

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

Adriano Di Giovanni for the Light-1 collaboration
adriano.digiovanni@nyu.edu

وكالة الإمارات للفضاء
UAE SPACE AGENCY



جامعة نيويورك أبوظبي
NYU | ABU DHABI



جامعة خليفة
Khalifa University



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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”.

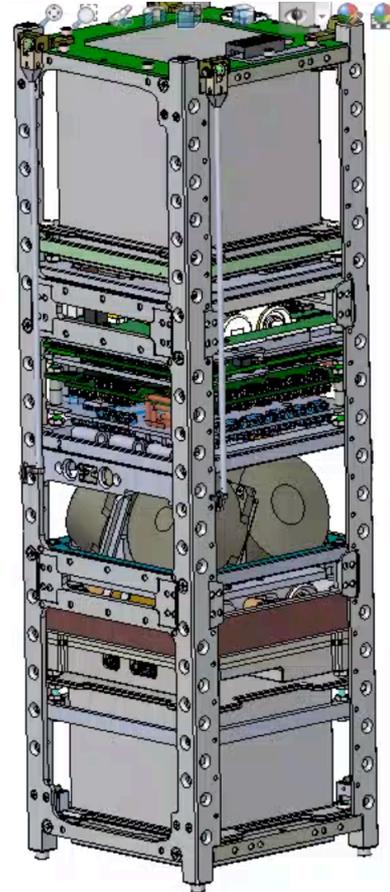
Modular satellite built up from 10 cm x 10 cm x 11.35 cm units (1U)

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

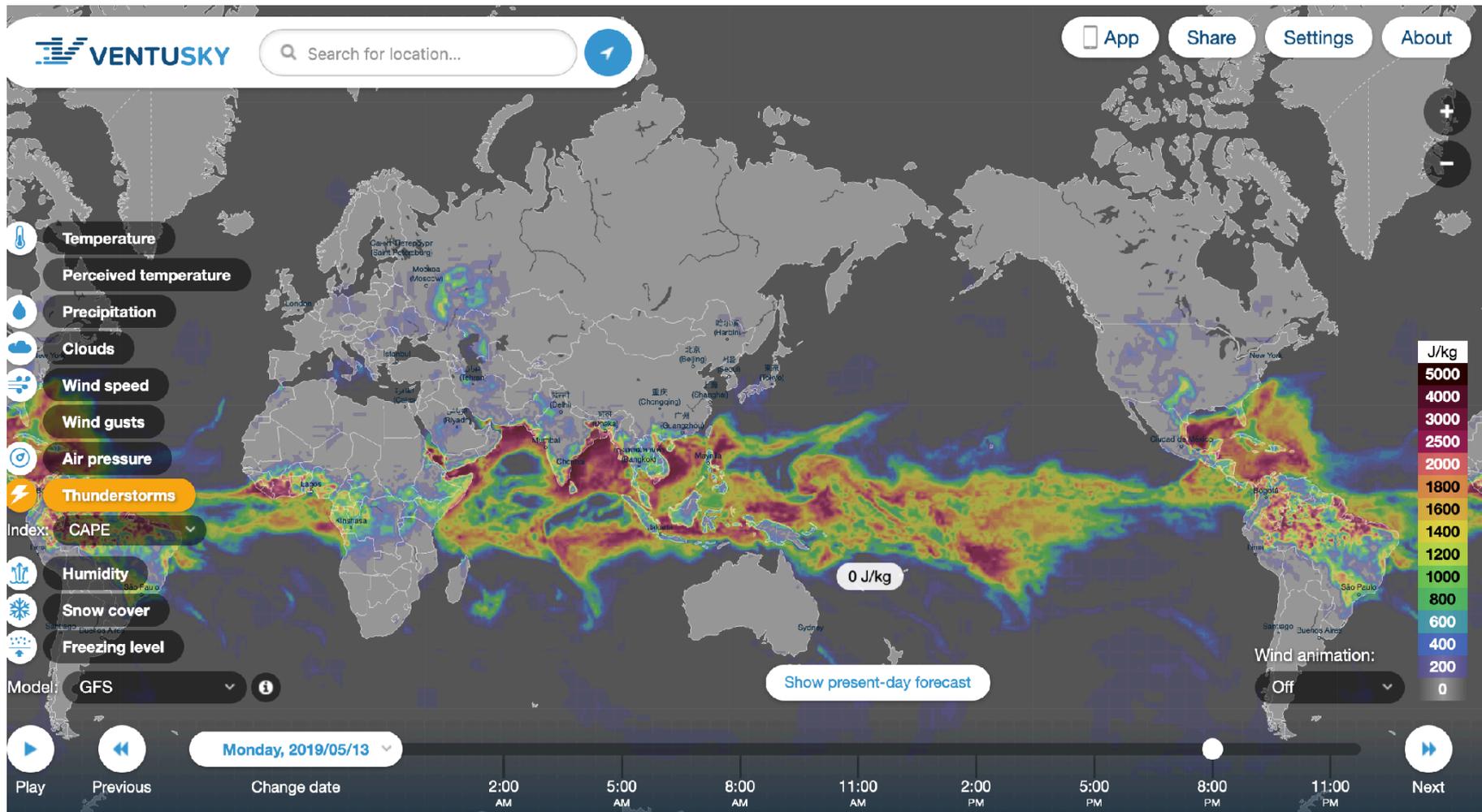
Missions relevant for TGF Science: RHESSI, AGILE, FERMI, BEPPO-SAX, RELEC, **ASIM***, **TARANIS+**
A TGF catalogue is available here: <https://openuniverse.asi.it>

*(**A**tmosphere-**S**pace **I**nteractions **M**onitor): in data taking on board of the ISS

+(**T**ool for the **A**nalysis of **R**adiation from light**N**ing and **S**prites): scheduled launch in Q3 2020

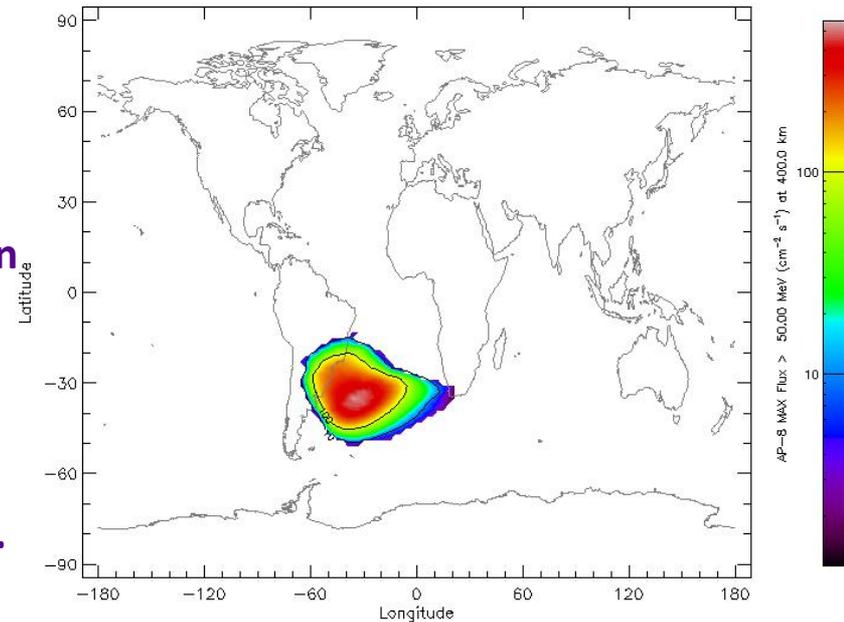
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Terrestrial Gamma-Ray Flashes: mostly from equatorial storms



