The Zirè instrument on board the NUSES space mission

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(on behalf of the NUSES collaboration)

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ASAPP 2023:
Advances in Space AstroParticle Physics
Perugia, June 19-23, 2023

NUSES

An italian led mission conceived as a pathfinder for new observation methods and technologies in the study of high and low energy radiations enabling new sensors and tools

The NUSES proposal has been approved by the Italian government as a flagship initiative to relaunch the economy of the L'Aquila area.
It is a joint GSSI-Thales Alenia Space Italy (TAS-I) project.

The NUSES payloads are funded (to GSSI) by the Italian government and the Italian Minister for economic development.
Thales Alenia Space Italy (TAS-I) has been funded for the OASIS project, providing the NIMBUS platform to host the NUSES payloads.

GSSI-INFN collaboration for detector design and operation.

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

Participation of 60+ persons from many italian universitites/INFN units , the University of Geneva, and the University of Chicago. Possible interest from other institutions.

A joint effort is ongoing for the design/construction of the payloads.

Ongoing work also with other industrial partners, e.g. FBK , Officina Stellare,…

The NUSES Collaboration

60+ persons from many institutions.

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

Current list of the italian groups:

- Gran Sasso Science Institute
- INFN – 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
- Università di Padova and INFN
- Università "Federico II" and INFN Napoli
- Università del Salento and INFN

University of Geneva +
University of Chicago +
Possible interests from:
- other US institutions
- Spain
-……

First “in person” General Meeting. GSSI May-Jun 2022 (after many zoom meetings in the COVID19 era….)

Four half-day sessions, about 25 talks, **more than 80 participants** (academy and industry)

The NUSES mission: two payloads

Terzina

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

See talks from:
R.Aloisio and L.Burmistrov

Zirè

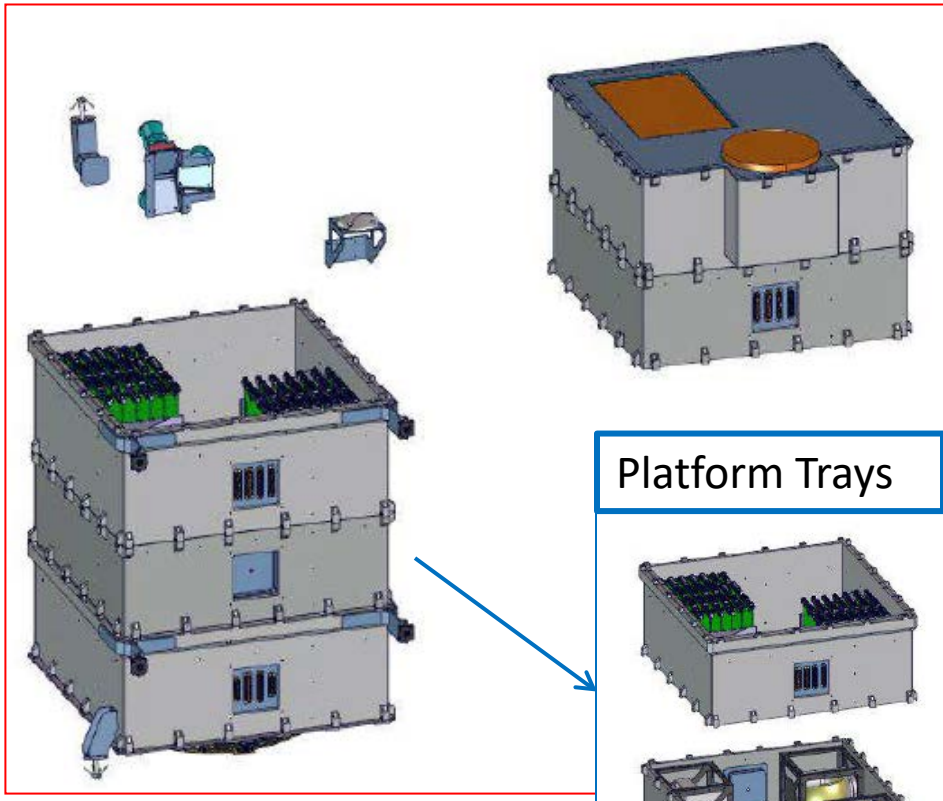
Measure the fluxes **of low energy (<250 MeV) CR**, mainly electrons and protons, to study cosmic rays, Van Allen belts**,** space weather and the magnetosphere-ionosphere-litosphere couplings (MILC) in case of seismic / volcanic activities.
Detect **0.1-10 MeV photons** for the study of transient (**GRB**, e.m. follow up of GW events, SN emission lines,…) and steady gamma sources.

New technologies and approaches

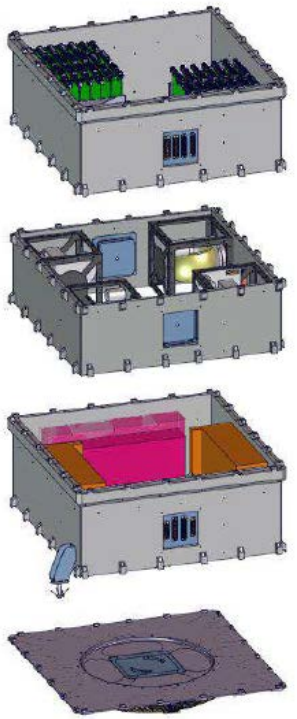
Developement of new observational techniques , testing new sensors (e.g. **SiPM**) and related electronics/DAQ for space missions. New solutions for the satellite platform.

The satellite / platform

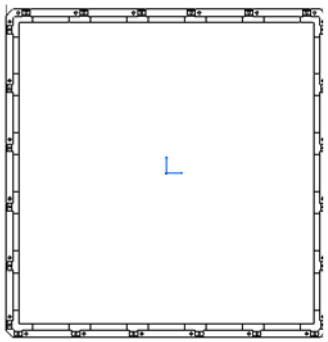
NIMBUS (**N**ew **I**talian **M**icro **BUS**)
is a new Platform concept which foresees a modular approach relying on standard trays.



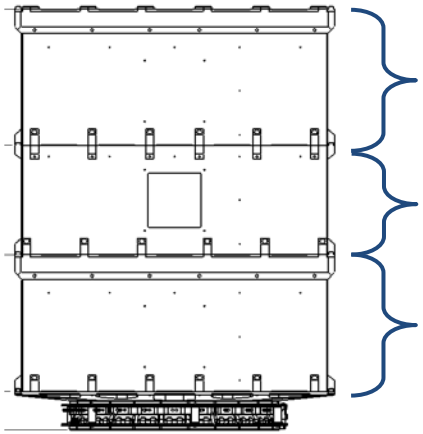
Platform Trays



Top view



Side view

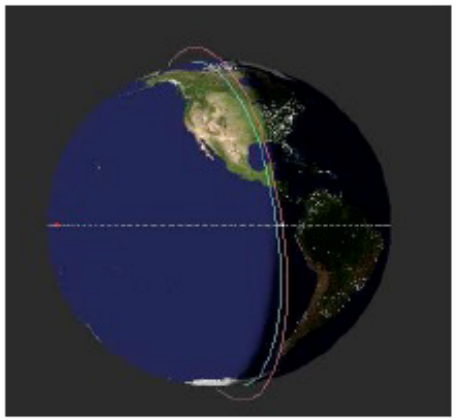


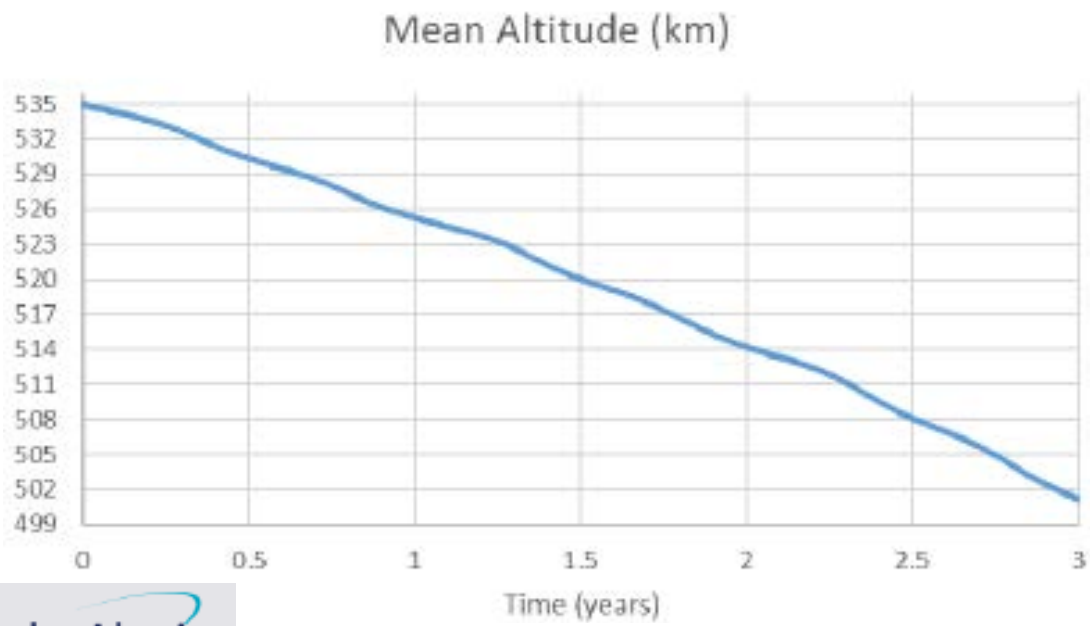
AOCS, Telemetry and Tele-command (TT&C) and GPS Receiver units

