High Dose Rates by Relativistic Electrons: Observations on Foton M2/M3 satellites and on International Space Station

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Introduction

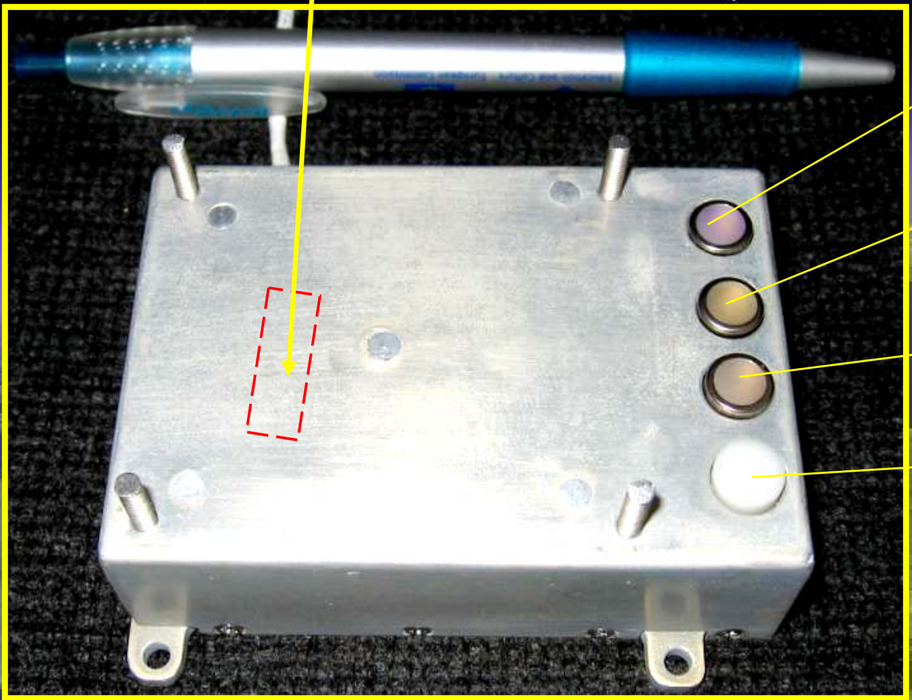
Relativistic electron precipitations (REP) are observed since many years. First of them are those reported in 1972 by Brown and Stone and Imhov et al. in 1986 and 1991. Most comprehensive study of the long term observations of REP using the 2–6 MeV electron data from the SAMPEX satellite during 1992–2004 is made by Zheng et al. in 2006.

In the book “*Radiation and the International Space Station: Recommendations to Reduce Risk”, US National Research Council published in 2000* the total dose of astronaut, which is spending 6 hours on Extra Vehicular Activity (EVA) inside of REP, is estimated. The conclusion is that the dose will “be great enough to force an astronaut over the short term limit for skin and eyes”. One of the recommendations (3b on page 37) is: “As soon as possible, JSC should install an electron dosimeter and an ion dosimeter outside the ISS that can return data in real time to Space Radiation Analysis Group (SRAG) at the Johnson Space Center”

R3D-B2/B3 instruments for ESA Biopan 5/6 facilities were successfully flown outside of Foton M2/M3 satellites in June 2005 and September 2007. The spectrometers are mutually developed with Prof. D.-P. Haeder, University of Erlangen, Germany

