DESIGN AND DEVELOPMENT OF THE

IGOSAT SCINTILLATOR PAYLOAD

FOR MEASURING THE SPECTRUM OF GAMMA RADIATIONS AND ELECTRONS

ON LOW-EARTH ORBIT

IGOSat – **I**onospheric & **G**amma-ray **O**bservations **Sat**ellite

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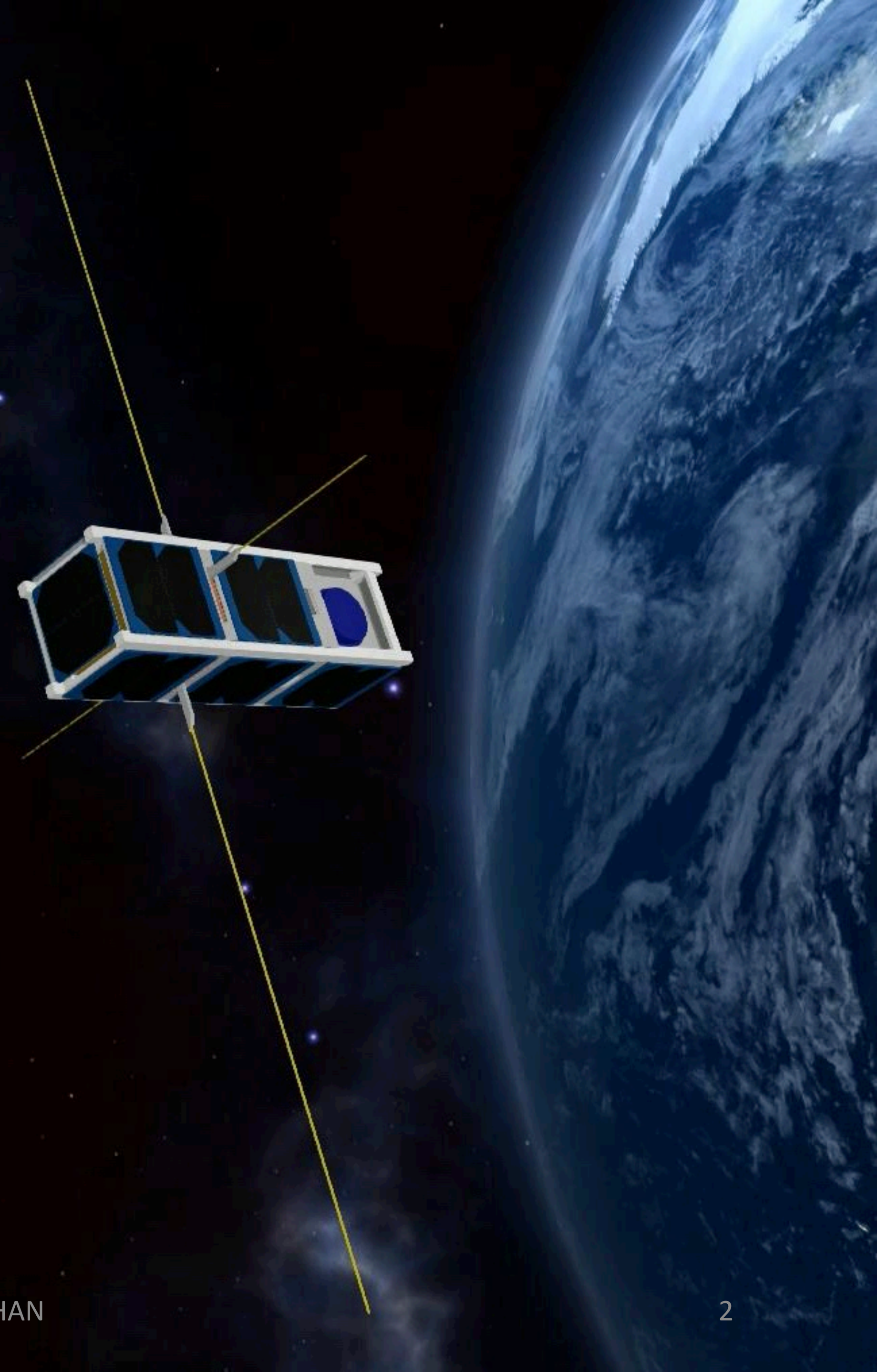
Contents

- Introduction
- The Scintillator Payload
- The Simulation
- The Latest Design
- The Test Bench



Introduction

- The radiation environment in Low Earth Orbit (LEO) is contributed by following sources: X-ray and gamma ray albedo, the albedo charged particles, albedo neutrons, the primary protons, and the diffuse extragalactic background radiation.
- But we still have very few data. Some obsetvations of the electrons spectra around the Earth have been performed in the past, leading to the distribution of the AE-8 model (NASA).
- The DEMETER mission from CNES (Sauvaud et al., 2006) updated the data between 2004 − 2006 in the energy ranged from 70 to 2500 keV at an altitude 710 km.
- AMS-02 experiment (Battiston, 2008) carried onboard the ISS measured high energetic electrons (above 200 MeV).
- The CORONAS-1 (Bucik et al, 1999) mission measured spectrums between 0.12 – 0.32 MeV and 3.0 – 8.3 MeV, and a lot of instruments observed the gamma rays from the atmosphere below 1 MeV (such as Beppo-SAX, SWIFT, INTEGRAL) (Ajello et al., 2008).

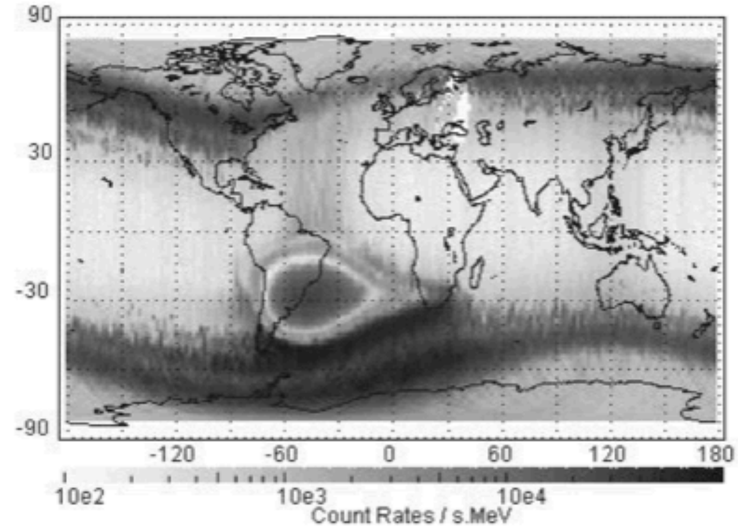


Fig. 1a. Geographycal map of gamma ray flux of 0.12-0.32 MeV

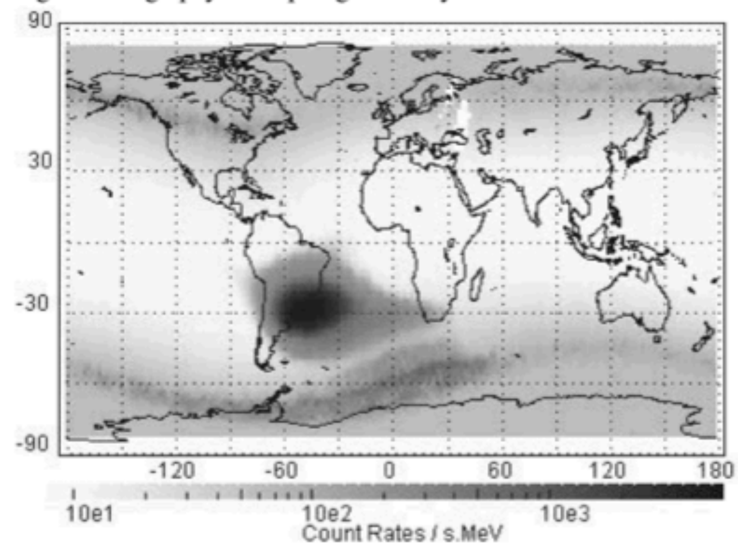


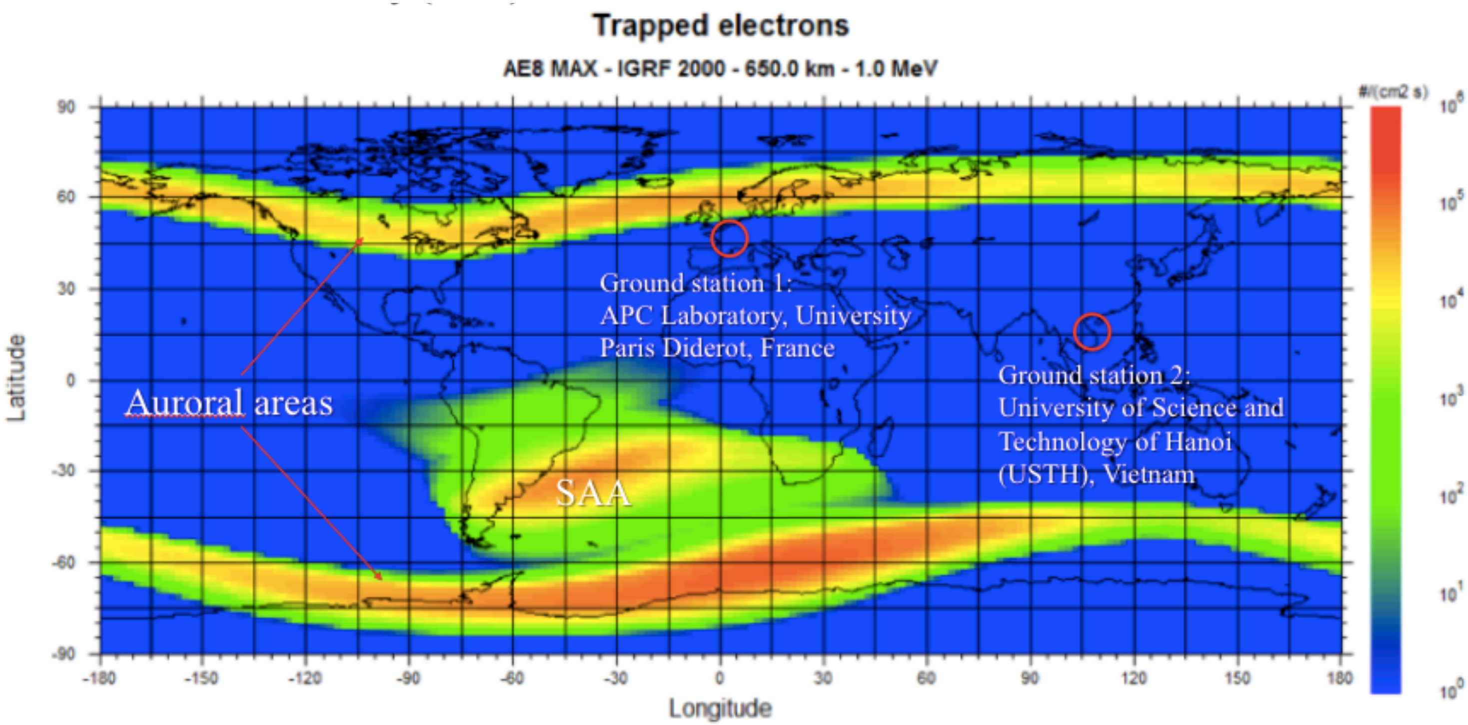
Fig. 1b. Geographycal map of gamma ray flux of 3.0-8.3 MeV