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

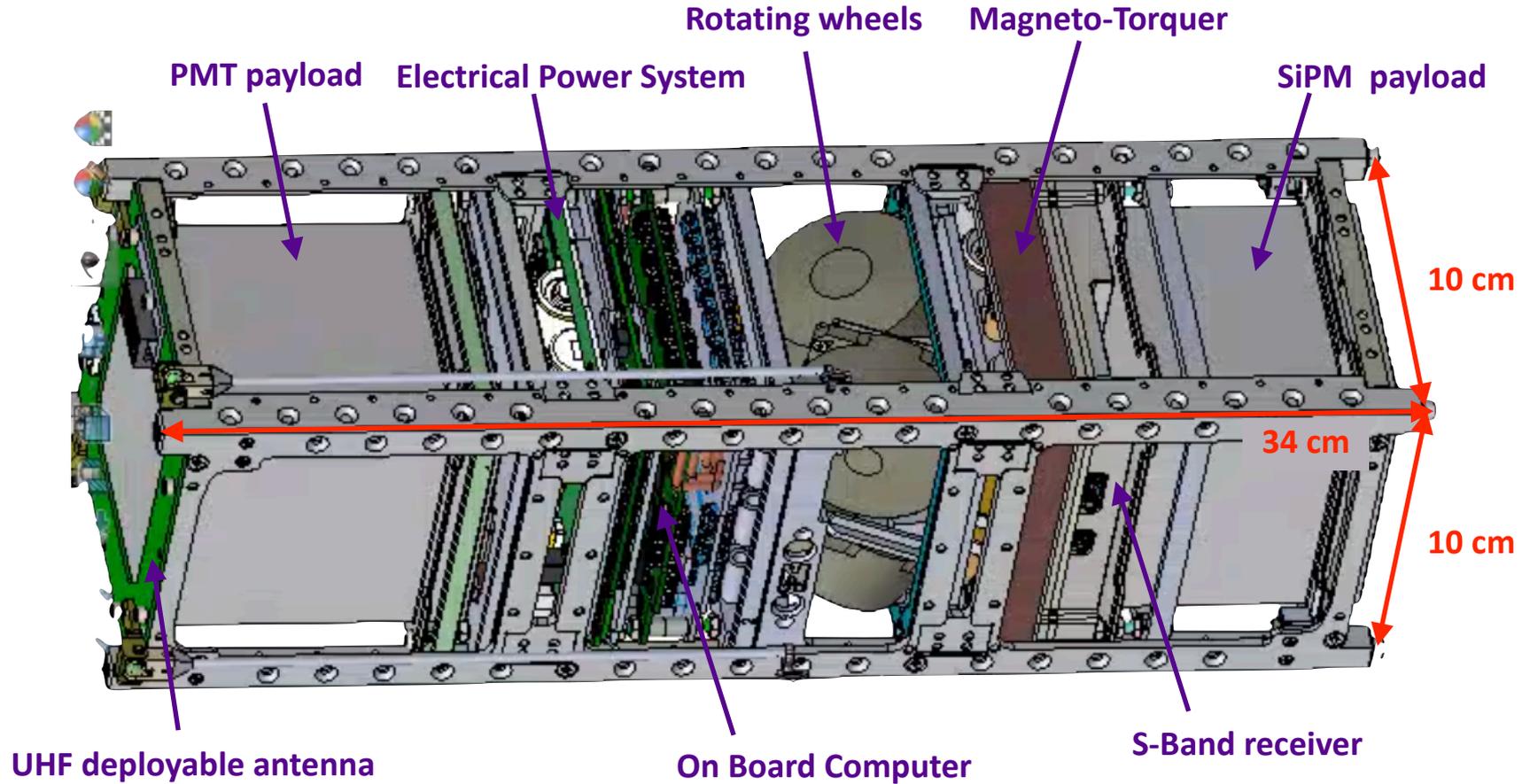


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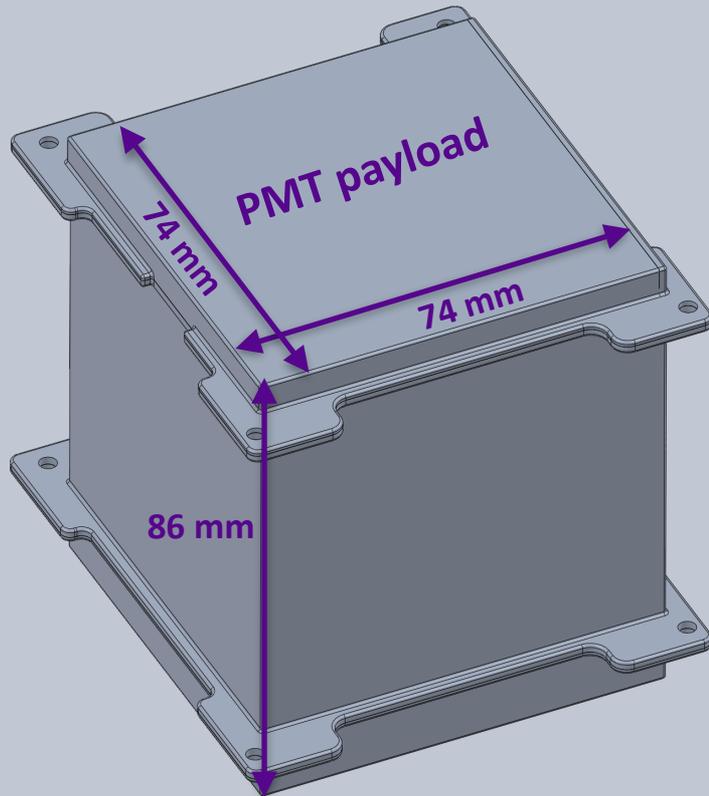
Light-1 Satellite



