Overview of "Liulin" portable devices – High Altitude and Latitude ground based and Air/Space Applications

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Outlook

- Introduction
- Liulin type spectrometers
- Calibration results
- Space experiments
- In-flight Inter-calibrations with other instruments
- Short term and unique In-flight results
- Long term flights on CSA airline Boeing A310-300 aircraft
- Ground-level event (GLE60) on 15.04.2001 in-flight results
- Comparison of data from aircrafts and ISS & Forbush decrease study
- Who is using Liulin type spectrometers and where?
- Conclusions

Introduction

The Solar-Terrestrial influences are part of the International Living with a Star Program (ILWS) (A New Collaborative Space Program in Solar, Heliospheric and Solar Terrestrial Physics)

ILWS Contributing Agencies and Delegates:

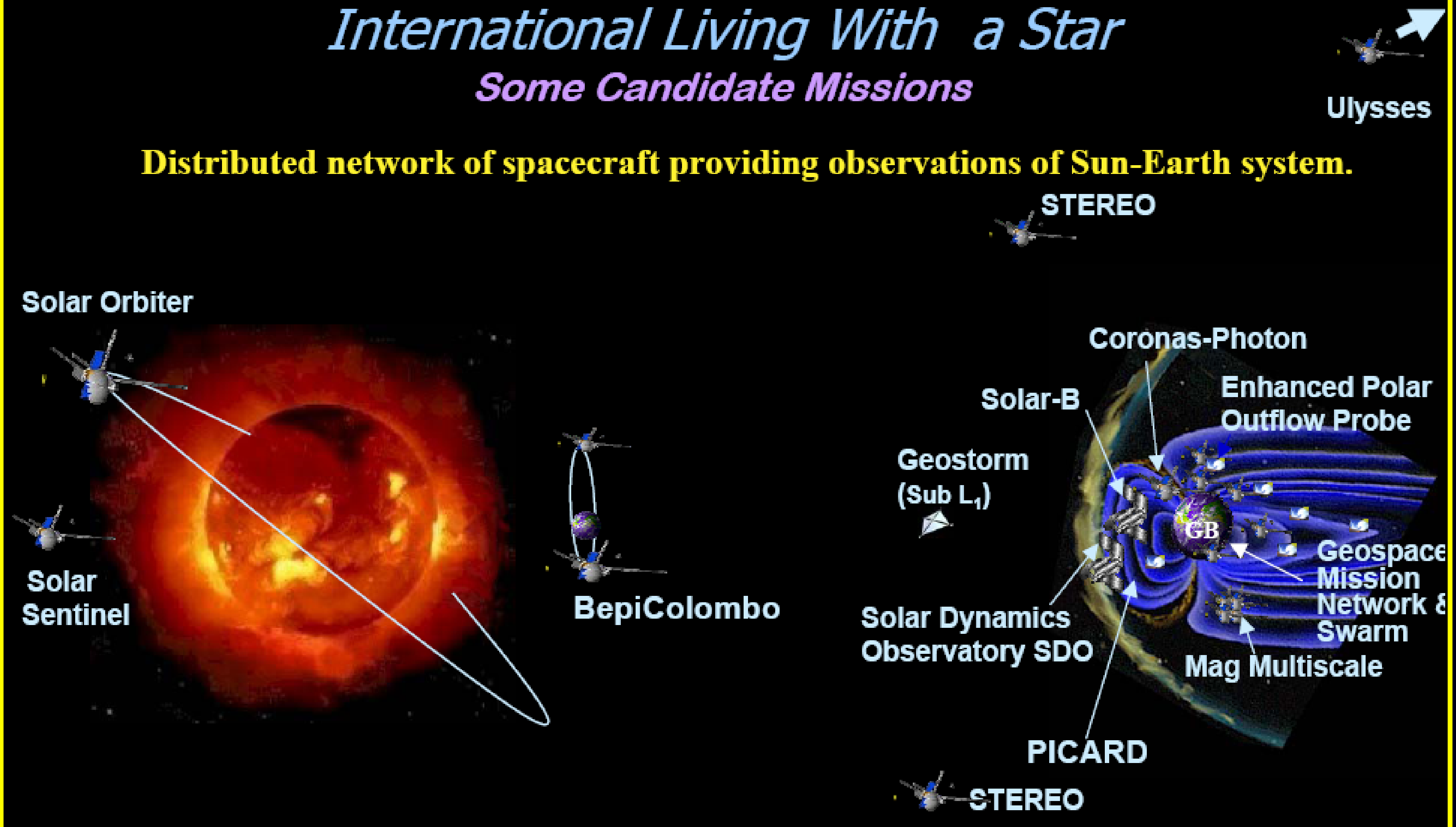
- CNES (Centre National de'Etudes Spatiales) - PRADO, Jean-Yves
- CSSAR (Center for Space Science and Applied Research) - CAO, Jin Bin
- ESTEC-ESA - OPGENOORTH, Hermann
- Finish Meteorological Institute - PULKKINEN, Tuija
- IWF/OEAW Austrian Academy of Sciences - RUCKER, Helmut O.
- NSAU Ukrainian Space Agency - KOREPANOV, Valery
- CSA (Canadian Space Agency) - LIU, William
- NASA HQ - GUHATHAKURTA, Lika
- PPARC Particle Physics and Astronomy Research Council - HORNE, Sue
- KFKI RESEARCH INSTITUTE FOR PARTICLE AND NUCLEAR PHYSICS - KECSKEMETY, Karoly
- IKI (Space Research Institute) - PETRUKOVICH, Anatoli
- DLR German Aerospace Center - FRINGS, Wolfgang
- SNSB Swedish National Space Board - MAGNUSSON, Per
- PMOD/WRC Davos Physical Meteorological Observatory - SCHMUTZ, Werner
- IAC Astrophysical Institute, Canaries - MARTINEZ PILLET, Valentin
- INAF - ASI Turin Astronomical Observatory - ANTONUCCI, Ester
- INPE National Space Research Institute - GONZALEZ, Walter
- JAXA - KOSUGI, Takeo
- NSC - ANDERSEN, Bo
- DSRI - NEUBERT, Torsten
- IPS Radio and Space Services, Australia - COLE, David
- Institute of Experimental Physics, Slovak Academy of Sciences (SAS), Kosice (in collaboration with Technical U. and P.J. Safarik U. in Kosice) - KUDELA, Karel
- Indian Space Resource Organization (ISRO), Bangalore, India - Chakrabarthy, S. C.

