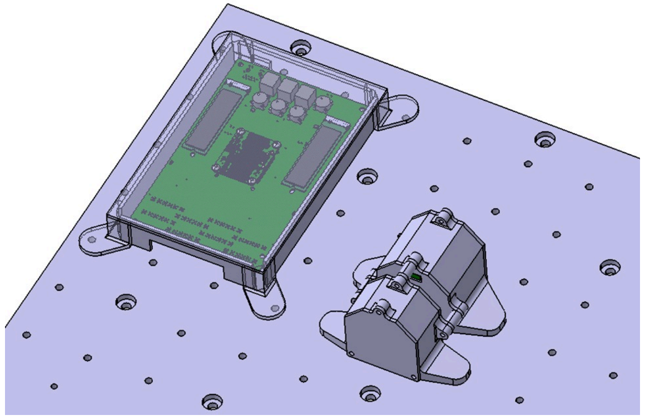
WINK: the Crystal Eye pathfinder

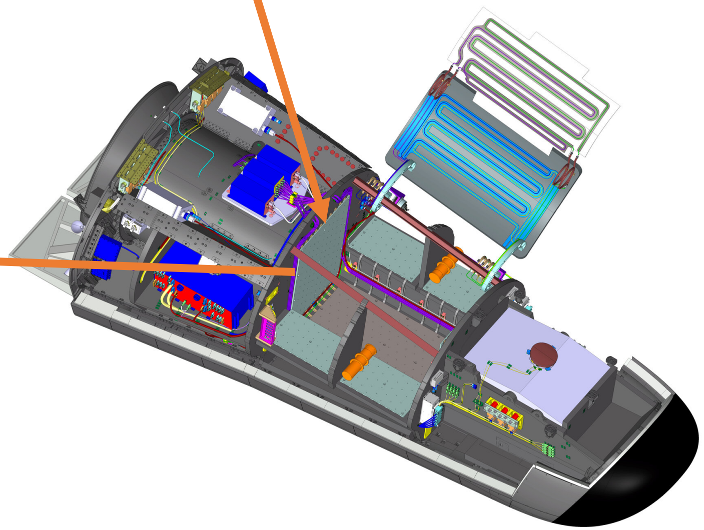
WINK consists of 3 Crystal Eye pixels and its operations will validate the Crystal Eye technology observing deep space and Earth.

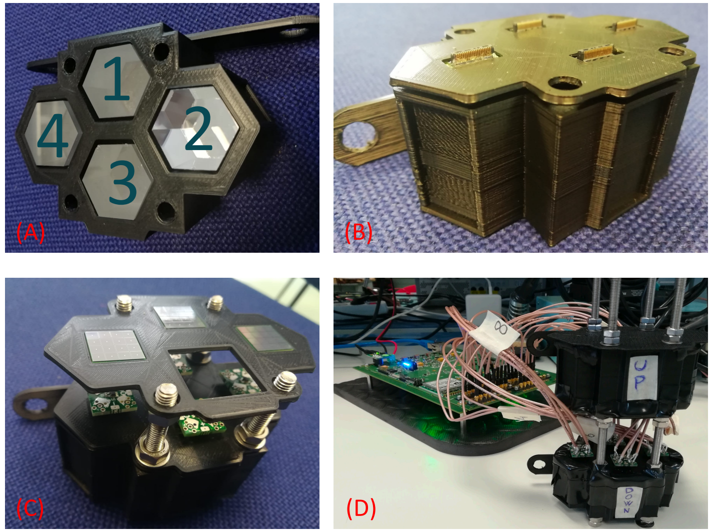




Number of pixels: 3
Material: LYSO
Photodetectors: SiPM-array
Weight: 2kg
Power consumption: <15 W
FOV: 30°

