Selective detector of cosmic particles based on diamond sensitive elements

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Abstract. The article describes the device for selective registration of electrons, protons and heavy ions fluxes from the solar and galactic cosmic rays in the twelve energy ranges, built on a base of diamond detector. The use of the diamond detectors allowed for the creation a device for registration of cosmic particles fluxes at the external spacecraft surface with the resource not less than 20 years. Selective detector is aimed for continuous monitoring of radiation situation on board the spacecrafts, in order to predict the residual life of their work and prompt measures to actively protect the spacecraft when the flow of cosmic particles is sharply increased.

1. Introduction

Portable devices creation for continuous monitoring of dose and spectral characteristics the cosmic rays on an external spacecrafts surface is an actual task. This device solves the problem of increase the duration of a space systems operation and increase of crews safety on the spaceships. Continuous monitoring the cosmic rays with definition of spectral composition makes possible to obtain information about the change dynamics in the field of cosmic rays on the spacecraft orbit. This allows predicting the development of radiation impact on equipment and crew. Such information makes it possible to apply the necessary anti-radiation efforts: hibernate the insurance electronic equipment and use of additional measures for crew radiation protection.

Monitoring the dose and spectral characteristics of the cosmic rays fields on spacecraft board allows calculating more accurate the life-cycle costs and planned replacement, to ensure the safe operation of the spacecrafts constellation. The use of diamond detectors for such devices creation is caused by the high radiation resistance (up to 500 Mrad) and increase of exploitation resource [1,2].

This paper is focused on the selective-board recorder of cosmic rays developed by Industrial-Technological Center «UralAlmazInvest», with participation of specialists from National Research Nuclear University “MEPhI” and RSC "Energia". The main purpose of this device is a continuous monitoring of the radiation situation on the spacecraft board, including the registration of the absorbed

dose from electron and proton component of cosmic rays. The detector also provides measurement of radiation flux density in 12 energy ranges (electrons in four energy ranges; protons in the four energy ranges, heavy charged particles in four ranges of linear energy transfer (LET)).

2. Description of the construction of the selective detector

As mentioned earlier, the basic operating principle of the selective detector for cosmic rays spectra measurement is based on the particles separation in the energy range using a multi-detector registration scheme with selective filters [3].

Figure 1 shows the external view of the selective detector unit, and figure 2 shows the principal composition of the device.

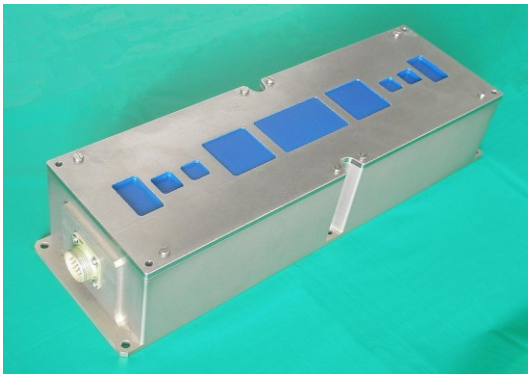

Figure 1. External view of the selective detector unit.

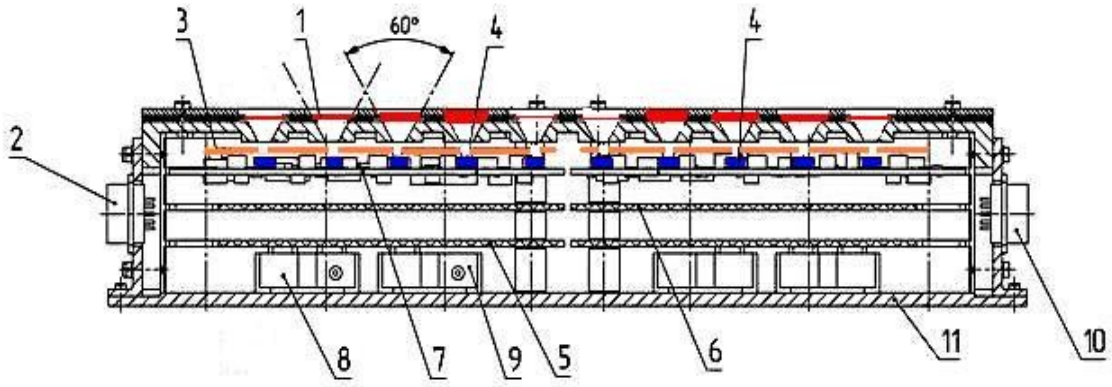

Figure 2. The design of selective detector of the cosmic rays 1 - selective filters; 2 - power connector; 3 - electrostatic screen; 4 - DSE; 5 - power supply board assembly; 6 - host interface board; 7 - board detection unit; 8 - the filter unit; 9 - power supply; 10 - connector interface; 11 - case.