R. Bucik et al. 1999

Introduction (2)

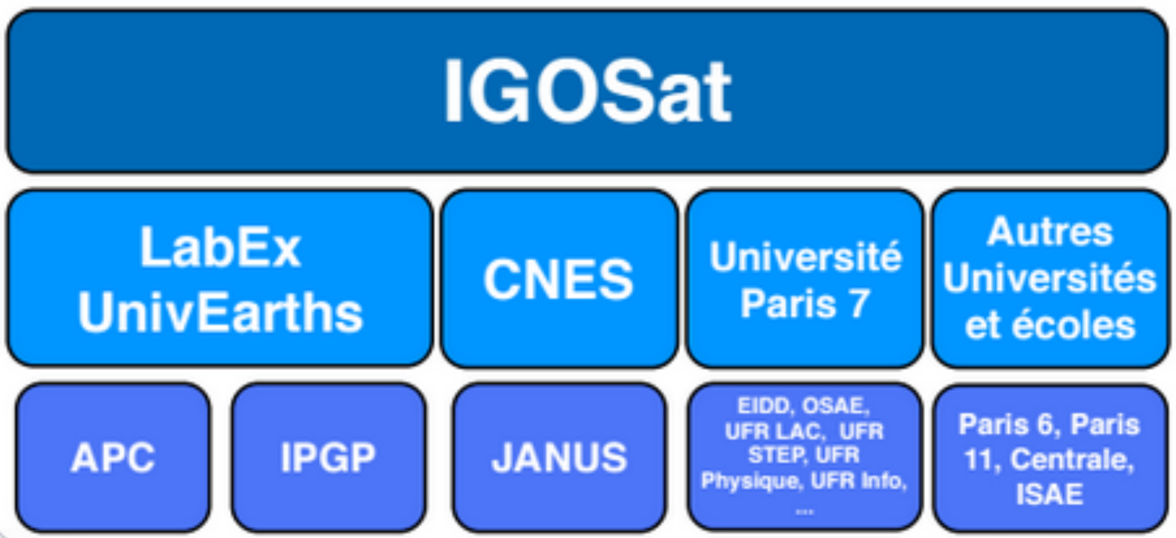
Since 2012, the IGOSat project has started. IGOSat (**I**onospheric & **G**amma-ray **O**bservations **Sat**ellite) is a nanosatellite aims to measure:

- Total Electronic Content (TEC) of the ionosphere.
- The spectrum of gamma radiation (20 keV to 2 MeV) and electrons (1 MeV to 20 MeV) in auroral zones and South Alantic Magnetic Anomaly.
- The satellite is planned to use 2 ground stations: one at APC, Paris, and another at University of Science and Technology of Hanoi (USTH), Hanoi, Vietnam.



Introduction (3)

- The IGOSat project is proposed by the LabEx UnivEarthS
- Funded by CNES/JANUS program for educational cubesat
- In collaboration with the APC and IPGP laboratories from Paris-Diderot University.
- The project has started in 2012, and the satellite is planned to be launched in 2019.



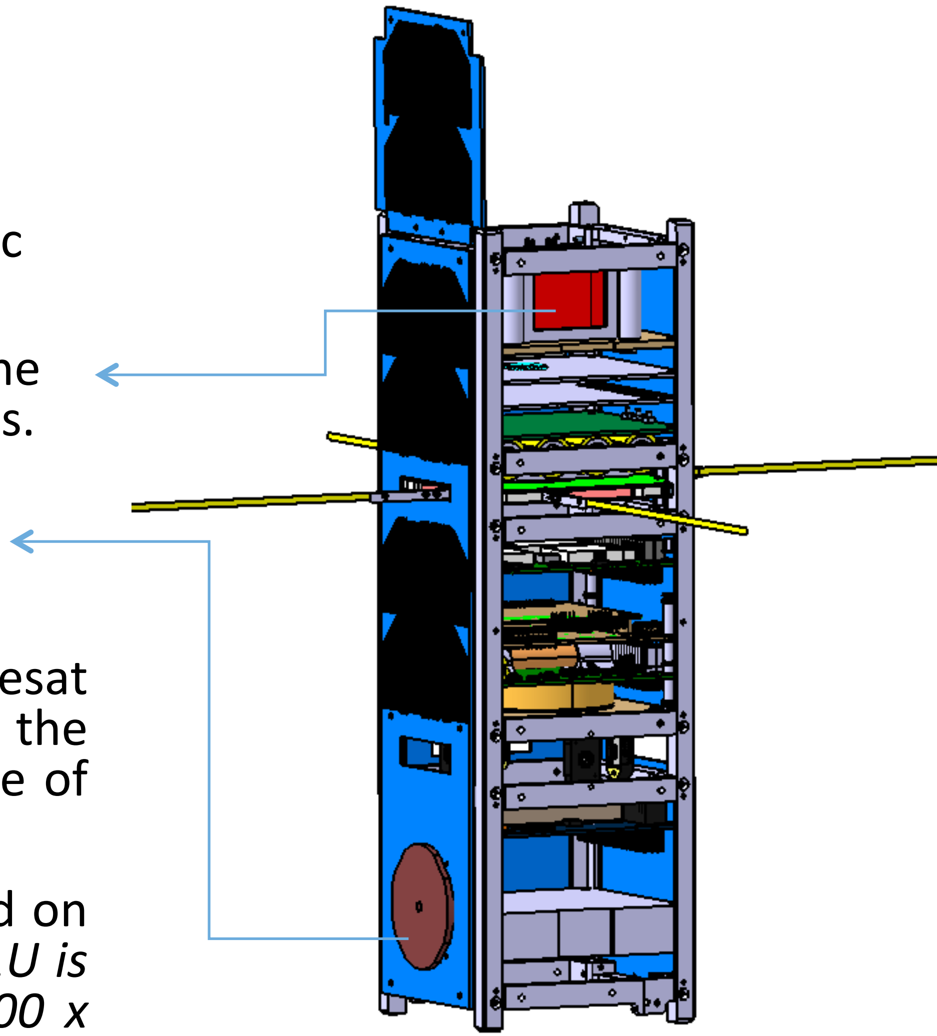
Introduction (4)

IGOSat consists two payloads corresponding to the two main scientific missions:

- A Scintilator payload for measuring the spectrum of gamma-ray and electrons.
- A Dual-frequency GPS payload for measuring Total Electronics Content (TEC).

These payloads will be hosted in a cubesat platform in a near polar orbit (with the inclination of about 97°) at the altitude of about 650 km.

The iGOSAT is a 3U nanosatellite based on the U-class spacecraft standard *(with 1U is a CubeSat Unit which has a size of 100 x 100 x 113.5 mm and a mass of 1.33 kg maximum)*.

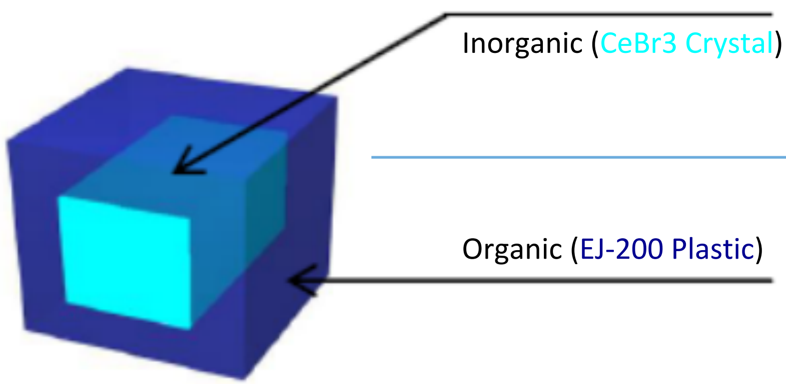


The iGOSAT latest design

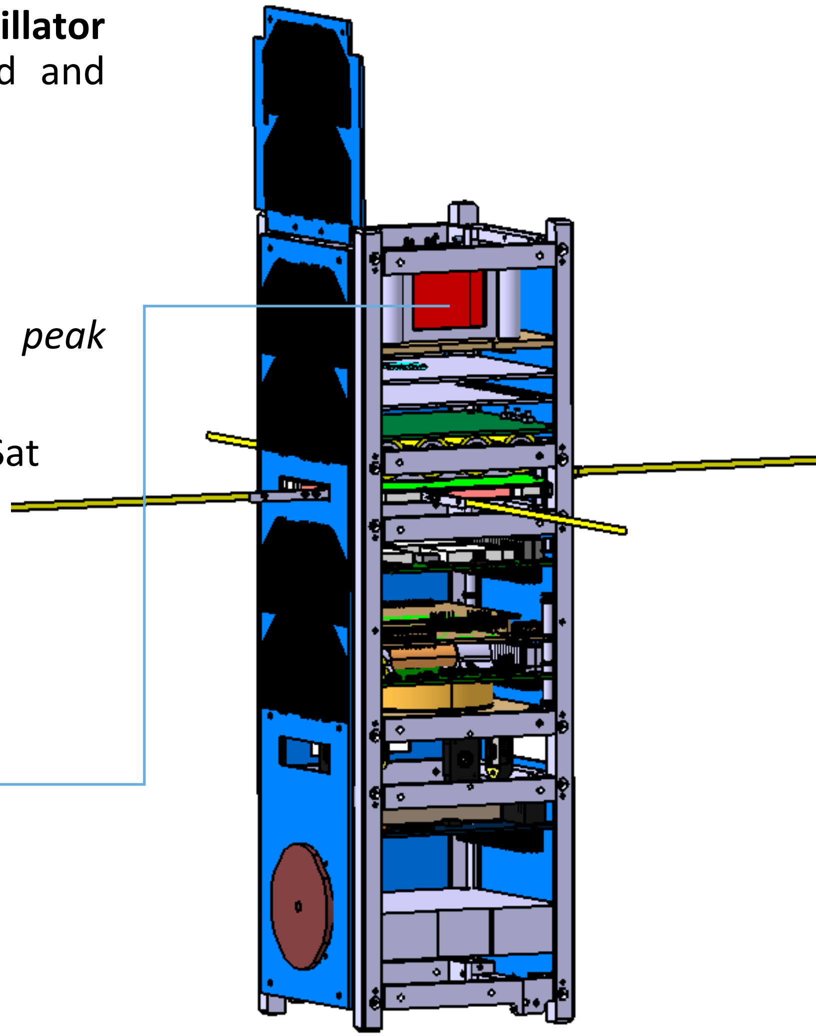
The Scintillator Payload

The Scintillator payload is composed of a **Crystal scintillator (inorganic)** and 5 **Plastic scintillators (organic)** surround and readout by a 4x4 MPPC and 10 single SiPMs.

- ✓ *CeBr3 emission wavelength: 380 nm*
- ✓ *EJ-200 max. emission wavelength: 425 nm*
- ✓ *The SiPM spectral response range: 320 – 900 nm, peak sensitive wavelength: 450 nm*
- The position of the payload is at the top cube of the IGOSat satellite.



