

# 11<sup>th</sup> 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



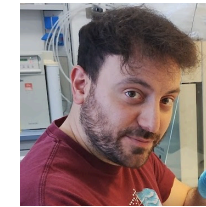
Sindor Ashurov  
PhD student



Diptiranjana Pattanaik  
Postdoc



Abhijit Roy  
Postdoc



Dimitrios Kyratzis  
Postdoc



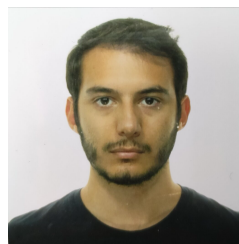
Irene Cagnoli  
PhD student



Giulio Fontanella  
PhD student



Rodrigo Alberto  
Torres Saavedra  
PhD student



Uygur Atalay  
PhD student



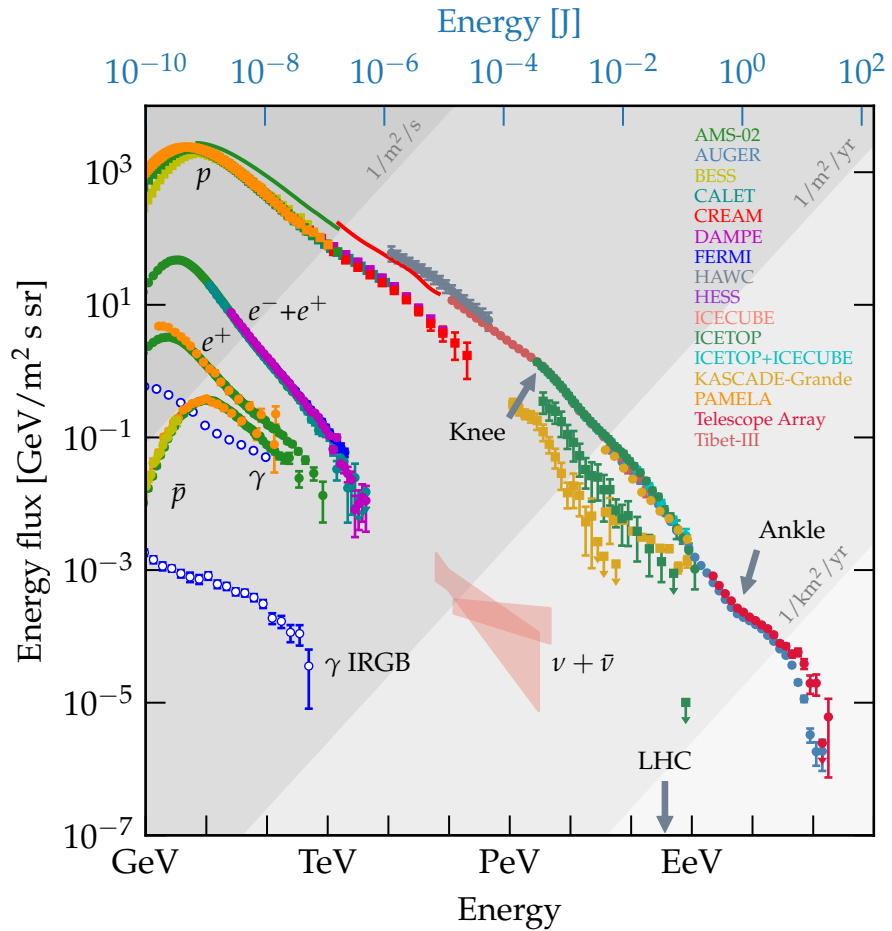
Ritabrata Sarkar  
Assistant Researcher



Aleksei Smirnov  
PhD student



Zheng Xiong  
Postdoc



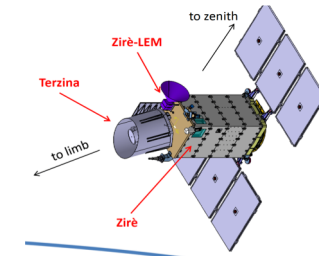
## Direct



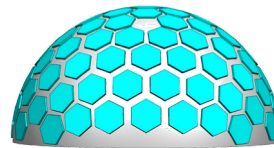
Dampe



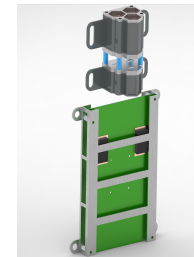
HERD



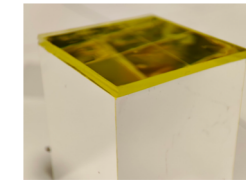
NUSES



Crystal Eye



W  
I  
N  
K



Space it up

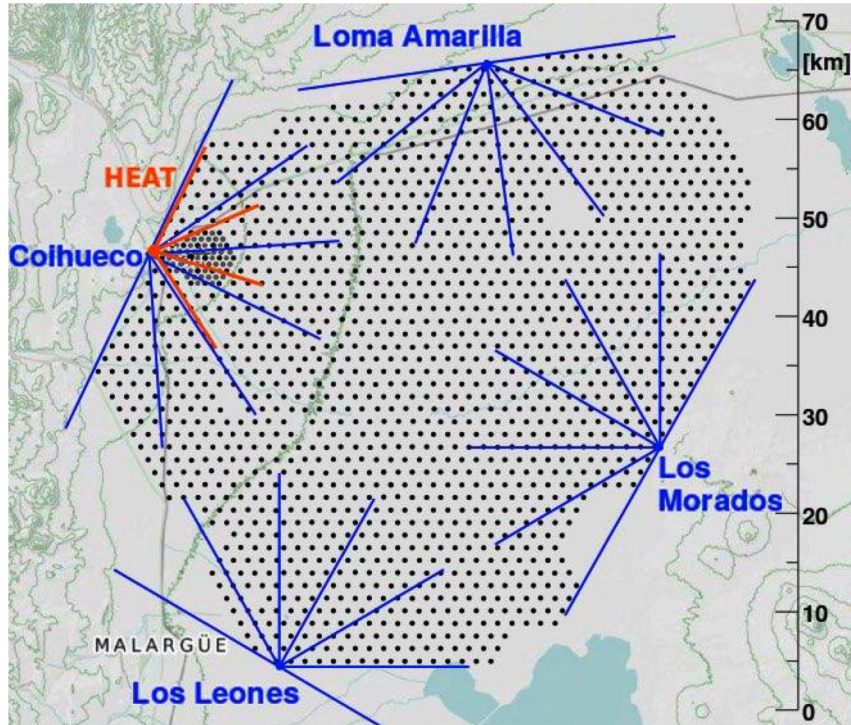
## Indirect



AUGER



## Southern hemisphere: Malargüe, Province Mendoza, Argentina



### Surface detector (SD)

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

### Fluorescence detector (FD)

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

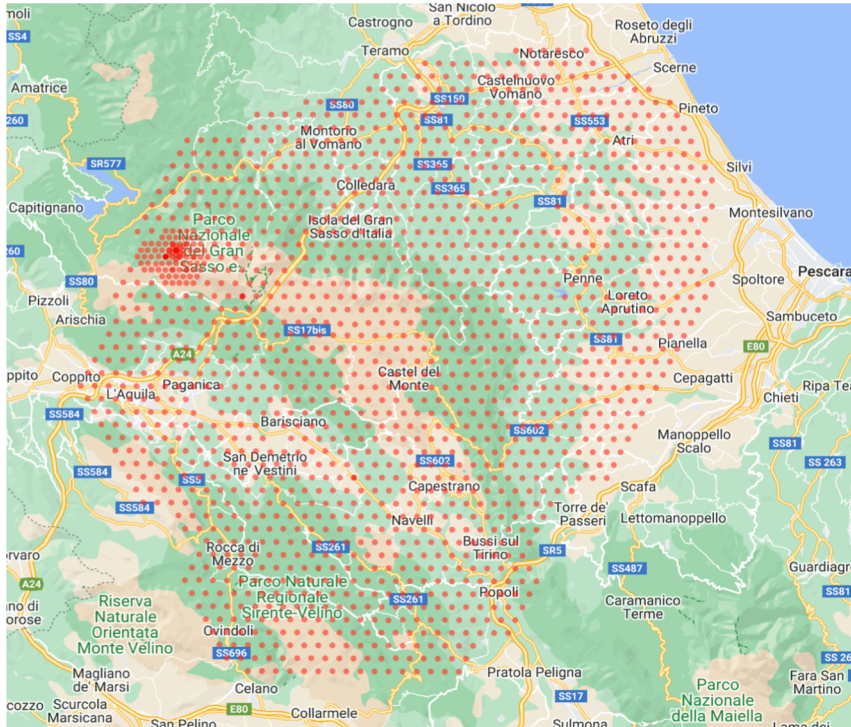
### Auger Engineering Radio Array (AERA)

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

### Underground muon detector

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

- *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...*



## 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



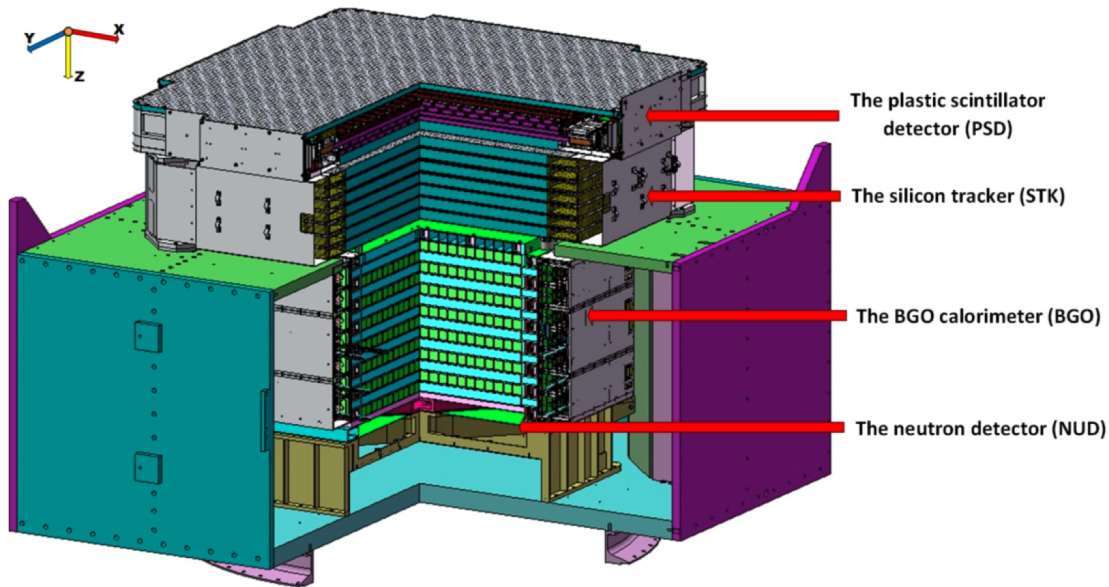
## The DAMPE Space Mission

*Launched on 17 December 2015, currently taking data*

Detection of  
10 GeV - 10 TeV  $e/\gamma$   
50 GeV - 200 TeV protons and nuclei



