# SPaRKLE a bordo di Space Rider

## Un laboratorio miniaturizzato in orbita bassa terrestre per particelle a bassa energia

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for the SPaRKLE collaboration

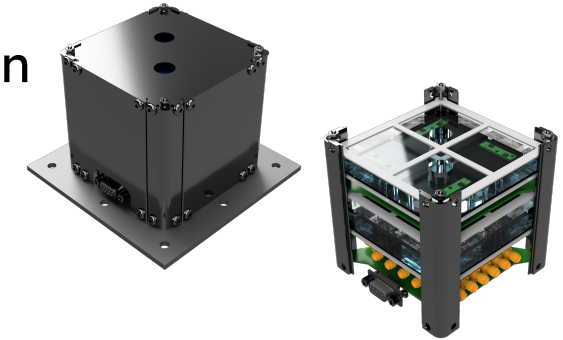
Incontri di Fisica delle Alte Energie 2024

Firenze, 04/04/2024

# ***SPaRKLE*** in una slide…

**S**mall
**Pa**rticle
**R**ecognition
**K**it for
**L**ow
**E**nergies

Progetto selezionato per il nuovo ciclo di **ESA Academy** Experiments programme



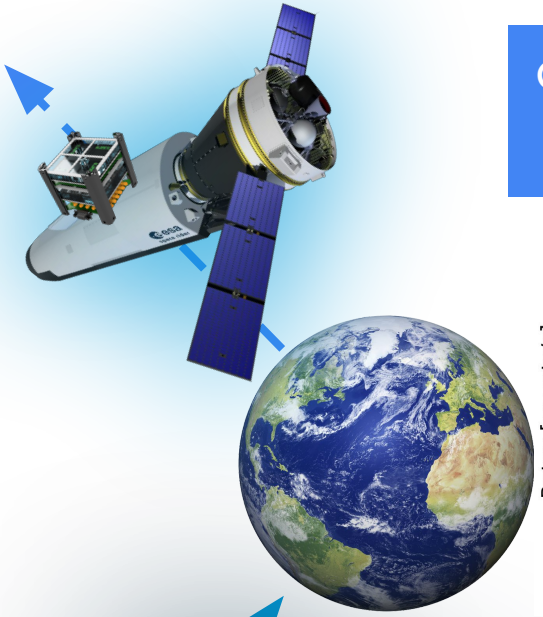
Laboratorio in miniatura per lo studio dallo spazio di fenomeni come **GRBs**, **TGFs**, **Space Weather**

Ospitato su **Space Rider** per un volo di 2 mesi in orbita bassa terrestre

Space Rider: Uncrewed robotic lab

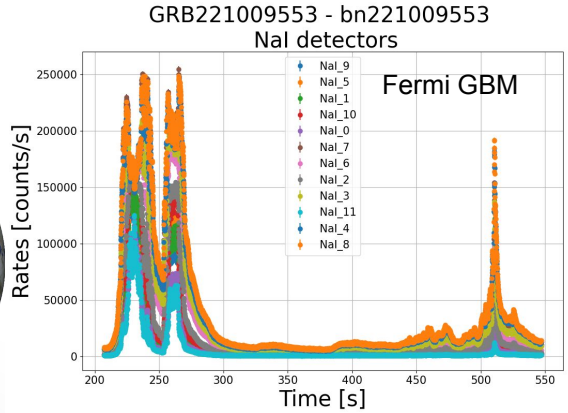
Recupero del payload dopo l'atterraggio

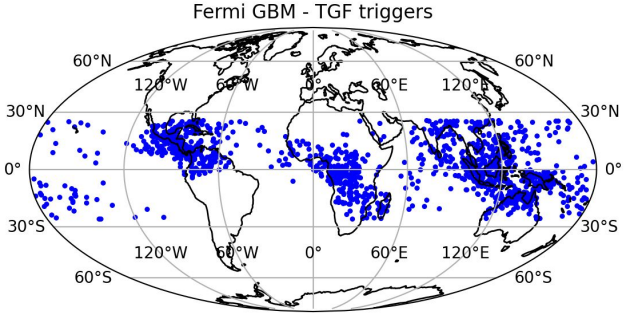
# *SPaRKLE*: un laboratorio in miniatura versatile…

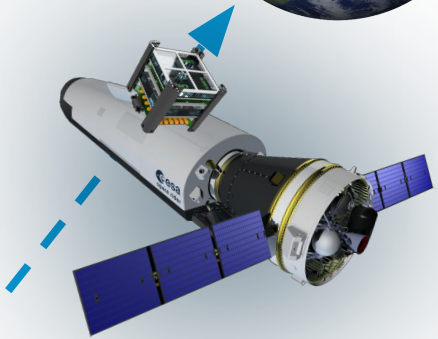


Campo di vista di SPaRKLE verso **Zenith - spazio profondo**

**Gamma Ray Bursts (GRBs)**



Campo di vista di SPaRKLE verso **Nadir - terra**

**Terrestrial Gamma-ray Flashes (TGFs)**



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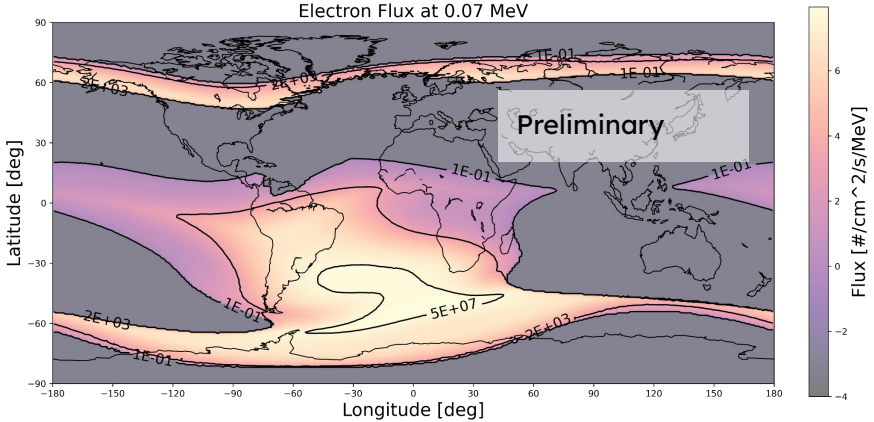
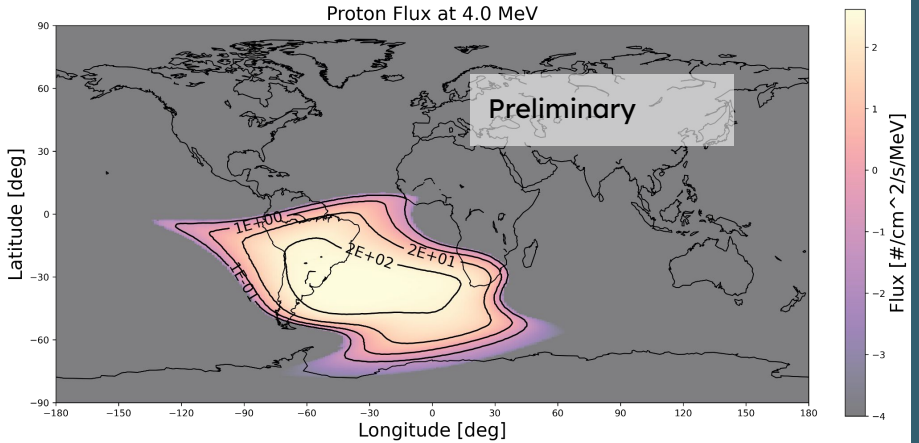
# ***SPaRKLE***: un laboratorio in miniatura versatile…

