

Light-1 (former RAADSat): a cubesat mission for the detection of Terrestrial Gamma-ray Flashes

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وكالة الإمارات للفضاء
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Outline

- Cubesats (a quick introduction)
- Terrestrial Gamma-ray Flashes (a quick introduction)
- LIGHT-1 scientific goals
- The LIGHT-1 payload
- A preliminary 5000 s mission simulation

Cubesats: a new paradigm for space missions

“A picosatellite standard that significantly reduces the cost and development time of student satellites”.

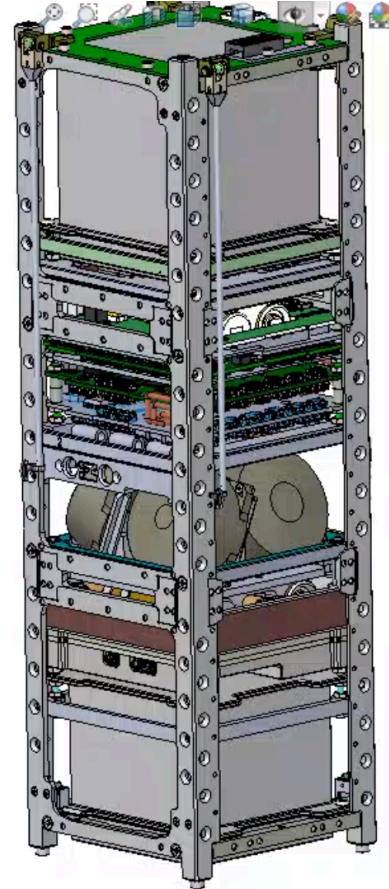
Modular satellite built up from 10 cm x 10 cm x 11.35 cm units (1U)

Relatively low cost both to build and launch (typically \ll \$1M)

Can be launched by piggybacking on other missions and/or from International Space Station

Strict size and weight limits (<1.5 kg/U), and very limited power budget (a few W per U)

Scientific, Educational and Commercial component



Terrestrial Gamma-Ray Flashes: an introduction

| | |
|--------------------------------|--|
| Origin | Atmospheric Processes: Lightning, Thunderstorms, Tropical Storms |
| Primary particle counterpart | Gamma via bremsstrahlung |
| Secondary particle counterpart | Electron Beams - Neutrons from photoproduction |
| Other detectable counterparts | Radio emission (sferics) |
| Energy Range | 10 keV up to ~100 MeV |
| Event Duration | < 100 μ s |
| Fluence @ 400-500 km | ~ 1 gamma/cm ² |
| Estimated rate (FERMI) | 400k events per year |
| Originating Altitude | (usually) 9 km to 15 km |
| Generation Mechanism | Not yet fully understood |



Credits: Nasa

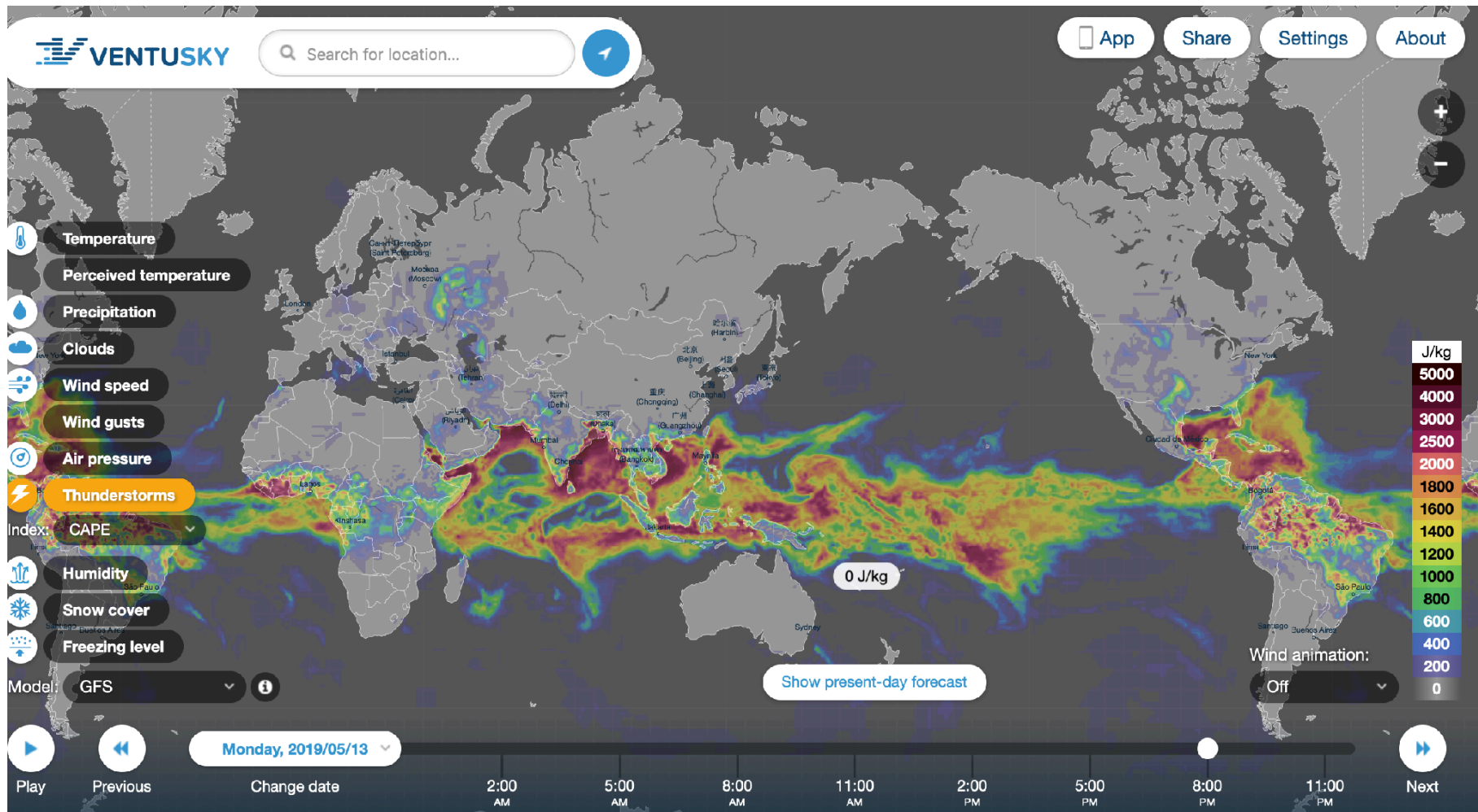
Missions relevant for TGF Science: RHESSI, AGILE, FERMI, BEppo-SAX, RELEC, ASIM*, TARANIS+
A TGF catalogue is available here: <https://openuniverse.asi.it>

***(Atmosphere-Space Interactions Monitor):** in data taking on board of the ISS

+(Tool for the Analysis of Radiation from lightning and Sprites): scheduled launch in Q3 2020