AOCS (Attitude and Orbit Control System): units\actuators

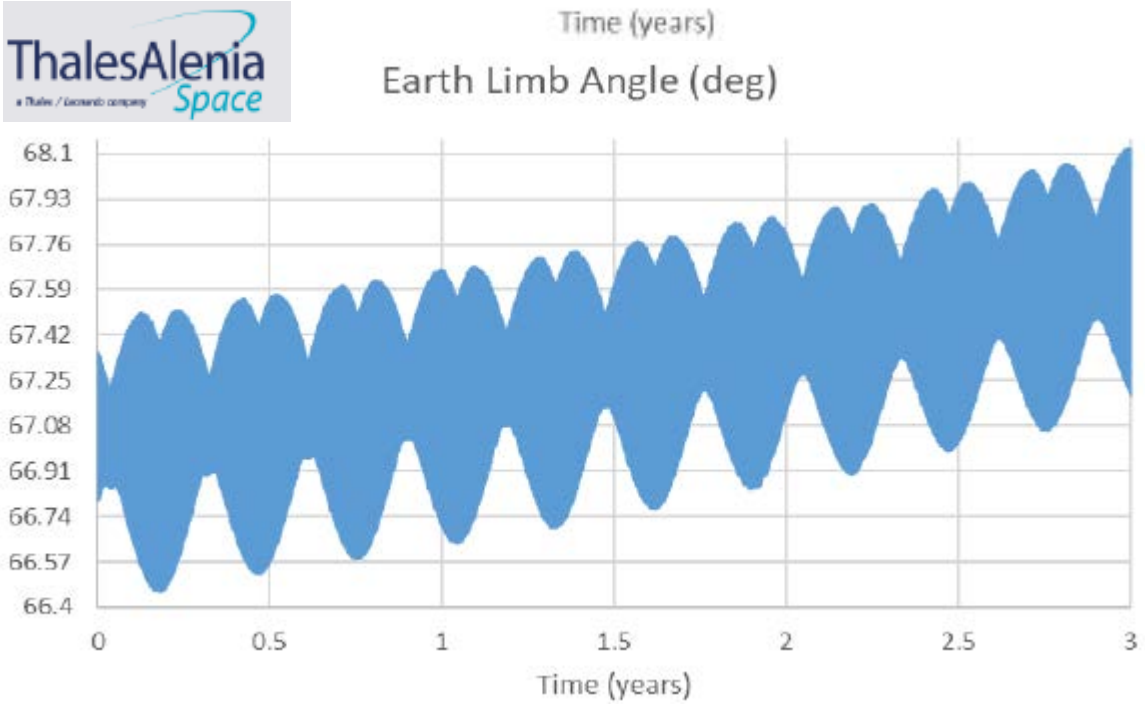
EPS (Electric Power system)

The orbit

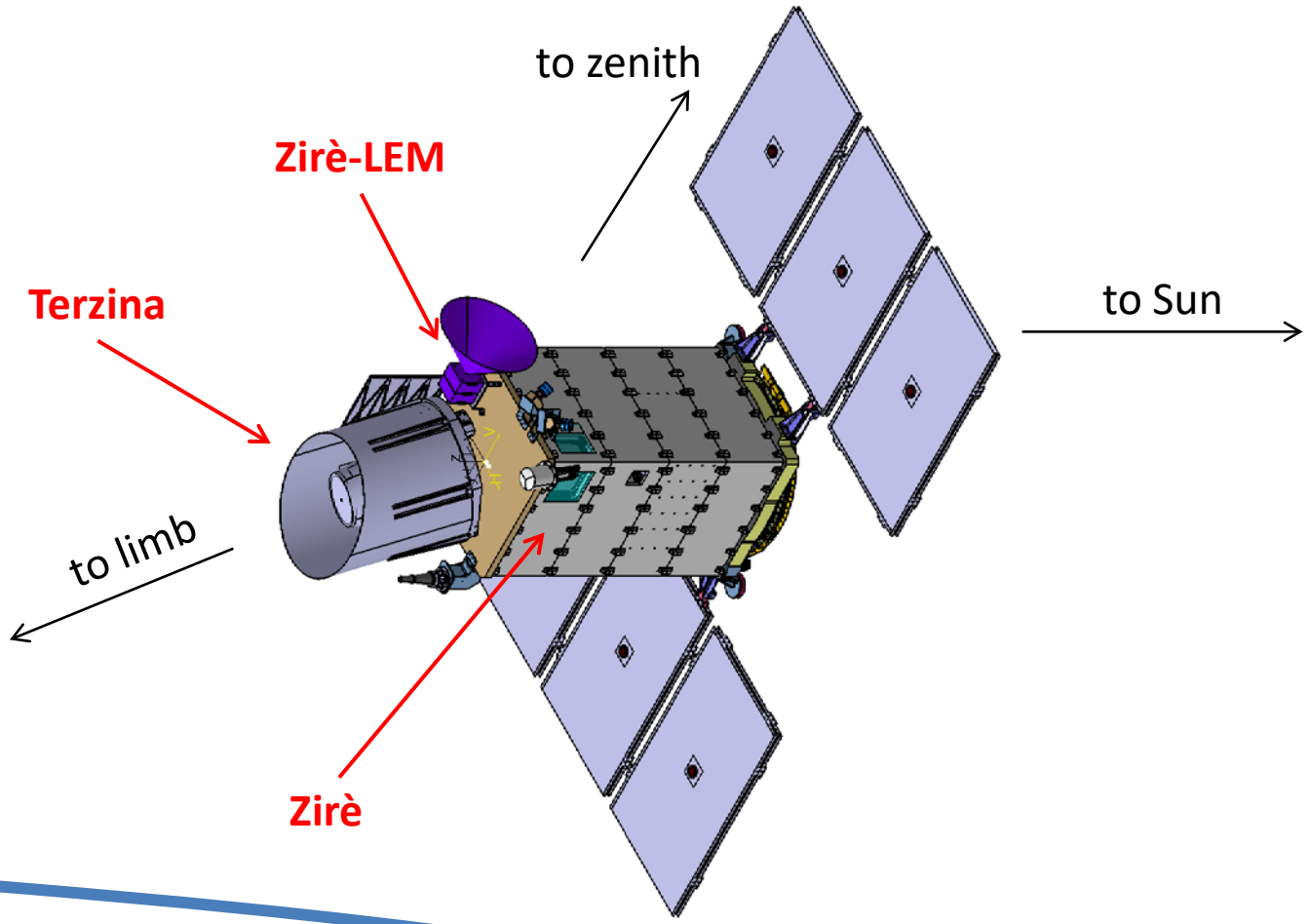




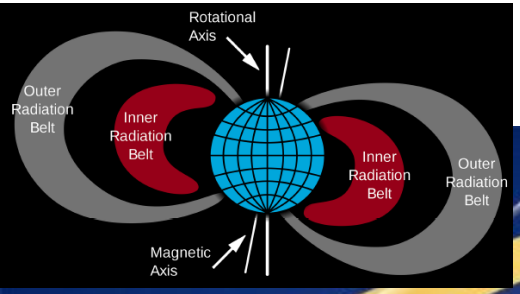
- Low Earth Orbit (LEO) with high inclination, sun-synchronous orbit on the day-night border (mean altitude ~ 600 Km, inclination = 97.8°, LTAN = 18:00);
- Orbit optimization for Cherenkov photons detection;
- Ballistic mission (no propulsion for orbital control).