The device case was made from an aluminum alloy, in which two identical spectrometer registration units were installed, one of which is working device, and the second one is used as a backup. The double backup registering node ensures a longer life of the device for up to 20 years. The device case has equivalent thickness value, near to 6 mm of aluminum (thickness including the heat sinks and fixing construction elements). This thickness value provides reliable radiation protection of the device electronic circuit.

Spectrometric unit includes the amplification module board – 7, the digital processing module board – 6, and the power supply module board – 5. Diamond sensitive elements (DSE) were mounted

on the amplification module, placed under collimation windows of the spectrometer case. Collimation window are covered with selective filters, providing separation of cosmic rays in energy ranges. The power connector – 2 and the interface connector – 10 are installed at the end faces of the case.

The detectors used are the caseless DSE, shown in figure 3. DSE consists of diamond plate with the deposited aluminum plates mounted on the dielectric base. The electrodes of the diamond plate with gold conductors are connected to the ground terminals. DSE is lacquered for sealing. This design allows placement of DSE close to the signal preamplifier input, ensures minimization of the electronic noise on the gain path, and minimization of the electromagnetic interference effect.

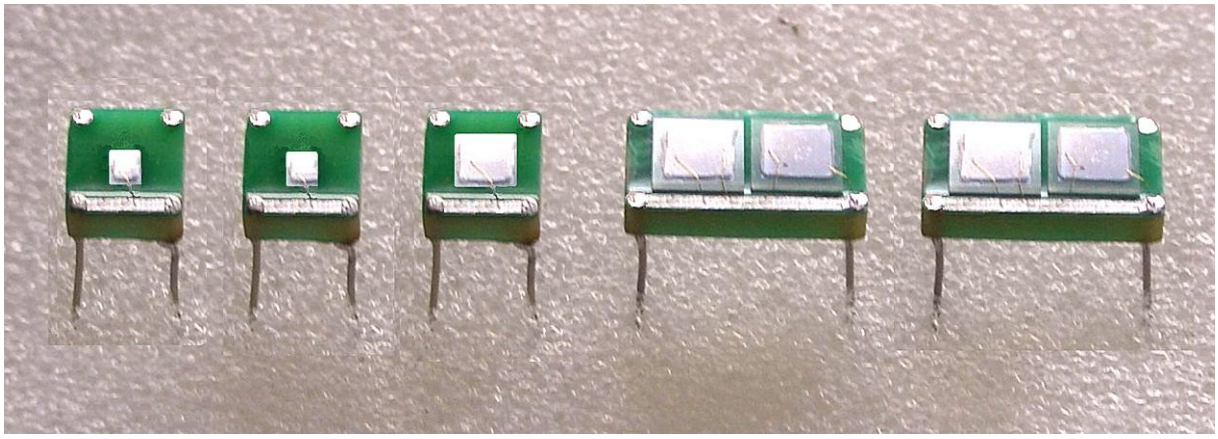

Figure 3. External view of the DSE.

The DSEs have different area of sensitive surface. Two DSE with surface areas of 2×2 mm^2 are used to register the total flux of electrons, protons and heavy ions. The DSE with surface area of 3×3 mm^2 are used for registration an low energy protons and electrons with energies more than 3 MeV. Last one DSE, containing two diamond plates with surface area of 4.5×4.5 mm^2 are used for registration an protons with energies more than 30 MeV and heavy ions. The use of DSE ensures that the statistical errors in the measurement of cosmic particles flow in different energy ranges will not exceed 10% for the measurement time from 5 to 10 min.

3. Selection of cosmic rays

Selection of cosmic particles (electrons and protons) is provided by using the four DSEs, that covered by filters with different thicknesses. Figure 4(a, b, c) shows that the signal spectra of 1st, 2nd, 3rd and 4th DSE are shifted in the energy scale in accordance with the thickness of the selective filter. The shift allows observing particles from given energy range in a particular registration channel. The graphs also show that signals from electrons and protons have different amplitudes, and that is why it is possible to separate these signals using amplitude discrimination. The signal range from 0.2 to 0.3 MeV is used to register the electronic component of cosmic rays. The signal range from 2 to 10 MeV is used to register the proton components. To register heavy ions the fifth channel recording is used. Selection of the heavy ions in this channel carried out by selection their amplitudes in the range of amplitudes from 100 to 1000 MeV. The ranges of signals amplitude are given in equivalent energy.