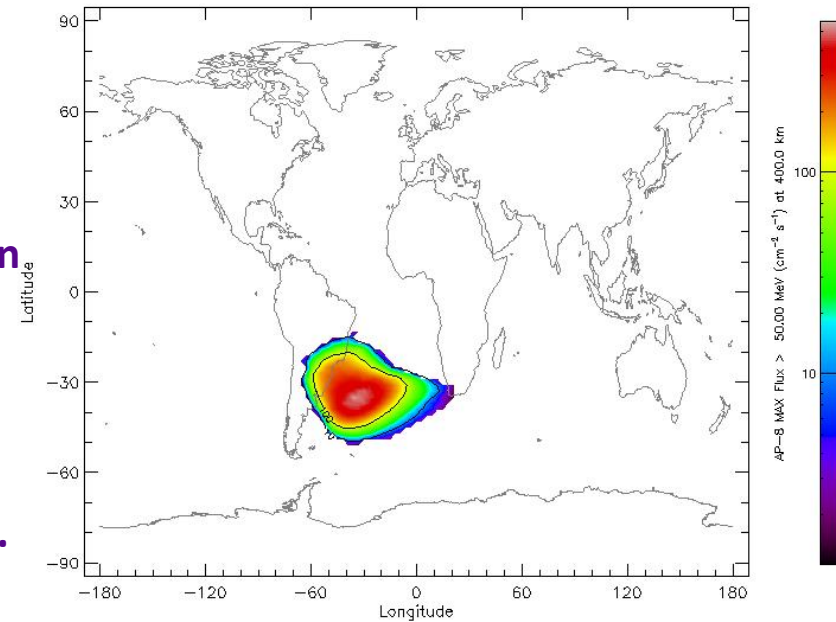
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Terrestrial Gamma-Ray Flashes: mostly from equatorial storms



Light-1 Scientific and Technological goals

- To study TGFs down to **sub-microsecond** timescales.
- To detect (Short) Gamma-Ray Bursts (GBR) (> 1 second time scale).
- To probe the low energy spectral cutoff to measure atmospheric attenuation.
- To search for positron-electron annihilation line.
- To measure the activity in the **South Atlantic Anomaly** region.
- To **space-qualify the technology** and prove the detection concept.
- To provide **sub-microsecond time** resolution.
- **To survive** (launch, deployment from ISS, environment).



Light-1 characteristics

| Parameter | Value |
|-------------------------------|---|
| Detection Energy Threshold | ~ 20 keV |
| Spectral Resolution | 15% @ 20 keV, < 5% @ 511 keV |
| Time resolution | < 200 ns |
| Absolute Timing | < 2 μ s |
| Effective Area | 40 cm ² @ 50 keV, 20 cm ² @ 511 keV |
| PMT Payload Size | 74 x 74 x 86 mm |
| SiPM Payload Size | 74 x 74 x 68 mm |
| PMT Payload Weight | 1,183 g |
| SiPM Payload Weight | 1,006 g |
| Power Consumption | < 4.5 W average |
| Data Budget | ~50 MB/day |
| Operational Temperature Range | Between -20° C to 40° C |
| Survival Temperature range | Between -40° C to 60° C |
| Orbit Radius | ~410 km (ISS) |
| Orbit Inclination | Nadir Oriented, (Polar) 51.6° |
| Duty Cycle | > 60 % |
| Expected Lifetime | 6 months from the ISS deployment |



CHALLENGING



CHALLENGING

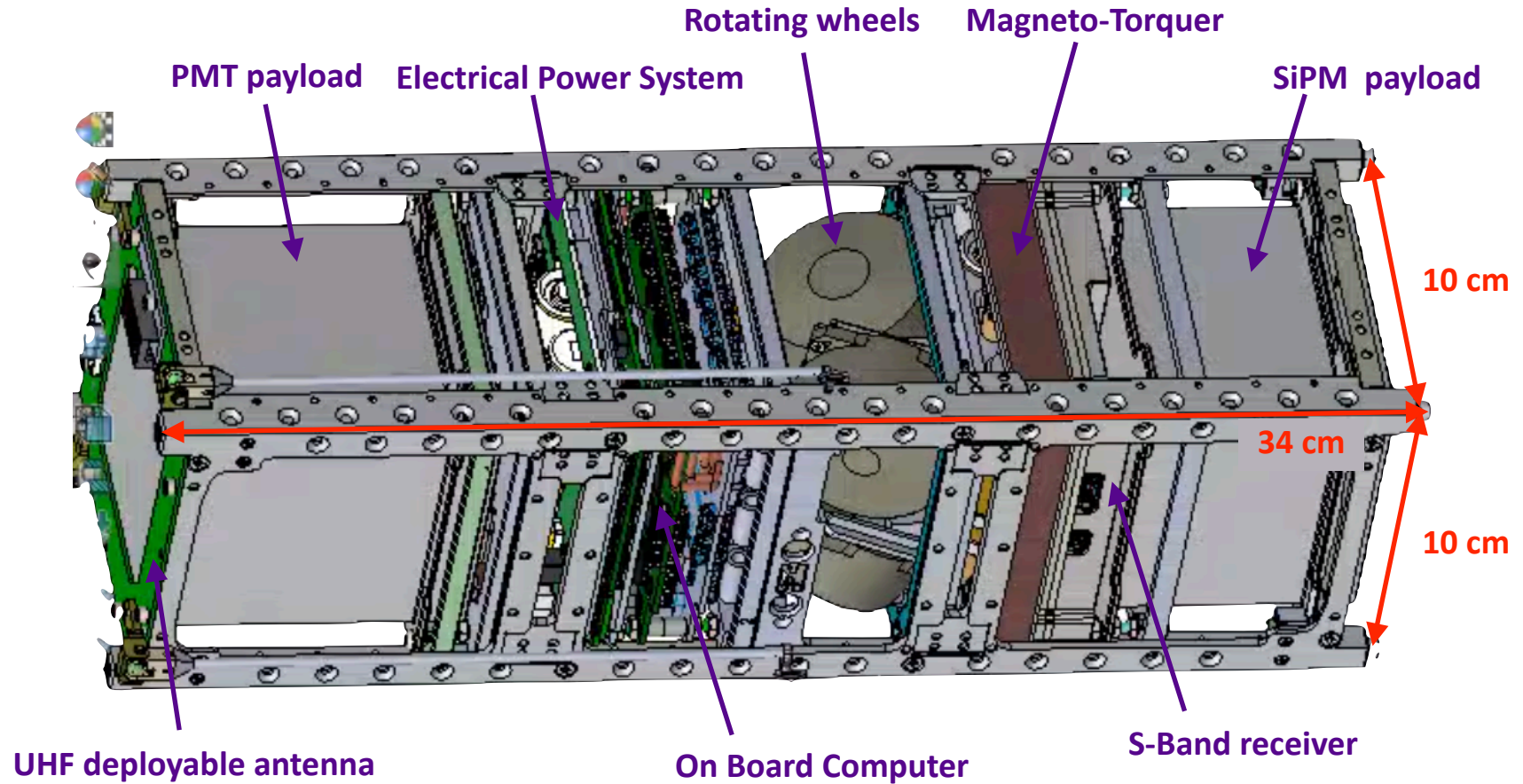


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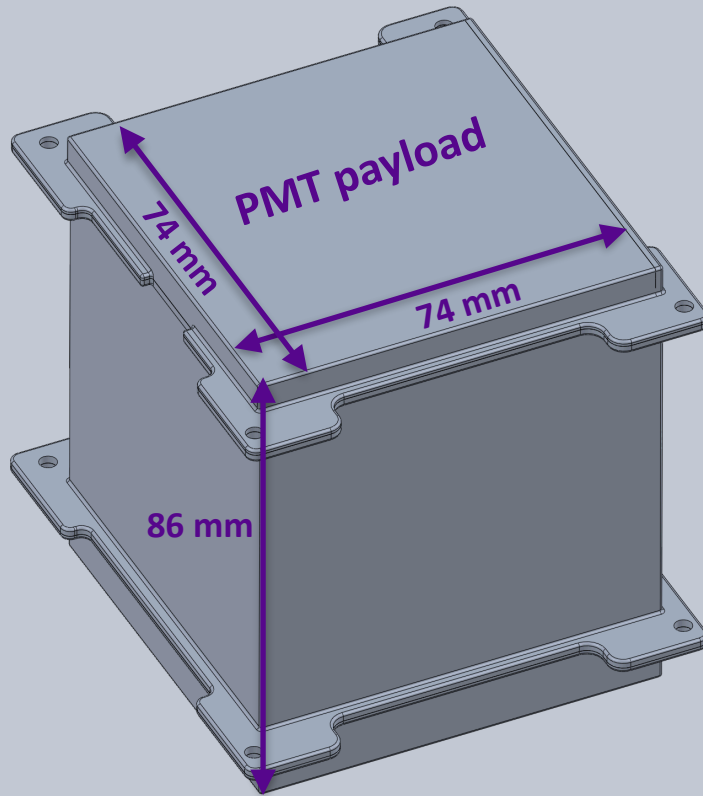
Light-1 Satellite



