The analysis of charged particles flux spikes in DEPRON data

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Introduction

Educational satellite Lomonosov with the DEPRON instrument was launched on April 28, 2016 from the Vostochnyi into sun-synchronous orbit about 480 km altitude, the main objective of the mission is to study the transient phenomena in the Earth's atmosphere.After the in-flight tests, DEPRON instrument operates in a permanent mode, as a primary radiation monitoring device of the mission.For early 2017 it has nearly a half of the year power up time. Figure 1 shows data received in August 2016, special interest was accepted to spikes, believed to be a significant rising of high-energy electrons flux i.e. relativistic electron precipitation (REP).

DEPRON Instrument at Lomonosov satellite

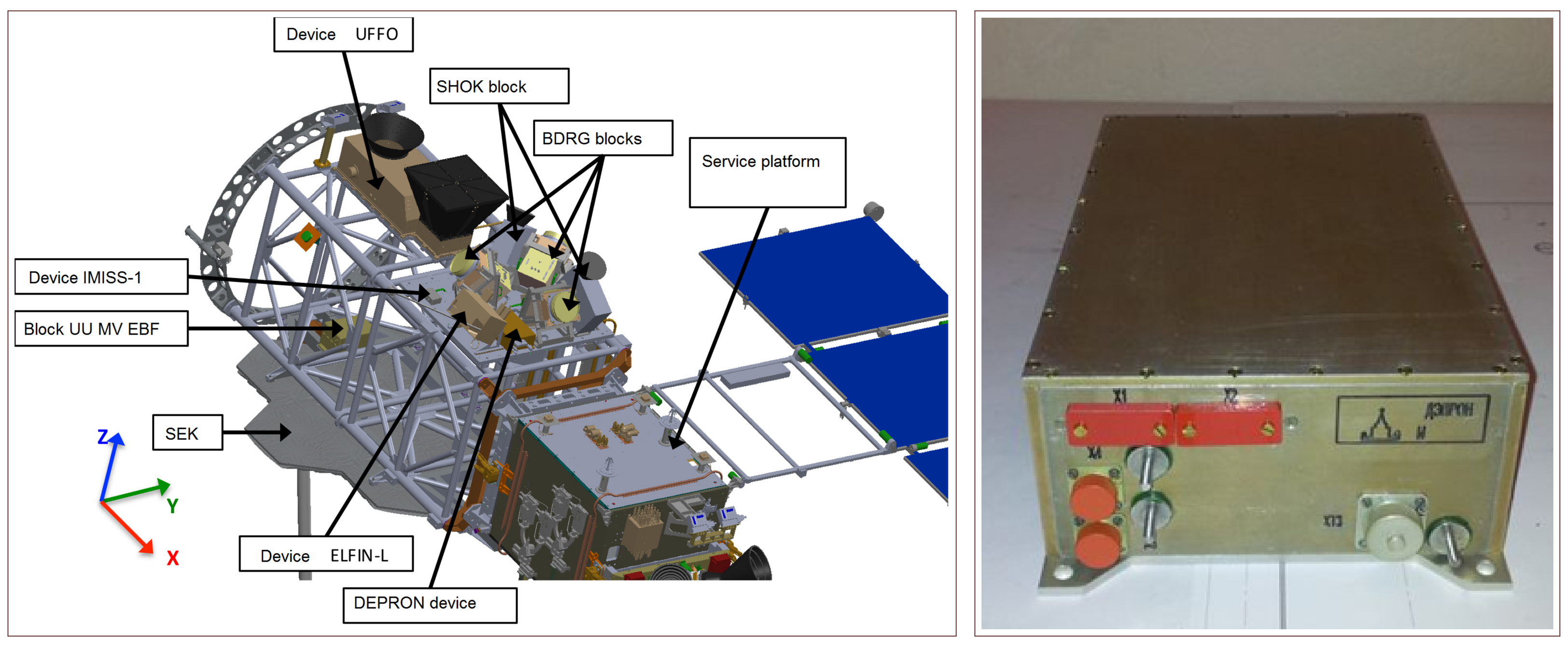
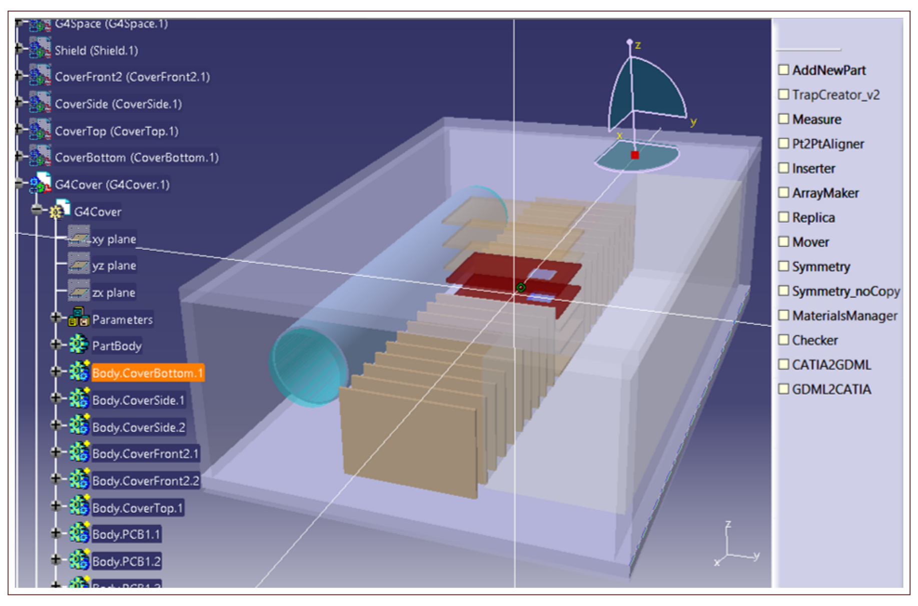
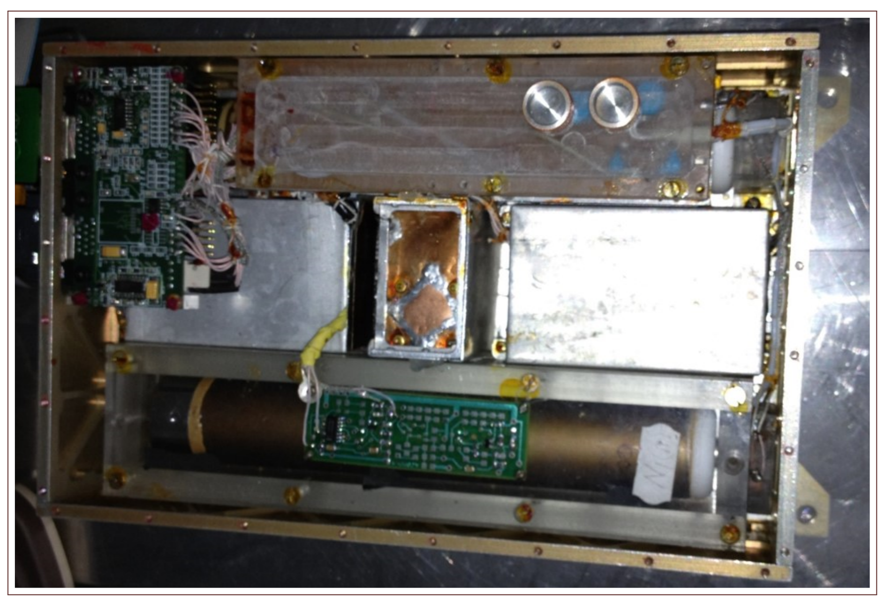