# The DAMPE Space Mission



- The plastic scintillator detector (PSD)
- The silicon tracker (STK)
- The BGO calorimeter (BGO)
- The neutron detector (NUD)

## PSD

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

## STK

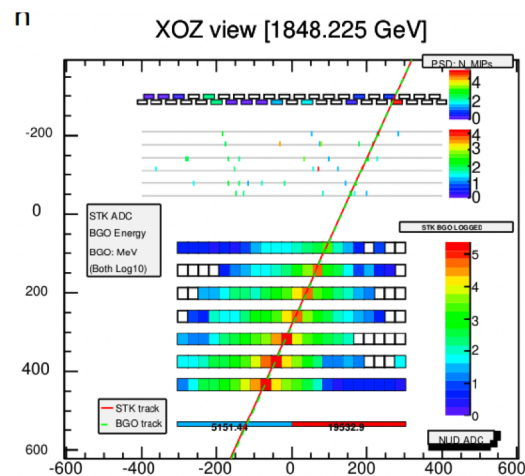
Track reconstruction + additional charge measurement  
6 planes of Si microstrip detectors + 3 W layers

## BGO

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

## NUD

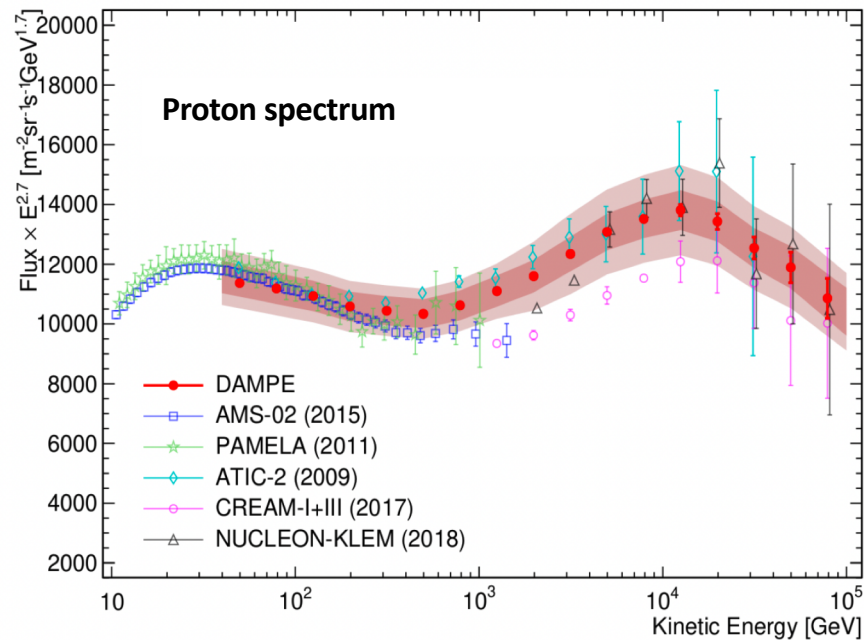
Further em/had showers separation  
4 boron-doped scintillator tiles



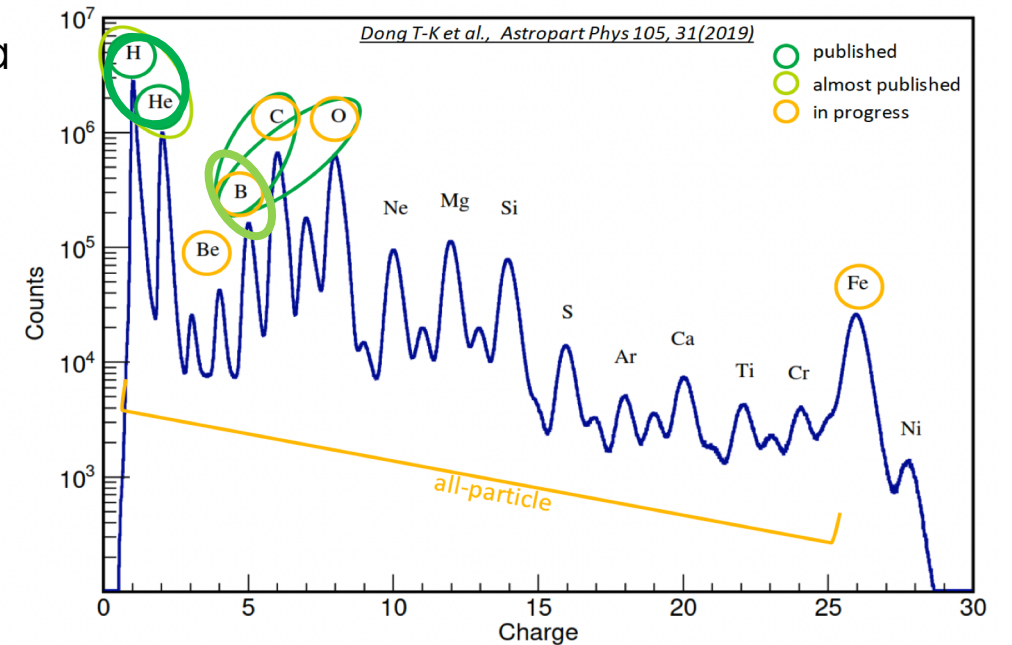


## Primary scientific goals

- **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



1<sup>st</sup> strong evidence of the softening at 10TeV



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

**Dark Matter Particle Explorer**  
**DAMPE**  
High energy cosmic electrons, photons and nuclei in space  
Irene Cagnoli, on behalf of the GSSI HE-EXP group

### The space mission

- International collaboration of Chinese, Italian and Swiss scientific institutions.
- The satellite was launched in orbit on December 2015:
  - sun-synchronous orbit
  - at an altitude of ~500 km
  - orbit period of 95 min
- 9 years of data taking in excellent working conditions.

### Research goals

- Indirect search for Dark Matter.
- High energy  $\gamma$ -ray astronomy.
- Measure the cosmic  $e^+e^-$  spectrum.
- Study CR protons and nuclei (GSSI activities).

### GSSI activities & DAMPE results

Leptons and light nuclei spectra

Secondary CR spectra

Heavier nuclei spectra

All particle

Charge PSD measurement and  $\gamma$ -ray veto  
Track reconstruction and  $\gamma$ -ray conversion in  $e^+e^-$  pairs  
Energy measurement BGO  
Discrimination between EM and HAD showers NUD

### Spectral Analyses highlights

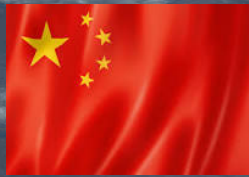
Geometric acceptance	- 0.3 m <sup>2</sup> sr
BGO thickness	2X <sub>0</sub> (~1.6 $\lambda$ )
Energy resolution	1.2% at 100 GeV (e $\gamma$ ) ~40% at 800 GeV (nuclei)
Detection	10 GeV - 10 TeV (e $\gamma$ ) 50 GeV - 300 TeV (p/nuclei)

- Use on-orbit & MC datasets;
- selection of well reconstructed events, e.g. exclusion of the South Atlantic Anomaly, BGO fiducial volume, rejection of side-entering CR, etc;
- track selection,\*
- charge selection,\*
- Unfolding: reconstruction of the primary nucleus energy spectrum;
- background estimation;
- estimation of the statistical and systematic uncertainties.

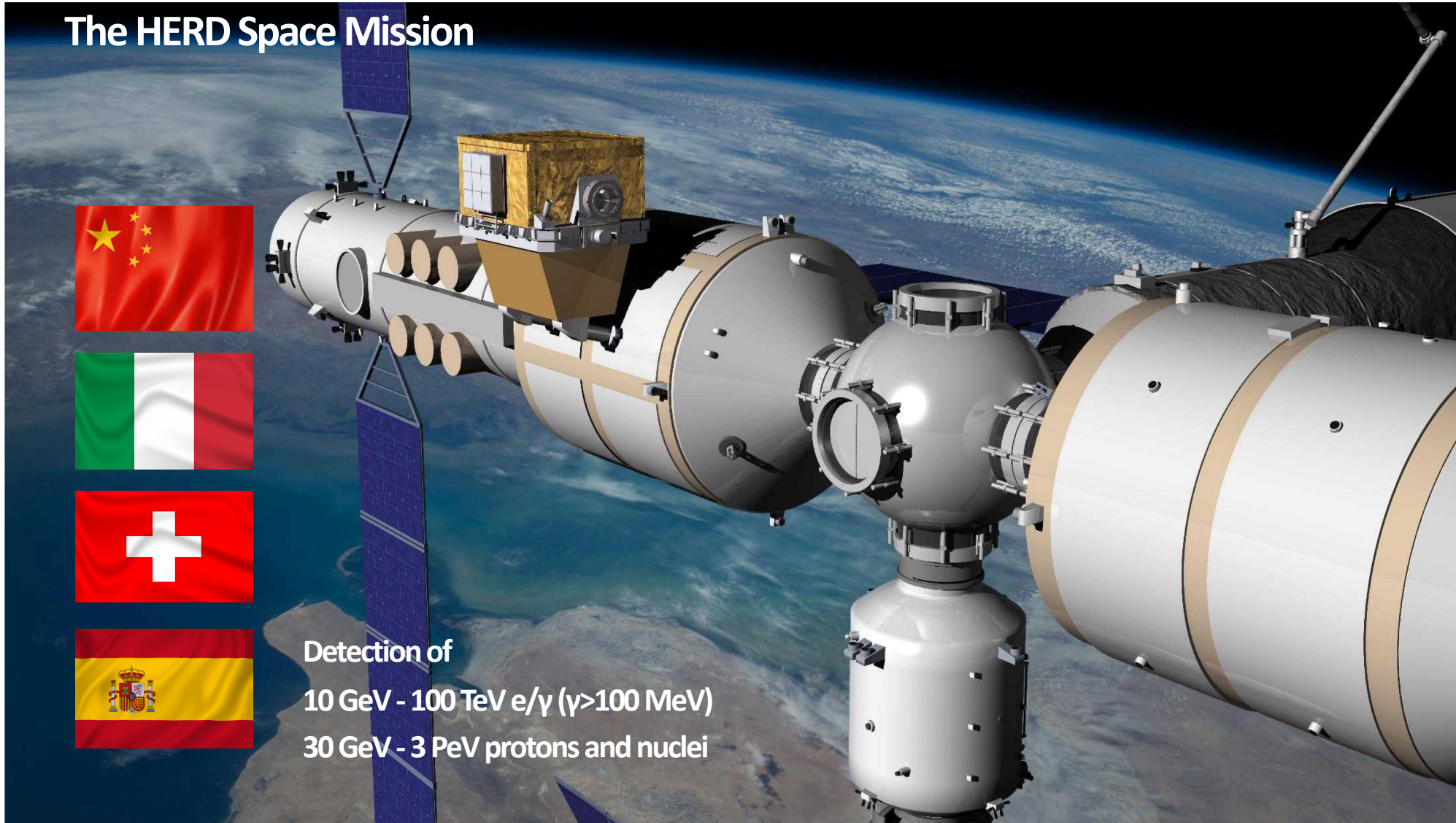
\* steps not included in the all-particle spectrum analysis.