Detector of 256 Channels LET spectrometer

4 Channels UV spectrometer

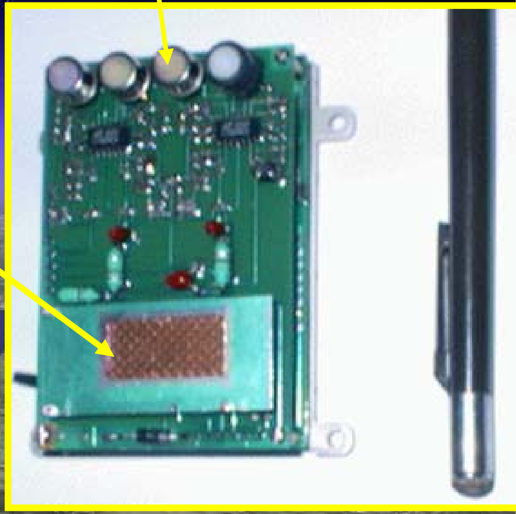


UV-C channel

UV-B channel

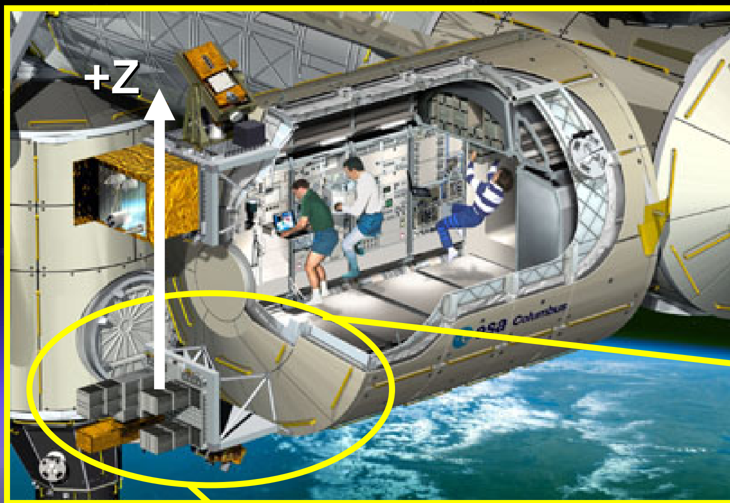
UV-A channel

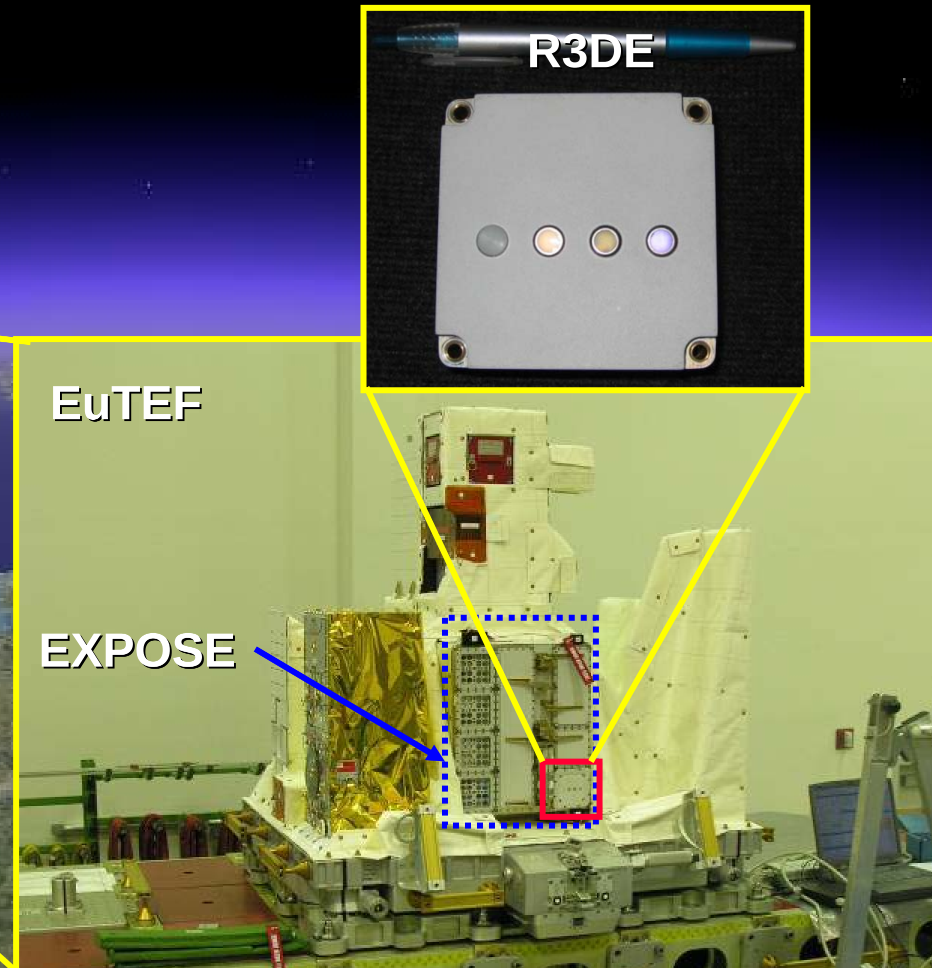
PAR channel



Size: 82x57x25 mm
Weight: 129 g
Consumption: 84 mW

R3DE instrument, which is apart of the EXPOSE facility is working continuously on the EuTEF facility of Columbus module on International space station since February 20th 2008





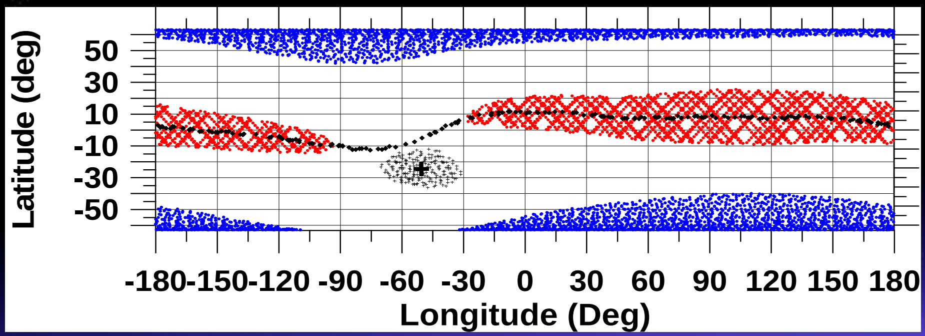
Geographic positions of the selecting procedures and radiation sources

0.9<L<1.1

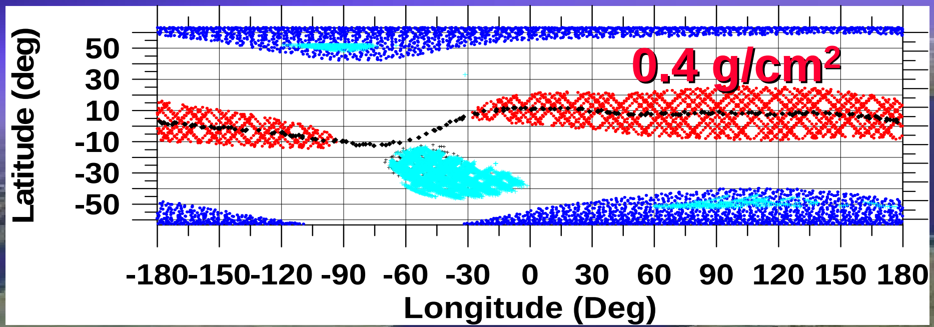
L>2.8

Gmag=0.21 Gauss (SAA)

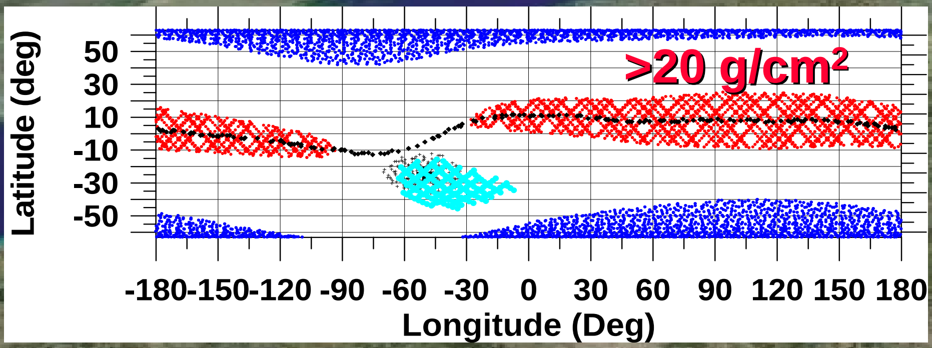
Magnetic Equator



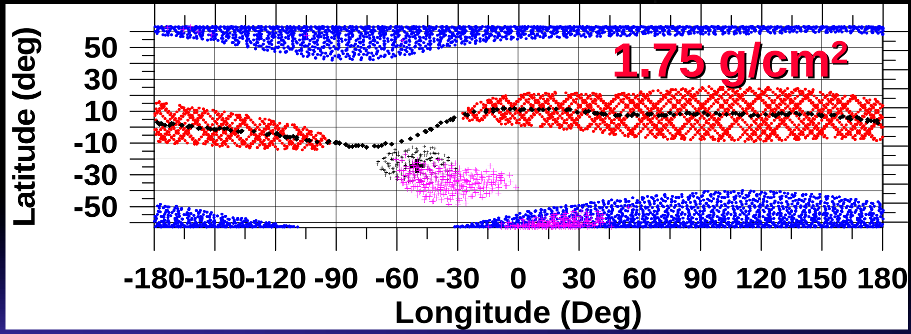
+ ISS, R3DE; EuTEF, Feb.-Mar. 2008; D>100 µGy/h



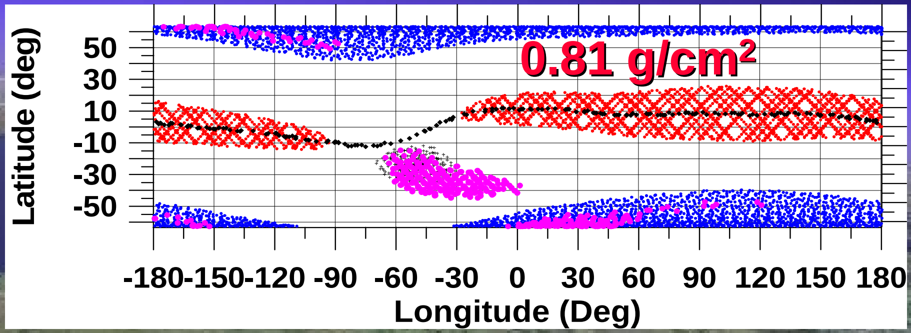
+ ISS, Liulin E094 D#3; July 2001; D>50 µGy/h



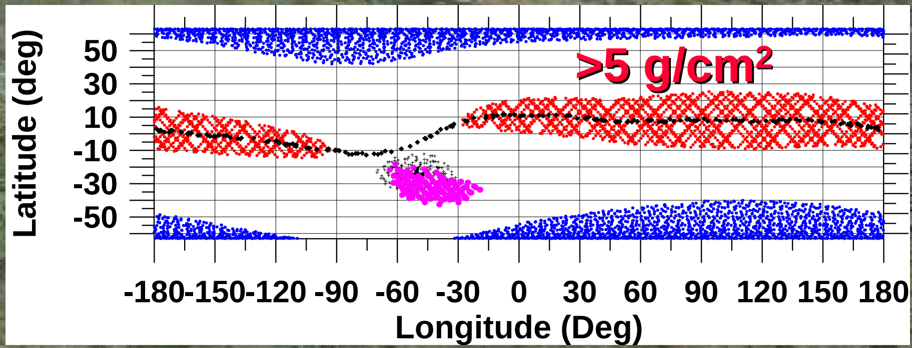
+ Foton M2, R3D-B2; June 2005; D>50 µGy/h