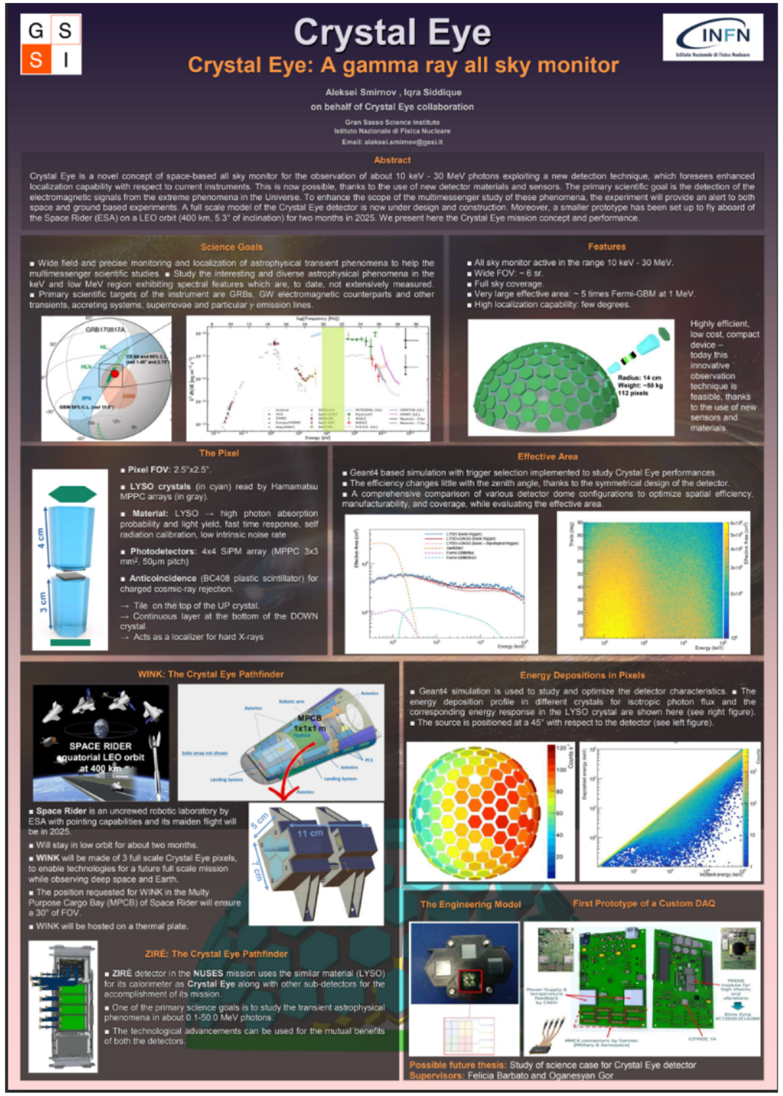




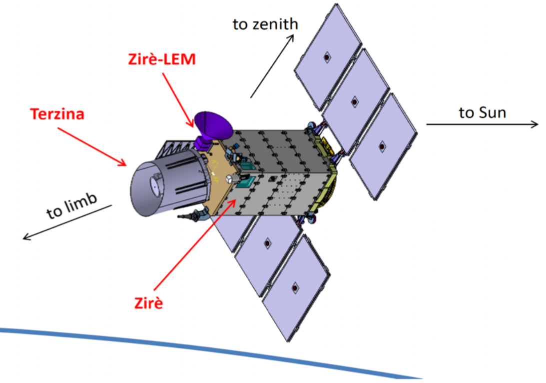


Crystal Eye & WINK

Crystal Eye: for a more detailed overview see Aleksei and Iqra's poster



NeUtrino and Seismic Electromagnetic Signals



A joint Gran Sasso Science Institute -Thales Alenia Space Italy (TAS-I) **mission conceived as a pathfinder for new observation methods and technologies in the study of high and low energy radiations enabling new sensors, tools and detection techniques.**

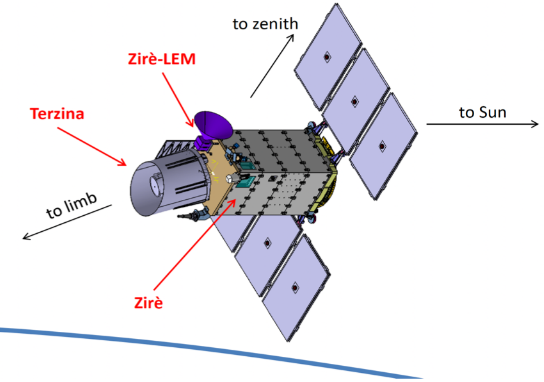
>60 scientists from Italian Universities and INFN sites, international research and academic institutions and industrial partners.

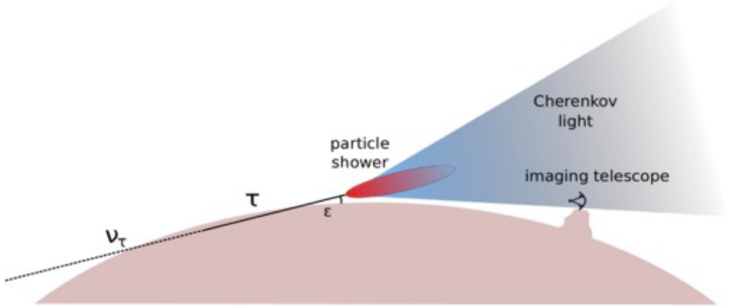
Large expertise (and synergies) from space missions/R&D programs: AMS, DAMPE, ASTROGAM, FERMI, GAPS, HERD, LIMADOU, PAMELA, POEMMA, SPB2 , …

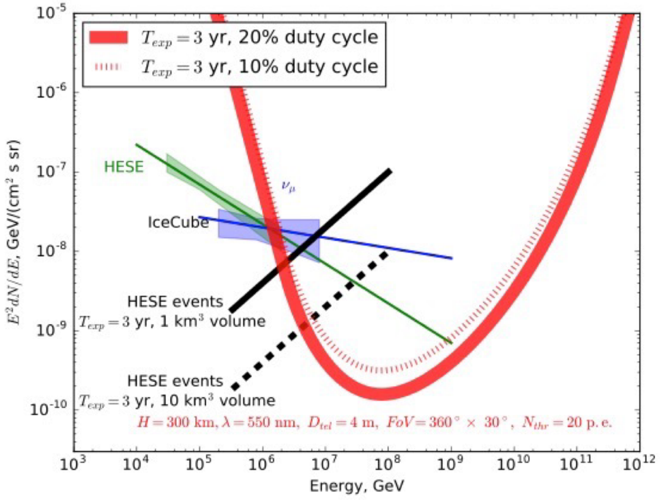
- To measure UHE cosmic rays and enable neutrino astronomy through **space-based atmospheric Cerenkov light detection**.
- To **monitor the fluxes of low energy (<250 MeV) e, p, CR** to study Van Allen belts, space weather and the magnetosphere-ionosphere-litosphere couplings (**MILC**) in case of seismic / volcanic activities.
- To detect 0.1-10 MeV photons for the study of **transient** (GRB, e-m follow up of GW events, SN emission lines,…)
- To develop new observational techniques, to test sensors (e.g. Silicon PhotoMultiplier, SiPM) and related electronics/DAQ for space missions.

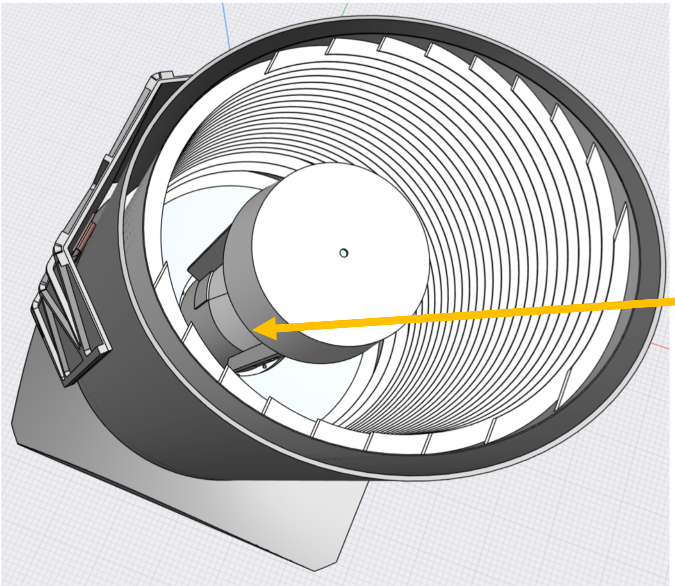
The NUSES Space Mission: TERZINA

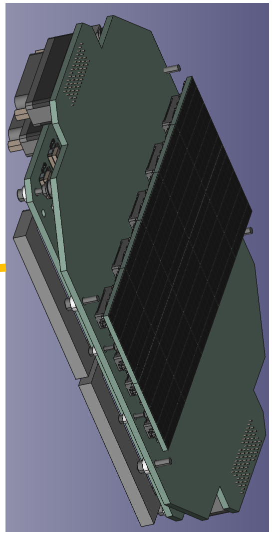
The science case: Astrophysical neutrinos and High Energy CR