Figure 1: DEPRON mounted on the top of truss frame. This provides the direction of z-axis of instrument in Zenith

Appearance of DEPRON device





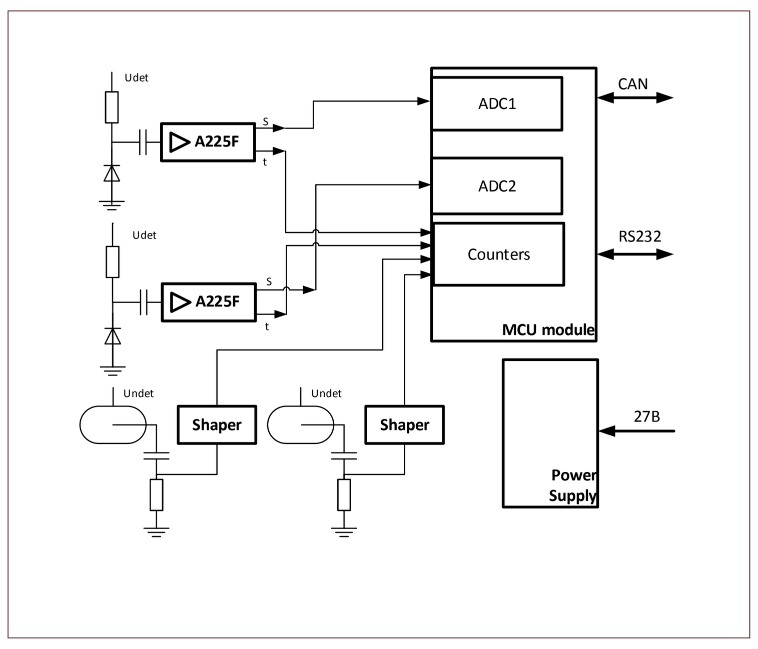
Using the " CATIA-GDML geometry builder " macro set [7, 12], the geometry of the Depron instrument was prepared for use in the Geant4 environment. 1.

Technical details

DEPRON - Dosimeter of Electrons, PROtons and Neutral particles

1. casing - aluminium;
2. copper foil — 10 μm;
   detectors:
   - D1 SD — 0,3 mm
   - D2 SD — 0,3 mm
   - D3 **He-3** counter scheme
   - D4 **He-3** covered by 1sm plexiglass

Both semiconductor detectors in the detection nodes are arranged in parallel, forming a telescope, this device construction scheme was used to obtain information about the LET particles that passed simultaneously through both detectors.
Estimates showed that the DEPRON top semiconductor detector is sensitive to electrons of energies greater than 0.5 MeV and protons with energies greater than 5 MeV. Bottom detector is capable to register electrons with energies higher than 1.8 MeV.



Dose registration methods

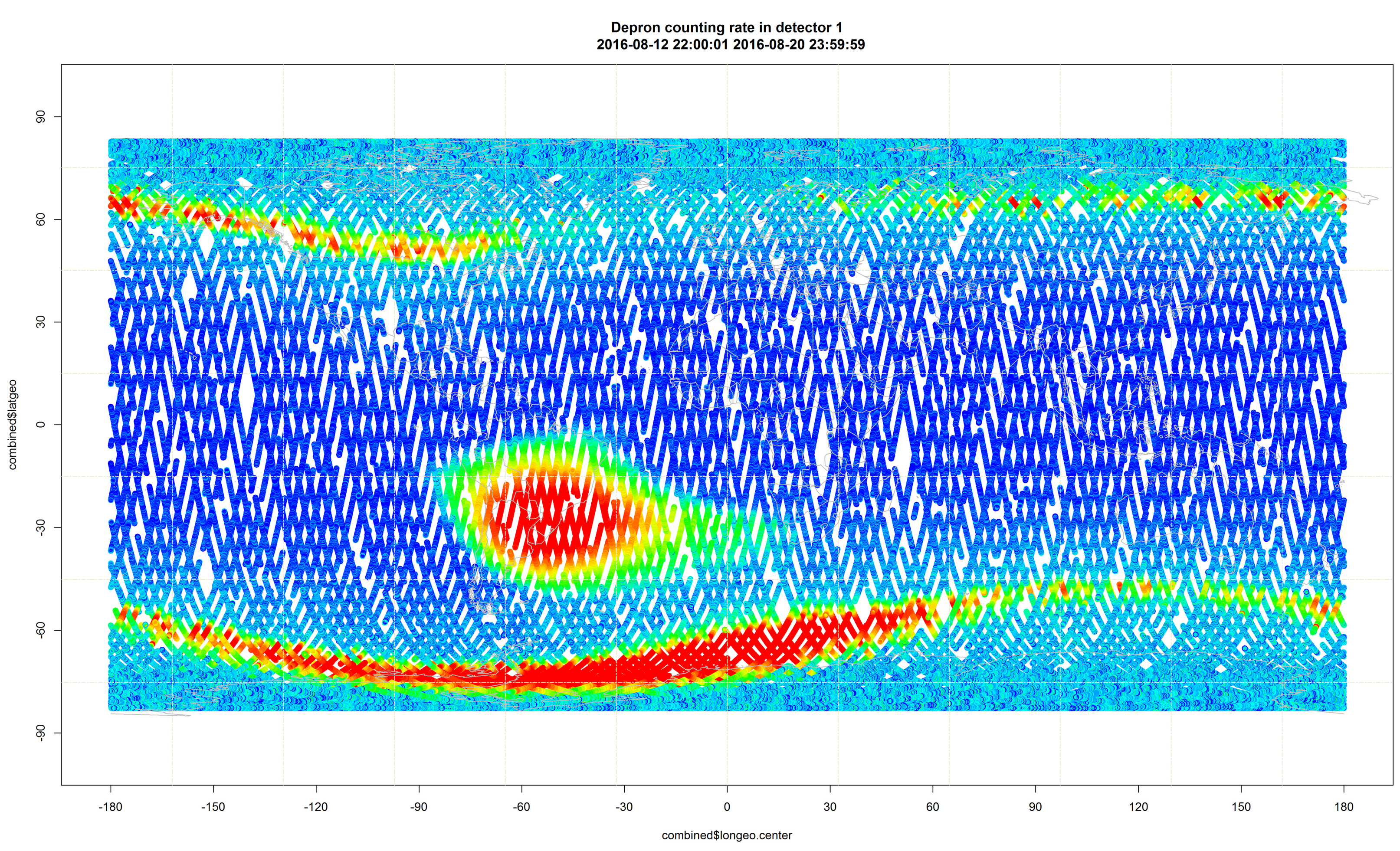
The absorbed dose is recorded by the nodes with semiconductor detectors. To obtain information on the amount of absorbed dose, the principle of recording the charge in the volume of a semiconductor proportional to the energy deposition in a given volume is used:

