Detailed feasibility study of a gamma ray detector system for nanosatellites using GEANT4 simulations

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Introduction

High energy astrophysics

Aim of the simulation

The main aim of the paper, therefore this thesis is to optimize the scintillators of the CubeSats (miniaturized satellites) in the Constellation Gamma satellites. The second aim is to understand how the material of the CubeSat would affect the gamma photons that the satellite is meant to detect.

The Constellation Gamma (ConGa) fleet

The simulated setup

HAMAMATSU S13360-6050CS

datasheet of QE:

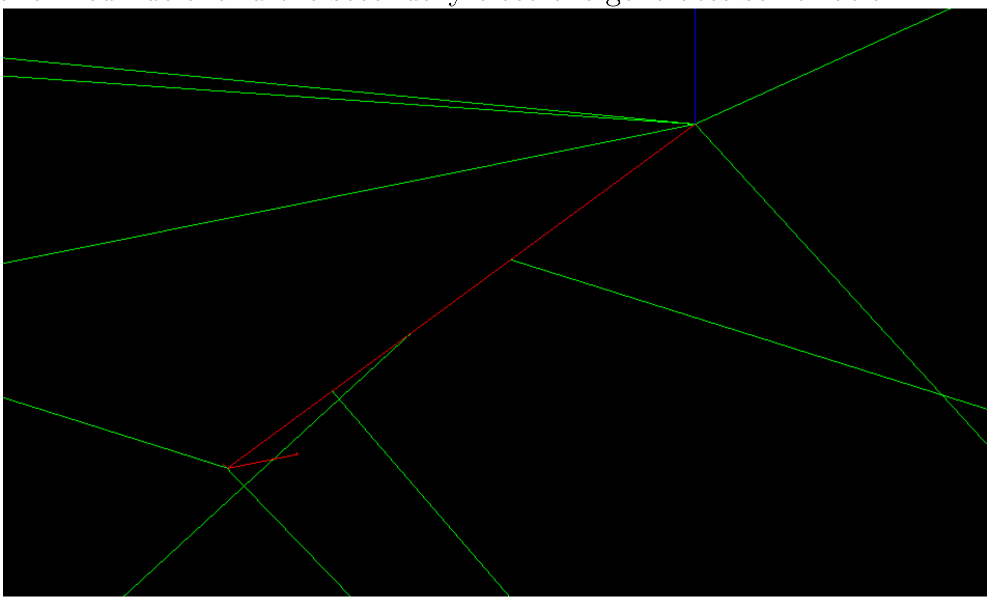
esr foil: Please check "ESR from 3M" company. e.g.,