Indipendentemente dal puntamento di Space Rider

**Particelle intrappolate Space Weather**

- Lungo orbite terrestri basse, l'ambiente radioattivo è molto ostile
- Regioni come la **South Atlantic Anomaly** sono poco esplorate a causa dei **flussi** di particelle cariche **proibitivi**
- Effettuare **identificazione di particella** in queste zone può aiutare ad indagare meglio meccanismi di intrappolamento delle particelle nella magnetosfera



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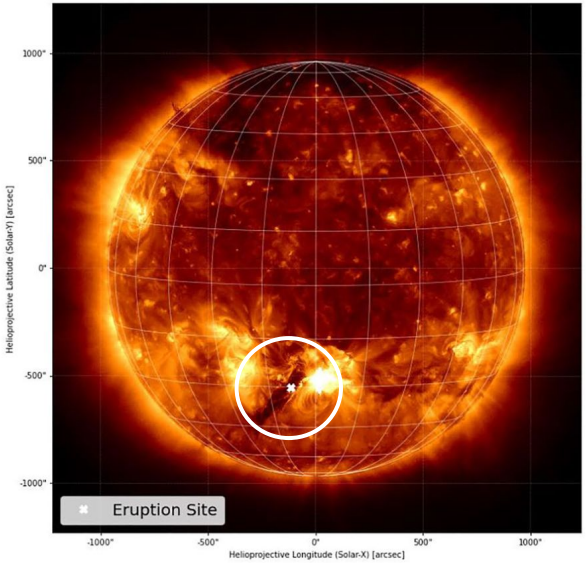
# *SPaRKLE*: un laboratorio in miniatura versatile…

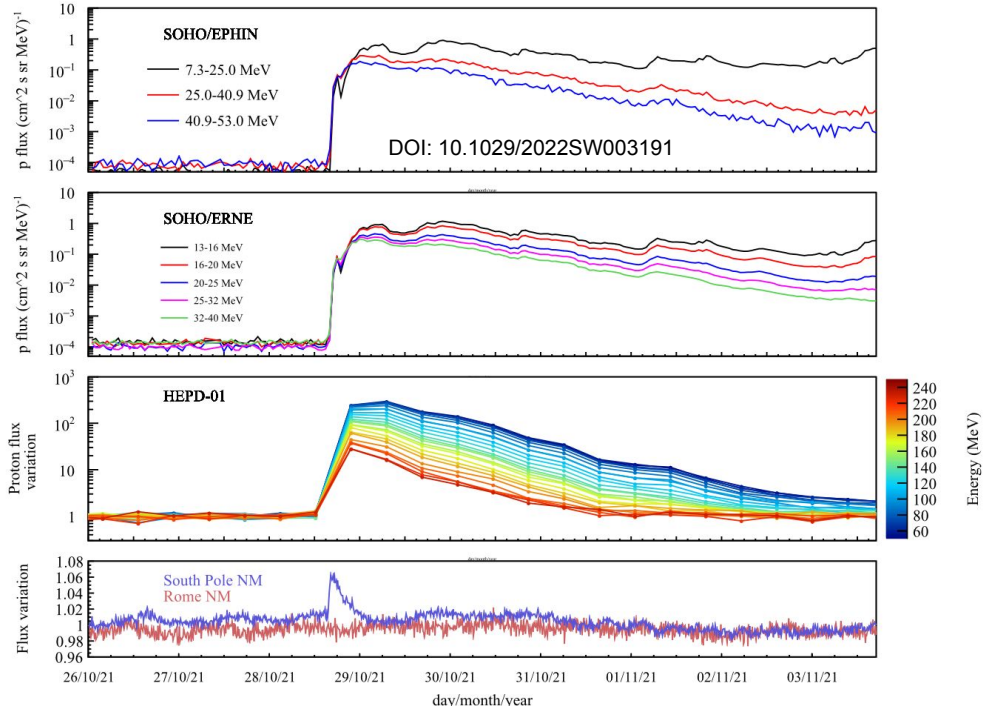
**Indipendentemente dal puntamento di Space Rider**

**Particelle intrappolate Space Weather**

- Misura di transienti dovuti a fenomeni solari (SEPs, CMEs)




CME effect



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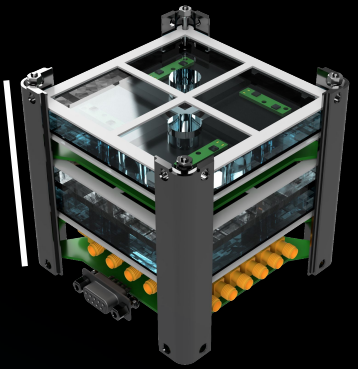
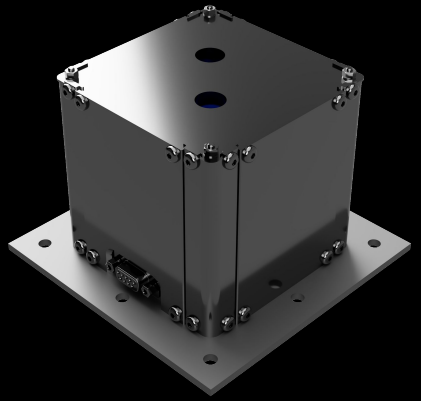
# SPaRKLE | The Detector



Scintillatore Plastico forato (collimazione attiva) letto da SiPMs

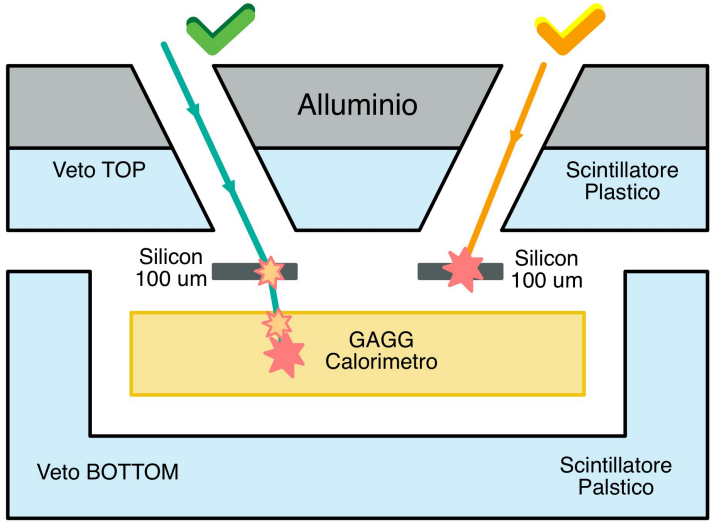
Silicon Photomultipliers (SiPMs)