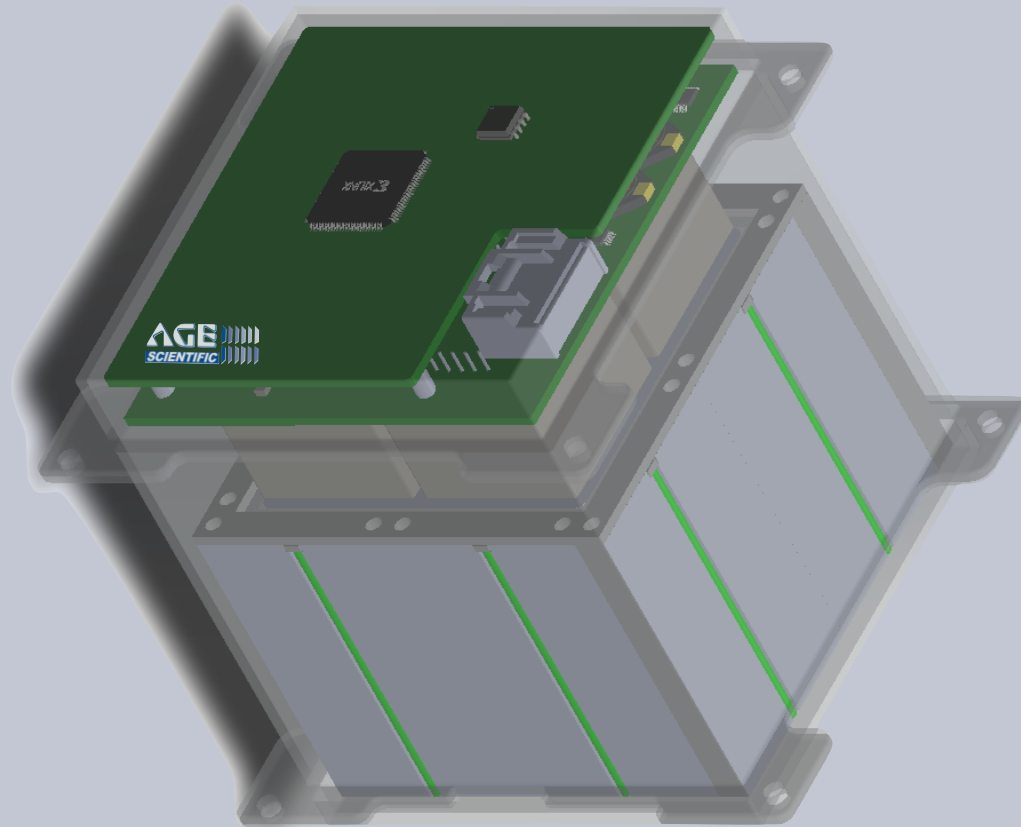
Bus component from [NanoAvionics](#)