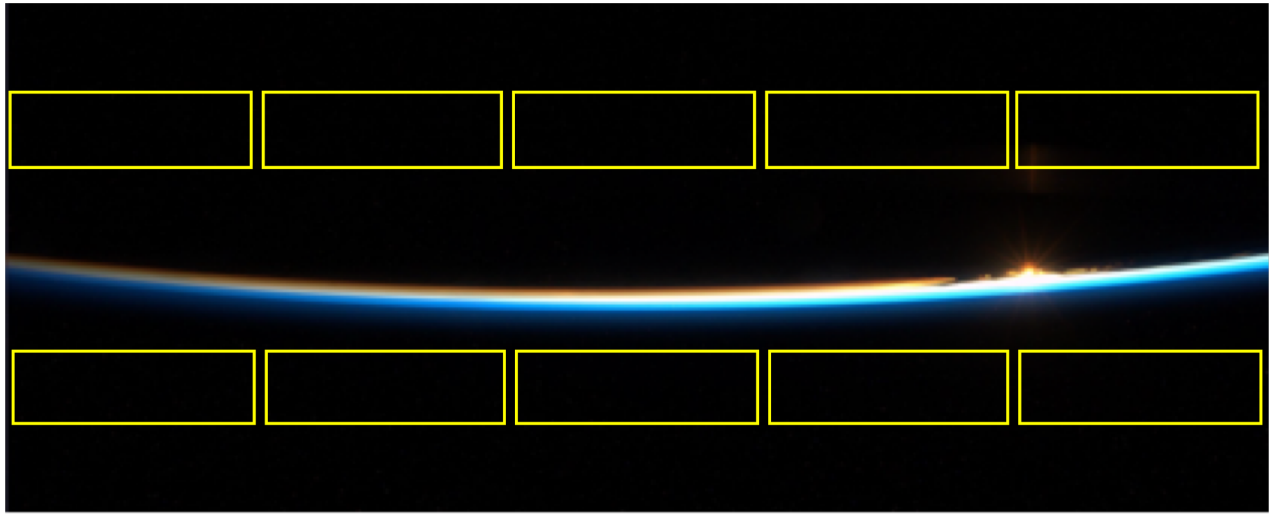






- The observation of astrophysical neutrinos at energies larger than few PeV can be achieved only from space.
- High energy CR (E>1 PeV) can be efficiently observed through EAS Cherenkov emission.