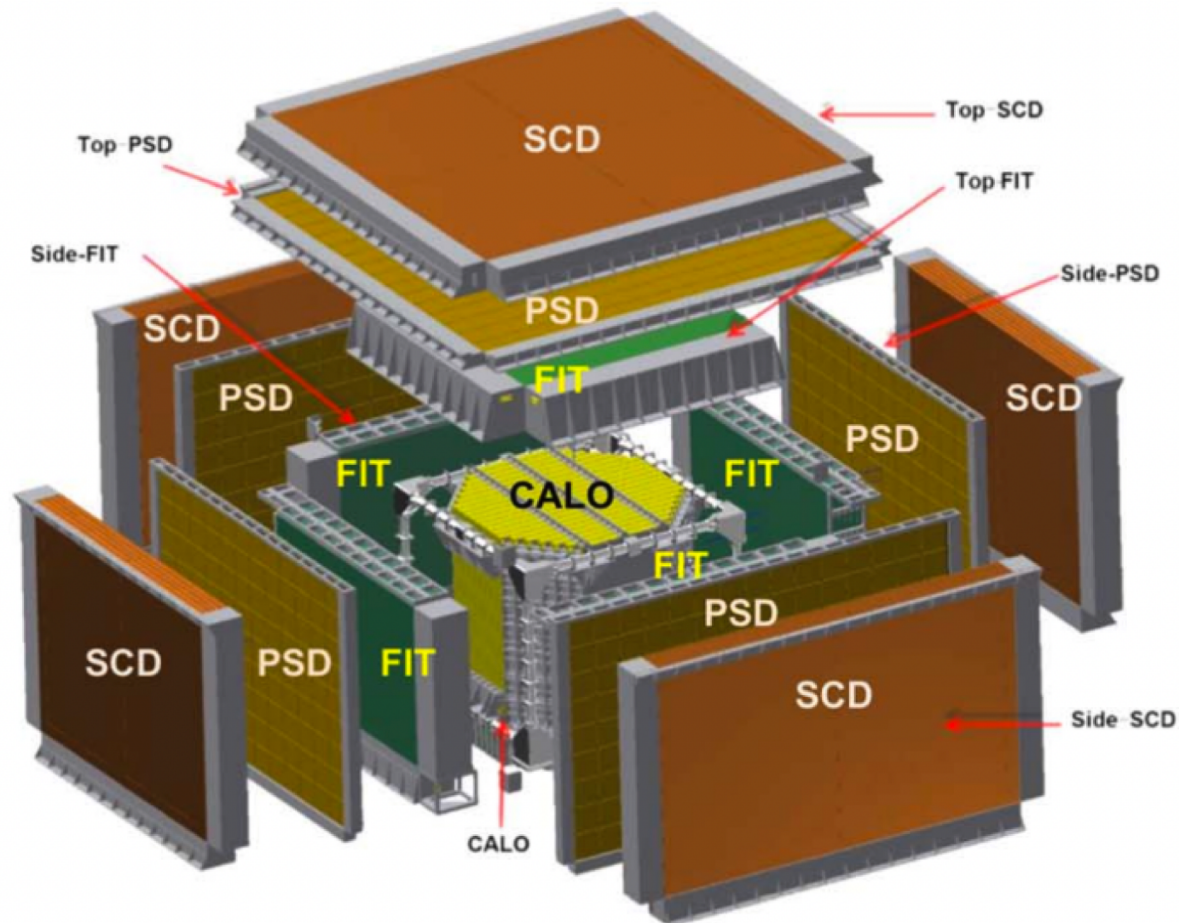


## The HERD Space Mission



Detection of  
10 GeV - 100 TeV  $e/\gamma$  ( $\gamma > 100$  MeV)  
30 GeV - 3 PeV protons and nuclei





A deep ( $\sim 55 X_0$ ,  $3 \lambda_I$ ) 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)



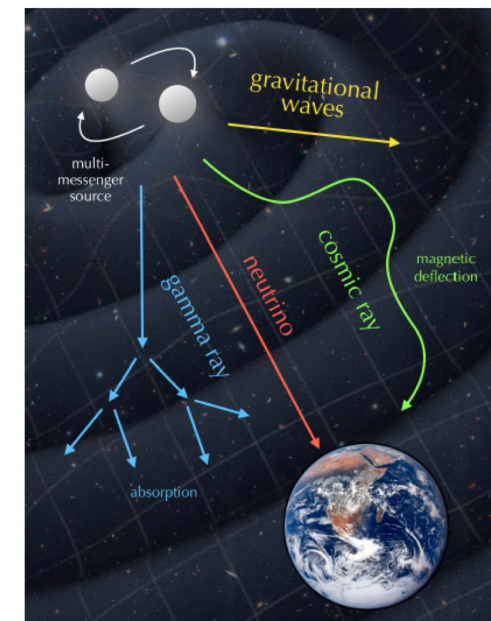
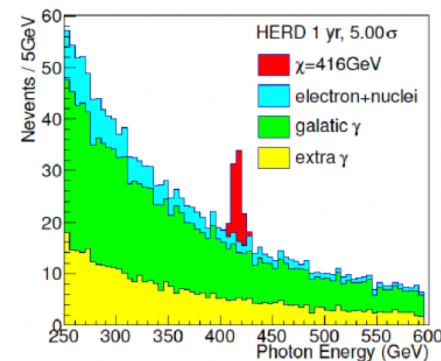
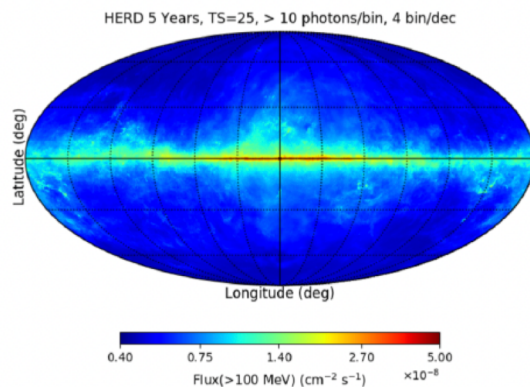
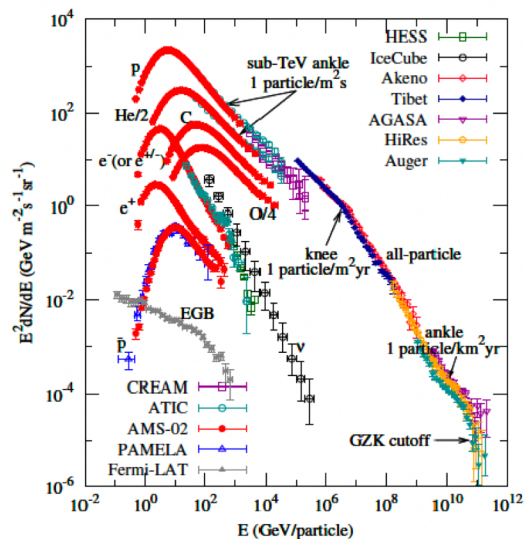
## HERD primary scientific goals include

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

## HERD space mission

### Probing the Galactic Cosmic Ray frontier

Cagnoli I. and Kyrtzidis D., on behalf of the GSSI HE-EXP group

#### The space mission

- Launch scheduled for 2027
- On board of the Chinese Space Station (CSS):
  - circular LEO orbit inclined at 42°
  - altitude of ~ 340 - 450 km
  - lifetime >10 y

Calorimeter	55 X <sub>0</sub> (~ 3 λ <sub>r</sub> )
Geometric acceptance	~ 3 m <sup>2</sup> sr
FOV	± 70°
Energy resolution	1% at 200 GeV (e/γ) ~20% at 100 GeV - 1 PeV (nuclei)
Detection	0.5 GeV - 100 TeV (γ) 10 GeV - 100 TeV (e) 30 GeV - 3 PeV (p/nuclei)

#### Research goals

- Indirect dark matter search.
- γ-ray astronomy & transient studies.
- Electron spectra up to tens of TeV.
- CR spectra and composition up to the knee.

#### Expected HERD 5-year-sky-map

HERD 5 Year: 10<sup>12</sup> - 10<sup>13</sup> photons/cm<sup>2</sup> - 4 scales

#### Expected HERD results on the e<sup>±</sup>e spectrum

#### Expected HERD results on the p and He spectra

#### SCD

- For charge measurement up to Z = 28
- Outermost detector
- Highly segmented

#### PSD

- For γ-rays ID (in anti-coincidence) and charge measurement up to Z = 26
- Requirements
  - High detection efficiency (>99.8%)
  - Wide dynamic range in nuclei ID
  - Highly segmented

#### FIT

- For charged particles track reconstruction and γ-ray conversion in e<sup>±</sup>e<sup>-</sup> pairs

#### CALOrimeter

- 3D imaging calorimeter
- Isotropic & homogeneous
- Highly segmented
- Double read-out system

#### Design

#### Design

Sector: 2 double X-Y layers of scintillating tiles

Read-out system: Printed Circuit Board Housing 8 SiPMs

#### GSSI activities

- Simulations and software development
- Hardware
  - Test beam campaign at CERN and CNAO
  - Prototype assembling
  - Single components testings

#### Design

- 3D imaging calorimeter
- Isotropic & homogeneous
- Highly segmented
- Double read-out system

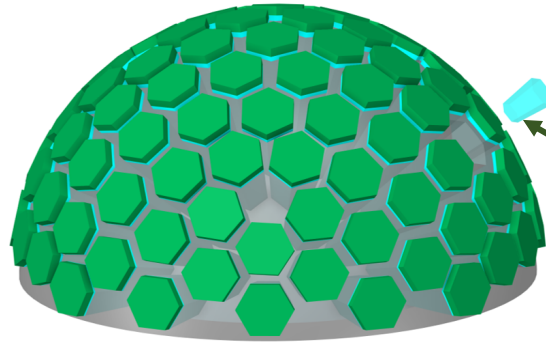
#### Design

Top read-out: Wavelength shifting fibers (WLS) coupled to image intensified scientific CMOS