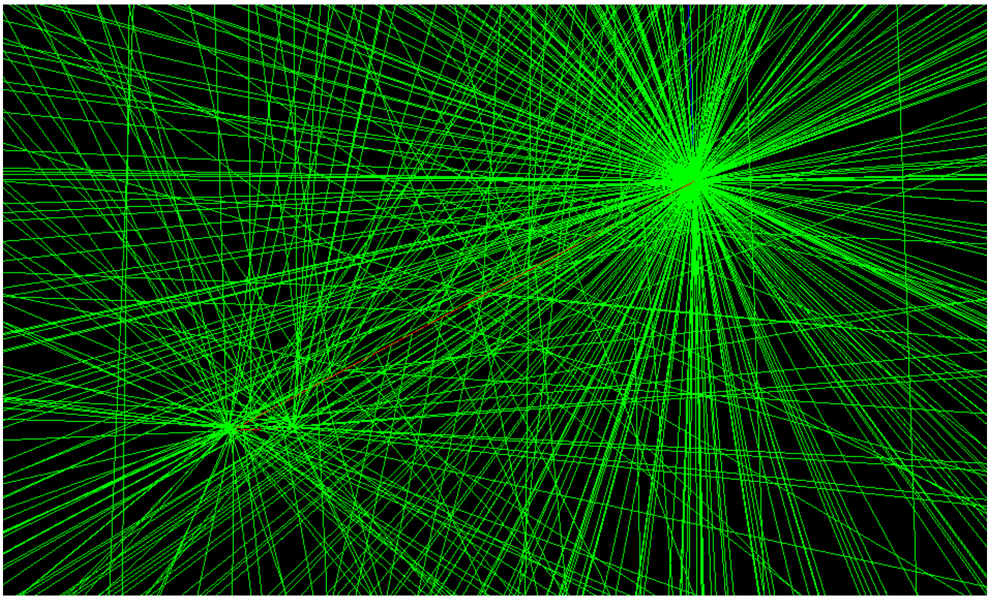
Simulation

In order to understand how the γ photons – that the CubeSat is meant to detect – interact with the matter of the satellite simulations are needed. In a simulation it is also possible to determine the optimal geometry that would lead to the best GRB detection.

The Geometry... XXX TRacking (Geant4)

The cross section for photoeffect is far the largest by far for low energy gamma photons. The ionized nuclei and the secondary electrons generates scintillation.





Also the nuclei that is ionized by the gamma produces photons.

Fine tuning the optical parameters

Most relevant parameters:

- absoprtion length of the scintillator material
- scintillation yield

Setup

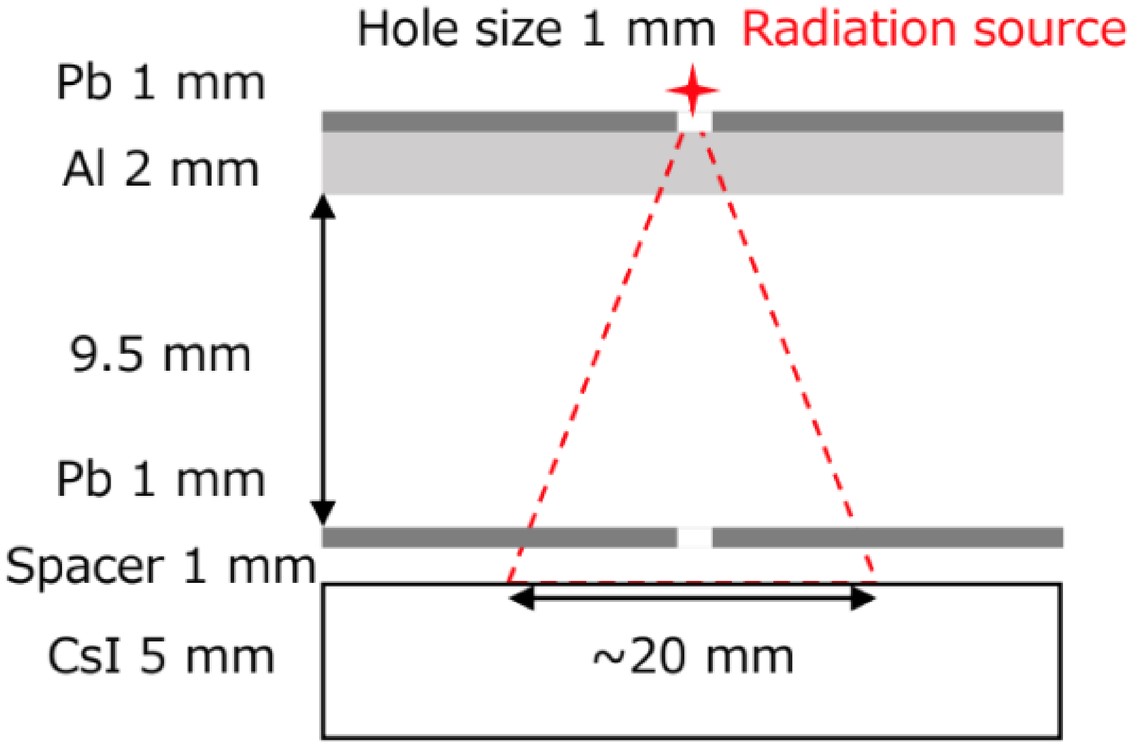
Size of the scintillator is, the aluminium housing thickness is, the size of the SiPM is... Parameters of the CsI(Tl) scintillator REF

- Scintillation yield (Number of photons produced by given keV depleted in the scintillator)
- The energy spectra of the produced scintillation
- The time constant of the scintillation photon creation
- The absorbtion length of the optical photons
- Birks constant?