$$D = \frac{E}{m} = \frac{w_i \cdot \frac{q}{e}}{m} \tag{1}$$

Methods for converting signals from detectors to digital form and then processing them on a microcontroller remain analogous to the algorithms used in the instruments DB-8, DB-8M.

Radiation Conditions Maps

As a result of this work, we get a map of charged particles flux measured with semiconductor detectors and dose rates maps while REP events.



Datasets of the experiment and additional materials are available on the mission site at lomonosov.sinp.msu.ru

Questions requiring detailed study

The origin and dynamics of the fluxes of relativistic electrons in the outer radiation belt still causes the active interest of the world community, in spite of a lot of research in more than half a century of research [1, 3–6, 8–11, 13, 14, 16]. This interest is primarily determined by the radiation hazard, which is represented by extremely high electron fluxes for devices in the orbits of polar satellites. The severity of radiation risks associated with energetic electrons is confirmed in projects for constructing artificial orbital structures designed to reduce the population of the external electronic belt with the help of electrostatic fields [2].
Modern studies show the possibility of penetration of high-energy electrons and into the region of the inner belt [17].
Nevertheless, there is an opinion that the detection of relativistic electrons in the inner belt can, in fact, be an instrumental ambiguity-coincidence with simultaneous detection of protons of the inner belt and low-energy electrons [15]. Numerical simulation of charged particle spectrometers also shows that reliable separation of protons and electrons is possible only with very strict selection criteria for the devices [18]. Narrowing the criteria leads to a huge drop in the sensitivity of the instrument and the acting geometric factor, for some energy channels, a reduction of up to 100 times is possible [18].

Flux Spikes

In the DEPRON data, the circumpolar regions are characterised by high variability in time and space of particle fluxes and, accordingly, doses. In the obtained data, the increase in the count rates in the first detector was identified. The magnitudes of the increased fluxes recorded in the first semiconductor detector are on the average 30-100 times higher than in the second detector (and simultaneous detection). Taking into account that the geometrical factor of the telescope of the detectors is 3 times smaller than in the upper detector, we can assume that the particle energy energies are low in these fluxes.For the highest increases in the count rates, the ratio of the count rates is less than one order, therefore the energy of the particles in that flashes is larger. We observe a clear separation of the counting rate and the ratio in the upper and lower detectors. The count rate of charged particles in raw data shows that we underestimate processed count rates and dose rates in the top detector. But count and dose rates in the second detector are accurate enough.