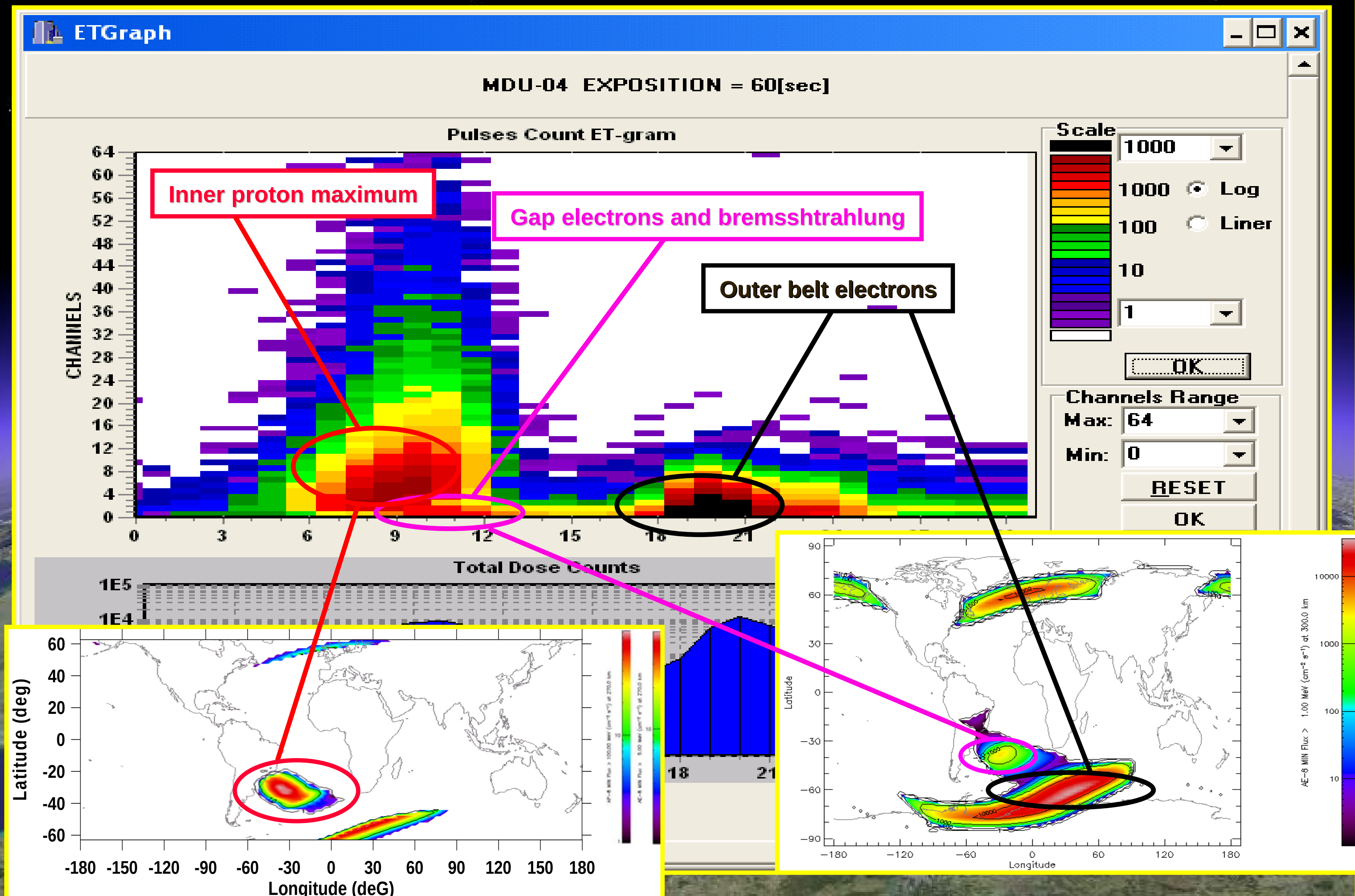
+ Foton M3, R3D-B3; Sept. 2007; D>50 µGy/h



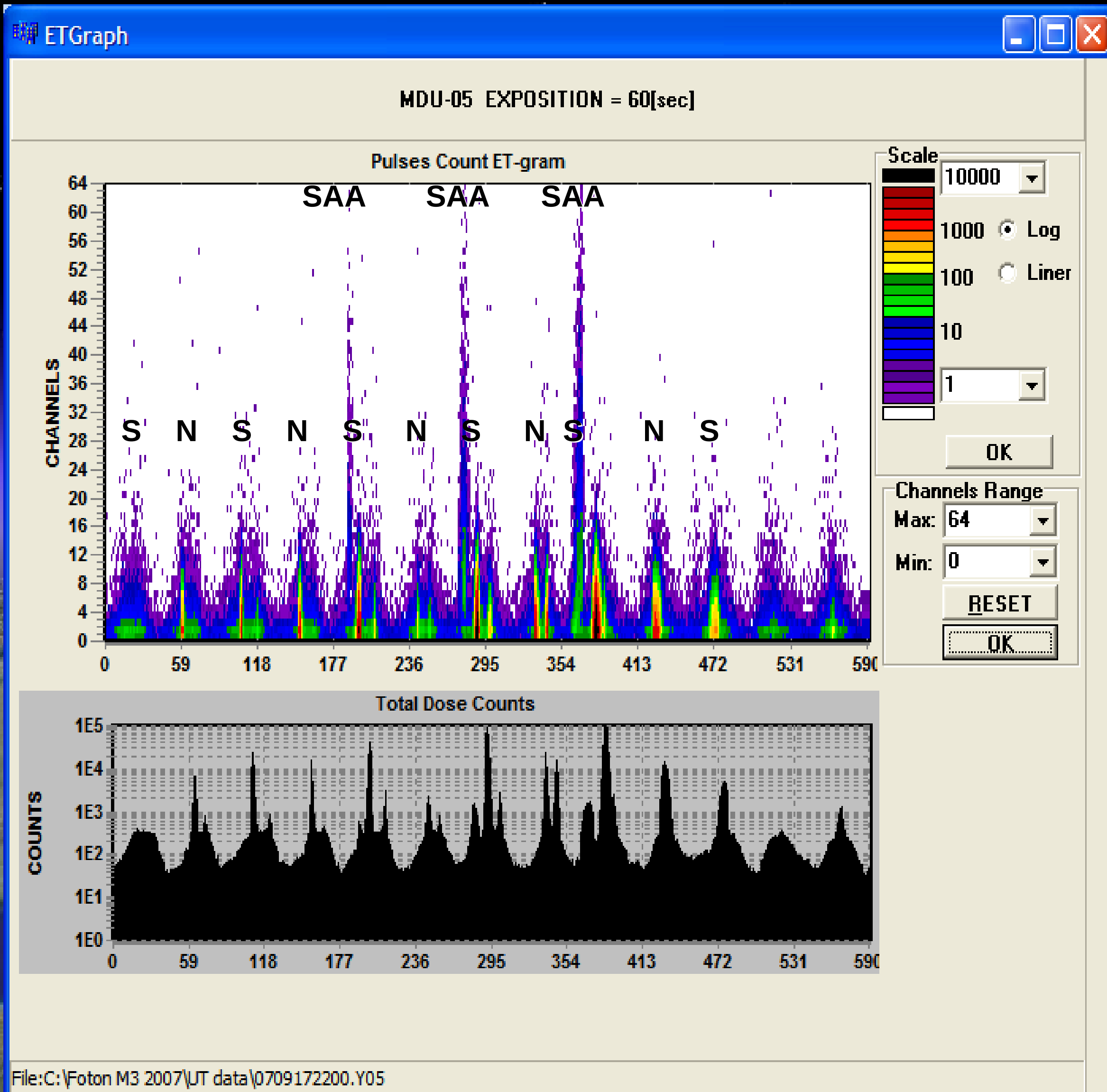
+ Foton M3, Liulin-Ph.; Sept. 2007; D>50 µGy/h