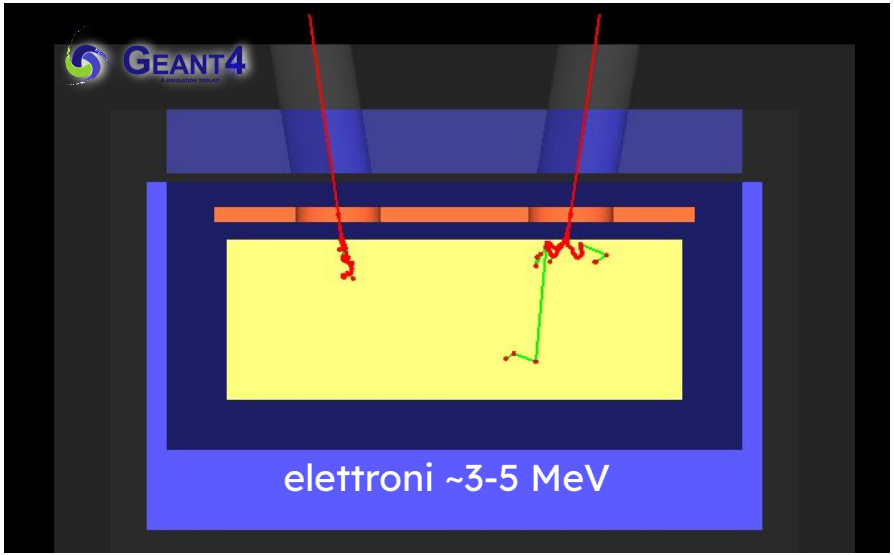
Detectors a Silicio 100 um (fully depleted silicon detectors)

4 Calorimetri GAGG (Scintillatori Inorganici) letti da SiPMs

Anticoincidence Detector (Veto) Scintillatore Plastico letto da SiPMs

# Strategia di misura di SPaRKLE




- **Identificazione di particella** possibile con
  - Deposito parziale di energia nel Silicio - **ΔE**
  - Deposito energia rimanente nel GAGG - **E**
  - Veti non attivati
- Altri casi di interesse (PID non possibile):
  - Deposito di energia nei detector a silicio

$$\Delta E \propto \frac{Z^2}{\beta^2}$$

$$E_{tot} = E + \Delta E$$
$$E_{tot} \approx \frac{1}{2} m \beta^2$$

$$\Delta E \times E_{tot} \approx \frac{1}{2} m Z^2$$



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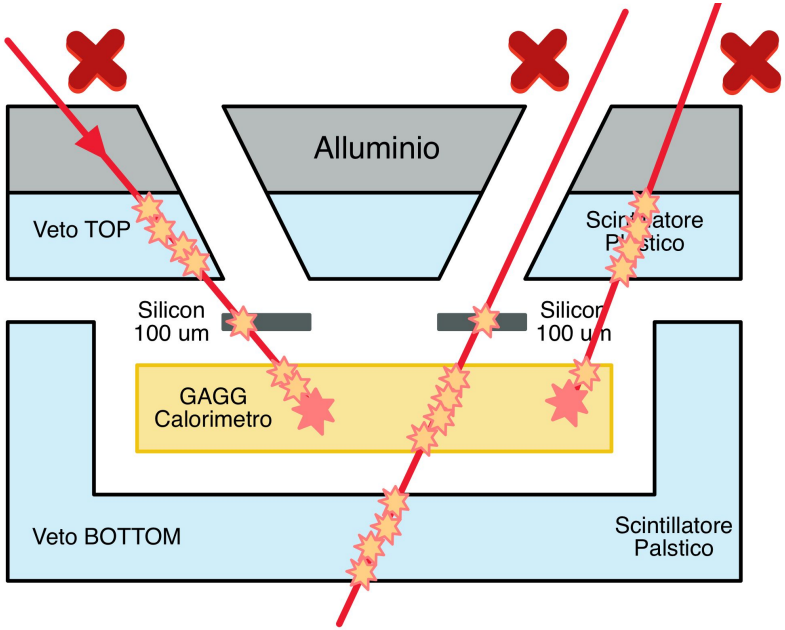
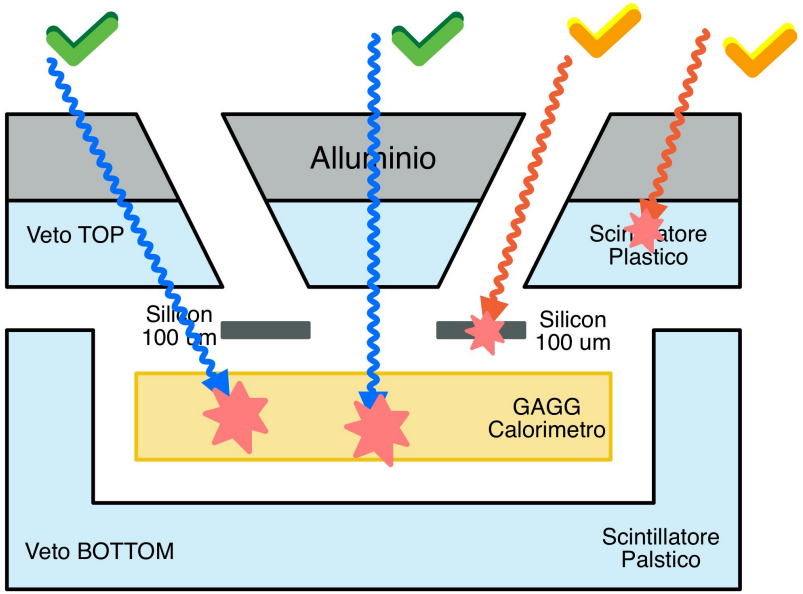
# Strategia di misura di SPaRKLE




- Un fotone viene identificato se solo lo scintillatore GAGG viene triggerato
- In fase di sviluppo l'algoritmo di trigger per transienti di tipo TGF/GRB

- Eventi che colpiscono i veti vengono rigettati
- Acquisizione del numero di eventi rigettati al secondo per analisi di transienti



