DO MIRA_ep CUBESAT DETECTORS ALLOW TO DISTINGUISH BETWEEN ELECTRON AND PROTON CONTRIBUTION: A GEANT4 MODELLING APPROACH

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OVERVIEW

Particle dynamics in both Van Allen electron belts is one of significant component of space weather. The latest CubeSats are equipped with particle recorders with a habitual quantity of energy ranges of < 10 (CSSWE, FIREBIRD-II), while solid-state detectors composing these instruments are capable to register spectra of much higher energy resolution.

We present a concept of the instrument with a similar quantity of energy channels but all the detectors in the telescopic system are based on the organic *p*-terphenyl single crystals.

The miniaturized recorder-analyzer MiRA_ep is aimed to study the nature of charged particles microbursts at LEO. The functional diagram, a description of the modules and the technical characteristics of the MiRA_ep instrument are shown.

We present the results of the deposited energies simulation caused by electron and proton passage through the *p*-terphenyl sensors. A conclusion on the effective particle energy ranges and the possibility to distinguish electrons and protons in the proposed instrument is made.

1. Scientific tasks of the experiment with a MIRA_ep instrument

1. Verification of the existence of additional inner electron radiation belt at $L \sim 1.6$ for particles with energies from tens of keV to $E \sim 0.5$ MeV in geomagnetically quiet conditions;
2. Determination of the energy spectra of particles in stationary radiation belts and in microbursts outside of the belts;
3. Determination of the degree of anisotropy for directions of the electron velocities in the midpoint of the radiation belts and in micro splash at the edges of Van Allen belts and beyond belts during solar, magnetospheric and ionospheric activities.
4. Search and identification of distinctive features between micro-bursts of electrons generated due to magnetospheric, solar and interplanetary activities, and bursts correlated with seismic activity.

2. Brief description of the MIRA_ep instrument

The MiRA_ep (*Miniaturized Registrant-Analyzer of electrons and protons*) **instrument** as a payload of the nanosatellite in a CubeSat format will comprise of three modules: detector head as well as analog and digital units (see Figure 1). Each of the modules is a separate block, which is connected with each other with cables and connectors. The DC/DC voltage converters will be installed in the analog and digital modules, which will provide these modules with necessary voltage levels.

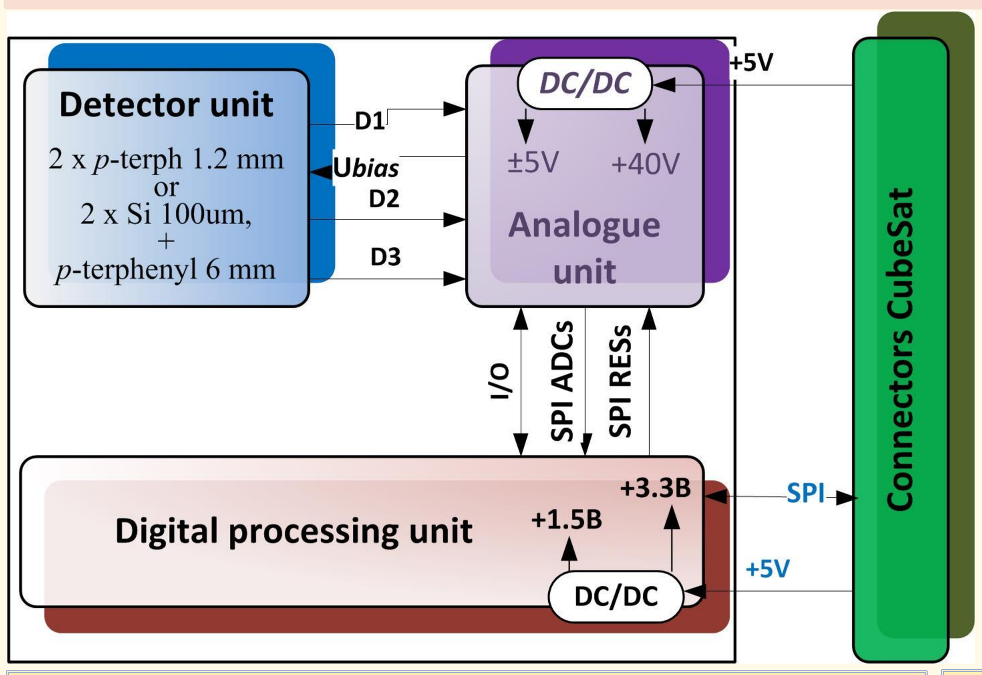


Figure 1. A structural scheme of the MiRA_ep.