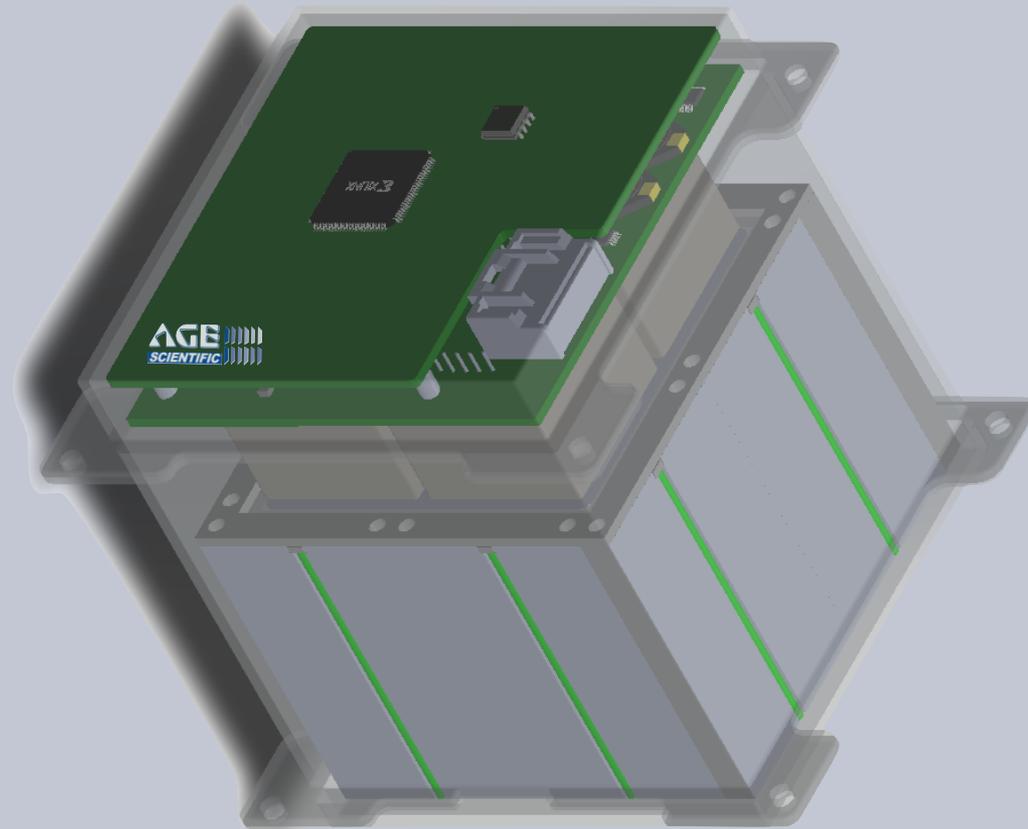
Bus component from [NanoAvionics](#)



