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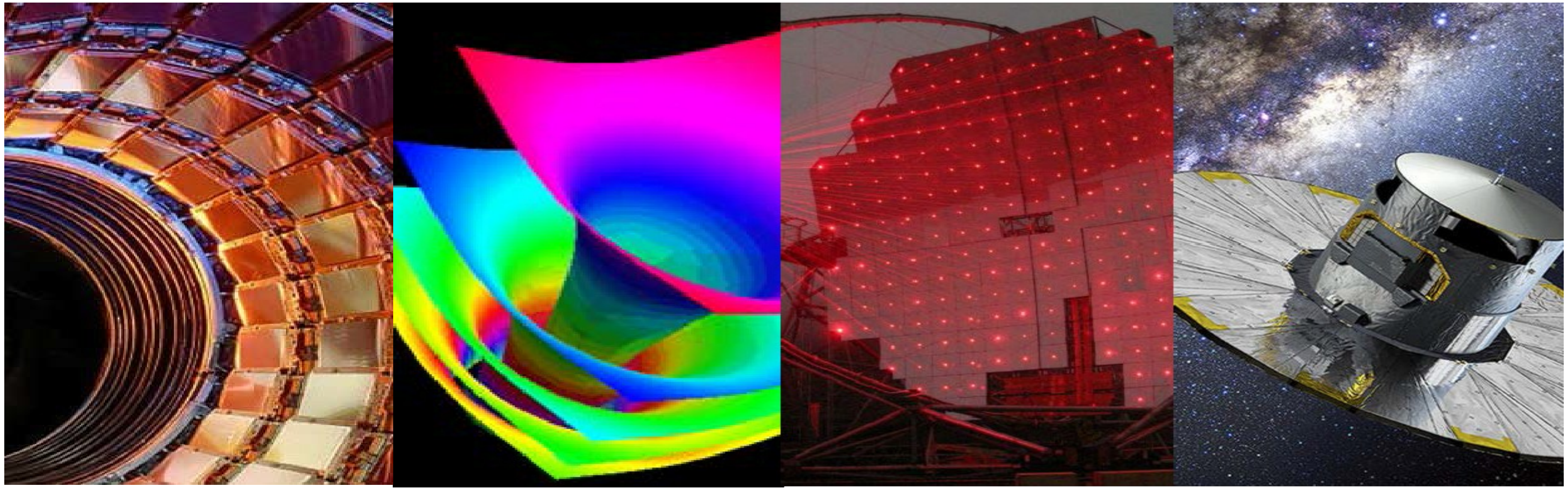

Status of the LISA Radiation Monitor

D. Guberman, R. Català, L. Di Venere, A. Espiña, F. Gargano, F. Licciulli, P. Loizzo, L. Martí, J. Mauricio, M. Orta, D. Roma, A. Sanuy, D. Serini, M. Nofrarias

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Institute of Cosmos Sciences
Universitat de Barcelona

LISA Spain Meeting 2024

15/10/2024

UNIVERSITAT DE BARCELONA

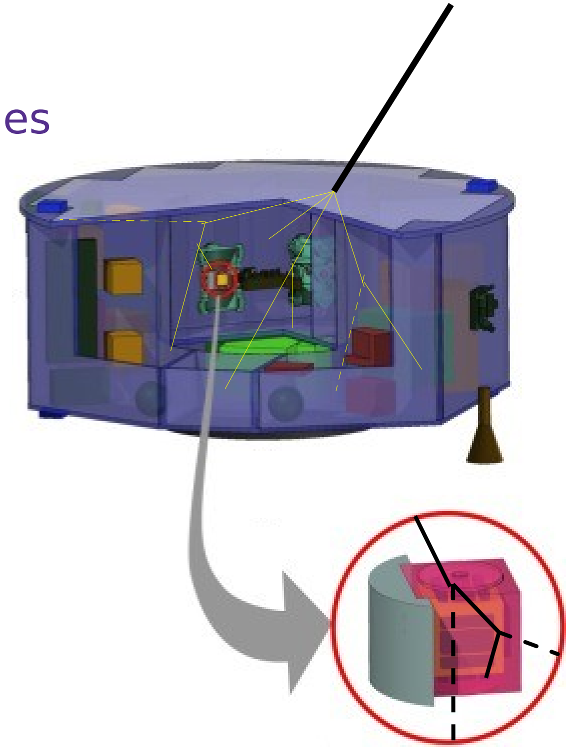
Outline

- Why a Radiation Monitor?
- Radiation Monitor design + 1st prototype
- Preliminary performance
- The Radiation Monitor beyond LISA

Why a Radiation Monitor?

GOAL: Monitor the *charging background* of the LISA Test Masses (TMs)

- Background radiation can interact with the spacecraft, producing secondary particles
- The Test Masses (TMs) may get charged → acceleration noise



Grimani et al., 2024, https://doi.org/10.1016/j.jheap.2024.03.004

What a Radiation Monitor can do:

- Help optimizing our understanding the TM *charging nature* by:

  → Measuring the background radiation flux

  → Which could be use as input for TM charging simulations

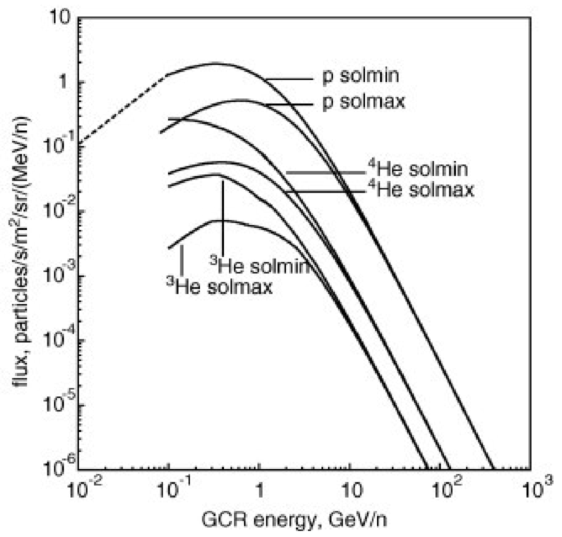
  → And compared with the measurements of the TM charging rate

- Provide a veto for fake GW triggers
- Hopefuly some other stuff beyond looking after the TMs...

