Characterization of Near Earth Radiation Environment by Liulin Type Instruments

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Outlook

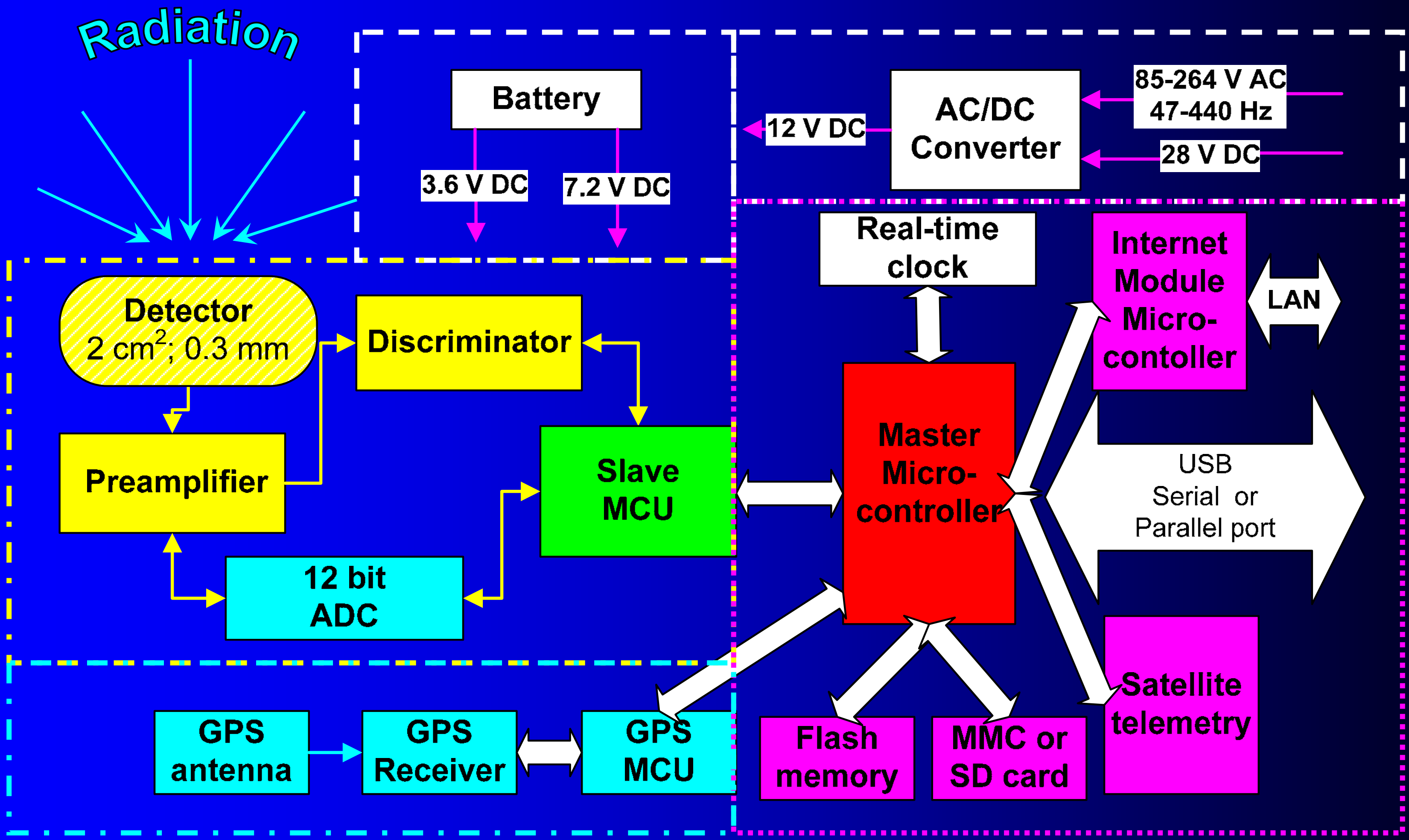
- Introduction
- Liulin spectrometers
- Examples of space radiation characterization by data from Liulin type instruments
- Future experiments
- Conclusions

Introduction

Since 2001 following Liulin-4 type spectrometers were developed and used in the Earth radiation environment:

- **MDU-5** was flown more than 6000 hours between 2001 and 2008 on aircrafts of Czech Airlines (CSA) at different routes;
- **Liulin-E094** worked successfully between May and August 2001 on the board of US Laboratory module of ISS;
- **R3D-B2** was successfully flown 31 May – 16 June 2005 inside of the ESA Biopan 5 facilities on Foton M2 satellite;
- **Liulin-MKC** (Liulin-ISS) contains 4 spectrometers with displays and is part of the Service Radiation Monitoring System of the Russian segment of ISS. The operation of it was postponed and start in August 2008;
- **R3D-B3** spectrometer was successfully flown 14-29 September inside of the ESA Biopan 6 facilities on Foton M3 satellite;
- **Liulin-Photo** instrument (Similar to MDU-5 instrument) was also flown Foton M3 satellite but inside of the capsule;
- **Liulin-R** was launched successfully on HotPay2 rocket January 31, 2008 at 19:14:00 up to 380 km altitude from Andoya Rocket Range;
- **R3DE** instrument is working on EuTEF platform outside of Columbus module of ISS since 20th of February 2008;
- **Liulin-6I**, **Liulin-6R** and **Liulin-6MB** internet based instruments worked for different periods between 2005 and 2008 at Jungfrau (3453 m asl) and Mousala (2925 m asl) peaks in Switzerland and Bulgaria and at ALOMAR observatory in Norway.

Integrated Block - diagram of the Liulin type 256 channels spectrometers of the deposited energy in the Si diode

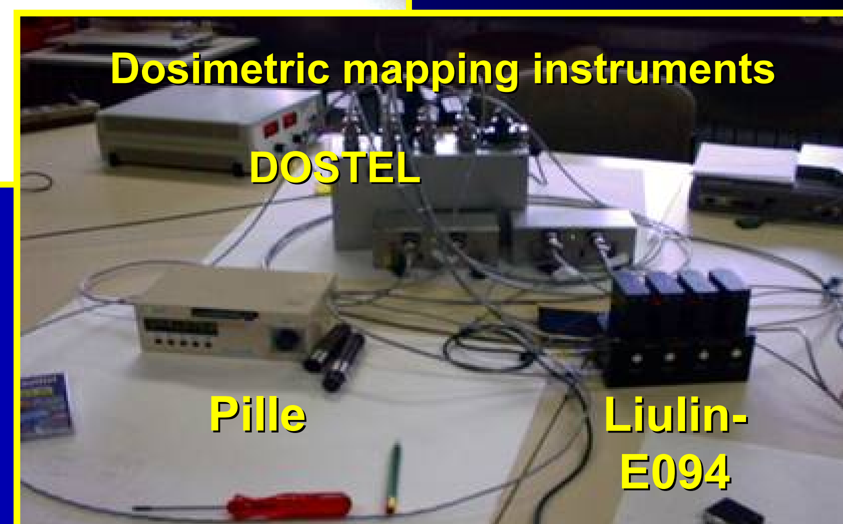


Liulin-E094 spectrometer with 4 independent battery operated Mobile Dosimetry Units (MDU) was flown successfully on ISS (American Laboratory module and Node1) in May-August 2001 as a part of Dr. Reitz lead Dosimetric mapping experiment

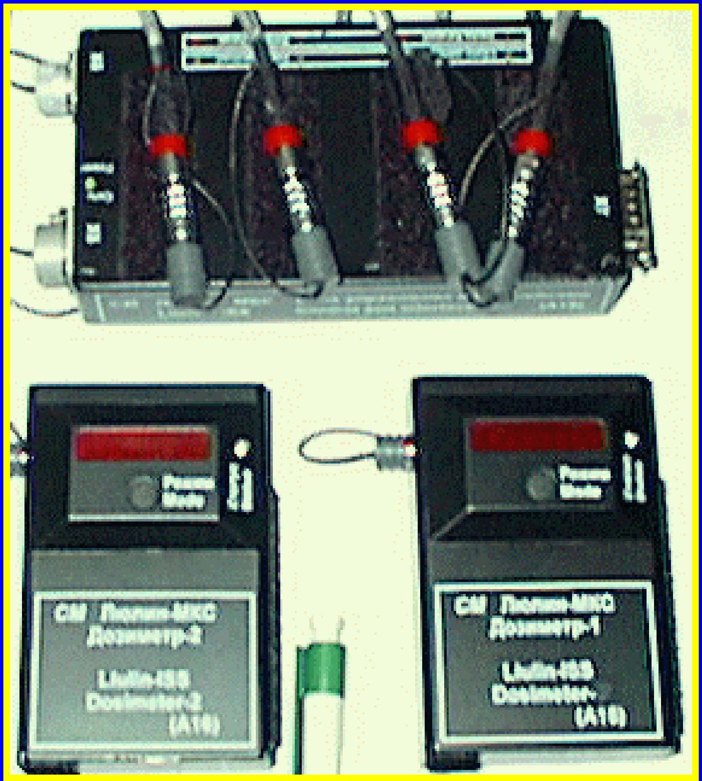
Liulin Control And Interface Unit (CIU)

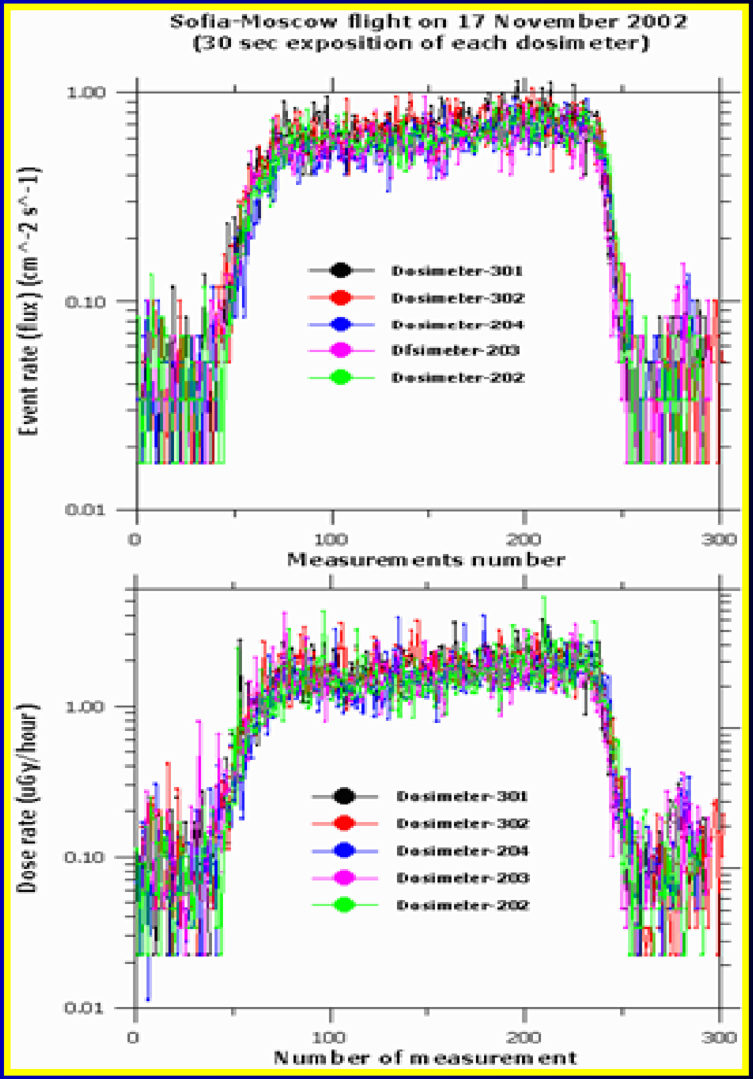
Liulin Mobile Dosimetry Unit (MDU)