The NUSES Space Mission: TERZINA



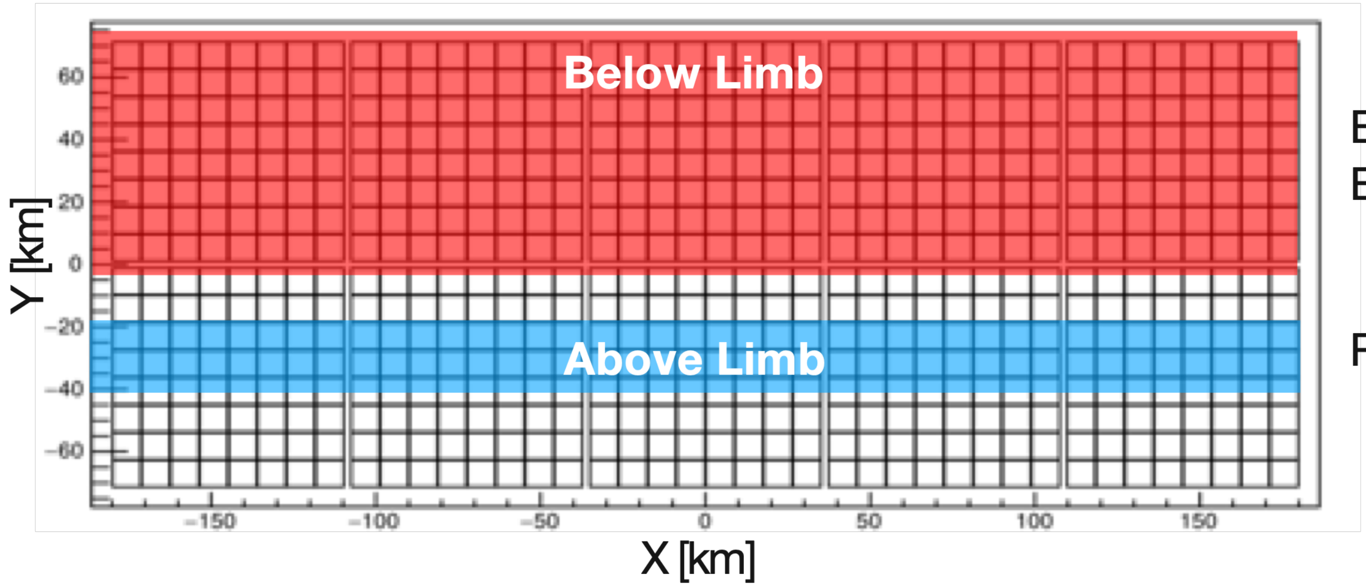
N.10 8x8 SiPM arrays

640 pixels/channels/SiPMs in total

Each is SiPM is 3 x 3 mm^2

Pixel F.O.V. 0.18°

24 x 24 mm^2 effective area per array

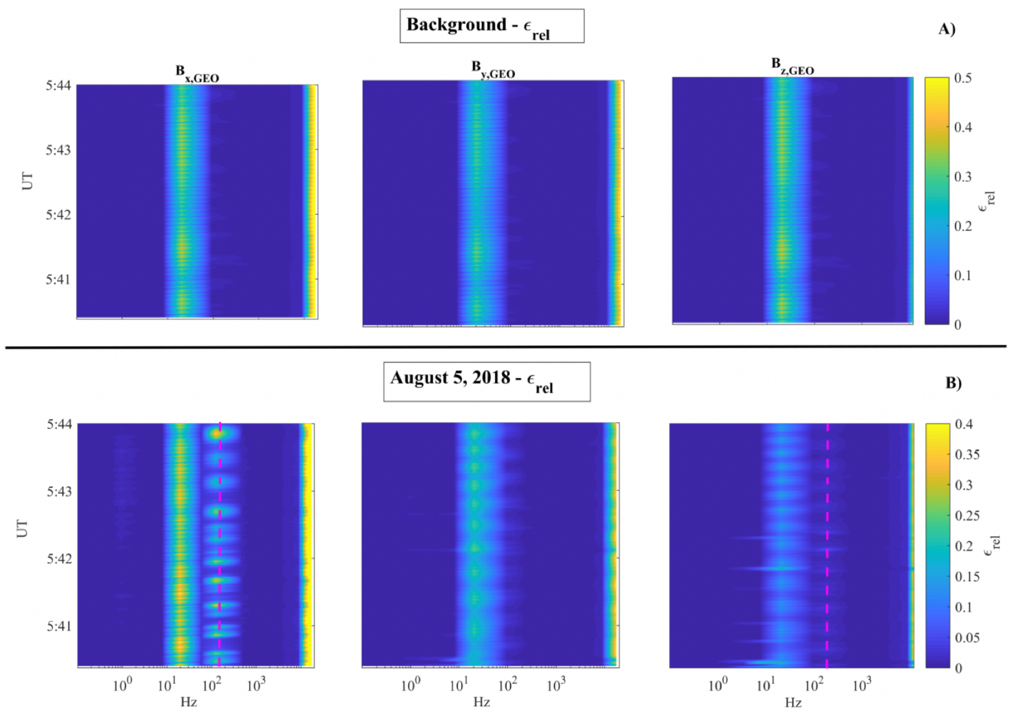


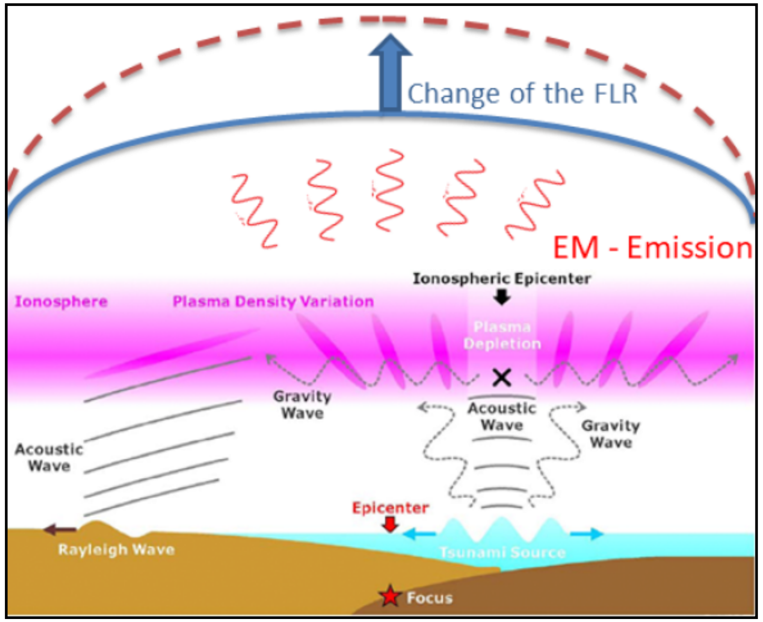
Background Evaluation
Earth Skimming Neutrino Shower

ROI: CR EAS

The NUSES Space Mission: ZIRE'

The science case: Magnetospheric Ionospheric Lithospheric Coupling (MILC)



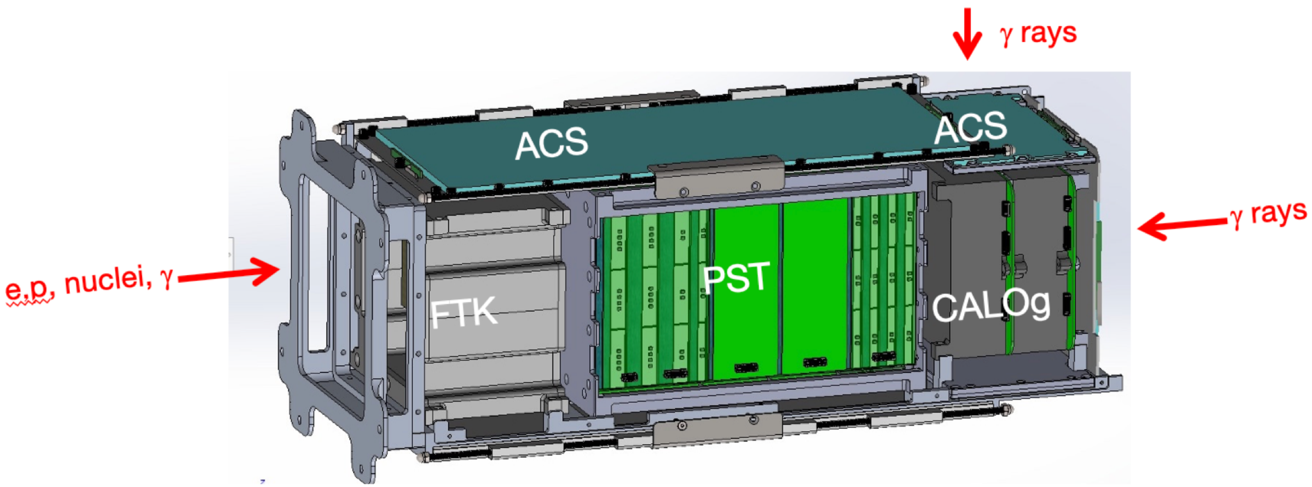


https://doi.org/10.3390/rs12203299

Study of possible time correlations between earthquakes and variations of the orbital particle background

The NUSES Space Mission: ZIRE'