The LISA (expected) background flux

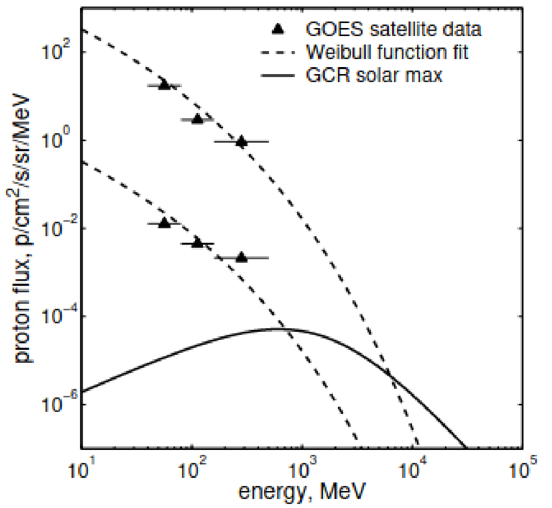
Galactic Cosmic rays (GCRs)

- Steady isotropic source of background with slow and dim flux variations:
  - → Solar cycle variations (an order of magnitude in ~11 yr)
  - → Short-term variations (~10% in ~ days)



Solar Energetic Particles (SEPs)

- Sporadic, fast evolving, orders of magnitude more intense than CRs
  - → Relevant ones ~ 1/yr (order of magnitude)
  - → Timescales: seconds to days



- ~90% of the particles interacting with the S/C will be protons
- Only those with **E>100 MeV** affect the TMs
  - → Several dedicated simulation studies (e.g., Araujo et al., Grimani et al.…)

Araujo et al., 2005, 10.1016/j.astropartphys.2004.09.004

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RM Requirements

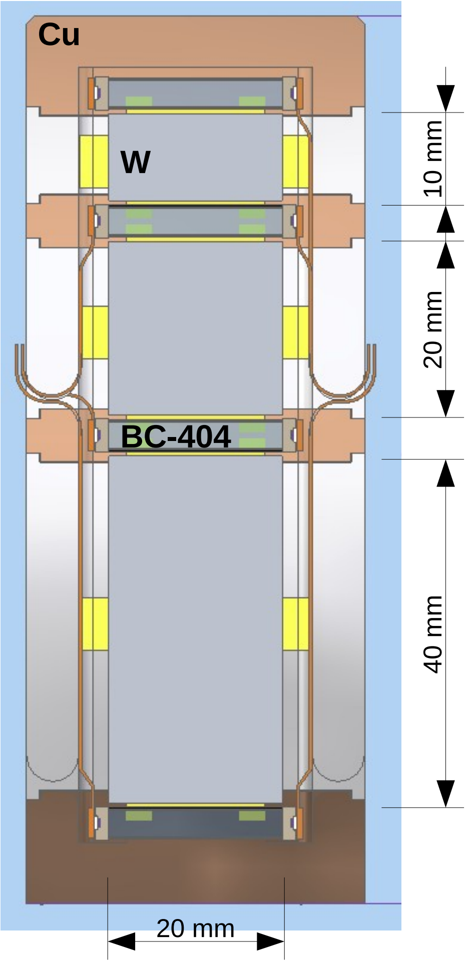
Scientific Requirements:

- **TM-driven:** should detect p^+ at 0.1–10 GeV
- **~1 % statistical error** in the integral **cosmic-ray flux >70 MeV** in **~1 hour**
- Moderate energy resolution at a few hundred MeVs for spectrum reconstruction

Technical Requirements:

- Volume ~ 1l
- Mass $<$ 1.5 kg
- Power consumption $<$ 2W

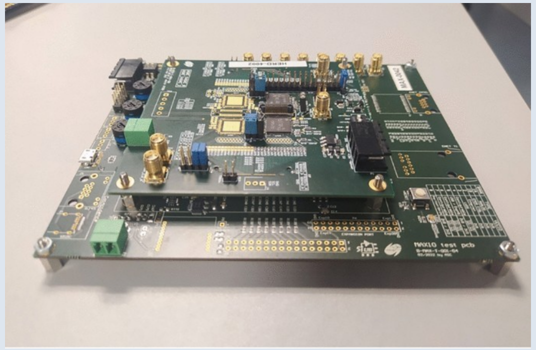
LISA Radiation Monitor: design overview

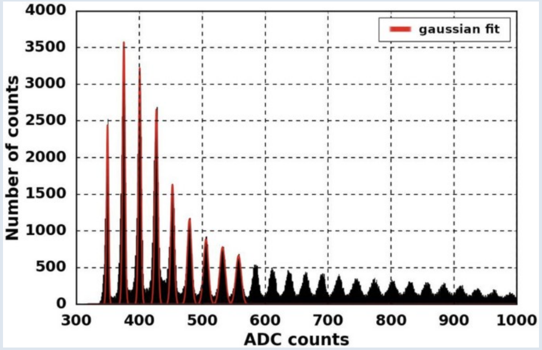


- **Plastic scintillators + SiPMs** for particle detection
- **W absorbers** to “slow down” high-energy protons
- **Cu** pieces as **Low Energy shield** for p^+<70 MeV
- SiPM **signals** are **processed** and **digitized** with the **BETA ASIC**
- **FPGA** controls the **trigger** and **reduces** the digitized **data**
  - Maximum trigger rate ~ 10 kHz
  - Different trigger levels to process individual and coincidence events

BETA, an ASIC for portable systems

- **Digital** output in 16 (64) channels
- **Low power** (~ 1 mW/ch)
- High **SNR** for **single photons**
- High **dynamic range**
- Designed to be **radiation tolerant**