Descending crossing of SAA by Foton M2 satellite



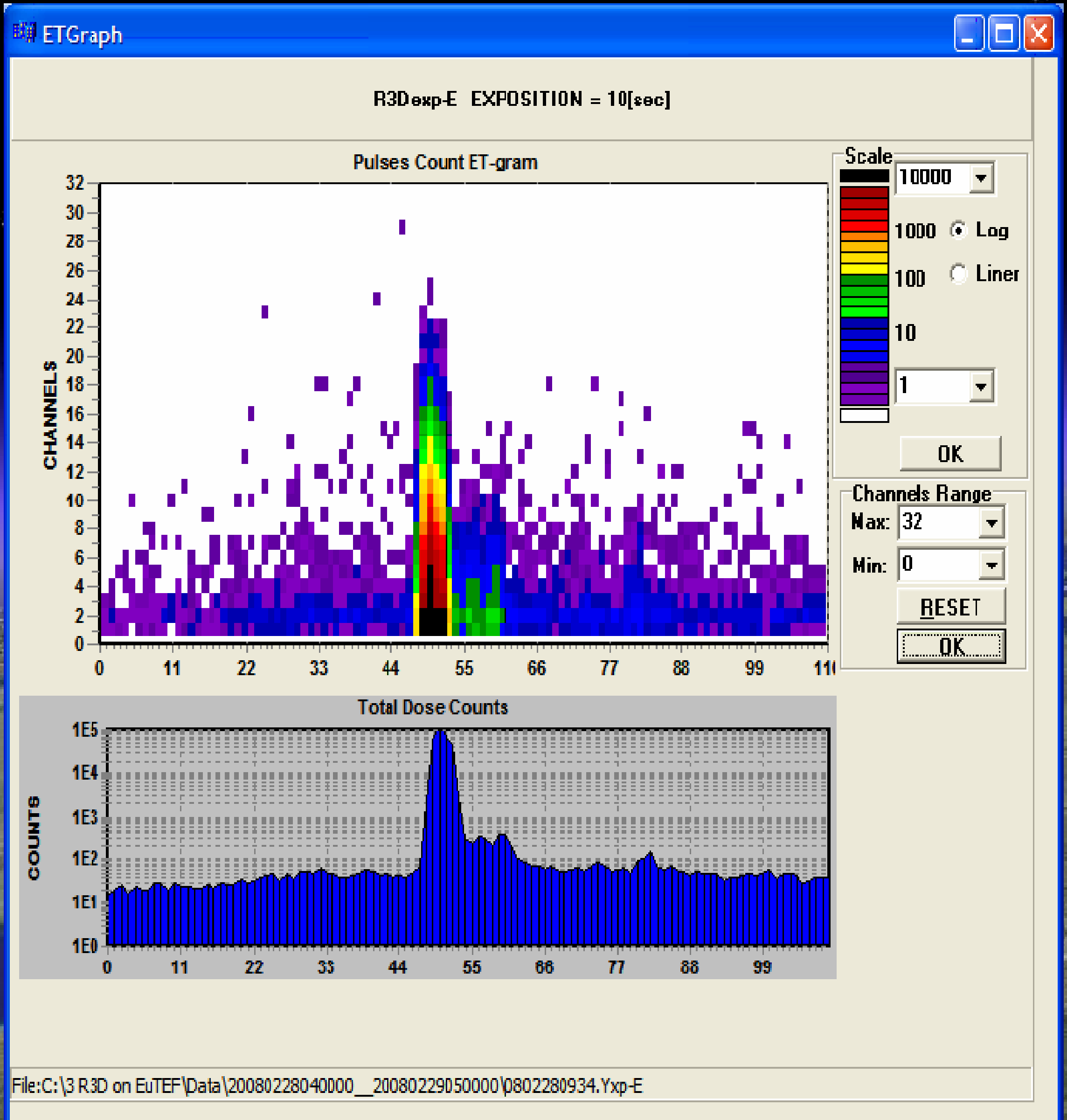
Sequence of Foton M3 60 seconds data with observations of other radiation belt relativistic electrons and SAA region



On the energy-time 3D diagram the relativistic (>1 MeV) electron bursts are seen with red color bars in the upper panel and with black bars above 500 counts per minute in the lower panel. In this case the R3D-B3 spectra in Northern "N" and Sothern "S" hemisphere are relatively short and reach up to 50th channel;

The 3 cases of crossing of inner radiation belt in the region of SAA are shown with labels "SAA". The spectra in SAA are much wider reaching even the 256th channel.

Example of observation of relativistic electrons with R3DE instrument on ISS on 28 February 2008