Candidate missions in ILWS

International Living With a Star

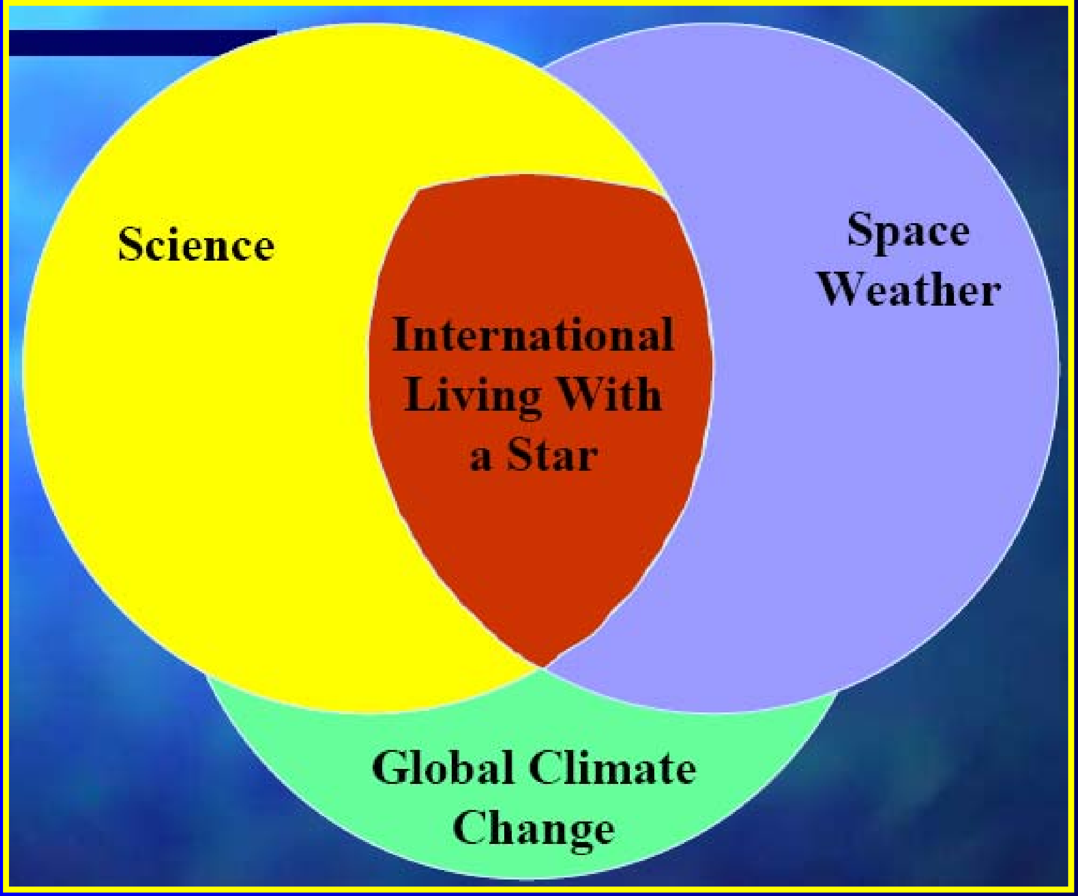
Some Candidate Missions

Distributed network of spacecraft providing observations of Sun-Earth system.