The PMT and SiPM payloads

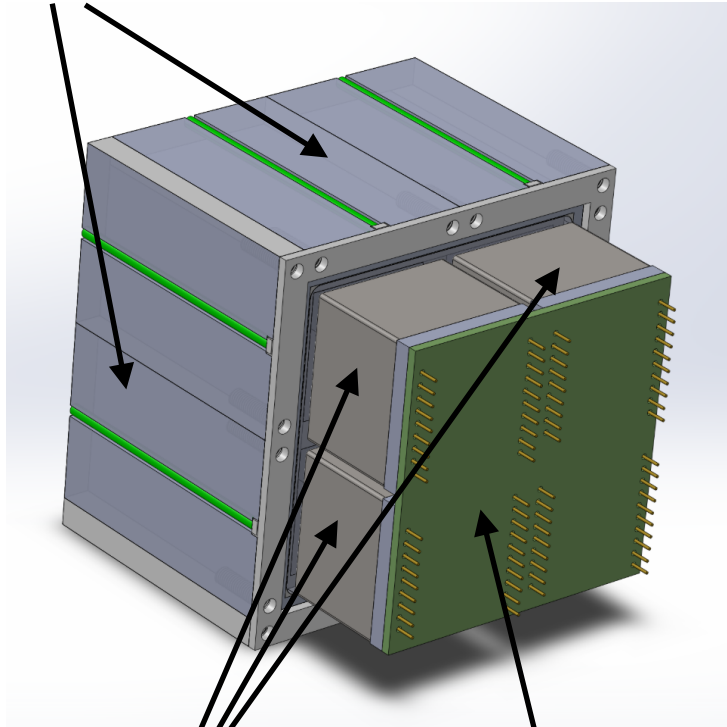


$M = 1,183 \text{ g}$



The PMT and SiPM payloads

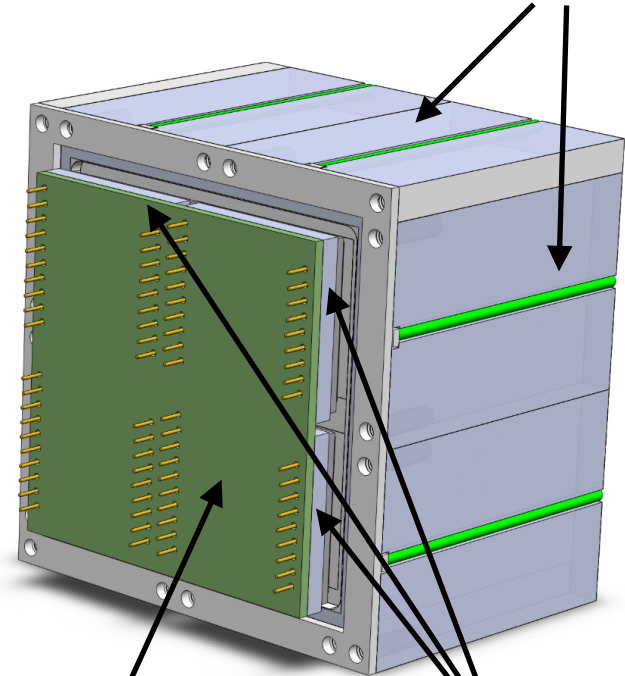
Veto System



PMT

Electronics

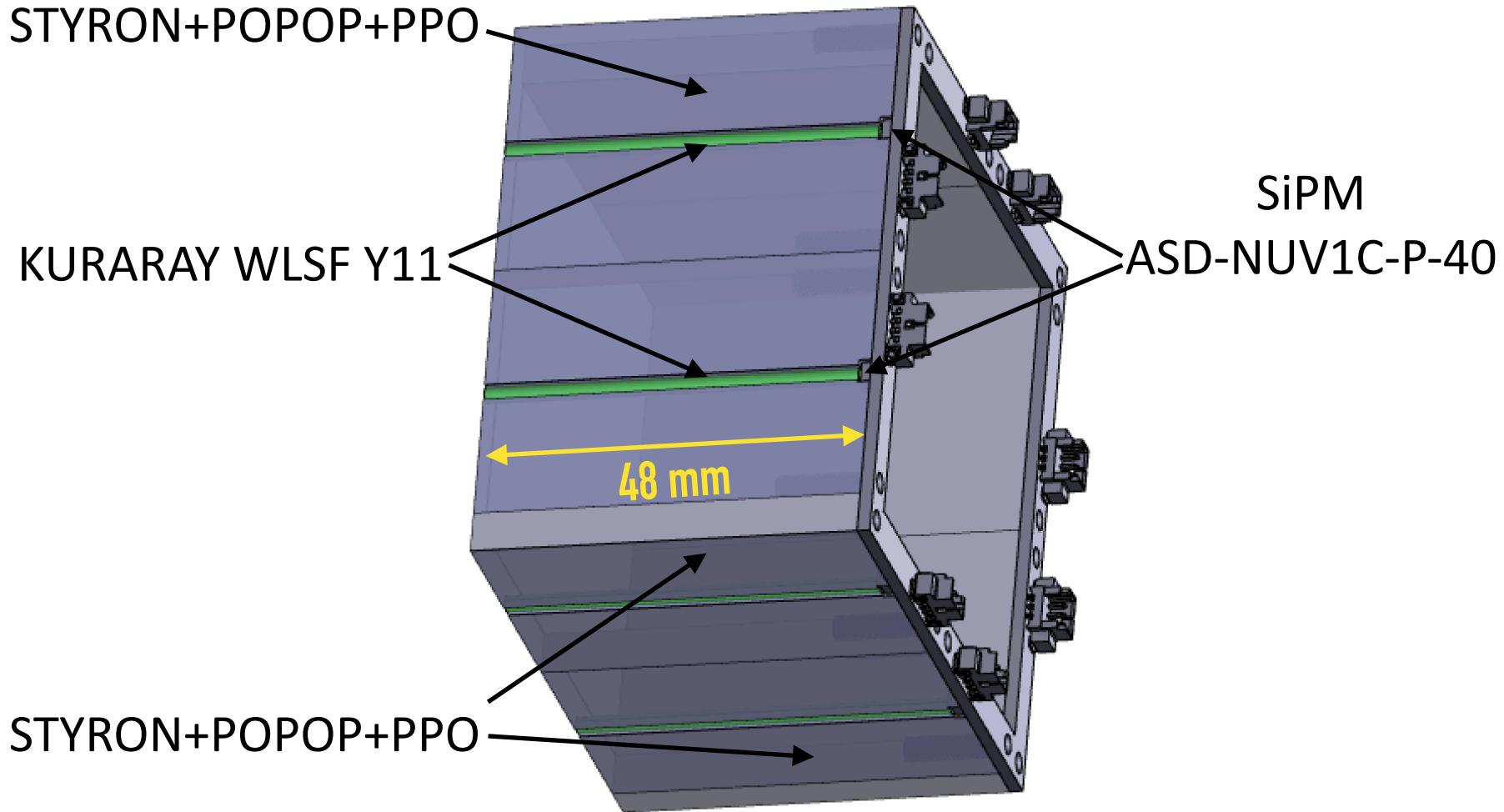
Veto System



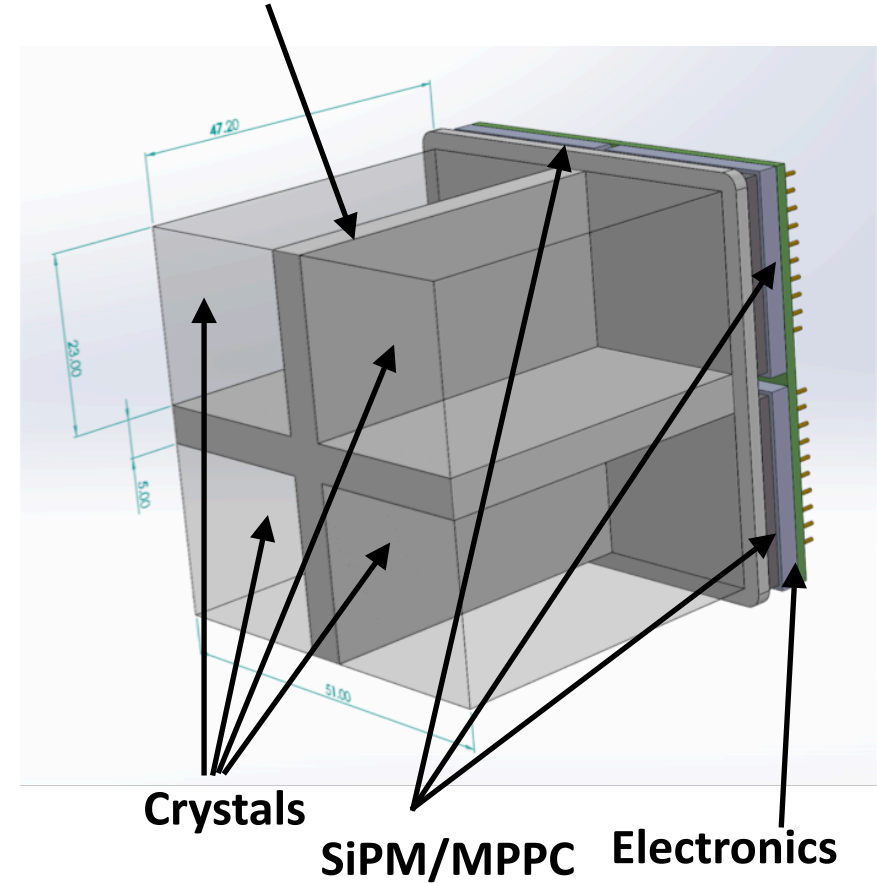
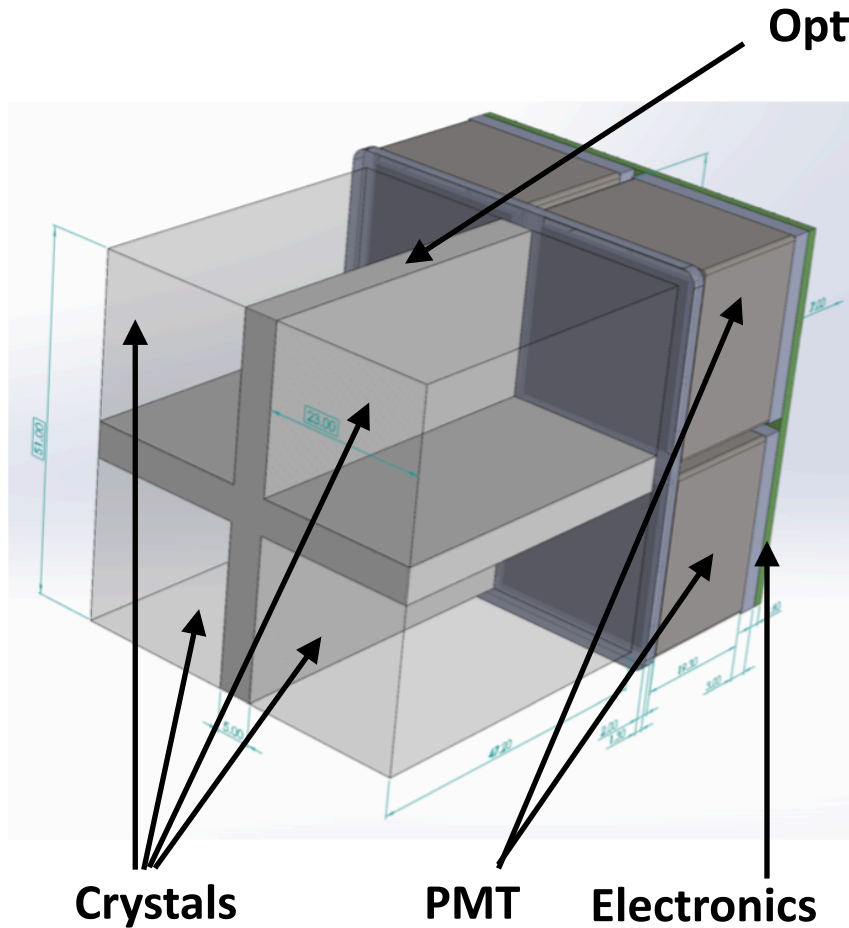
Electronics