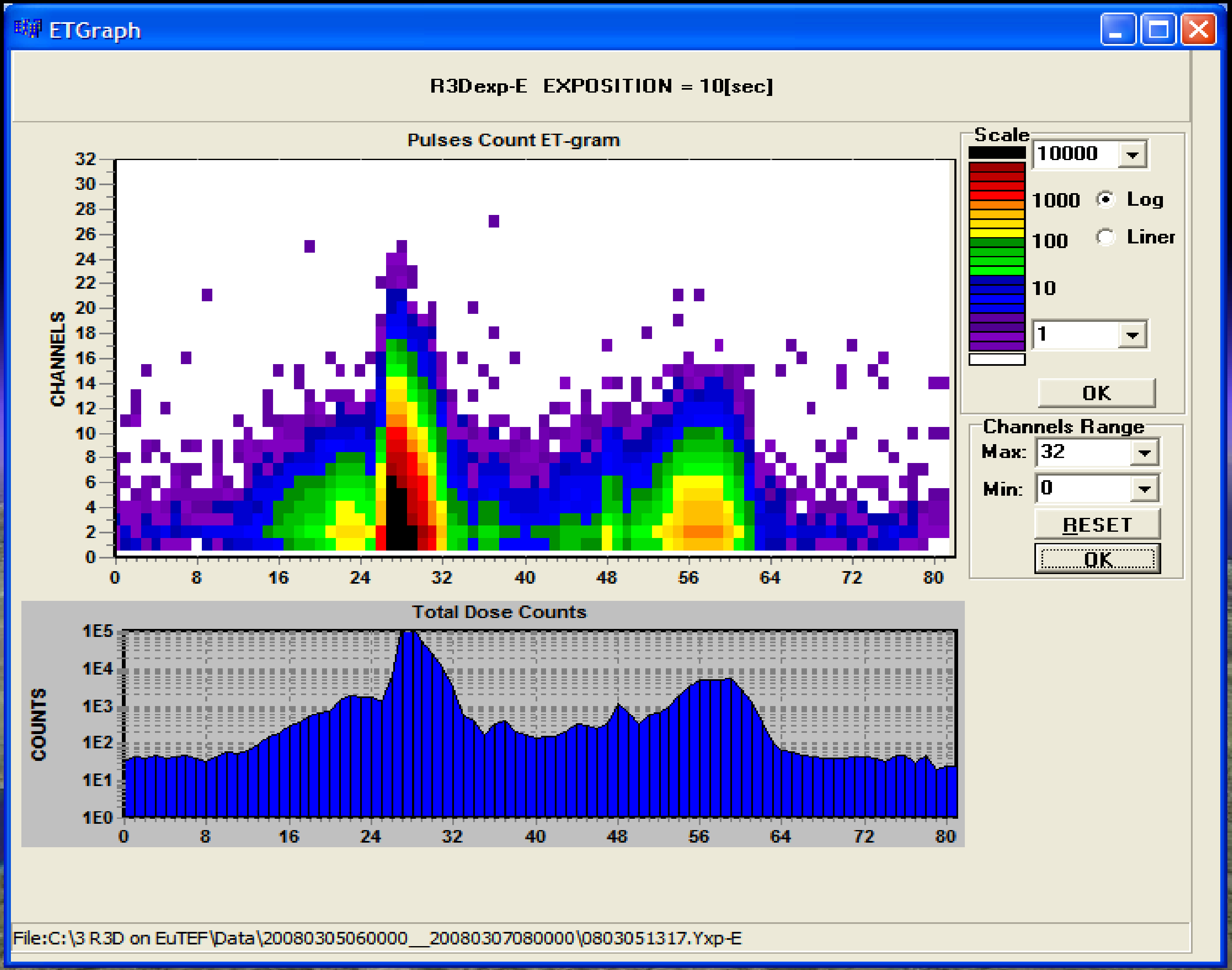


Relativistic (>1 MeV) electron bursts with maximum duration few minutes was observed by us first at the Foton M2 satellite behind 1.75 g/cm^2 shielding. The maximum dose observed is 304 µGy/h at 280 km altitude.

At Foton M3 satellite behind 0.71 g/cm^2 shielding the maximum dose observed is 2314 µGy/h at 295 km altitude.

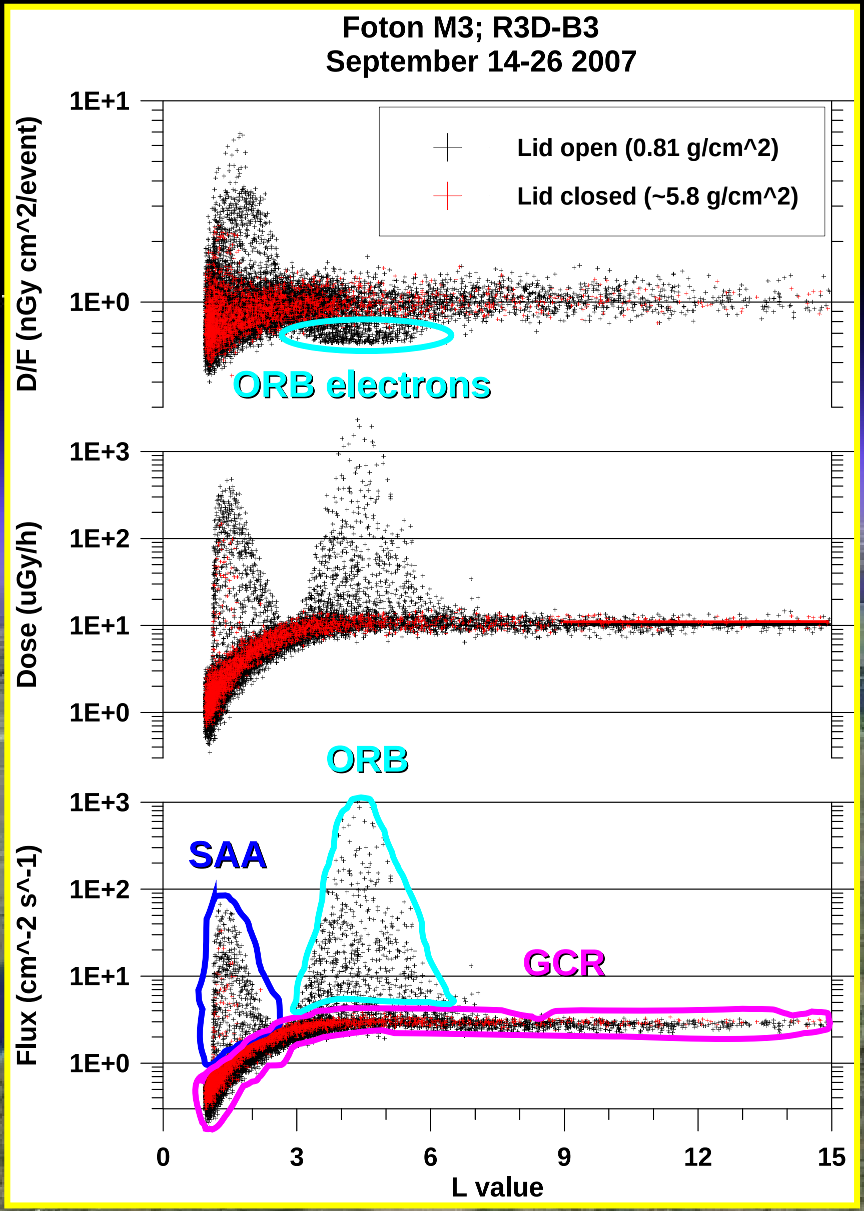
At the EuTEF platform of Columbus module at ISS with R3DE instrument behind less than 0.4 g/cm^2 shielding the maximum dose is 19195 µGy/h at 361 km altitude. The flux of electrons reach 8363 cm^{-2} s^{-1}.

REP observed on ISS on 5th of March 2008 between 14:27 and 14:46 hour



High dose...