Bottom read-out: Photo-diode connected to custom electronics chips

7500 LYSO crystals

TOP-ACS for charged particles

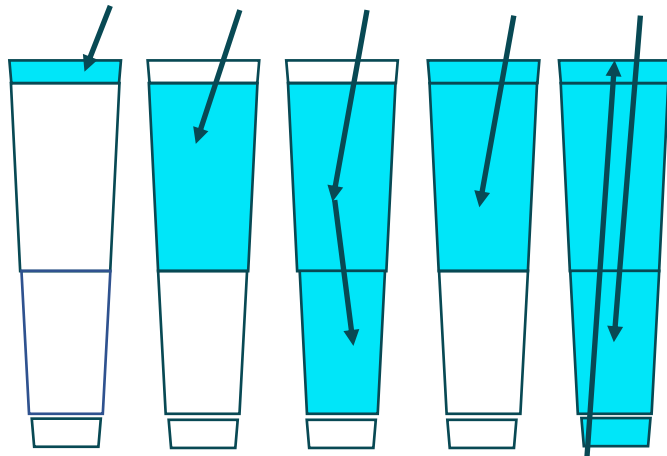
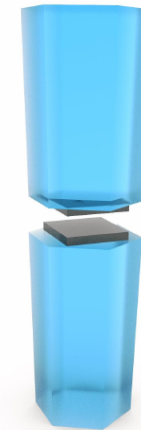


UP-PIXEL  $E_\gamma < 1\text{MeV}$

SiPM ARRAYS 4x4

DOWN-PIXEL  $E_\gamma > 1\text{MeV}$

Detection of  
10 keV - 30 MeV  $\gamma$   
All-sky Monitor

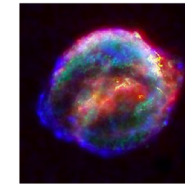
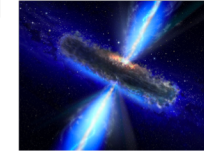


- a – Down-going hard X-ray
- b – Down-going LE g-ray
- c – Down-going ME g-ray
- d – Down-going LE charged particle
- e – HE charged particle

a b c d e

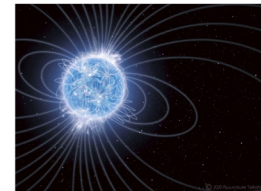
- Pixel FOV:  $2.5^\circ \times 2.5^\circ$ .
- LYSO+GAGG crystals
- Photodetectors: 4x4 MPPC array
- VETO for charged cosmic-ray rejection.

- 1) Monitoring the electromagnetic counterpart of gravitational waves
  - 2) Multimessenger observations
- Progress in understanding mechanism that power jets (like GRBs, AGNs)

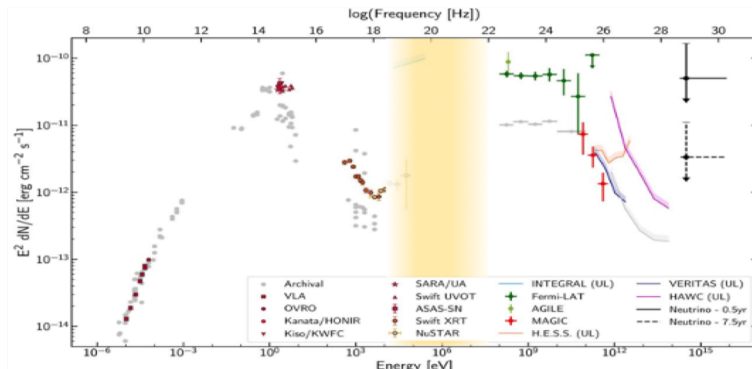


Possible joint thesis with Gor and Felicia to study Crystal Eye science case

- 3) Observation of gamma ray lines from supernovae?? (still under study)
  - 4) Searching for magnetars
  - 5) Study of X-ray binaries in MeV region
  - 6) TGF, space weather
- Progress in understanding the mechanism of element formation in extreme environment
- Understanding possible correlation with FRB

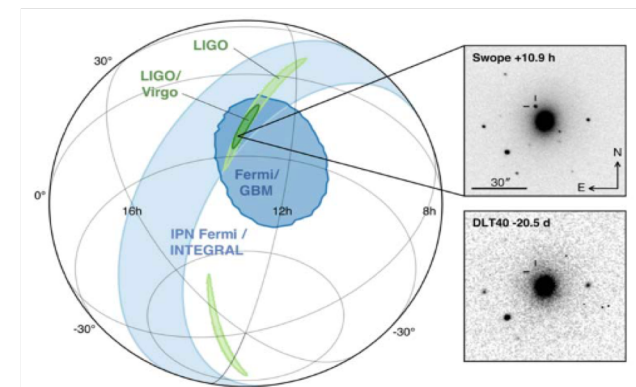


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Medium energies still under-explored (E ~ MeV)

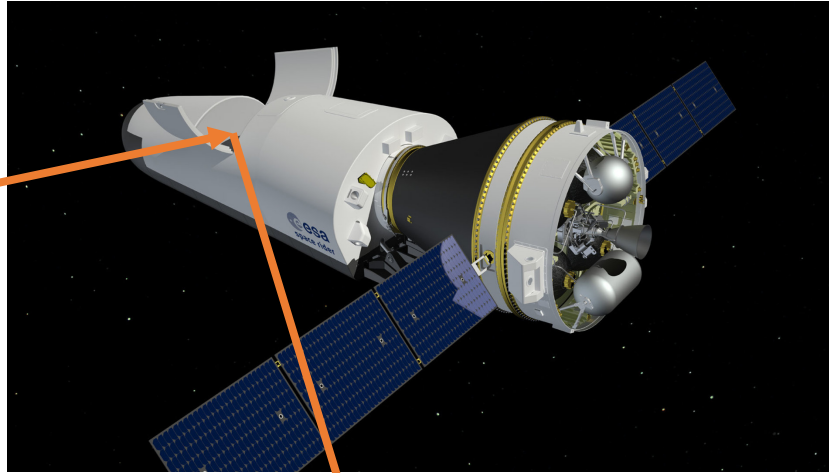
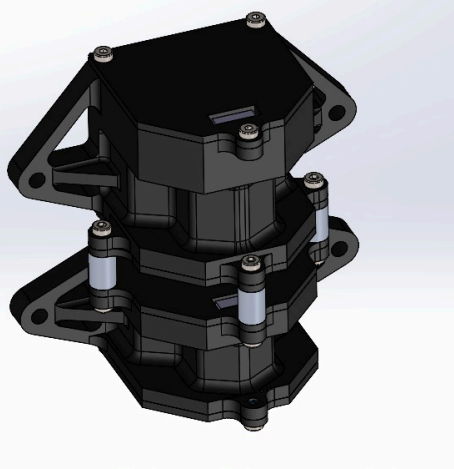
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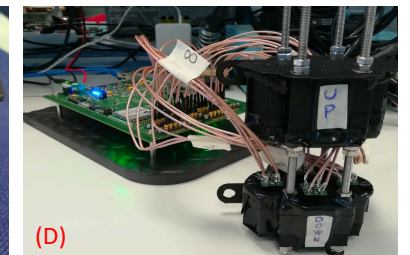
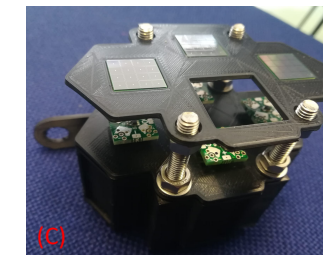
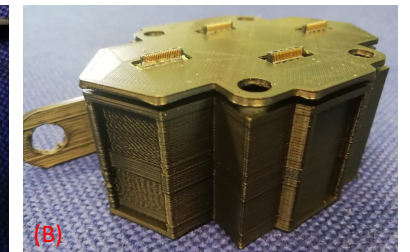
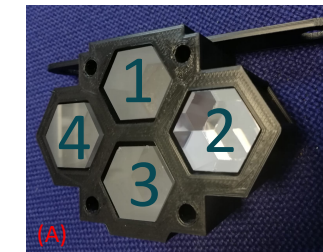
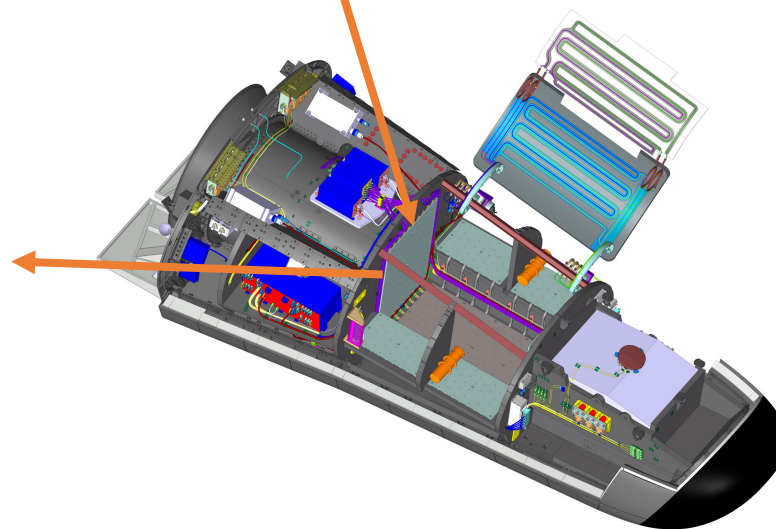
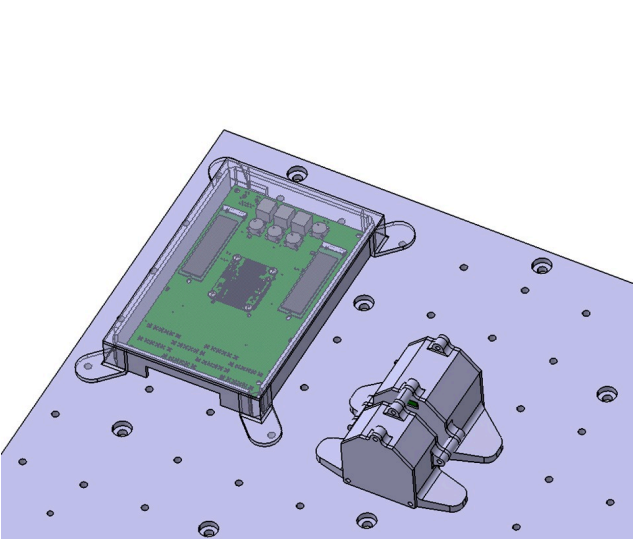


# WINK: the Crystal Eye pathfinder

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:** LY50  
**Photodetectors:** SiPM-array  
**Weight:** 2kg  
**Power consumption:** < 15 W  
**FOV:** 30°



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

### Crystal Eye

#### Crystal Eye: A gamma ray all sky monitor

Aleksei Smirnov, Iqra Siddique  
on behalf of Crystal Eye collaboration

Gran Sasso Science Institute  
National Institute of Physics, Italy  
Email: aleksei.smirnov@gssi.it

**Abstract**

Crystal Eye is a novel concept of space-based all sky monitor for the observation of about 10 keV - 30 MeV photons exploiting a new detection technique, which foresees enhanced localization capability with respect to current instruments. This is now possible, thanks to the use of new detector materials and sensors. The primary scientific goal is the detection of the electromagnetic signals from the extreme phenomena in the Universe. To enhance the scope of the multimessenger study of these phenomena, the experiment will provide an alert to both space and ground based experiments. A full scale model of the Crystal Eye detector is now under design and construction. Moreover, a smaller prototype has been set up to fly aboard of the Space Rider (ESA) on a LEO orbit (400 km, 5.3° of inclination) for two months in 2025. We present here the Crystal Eye mission concept and performance.