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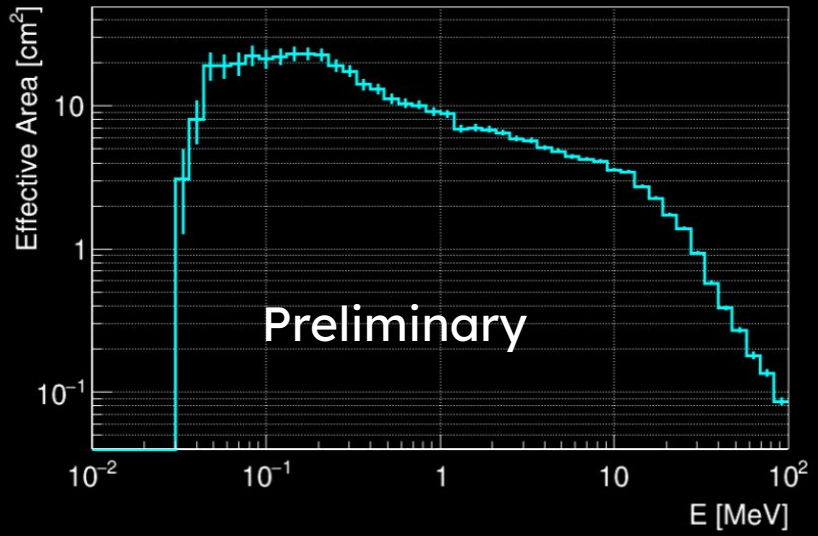
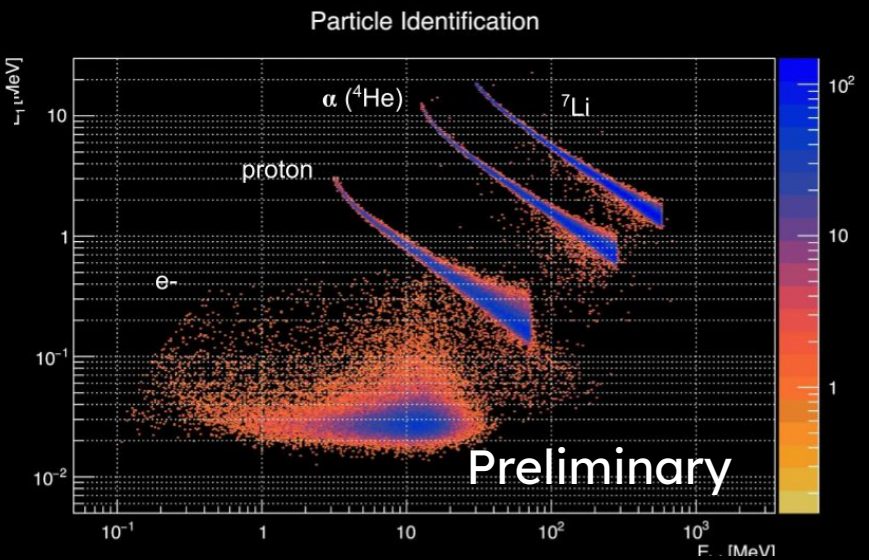
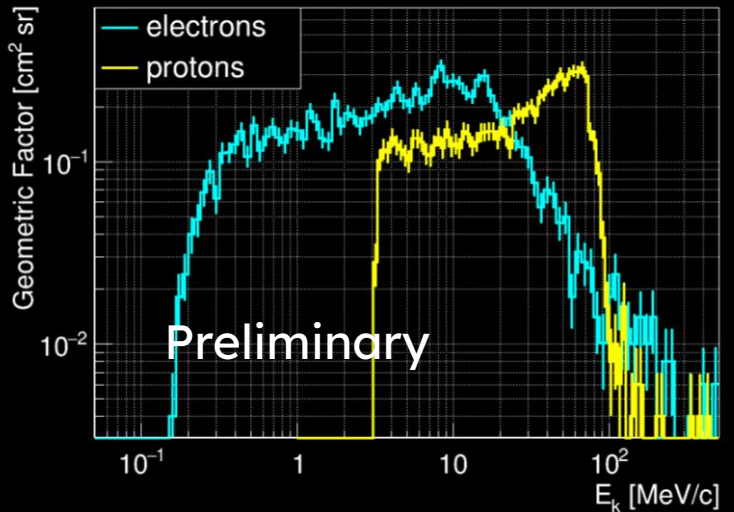
# Performance di **SPaRKLE**




- Area efficace **~10 cm²**
- Fattore geometrico di **~0.2 cm²** sr per protoni ed elettroni
- Buona Particle Identification
  - elettroni: **[0.3, 15] MeV**
  - protoni **[3, 100] MeV**
  - fotoni: **[~0.05, ~10] MeV**

# Il futuro del progetto

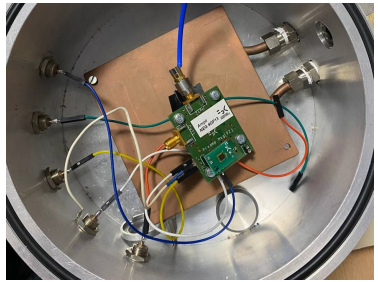
SPaRKLE si trova al momento in **Fase A:** Studio di fattibilita`

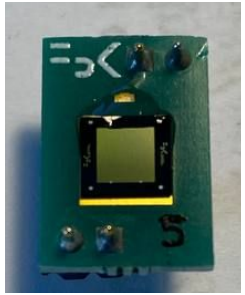
A breve SPaRKLE entrerà in **Fase B:** Preliminary Design

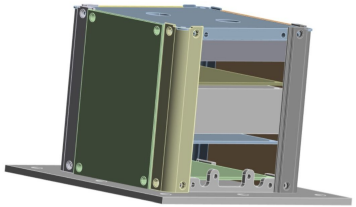
Attività di caratterizzazione dei SiPM fabbricati da FBK in corso

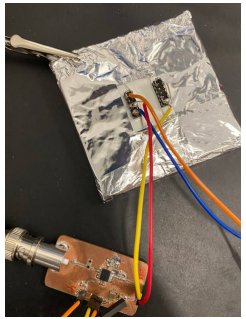
Costruzione di un Breadboard Model funzionante prima di Giugno e Test Beam