Different radiation sources seen in Foton M3 data with lid open/closed

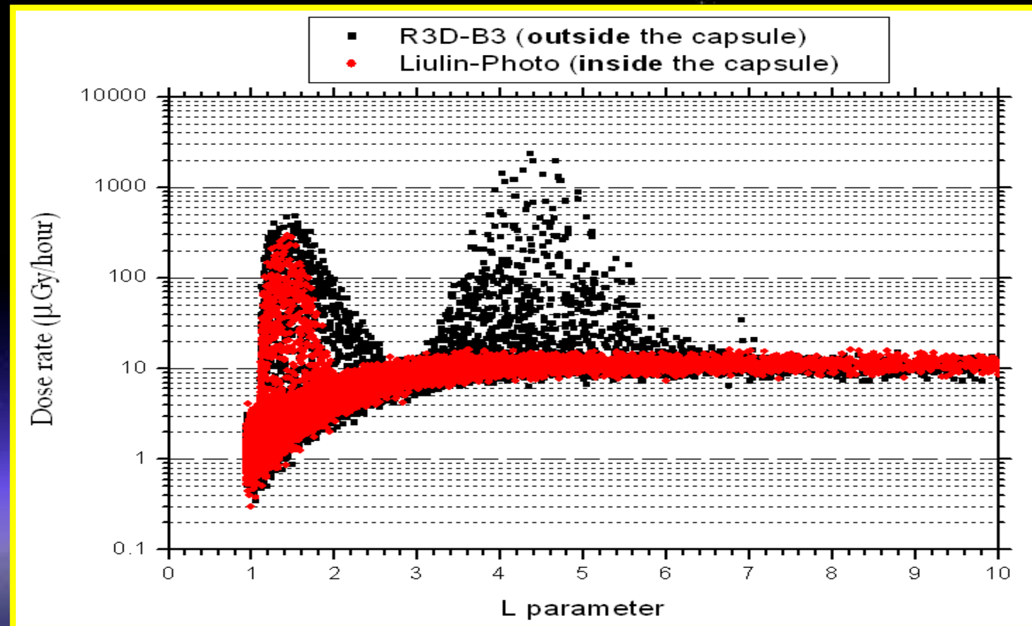


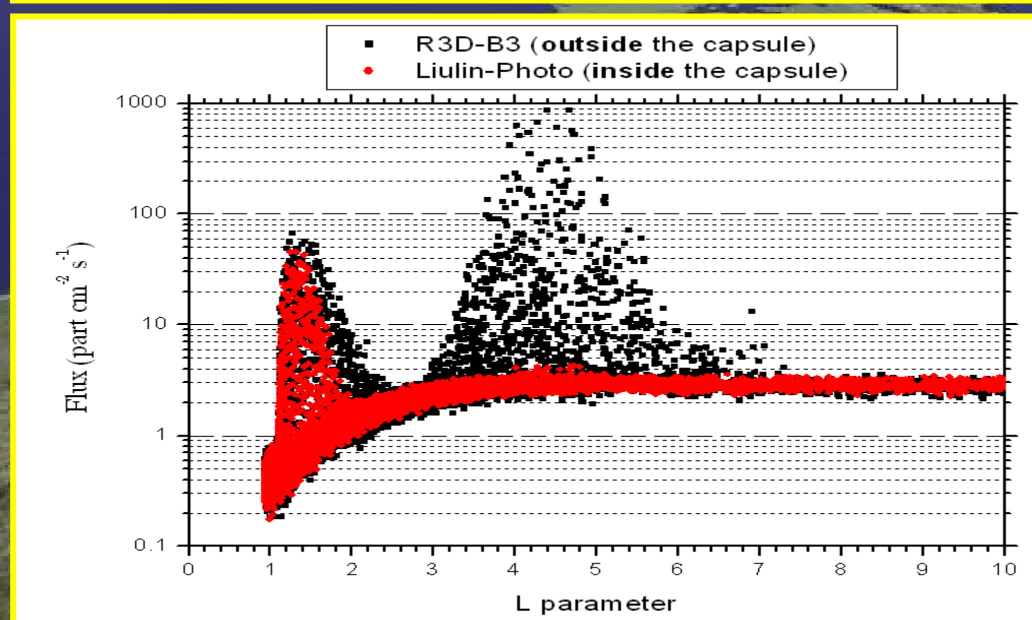
When the lid of Biopan 6 is closed (~5.8 g/cm^2) only protons from the region of SAA and GCR penetrate down to the detector of R3D-B3

When the lid is open (0.81 g/cm^2) , because of lower shielding relativistic electrons with energy above 1 MeV start to penetrate to the detector also

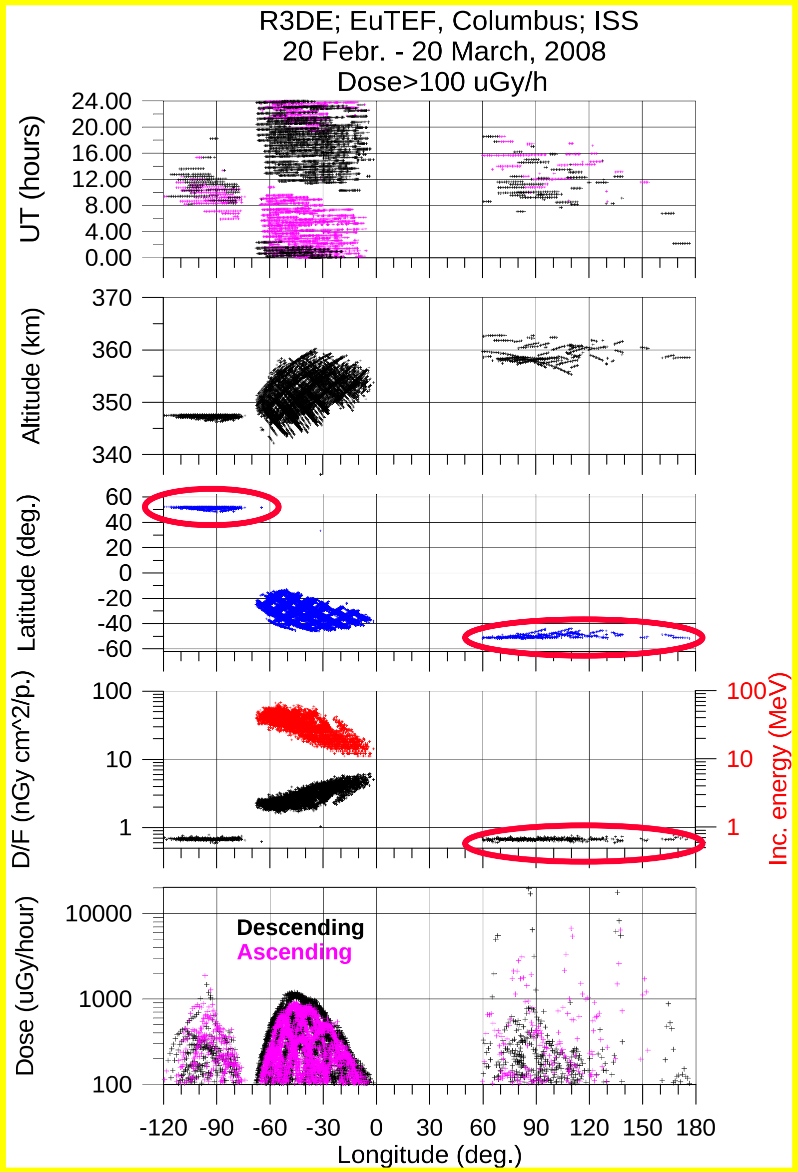
The GCR dose and flux for L>10 are higher (11.12 μGy/h) when lid is closed (11.04 μGy/h), because the secondary's and neutrons produced in the shield

Comparison of data obtained at Foton M3By R3D-B3 instrument outside and Liulin-Photo instrument inside the capsule





Main characteristics of the measurements by R3DE in geographic coordinates, in which the dose is more than 100 mGy/h in period 20 February- 20 March 2008



Descending data are clustered around evening UT, while ascending around morning UT.

Small difference in the averaged altitude of SAA data in descending (353 km) and ascending (351 km) orbits can't describe the large (with 56 mGy/h) averaged descending doses.