**Science Goals**

- Wide field and precise monitoring and localization of astrophysical transient phenomena to help the multimessenger scientific studies
- Study the interesting and diverse astrophysical phenomena in the keV and low MeV region exhibiting spectral features which are, to date, not extensively measured.
- Primary scientific targets of the instrument are GRBs, GW electromagnetic counterparts and other transients, accreting systems, supernovae and particular  $\gamma$  emission lines.

**Features**

- All sky monitor active in the range 10 keV - 30 MeV.
- Wide FOV - 6 sr
- Full sky coverage
- Very large effective area - 5 times Fermi-GBM at 1 MeV.
- High localization capability, few degrees.

QRB170412A  
100% duty cycle  
100% duty cycle  
100% duty cycle

Radius: 14 cm  
Weight: ~10 kg  
112 pixels

Highly efficient, low cost, compact device - today this innovative observation technology is feasible, thanks to the use of new sensors and materials.

**The Pixel**

- Pixel FOV:  $2.5 \times 2.5^\circ$
- LYSO crystals (in read) by Hamamatsu MPPC arrays (in gray)
- Material: LYSO - high photon absorption probability and light yield, fast time response, self radiation calibration, low intrinsic noise rate
- Photodetectors: 4x4 SPM array (MPPC 3x3 read: 50µm pixel)
- Anticoincidence (BC408 plastic scintillator) for charged cosmic-ray rejection.
  - Tile on the top of the LP crystal.
  - Continuous layer at the bottom of the DOWN crystal.
  - Acts as a localizer for hard X-rays

**Effective Area**

- Geant4 based simulation with trigger selection implemented to study Crystal Eye performances
- The efficiency changes little with the zenith angle, thanks to the symmetrical design of the detector.
- A comprehensive comparison of various detector dome configurations to optimize spatial efficiency, manufacturability, and coverage, while evaluating the effective area.

**WINK: The Crystal Eye Pathfinder**

- Space Rider is an uncrewed robotic laboratory by ESA with pointing capabilities and its maiden flight will be in 2025.
- Will stay in low orbit for about two months.
- WINK will be made of 3 full scale Crystal Eye pixels, to enable technologies for a future full scale mission while observing deep space and Earth.
- The position requested for WINK in the Multi Purpose Cargo Bay (MPCB) of Space Rider will ensure a 30° of FOV.
- WINK will be hosted on a thermal plate.

**Energy Depositions in Pixels**

- Geant4 simulation is used to study and optimize the detector characteristics.
- The energy deposition profile in different crystals for isotropic photon flux and the corresponding energy response in the LYSO crystal are shown here (see right figure).
- The source is positioned at a  $45^\circ$  with respect to the detector (see left figure).

**ZIRE: The Crystal Eye Pathfinder**

- ZIRE detector in the NUSES mission uses the similar material (LYSO) for its calorimeter as Crystal Eye along with other sub-detectors for the accomplishment of its mission.
- One of the primary science goals is to study the transient astrophysical phenomena in about 0.1-50.0 MeV photons.
- The technological advancements can be used for the mutual benefits of both the detectors.

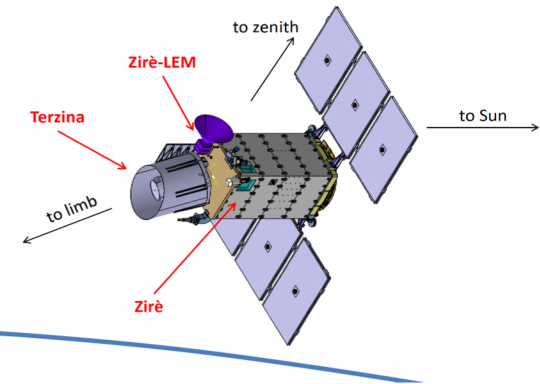
**The Engineering Model**      **First Prototype of a Custom DAQ**

Possible future thesis: Study of science case for Crystal Eye detector  
Supervisors: Felicia Barbato and Oreste Bianchi Cor.



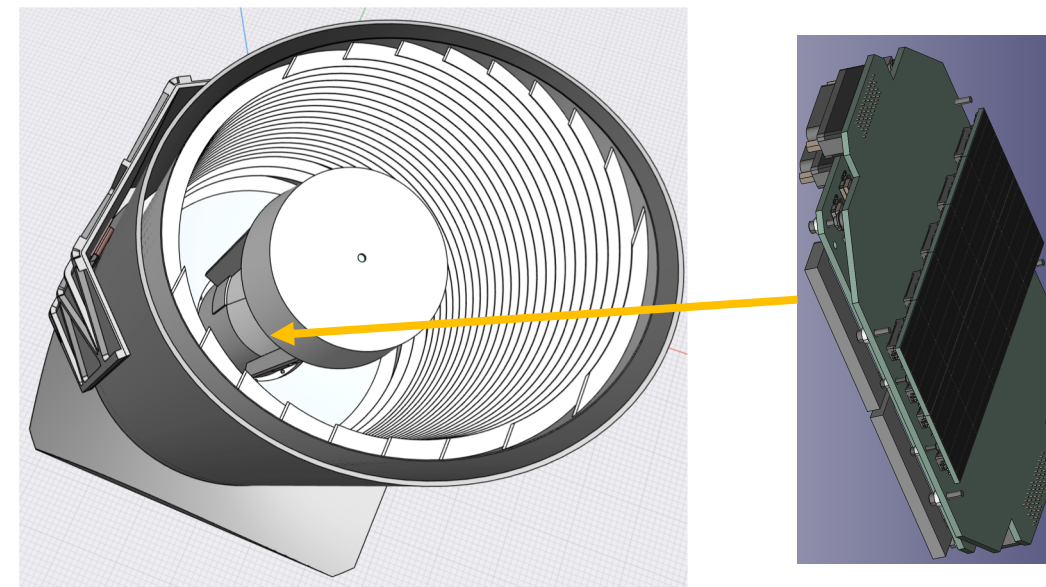
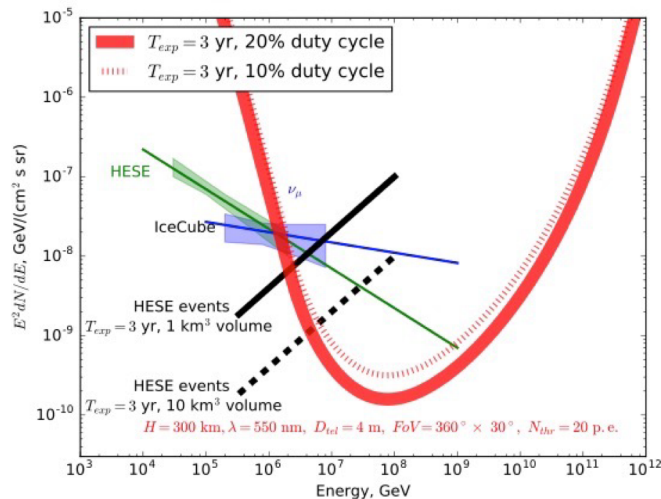
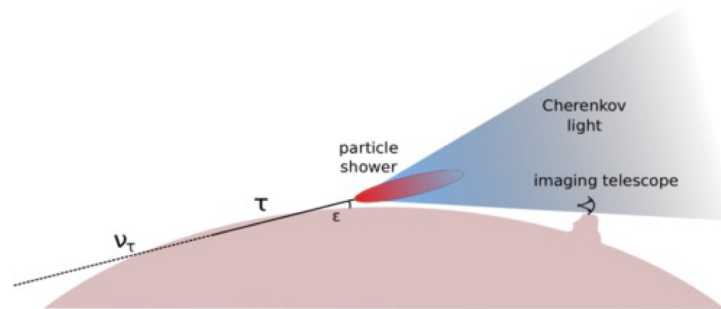
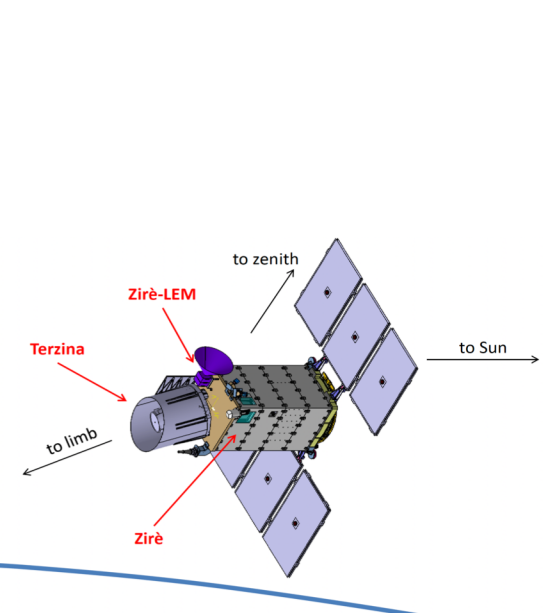
A joint Gran Sasso Science Institute -Thales Alenia Space Italy (TAS-I) mission conceived as a **pathfinder for new observation methods and technologies in the study of high and low energy radiations enabling new sensors, tools and detection techniques.**

>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.