American astronaut James Voss working with Dosimetric mapping experiment on 26.06.2001



Liulin-ISS Instrument was launched in September 2005 to the Russian Segment of ISS. It is a part of Russian segment service dosimetric system and was activated by the current crew in August 2008



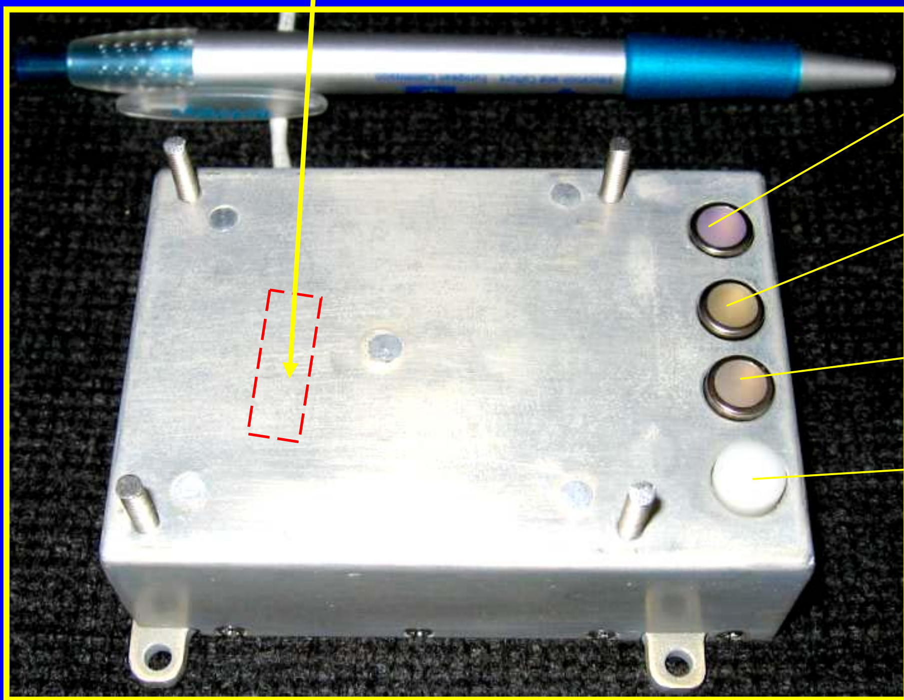


MDU Liulin-ISS dimensions:
Weight: 229 g incl. 80 g battery
Size: 110x80x25 mm
Consumption: 84 mW

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

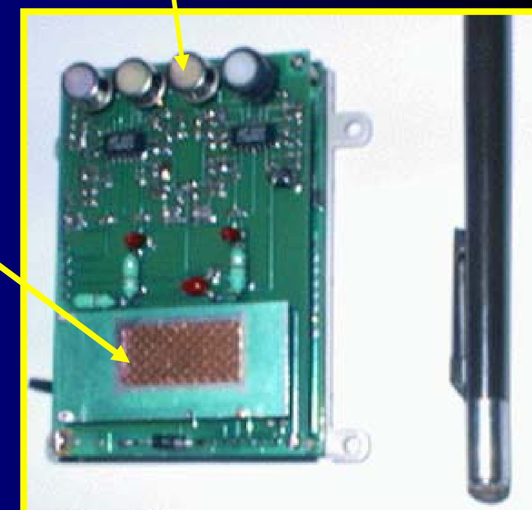


UV-C channel

UV-B channel

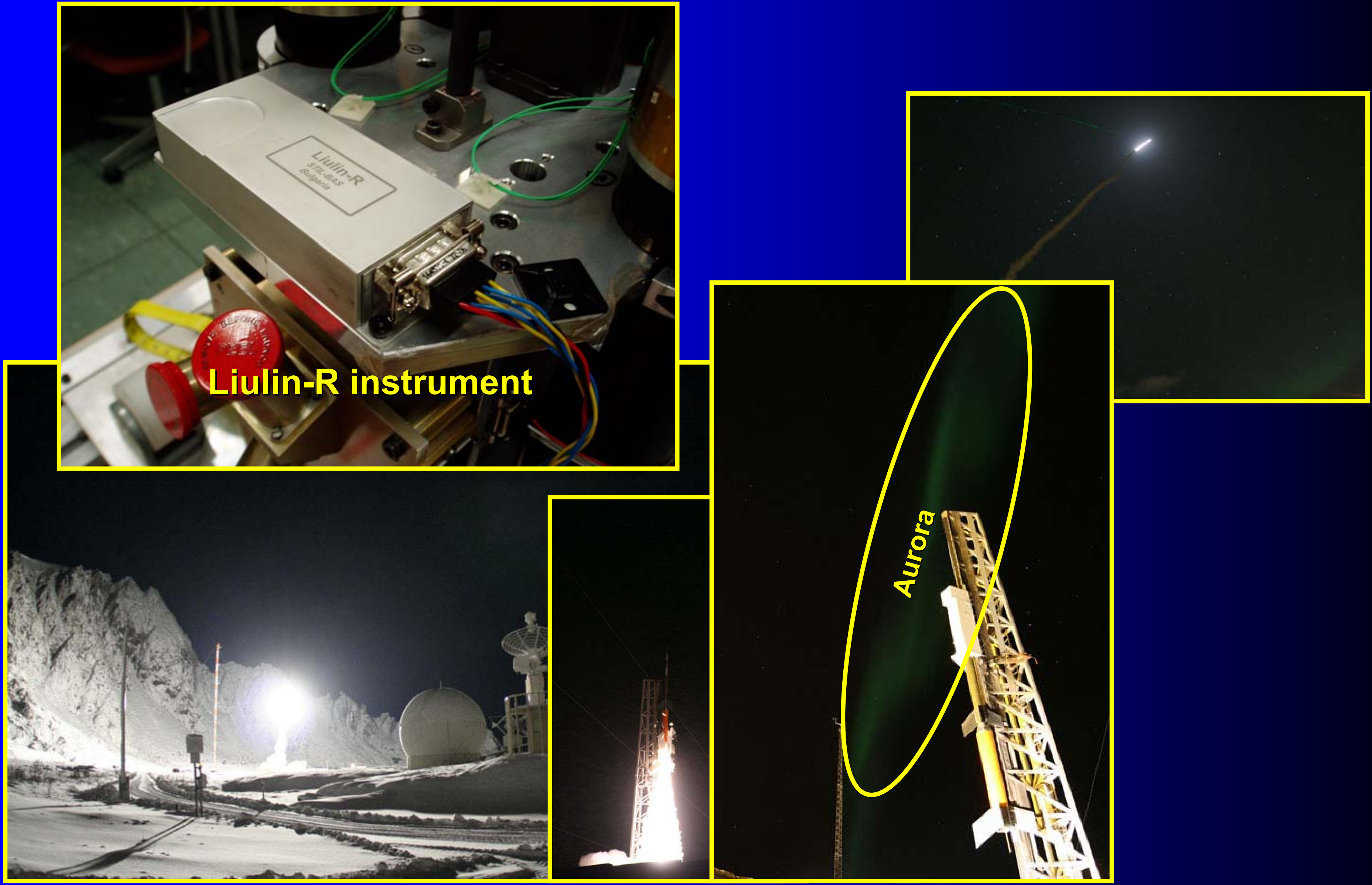
UV-A channel

PAR channel

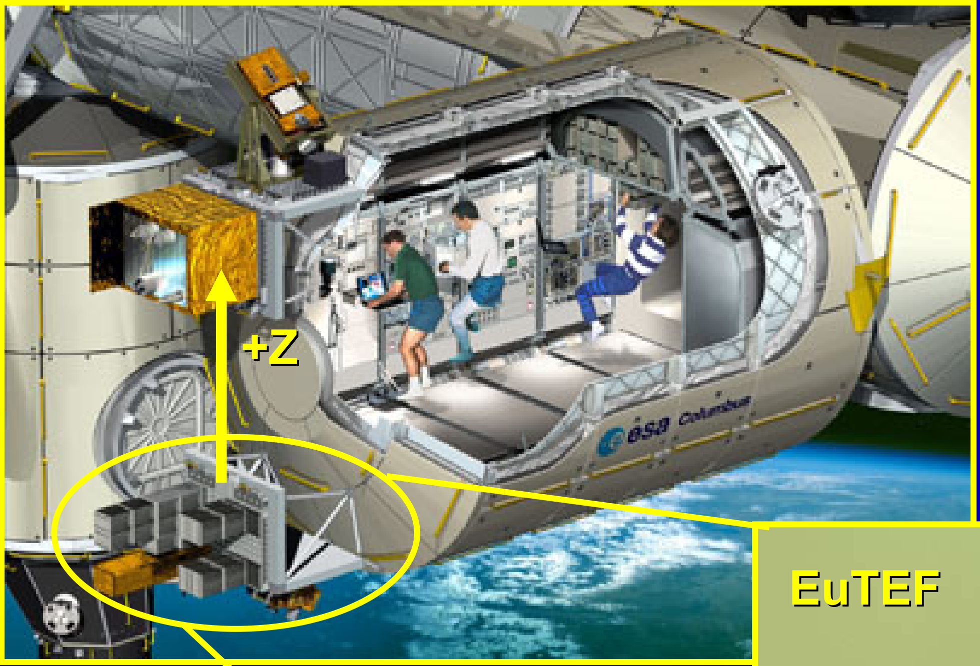


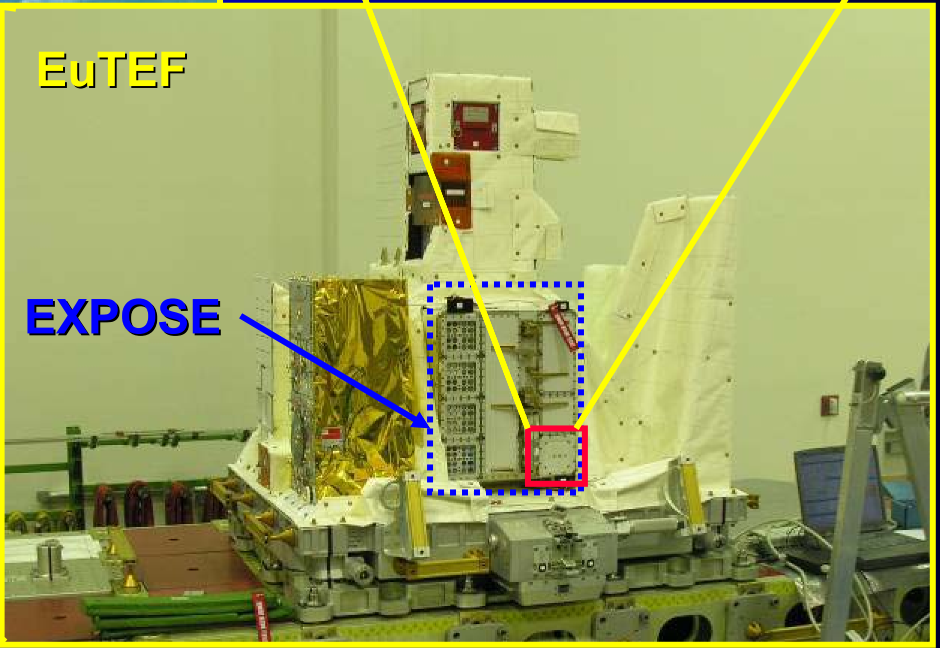
Size: 82x57x25 mm
Weight: 129 g
Consumption: 84 mW