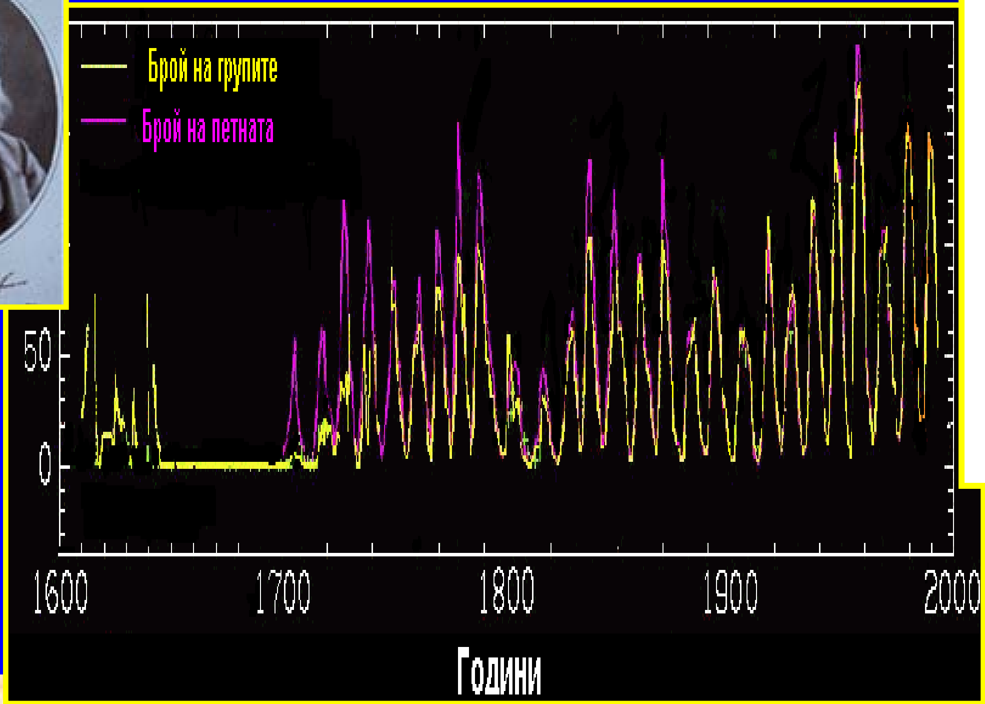
- ***Solar-Heliospheric Network*** **observing Sun & tracking disturbances from Sun to Earth.**
- ***Geospace Mission Network*** **with constellations of smallsats in key regions of geospace.**

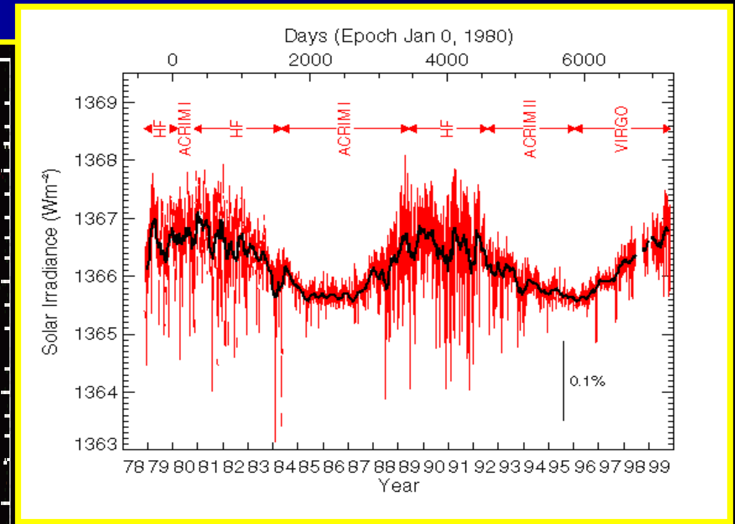
Relations of ILWS

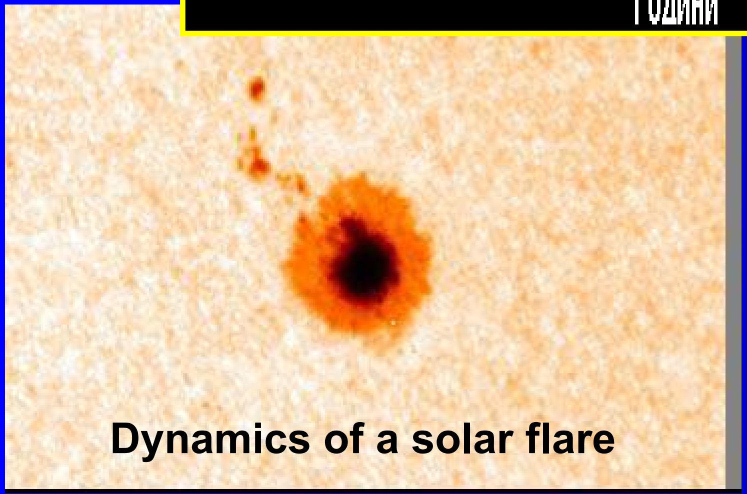


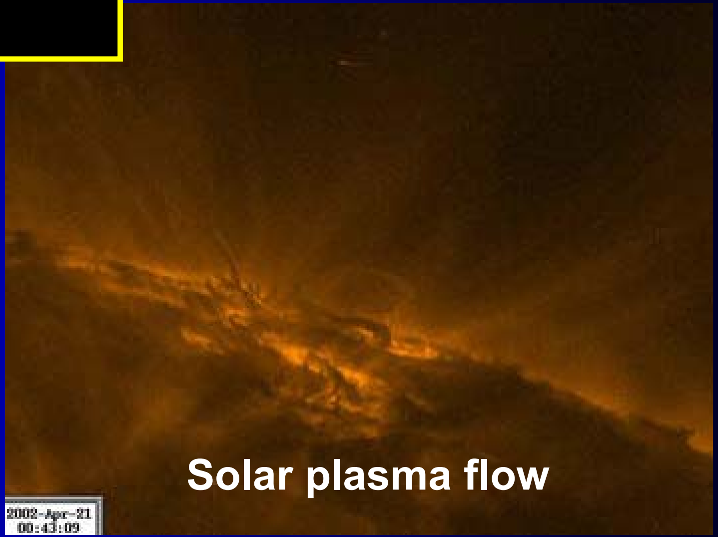
Mission: Stimulate, strengthen and coordinate space research to understand the governing processes of the connected Sun-Earth system as an integrated entity