The PMT and SiPM payloads

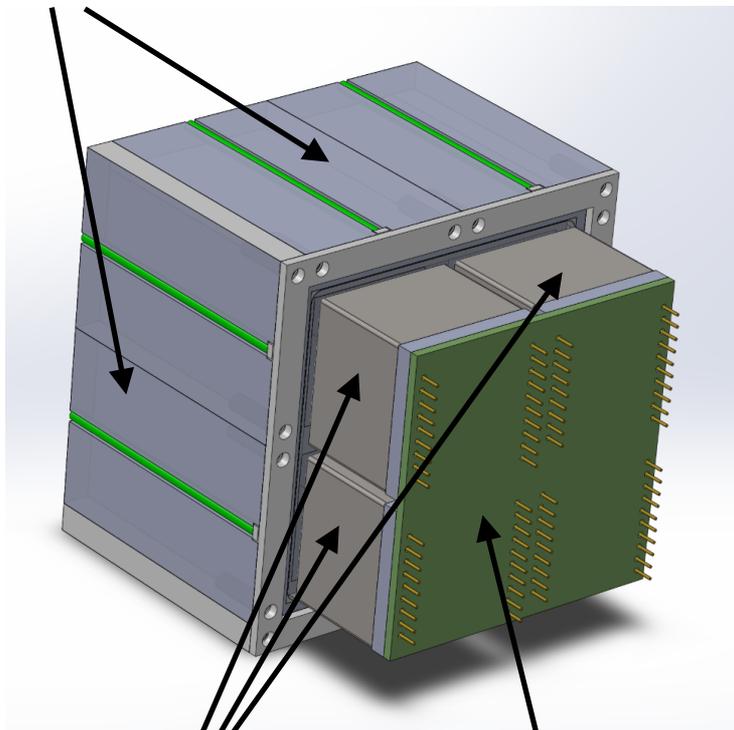


$M = 1,183 \text{ g}$



The PMT and SiPM payloads

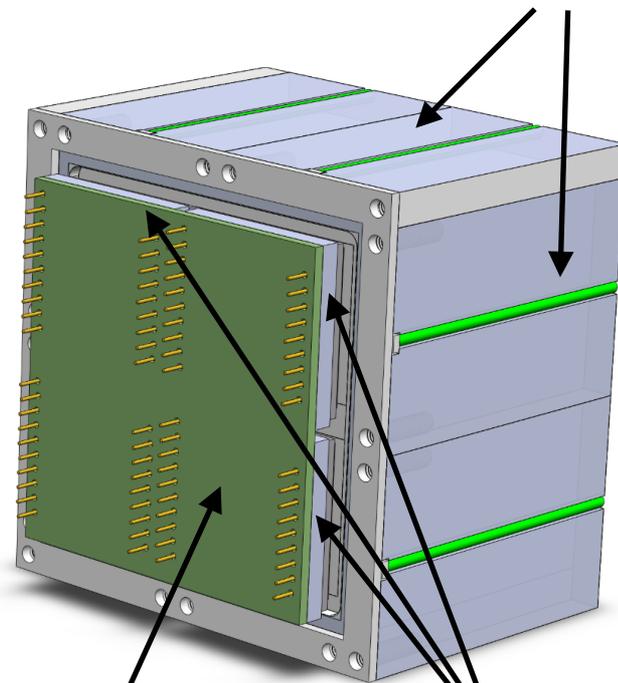
Veto System



PMT

Electronics

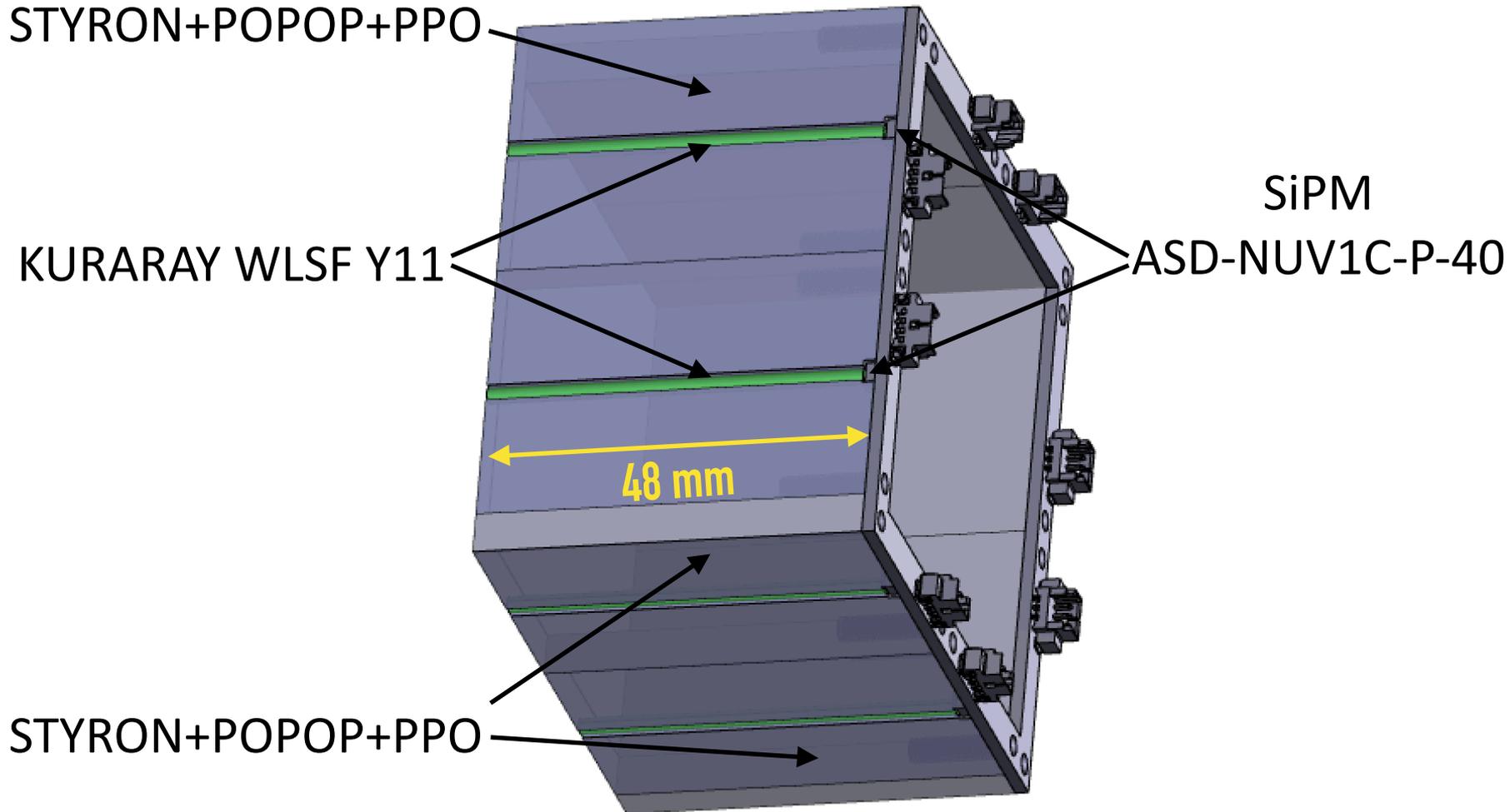
Veto System



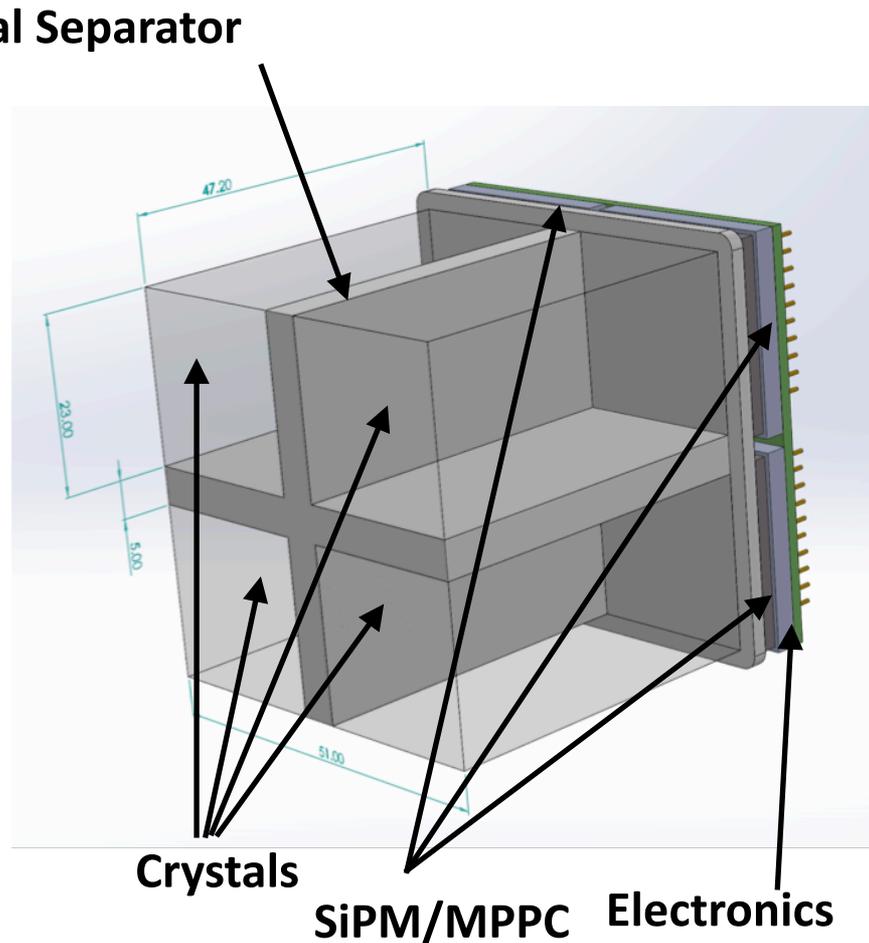
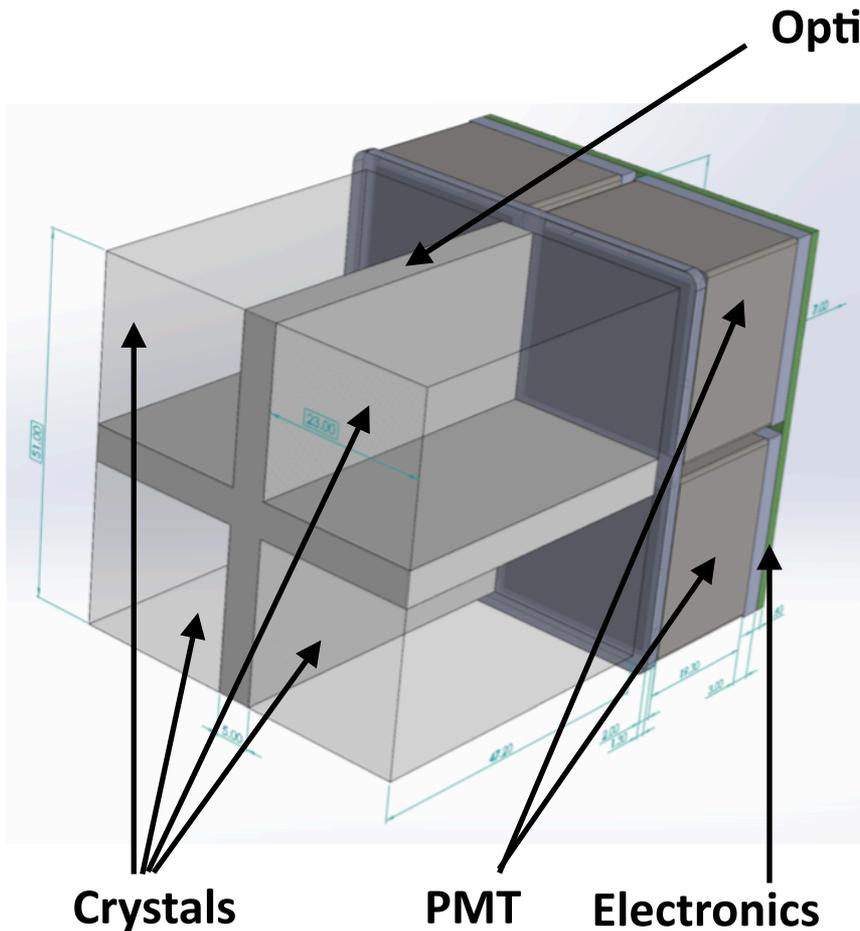
Electronics