Liulin-R experiment on HotPay2 rocket up to 380 km altitude from Andoya, Norway on January 31st 2008 at 21:14 UT



R3DE instrument was successfully launched to the EuTEF platform together with the European module Columbus in February 2008





The detector of R3DR instrument is shielded by less than 0.4 g/cm^2 material including: 1 mm aluminum + 0.1 mm cuprum +0.2 mm plastic

STIL-BAS spin-off produced Liulin type spectrometers for measurements of the space radiation on aircrafts are used by scientists from Japan, USA, Germany, France, Canada, Spain, Austria, Australia, Poland, Russia, Czech Republic and others

GPS receiver;
Li-Ion batteries;
Galvanically ins. 20-35 V DC
512 MB SD/MMC card.

*Weight: 470 g**
Size: 100x100x45 mm

More than 30 days working time from accumulator

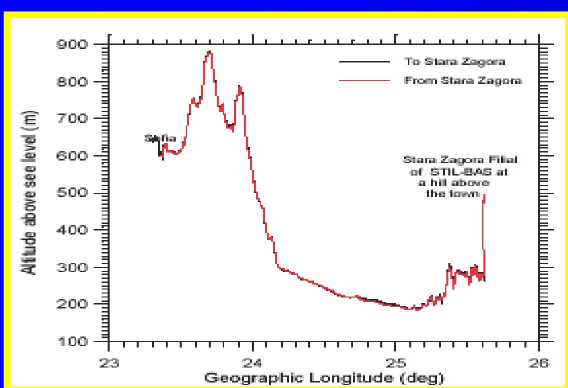
*Weight: 280 g**
Size: 95x85x55 mm

More than 4 days working time from Li-Ion accumulator

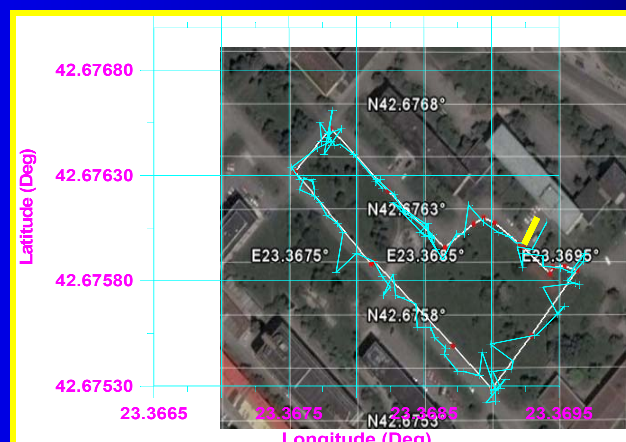
*Weight: 115 g**
Size: 124x40x20 mm

Spectrometer with GPS receiver and display for monitoring of the space radiation doses by aircraft pilots

Weight: 280 g
Size: 110x80x45 mm



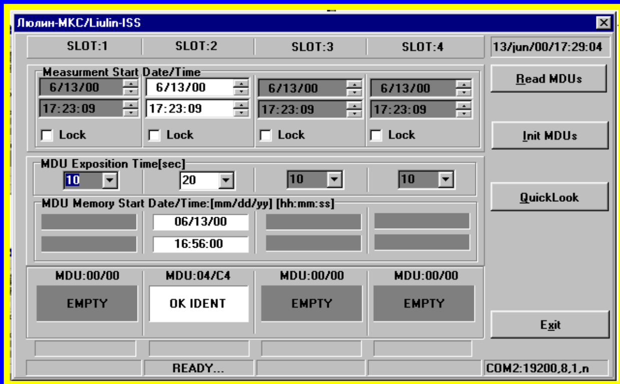
Altitude above the see level as measured by Liulin type spectrometer on the route Sofia-St. Zagora town



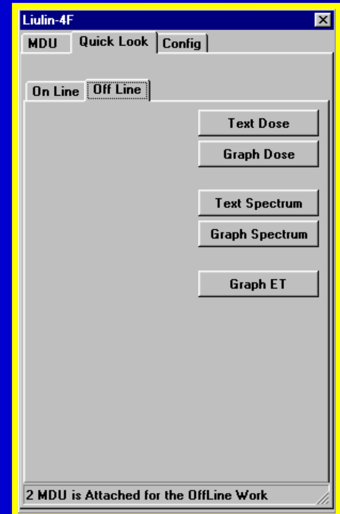
Walk in STIL-BAS area as obtained by GPS receiver mounted in Liulin type spectrometer. Yellow line is 20 m.

11 Liulin type spectrometers during calibrations in CERN, October 2006

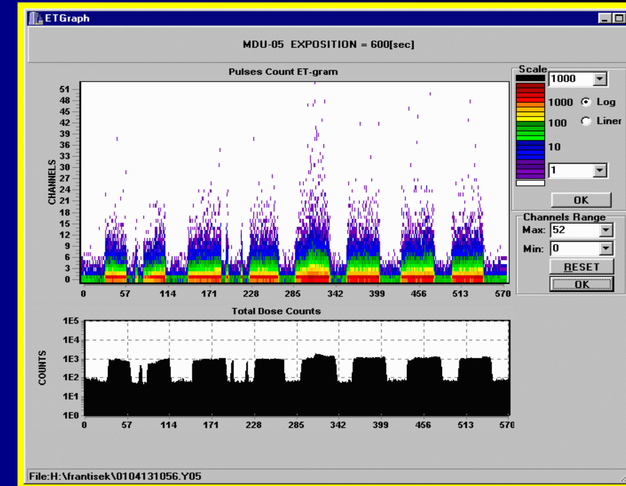
Examples of Windows Environment Software for "Quick look" of Liulin data



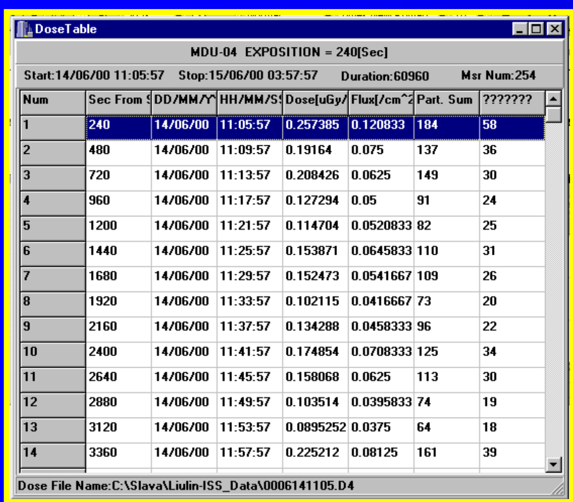
Initialization screenshot of 4 slot CIU with 4 MDUs



Initialization screenshot



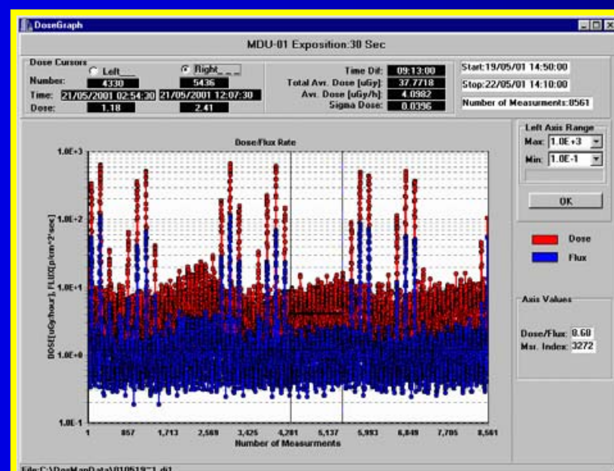
Quick look graph of ET spectrogram



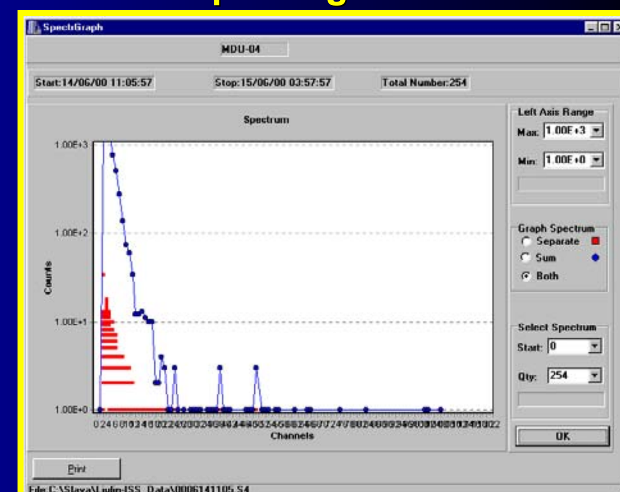
Num	Sec From S	DD/MM/YY	HH/MM/SS	Dose[uGy/	Flux[/cm^2	Part. Sum	???????
1	240	14/06/00	11:05:57	0.257385	0.120833	184	58
2	480	14/06/00	11:09:57	0.19164	0.075	137	36
3	720	14/06/00	11:13:57	0.208426	0.0625	149	30
4	960	14/06/00	11:17:57	0.127294	0.05	91	24
5	1200	14/06/00	11:21:57	0.114704	0.0520833	82	25
6	1440	14/06/00	11:25:57	0.153871	0.0645833	110	31
7	1680	14/06/00	11:29:57	0.152473	0.0541667	109	26
8	1920	14/06/00	11:33:57	0.102115	0.0416667	73	20
9	2160	14/06/00	11:37:57	0.134288	0.0458333	96	22
10	2400	14/06/00	11:41:57	0.174854	0.0708333	125	34
11	2640	14/06/00	11:45:57	0.158068	0.0625	113	30
12	2880	14/06/00	11:49:57	0.103514	0.0395833	74	19
13	3120	14/06/00	11:53:57	0.0895252	0.0375	64	18
14	3360	14/06/00	11:57:57	0.225212	0.08125	161	39

Dose File Name:C:\Slava\Liulin-ISS_Data\0006141105.D4

List of dose and flux data



Quick look graph of dose and flux data



Quick look graph of spectra

Liulin 256 channels spectrum interpretation procedure

1) Dose and flux in Si is calculated as:

Dose (μGy) = K*∑(Ei x Ai)/MD

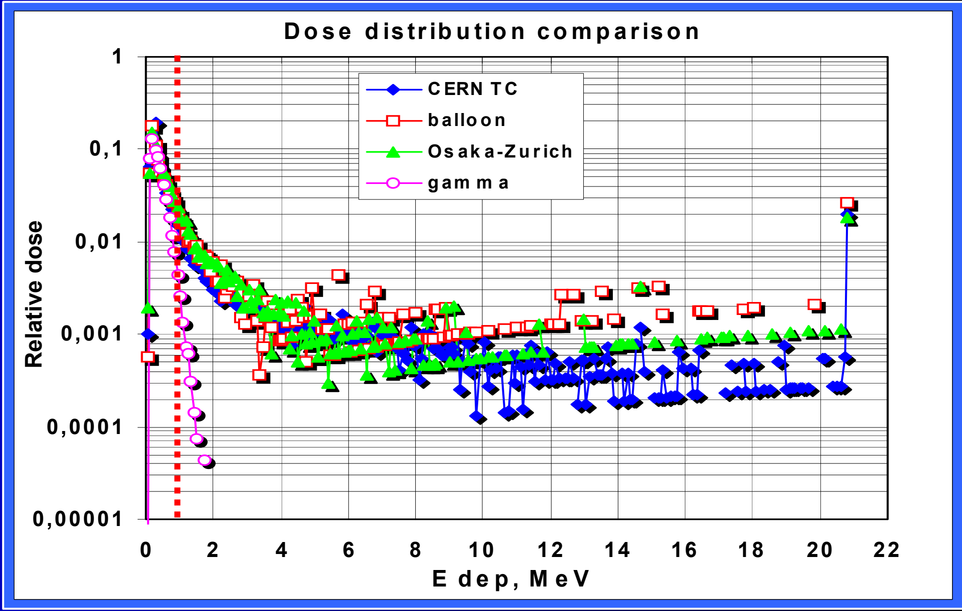
MD – mass of the detector;

Ei – energy loss in the channel i;

Ai – events number in the channel i;

K – coefficient based on ω_e in Si

Flux (cm^{-2} s^{-1})= ∑Ai



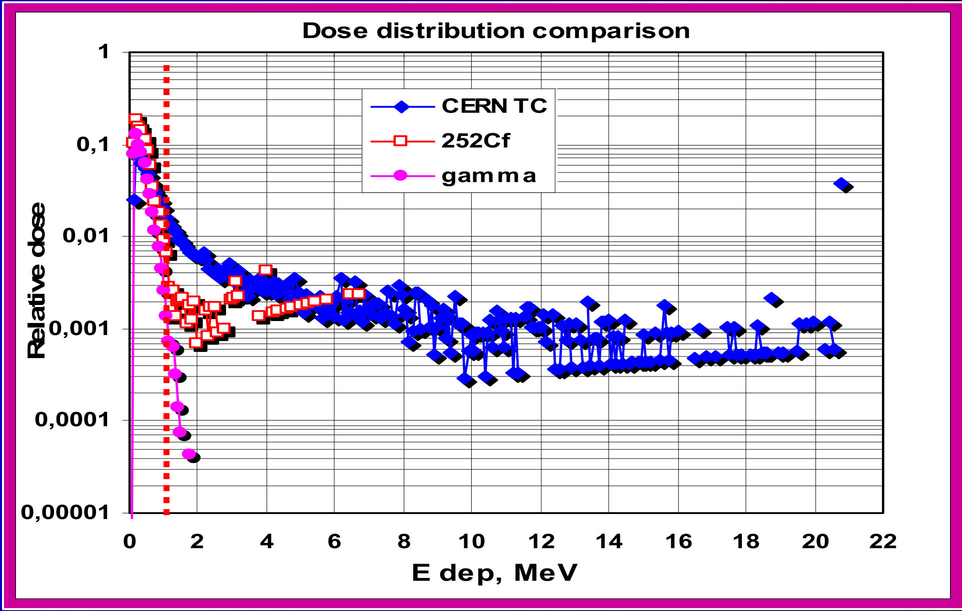
2) Apparent dose equivalent Happ (Ambient dose equivalent - H*(10)) is calculated as:

D(Si)high above ~ 1 MeV (D_{high}) neutron like component

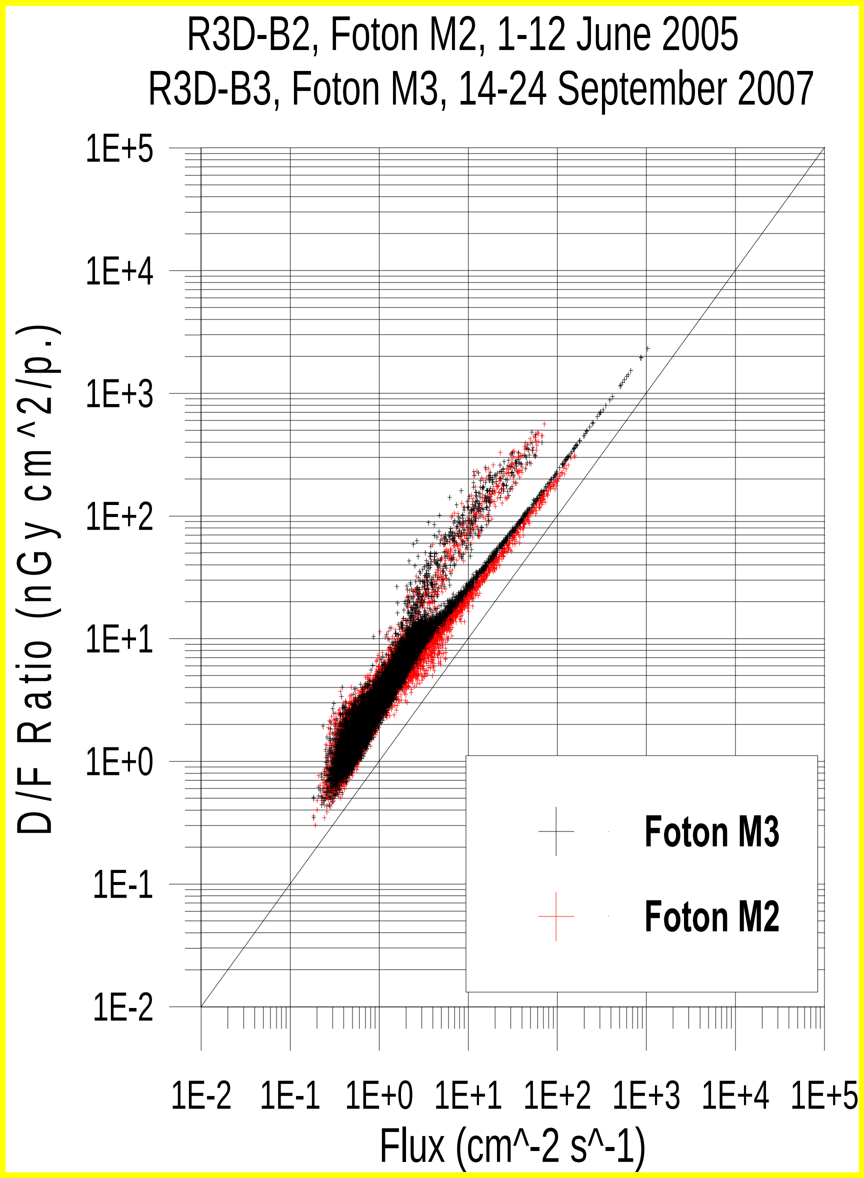
D(Si)low below ~ 1 MeV - (D_{low}) non-neutron component

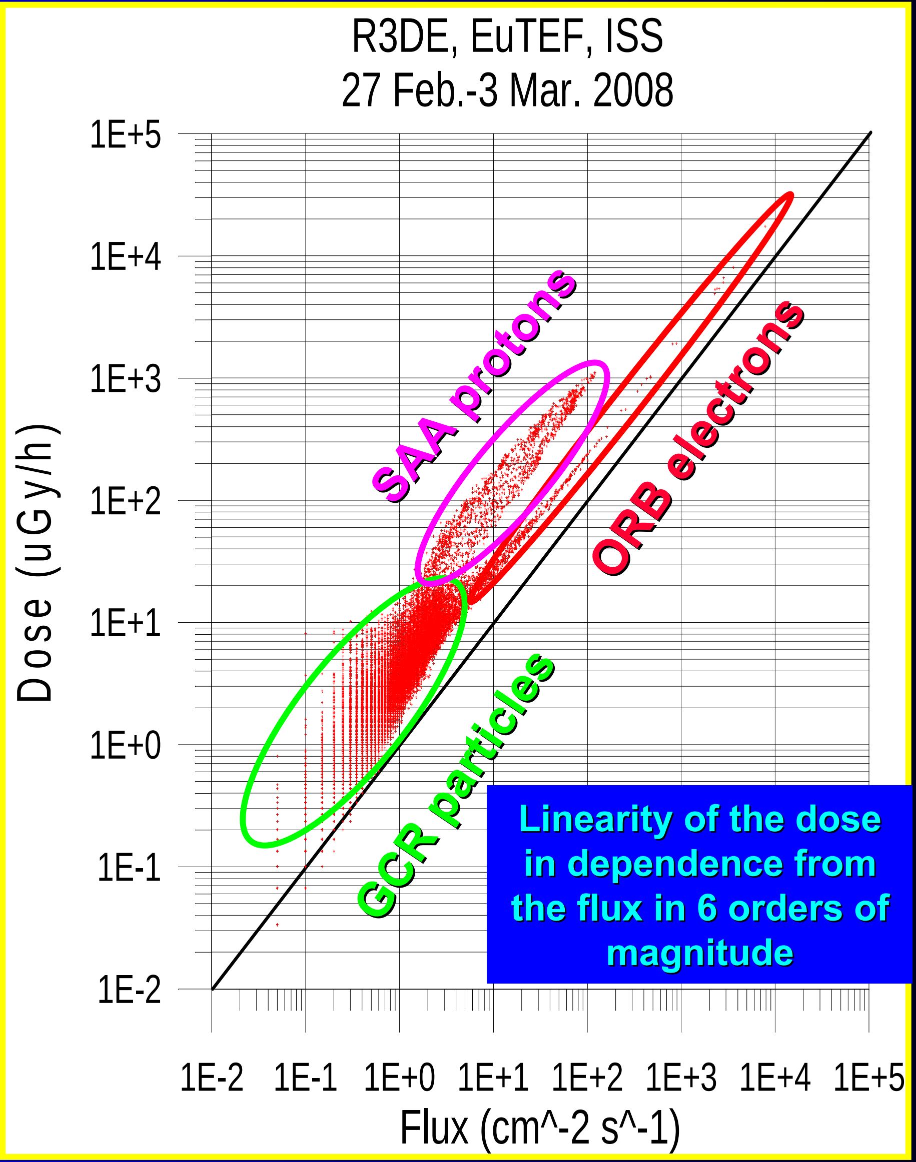
H*(10*)=k1Dlow + K2Dhigh

*k1and k2 coefficients – established in CERF fields and/or on the base of comparison with TEPC results