The NUSES particle detector payload: Zirè

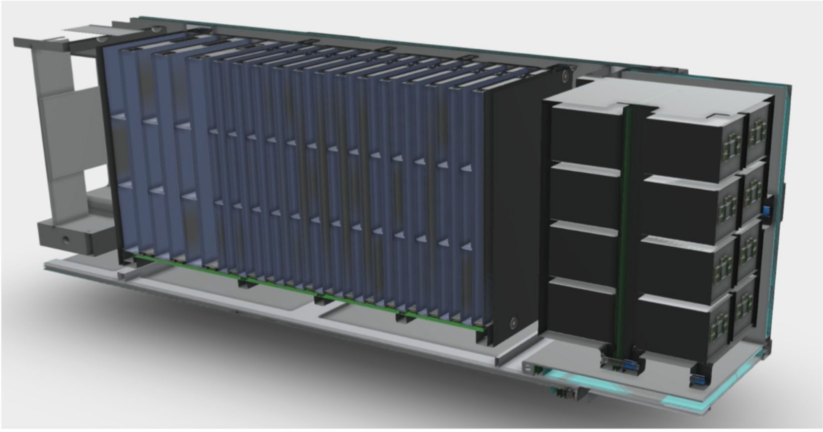


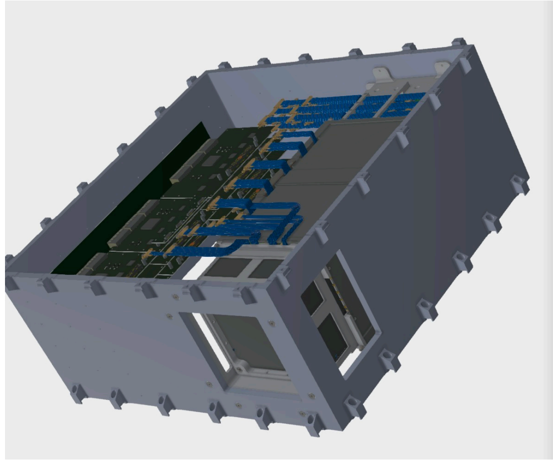
FTK (Fiber TracKer): N.3 X-Y modules made of scintillating fibers read out by linear arrays of SiPMs

PST (Plastic Scintillator Tower): N. 16 X-Y modules made of scintillating tiles read out by two setsvof SiPMs of different sensitive area

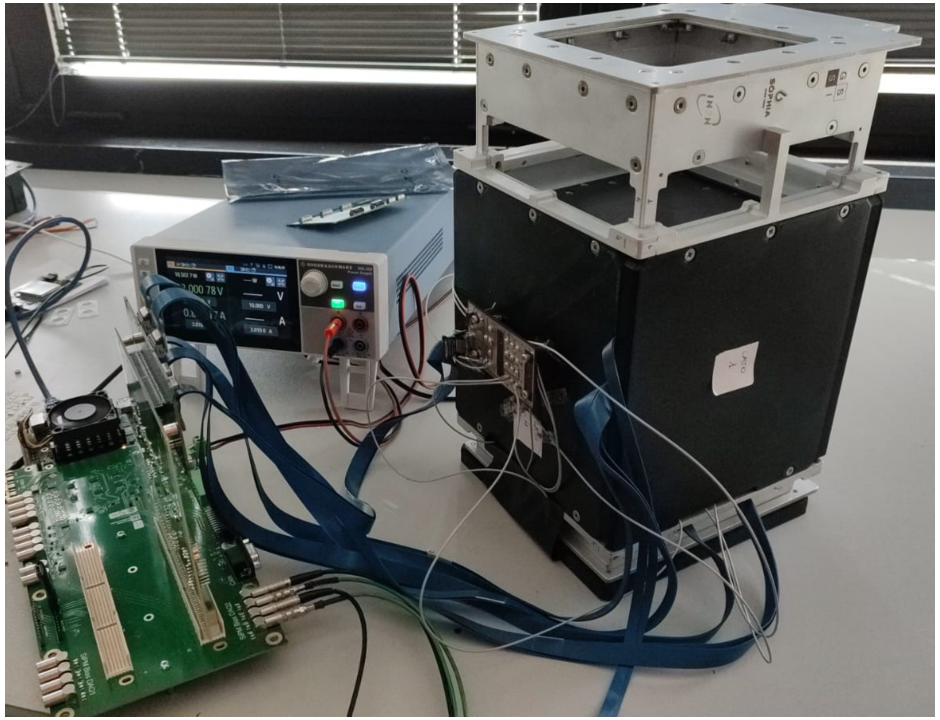
CALOg: N.2 4X4 matrices of LYSO crystals read out by three sets of SiPMs of different sensitive area

ACS (Anti-Coincidence System): a VETO for charged particle induced events made of plastic scintillator tiles and read out by SiPMs