SiPM/MPPC

The Light-1 VETO to reject charged particle induced events



The PMT and SiPM payloads



The Hamamatsu Photosensors



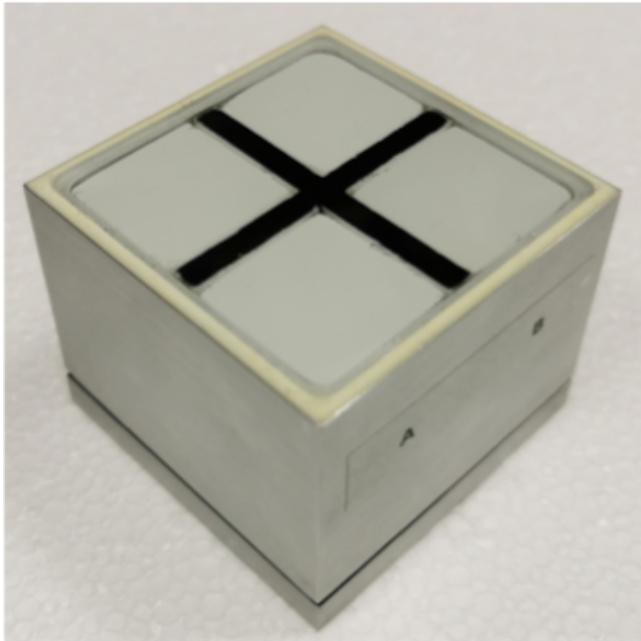
R11265-200



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:

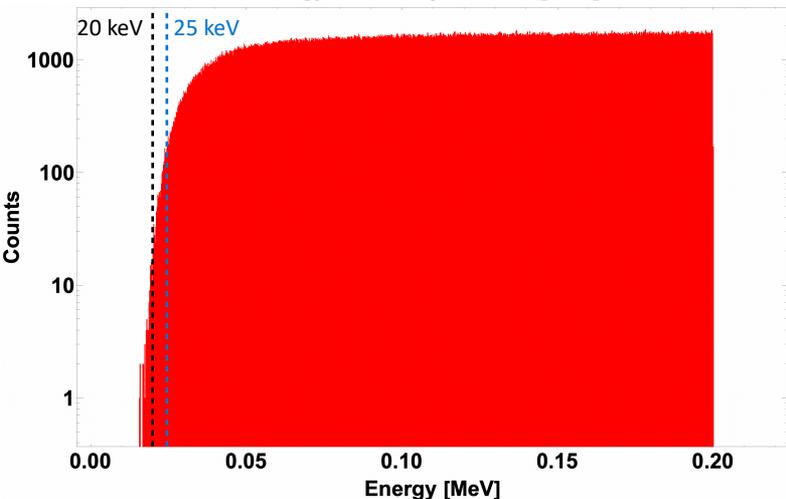
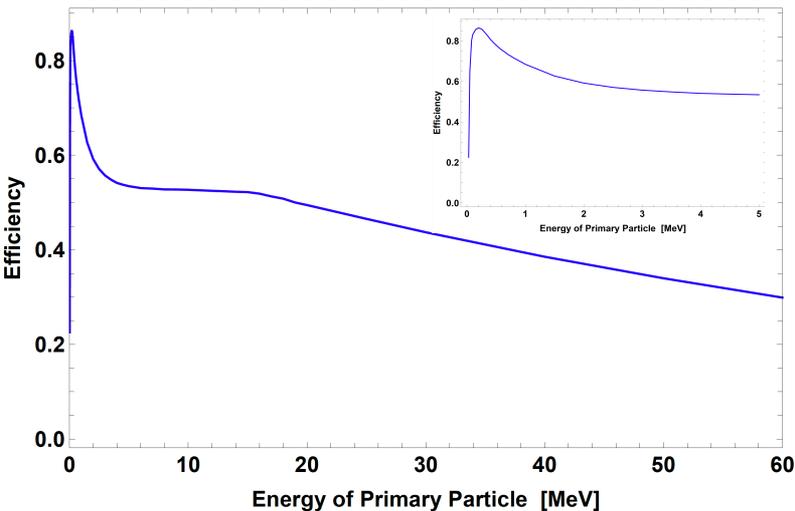
6X (23 mm X 23 mm X 45 mm) Low Background Cerium Bromide (CeBr₃(LB))

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>

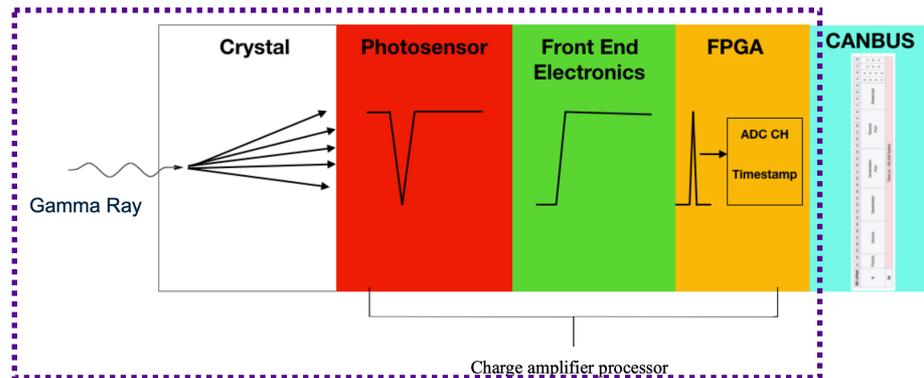
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The Light-1 Particle and Signal Simulation