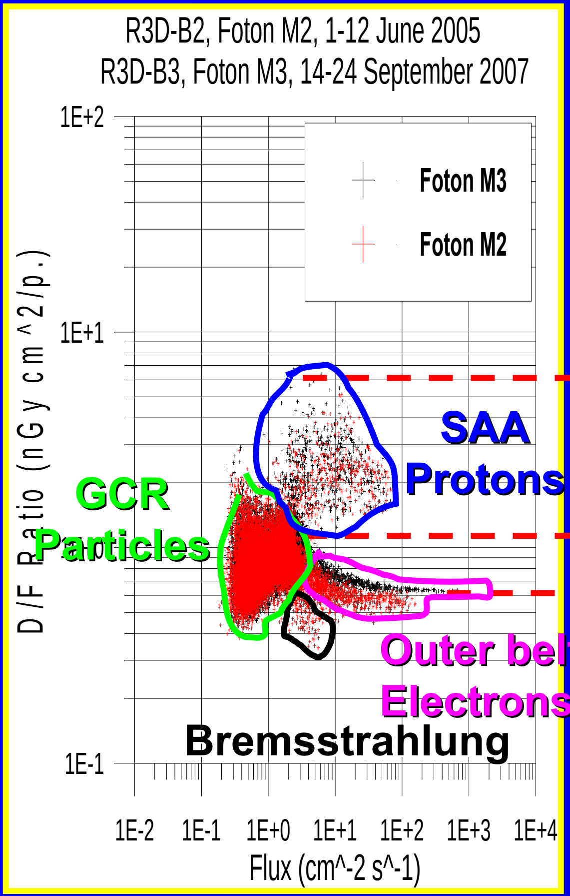
Characterization of the radiation sources in the coordinates flux/dose



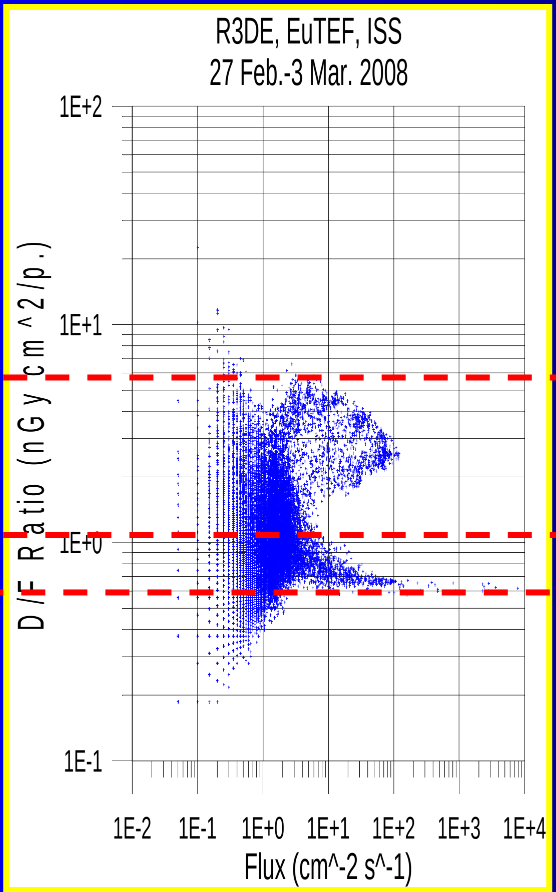


Characterization of radiation sources by the dose to flux ratio and Heffner's formulas calculations

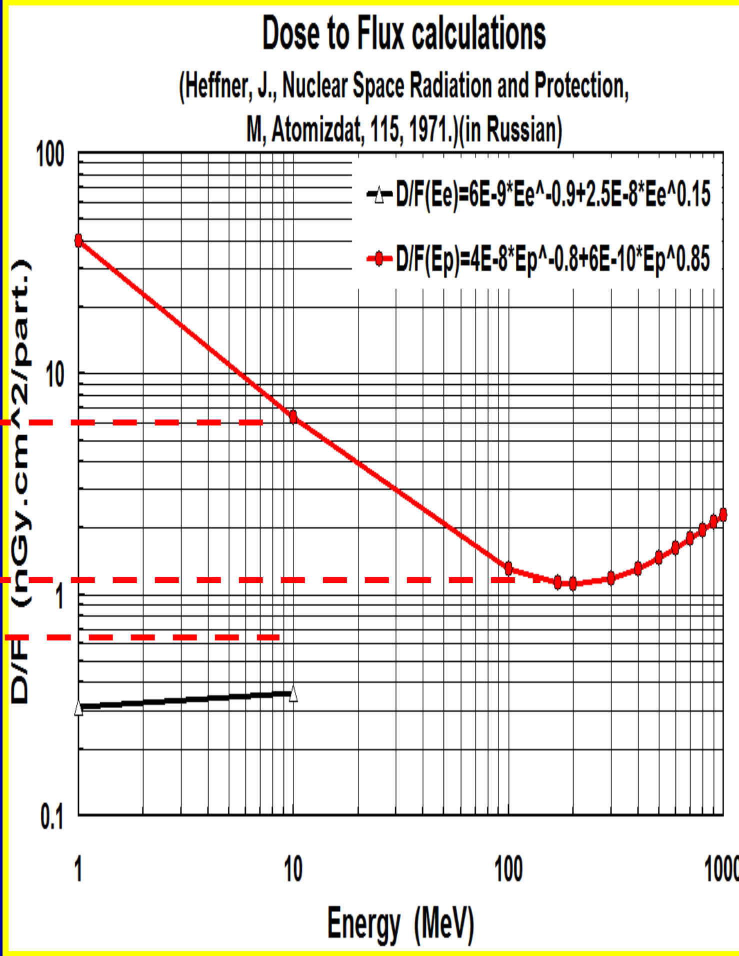
Foton M2/M3
60 sec resolution
260-300 km