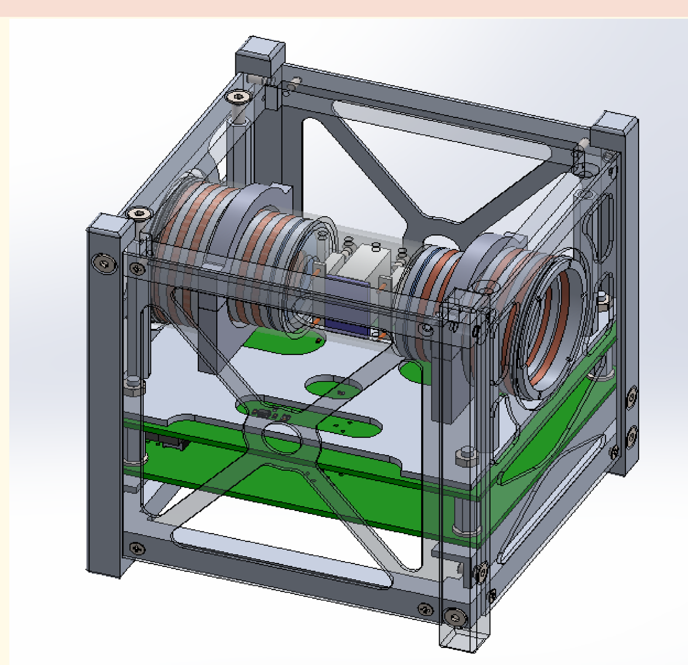


Figure 2. The MiRA_ep design view.

The p-terphenyl, doped with 1,4-diphenyl-1,3-butadiene we used as a material for sensors manufacturing of the MiRA_ep instrument (Figure 4).

The p-terphenyl single crystal was grown with the purpose to produce two thin detectors (ΔE-detectors) and a total energy absorption detector as constituent sensors of the detector head. The amount of 1.4 biphenyl-1.3-butadiene dopant was increased from 0.1 wt % (typical value) to 0.3 wt %. A cylinder of the thickness 7 mm (Figure 3) was cut out from the grown ingot at right angles to the growth direction of the single crystal.

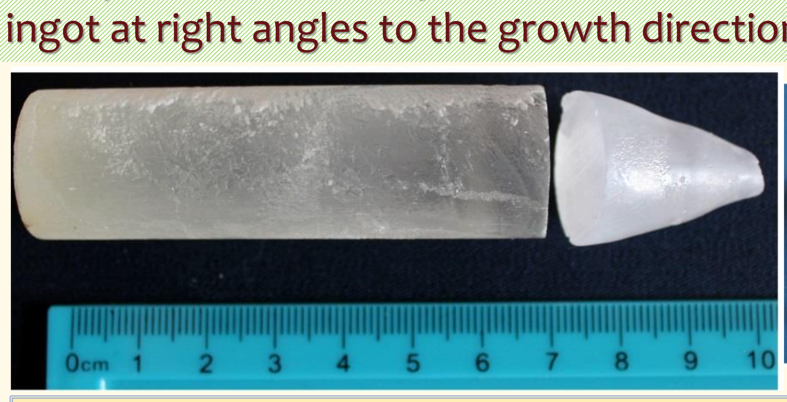


Figure 3. An ingot of the *p*-terphenyl single crystal grown by the Bridgman method.

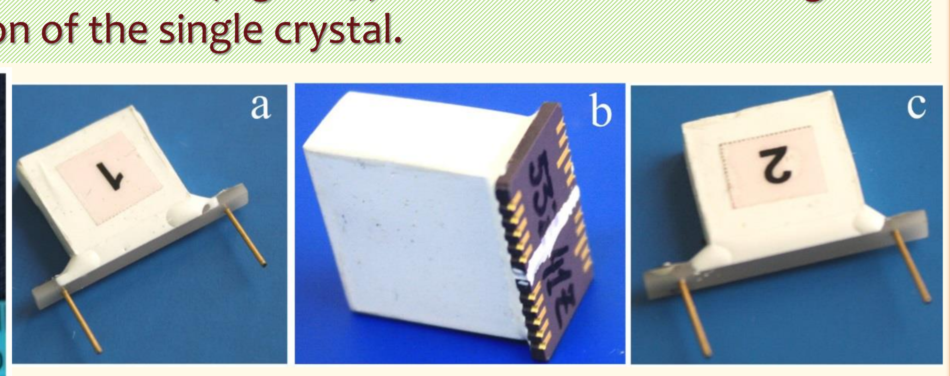


Figure 4. The *p*-terphenyl scintillation detectors of the MiRA_ep instrument.