Cycle of the solar activity



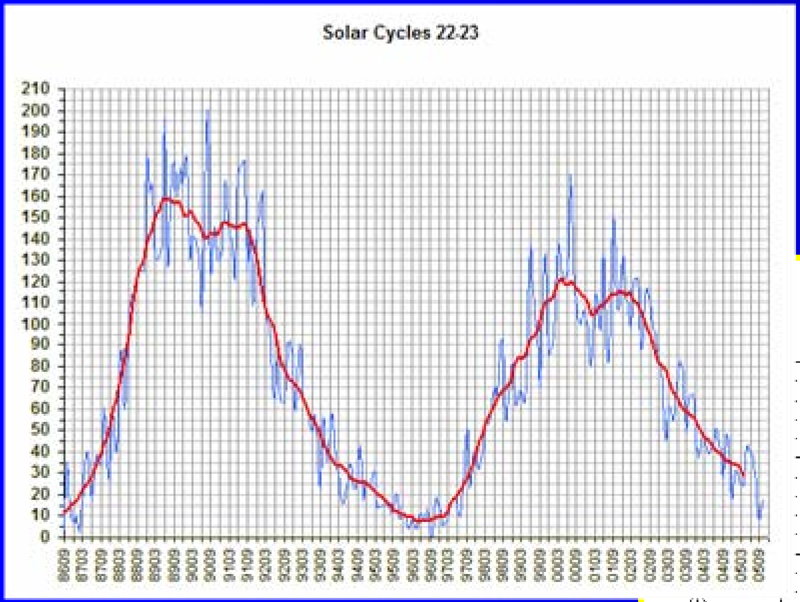


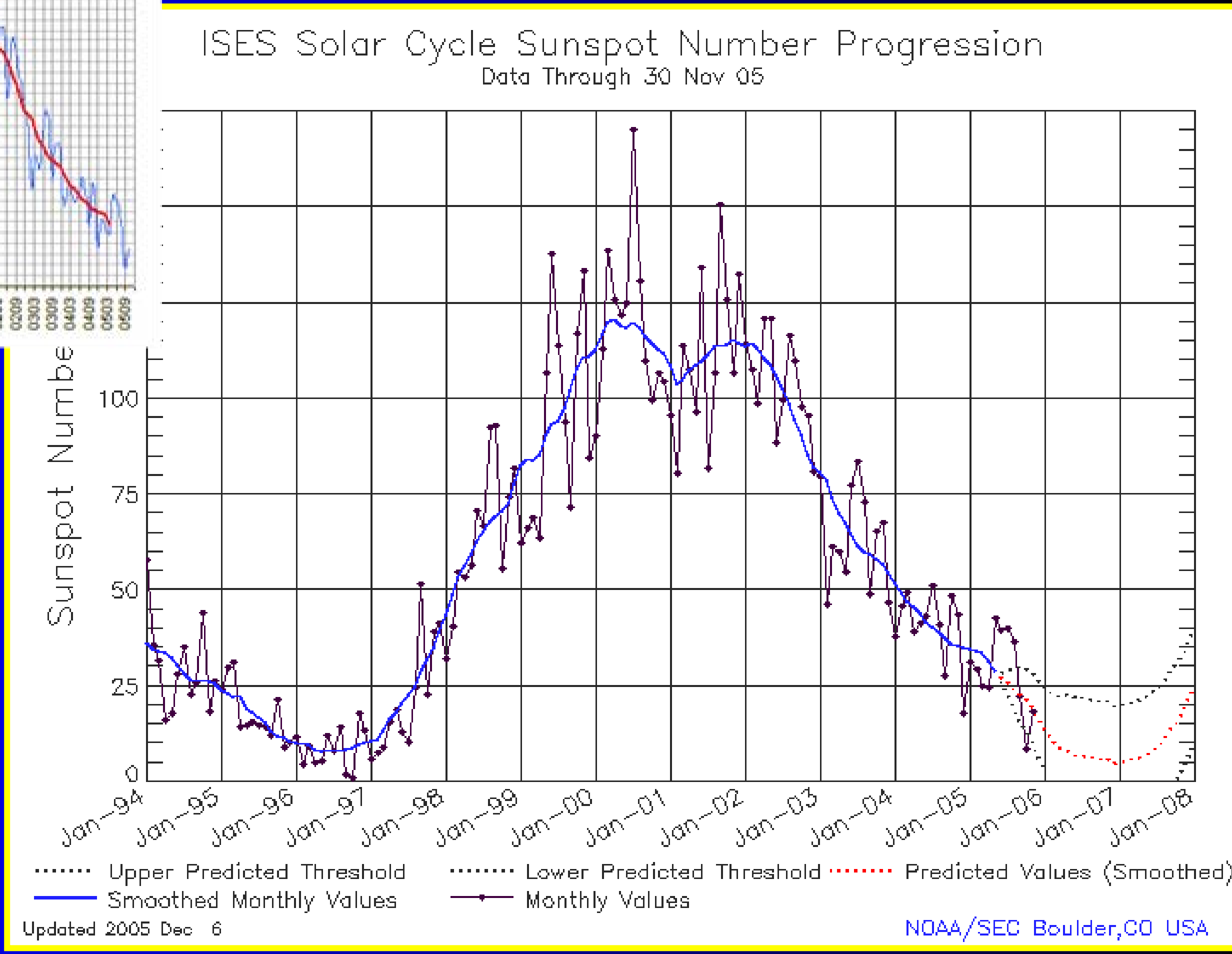

Dynamics of a solar flare



Solar plasma flow

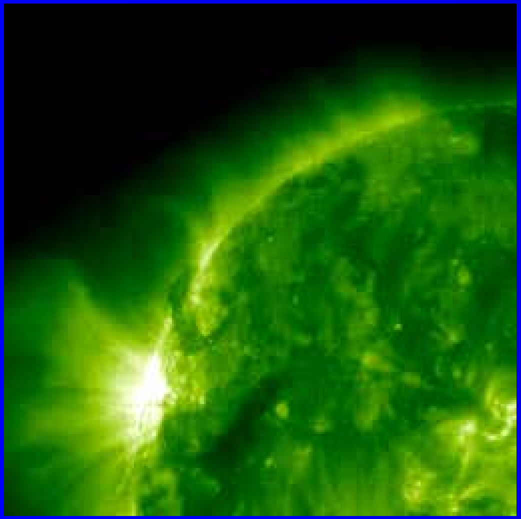
The solar minimum is expected in December 2006





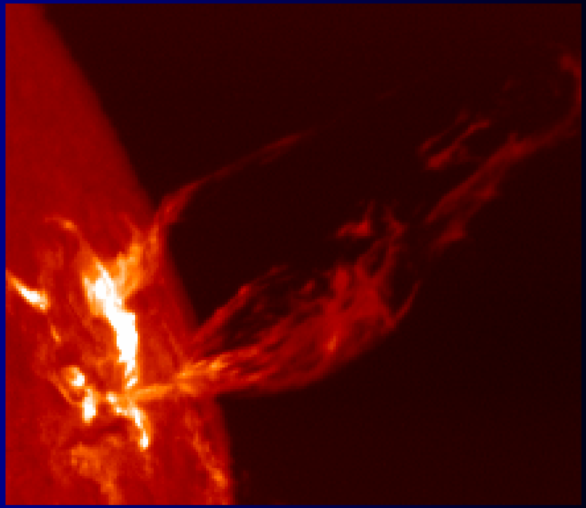
Coronal mass ejection (CMI)

The mass of the matter can be as high as 1 billion tons!