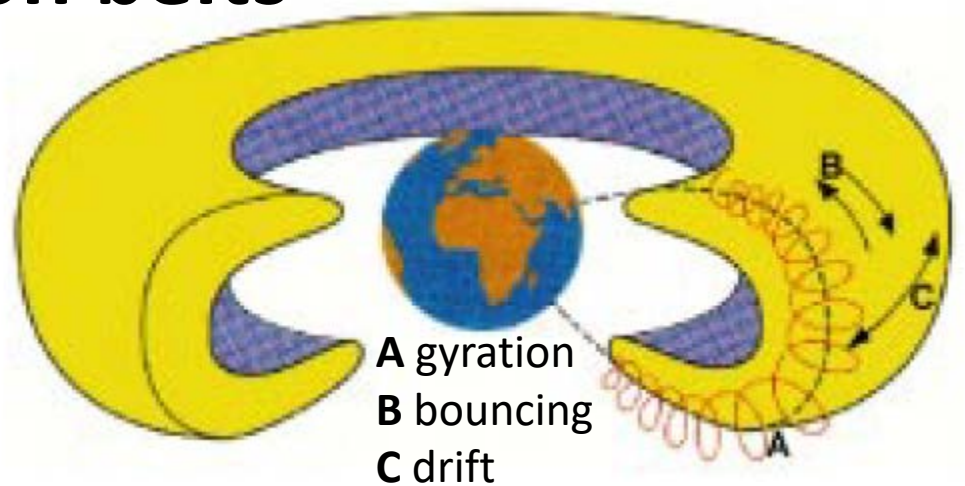


The satellite / payloads layout

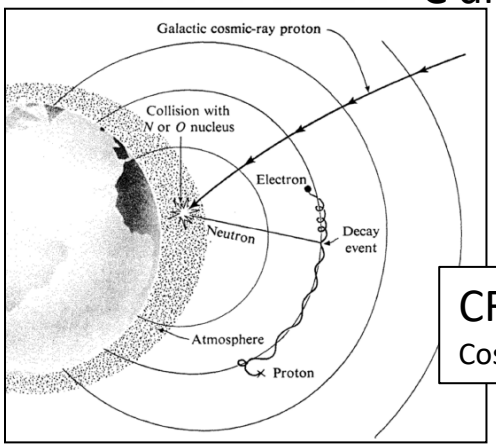


(Van Allen) radiation belts





A gyration
B bouncing
C drift



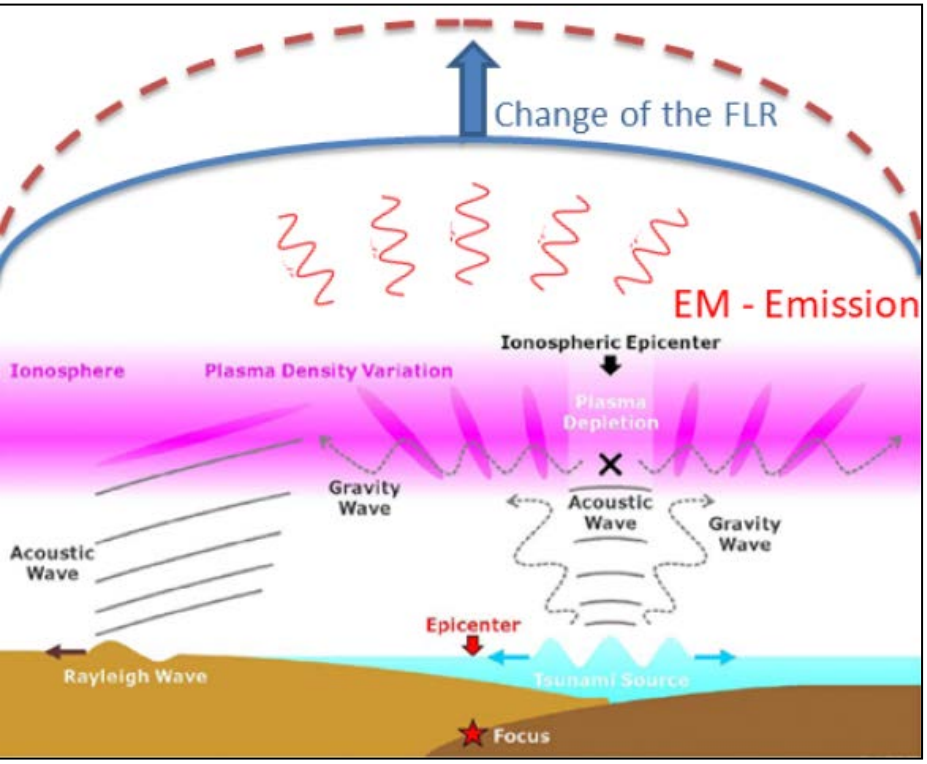
CRAND
Cosmic Ray Albedo Neutron Decay

Belt type	Composition	Rigidity [MeV/n]	Filling mechanisms	L	Residence time [d]
Van Allen (inner)	p e^-	$0.1-100$ $0.01-1$	$n \to pe^-\overline{\nu}_e$, external belts	< 2.5	$10-1000$
Van Allen (outer)	e^- p	$1-10$ $0.1-1$	solar wind	> 2.5	$1-10$
SAMPEX	N^{+x}, O^{+x}, Ne^{+x}	10 $10-100$	Anomalous CR	2	$10-100$

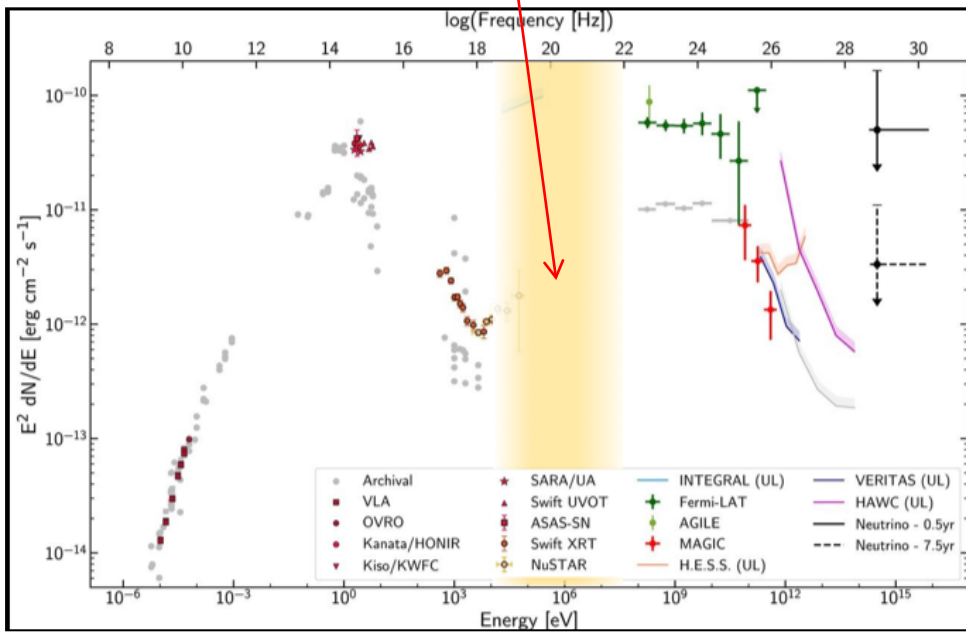
Magnetospheric Ionospheric Lithospheric Coupling