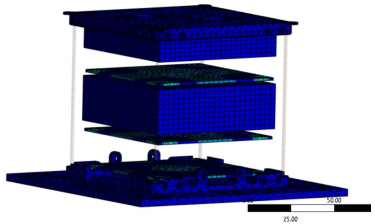
Volo previsto per Q2 2026

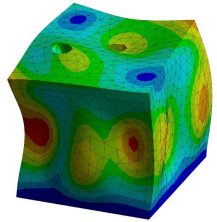






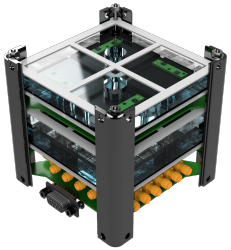






# Un saluto dal team

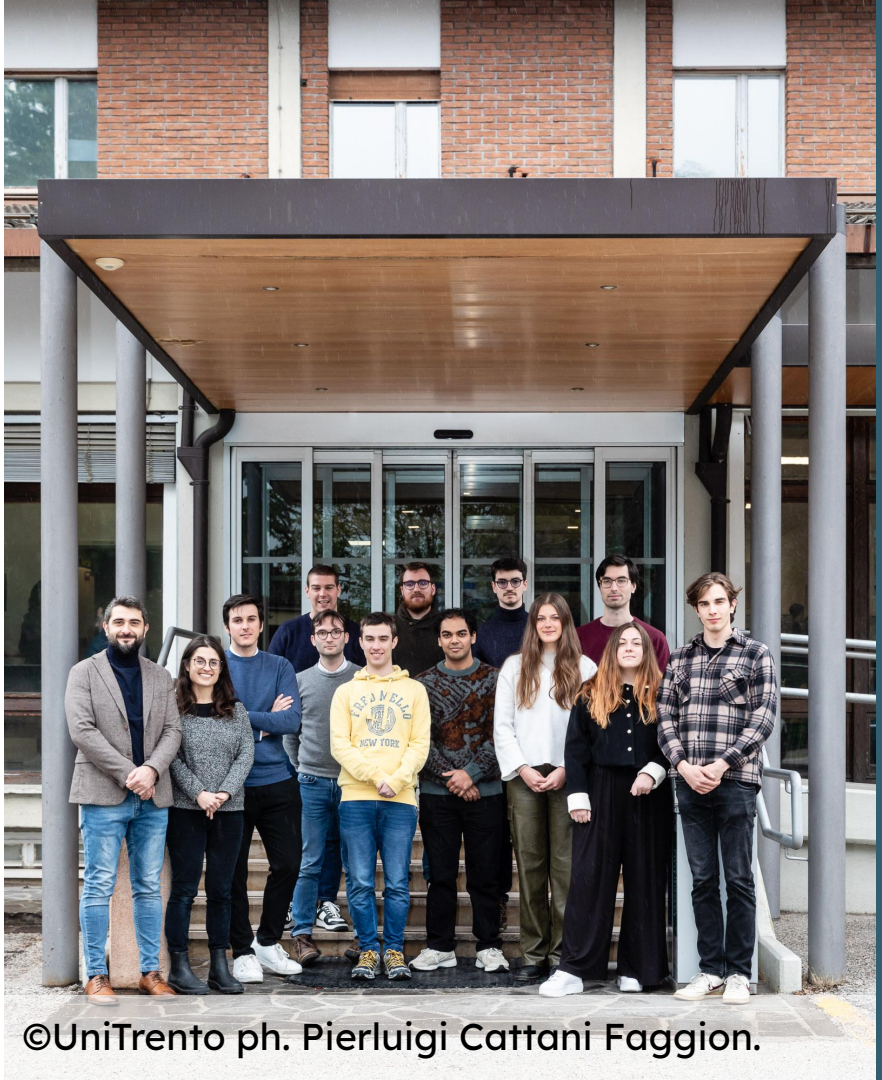
# SPaRKLE



Sei interessato al nostro progetto?
Seguici sui social!

Instagram: @sparkle_unitn

R. Nicolaidis, G. Brianti, E. Dalla Ricca, M. Framba, C. Giacchetta, R. Iuppa, F. Marzari, M. Polo, F. Rossi, M. Tomasi, M. Trettel, V. Vilona, M. Vukojevic



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# Backup

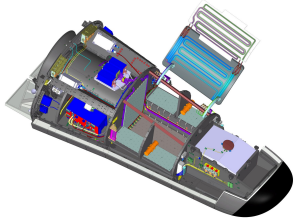
# **Space Rider** - Il primo spazioplano europeo riutilizzabile

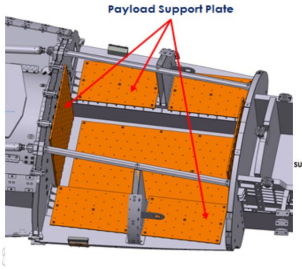
Un laboratorio robotico senza equipaggio

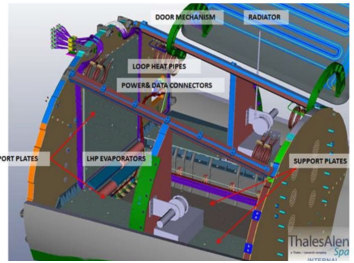
Dopo il lancio su Vega-C rimarrà in orbita bassa terrestre per due mesi

La ***multi-purpose cargo bay*** offre power, data transfer, controllo termico agli strumenti ospitati (payload)

Al rientro a terra sarà possibile recuperare il payload



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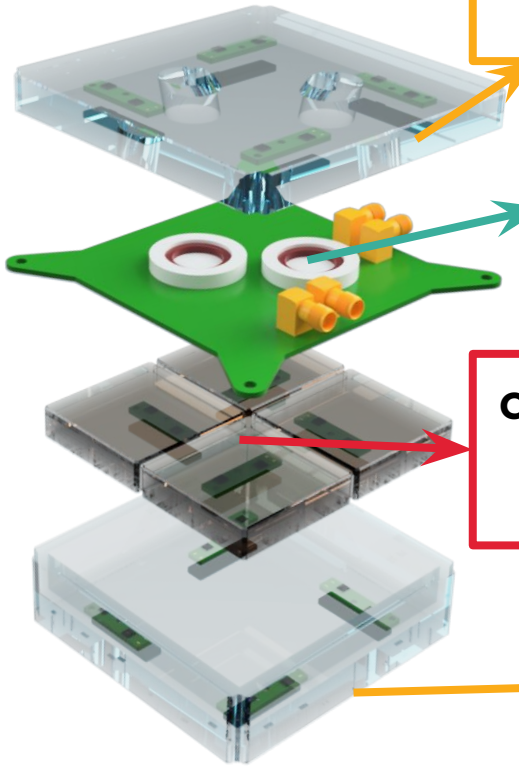
# Strategia di misura di SPaRKLE



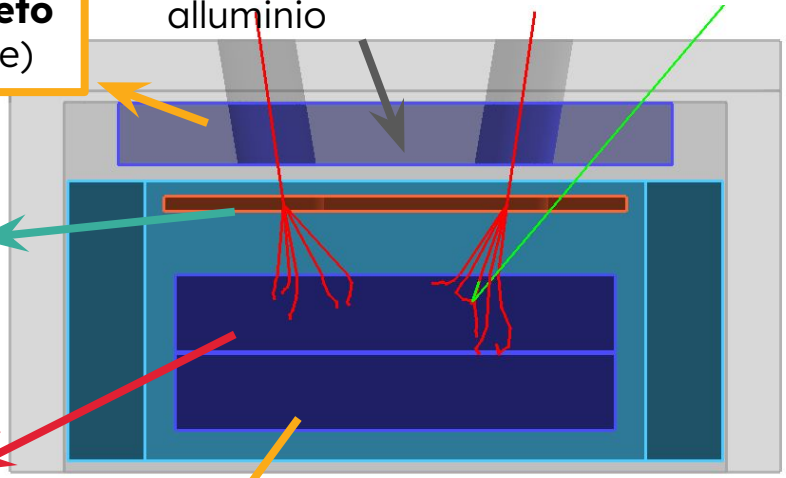
Scintillatore Plastico (**Veto** per **rigettare** particelle)