- Radiation Monitor: D. Mazzanti, et al., https://doi.org/10.22323/1.444.1494
- BETA ASIC: A. Sanmukh et al., https://doi.org/10.1007/s41365-024-01419-z

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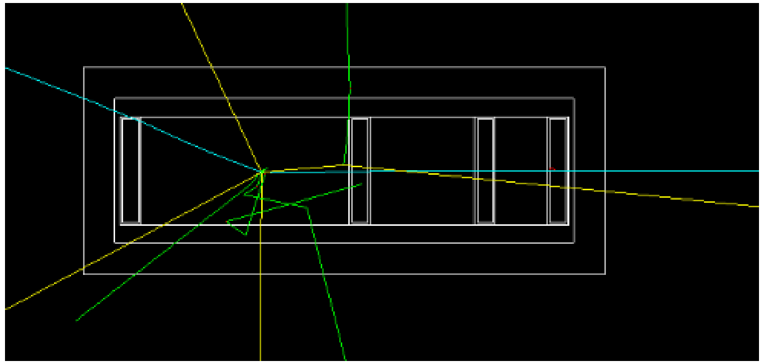
Preliminary performance

Simulated and optimized the system with Geant4 simulations

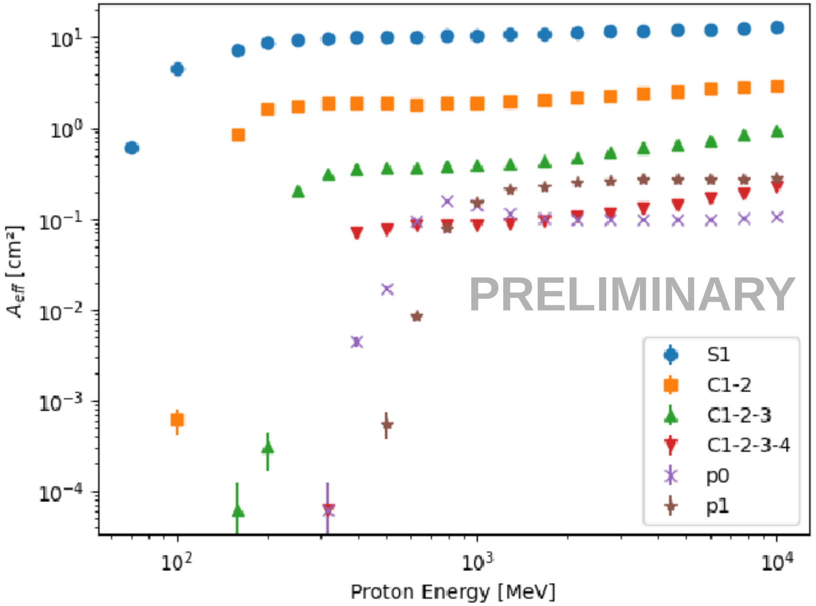
- By now we defined 6 integral energy channels
- Expected rates are a few times larger than those of the LPF RM
- Potential to identify alpha particles



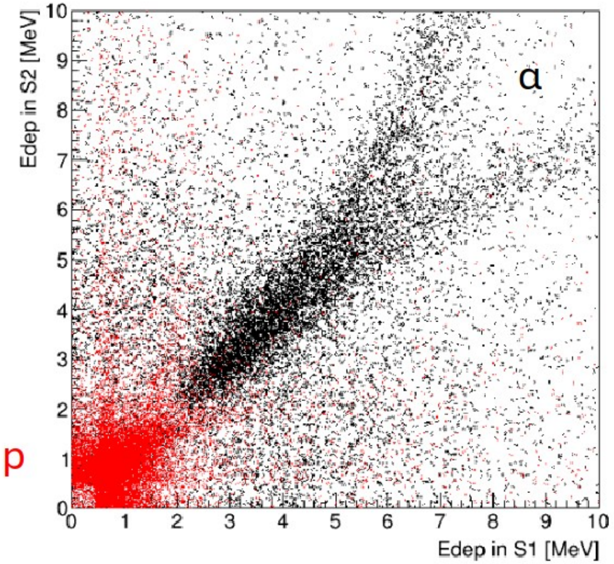
Channel	Energy threshold [MeV]	Simulated rates (solar min) [cts/s]
S1	~70	~46
C1	~150	~11
C2	~250	~2.2
C3	~350	~0.4
P1	~630	~0.4
P2	~1000	~0.6

PRELIMINARY

M. Orta



D. Mazzanti



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HECTOR: A CubeSat demonstrator of the LISA RM