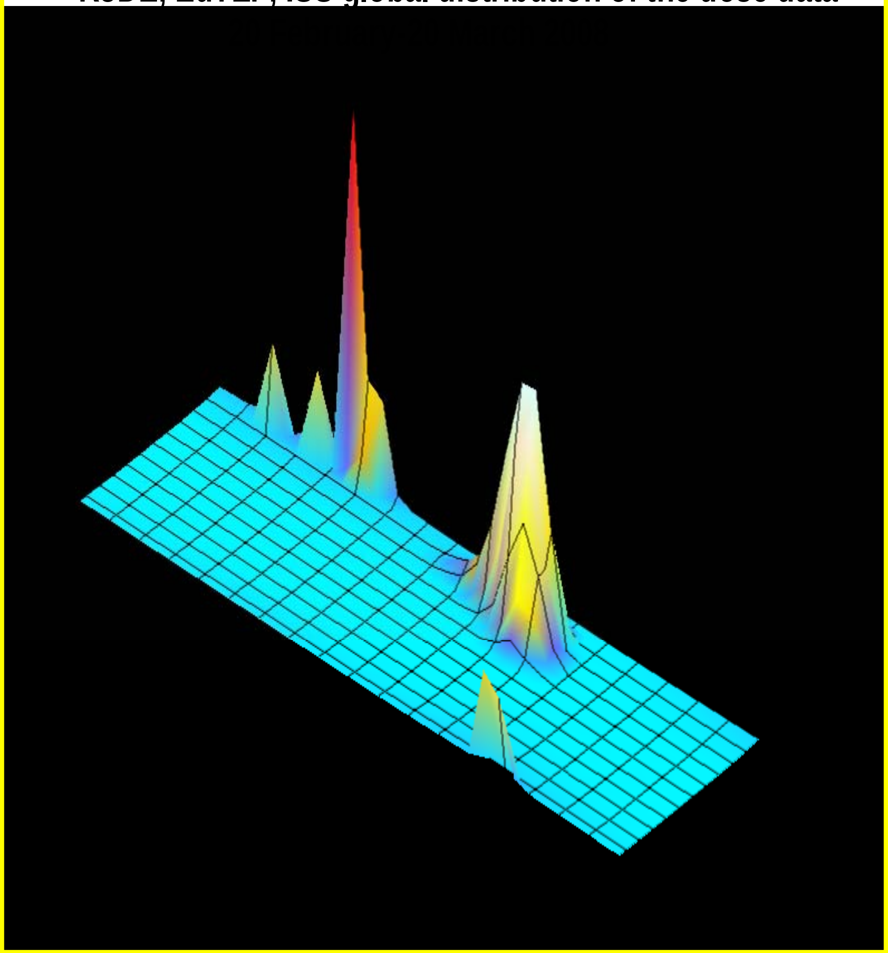
Places of observations of relativistic electrons are separated in narrow latitudinal range equatorialward from magnetic poles.

The calculated values of the incident proton energies in SAA region fall down from about 60 MeV at the west edge of the anomaly to 10 MeV at the east edge.

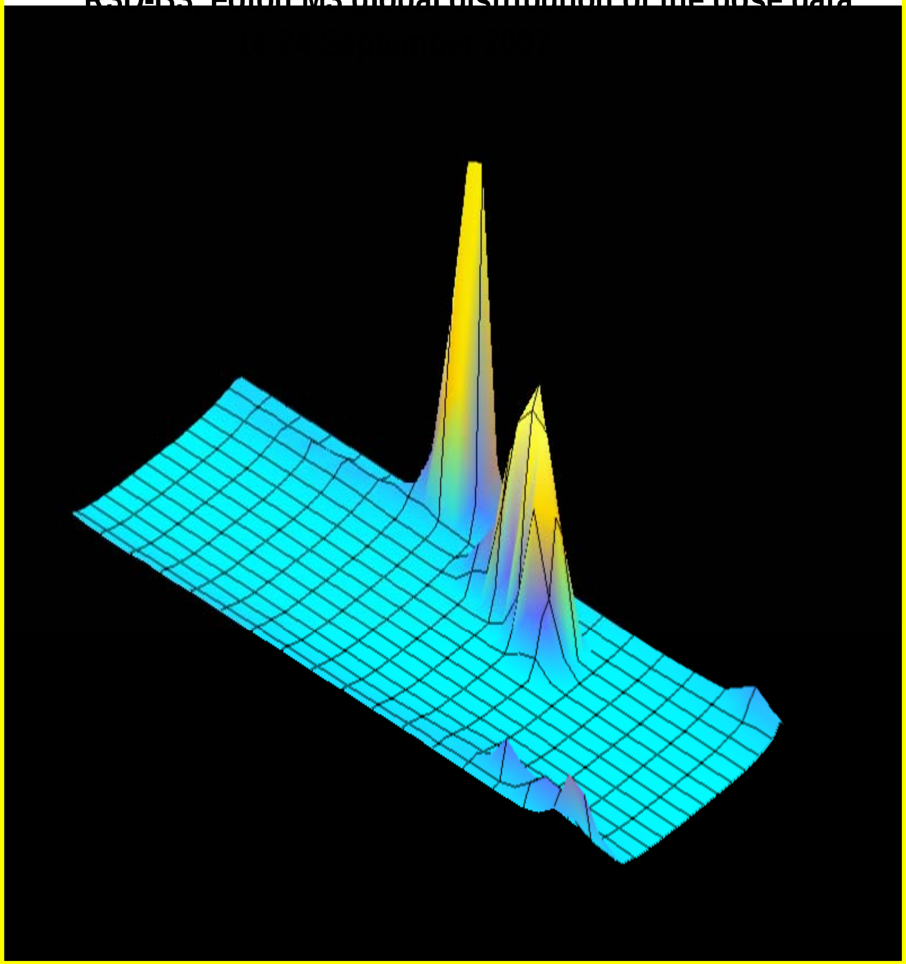
Very high doses (Up to 19 mGy/h) in the regions equatorialward from magnetic poles are generated by relativistic (>1 MeV) electrons, which seems to be the first observation of them at ISS.

ISS and Foton M3 global distributions of the averaged dose in pixels Long=10°, Lat=5°