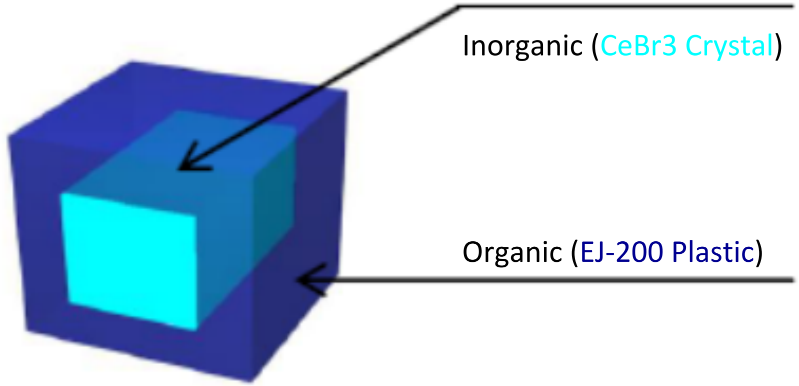
The Scintillator concept

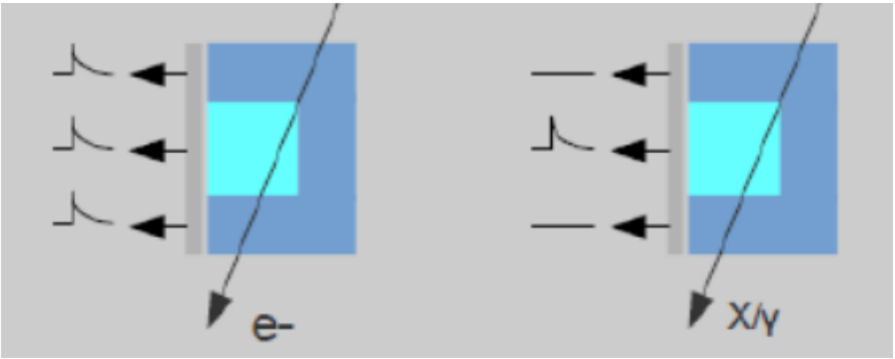


The Scintillator Payload

The gamma-rays and electrons interact with matters inside the scintillators and then emit the luminosity photon which will be captured by the MPPC.

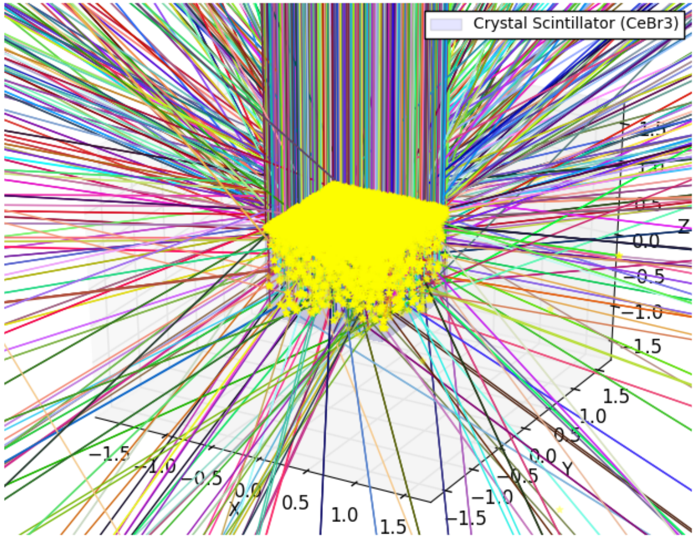
- When a high energy particle pass or is absorbed by a scintillator, it loses its energy and produces fluorescence. The longer the path is, the more fluorescence photons are produced.
- The Crystal part can detect gamma rays from 20 keV to 2 MeV while the Plastic scintillator can discover electrons from 1 MeV to 20 MeV.
- Since the CeBr3 can detect both gamma rays and electrons whereas the plastic scintillator can detect solely electron particles, the combination of two scintillator types is needed in order to discriminate these two kinds of particles.

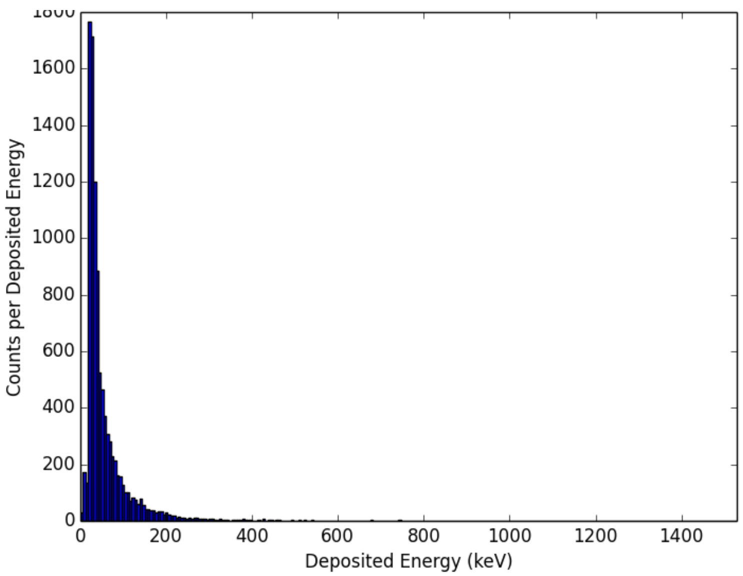


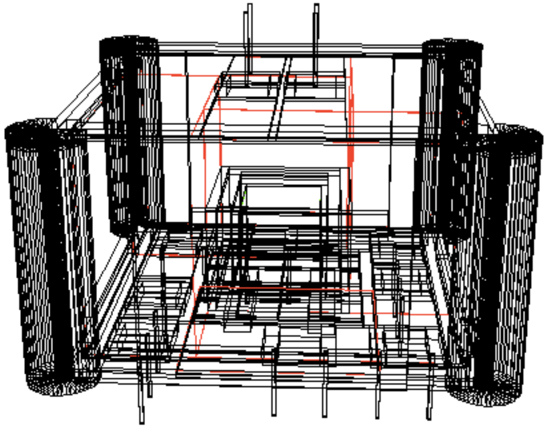


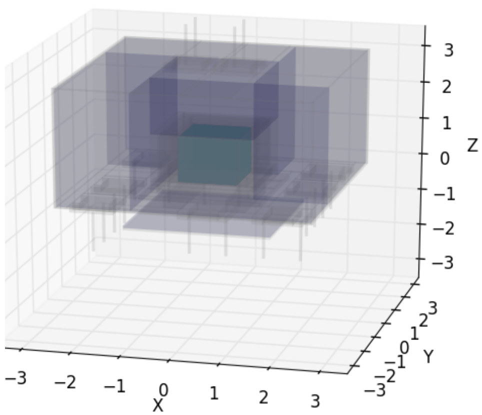
Simulation

- **Simulation with MegaLib:** Provides the sizing of the Scintillator, size of the shield. MegaLib is a GEANT-4 based simulation toolkit for particle physics. Inside Megalib, we use these build-in softwares:
  - Geomega: defines the geometry of sensors and the satellite for the simulations.
  - Cosima: defines the characteristics of the simulations.
  - Simulations were applied to each scintllator type and to the whole payload, with each energy level, or with the known model.