Steady and transient gamma ray sources

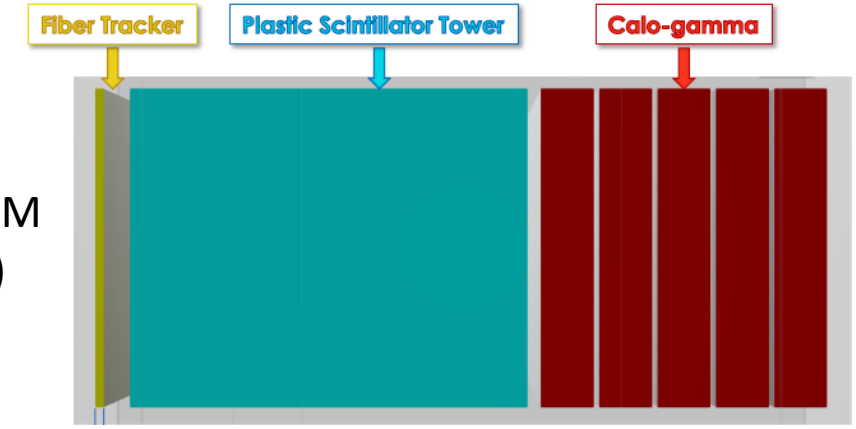
Electrons and protons



MeV photons

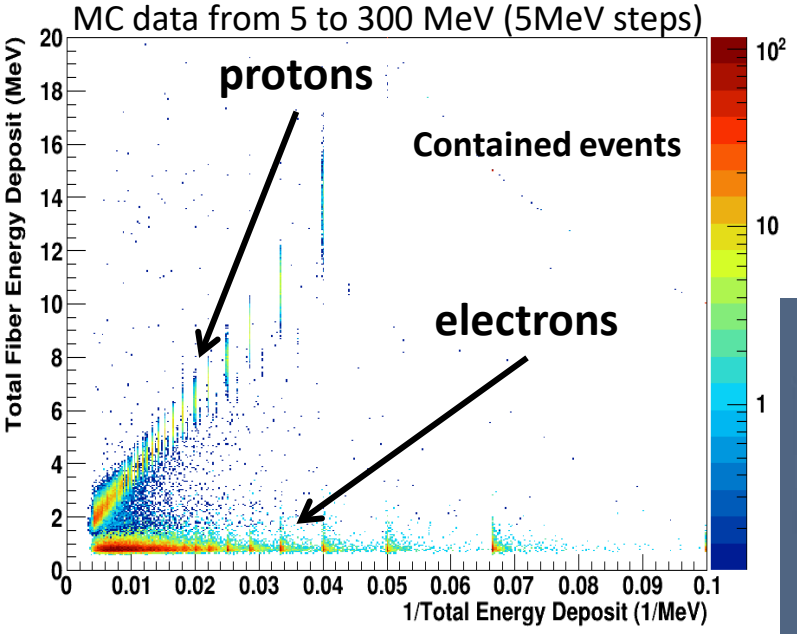


Zirè layout - 1

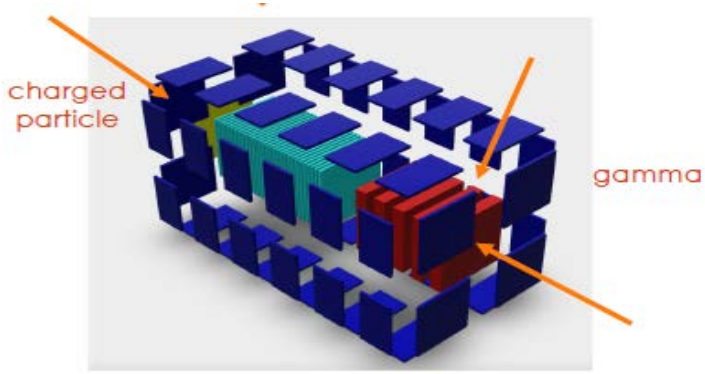


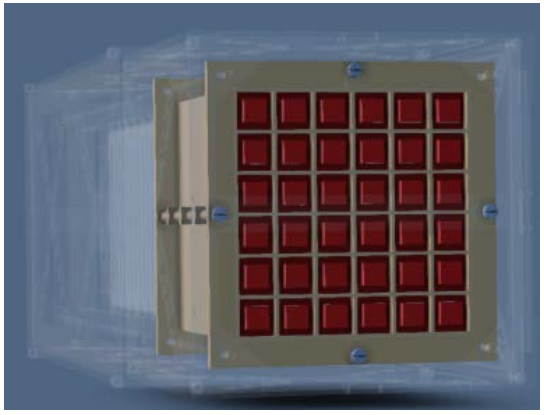
- A fiber tracker, readout by SiPM arrays
- Layers of plastic scintillators X-Y bars, readout by SiPM
- Absorption calorimeter (LYSO cubes radout by SiPM)
- A surrounding active veto system

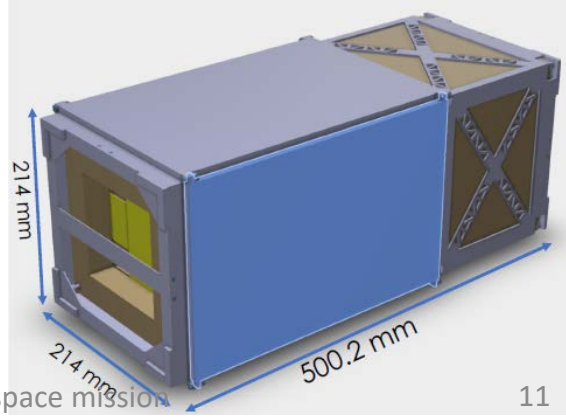
Energy ranges:
- From few up to hundreds MeV for electrons and protons / nuclei + Low Energy electrons
- 0.1 – 10 MeV for gammas