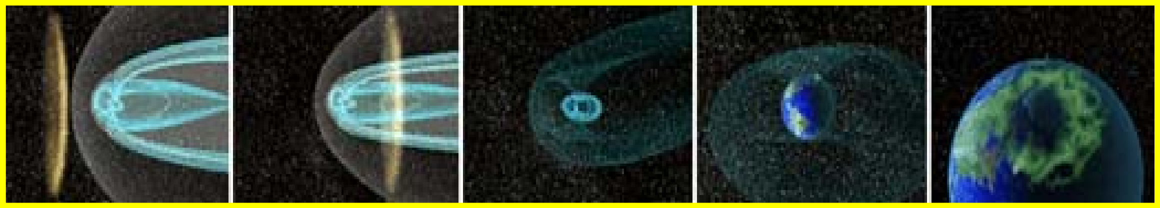
CME start with a blast on the Sun

CME as seen by SOHO



CME as seen from the Earth

Magnetospheric effects during a magnetic storm



Some sub sequential phases in a magnetic storm

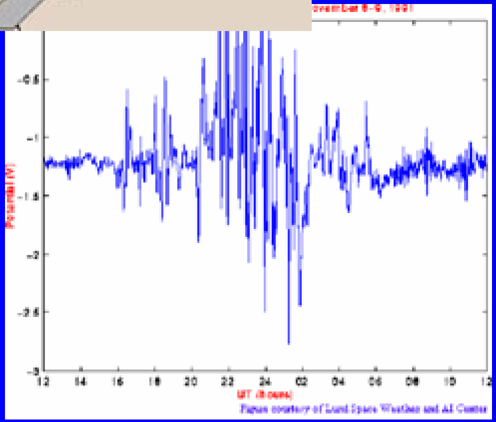
Saturn aurora

Jupiter aurora

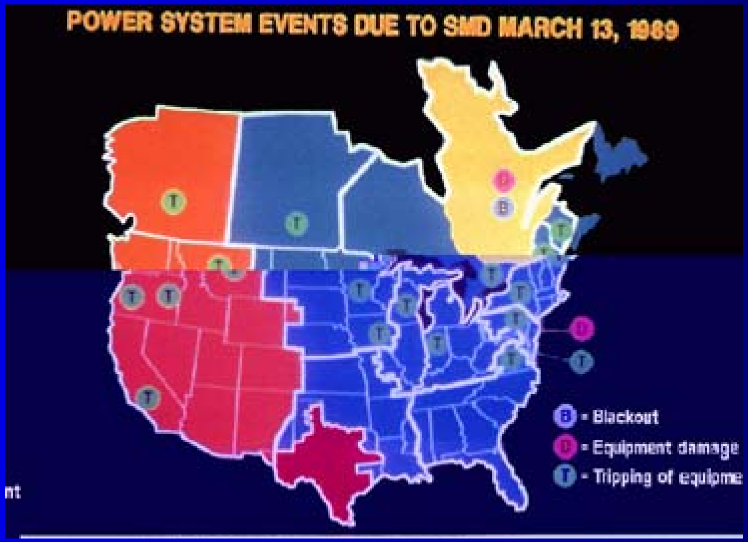
Earth aurora

Auroras are the most beautiful effect of the magnetic storms

Magnetic storm effects on the Earth

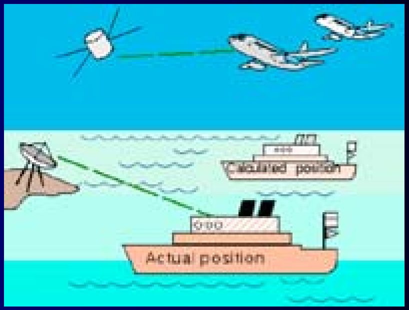