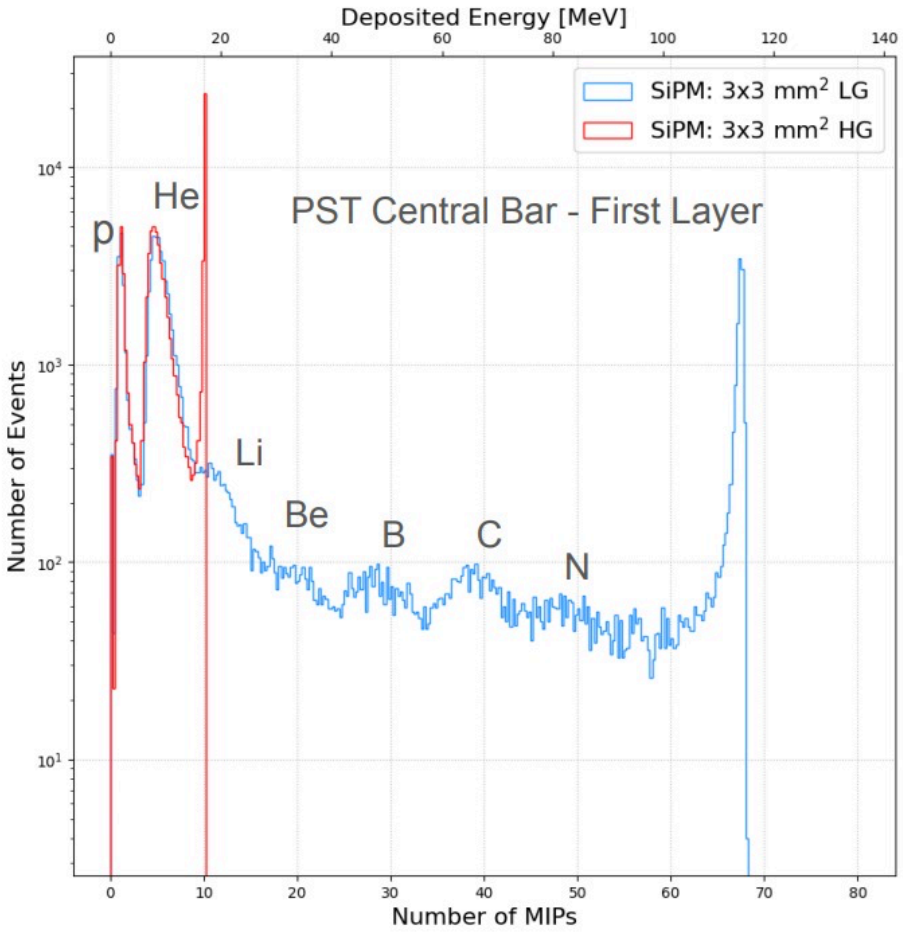


The ZIRE' prototype: ZIRETTINO

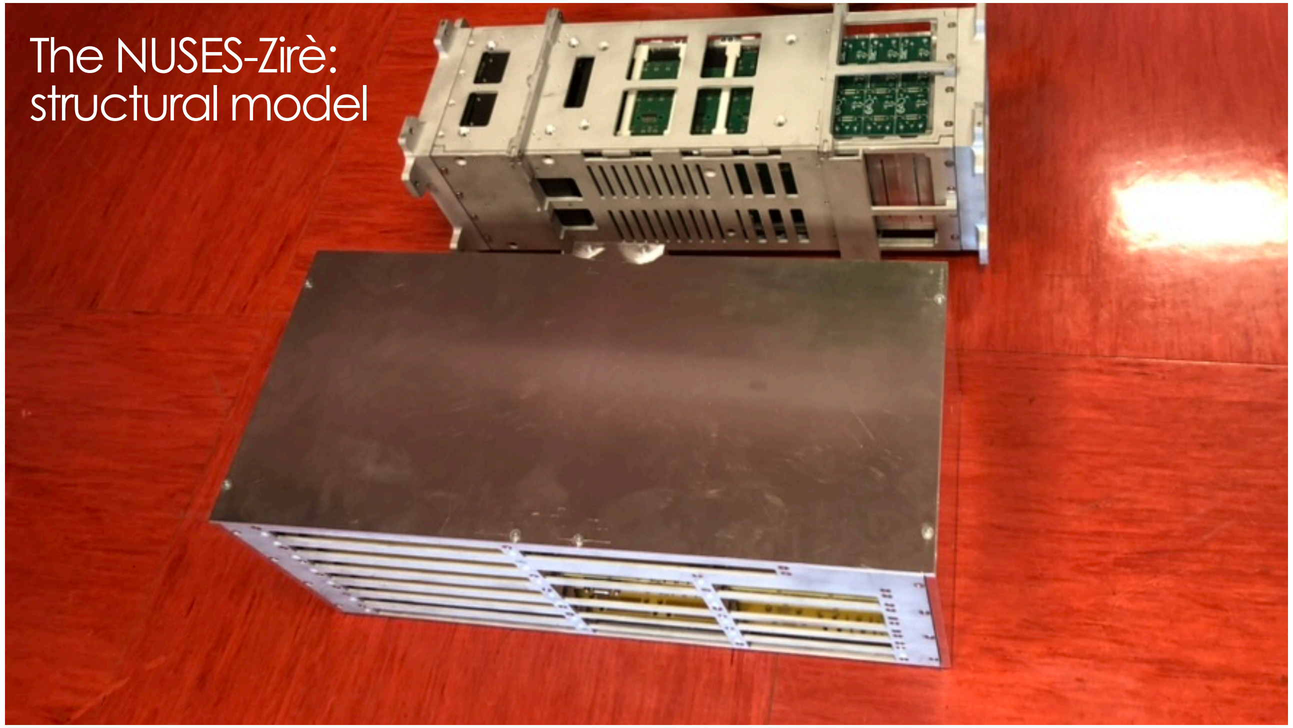


A fully representative tested at CERN (PS-SPS) with MIP and ions, and at BTF at LNF with electrons.

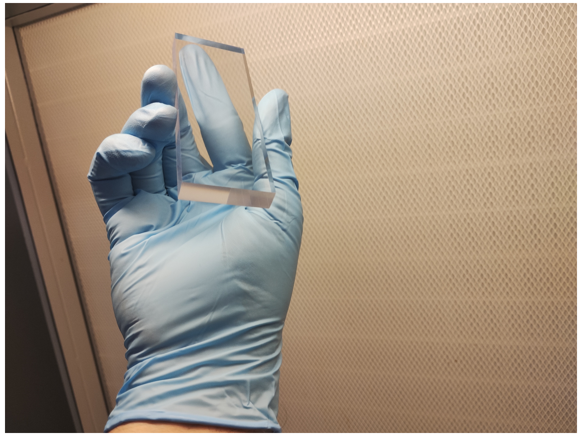
Preliminary tests done using a Ion beam show that the detector is sensitive to light nuclei and can measure Z up to nitrogen.