$(dE / dX)_{NR} \propto 1/\beta^2 \propto 1/E_{kin}$







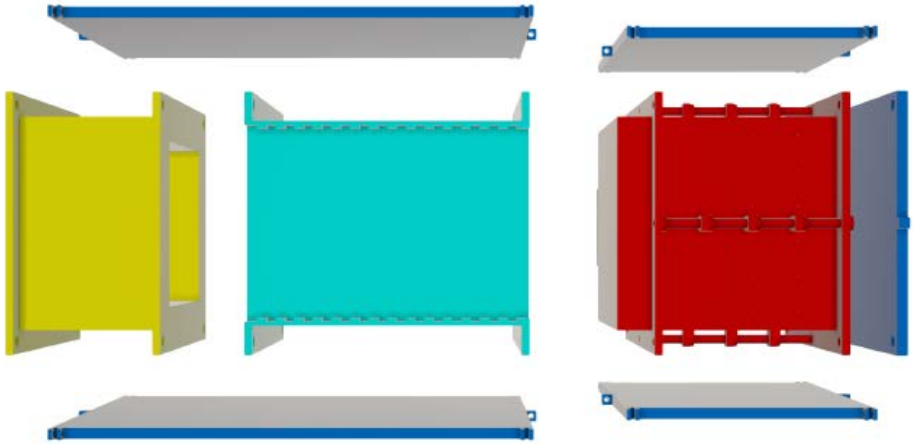
Zirè layout - 2

FTK - Fibre Tracker

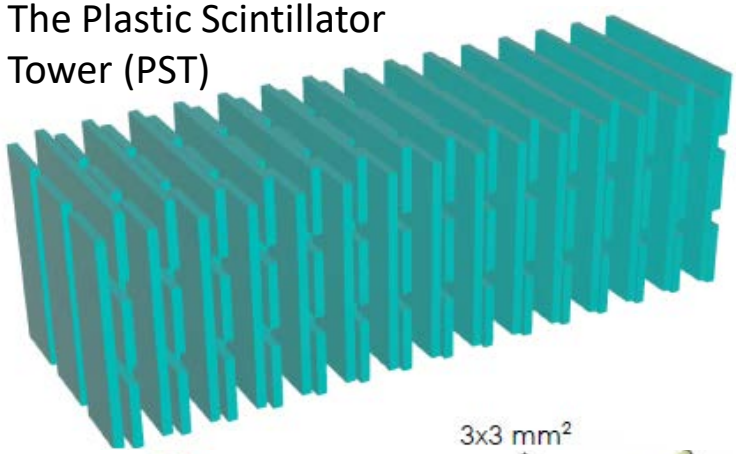
PST – Plastic Scintillating Tower

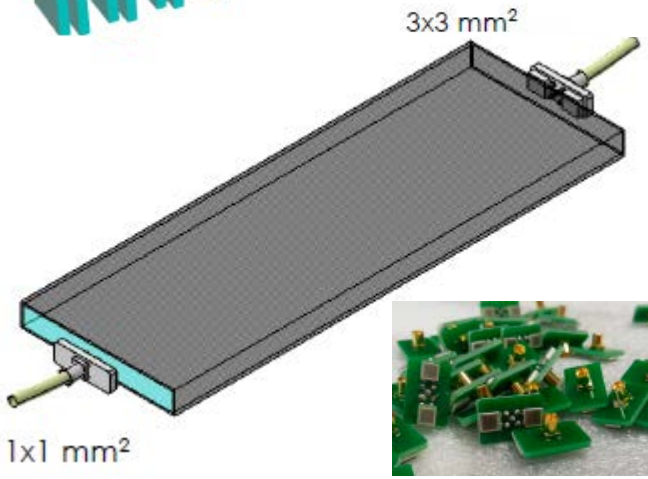
CALOg Calorimeter

ACS – AntiCoincidence System

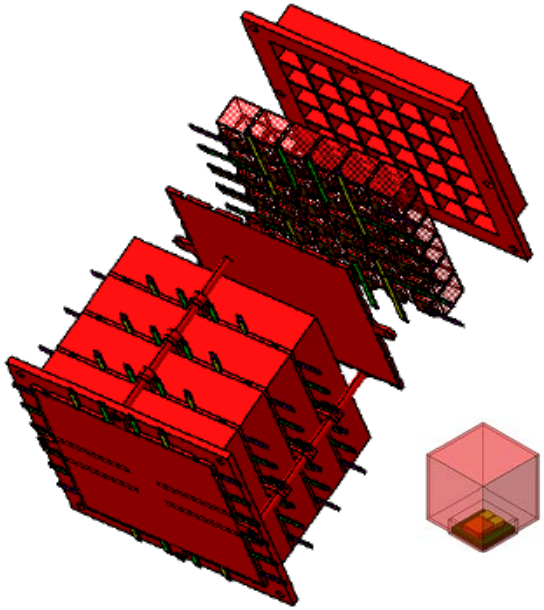


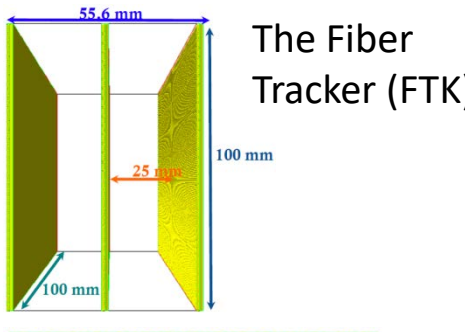
The Plastic Scintillator Tower (PST)





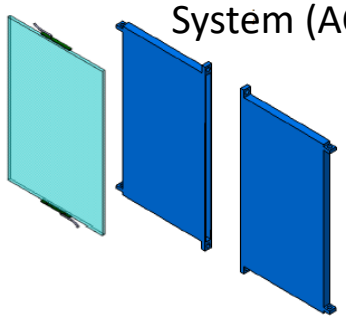
The calorimeter (CALO)





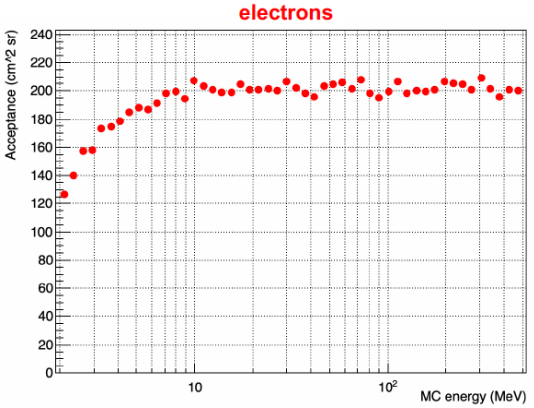
The Fiber Tracker (FTK)

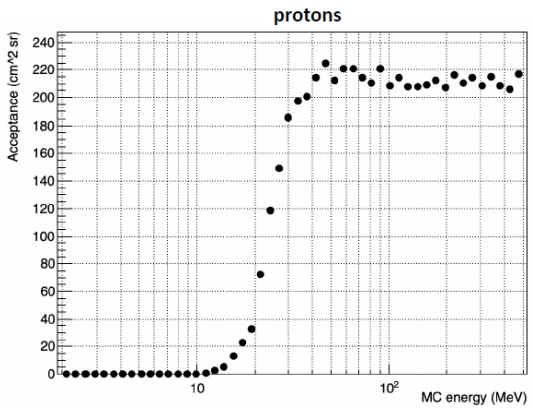
The Anti-Coincidence System (ACS)

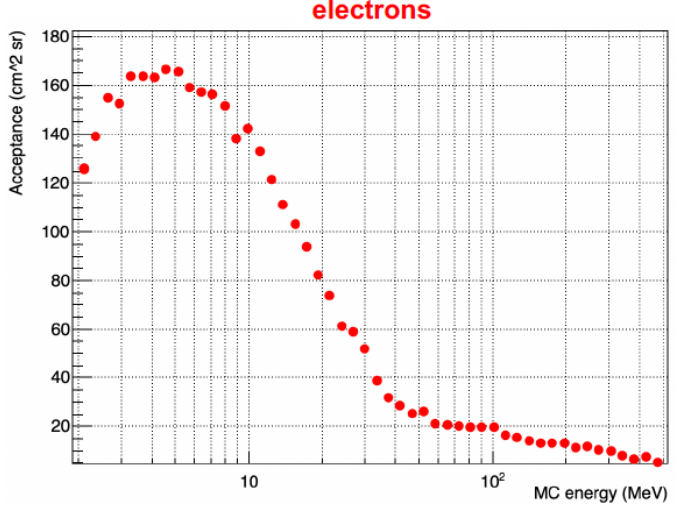


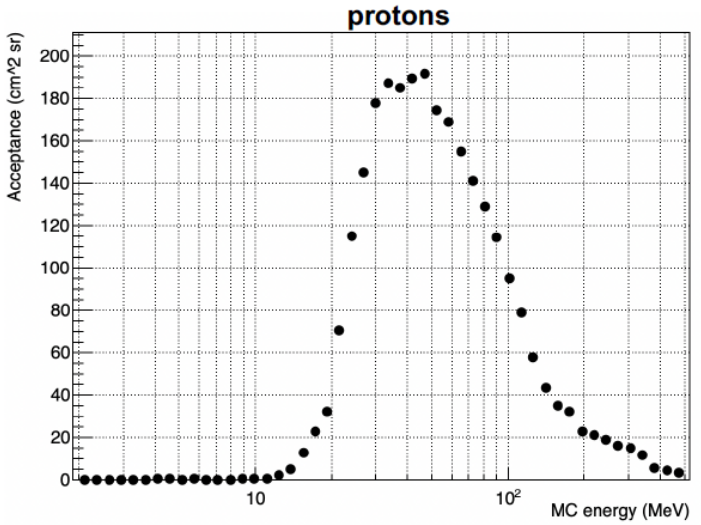
Zirè: G4 simulation

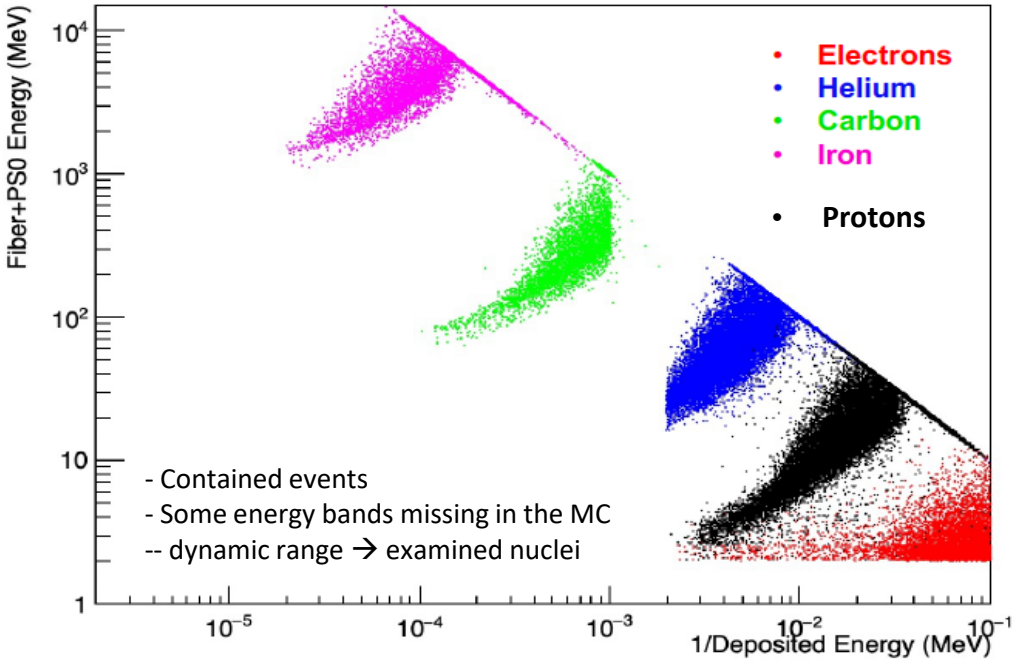
Acceptance , efficiency, PID,… evaluations and detector layout optimization