Optical parameters of the materials and surfaces:

- Refractive indices of all relevant materials
- Reflection
- The detection efficiency of the SiPM detectors

1 channel setup



2 channel read out setup

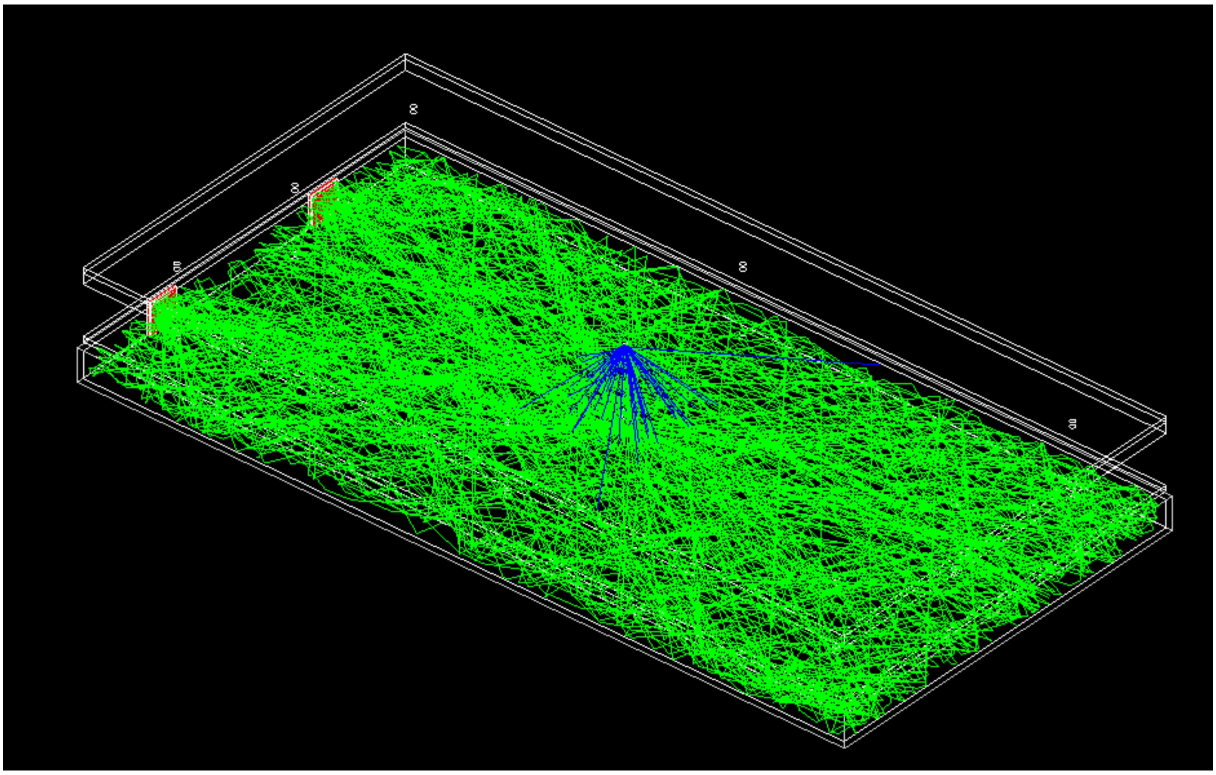
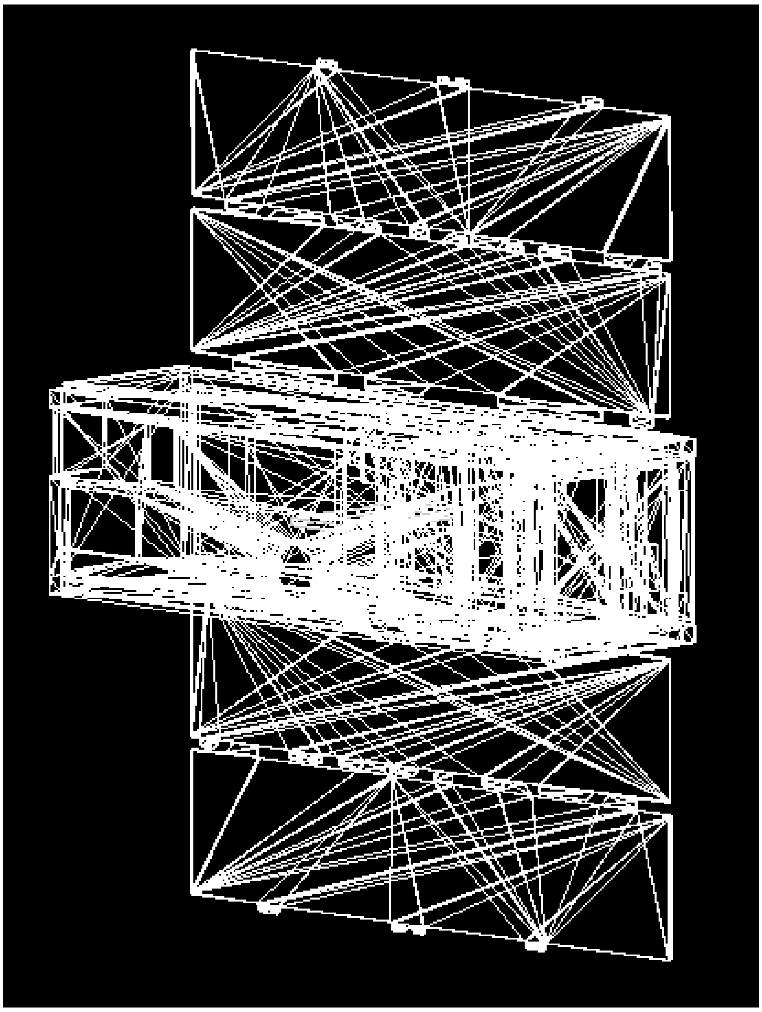


