

# High depositing energy events in the ISS radiation environment

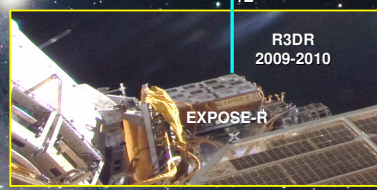
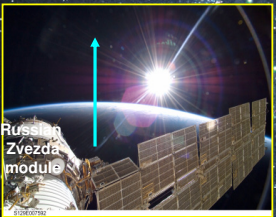
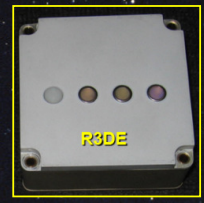
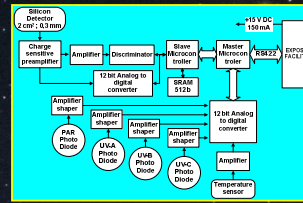
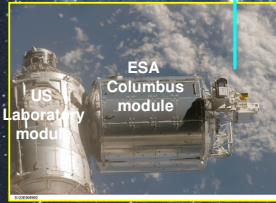


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**Abstract:** The R3DE (Radiation Risks Radiometer-Dosimeter (R3D) for the EXPOSE-E platform on the European Technological Exposure Facility (EuTEF) worked successfully outside the European Columbus module of International space station (ISS) between February 2008 and September 2009. Very similar instrument named R3DR for the EXPOSE-R platform worked outside Russian Zvezda module between March 2009 and August 2010. They accumulated about 5 million deposited energy spectra used for calculation of the flux and absorbed dose rate with 10 seconds resolution behind less than 0.41 g cm<sup>-2</sup> shielding and for identification of predominating radiation sources in the ISS environment. The large data base is used for analysis of the high depositing energy events, which are distributed in 2 classes: 1) Very rare events when the deposited in the detector energy is higher than the upper limit of the deposited energy range (20.8 MeV) and manifested with counts in the 256th channel of the spectrometer. These events can be explained with registration of heavy ions in the Galactic cosmic ray (GCR) source and with long path proton crossings of the detector in the region of the South Atlantic anomaly (SAA); 2) Events with specific dose (SD) higher than 4 nGy cm<sup>2</sup> particle<sup>-1</sup>. These events are more frequent than the previous class events and are associated with registration of He<sup>+</sup> ions and neutrons in GCR source at low and middle latitudes and with relatively low energy protons and He<sup>+</sup> ions in the south-east edge of the SAA.

## Instruments

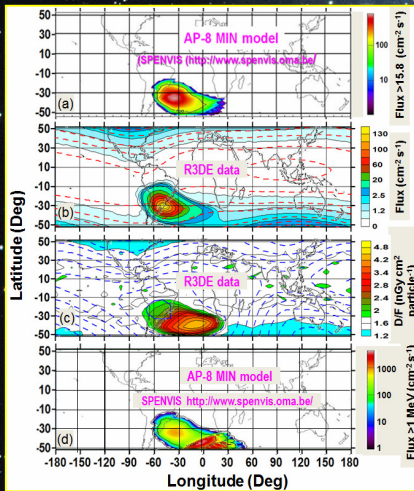


$$D[\text{Gy}] = K \sum_{i=1}^{256} (EL_i) [J] / MD[\text{kg}]$$

The detectors of R3DE/R instruments are shielded by less than 0.4 g cm<sup>-2</sup> material including: 1 mm aluminum + 0.1 mm cuprum + 0.2 mm plastic. This allows direct hits on the detector by electrons with energies larger than 0.78 MeV and protons with energies larger than 15.8 MeV.

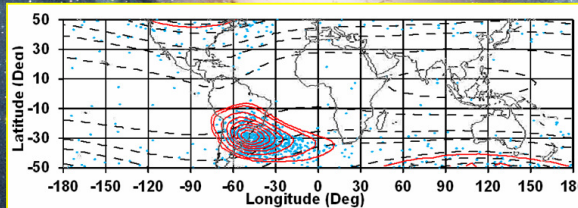
## Analysis of the high depositing events

Global distribution of the R3DE flux, D/F ratio and energy in the period 21 October 2008-24 February 2009



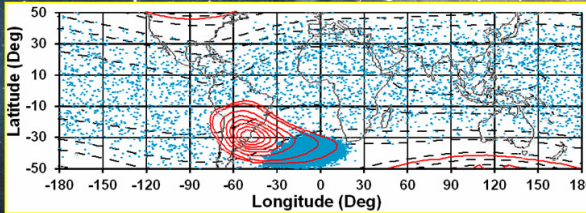
The R3DE data are compared with the predicted by the AP-8 MIN model proton fluxes above 15.8 MeV for Figure 4a and above 1 MeV for Figure 4c.