EuTEF, ISS
10 sec resolution
340-360 km



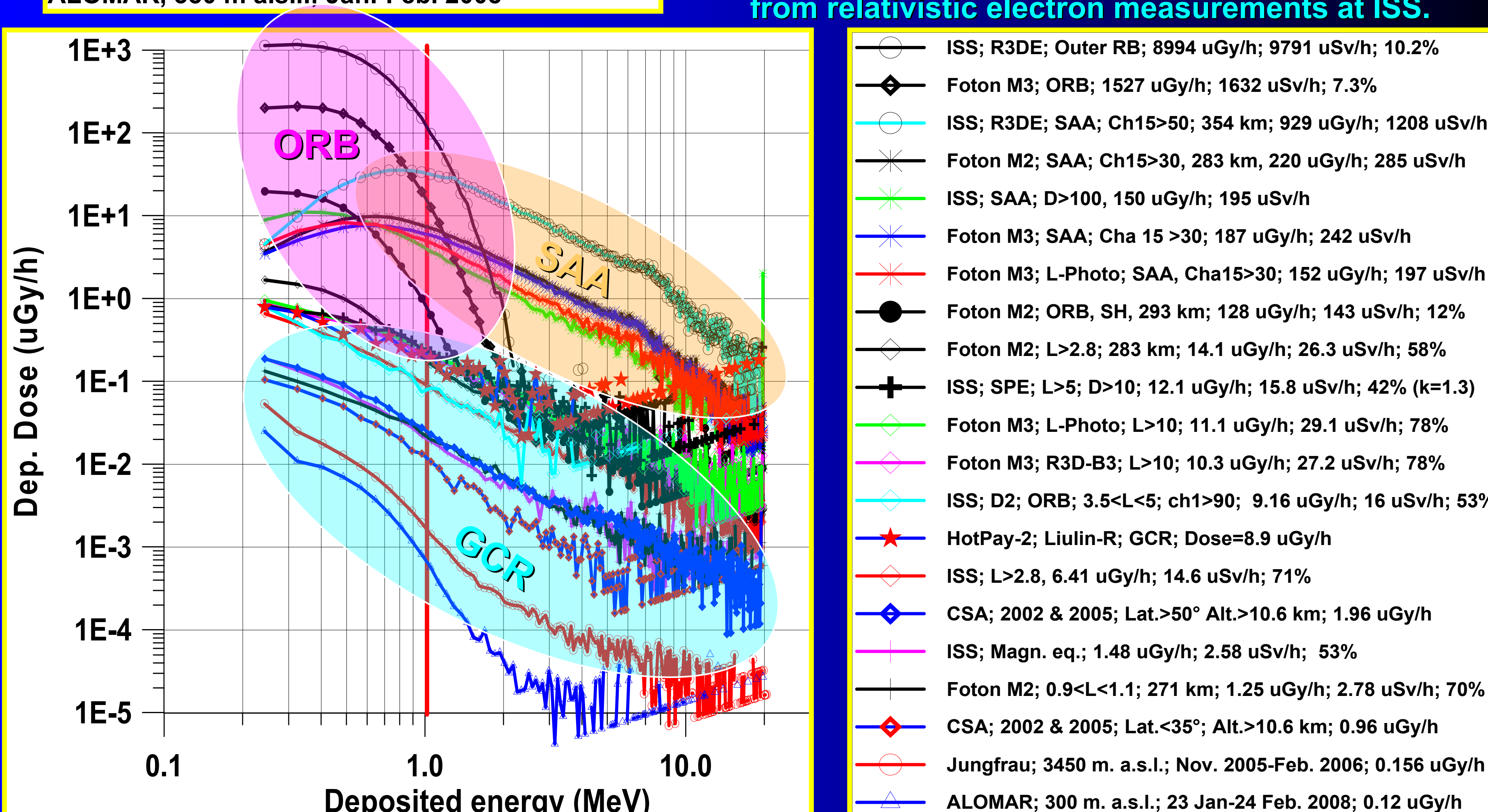
Heffner's formulas
and calculations



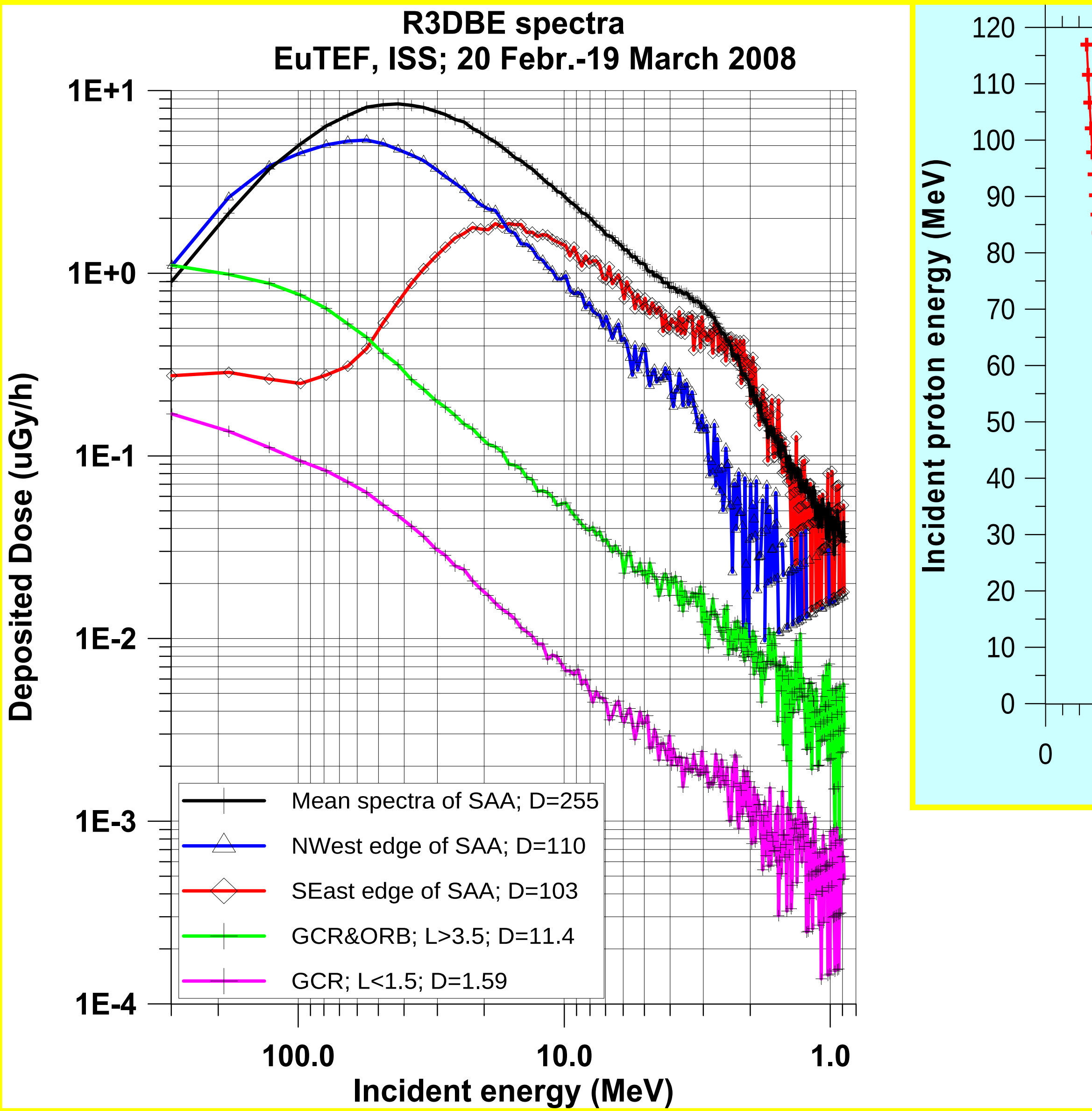
ISS; MDU#4; July 6-13 2001
CSA aircraft; MDU#5; 5 May - 28 June 2002
Foton M2; R3D-B2; June 1-12 2005
CSA aircraft; MDU#5; 6 May - 25 June 2005
Jungfrau; 3450 m a.s.l.; Nov.2005-Feb. 2006
Foton M3; R3D-B3 & Liulin-Photo; Sept.14-26 2007
HotPay-2 rocket; Liulin-R; 31 January 2008
ISS; R3DE; 20 Febr.-20 March 2008
Jungfrau; 3450 m a.s.l.; Nov. 2005-Feb. 2006
ALOMAR, 380 m a.s.l.; Jan.-Feb. 2008

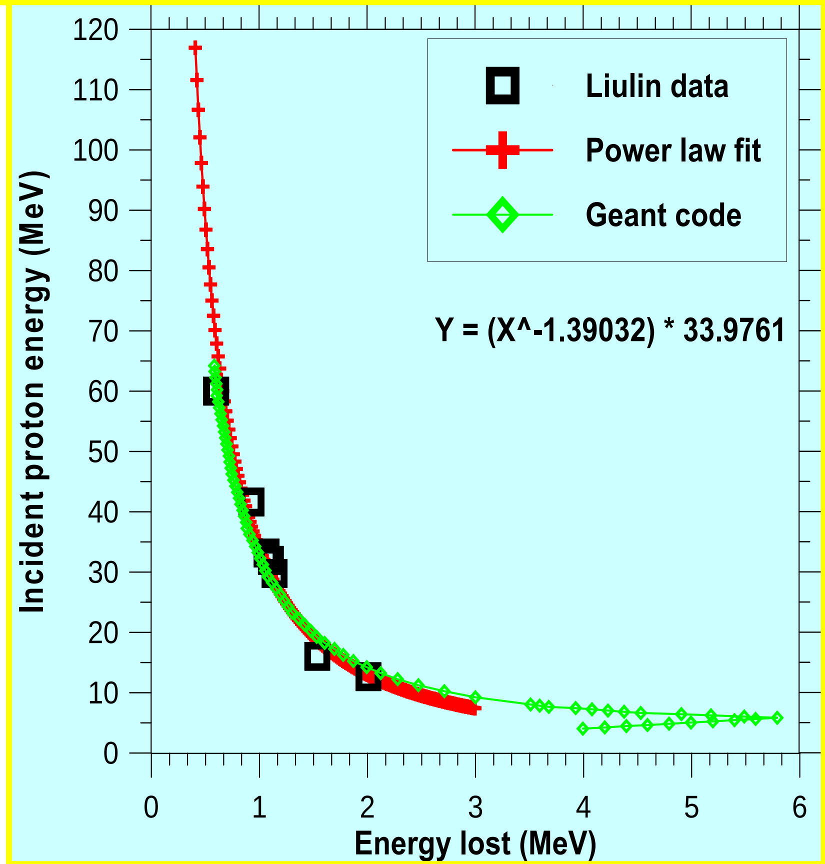
Characterization by spectrum shape and slope

Examples of the averaged spectra shapes and slopes for almost all available data. From below to up spectra are ordered in dependence of the absorbed dose. Lowest is from ground natural radiation = 0.12 while the highest = 9000 μGy/h is from relativistic electron measurements at ISS.

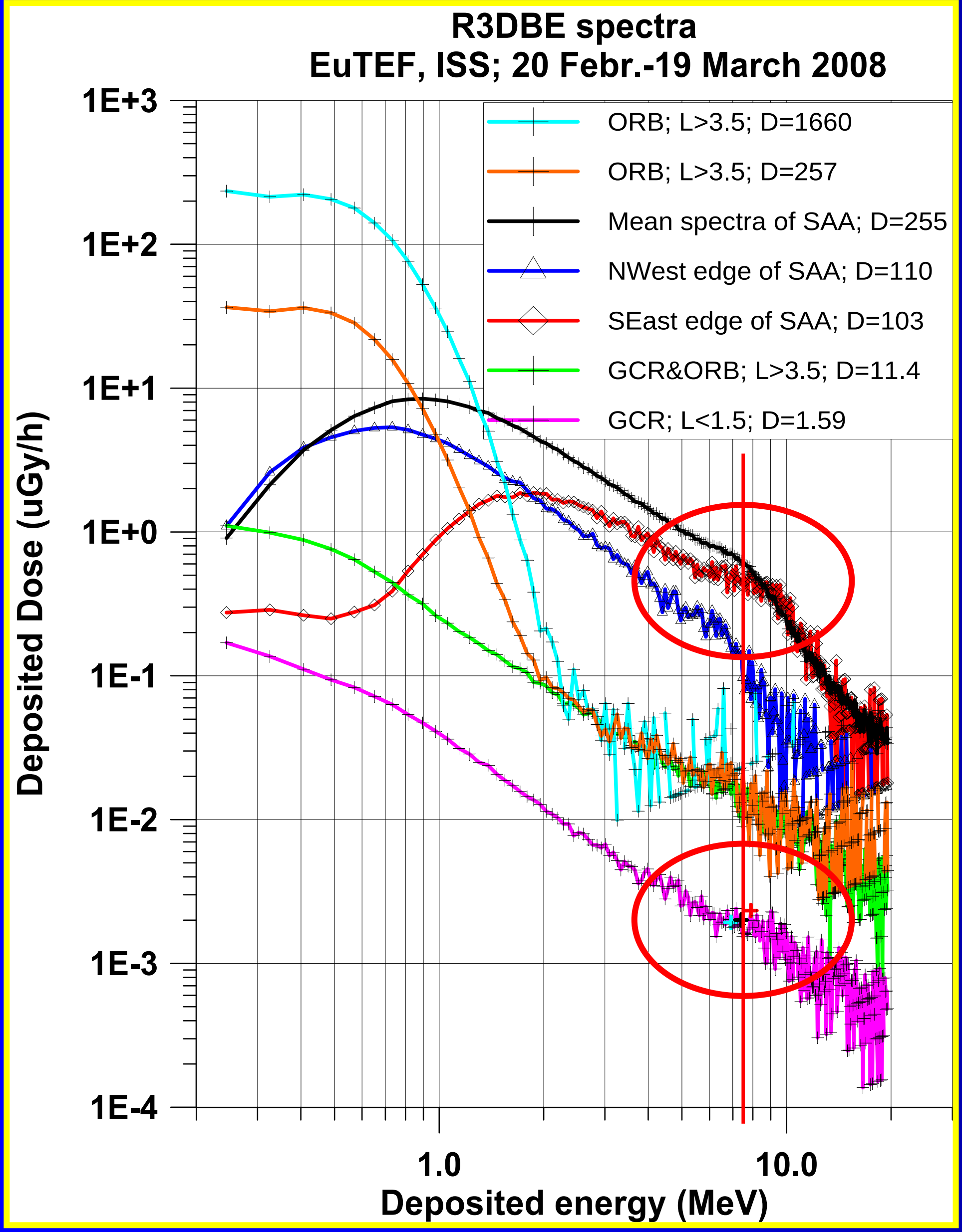


Shape and slope of the spectra with predominant proton population in dependence by the incident energy





Characterization of the type of radiation source by the shape and slope of the spectra

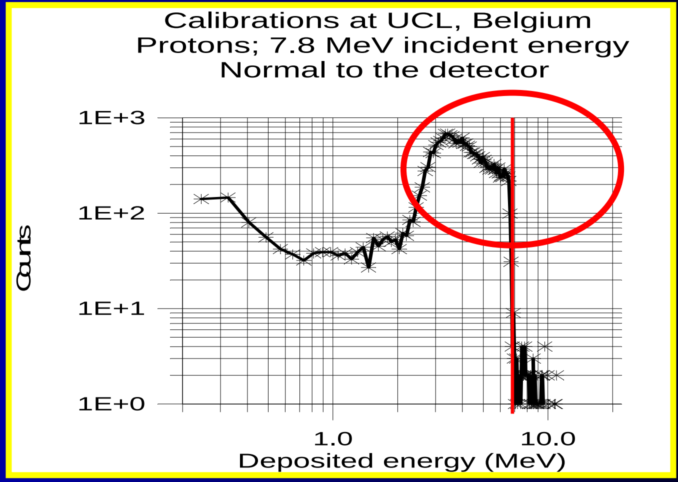


Sky blue and light brown lines presents 2 different dose level spectra of the other belt relativistic electrons, which are observed till 2.5 MeV depsited energy. Further the spectrum coincide with the GCR spectrum.