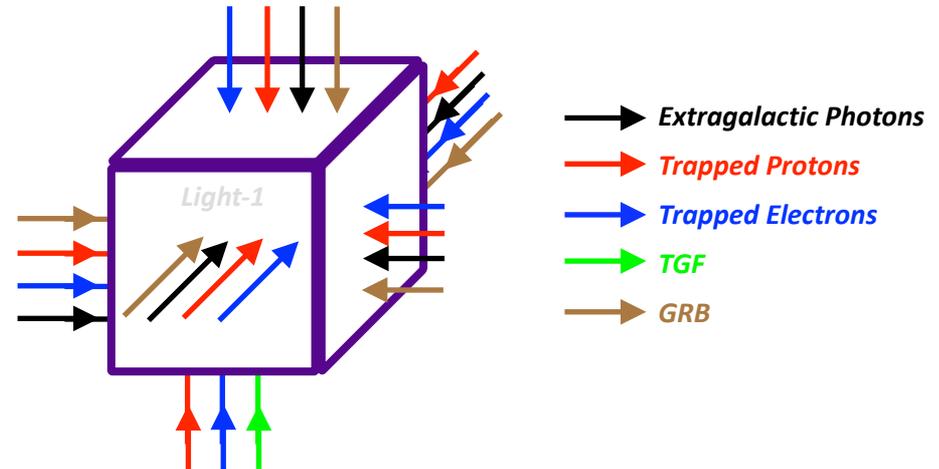
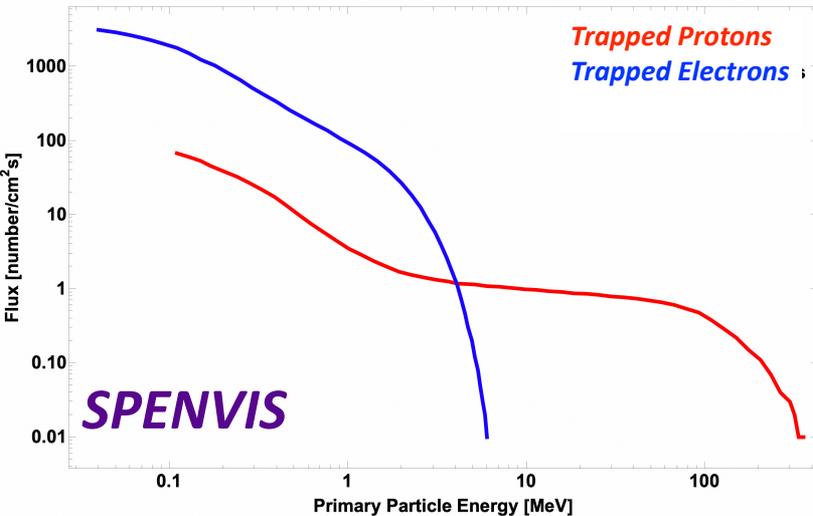
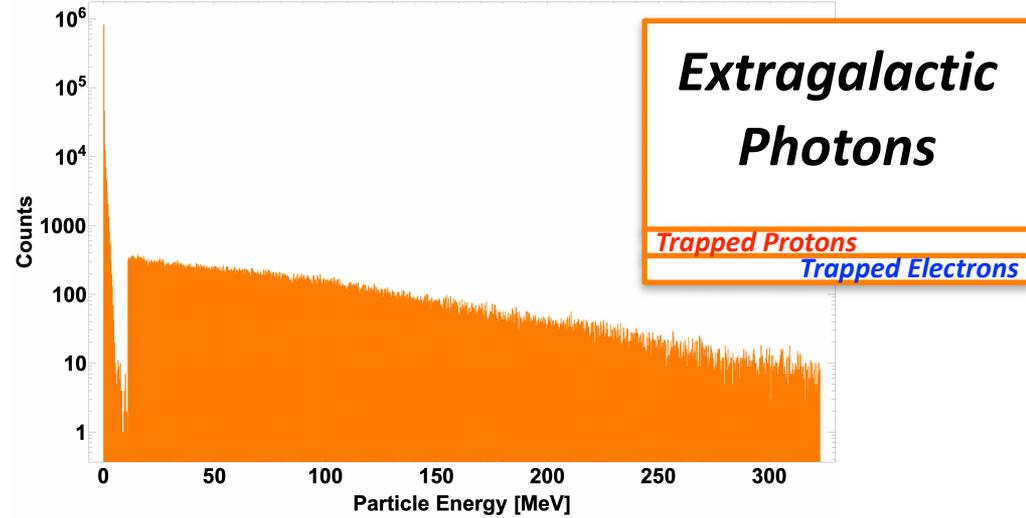
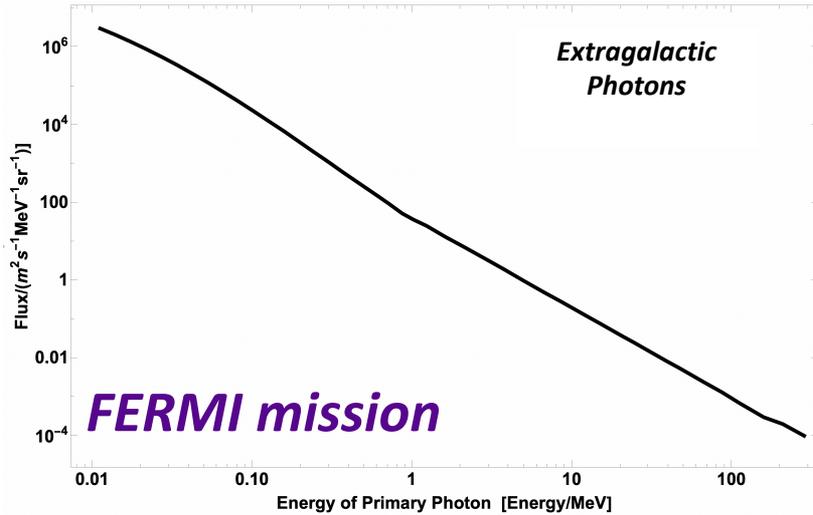