Higher pipe corrosion



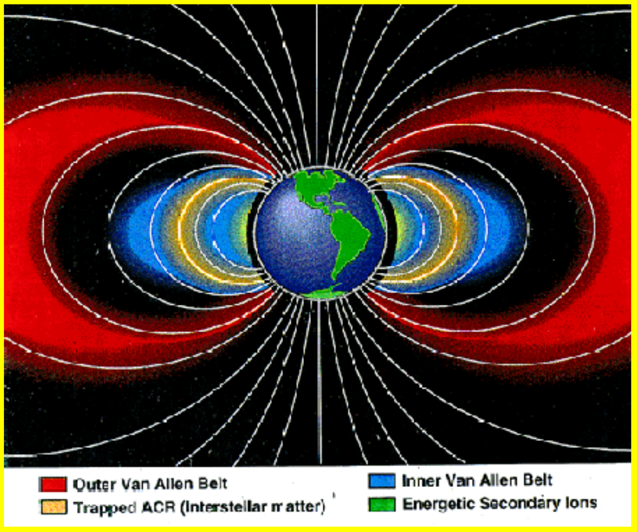
Power blackouts

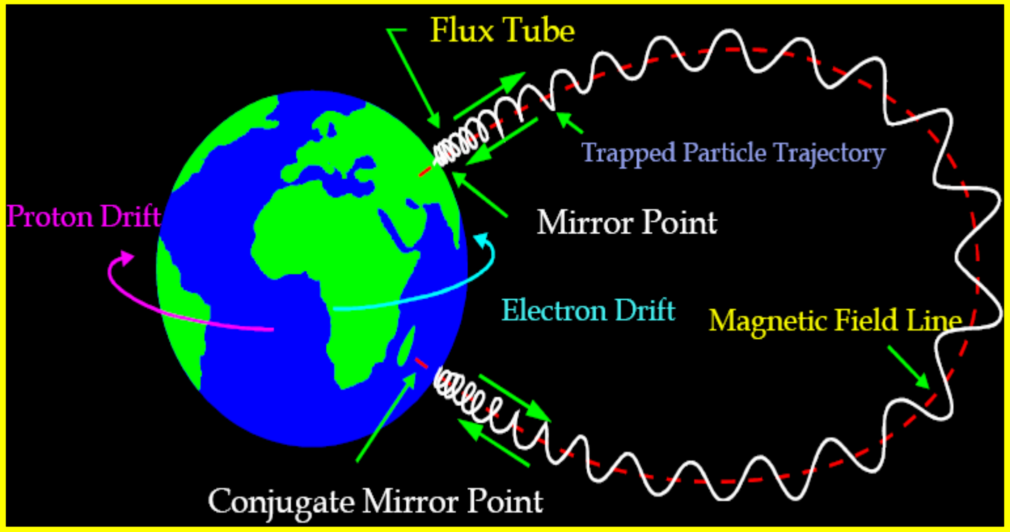
Radiocommunication problems

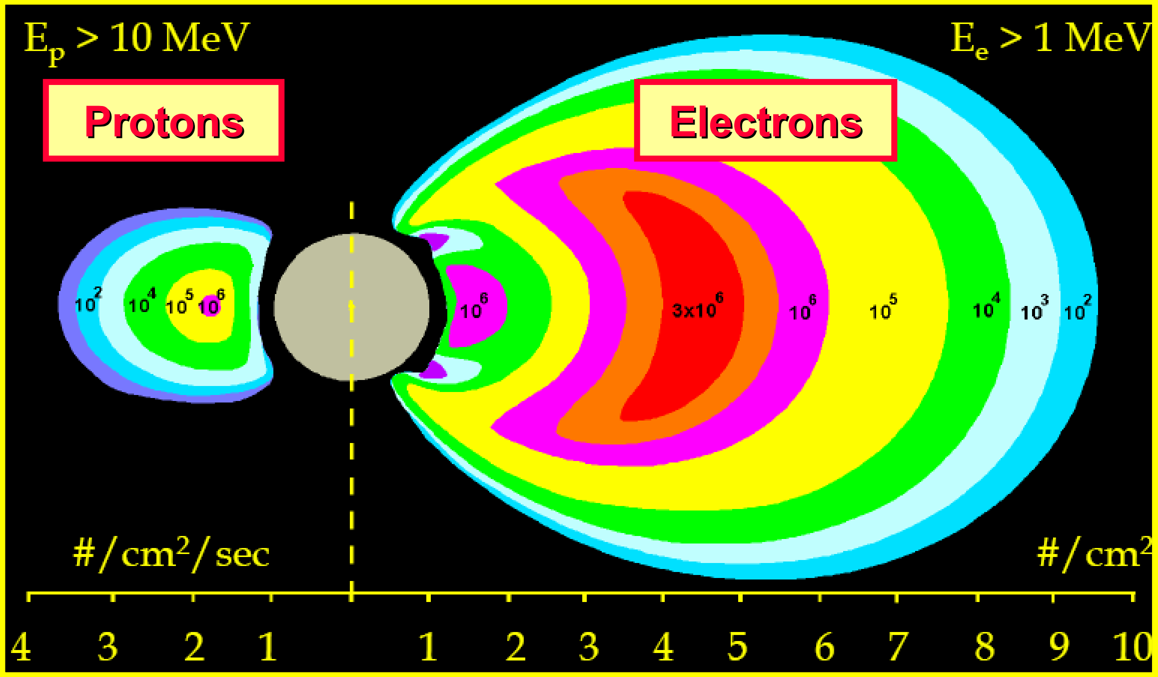


Less accuracy in the navigation

Van Allen Belts

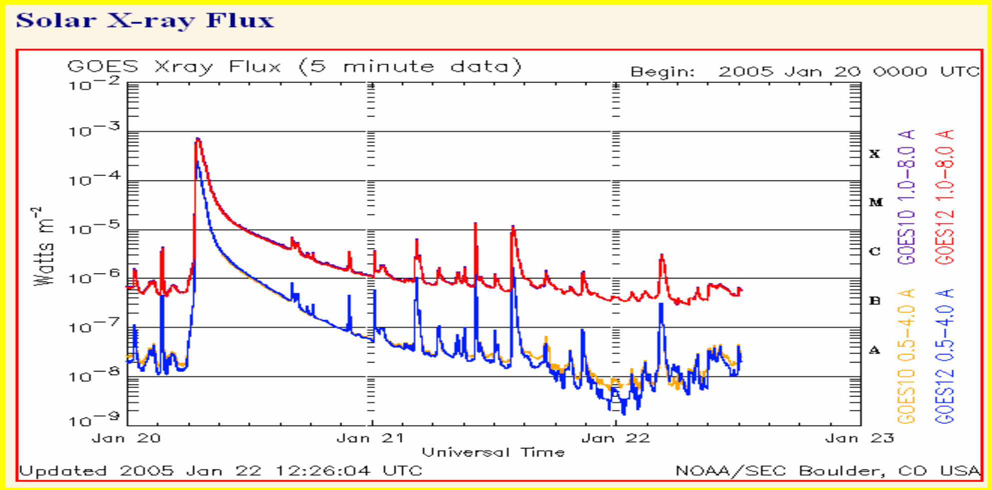


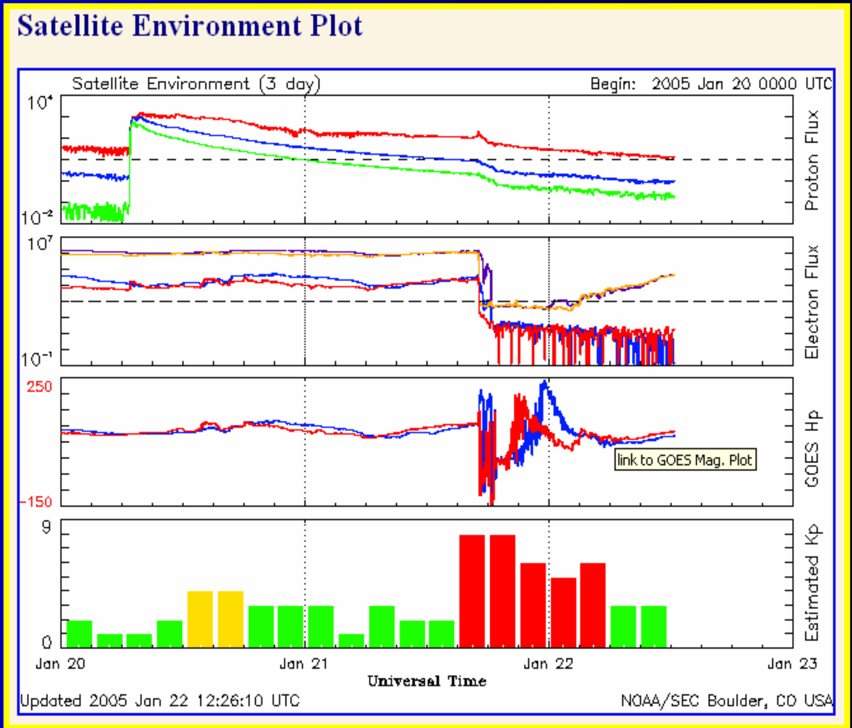


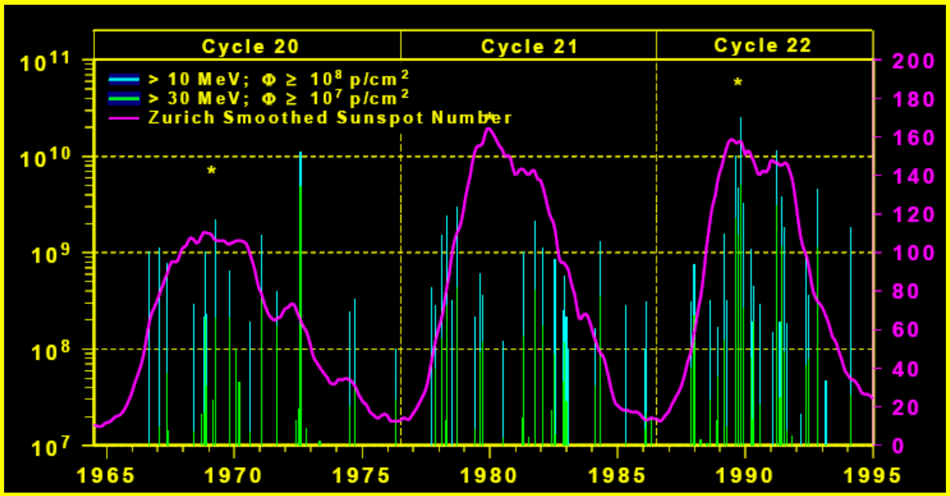


Solar Energetic Particles

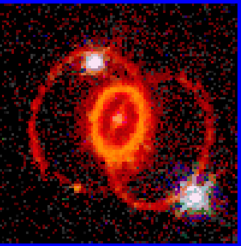