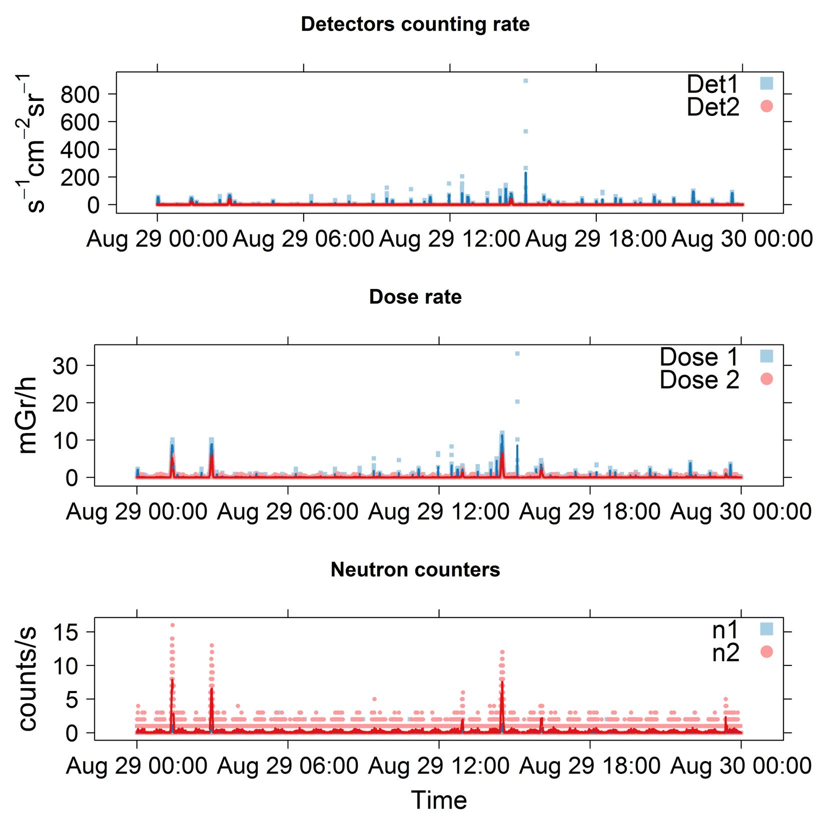


Figure 2: Depron data time series of count rates and dose rates for 29 August 2016. Actual measurements shown by dots and lines shows a smoothed data with a triangle filter.

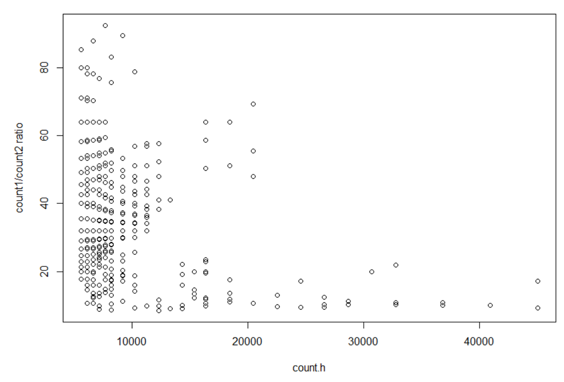


Figure 3: The ratio of the count rates in the detectors allows us to divide the increases in rigidity and power into two groups.