R3DE, EuTEF, ISS global distribution of the dose data

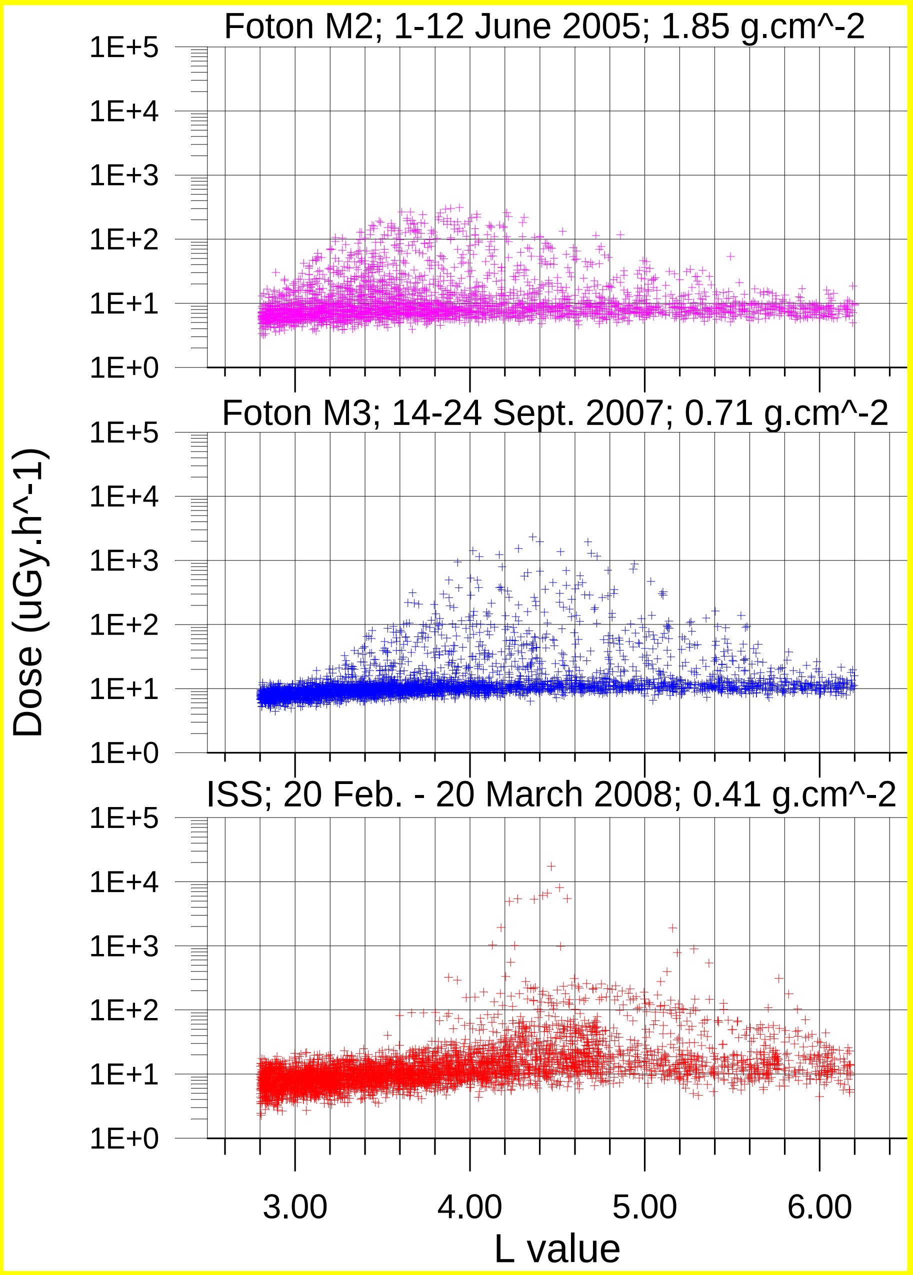


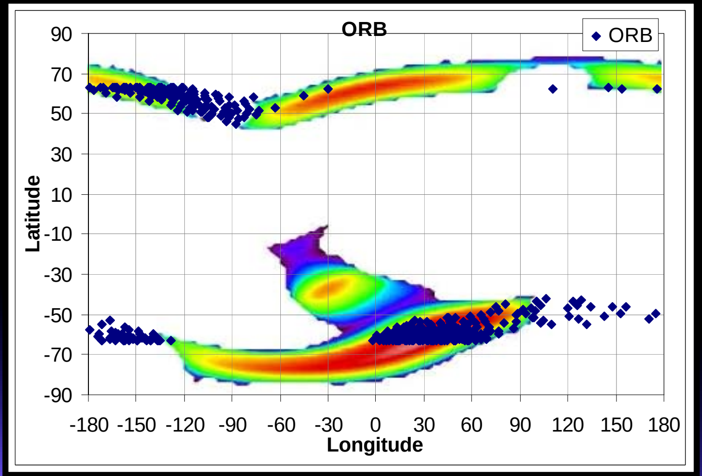
R3D-B3, Foton M3 global distribution of the dose data



High dose...

Comparison of the observed doses at 3 satellites

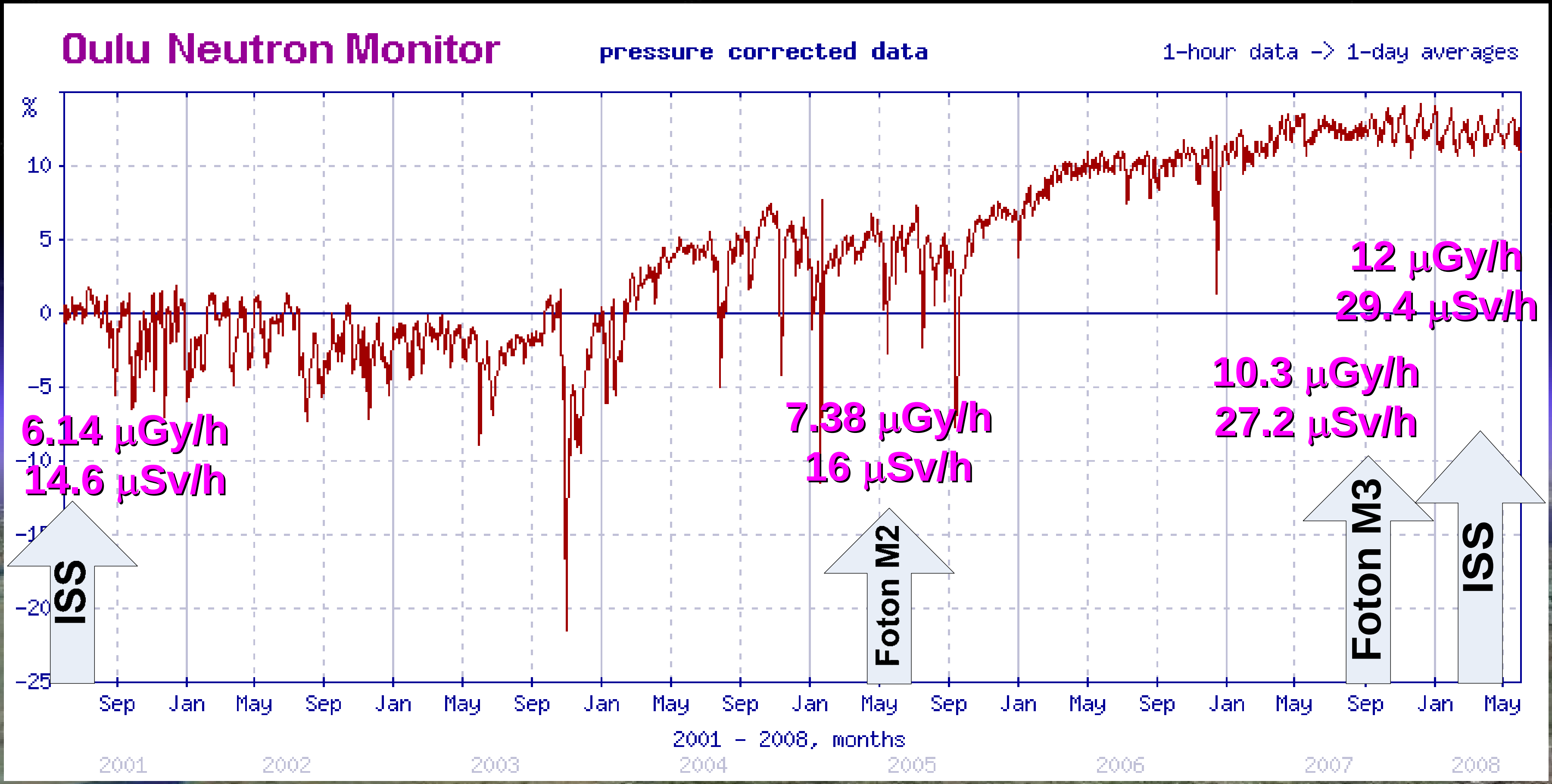




High doses are regularly observed on Foton M2/M3 satellites in the Southern hemisphere at latitudes above the inclination oof ISS

The REP on ISS are rare and very sporadic. Till the whole operation period of the R3DE instrument on ISS between February and July 2008 we have only 8 events when the doses are above 2000 μGy.h^{-1}

Comparison of doses obtained on ISS and Foton M2/3 with Oulu neutron monitor data



Solar minimum GCR doses in low earth orbit rise twice during the solar maximum, while neutron component on Earth surface rise up only with 10%

Conclusions

If we will consider that the danger for the astronauts being on EVA relativistic electrons events are with dose above 500 µGy.h^{-1} than for the period 22 February 18 March 2008 we collect totally 132 10 seconds intervals, which is only 22 minutes. From other hand this observations are made in very low solar activity. The long period observations with SAMPEX satellite and others show increase of the REP observations when the solar activity is larger. This confirm another time the necessity of permanent active monitoring of the ISS radiation environment.