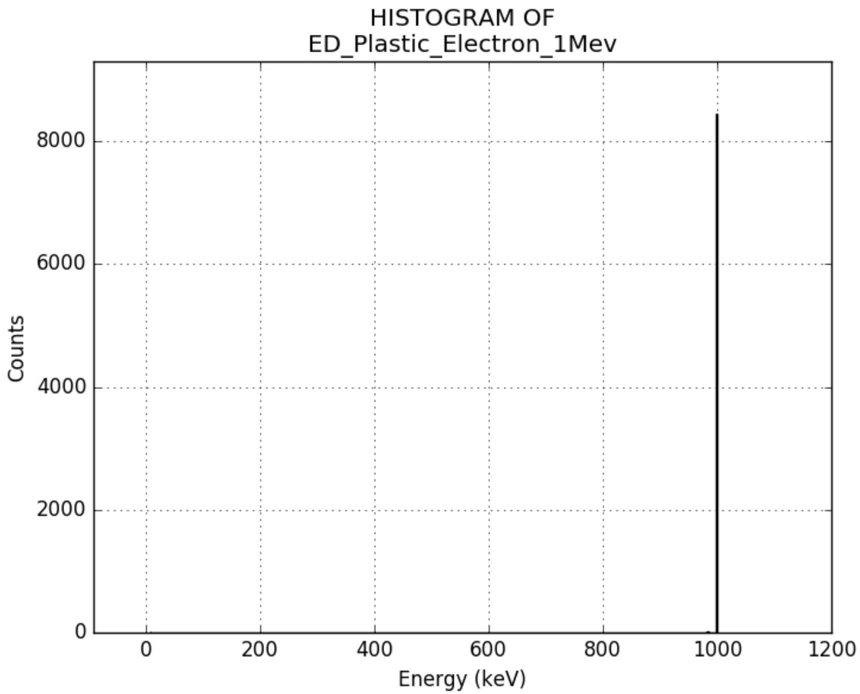


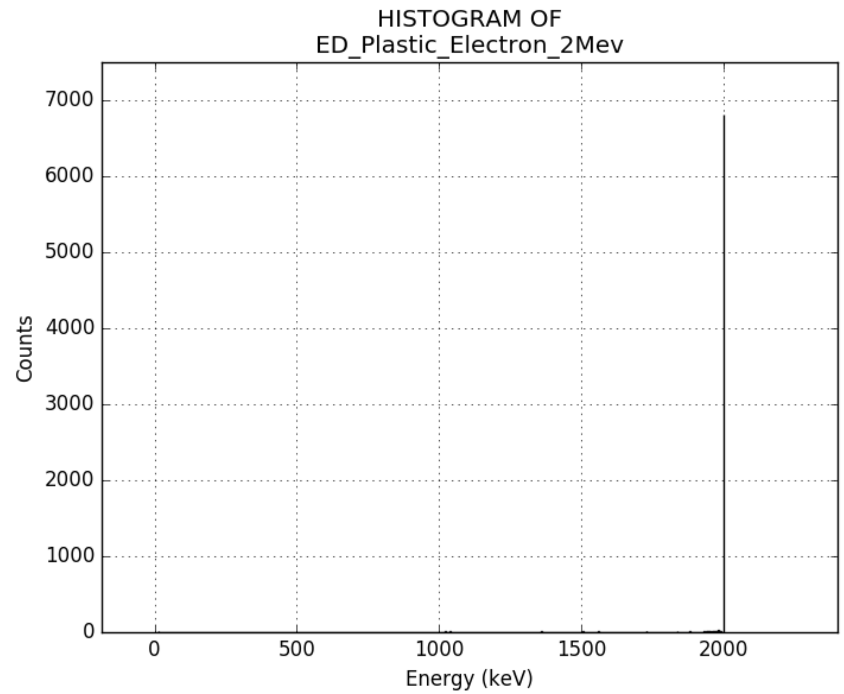






Simulation: Plastic EJ-200

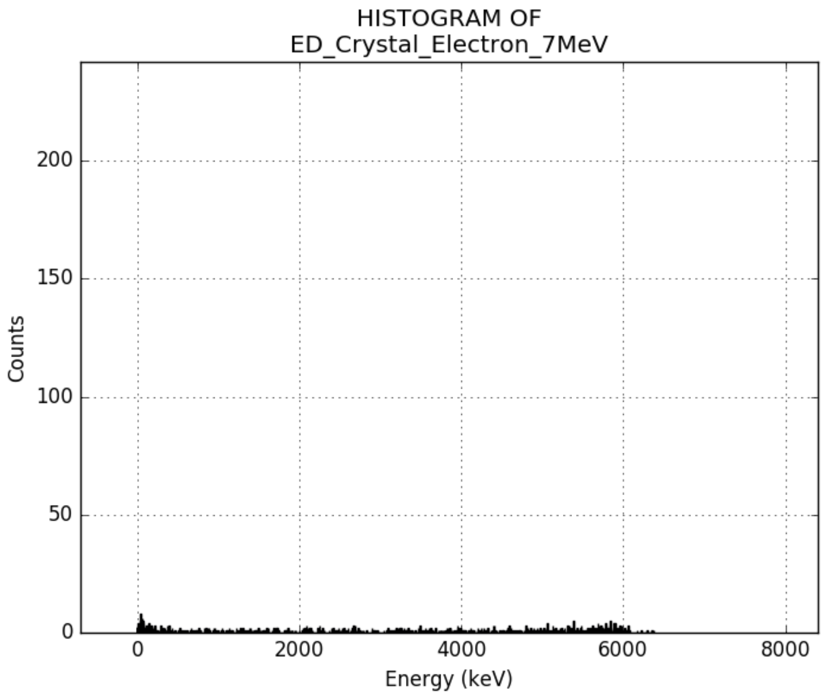


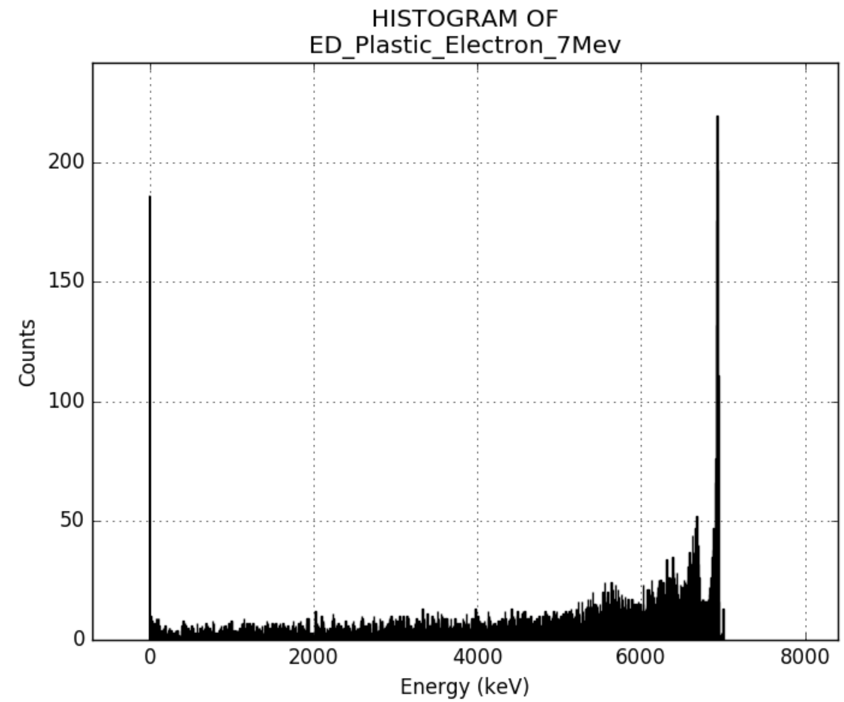


Electron flux of 1 MeV
Plastic_Only: 10000 events
Total event:10000 events / 2867065
Simulated events.

Electron flux of 2 MeV
Plastic_Only: 10000 events
Total event:10000 events / 2877983
Simulated events.

Electron flux of 7 MeV, flux direction: -z, 0.6 mm Tantalum + 0.6 mm Aluminium Shield





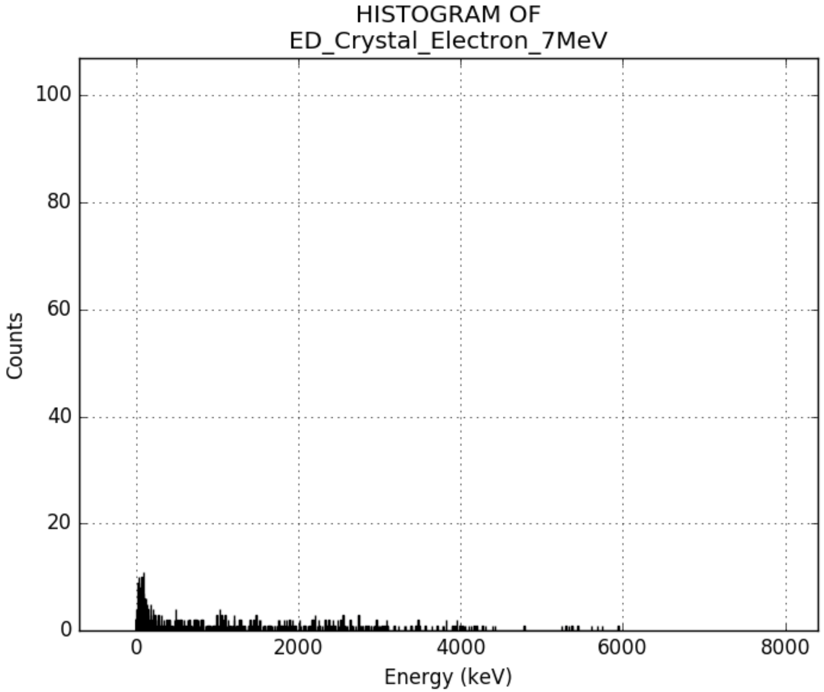
Crystal_Only: 356 events

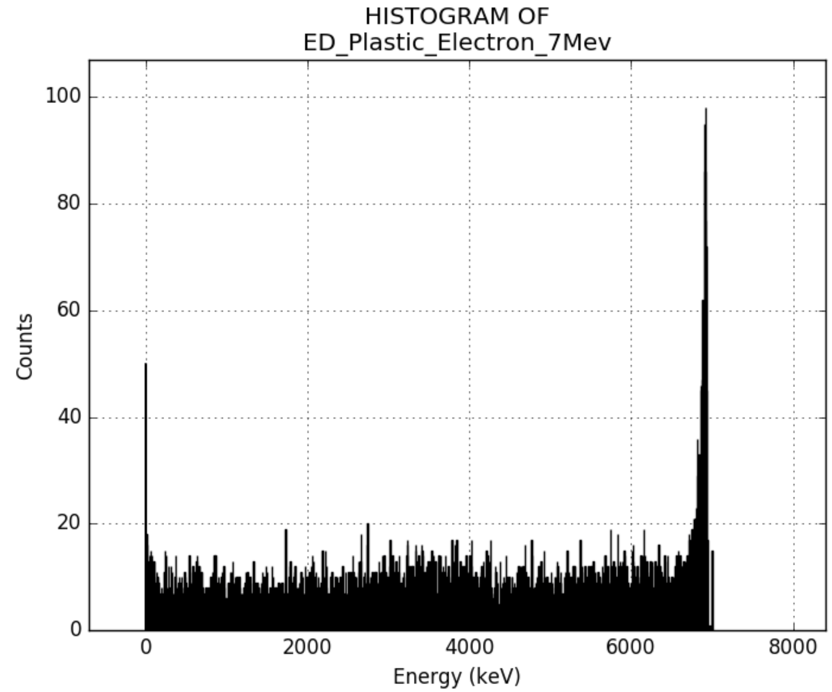
Plastic_Only: 9245 events

Both Plastic and Crystal: 399 events

Total event:10000 events / 454946 Simulated events.

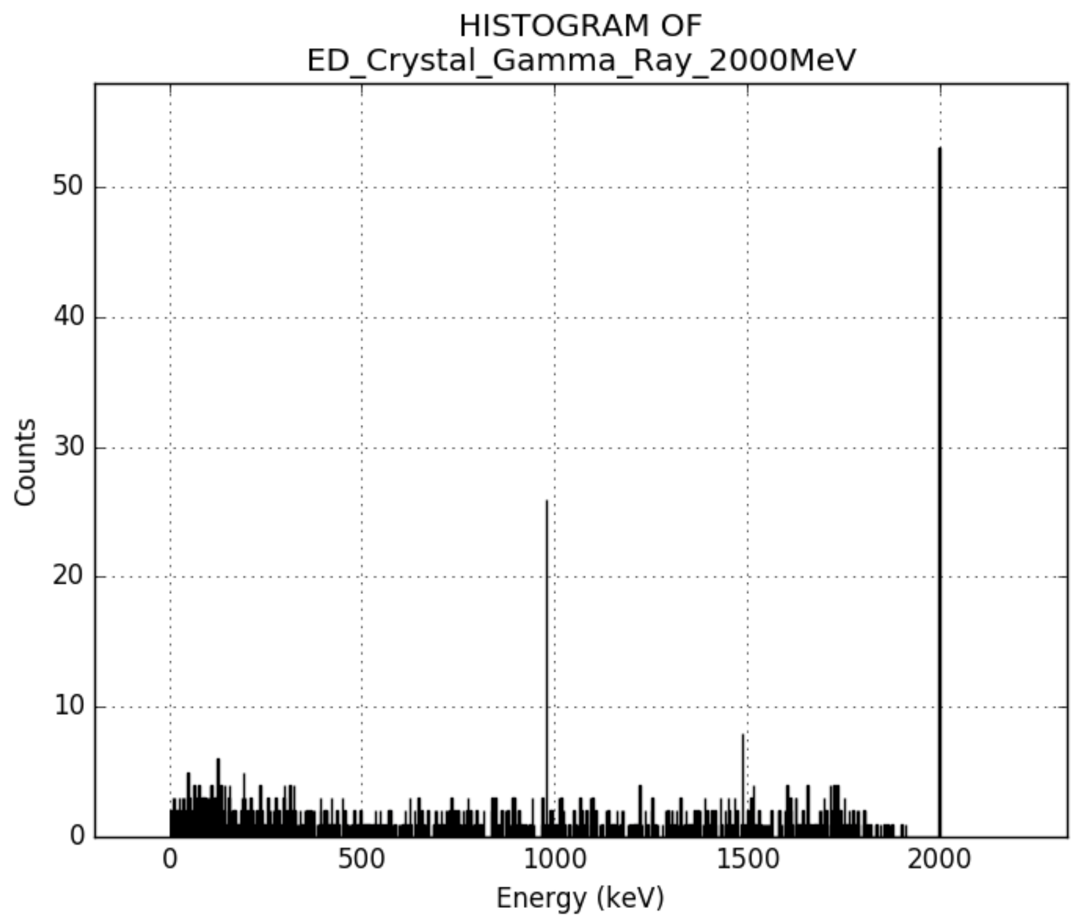
Electron flux of 7 MeV, flux direction: ISOTROPIC, 0.6mm Tantalum + 0.6 mm Aluminium Shield