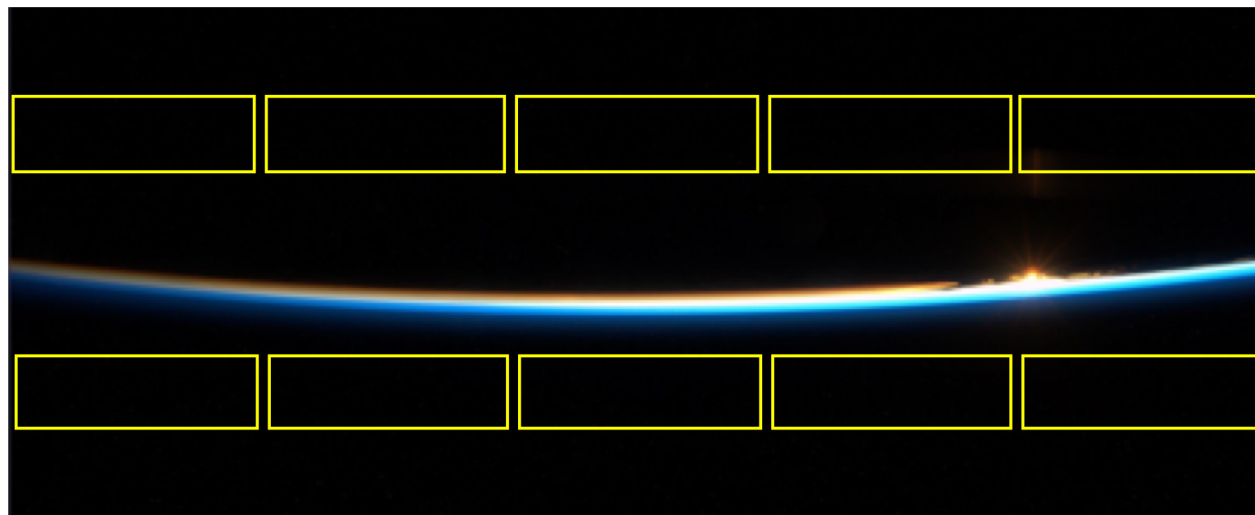
## The science case: Astrophysical neutrinos and High Energy CR



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



# The NUSES Space Mission: TERZINA



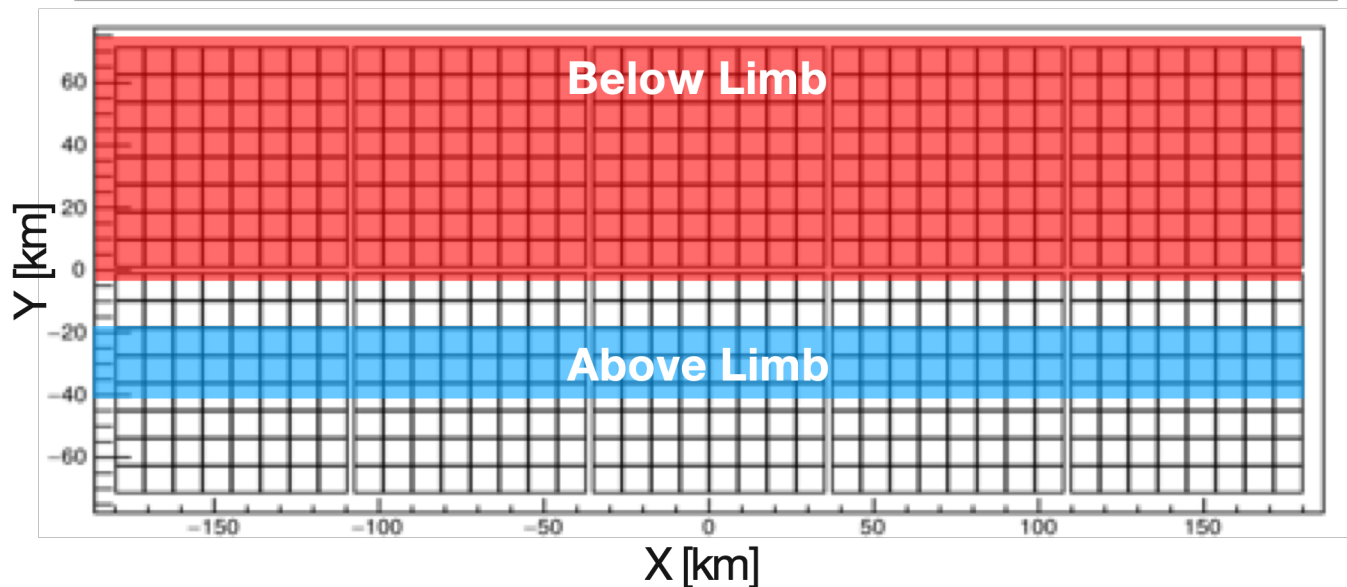
N.10 8x8 SiPM arrays

640 pixels/channels/SiPMs in total

Each SiPM is  $3 \times 3 \text{ mm}^2$

Pixel F.O.V.  $0.18^\circ$

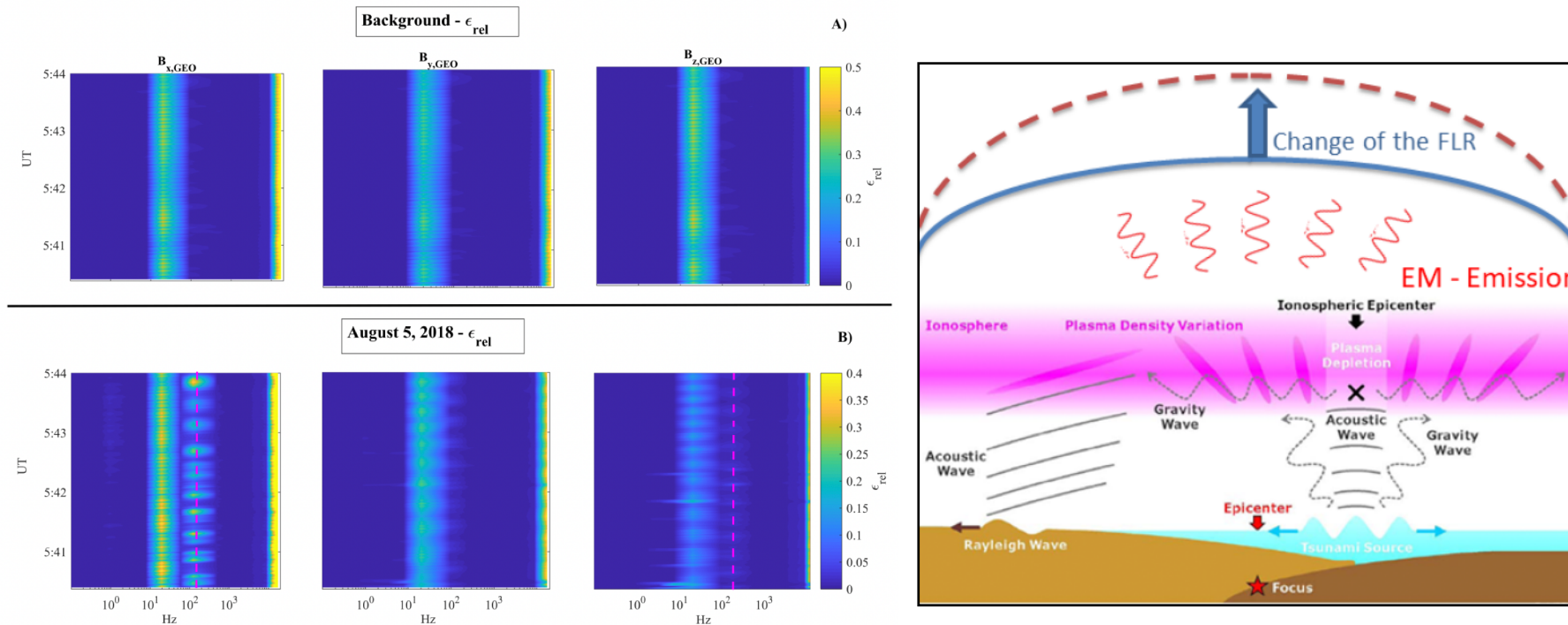
$24 \times 24 \text{ mm}^2$  effective area per array



Background Evaluation  
Earth Skimming Neutrino Shower

ROI: CR EAS

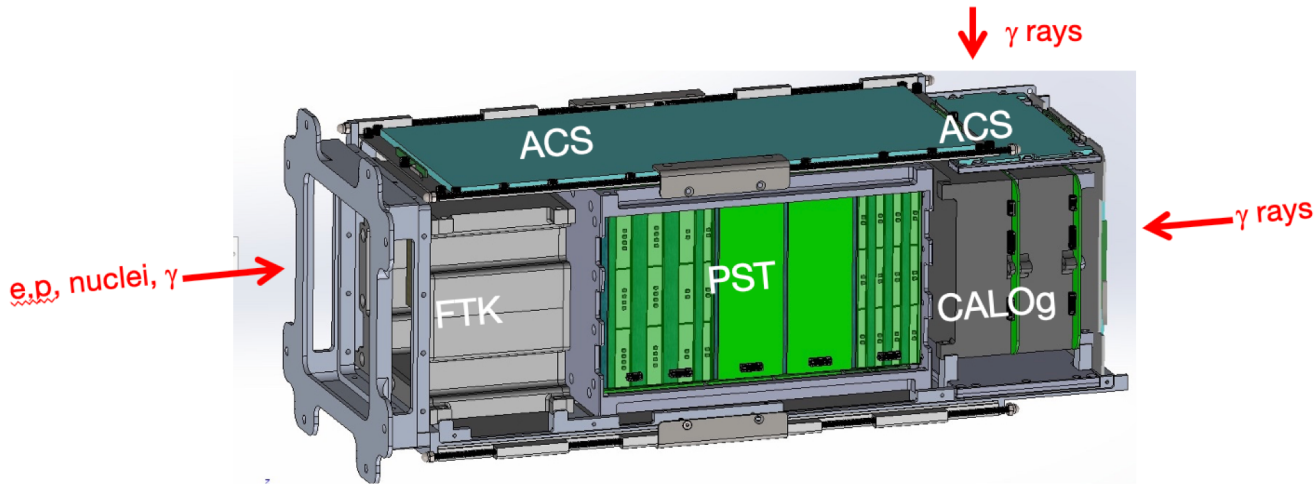
## The science case: Magnetospheric Ionospheric Lithospheric Coupling (MILC)



<https://doi.org/10.3390/rs12203299>

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

## The NUSES particle detector payload: Zire'

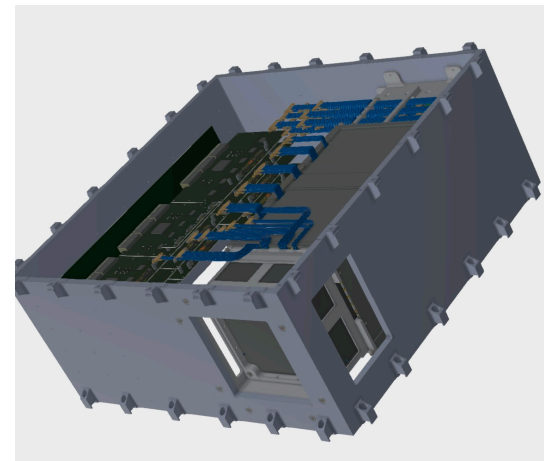
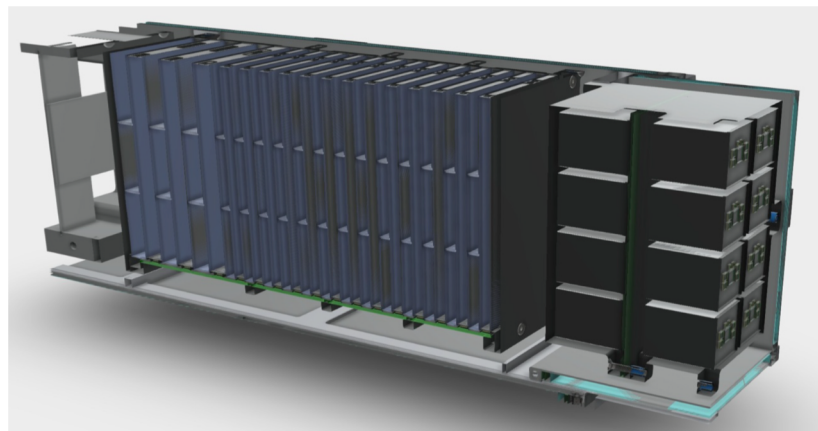