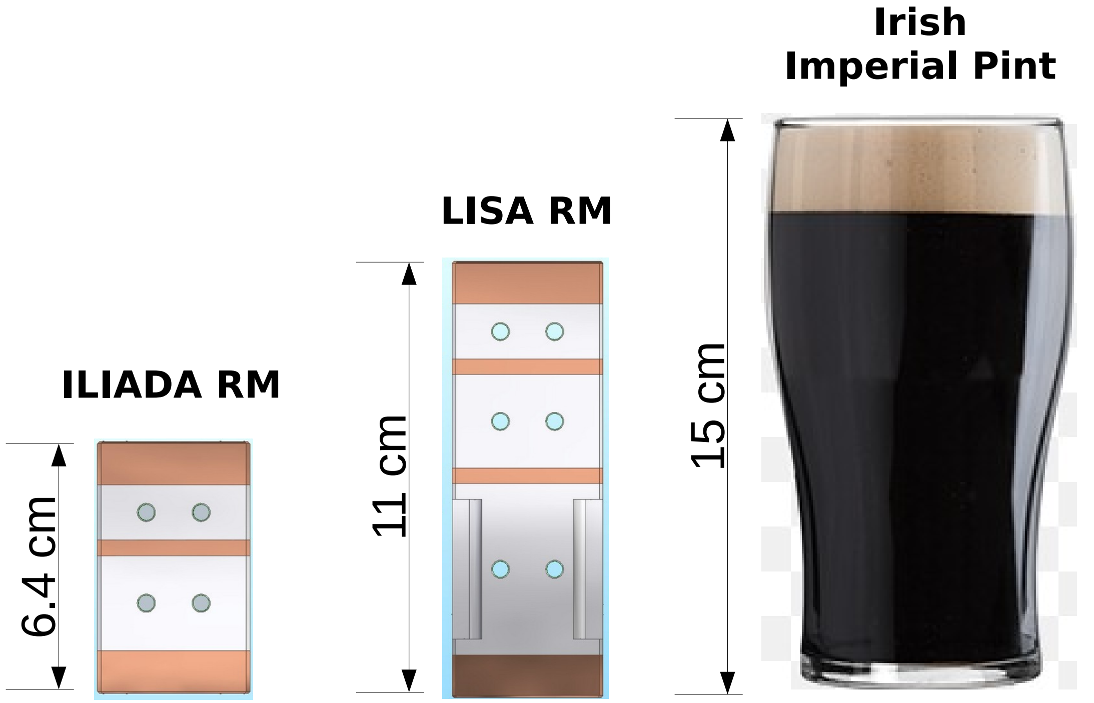
Wikipedia

High-**E**nergy particle dete**CTOR** (**HECTOR**)

(a.k.a ILIADA RM) Proof-of-concept prototype of the LISA RM, will fly in a *SmallSat* as part of the ILIADA consortium (see talk by M. Nofrarias):

> "Like the LISA Radiation Monitor, but without the last absorber-scintillator pair"

- GOALS:
  - Testing the technology and analysis algorithms
  - Compare with expectations from simulations
  - ILIADA scientific case
- Expected launch: beginning of 2026



RM images: R. Català

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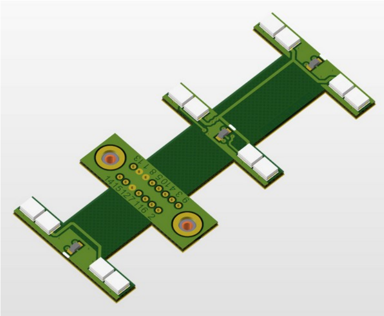
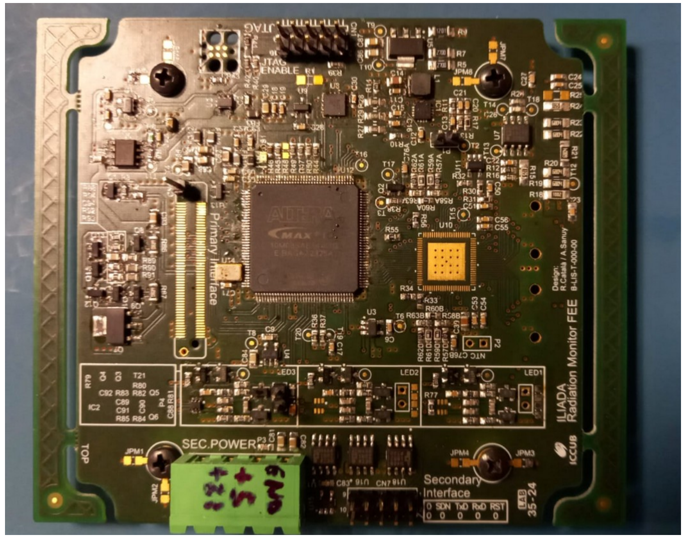
A tight schedule, a huge team effort

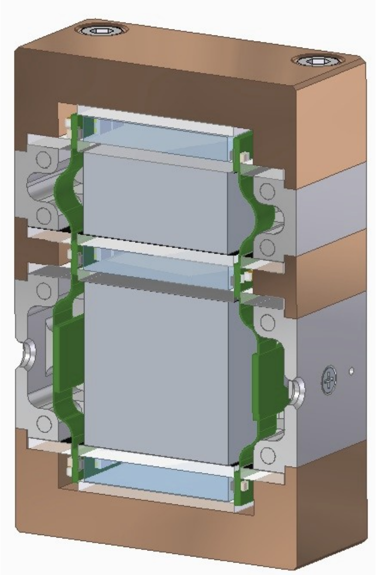
HECTOR TIMELINE

- **April 2024**
  ILIADA is approved
- **June, 2024**
  Test-beam characterization
- **October, 2024**
  We are here!
- **December 2024**
  Integration in ILIADA



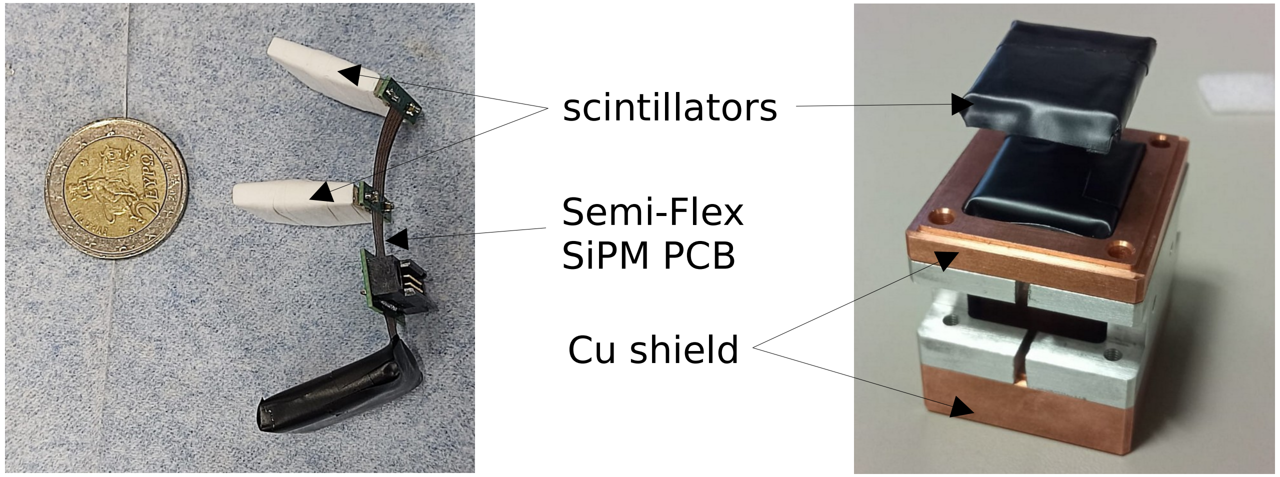
- Mechanic design
- Electronics
- Software and Firmware
- Simulations
- Prototyping
- Characterization