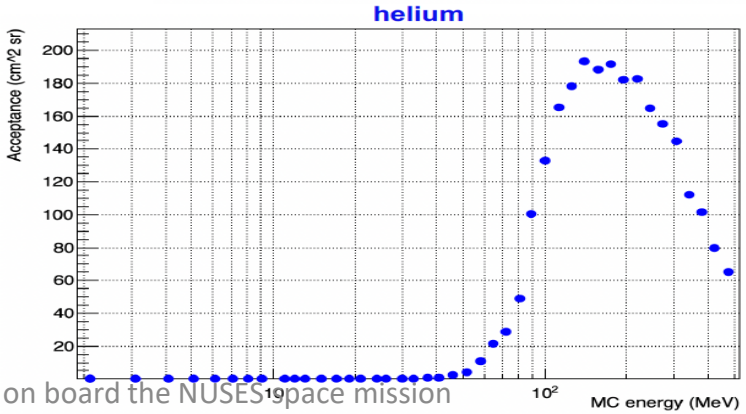




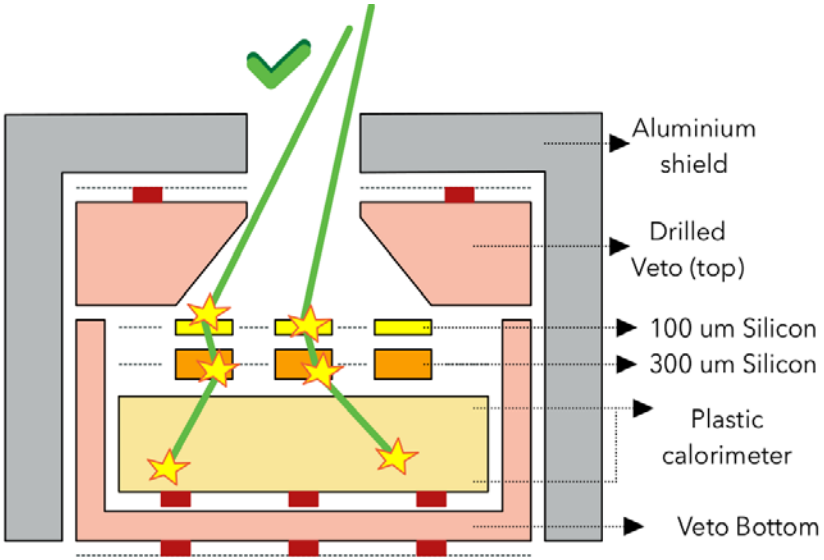


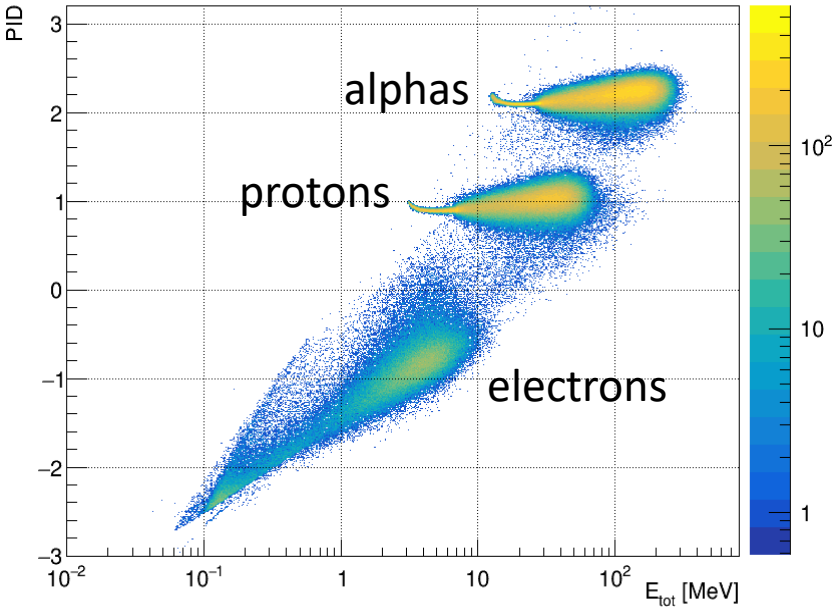


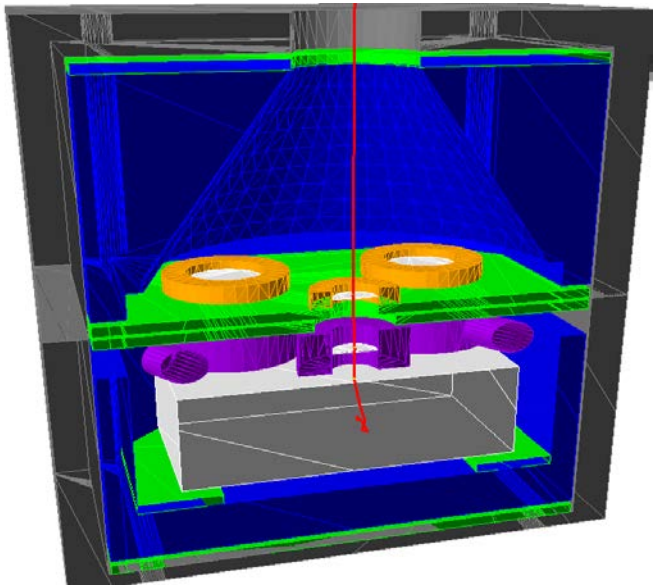




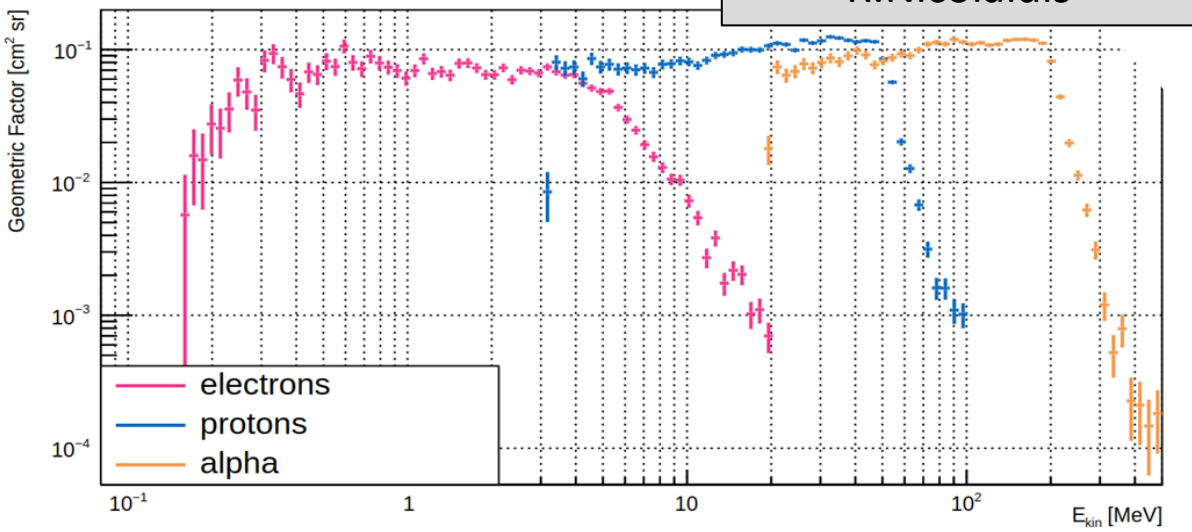
The Zirè-LEM (Low Energy Module)