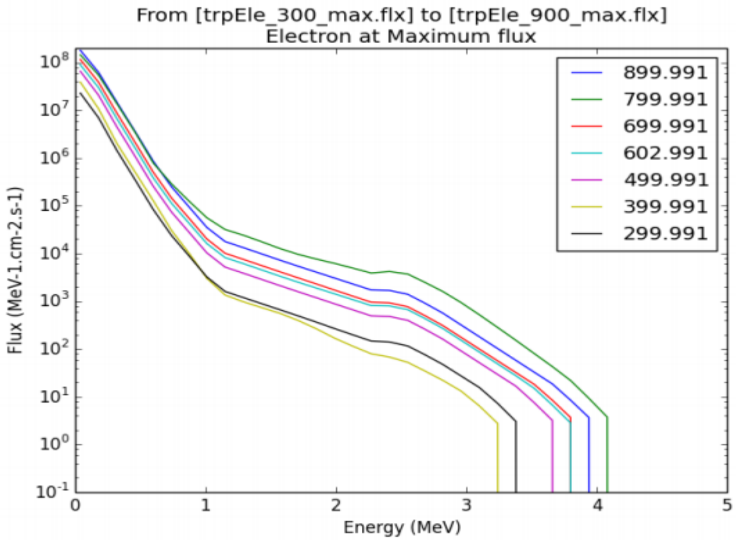


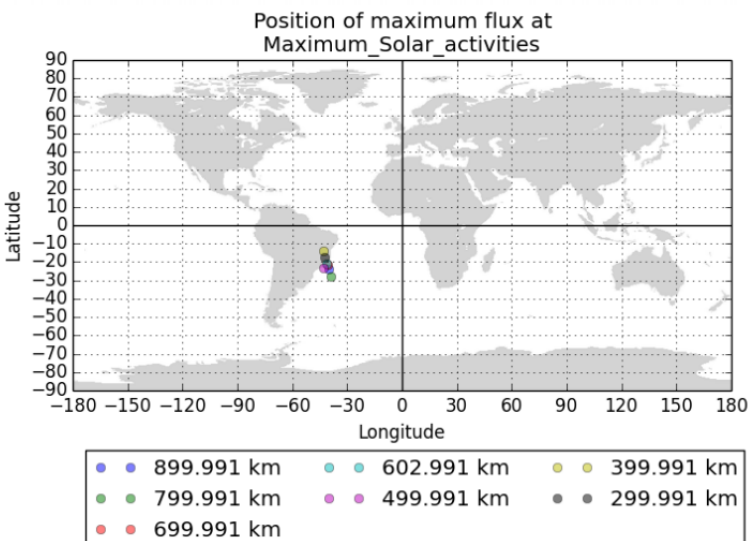
Crystal_Only: 65 events
Plastic_Only: 9452 events
Both Plastic and Crystal: 483 events
Total event:10000 events / 474815 Simulated events.

Gamma ray flux of 2 MeV, flux direction: -z, 0.6 mm Tantalum + 0.6 mm Aluminium Shield



Simulation: OMERE data



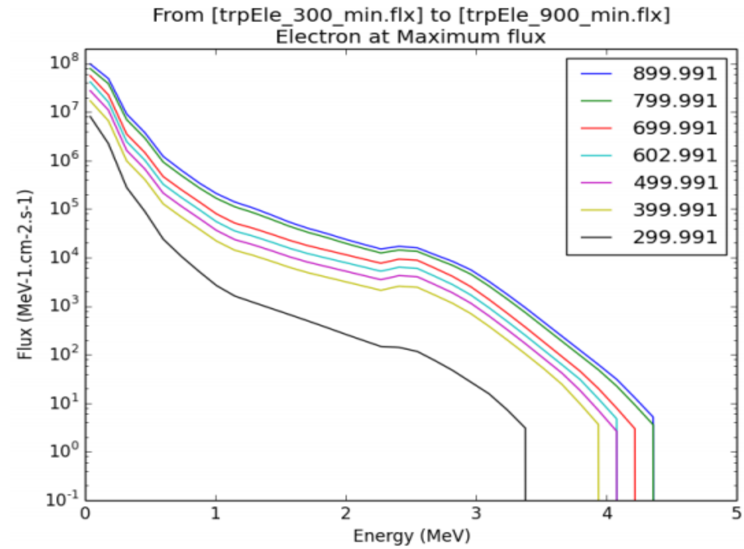


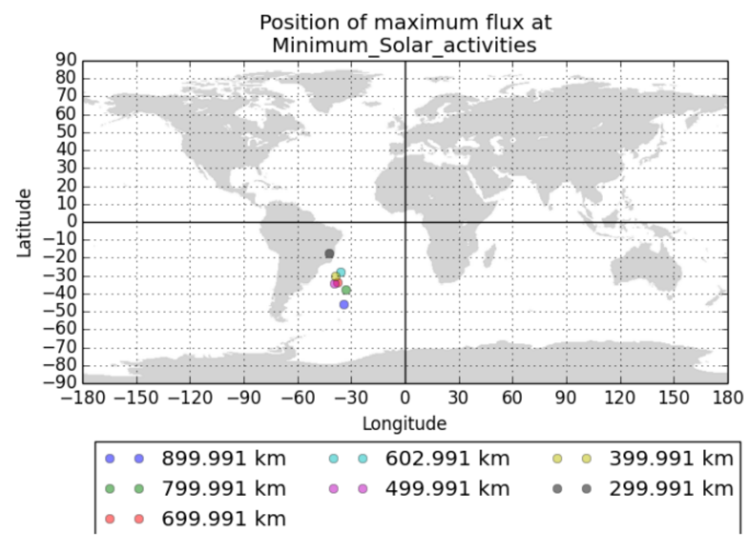
Analyse with electron data from OMERE.

The altitude: from 300 km to 900 km.

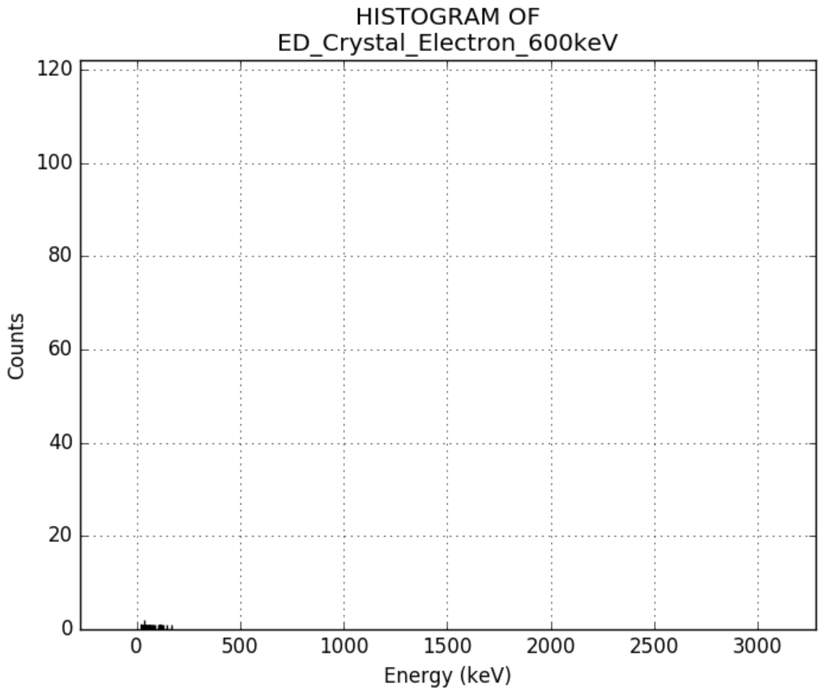
Left: Max. Solar activities

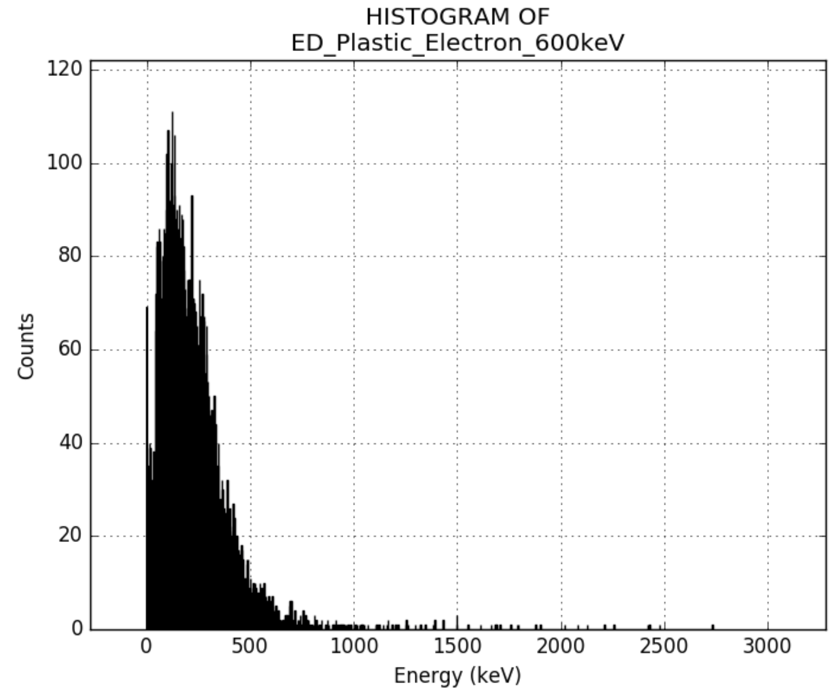
Right: Min. Solar activities





OMERE 600 km, Max. Solar activities flux direction: -z, 0.5 mm Tantalum Shield



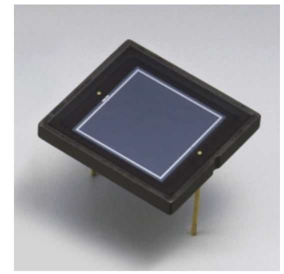


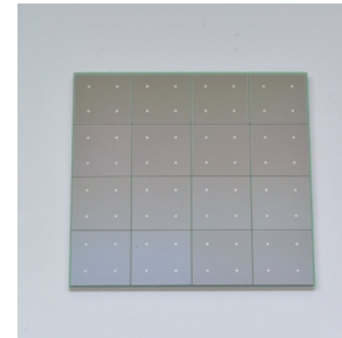
Crystal_Only: 36 events
Plastic_Only: 9959 events
Both Plastic and Crystal: 5 events
Total event:10000 events / 11667574 Simulated events.