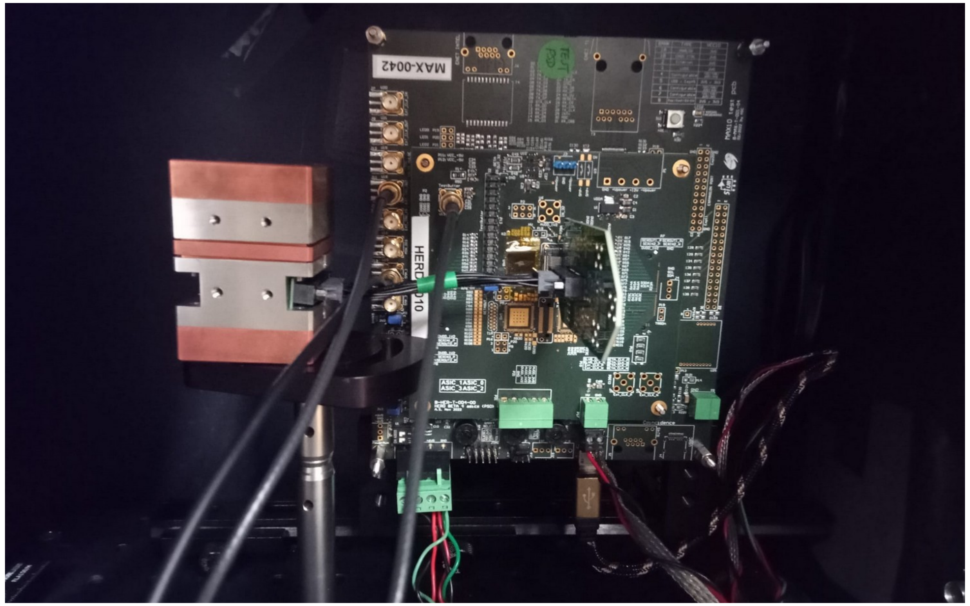


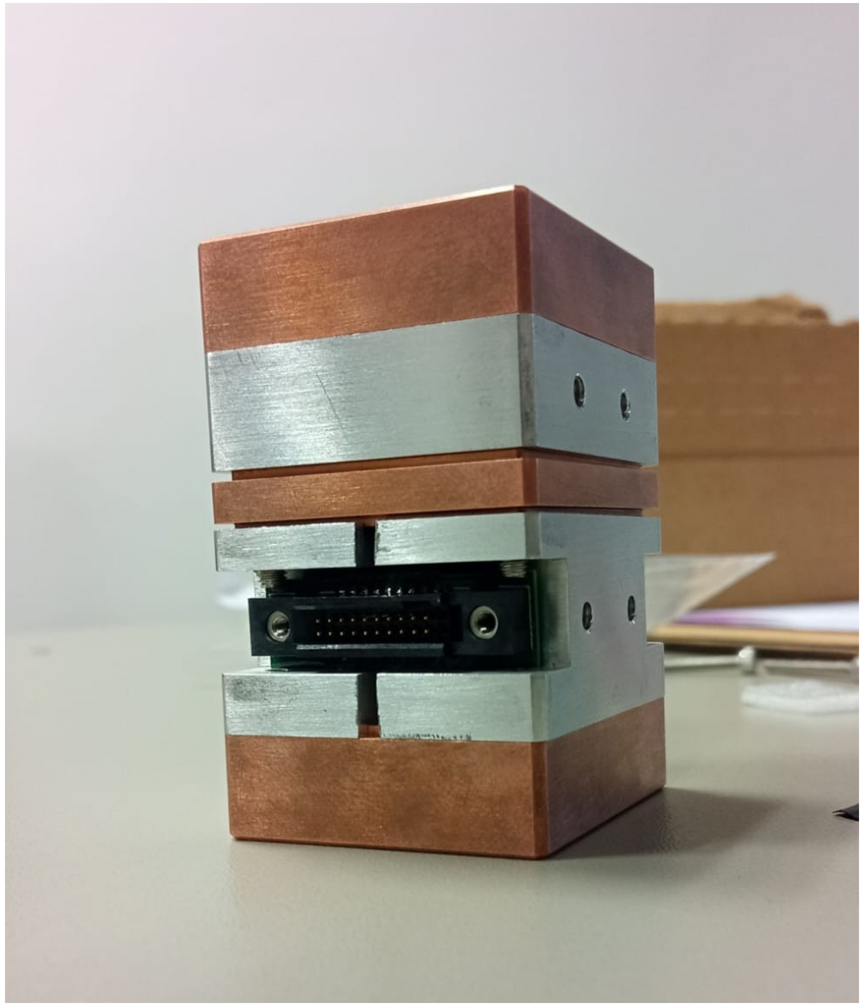


Special thanks to R. Català, A. Espiña, P. Loizzo, M. Orta, M. Pagès, J. Salvans, A. Sanuy and D. Serini!