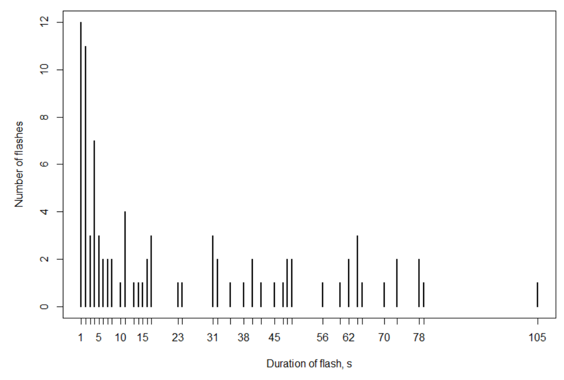


Figure 4: Duration distribution of all founded flashes

Flashes contribution in day dose

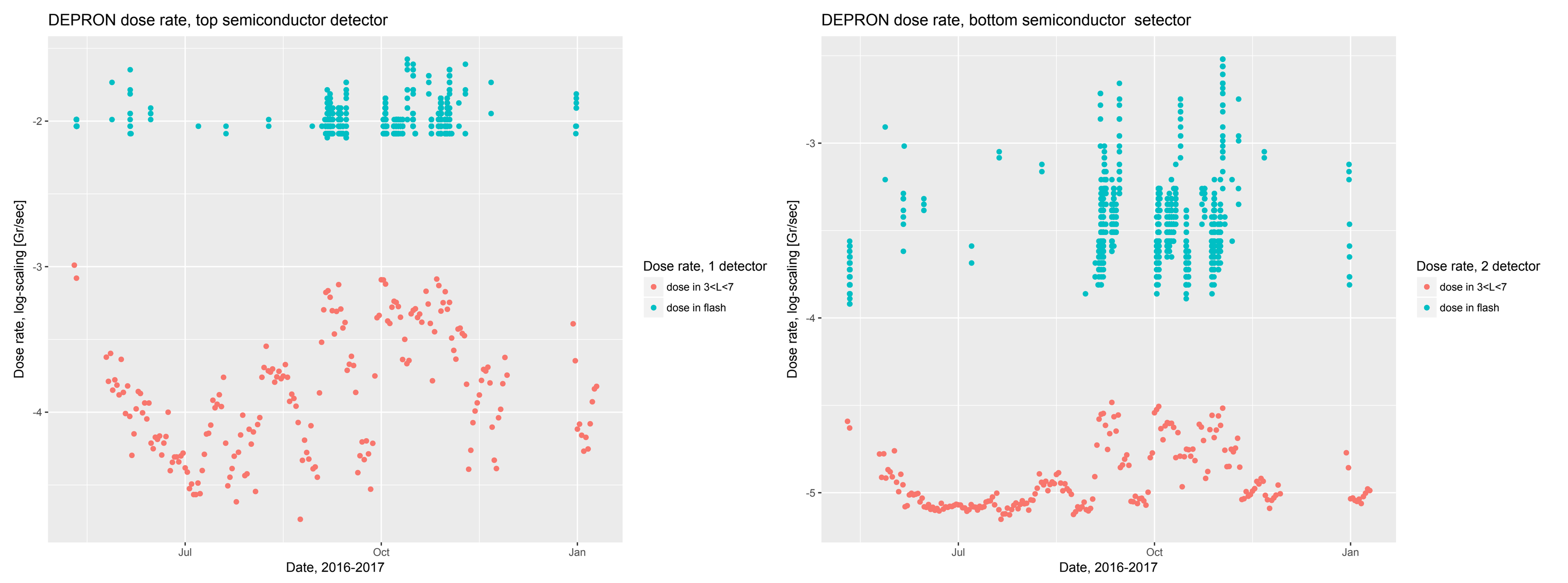


Figure 5: Red dots shows daily mean dose rate in polar regions registered at Lomonosov. Blue dots - dose rate in moments of high count rate in top DEPRON detector.

Based on the analysis of the samples of all the moments of time when the count rates in top detector were registered more than 800 Counts/(s*cm*sr) we separate 90 flashes.
We can consider that short flashes contribute to total dose in both detectors. This contribution is more significant in polar regions and reaches one order of magnitude for the top detector and half of order for the bottom detector in absorbed dose. For the flash registered at 2016-10-28 21:43:42 — 21:45:26UTC absorbed dose for the top detector exceeds 1 Gr.

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Conclusions

More than 90 short flashes of energetic particles founded in DEPRON data collected by the half of a year. The magnitudes of the increased fluxes recorded in the first semiconductor detector are more than 800 Counts/(s*cm*sr). We can consider that short flashes contribute to total dose in both detectors. This contribution is more significant in polar regions and reaches one order of magnitude for the top detector and half of order for the bottom detector in absorbed dose. For some flashes total dose for the top detector may exceeds 1 Gr.

Contacts

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