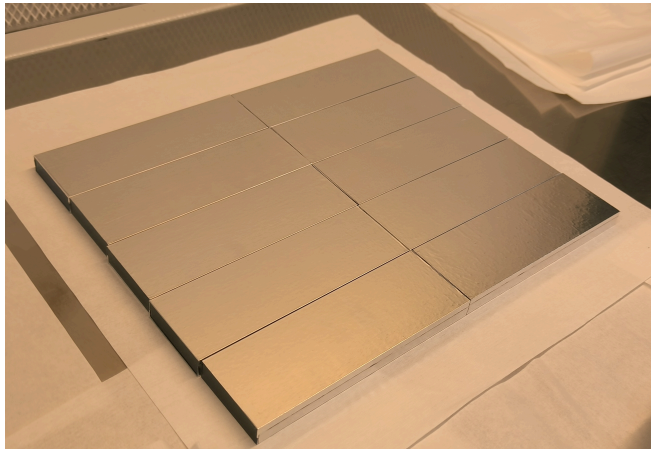


The NUSES Space Mission



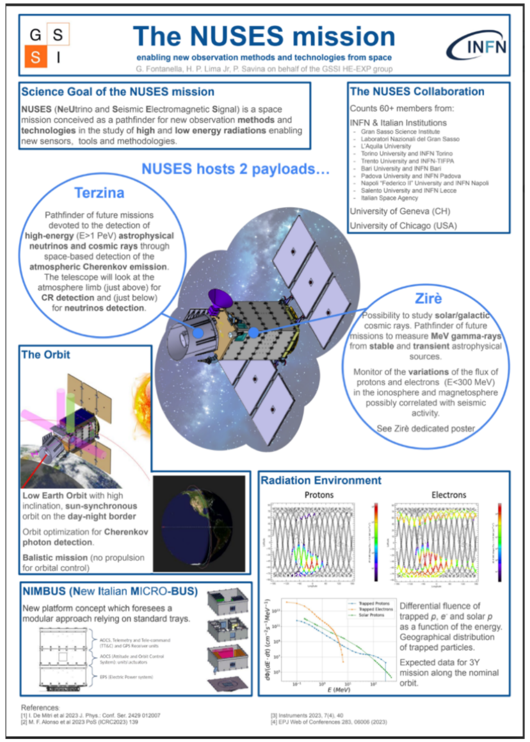
EQM assembly

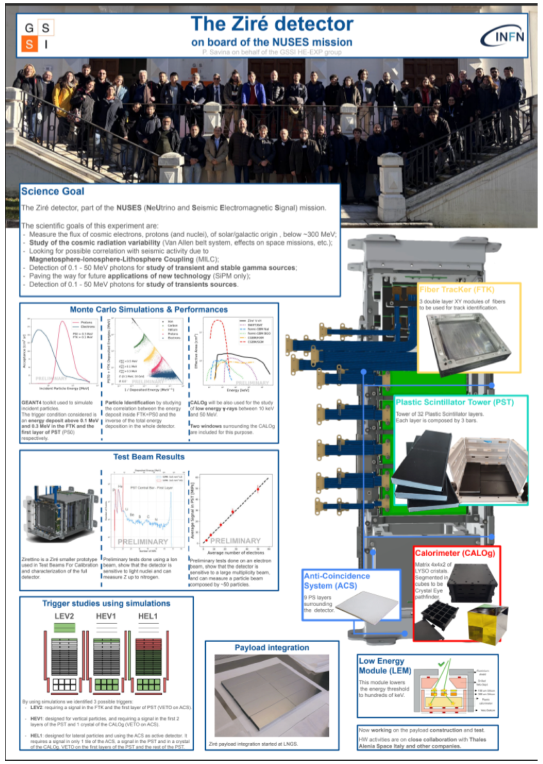


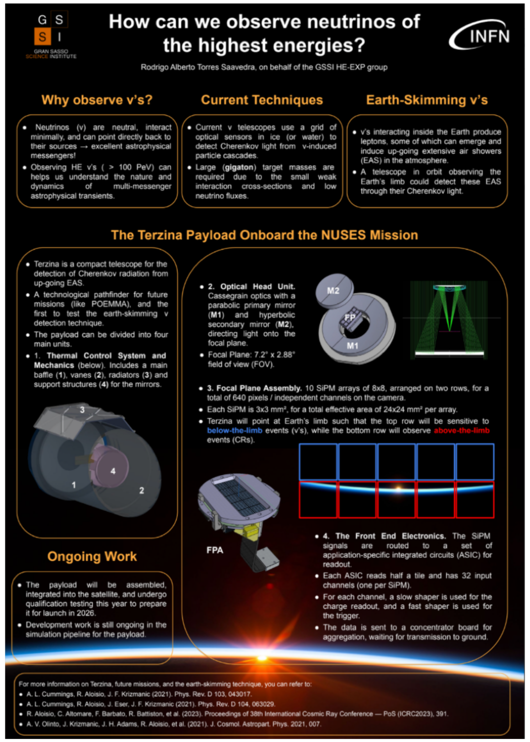


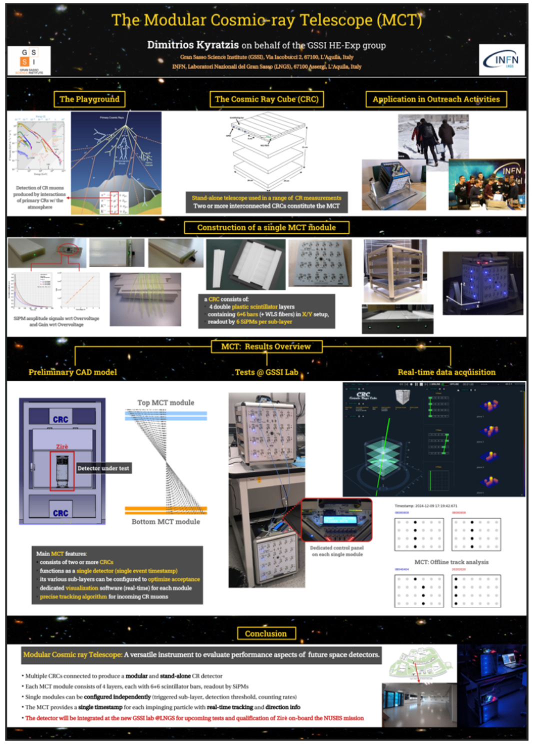
The NUSES Space Mission

The NUSES space mission: for a more detailed overview see the posters



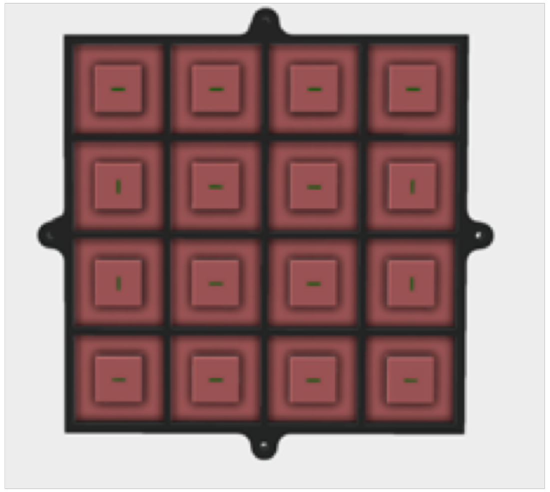


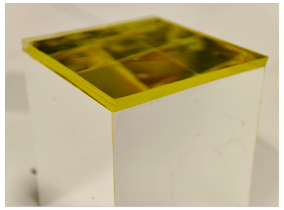




Space it up

New Project just started...