HECTOR 1st prototype

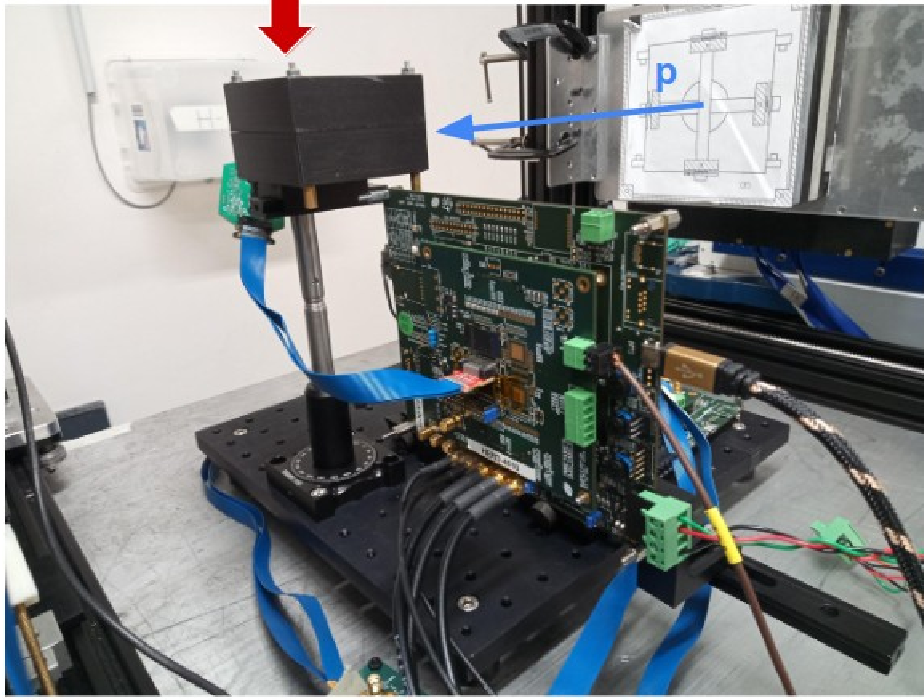


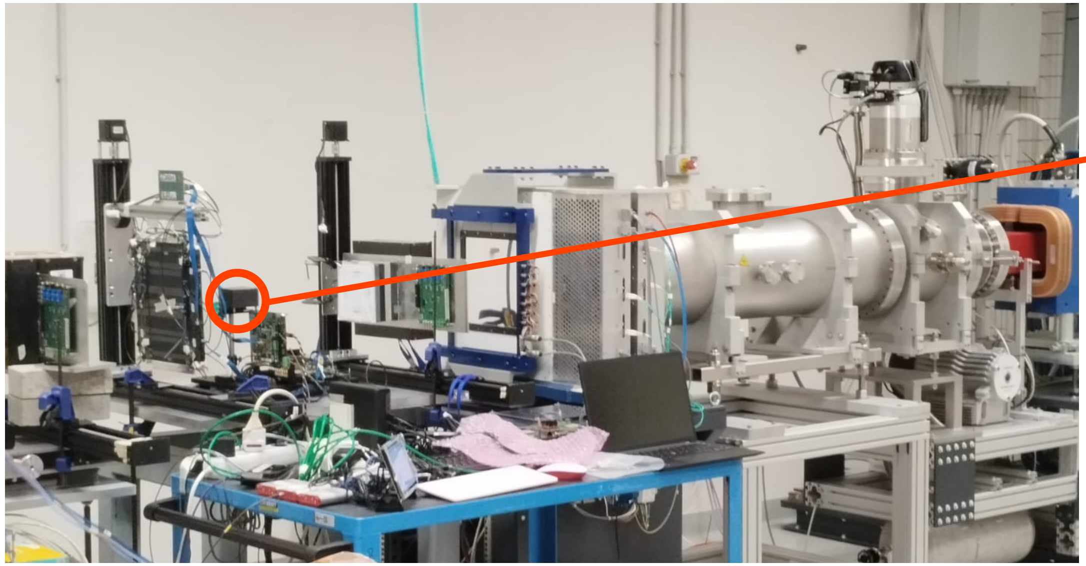




Test-beam preliminary results

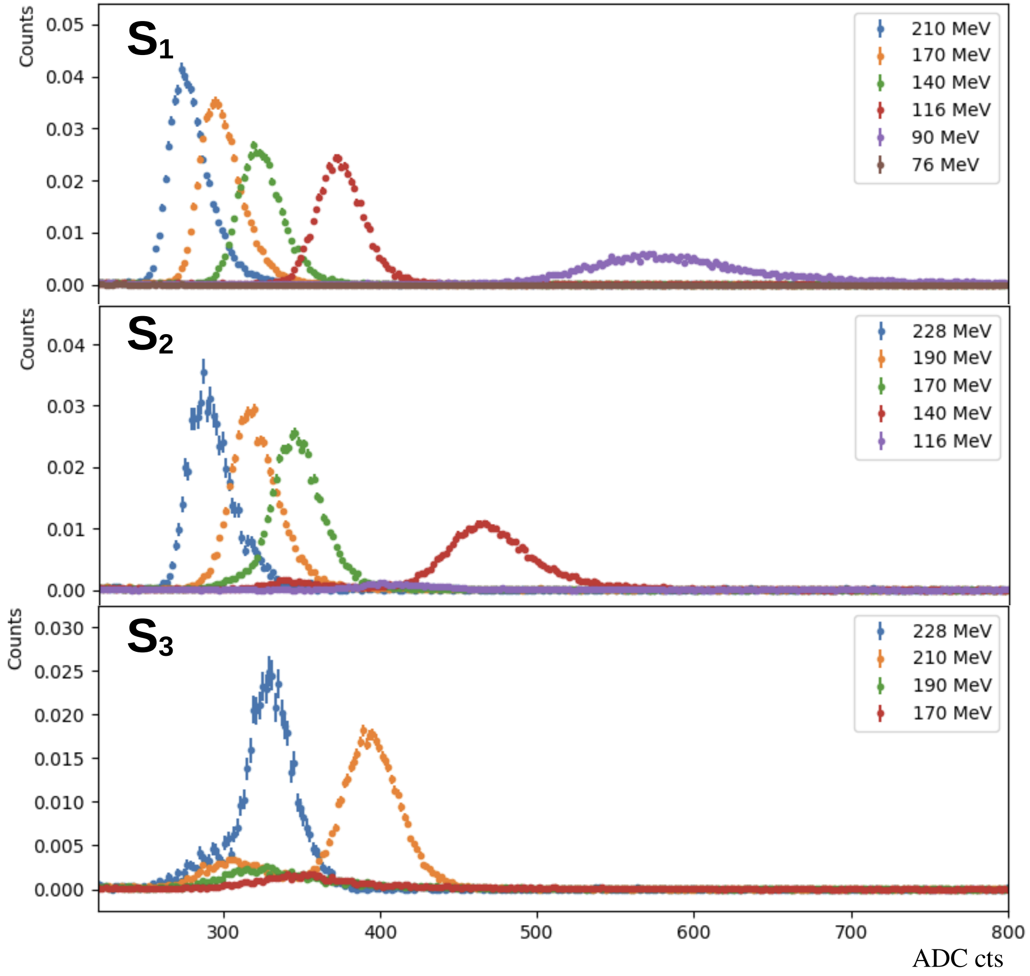
- Test Beam at CNAO (Pavia, Italy) performed on June 2024
- **p^+** beam: **~60 to ~230 MeV**
- Beam intensity tunned to achieve a trigger rate of ~ 100 Hz
- Test-beam prototype had **Cu absorber blocks** (instead of W)