SiPM/MPPC

The Light-1 VETO to reject charged particle induced events



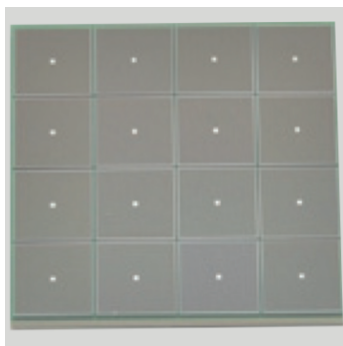
The PMT and SiPM payloads



The Hamamatsu Photosensors



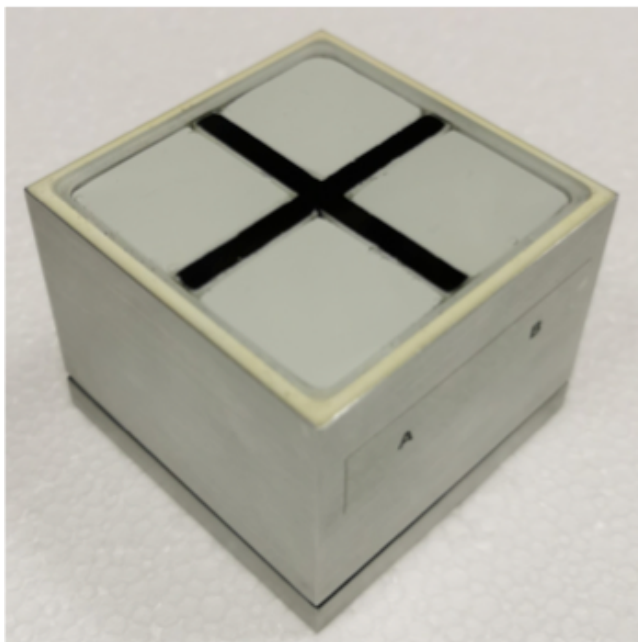
R11265-200



S13361-6050AE-04

| Characteristics | R11265-200 | S13361-6050AE-04 |
|--|------------------|------------------|
| Type of photosensors | PMT | MPPC (aka SiPM) |
| Dimensions(LXDXH) [mm ³] | 26X26X19 | 25X25X1.4 |
| Weight [g] | 24 | 2 |
| Peak Sensitivity [nm] | ~ 400 | ~ 450 |
| Q.E. [%] | 43 | - |
| P.D.E. [%] | - | 40 |
| Typical Operating Voltage [V] | 900 | 55 |
| Typical Gain at working point | ~10 ⁶ | ~10 ⁶ |
| Dark Count at working point, room temperature [Hz] | Negligible | > 10 M |
| Operating Temperature [°C] | -30 to +50 | -20 to +60 |
| # of photosensors in Light-1 | 4 | 4 |

The scintillating Crystals (from SCIONIX)



| Characteristics | CeBr ₃ (LB) | LBC |
|--|------------------------|------------|
| Density [g/cm ³] | 5.1 | 4.9 |
| Hygroscopic | YES | YES |
| Emission Peak [nm] | ~ 370 | ~ 380 |
| Typical Resolution @122 keV (⁵⁷ Co) [%] | 10 | 7 |
| Typical Resolution @662 keV (¹³⁷ Cs) [%] | 4 | 3 |
| Typical Decay Time [ns] | ~ 20 | ~ 35 |
| Activity [Bq/cm ³] | < 0.01 | ~ 1 |

The Light-1 detection target consists of:

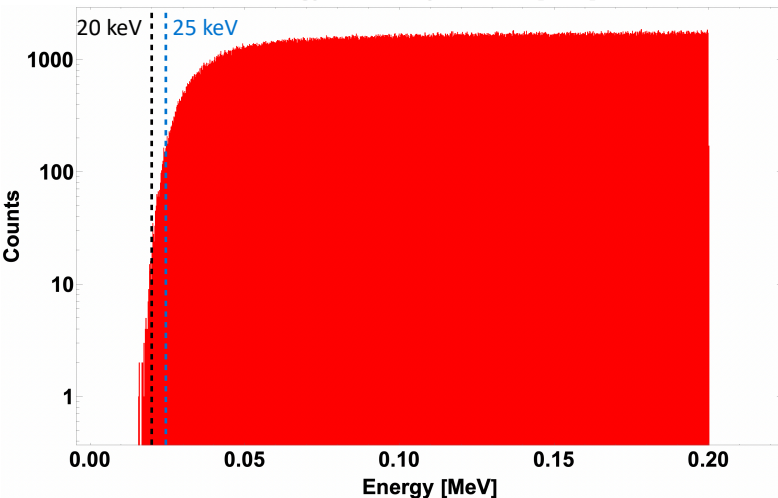
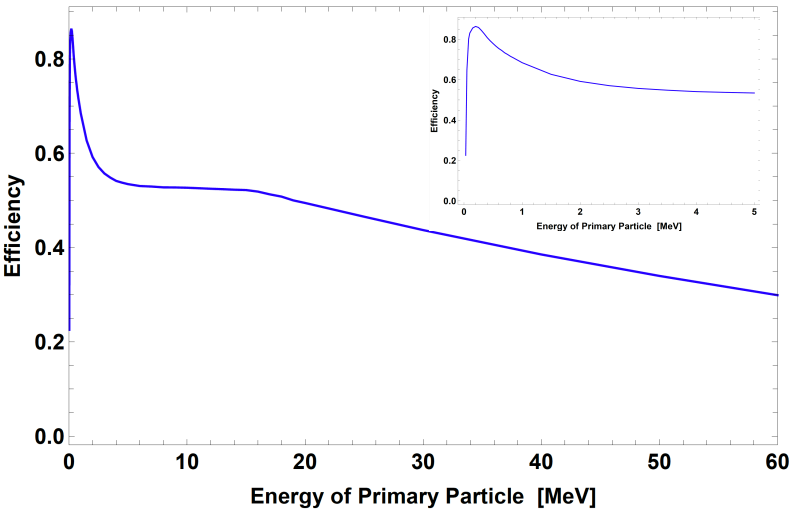
6X (23 mm X 23 mm X 45 mm) Low Background Cerium Bromide (CeBr₃(LB))

2X (23 mm X 23 mm X 45 mm) Lanthanum Bromo Chlorine (LBC)

For Basic Unit characterization see here: <https://doi.org/10.1088/1748-0221/14/09/P09017>