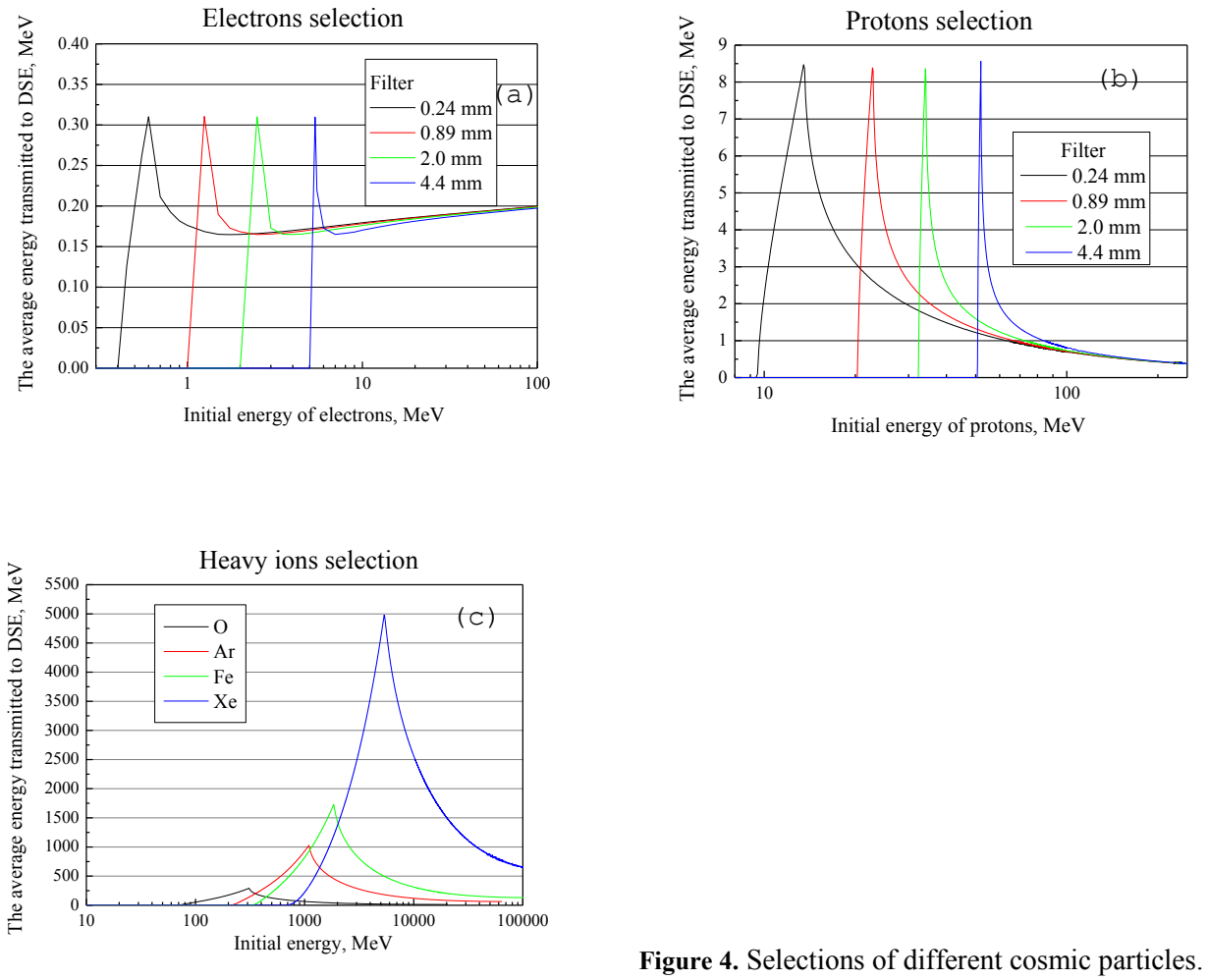

Figure 4. Selections of different cosmic particles.

The absorbed dose from electron and proton components as well as from heavy ions of cosmic rays is determined by calculation based on obtained spectra of cosmic rays.

4. Conclusion

Currently the prototypes of the cosmic particles selective detectors are made and samples are tested. Preparation for the production of flight models is started.

Acknowledgments

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