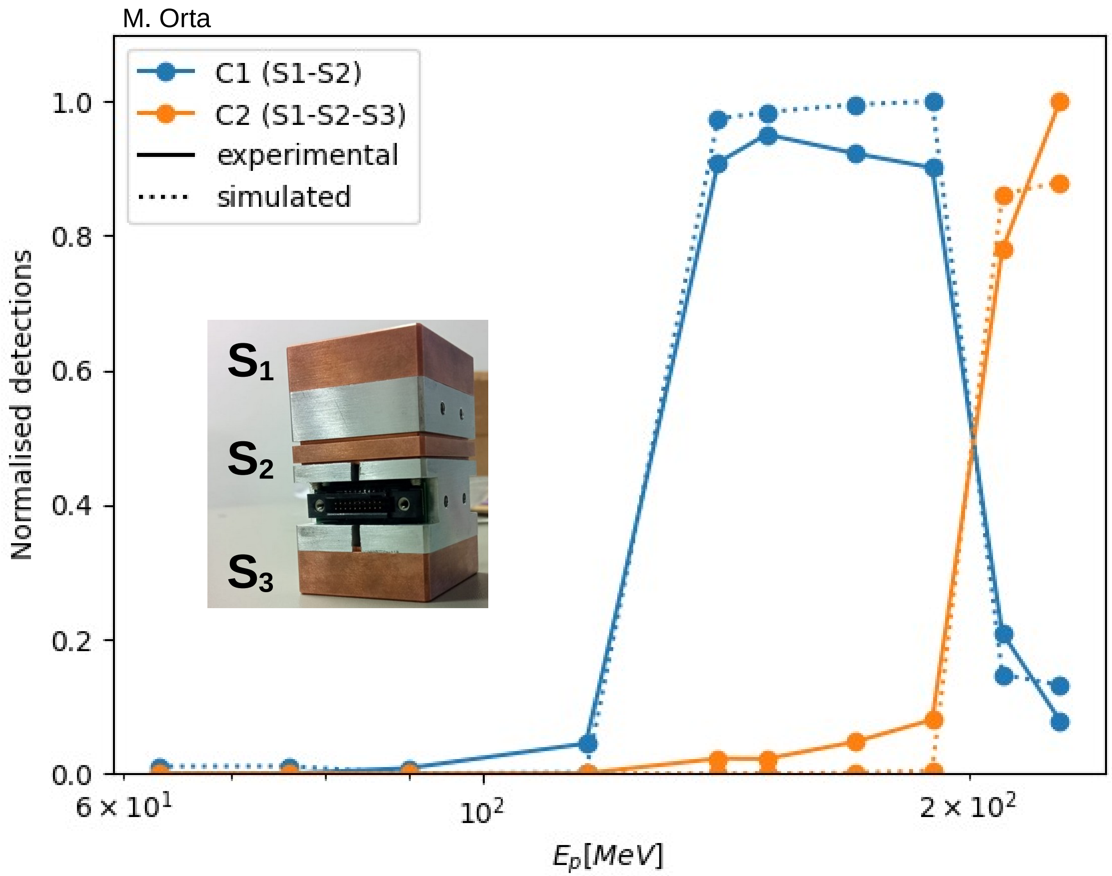


Test beam preliminary results

Scintillator output distributions



Coincidence channels trigger rate



Left: Distributions of the signal collected by the SiPMs of each sicntillator for different incident proton energies. **Right:** Normalized detection rate in the coincidence channels C_1 (S_1-S_2) and C_2 (S_1-S_2-S_3)