Objectives

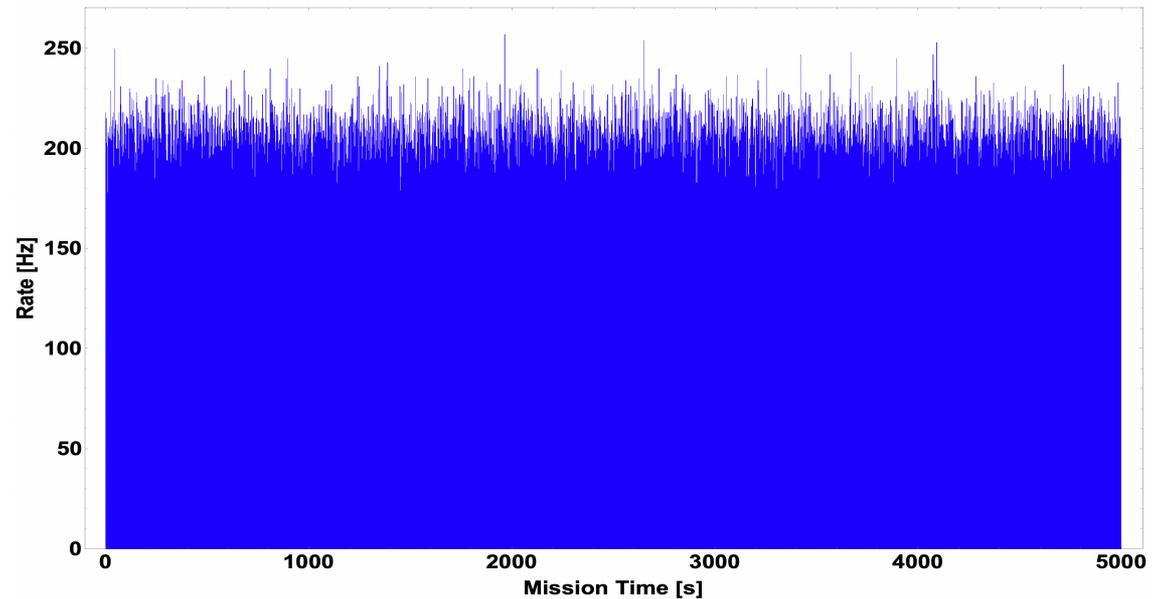
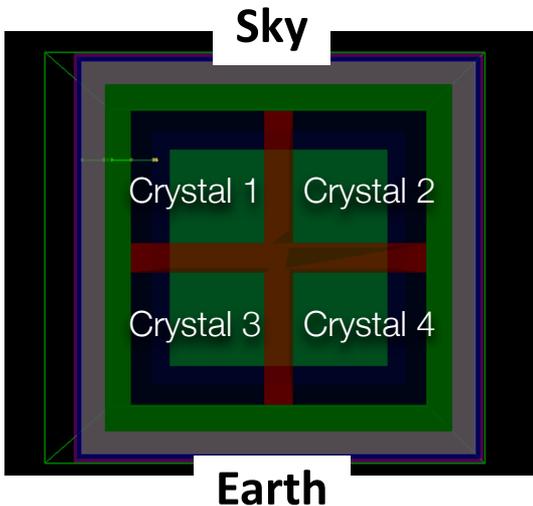
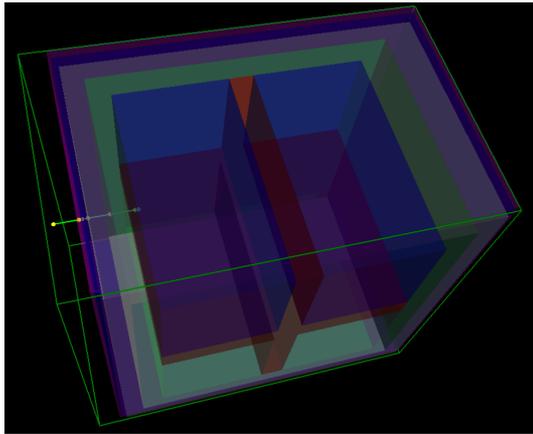
- Detection efficiency
- HDW threshold estimation
- Charged Particle rejection
- Create a background model
- TGF discrimination capability assessment
- Simulate the detection strategy



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

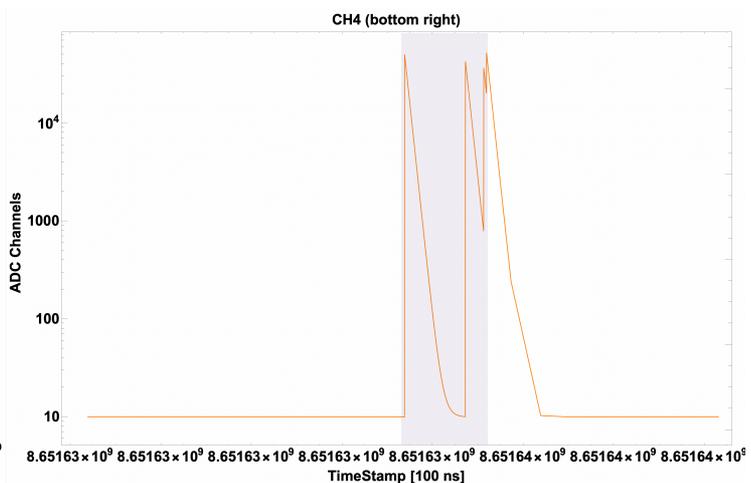
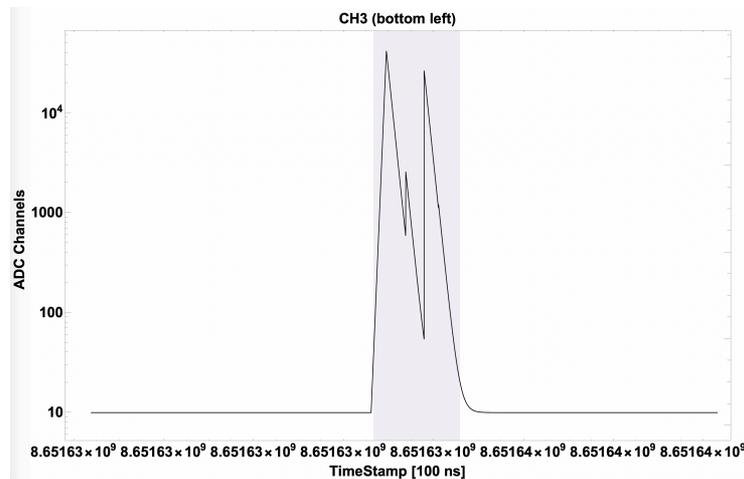
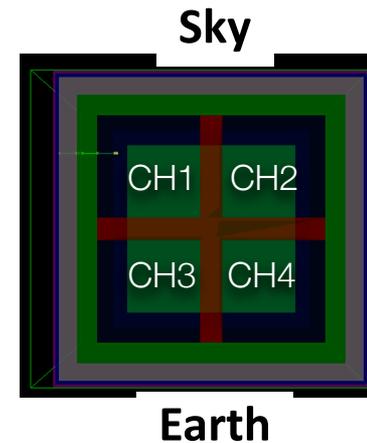
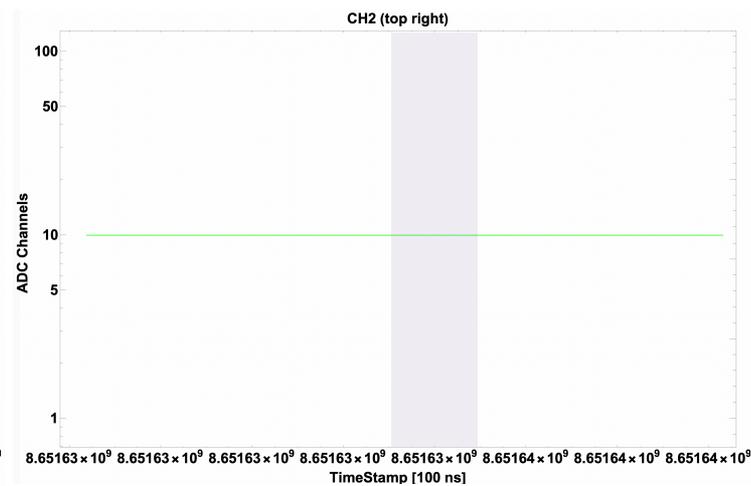
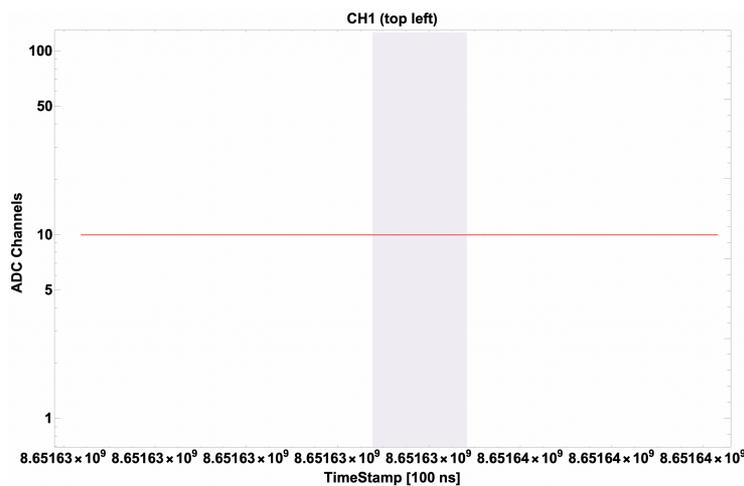
CUT 2: VETO OFF + >1 CH ON