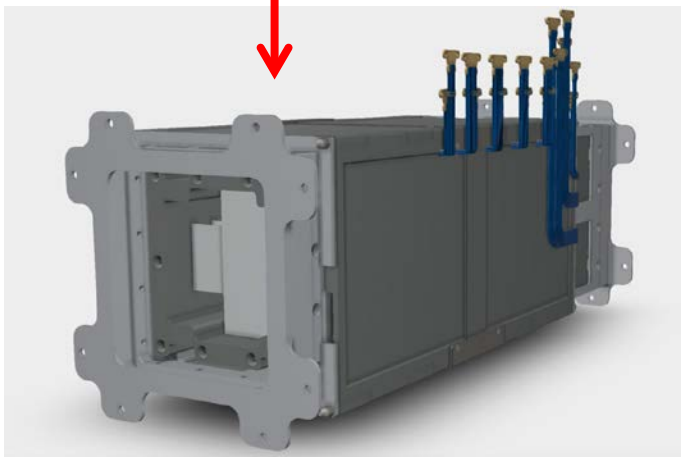


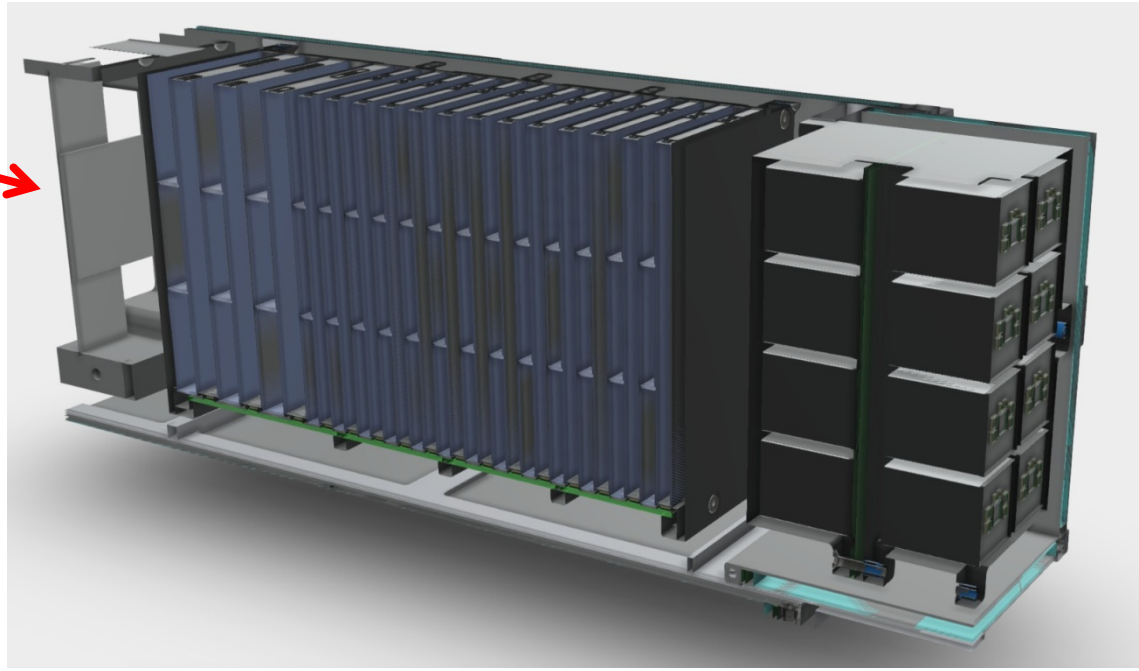


See talk from: R.Nicolaidis



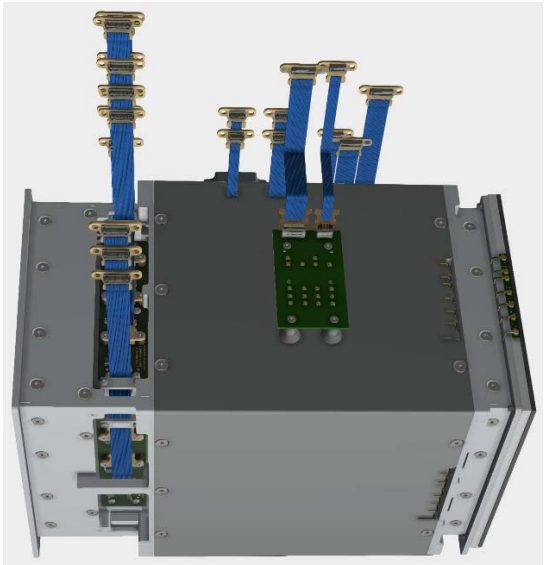
Zirè final design

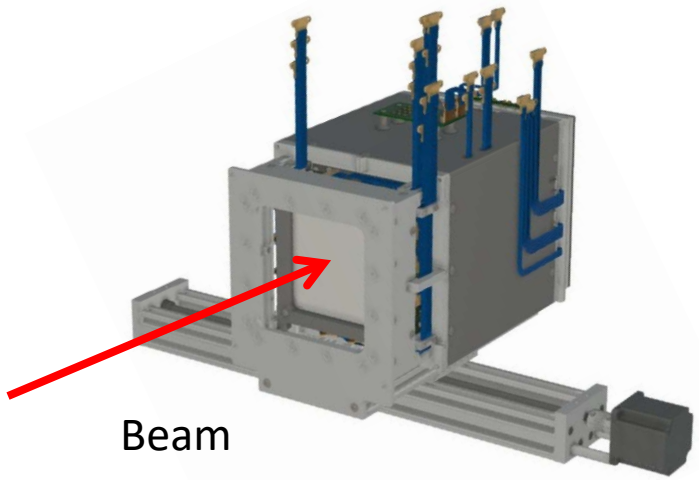




Zirèttino

(for tests and calibrations)



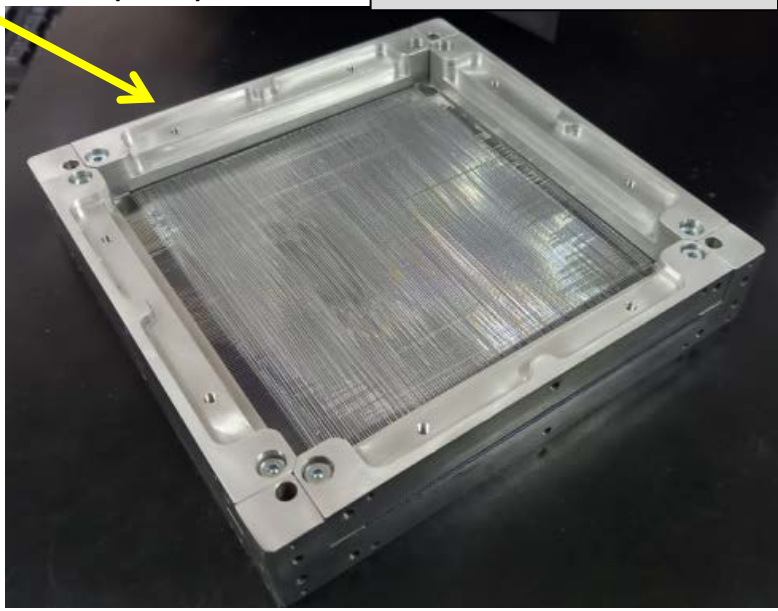


Beam

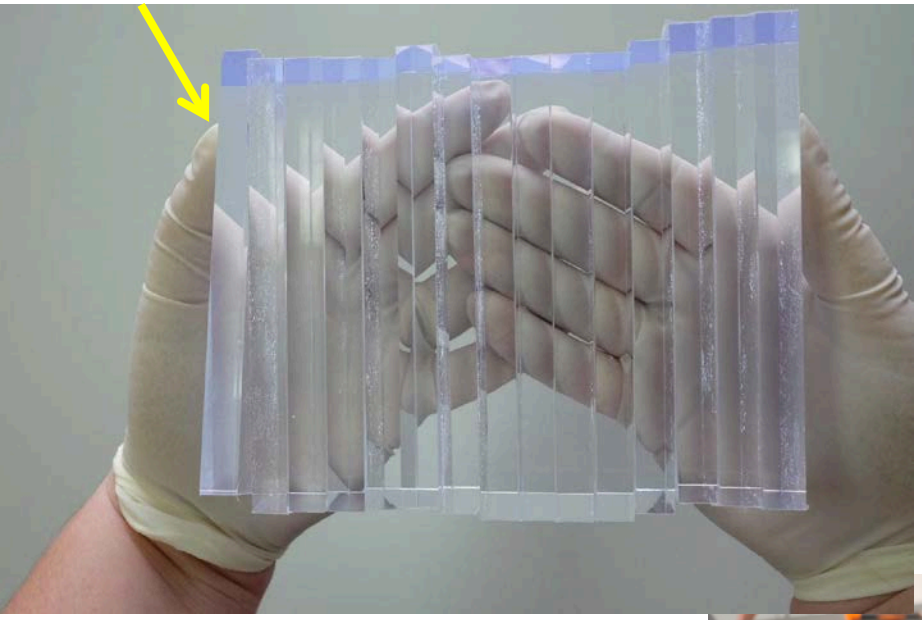
Zirèttino construction

See FTK poster from R. Pillera

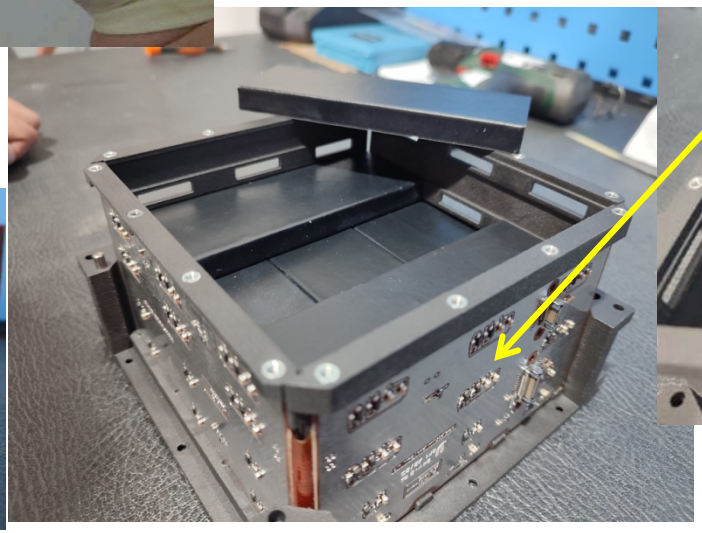
The fiber tracker (FTK)