3. Scientific and technical characteristics of MiRA_ep

№	Parameter	Value
1	Field of view	34°
2	Geometry factor	0.76 cm² x ster
3	Sorts and energy ranges of charged particles: electrons protons	 0.2 – 4.0 MeV 3.5 – 40.0 MeV
4	Quantity of directions for measurements (0 - 180°)	2
5	Quantity of energy channels for each sort of particles (*for each of two directions*)	5
6	Quantity of energy channels without definition of particle sort (*for each of two directions*)	5
7	Minimal temporal resolution for particle registration	0.1 s
8	Total information content	66 MB/day (averaged 6370 bits/s)
9	Total information content with scientific data	796 bytes
10	Duration of output frames formation	1 s
11	Weight	< 850 g
12	Power Supply: average Peak	 0.7 Watt 1 Watt

4. GEANT4 simulation of the instrument

We recreated the whole geometry of the detector (Figure 5): aluminium filter (thickness: 100 μm), collimators and *p*-terphenyl detectors. To obtain response of detectors, we used planar source covering the whole entrance window of the instrument. Particles of the source fell at the right angle and their distribution on the entrance window was assumed uniform. The number of incident particles was selected to be 10^6. We used G4EmLowEPPhysics physics list.

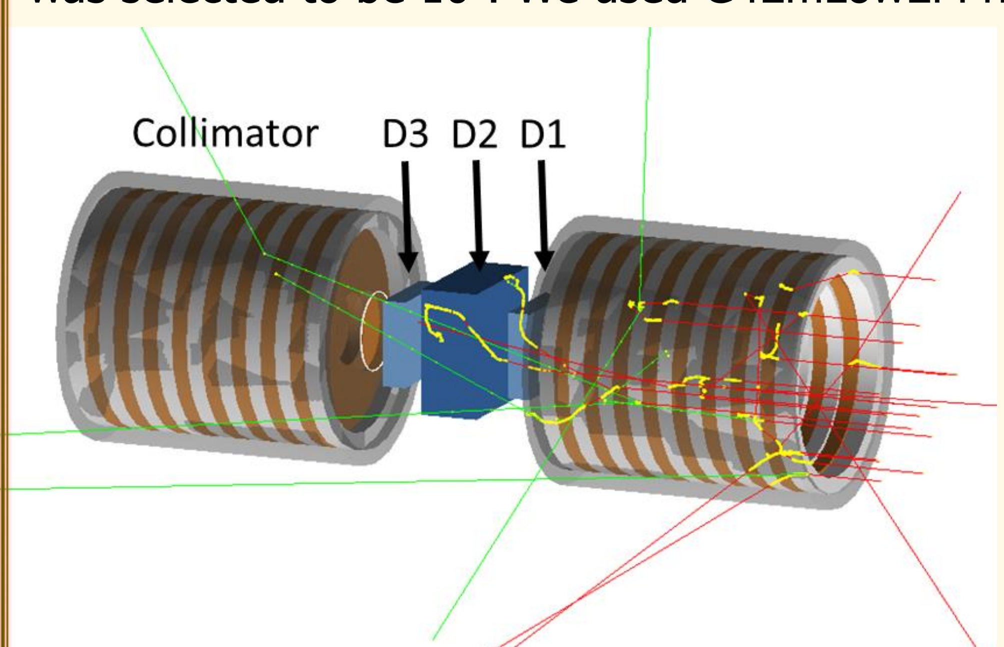
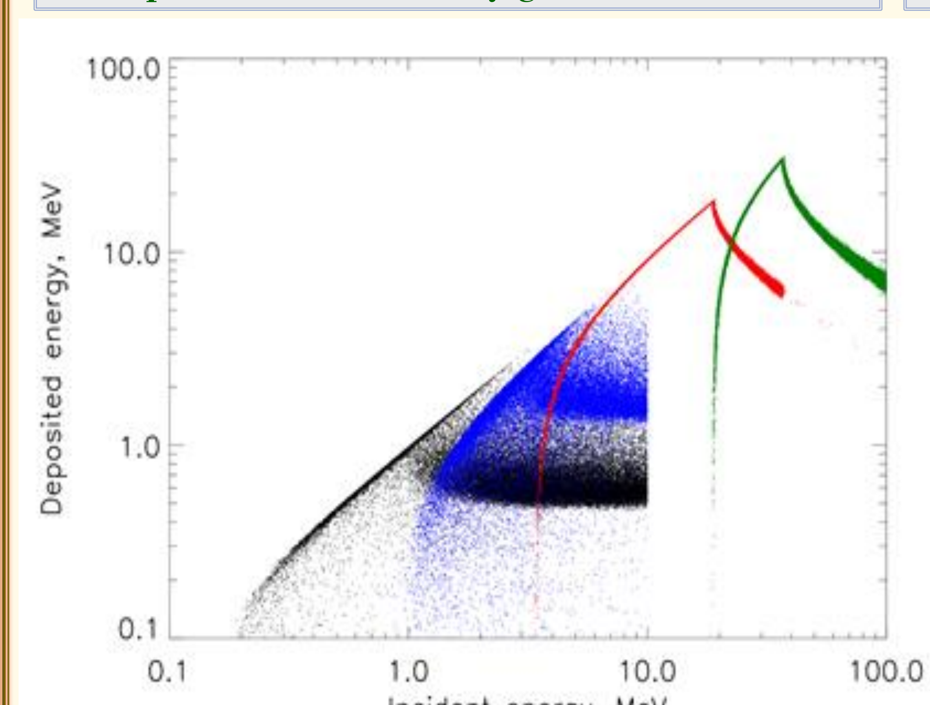