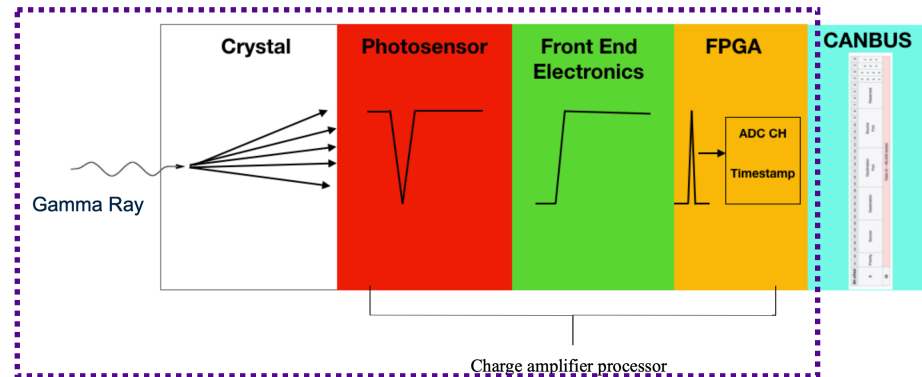
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The Light-1 Particle and Signal Simulation

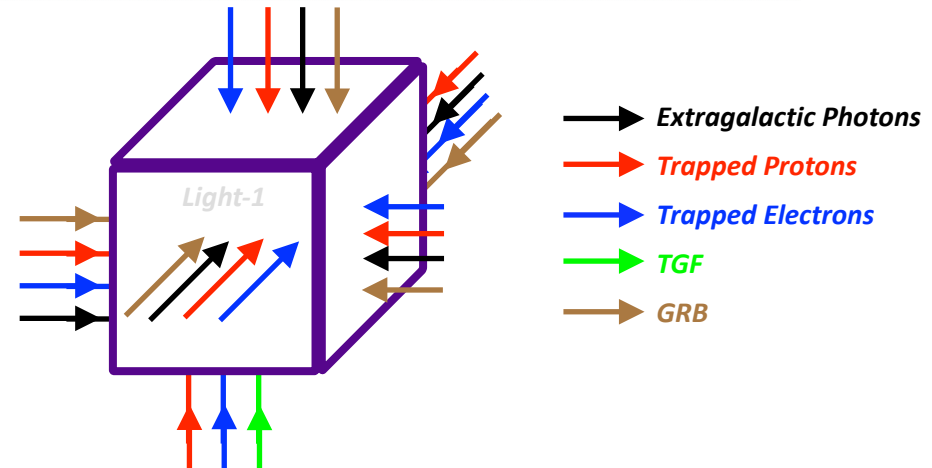
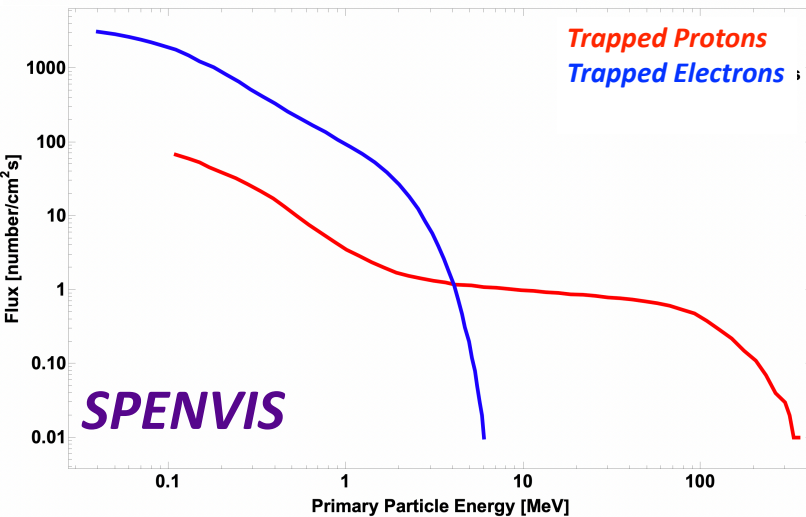
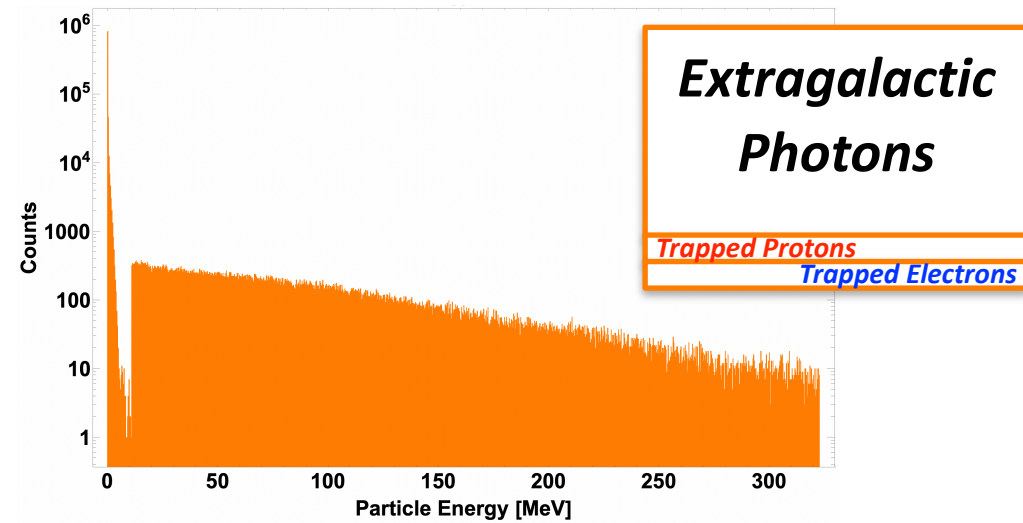
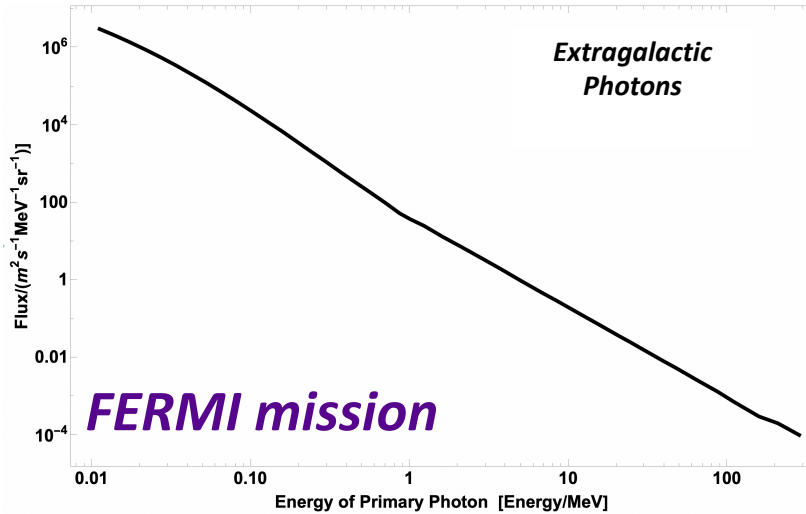