Detector a Silicio (per **Deposito di Energia ΔE**)

**Calorimetro GAGG** (per restante energia **E**)

Scintillatore Plastico (**Veto** per **rigettare** particelle)

Scudo di alluminio



Possibilità di identificare evento per evento:

- fotoni
- elettroni
- protoni
- ioni leggeri



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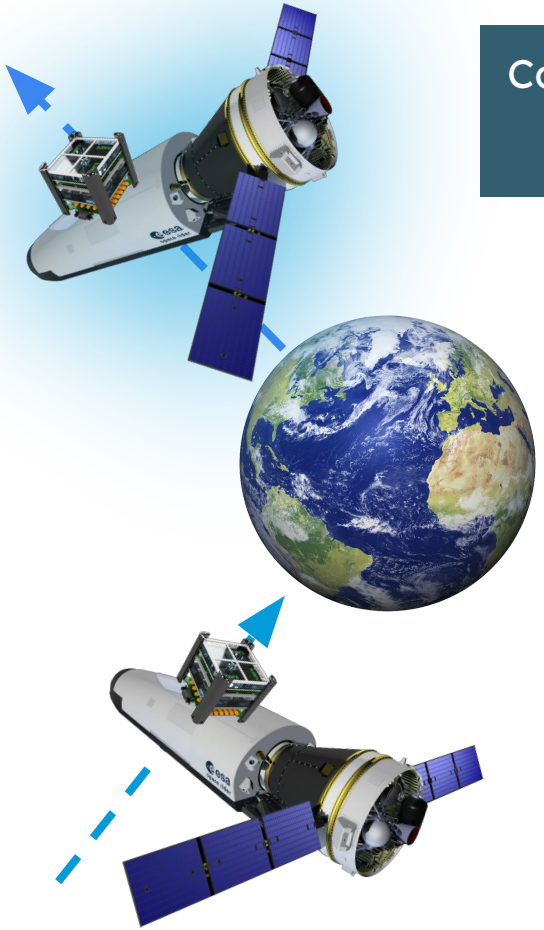
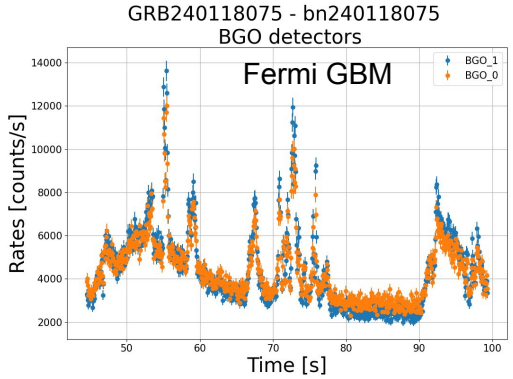
# *SPaRKLE*: un laboratorio in miniatura versatile…

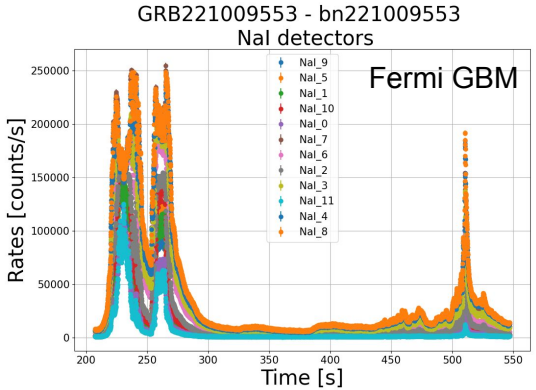


Campo di vista di SPaRKLE verso **Zenith - spazio profondo**

**Gamma Ray Bursts (GRBs)**

- Violente esplosioni nell'universo di **raggi X** e **gamma**
- Possono durare da pochi **secondi** a diversi **minuti**
- Gli strumenti in orbita si stanno avvicinando alla fine della loro vita operativa
- SPaRKLE vuole essere un pathfinder per nuove architetture distribuite lungo costellazioni di nanosatelliti



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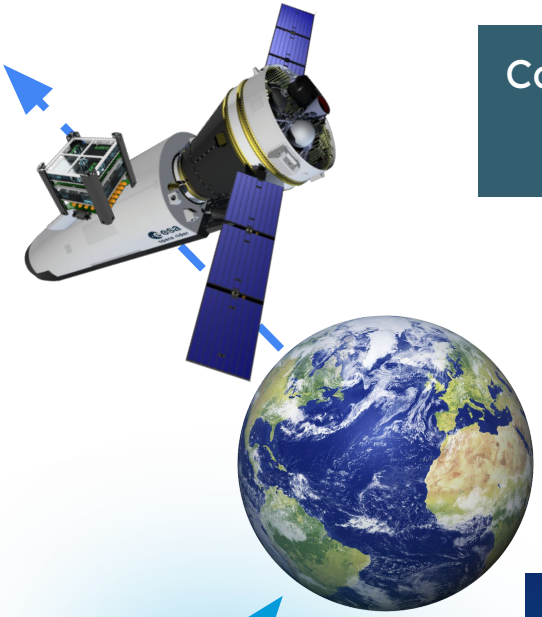
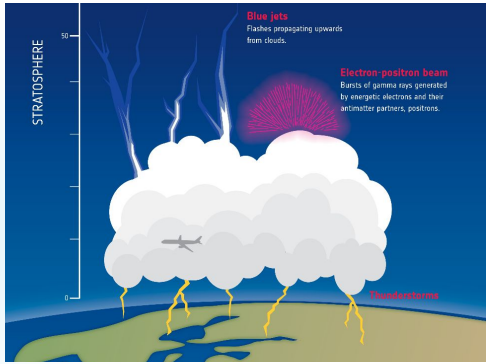
# *SPaRKLE*: un laboratorio in miniatura versatile…