The Scintillator Payload

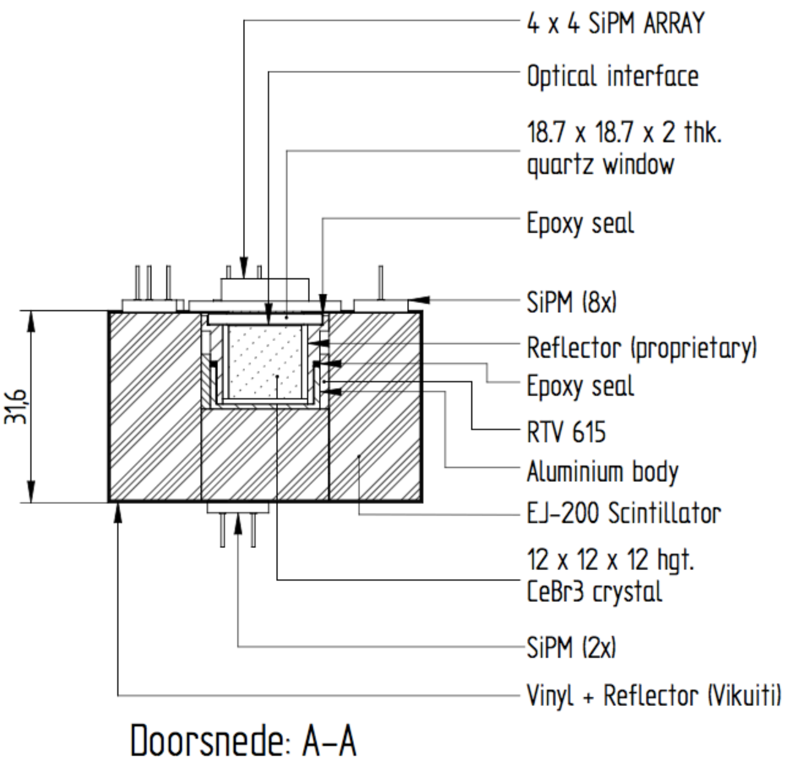
The latest design of the Scintillator

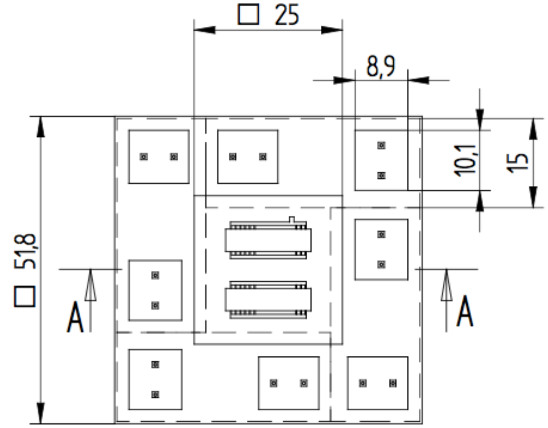
- 1 x Crystal Scintillator CeBr3 → 1 x MPPC 16 chanel (4x4 matrix, 4 central chanels for detection, 12 surround chanels for readout noise)
- 5 x Plastic Scintillator EJ-200 → 10 x single SiPM

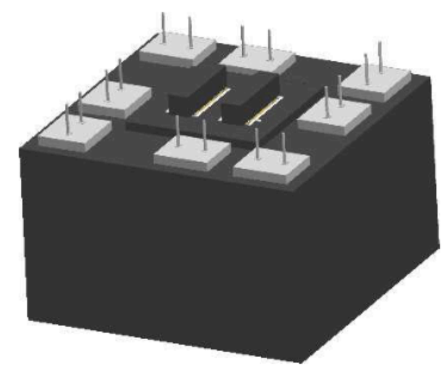




Single **SiPM** for Plastic Scintillators and **4x4 MPPC** for Crystal Scintillator



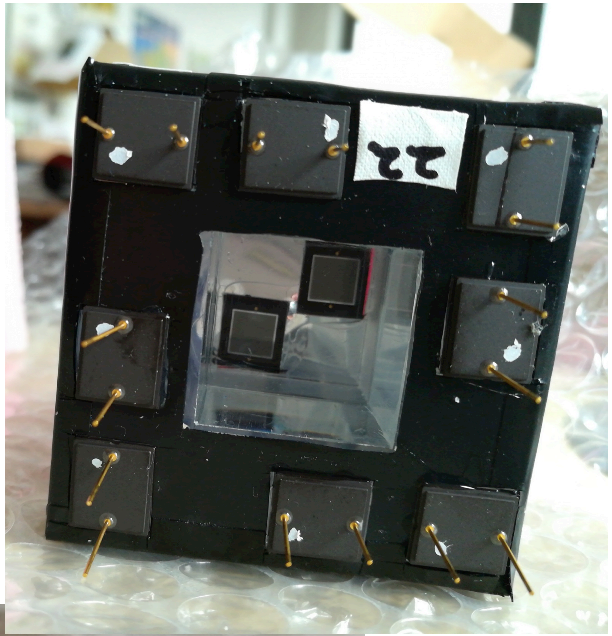


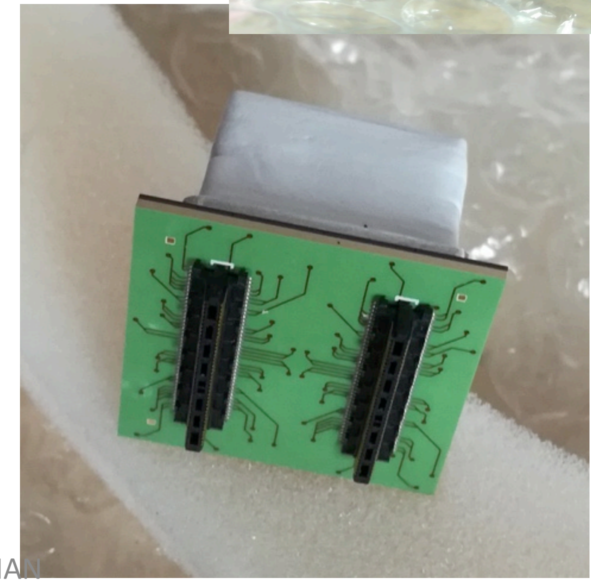


The Scintillator Payload

The Prototype of the Scintillator

- 1 x Crystal Scintillator CeBr3 → 1 x MPPC 16 chanel (4x4 matrix, 4 central chanels for detection, 12 surround chanels for readout noise)
- 5 x Plastic Scintillator EJ-200 → 10 x single SiPM



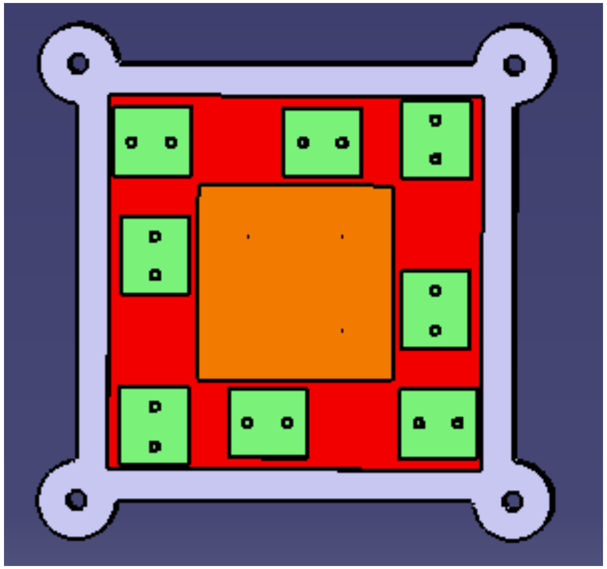


The Scintillator Payload

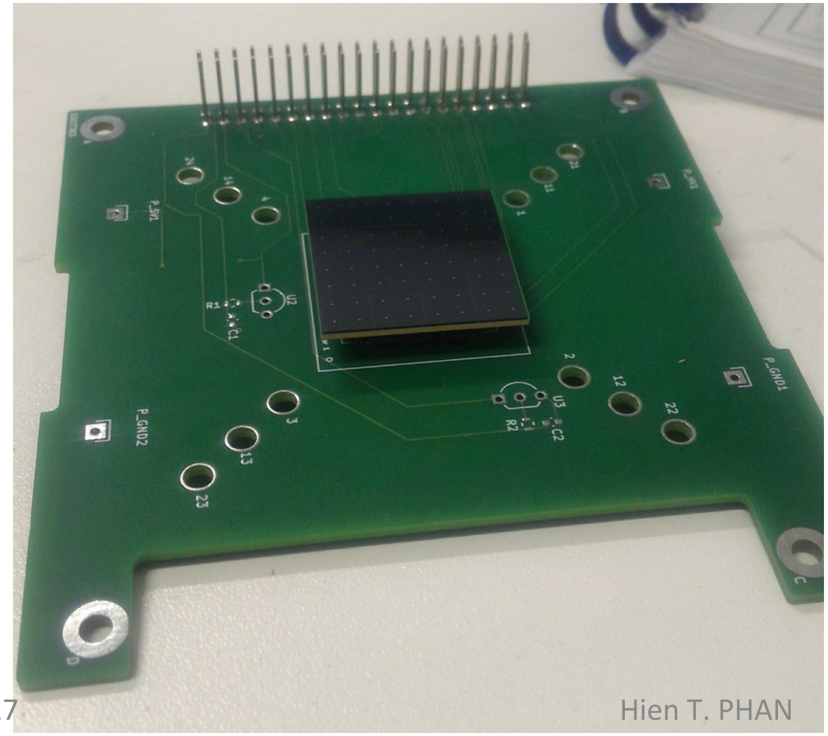
The Cage: Made by Aluminium with the thickness of 2 mm, covering the edges of scintillator and leave windows at the sides for the incomming particle.

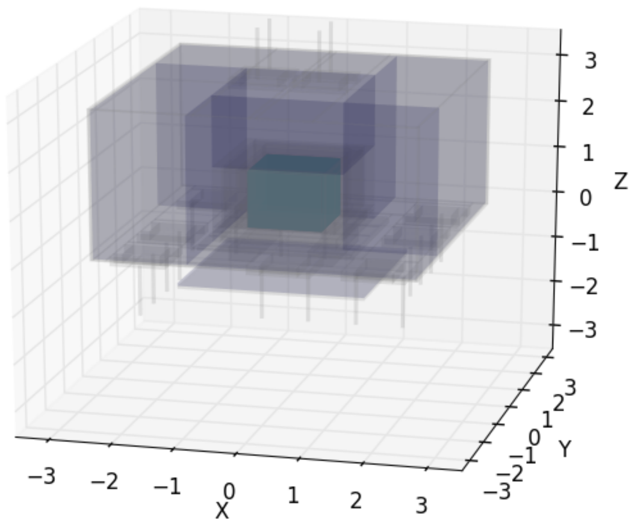
The Shield: Containing 2 layers of metal: Tantalum: 0.6mm and Aluminium: 1~2mm.

The scintillator is plugged to the **Support board**, which has connectors for all SiPMs and MPPC. Signals from the scintillator are transfering to the EASIROC board through this support board.