**FTK** (Fiber Tracker): N.3 X-Y modules made of scintillating fibers read out by linear arrays of SiPMs

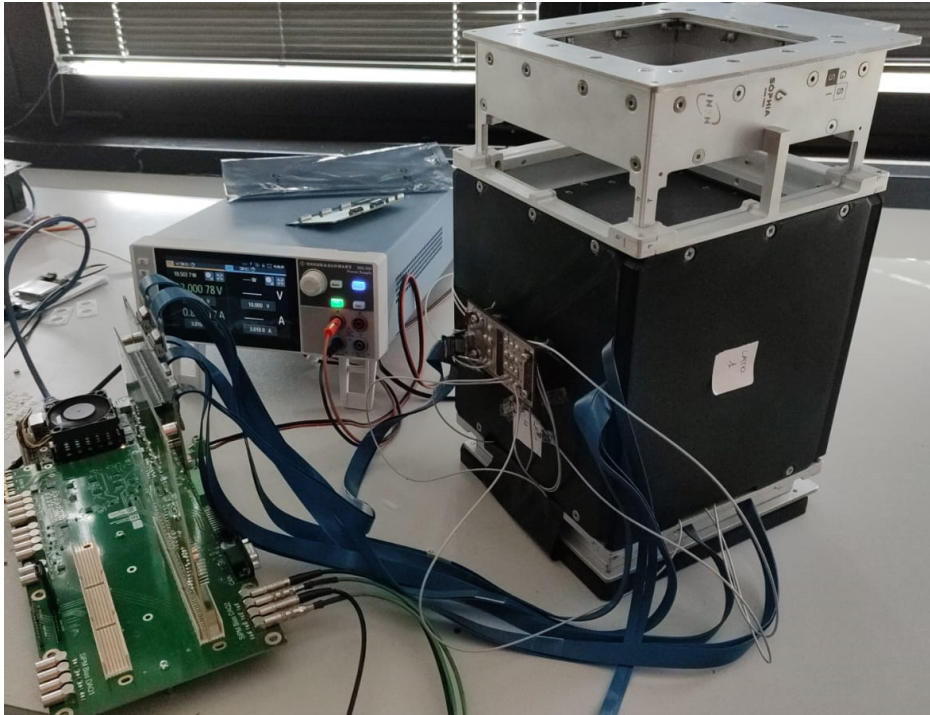
**PST** (Plastic Scintillator Tower): N. 16 X-Y modules made of scintillating tiles read out by two sets of SiPMs of different sensitive area

**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

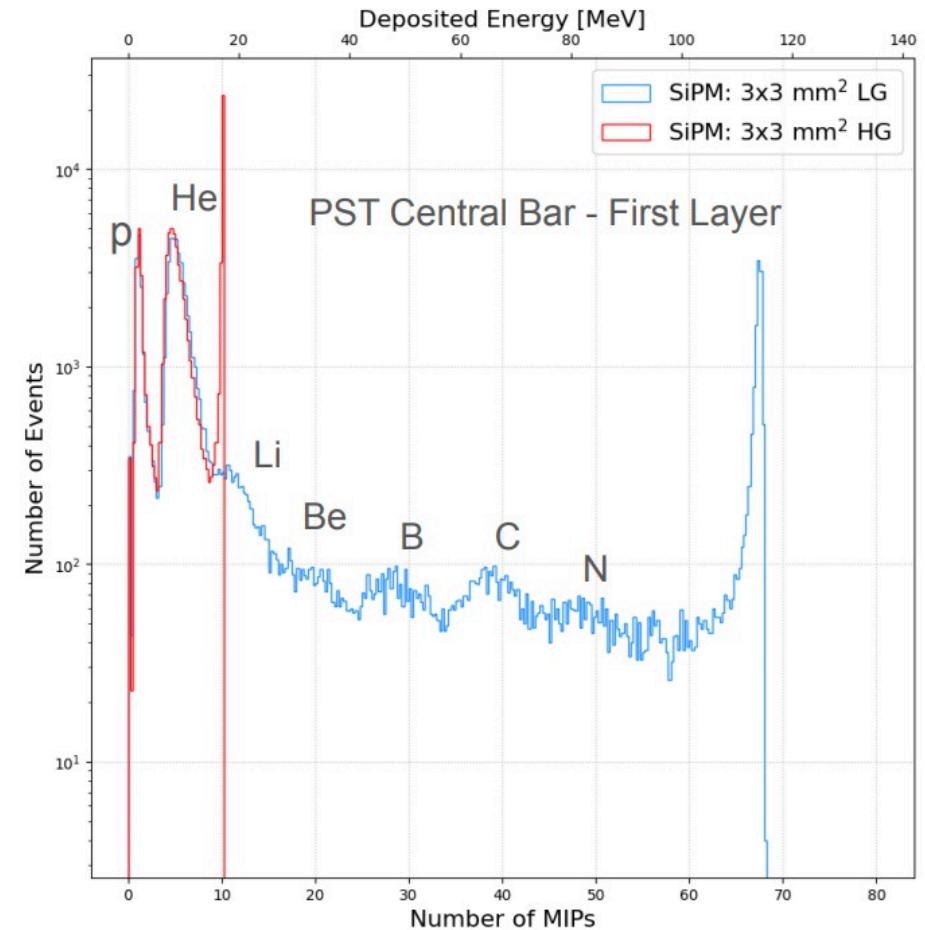


# The ZIRE' prototype: ZIRETTINO



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.



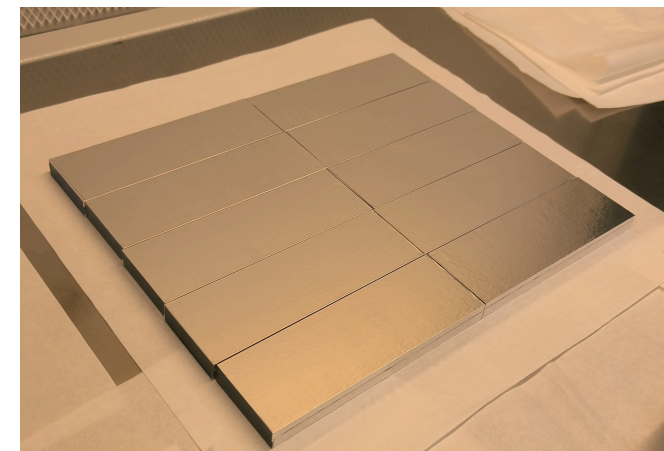


# The NUSES Space Mission

The NUSES-Zirè:  
structural model



EQM assembly



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

### The NUSES mission

enabling new observation methods and technologies from space  
G. Fontanello, H. P. Lima Jr., P. Savina on behalf of the GSSI HE-EXP group

**Science Goal of the NUSES mission**  
NUSES (Neutrino and Seismic Electromagnetic Signal) is a space 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 methodologies.

**The NUSES Collaboration**  
Counts 60+ members from:  
INFN & Italian Institutions  
Gran Sasso Science Institute  
Laboratoire National del Grand Sasso  
L'Aquila University  
Torino University and INFN Torino  
Trieste University and INFN T3PDA  
Bari University and INFN Bari  
Pisa University and INFN Pisa  
Napoli Federico II University and INFN Napoli  
Salerno University and INFN Salerno  
Italian Space Agency  
University of Geneva (CH)  
University of Chicago (USA)

**Terzina**  
Pathfinder of future missions devoted to the detection of high-energy (>1 PeV) astrophysical neutrinos and cosmic rays through space-based detection of the atmospheric Cherenkov emission. The telescope will look at the atmosphere limb (just above) for CR detection and (just below) for neutrinos detection.

**Ziré**  
Possibility to study solar/galactic cosmic rays. Pathfinder of future missions to measure MeV gamma-rays from stable and transient astrophysical sources. Monitor of the variations of the flux of protons and electrons (<300 MeV) in the ionosphere and magnetosphere possibly correlated with seismic activity. See Ziré dedicated poster.

**The Orbit**  
Low Earth Orbit with high inclination, sun-synchronous orbit on the day-night border. Orbit optimization for Cherenkov photon detection. Ballistic mission (no propulsion for orbital control).

**Radiation Environment**  
Protons  
Electrons  
Differential fluence of trapped p, e<sup>-</sup> and solar p as a function of the energy. Geographical distribution of trapped particles. Expected data for 3Y mission along the nominal orbit.

**NIMBUS (New Italian MICRO-BUS)**  
New platform concept which foresees a modular approach relying on standard trays.

References:  
[1] D. M. et al. 2022, J. Phys.: Conf. Ser. 2429 012007  
[2] M. F. et al. 2022, PoS(ICRC2022) 109  
[3] Instruments 2023, Vol. 65  
[4] EPJ Web of Conferences 351, 03006 (2023)

### The Ziré detector on board of the NUSES mission

**Science Goal**  
The Ziré detector, part of the NUSES (Neutrino and Seismic Electromagnetic Signal) mission. The scientific goals of this experiment are:  
- Measure the flux of cosmic electrons, protons and nuclei of solar/galactic origin, below ~300 MeV.  
- Study of the cosmic radiation variability (Van Allen belt system, effects on space missions, etc.)  
- Looking for possible correlation with seismic activity due to Magnetosphere-Ionosphere-Ultraviolet Coupling (MICU).  
- Detection of 0.1 - 50 MeV photons for study of transient and stable gamma sources.  
- Paving the way for future applications of new technology (SiPM only).  
- Detection of 0.1 - 50 MeV photons for study of transient sources.

**Monte Carlo Simulations & Performances**  
- Energy resolution (FWHM) vs Energy  
- Energy resolution (FWHM) vs Energy  
- Energy resolution (FWHM) vs Energy  
- Energy resolution (FWHM) vs Energy

**Test Beam Results**  
- Preliminary energy resolution vs Energy  
- Preliminary energy resolution vs Energy  
- Preliminary energy resolution vs Energy

**Trigger studies using simulations**  
- LEV2, HEV1, HEL1

**Low Energy Module (LEM)**  
- This module serves as a detector for low energy particles (below 10 MeV).  
- It is composed of a stack of SiPMs and a readout electronics.

**Calorimeter (CALoG)**  
- This module serves as a detector for high energy particles (above 10 MeV).  
- It is composed of a stack of SiPMs and a readout electronics.

**Anti-Coincidence System (ACS)**  
- This module serves as a detector for high energy particles (above 10 MeV).  
- It is composed of a stack of SiPMs and a readout electronics.

**Plastic Scintillator Tower (PST)**  
- This module serves as a detector for high energy particles (above 10 MeV).  
- It is composed of a stack of SiPMs and a readout electronics.

**2nd payload integration aspect of LEMG.**

### How can we observe neutrinos of the highest energies?

Rodrigo Alberto Torres Saavedra, on behalf of the GSSI HE-EXP group

**Why observe ν's?**  
- Neutrinos (ν) are neutral, interact minimally, and can point directly back to their sources → excellent astrophysical messenger.  
- Observing HE ν's (> 100 PeV) can help us understand the nature and dynamics of multi-messenger astrophysical transients.