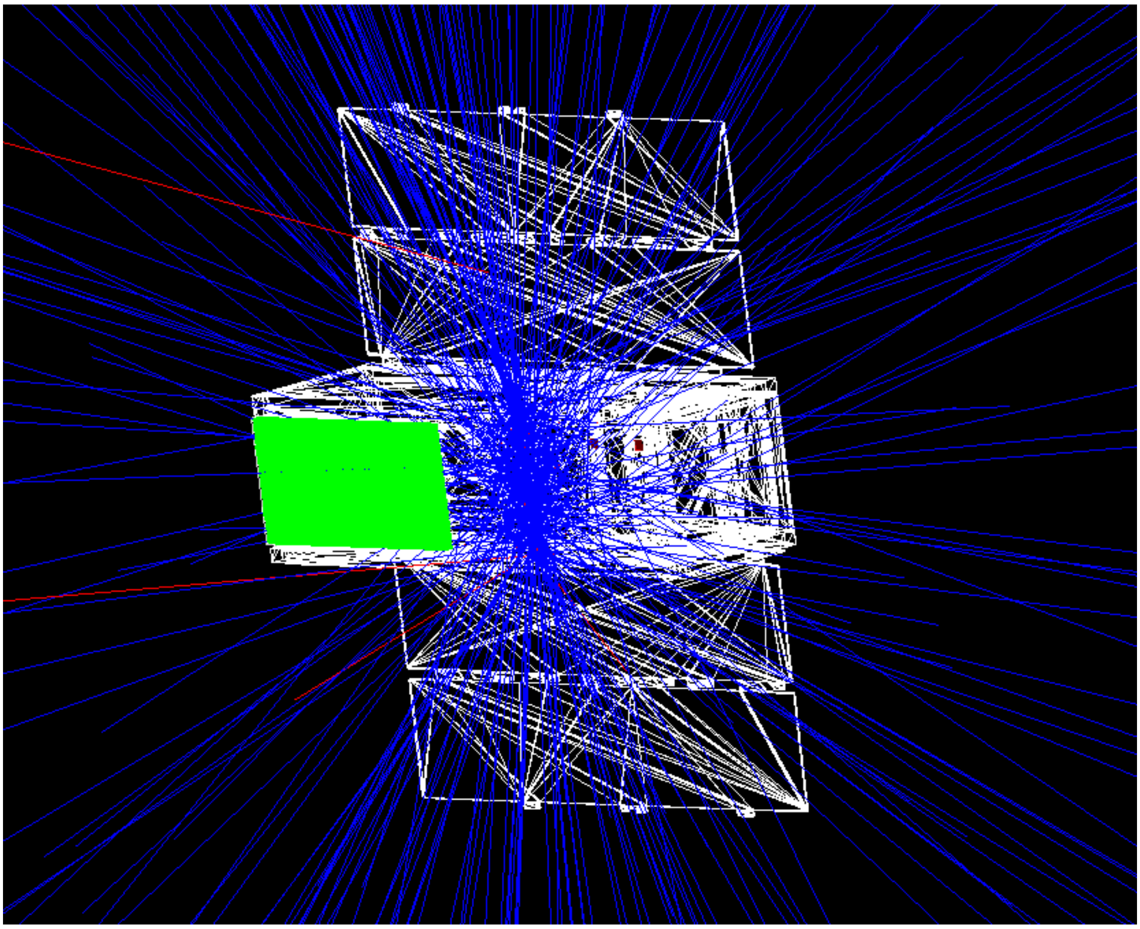
Figure 2.1: Simulation of 100 γs emitted from the source. The blue lines represent the track of the γs and the green lines represent the track of the optical photons created by scintillation. Only the photons that were detected are drawn.