SCINTILLATOR SIMULATION



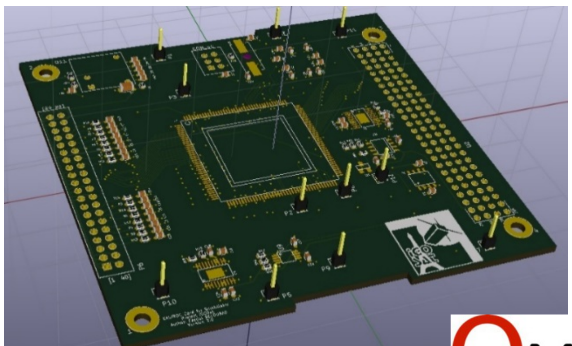


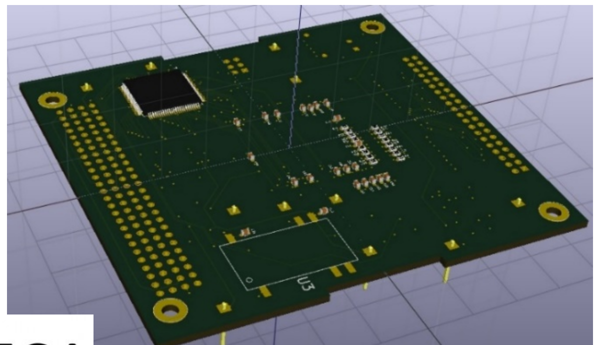
The EASIROC Board

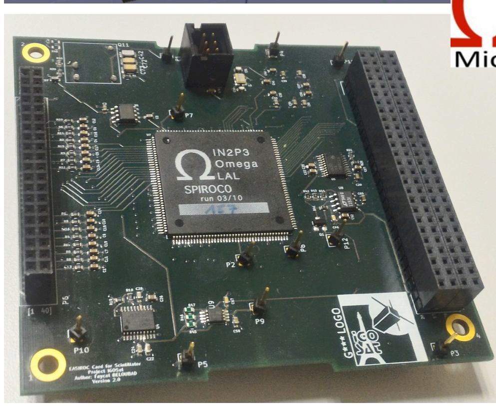
Receive the signal from SiPM and convert it in a comprehensive language for the computer, and then, it send data to the OBC (On Board Computer).

EASIROC Chip:

- electronic component made for particle physics in accelerators;
- 32 inputs (26 needed).





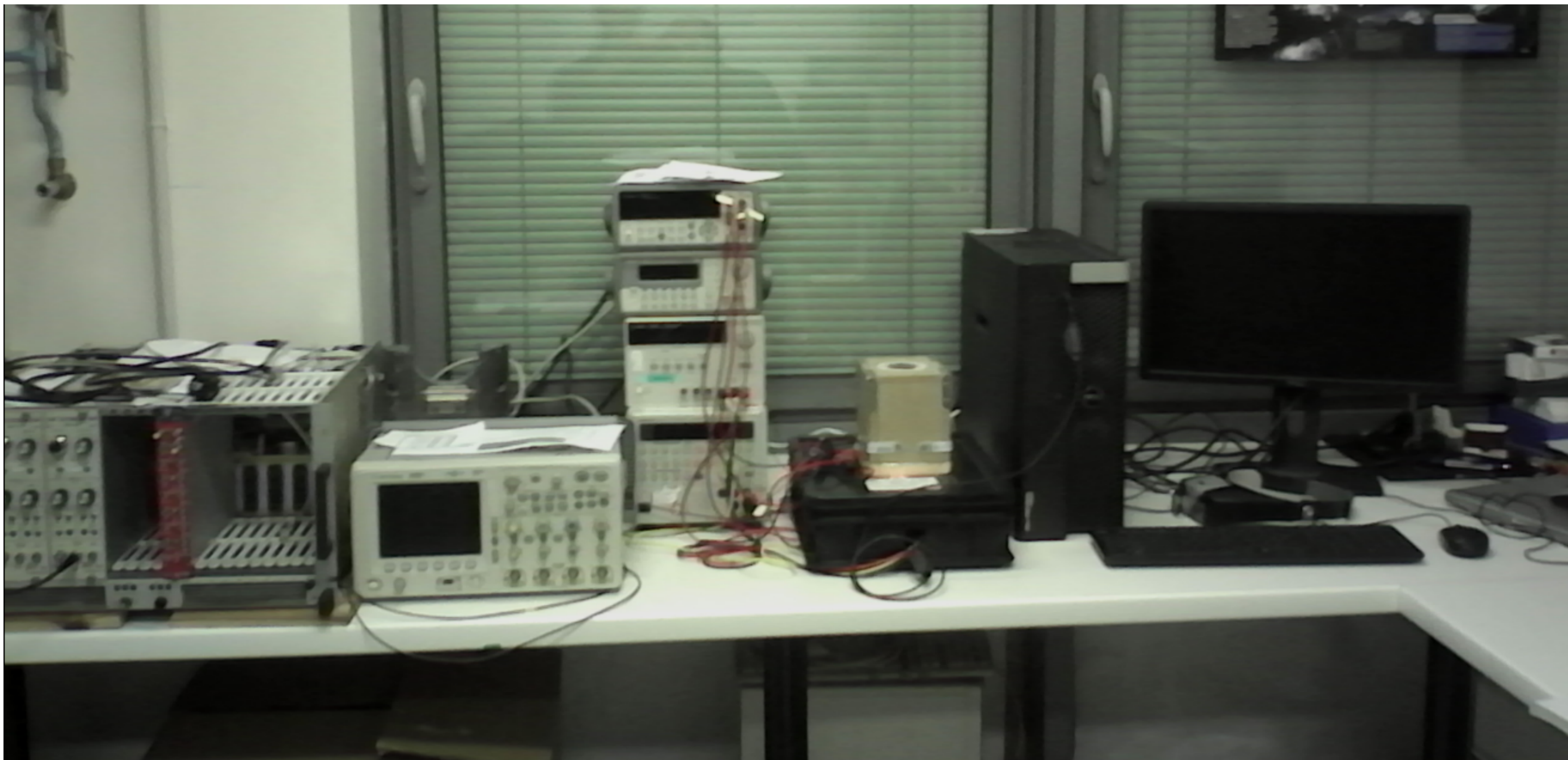


Scintillator

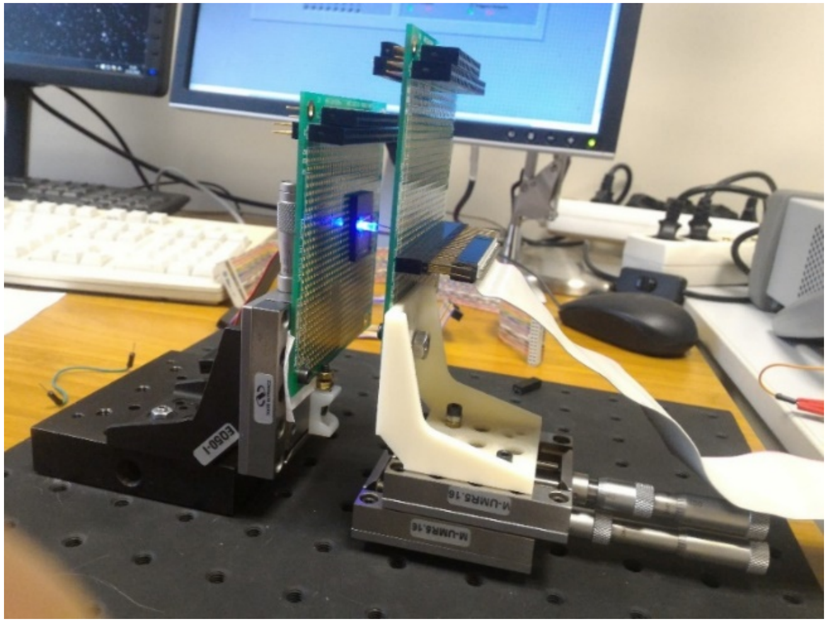
- Scintillator board
  - Crystal: **CeBr3** from SCIONIX
  - Plastic: **EJ-200** from SCIONIX
  - SiPM/MPPC: **S13361-6050AE-04** from HAMAMATSU
- EASIROC board
  - EASIROC chip
  - HV conversion
  - Microcontroller

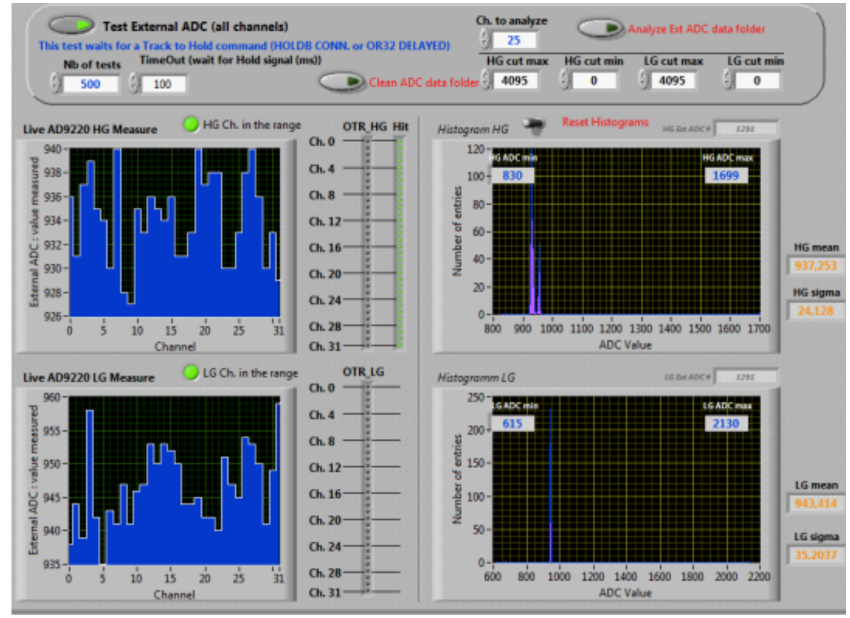
Test bench

- Aimed to test the performance of the MPPC, the test bench was set up with a blue LED (it is near the wavelength of the scintillation photons) and a MPPC sticking on the translation system (allows us to change the position of the LED pointing to every pixels of the MPPC). All of them were put in a black box.