**Current Techniques**  
- Current ν telescopes use a grid of optical sensors in ice (or water) to detect Cherenkov light from ν-induced particle cascades.  
- Large (gigaton) target masses are required due to the small weak interaction cross-sections and low neutrino fluxes.

**Earth-Skimming ν's**  
- ν's interacting inside the Earth produce leptons, some of which can emerge and induce up-going extensive air showers (EAS) in the atmosphere.  
- A telescope in orbit observing the Earth's limb could detect these EAS through their Cherenkov light.

**The Terzina Payload Onboard the NUSES Mission**

**1. Thermal Control System and Mechanics (TCSM)**  
- Includes a main baffle (1), vanes (2), radiators (3) and support structures (4) for the mirror.

**2. Optical Head Unit**  
- Cassegrain optics with a parabolic primary mirror (M1) and hyperbolic secondary mirror (M2), directing light onto the focal plane.

**3. Focal Plane Assembly**  
- 10 SiPM arrays of 6x6, arranged on two rows, for a total of 640 pixels independent channels on the camera.  
- Each SiPM is 3x3 mm<sup>2</sup> for a total effective area of 2424 mm<sup>2</sup> per array.  
- Terzina will point at Earth's limb such that the top row will be sensitive to below-the-horizon events (ν's), while the bottom row will observe above-the-horizon events (CRs).

**4. The Front End Electronics**  
- The SiPM signals are routed to a set of application-specific integrated circuits (ASIC) for readout.  
- Each ASIC reads out a tile and has 32 input channels (one per SiPM).  
- For each channel, a slow shaper is used for the charge readout, and a fast shaper is used for the trigger.  
- The data is sent to a concentrator board for aggregation, waiting for transmission to ground.

**Ongoing Work**  
- The payload will be assembled, integrated into the satellite, and undergo qualification testing this year to prepare it for launch in 2026.  
- Development work is still ongoing in the simulation pipeline for the payload.

For more information on Terzina, future missions, and the earth-skimming technique, you can refer to:  
- A. L. Cummings, R. Abbio, J. F. Kocumak (2021) Phys. Rev. D 103, 043017.  
- A. L. Cummings, R. Abbio, J. F. Kocumak (2021) Phys. Rev. D 104, 063029.  
- R. Abbio, C. Alvarado, F. Bariana, R. Saitama, et al. (2023), Proceedings of 35th International Cosmic Ray Conference — PoS(ICRC2023) 361.  
- A. V. Olmo, J. Kocumak, J. H. Adams, R. Abbio, et al. (2021) J. Cosmol. Astropart. Phys. 2021, 037.

### The Modular Cosmic-ray Telescope (MCT)

Dimitrios Kyrtzatis on behalf of the GSSI HE-EXP group

**The Playground**  
- Overview of the MCT design and components.

**The Cosmic Ray Cube (CRC)**  
- Detailed view of the CRC module.

**Application in Outreach Activities**  
- Images showing the MCT being used in educational and public outreach settings.

**Construction of a single MCT module**  
- Step-by-step process of building a module.

**MCT: Results Overview**  
- Summary of key findings and data.

**Preliminary CAD model**  
- 3D rendering of the MCT design.

**Tests at GSSI Lab**  
- Laboratory testing of the MCT components.

**Real-time data acquisition**  
- Screenshots of the data acquisition software.

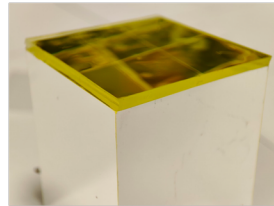
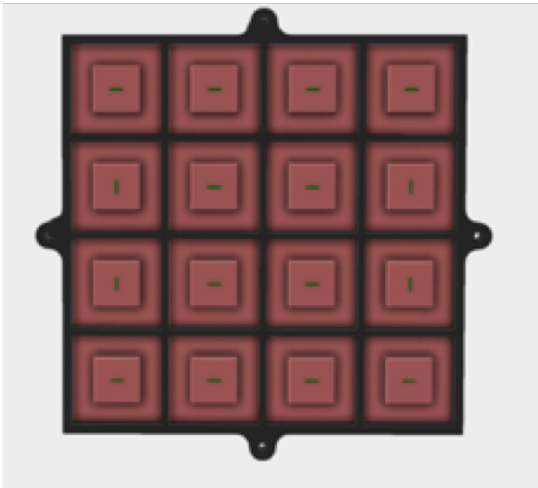
**Main MCT Features**  
- List of key features and capabilities.

**Conclusion**  
- Summary of the project and future outlook.

**Available Cosmic-ray Telescope: A versatile instrument to evaluate performance aspects of future space detectors**  
- Multiple CRCs connected to produce a modular and stand-alone CR detector.  
- Each MCT module consists of 6 layers, each with its own readout board, readout by SiPMs.  
- Single modules can be configured independently (rigidly and non-rigidly, counting rates).  
- Each module can be single counting for each impinging particle with real-time tracking and direction info.  
- The detector will be integrated in the next CRIS lab MCT for operating tests and qualification of this so-called the NUSES module.



## New Project just started...



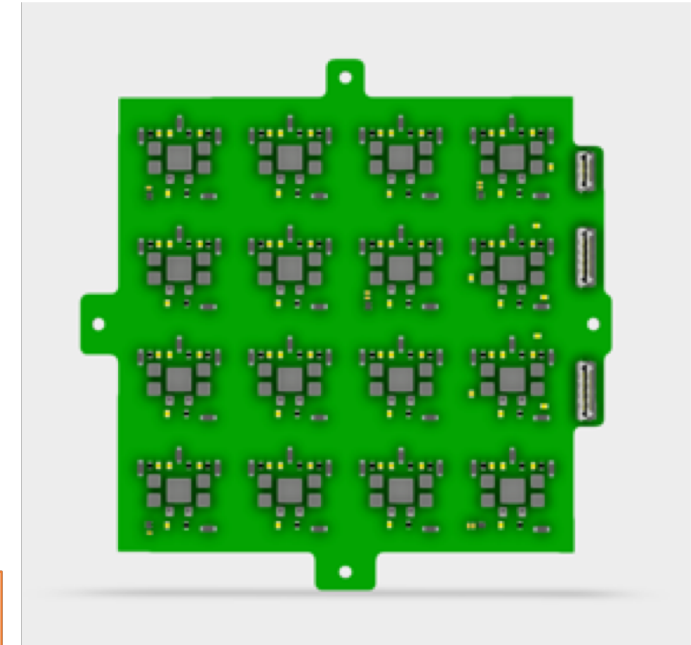
Test of different crystals:

- LYSO
- GAGG-F
- LaBr3 (SiPM NUV)

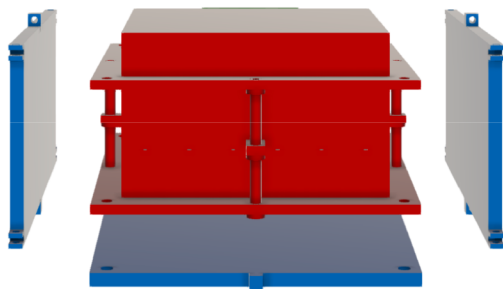
Test of different optical coupling



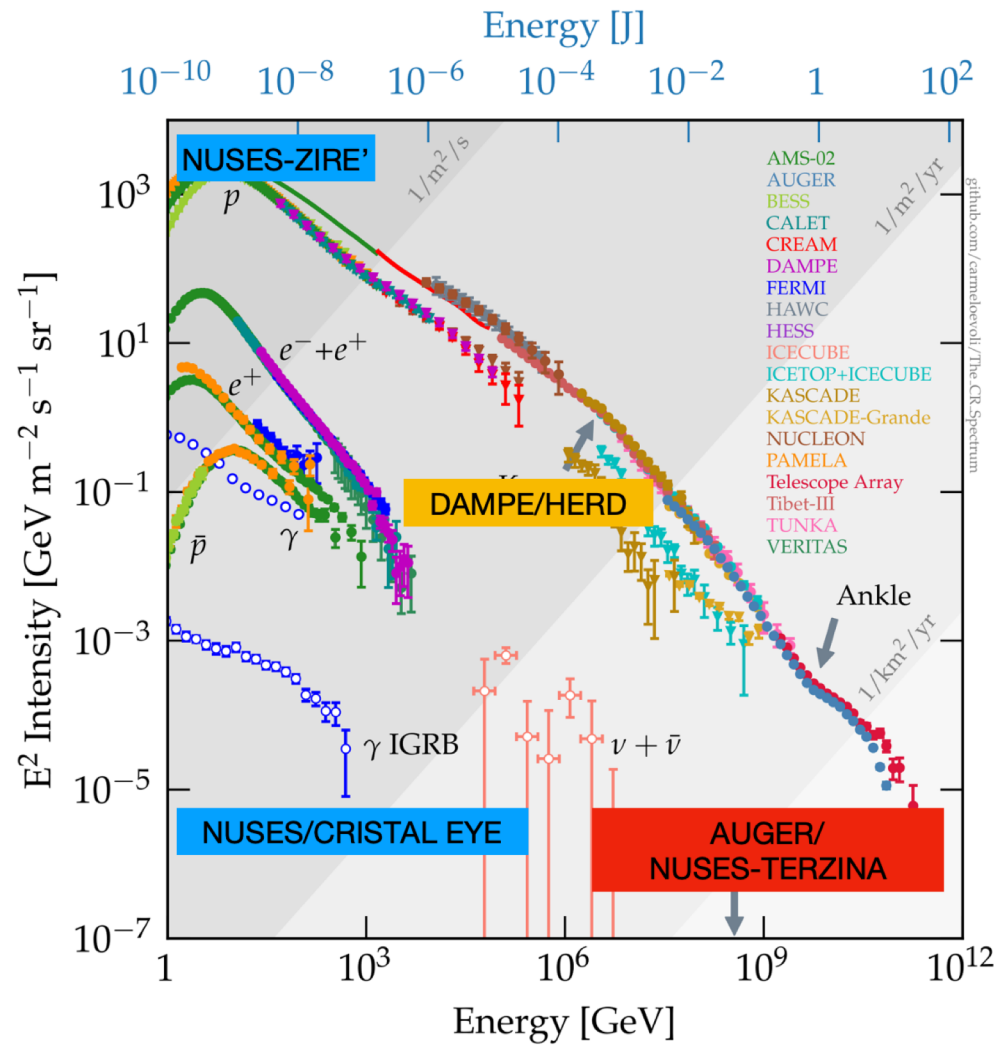
3 energies:  
6x6 mm<sup>2</sup> SiPM  
+  
3x3 mm<sup>2</sup> SiPM  
+  
1x1 mm<sup>2</sup> SiPM



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



# In conclusion...



*Just pick your energy range ...*