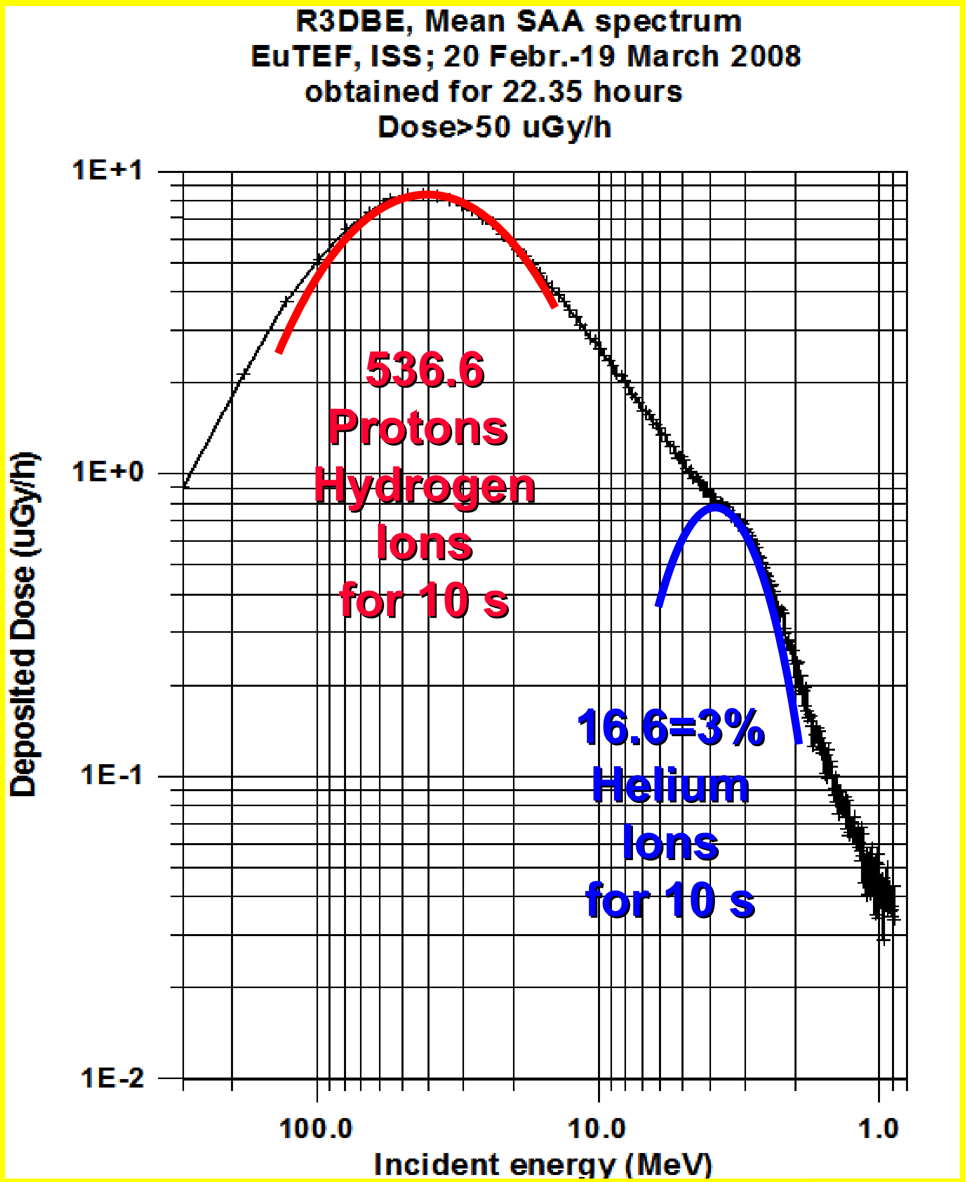
Blue (NW edge), black (Mean) and red (SE edge) lines presents 3 different positions spectra in the region of SAA.

Green (L>3.5) and magenta (1.5<L) lines presents 2 different positions GCR spectra with respective doses of 11.4 and 1.59 μGy/h

The change of slope at 6 MeV deposited energy is at the place where protons with energy 6 MeV are stopped in the detector

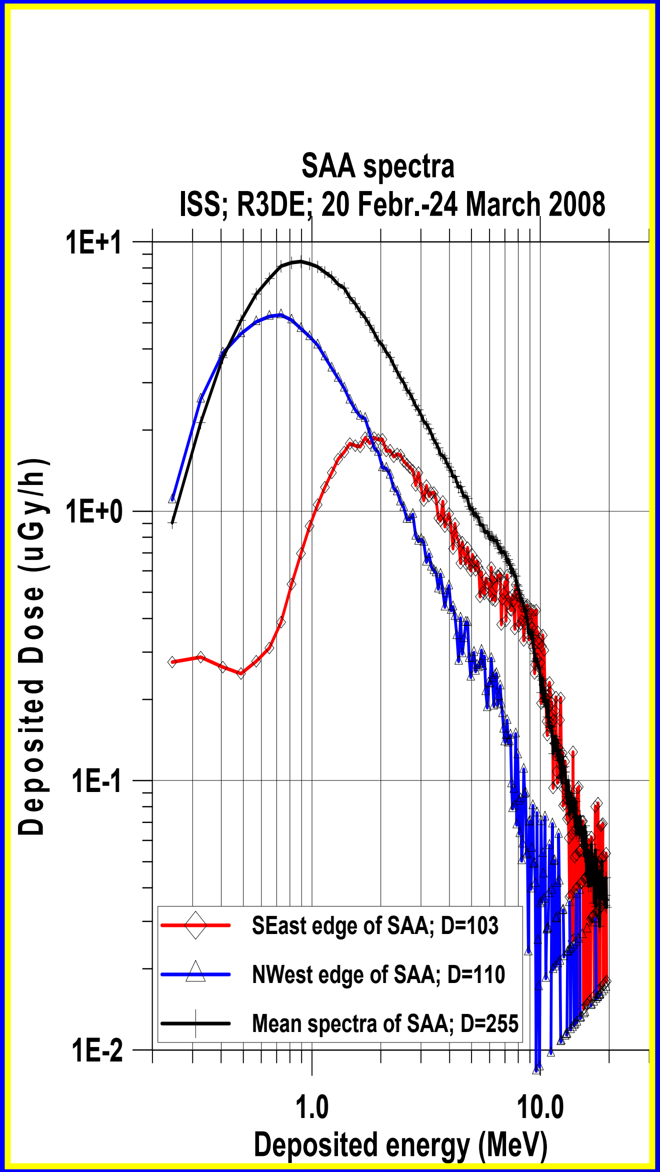


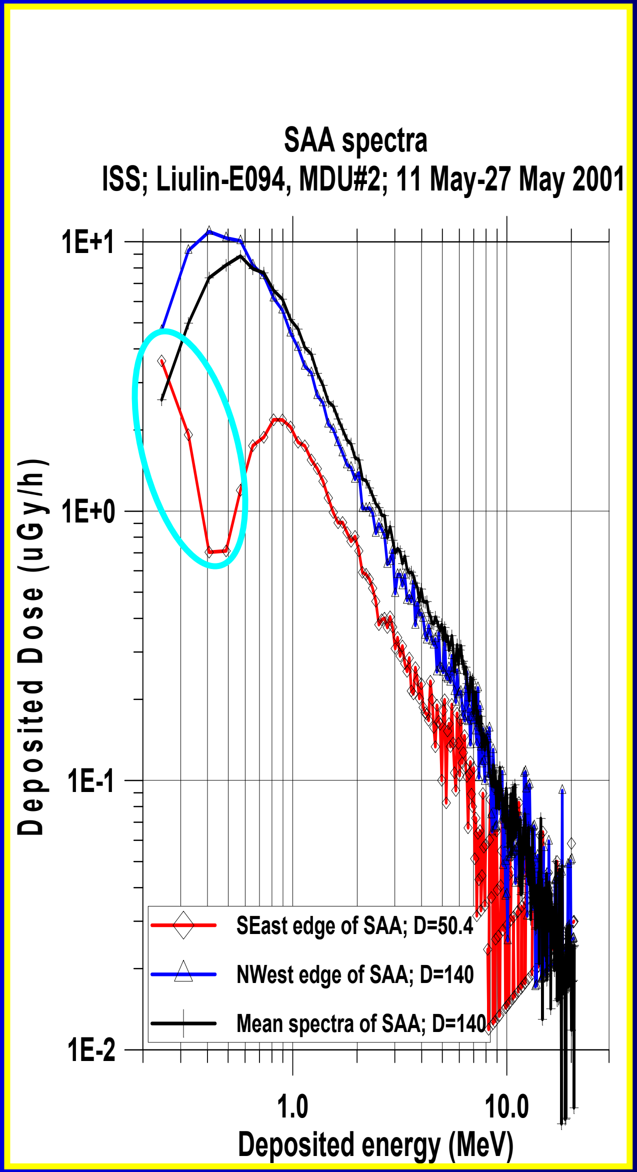
Characterization of the type of incident ions by the shape of the spectra in the region of SAA



Explanation of the shape of the spectrum with 2 maximums created by protons and helium ions. About 3% of all counts in SAA are created by Helium ions and protons falling at large angle toward the detector

Variations of the spectrum form in SAA region as measured by Liulin-E094 and R3DE on ISS in 2001 and 2008