The satellite



Name of module	mass [g]	Type of material	Mass ratio [%]
ADCS	710	Aluminum 6061-T6	50
		Copper Electric	25
		Glass Borosilicate	25
COM	90	Stainless Steel	2
		Brass Generic	25
		Aluminum 7075-T73	40
		FR4 Glass-Epoxy sheet	33
EPS	750	FR4 Glass-Epoxy sheet	25
		Aluminum 6061-T6	75
OBC	50	FR4 Glass-Epoxy sheet	100
STRU	980	Aluminum 6061-T6	100
SP	570	Solar Panel	100
Payload	1100	As you wish	100

Table 1: The mass ratio of materials that are used for the satellite



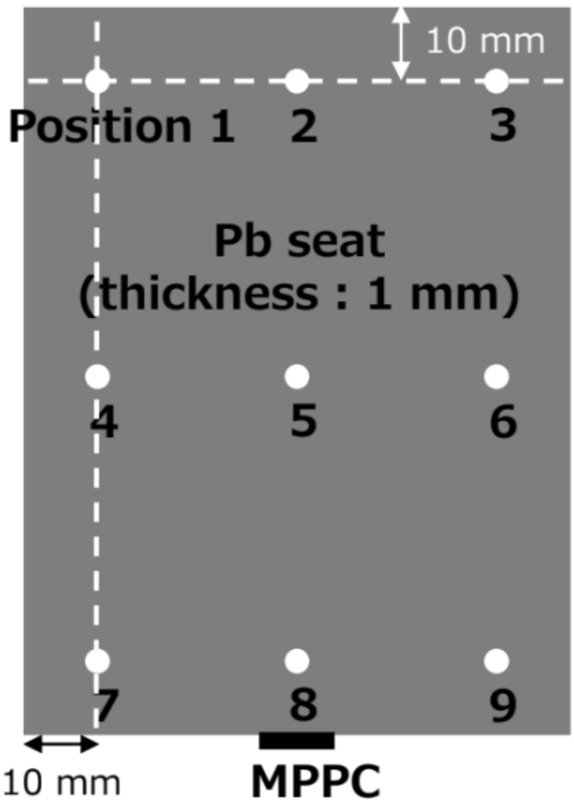
Material name												
Aluminum 6061-T6	Al	96.90	Mg	1.20	Si	0.80	Fe	0.70	Cu	0.40		
Aluminum 7075-T73	Al	88.60	Zn	6.10	Mg	2.90	Cu	2.00	Si	0.40		
Stainless Steel	Fe	66.50	Cr	20.00	Ni	10.50	Mn	2.00	Si	1.00		
Copper Electric	Cu	100.00										
Glass Borosilicate	Si	42.10	O	54.80	B	3.10						
FR4 Glass-Epoxy	Si	23.39	O	36.02	C	37.04	H	3.55				
Brass Generic	Cu	85.00	Zn	15.00								
Solar Panel	Ge	38.00	Si	24.00	O	20.00	C	13.00	H	4.00	B	1.00

Table 2: The chemical composition of materials that are used for the satellite

Results of the simulation

Comparison of the results of the simulation with experiments

1 channel read out:



The experimental results:

Pos. of source	1	2	3	4	5	6	7	8	9
Pos. of main peak	0.642	0.664		70.7	0.743		0.598		

The parameters set in the simulation: reflectivity: 0.995 and absoprtion length of 40 cm:

Pos. of source	1	2	3	4	5	6	7	8	9
Pos. of main peak	0.3389	0.3256	0.3355	0.3521	0.3555	0.3522	0.2060	1	0.203

The parameters set in the simulation: reflectivity: 0.995 and absoprtion length of 50 cm

Pos. of source	1	2	3	4	5	6	7	8	9
Pos. of main peak	0.4013	0.3917	0.3981	0.4045	0.4172	0.4140	0.2580	1	0.2739

Reflectivity of 0.997 and abs. length of 60 cm

Pos. of source	1	2	3	4	5	6	7	8	9
Pos. of main peak	0.4588	0.4587	0.4697	0.4734	0.4700	0.4737	0.3388	1	0.3365

X-ray fluorescence

Histogram without fluorescence, turned out in LXeEMPhysics line 140-159

Histogram with flo

Simulation of the cosmic background in space

In order to include the resonances in the cross section of the hadron-hadron interactions, additional physics models are needed to be included in the simulation. The signal induced by these resonances might affect the measurement of the protons.

Optimalization of the scintillator detectors

Conclusion

In order to simulate how the XXX CubeSat would interact with the cosmic background and how sensitive it would be to the GRBs that it is designed to investigate a Geant4 simulation was built.

As the first step, the experimental setup that was used to test the CsI(Tl) scintillator – the particle detector of the satellite – was implemented in Geant4. The optical parameters of the simulation were fine tuned by comparing the light yield of the MPPCs that was used to read out the scintillator.

Secondly, the CAD model of the satellite was exported to Geant4. The body of the satellite was divided into 8 modules. The chemical components of these modules were included in the simulation. The scintillator was placed on the side of the satellite.

Thirdly, the effect of cosmic radiation was invastigated by obtaining the energy spectra of cosmic protons and electrons at the XXX altitude of XXX. The satellite was radiated by these particles in Geant4 from all directions to investigate how large the signal of these particles would be. This needs to be minimalized as it versenyez with the signal of gamma particles from GRBs.

Finally, the γ absorption of the satellite was invastigated.

Acknowledgment

References

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Advances in Thick GEM-like gaseous electron multipliers—Part I: atmospheric pressure operation,
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