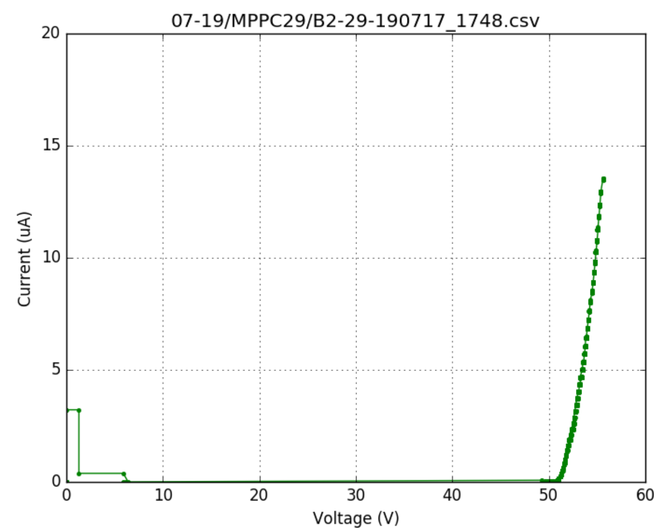


Test bench



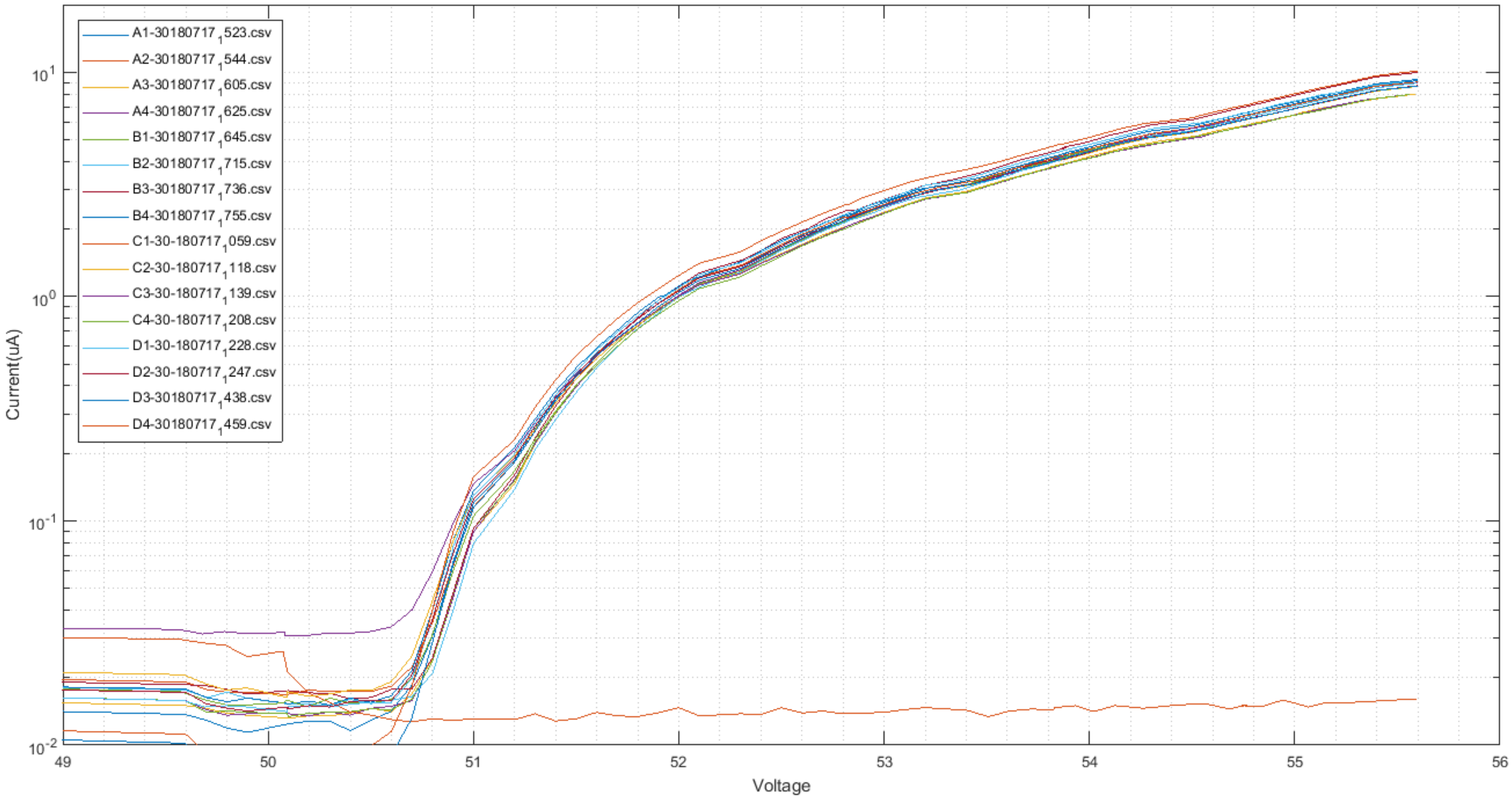


Data from EASIROC board is analyzed by a LabView program. From that, we could confirm the characteristic of SiPM.

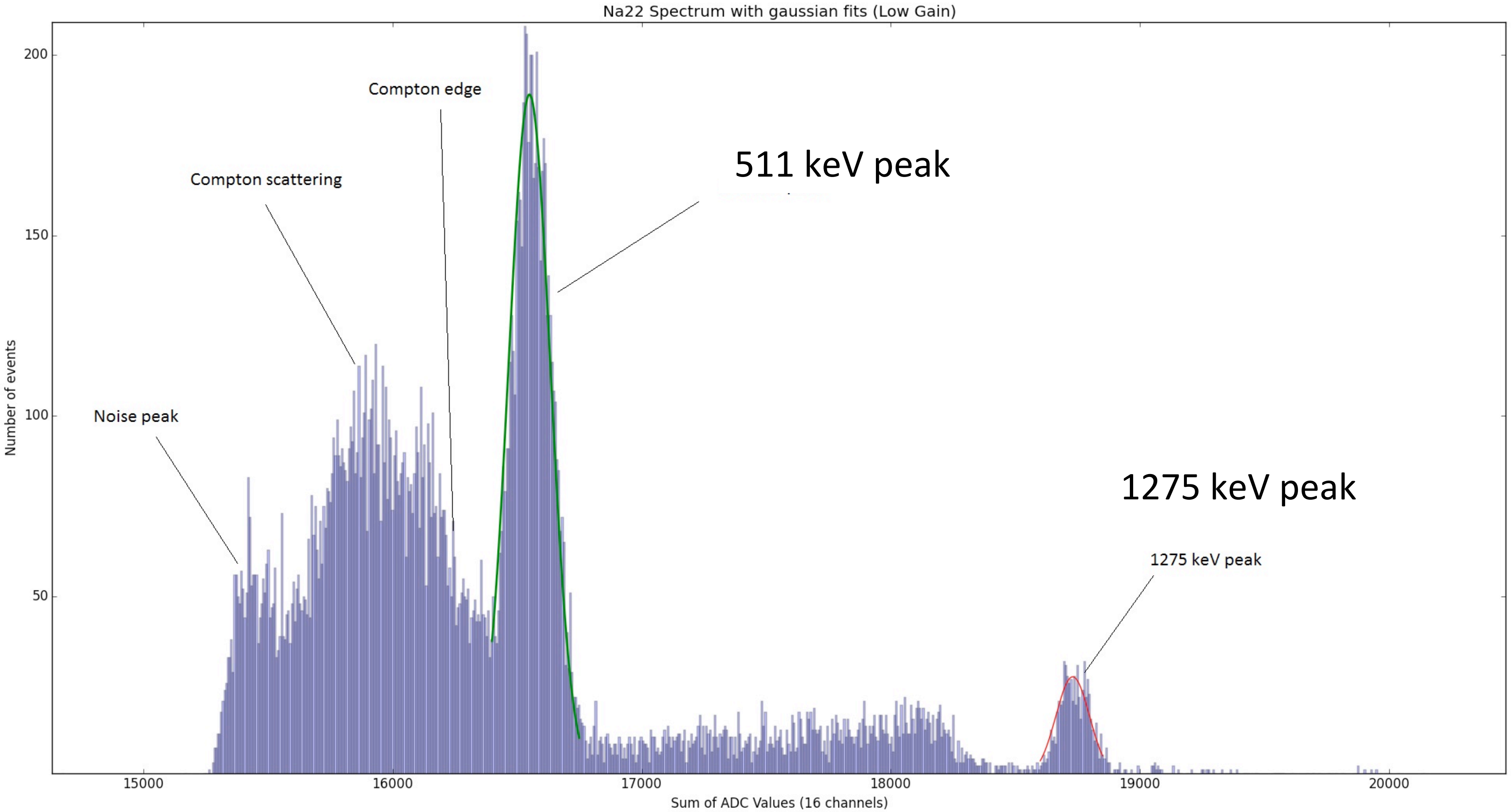


Test bench

I-V characteristics of individual pixels under illumination



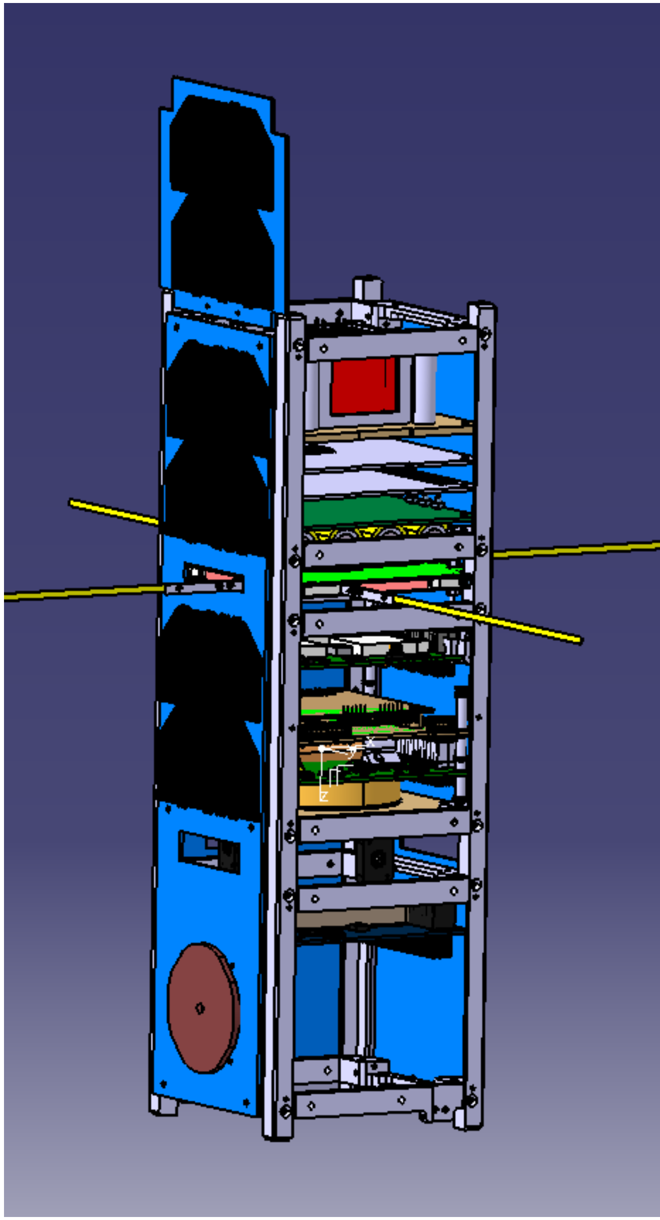
Test bench



Spectrum of Na-22 for Low Gain. The peak corresponds to the 511 keV peak and 1275 kev peak of Na-22. (Tested by Mathieu Leverge, 2016)

Summary

- The Scintillator's prototypes are available at the lab. In the next step, we will able to test the performance of the scintillator and the other component of the payload.
- The measurements with the radioactive sources will be made in laboratory. The results will be used to compare to the one of simulation.
- The Scintillator Payload will make measurements which will complete past measurements of Low Earth Orbit electrons and photons content, and will also be useful for Space Weather applications.
- This payload is a technological challenge as the CeBr3 Crystal and MPPC have never been used in a satellite in space for gamma-ray detection.
- After having completed its observations, the satellite should re-enter the Earth's atmosphere within 25 years from its launch.



The IGOSat team (2017)

Thank you for your attention!