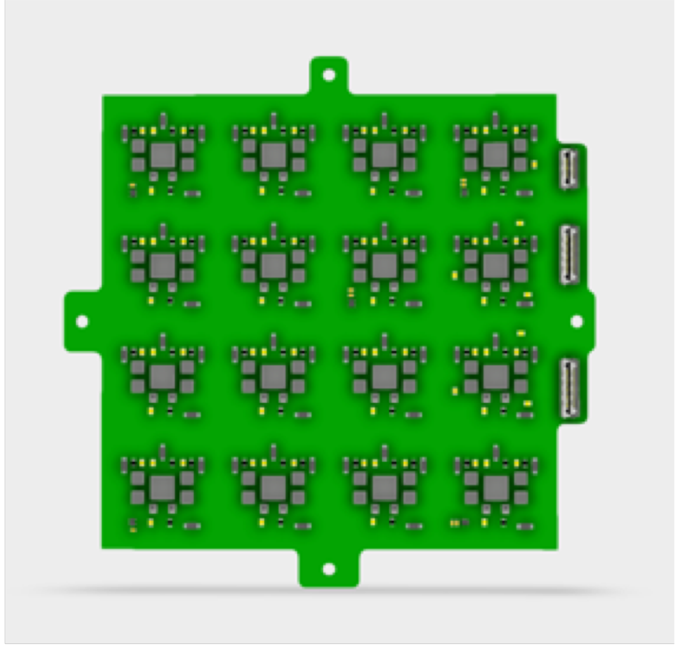




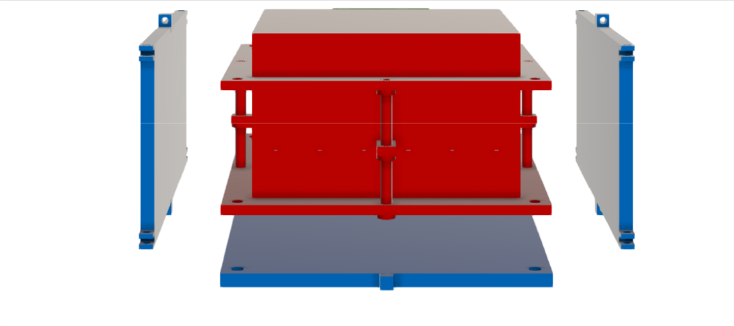
Test of different crystals:
- LYSO
- GAGG-F
- LaBr3 (SiPM NUV)

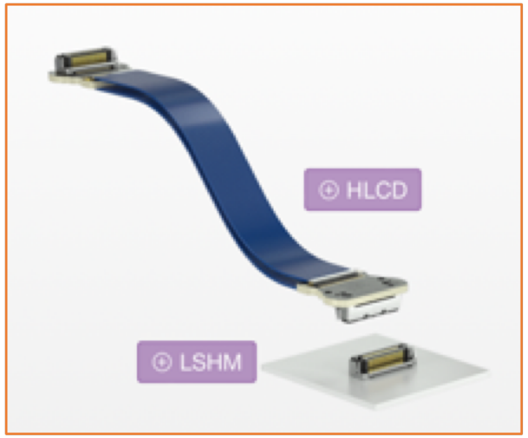
Test of different optical coupling

3 energies:
6x6 mm^2 SiPM
+
3x3 mm^2 SiPM
+
1x1 mm^2 SiPM

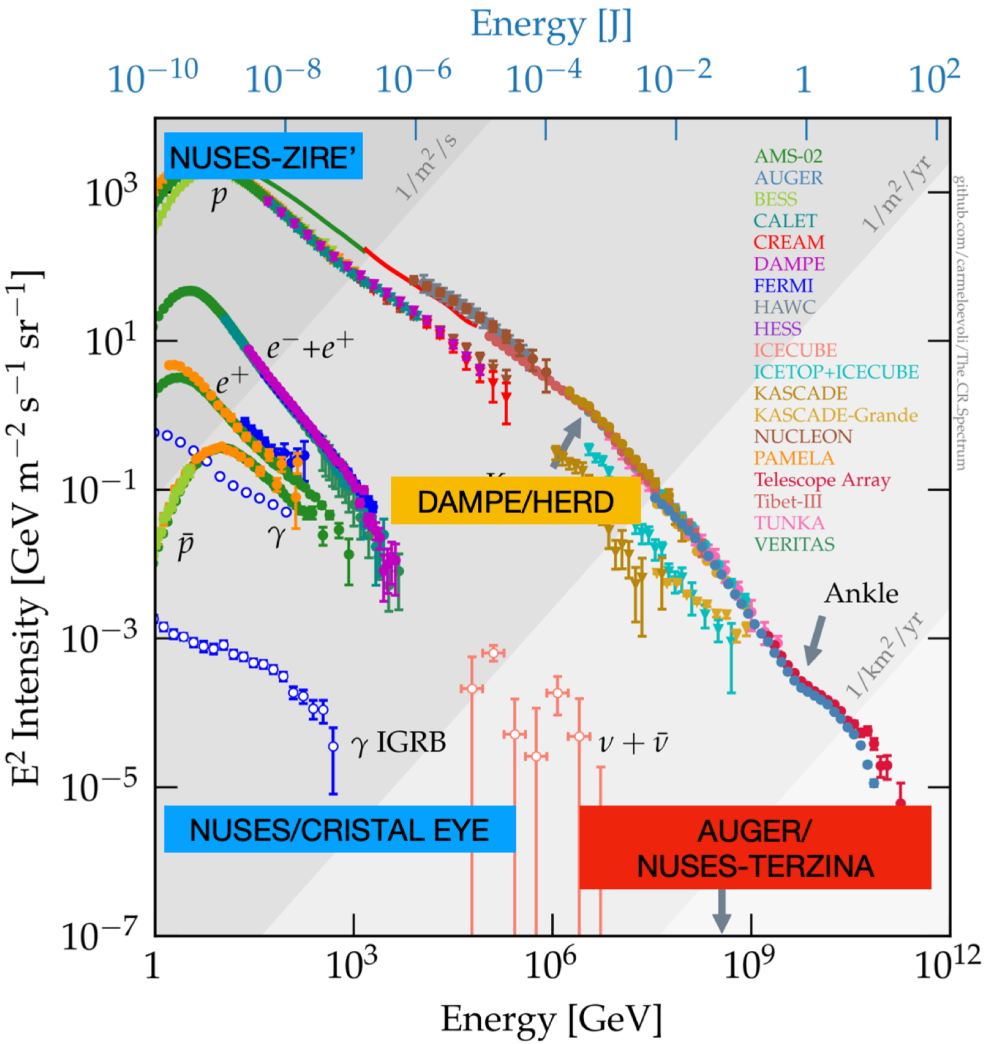


- Modular structure
- Each layer will have one PCB front-end board





In conclusion…



Just pick your energy range …