Objectives

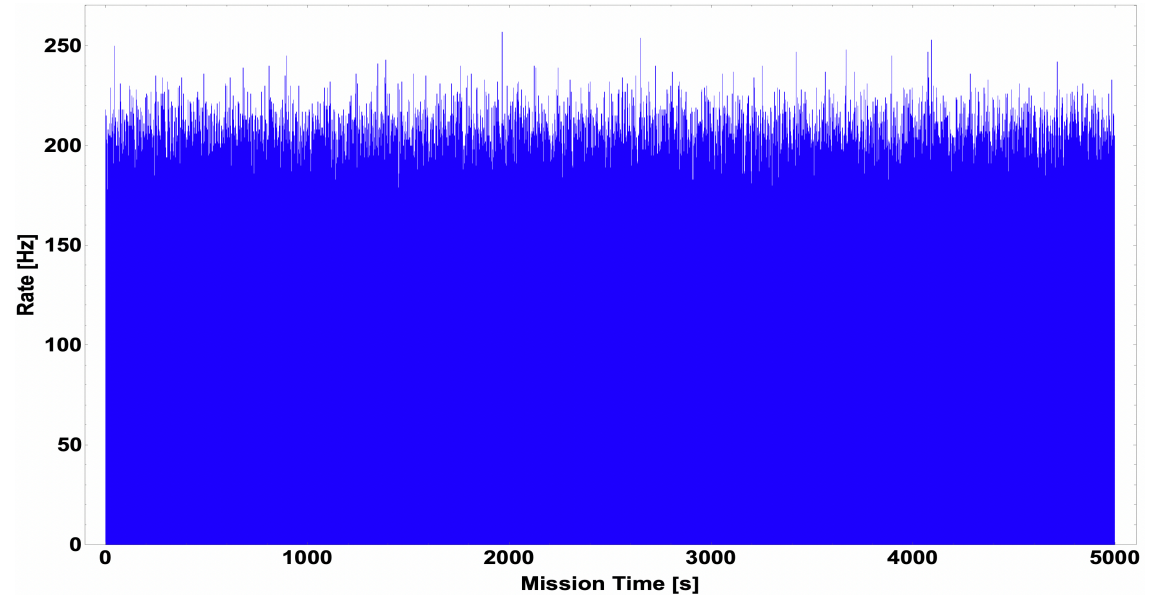
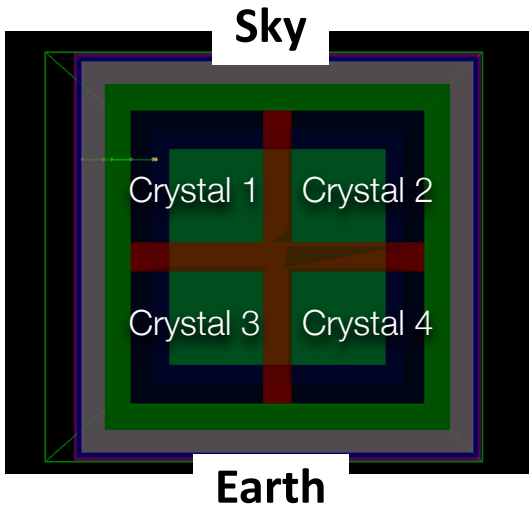
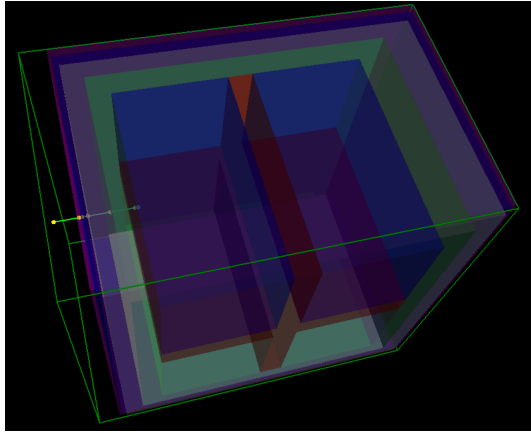
- Detection efficiency
- HDW threshold estimation
- Charged Particle rejection
- Create a background model
- TGF discrimination capability assessment
- Simulate the detection strategy



The particle environment (~410 km, LEO orbit)



From a “salted” bkg sample to TGF discrimination



Event selection strategy

CUT 1: Selection of all the events with VETO OFF

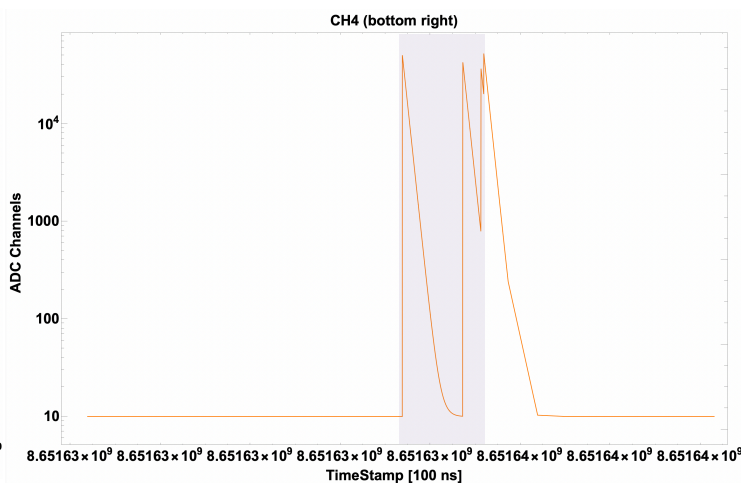
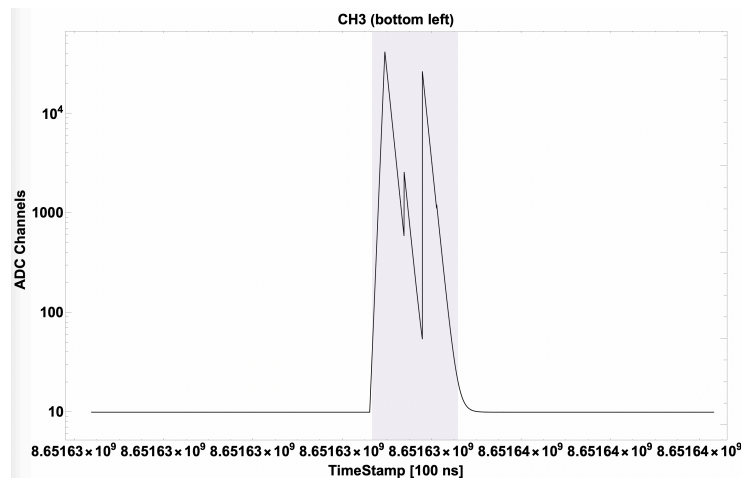
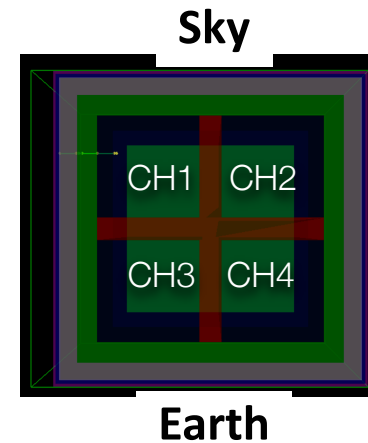
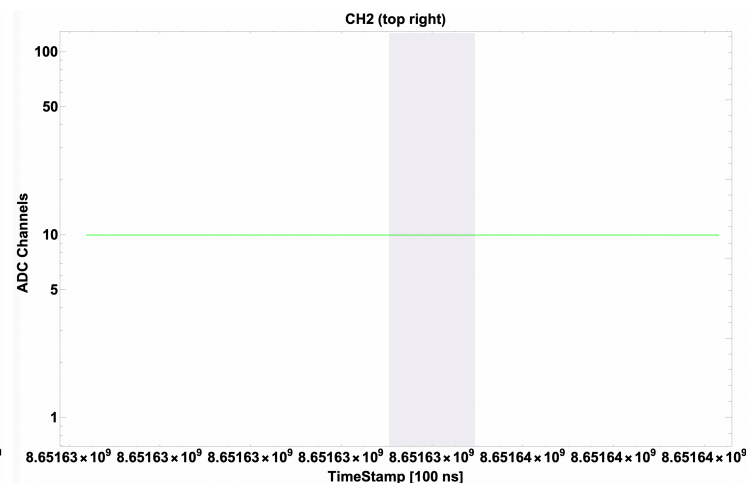
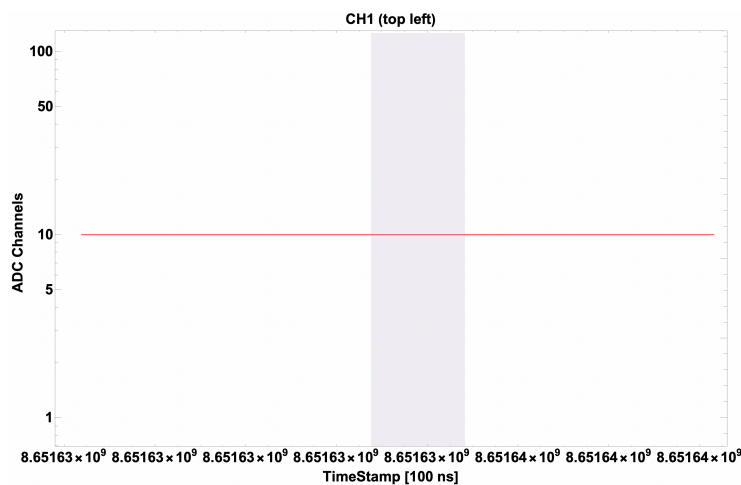
CUT 2: VETO OFF + >1 CH ON