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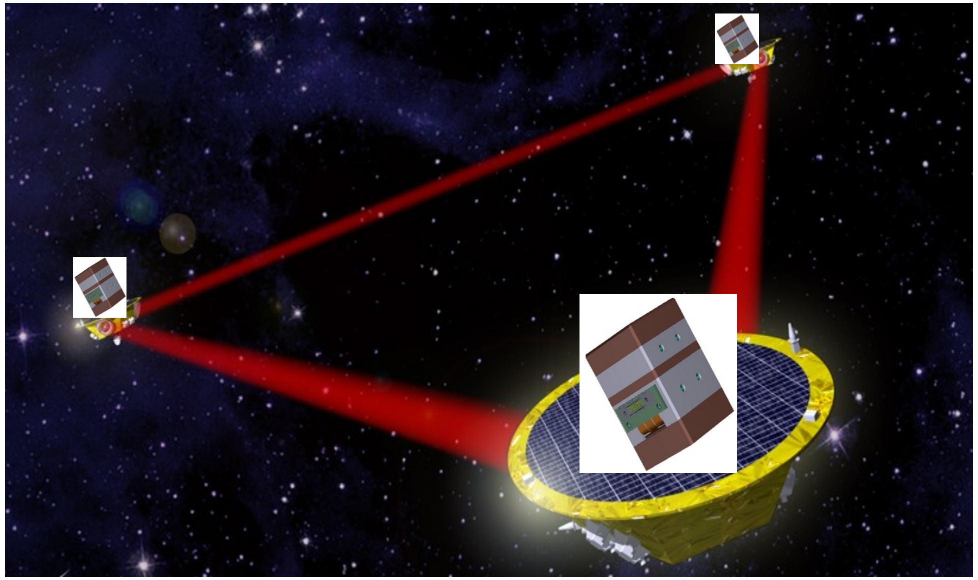
And beyond...

- We have 3 identical particle detectors...
- ~ 8 s away from each other (angular resolution!)
- Located in an unexplored region of space
- Sensitive to an energy band that is not typically accesible by other radiation monitors
- + the information of high-efficient magnetometers



sci.esa.int

→ Good opportunity to study the high-energy component of SEPs

Radiation Monitor and GRBs?

Journal of High Energy Astrophysics
Volume 42, June 2024, Pages 38-51

LISA and LISA-like mission test-mass charging for gamma-ray burst detection

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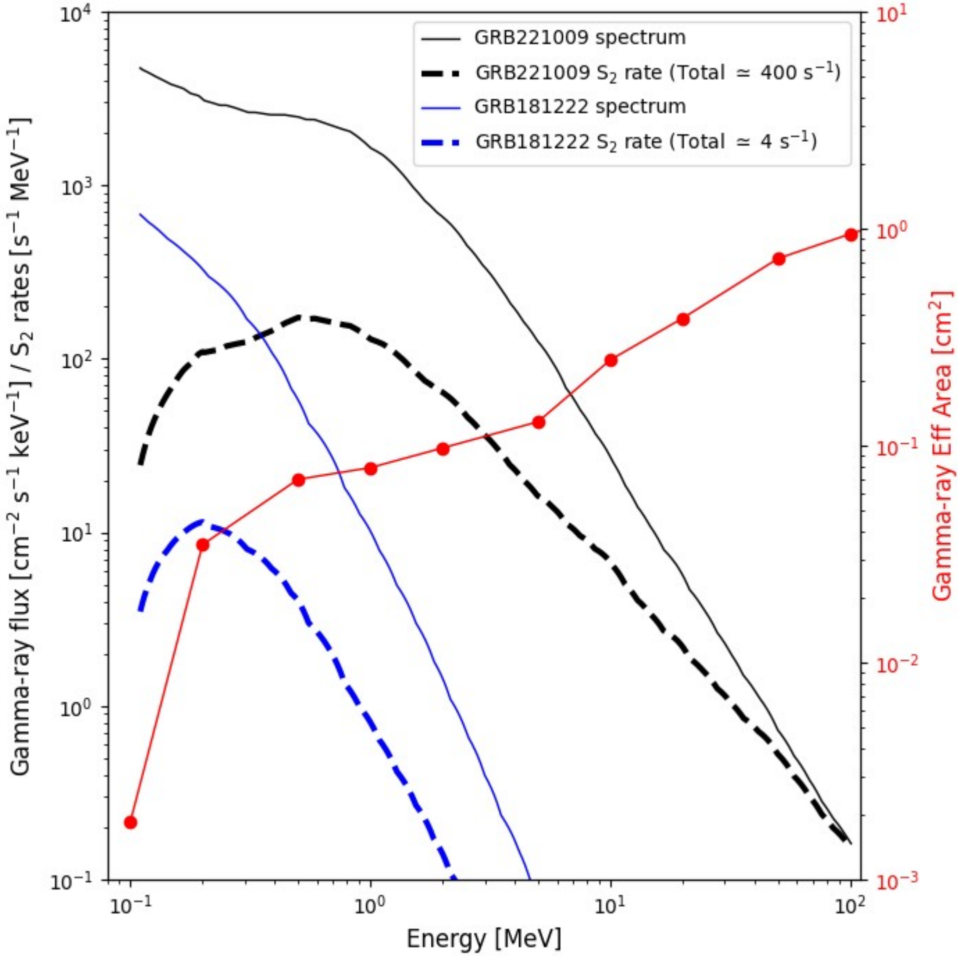
C. Grimani, et al., https://doi.org/10.1016/j.jheap.2024.03.004

- Thanks to the W absorbers, the RM should be sensitive to extreme (and rare) GRBs like GRB221009
- Unlikely, but LISA has a long lifetime and more LISA-like missions are expected to follow….
- Towards future missions: scintillators + SiPMs offer compactness and flexibility for the design. Room for compact GRB detectors?



Simulated differential count rates in S_2 (dashed) for two GRB spectra (solid), when gamma rays arrive from the side of the RM. In red, the RM effective area of S_2 for gamma rays arriving form the side.

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Summary

- We have a mature design and its preliminary performance is whitin requirements

- We built a 1st prototype that was characterized in a test beam, showing good afreement with simulations.

- By the end of the year we will have completed HECTOR, the CubeSat prototype with which we will test the proposed technology, analysis methods, etc.

- The Radiation Monitor**s** and scintillation-based detectors can open new opportunities beyond LISA

Thanks!

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INFN

IEEC
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Radiation Monitor: D. Mazzanti, et al., https://doi.org/10.22323/1.444.1494
BETA ASIC: A. Sanmukh et al., https://doi.org/10.1007/s41365-024-01419-z

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