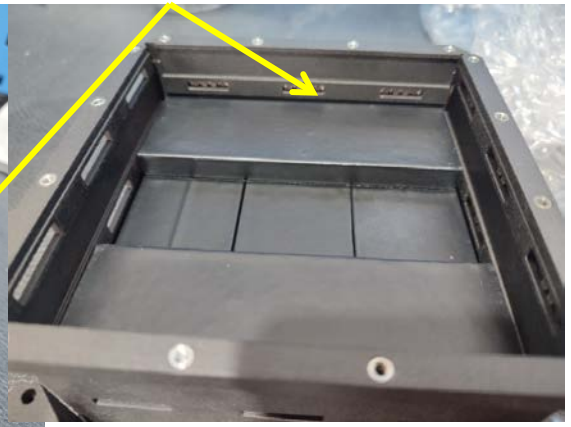


Plastic Scintillator Tower (PST) bars

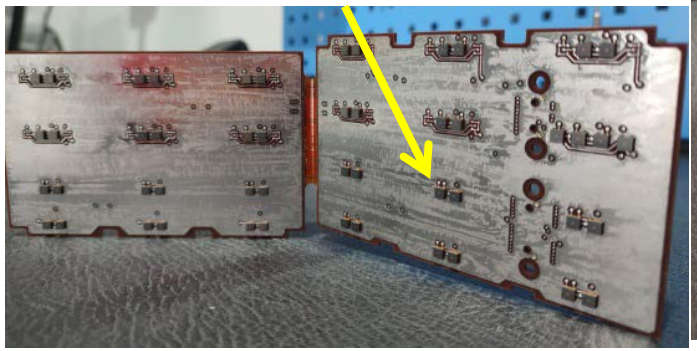


PST layout and readout board/ windows

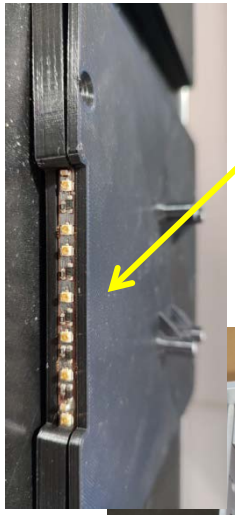




The readout PCB hosting SiPM
Plastic Scintillator Tower (PST)

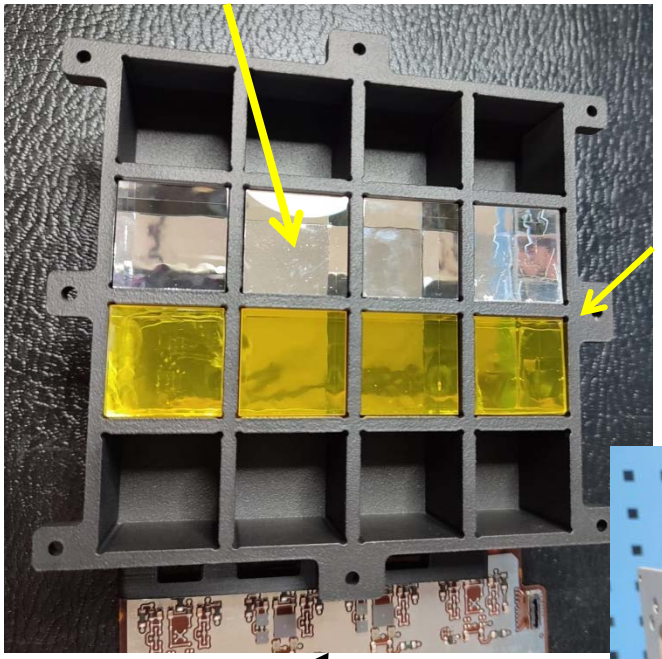


Zirèttino construction

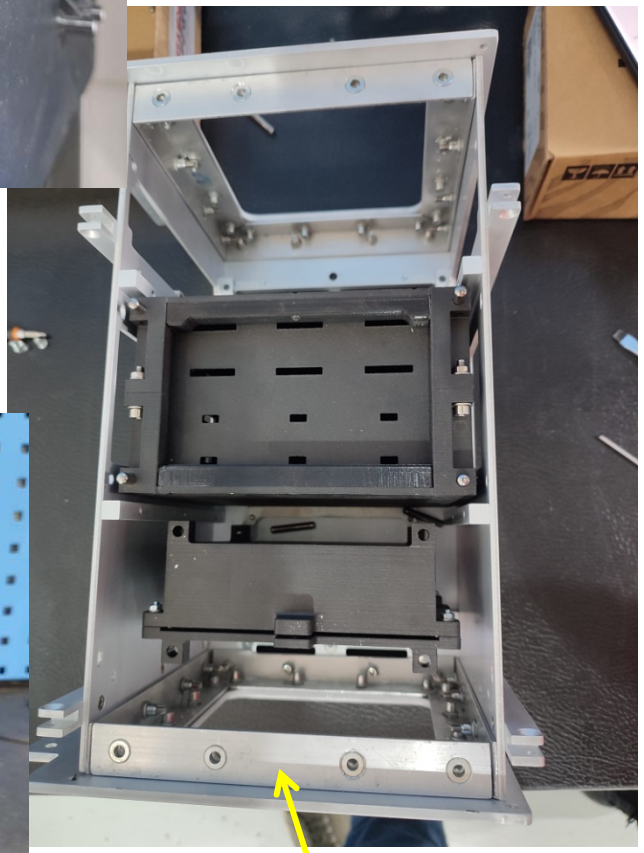


Anti-conicidence tile
and SiPM readout

LYSO and GAGG crystals in the CALO



3D printed
Windform case



PCB hosting SiPMs
for CALO readout

Al 6061-T6 external case

Summary of Zirè 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

See talk from:
R. Battiston

- Cross correlations among low-energy-electrons, protons-alfa, photons in coincidence with (high intensity) GRB's
- Measure photons in the 0.1-10 MeV for transient and steady gamma source detection

e.g. Crystal Eye

See talk from:
F. Barbato

- Interdisciplinary applications (TGF, Earth observation, etc.)

See talk from:
A. Di Giovanni

- ……..

And….

…new technologies/approaches (in space)

- Go from PMT to SiPM (fully testing them for future missions)
- Use a scintillating fiber tracker (~300μm) readout by SiPM arrays
- Optimize a LYSO /GAGG crystal array to act as a (astrophysical) γ detector (0.1-10 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
- Use 3D printing technologies for payload mechanics
- ….

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Join the GSSI group for
High Energy Astroparticle Physics group for the experimental study of cosmic radiation
(DAMPE, HERD, NUSES, CRYSTAL EYE,…)

Two years postdoc position:

The GSSI is seeking outstanding candidates to join the High Energy Astroparticle Physics group for the experimental study of cosmic radiation.
The ideal candidate should have a solid background in experimental particle and astroparticle physics with a PhD in the field.
Previous experience in the experimental study of cosmic radiation with space-based missions and in the related activities (R&D, data analysis, and
payload response simulations) would be an asset.
Total gross salary: **45.000,00 eur**. Deadline: July 6th, 2023.
See the position 1.2 at the link below:
https://www.gssi.it/albo-ufficiale-online-gssi/item/download/4396_26fc3b69b46a2d802e2f574daa9c2314

Two years position for a Payload/Satellite engineer:

The ideal candidate should have a solid background in aerospace or electronics engineering.
He/she will contribute to the design and optimization of the mechanical or electronic model of scientific payloads and/or satellite platforms, including the development of test beds used for single subsystems characterization.
Simulations and tests for space qualifications will also be part of the work.
Knowledge of the commonly used software tools for mechanical or electronic design is also required.
The selected candidate will join the High Energy Astroparticle Physics group for the experimental study of cosmic radiation.
See the call at line 313 at this link: https://www.gssi.it/albo-ufficiale-online-gssi

GSSI is also offering **four PhD positions** in the newborn PhD programme for
"Innovative Technologies for Space Missions and Radiation Detection", under the Astroparticle Physics area,
Applications from physicists, engineers, and young experts in the field are welcome till July 6th, 2023.
See the call at line 316 at this link: https://www.gssi.it/albo-ufficiale-online-gssi