CUT 3: VETO OFF + >1 CH ON + $E_{dep} < 30$ MeV

CUT 4: VETO OFF + >1 CH ON + $E_{dep} < 30$ MeV + $E_p < 2$ GeV

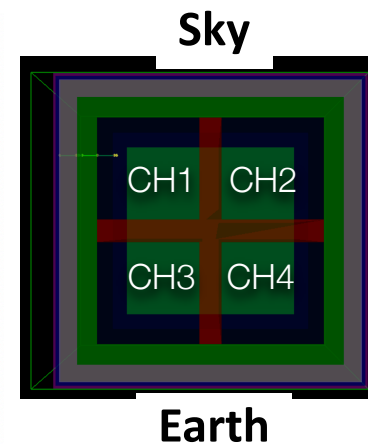
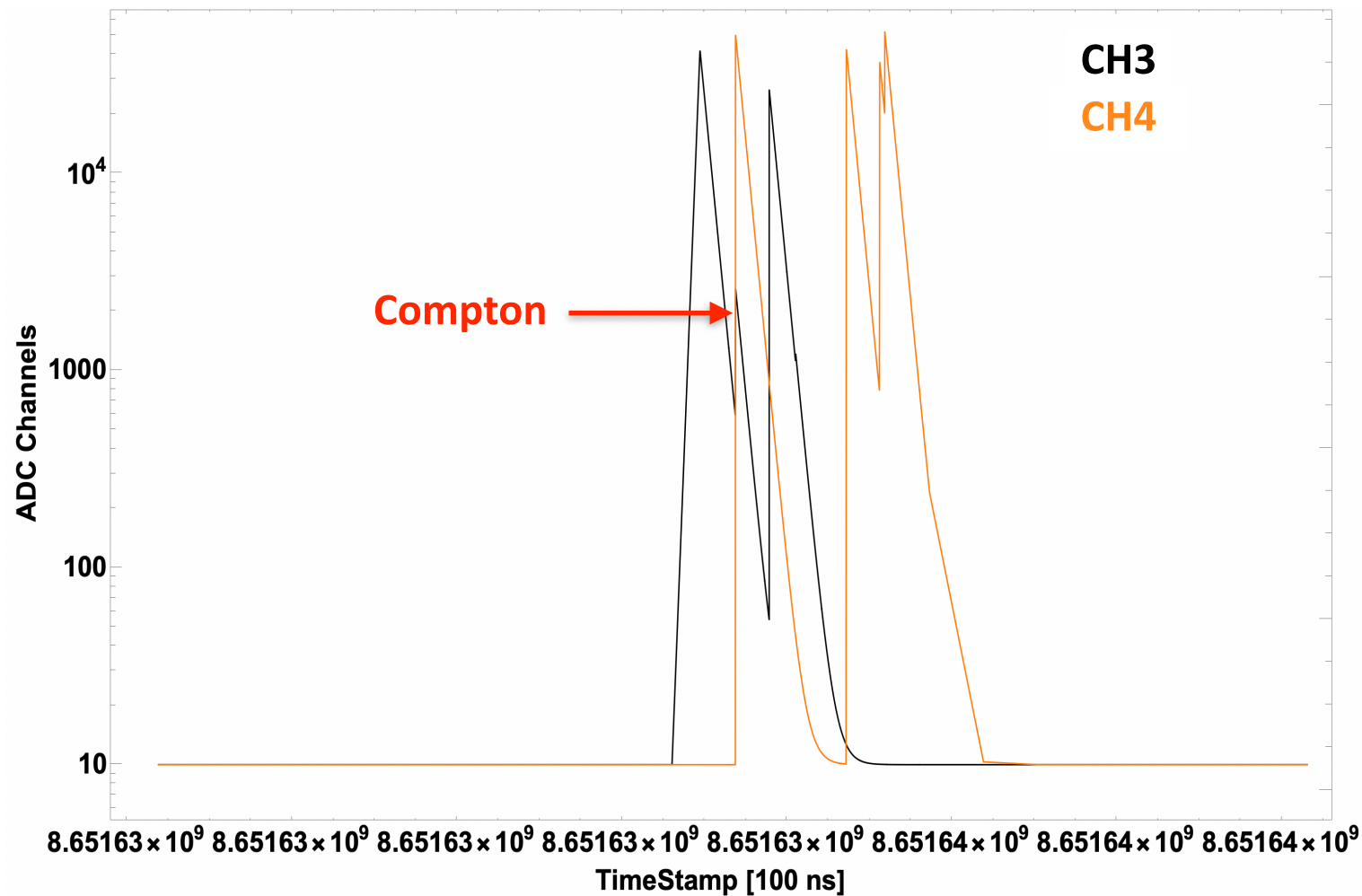
CUT 5: High rate in 1 ms windows (TGF signature)

TGF detection



| Parameter | Value |
|-------------------------------------|-------------|
| Time Duration | 175 μ s |
| # of γ at source | 8 |
| # of γ lost in the shielding | 2 |
| # of ph. detected | 6 |

TGF detection



| Parameter | Value |
|-------------------------------------|-------------|
| Time Duration | 175 μ s |
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Light-1: Summary

- Light-1 is a 3U cubesat mission for the detection of TGF
- Thanks to its sub-microsecond time resolution and absolute timing better than $2\text{ }\mu\text{s}$ (mainly due to orbit indetermination), Light-1 will be able to crosscheck TGF catalogues (and Radio Sferics)
- Light-1 can work with size, weight, and power restraints of a CubeSat
- Survive (and ideally measure the proton-antiproton rate) to the South Atlantic Anomaly
- **Space-qualify** the technology and prove the detection concept
- The design phase has been completed and all the components procured. The payload will be assembled in **September 2020**
- Light-1 simulation and the implementation of the payload communication software are in progress
- **Launch scheduled in Q2 2021**
- Light-1 will be the first particle detector payload built and operated in the UAE