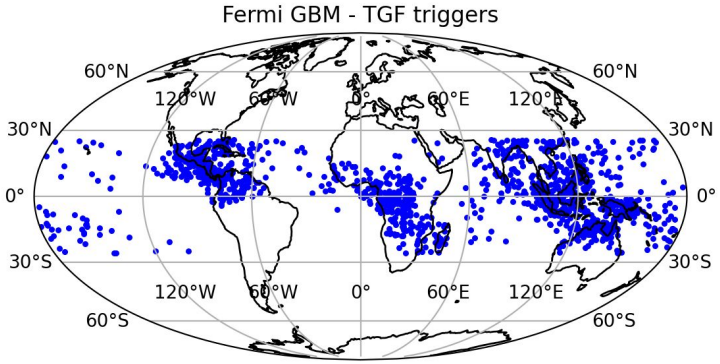


Campo di vista di SPaRKLE verso **Nadir - terra**

**Terrestrial Gamma-ray Flashes (TGFs)**

- Rapidi lampi di **raggi X** e **soft-gamma** che scaturiscono da violenti fenomeni temporaleschi (tempeste, temporali)
- Meccanismi di accelerazione e di produzione ancora incompleti
- Importante lo studio per l'effetto sull'uomo e sui dispositivi elettronici di volo



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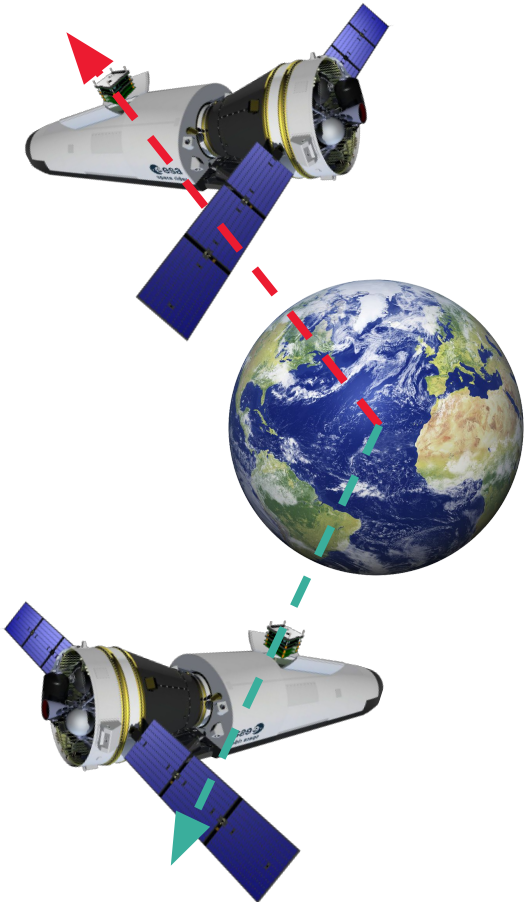
# Mission scenarios of SPaRKLE



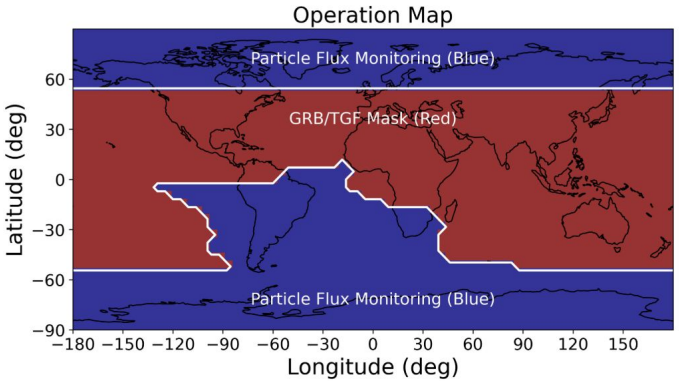
| γ: [0.03, 100] MeV<br>p: [3, 50] MeV<br>e: [0.1, 20] MeV | **Zenith pointing** | **Nadir pointing** |
|---|---|---|
| **Nearly equatorial orbit** | **GRBs**<br>Radiation environment | **TGFs**<br>Radiation environment |
| **Polar orbit** | GRBs<br>**Radiation environment** | TGFs<br>**Radiation environment** |

**Interesting Physics** with **different** orbit **inclinations, altitude** and Space Rider **configuration**.

# Optimal condition for SPaRKLE

Optimal orbit conditions for GRBs and TGFs are not requirements.
Orbits with these inclination values allow to study these phenomena out of the areas with high particle fluxes.

| **OPTIMAL ORBIT CONDITIONS** | | |
|---|---|---|
| Scientific case | Orbit inclination | Orbit altitude |
| GRBs | 45 ÷ 75 deg | **LEO** 300 ÷ 500 km (400 km) |
| TGFs | < 35 deg | |
| Space Weather | Any | |




Map of the areas with high fluxes (blue).
In the red areas we can identify TGFs and GRBs.

SPaRKLE can be adapted to any LEO orbit.



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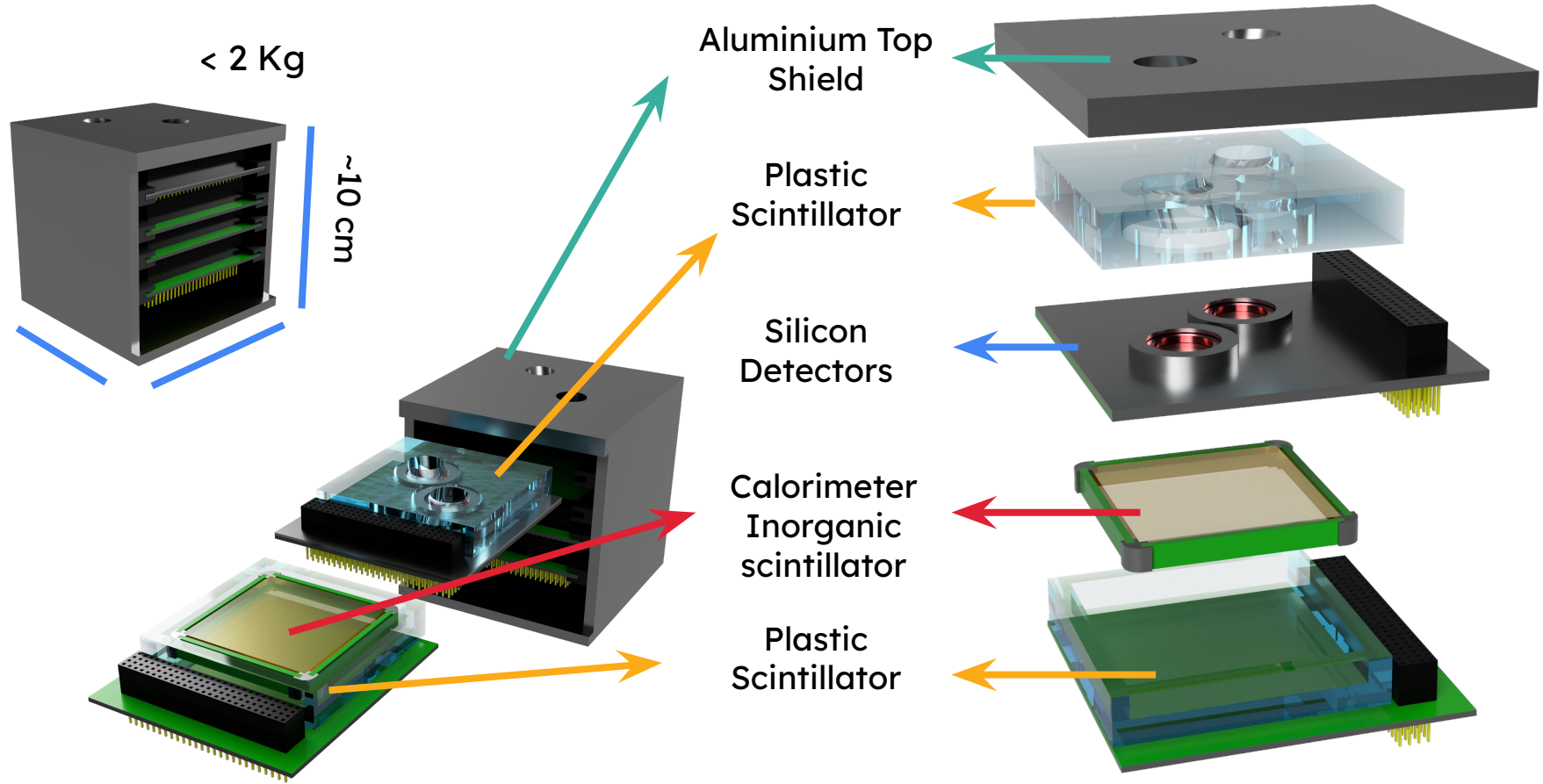
# SPaRKLE experiment