Figure 5. Electron tracks are presented by red color, photon's tracks are by green color .

Figure 6. An artistic view of the detectors head of the MiRA_ep instrument.



Results of detection capability modelling (Figure 7) shown that detector D1 measures electrons (black dots) up to 1.5 MeV, but it becomes transparent above 1 MeV. Most of the electrons with energies lower than 200 keV are stopped by the aluminum foil. For electrons with energy above 4 MeV, the second detector D2 becomes transparent.

Figure 7. Counts of MiRA_ep detectors. Black dots represent counts of electrons in D1 detector, blue one – electrons in D2 detector. Counts of protons are presenting by red (D1) and green (D2) dots.

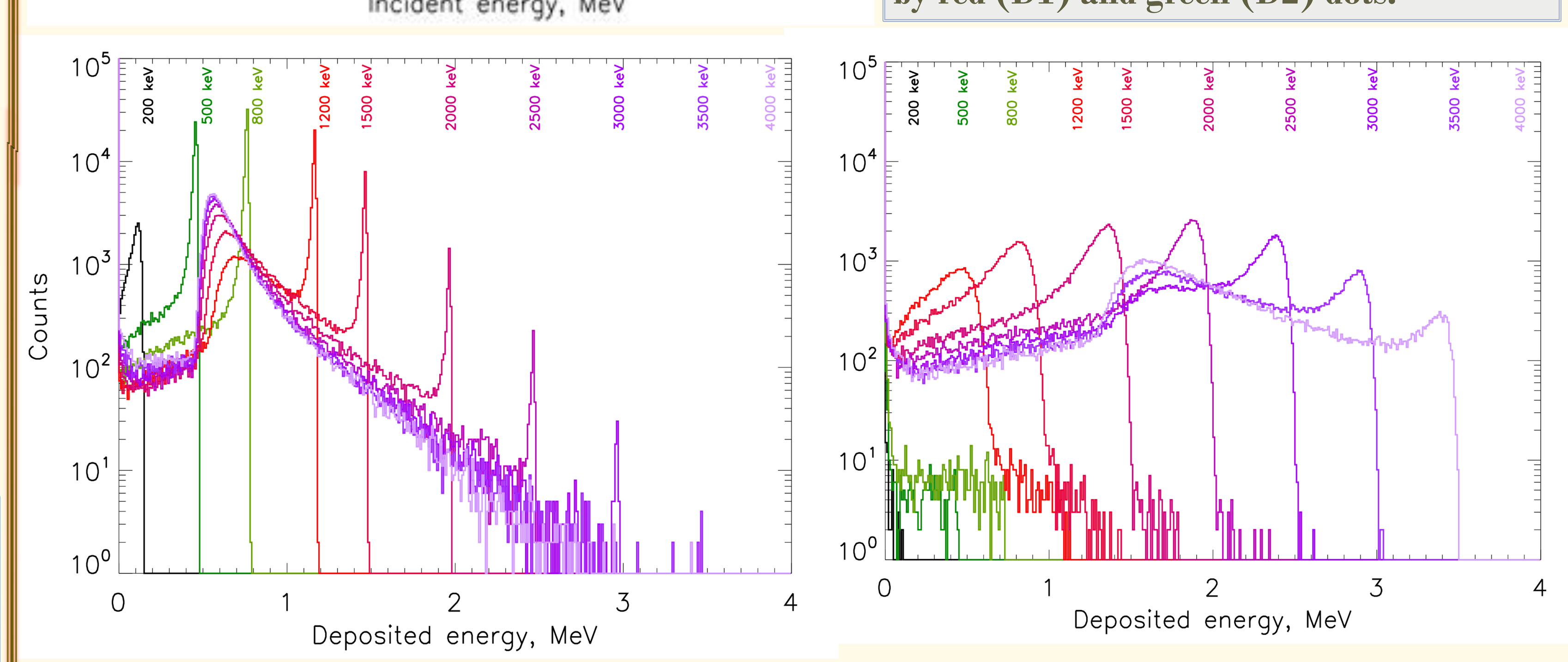
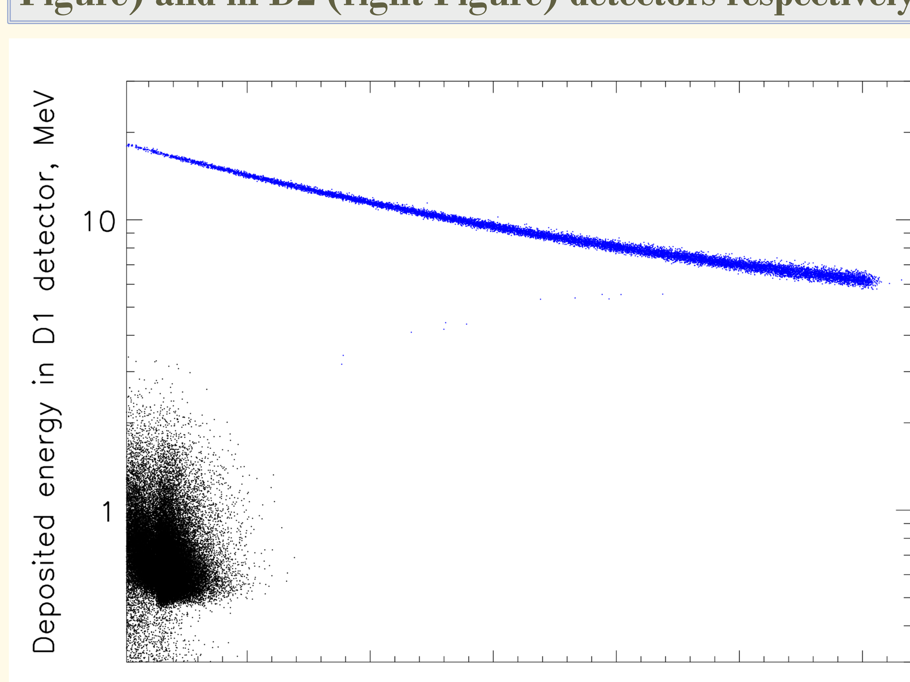


Figure 8. Spectra obtained with detectors being irradiated by monoenergetic electrons in D1 (left Figure) and in D2 (right Figure) detectors respectively.



To recognize the type of particle we need to know a dependence of deposited energies in a thin D1 detector on the deposited energies in the thick D2 detector. In Figure 9 there are shown events registered in both detectors, by black dots the electrons, by blue dots the protons.

Protons deposit much more energy to the p-terphenyl detectors comparatively with electrons in case of workable logics D1D2D3 or D1D2D3 of the MiRA_ep instrument so that electrons can be distinguished from protons very well.

Figure 9. Deposited energy in D1 detector vs deposited energy in D2 detector. Black dots presented the electrons, blue dots protons.

Conclusions

1. Further investigations of particle flux variations filling the Van Allen Earth radiation belts is proposed with the usage of miniaturized registrant-analyzer MiRA_ep in a CubeSat format. The distinctive features of this small-sized instrument are the application of organic scintillator on the base of *p*-terphenyl single crystal and registering of particles from the two mutually opposite directions.
2. Monte-Carlo simulation with the usage of GEANT4 package allowed estimating energy ranges of electrons and protons to be detected by the telescopic system. Incident electrons will be measured from $E_{emin} \approx 200$ keV up to energies of $E_{emax} \leq 4$ MeV, and incident protons can be registered from $E_{pmin} \approx 3.5$ MeV up to energy $E_{pmax} \leq 40$ MeV. Computer simulation of both detectors' responses demonstrated also confident way to distinguish between electron and protons.