Global distribution of the R3DE events in the 255th channel



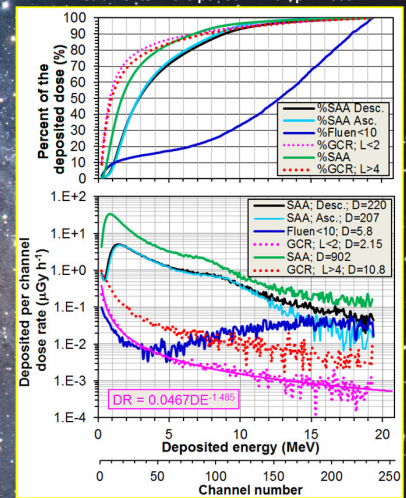
Some amount of the events in all sources are generated when high energy protons cross the detector under very small angles or even across the whole wide of 10 mm or length of 20 mm of the detector. In the GCR source counts can be generated also by heavier ions. This mechanism was experimentally observed at HIMAC heavy ion synchrotron facility.

Global distribution of the events with D/F ratio larger than 4 nGy cm<sup>2</sup> particle<sup>-1</sup>



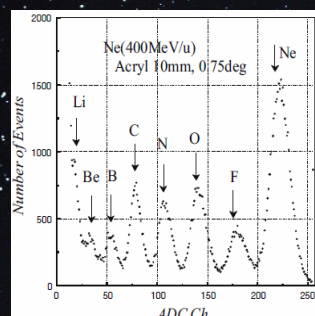
These events are associated with registration of He<sup>+</sup> ions and neutrons in GCR source at low and middle latitudes and with relatively low energy protons and He<sup>+</sup> ions in the south-east edge of the SAA.

Comparison of the dose rate and flux data measured with 10 s resolution by the R3DE/R instruments in the period 11-20 April 2009



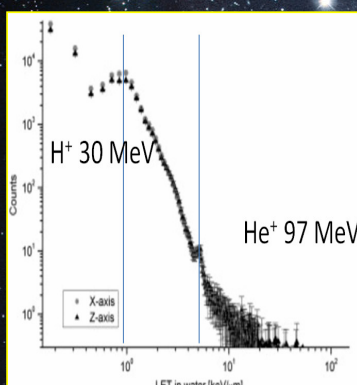
## Evidences for characterization of the ion population in the energy deposition spectra

Deposited energy distribution obtained from projectile fragments. The peaks in the spectrum correspond to ions lighter than the primary ions. The MDU was situated 0.75° relative to the beam line direction. The arrows indicate estimates of deposited energies for each fragment ion [1]



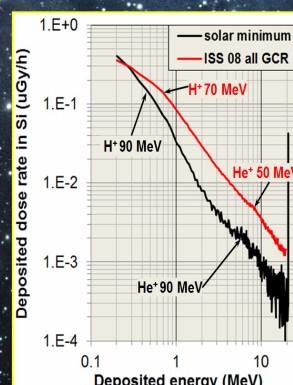
The deposited Liulin-4J spectra contains maximums of lighter than primary Ne ions, which follow the order of the masses of each secondary fragment.

LET spectra of protons and alpha particles [2]



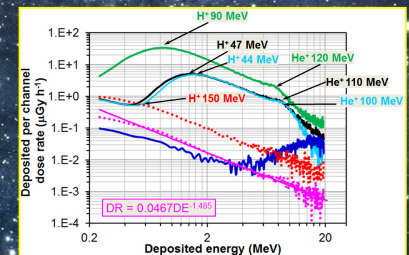
To estimate the deposited energy spectra the FLUKA Monte Carlo transport code was used [2]. Only protons and alpha particles were considered in the calculations [2].

Spectra of GCR protons and alpha particles



Only 2 maximums are identified in the spacecraft and aircraft GCR depositing energy spectra H<sup>+</sup> and He<sup>+</sup>. The calculated energies of the H<sup>+</sup> and He<sup>+</sup> ions are presented also.

Same spectra as in the picture above in logarithmic scale



Only 2 maximums are identified in the ISS SAA depositing energy spectra H<sup>+</sup> and He<sup>+</sup>. The calculated energies of the H<sup>+</sup> and He<sup>+</sup> ions are presented also.

### References

- [1] Uchihoi, Y., H. Kitamura, K. Fujitake, Ts.P. Dachev, B.T. Tomov, P.G. Dimitrov, Y. Matsumoto, Analysis of the calibration results obtained with Liulin-4J spectrometer-dosimeter on protons and heavy ions, Radiation Measurements, 35, 127-134; 2002. doi:10.1016/S1350-4485(02)00286-4
- [2] Hirn, Models of performances of dosimetric telescopes in the anisotropic radiation field in low earth orbit, Acta Astronautica, 66, 10, 1368-1372, 2010. http://dx.doi.org/10.1016/j.actastro.2009.11.016