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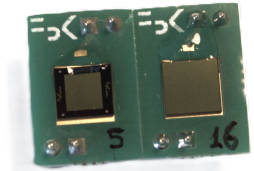
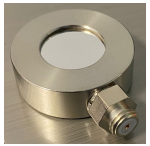
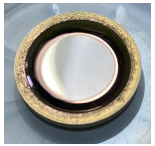
# Data AcQuisition (DAQ)



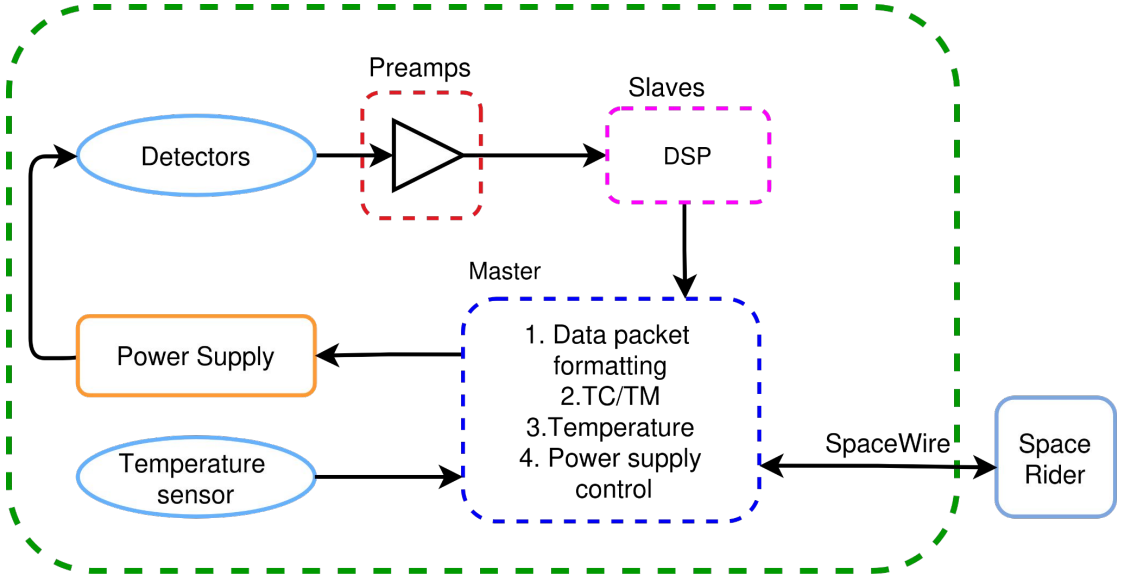

FONDAZIONE BRUNO KESSLER

Silicon Photomultipliers (SiPMs)





Silicon Detectors (already in house)




A customized electronic board will be designed to facilitate data acquisition and analysis. (Hot/Cold redundancy)



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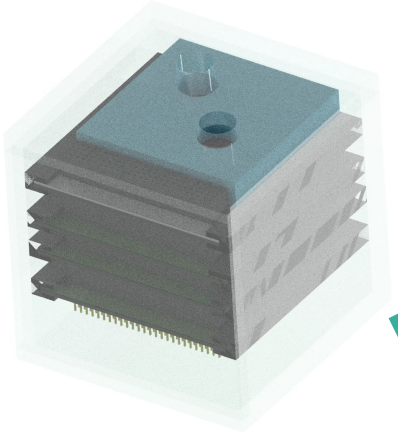
# Power and data budget

| **Power consumption** | |
|---|---|
| Detector | 5 mW |
| SiPMs | 700 mW |
| ADCs | 200 mW |
| Front-End Electronics | 500 mW |
| **Total including 30% margin** | **2 W** |

| **Data budget** | |
|---|---|
| Data packet | 0.80 kBytes/s |
| Housekeeping data | 0.02 kBytes/s |
| **Total** | **60 MBytes/day** |

# Design workflow

**Conceptual design**



**Design process**

- Structural analysis
- Thermal analysis
- Electromagnetic compatibility
- . . .

Refinement of the design

**Final design**

Virtual and physical models for testing

**Qualification Testing**

FM



Riccardo Nicolaidis

# Impact of the environment

Load effects

Ansys

- Low freq. accelerations
- Handling loads (during ground operations)
- Sinusoidal loads
- Random-vibrations
- Pressure loads
- Shock loads

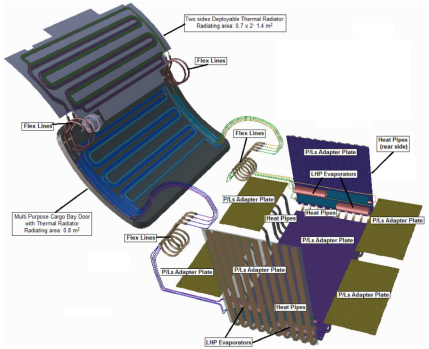
ECSS-E-ST-32

Thermal effects

Thermal analysis performed knowing orbit, pointing direction.

Space Rider offers terminally controlled plates: payload thermally coupled with plates.

ECSS-E-ST-31



*"The plate temperature range will be maintained between 15°C and 40°C [...]"*
From Space Rider User manual

Cosmic radiation

Metal shield to protect the payload from environmental radiation.

Non-susceptible and non-reactive materials shall be used

ECSS-E-ST-10-04C

Atomic oxygen



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