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

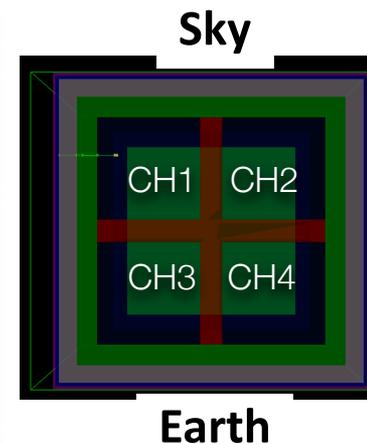
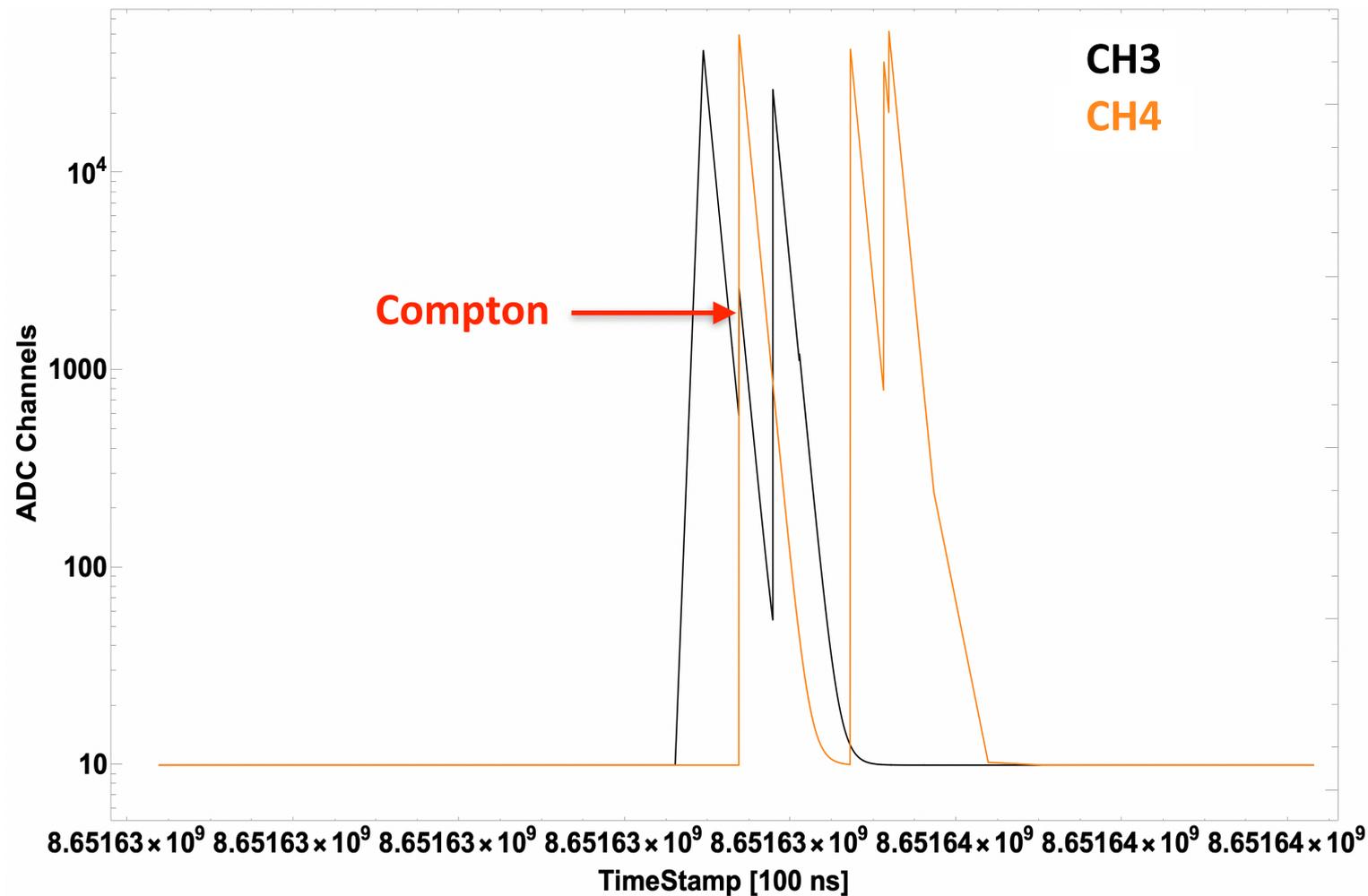
CUT 5: High rate in 1 ms windows (TGF signature)

TGF detection



Parameter	Value
<i>Time Duration</i>	175 μs
<i># of γ at source</i>	8
<i># of γ lost in the shielding</i>	2
<i># of ph. detected</i>	6

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

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 $2 \mu\text{s}$ (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