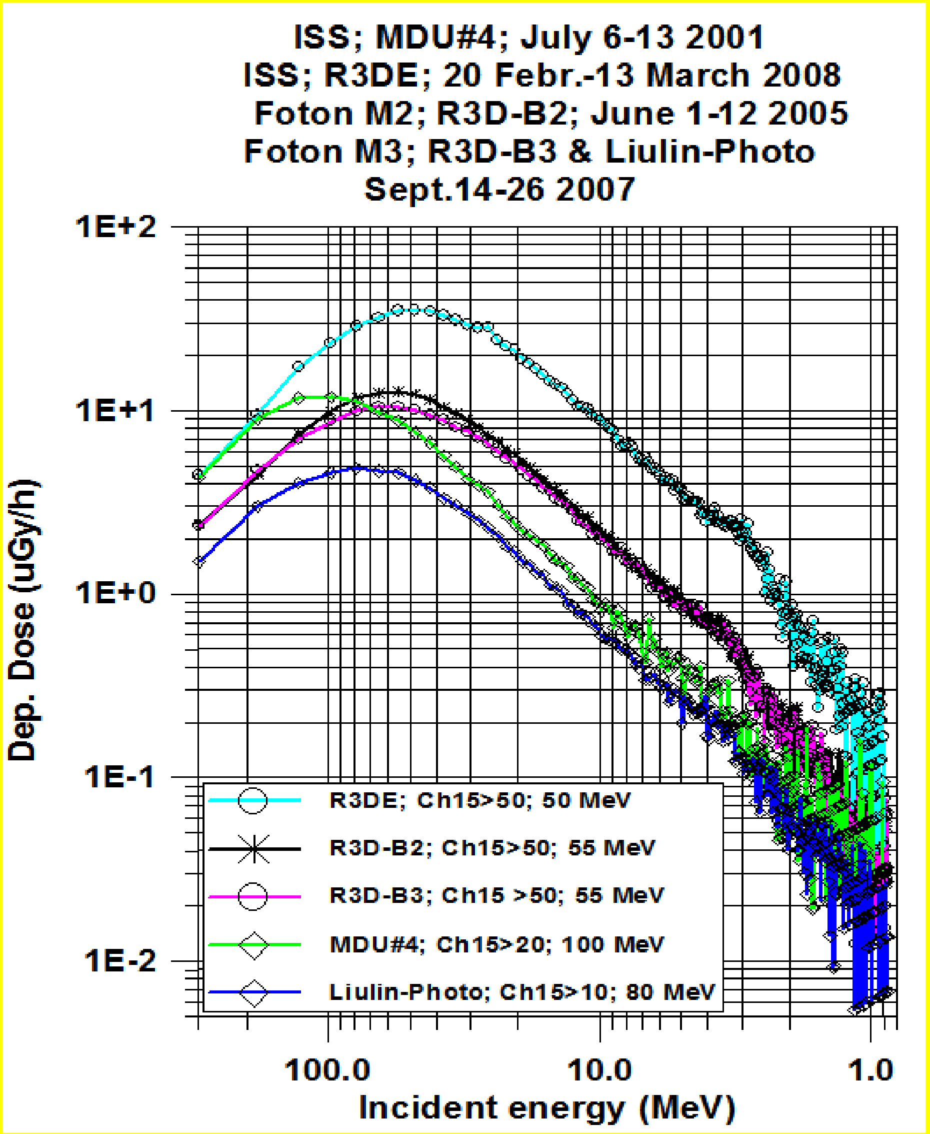




All spectra maximums in 2001 stay at higher deposited energy because higher shielding (>20 g/cm^2)

The part of the "red" spectrum in 2001, which is surrounded with sky blue ellipse is generated by slot region electrons and/or bremsstrahlung. In 2008 the slot is empty

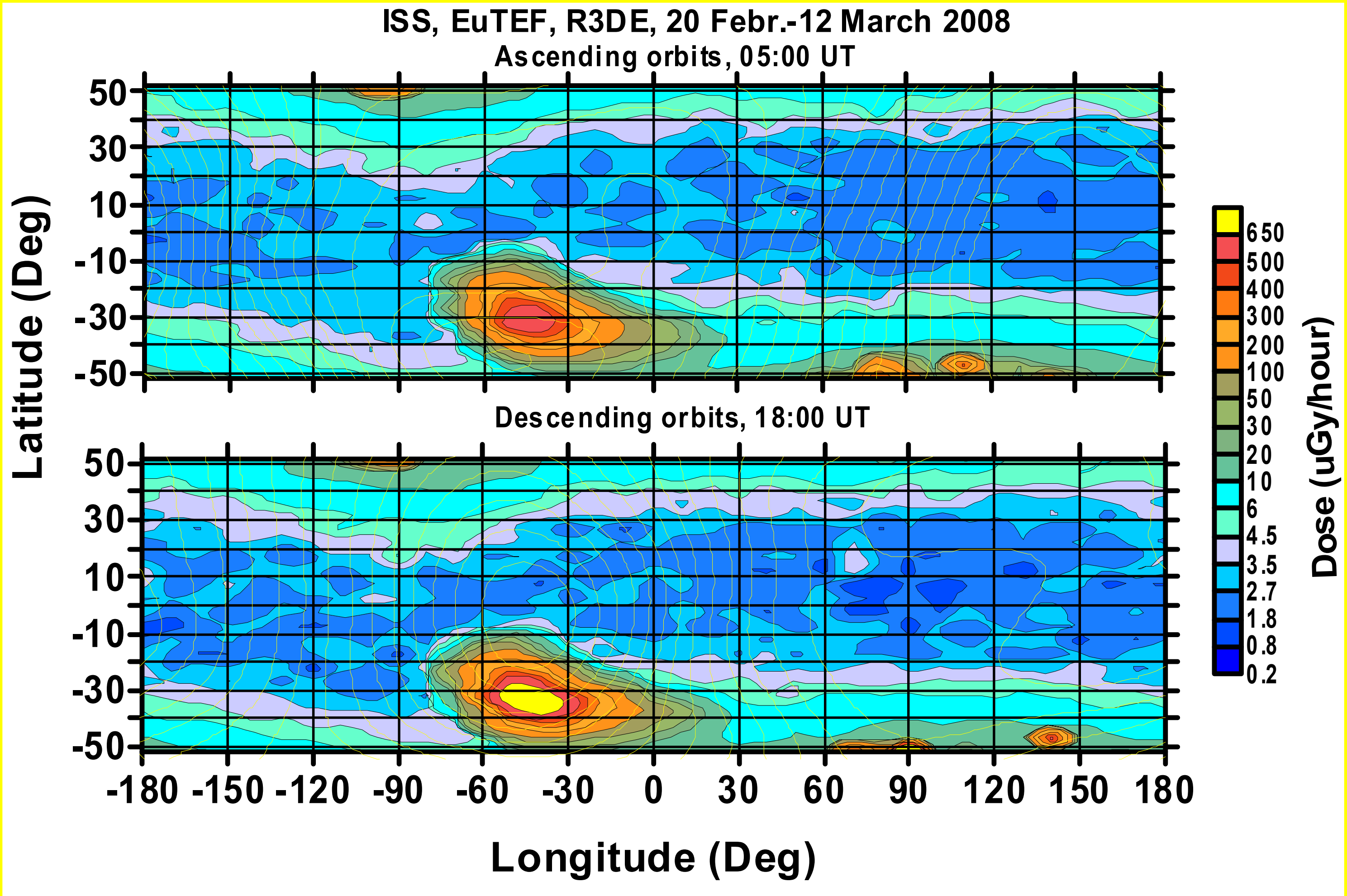
Movement of the place of SAA maximum in dependence by the shielding of the instrument



Spacecraft, Instrument	Shielding g/cm^2	Mean Energy MeV
ISS, R3DE	0.4	50
Foton M3, R3D-B3	0.75	55
Foton M2, R3D-B2	1.85	55
Foton M3, Liu-Photo	>5	80
ISS, MDU#4	> 20	100

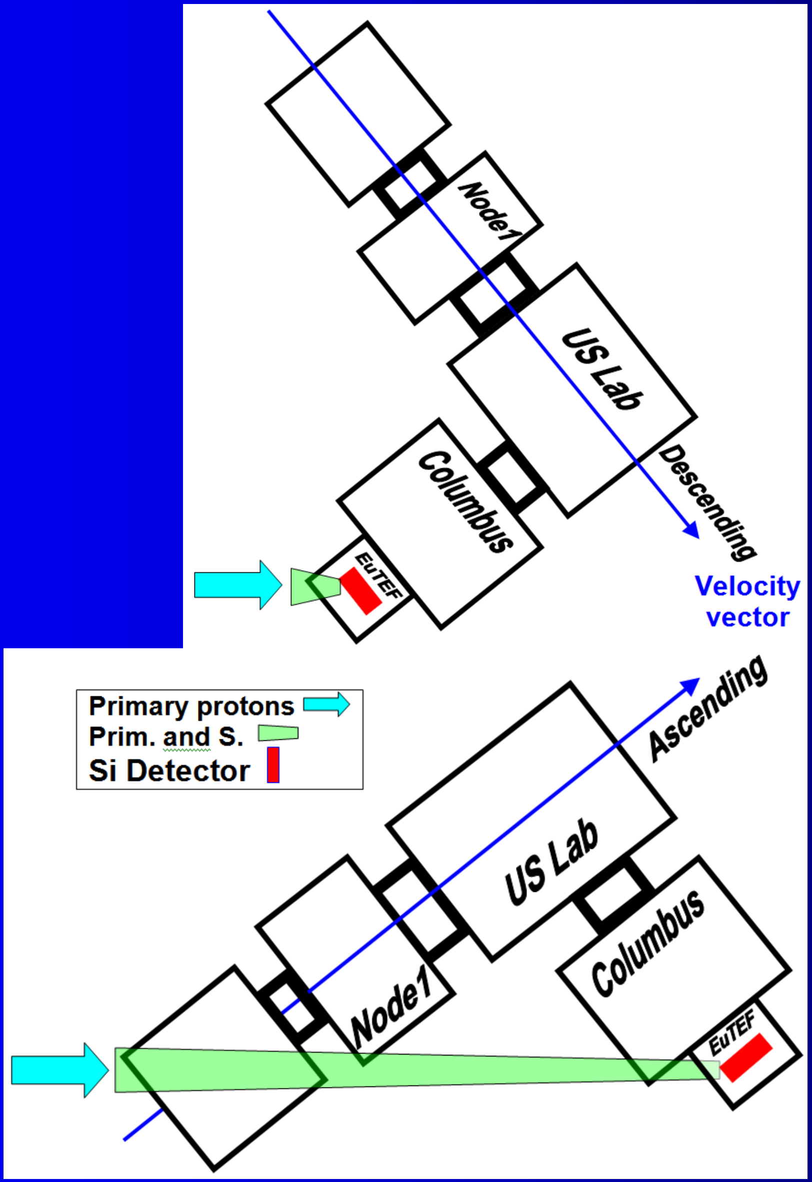
The proton mean energy maximum of the SAA spectrum moves toward lower energies when the shielding thickness of the instrument is lower.

Comparison of dose asymmetries with the global distribution of the upper atmosphere neutral density



Ascending: MD=740; MF=133; MUT=5.86
Descending: MD=1072; MF=171; MUT=20.15

Geometry of the R3DE detector against the predominate SAA proton drift from West to East



Future experiments

4 new space experiments are under development

Liulin-Phobos

Objectives: Measurements during the cruise phase, on Mars's orbit and on the surface of Phobos. Estimation of the radiation doses received by the components of spacecraft and assessment the radiation risk to crewmembers of future exploratory flights.

Cooperation: STIL (Bulgaria), IMBP (Russia), NIRS (Japan), NIH (Italy), Lavochkin Space Association, Russia

Liulin-EVA instrument for Space suit experiment. Beginning in 2009. Estimated lifetime 6 months.

RADOM instrument for Indian Chandrayaan-1 satellite. Launch in October 2008. Lifetime 2008/2010

Satellite at 100 km over the Moon surface for 2 years

Weight: 120 g
Size: 76x86x25 mm
Consumption: 120 mW

R3D-B3 instrument for Russian BION-M satellite. 1 month flight in the middle of 2010.

Conclusions

- Different modifications of Liulin type spectrometers was developed and build in STIL-BAS between 1985 and 2008. For the period the weight and power consumption of the instruments was decreased more than 100 times, while the obtained scientific information was increased more than 10 times;

- During this time dose interpretation procedure was improved and now it is available to characterize:

  - doses from different radiation sources in space, in atmosphere and on ground;

  - the incident energy of the incoming to the detector protons;

  - the type of incoming to the detector ions;

- Main advantage of the spectrometers are their low weight (<100 g), low power consumption (<100 mW), low cost (less than 10000 Euro) and high scientific and application value of the obtained data;

- Future experiments in space are under development and will be performed up to 2019;

Thank you