Solar energetic particles (SEPs) are atoms that are associated with solar flares. SEPs are a type of cosmic ray. They move away from the Sun due to plasma heating, acceleration, and numerous other forces. Flares frequently inject large amounts of energetic nuclei into space, and the composition varies from flare to flare. On the scale of cosmic radiation, SEPs have relatively low energies. SEP have to be more than 1 GeV to penetrate to sea level







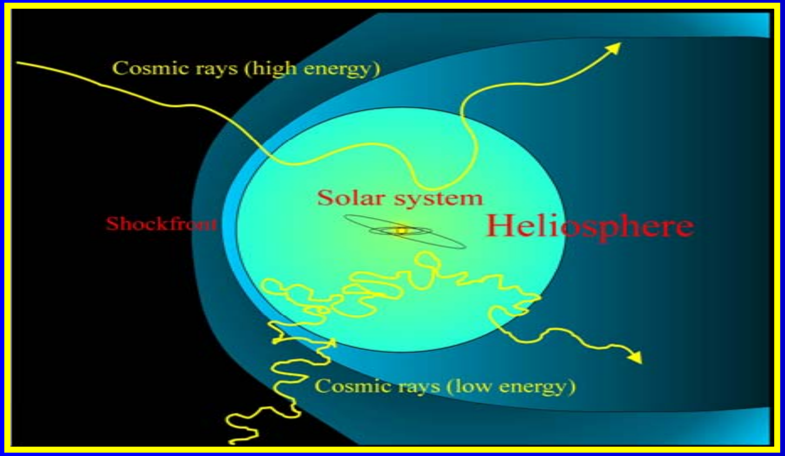
Galactic Cosmic Rays

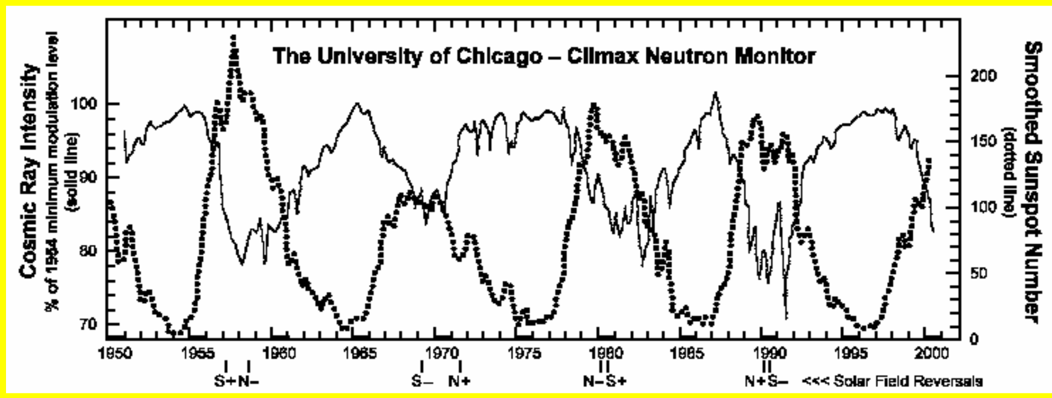


Remnant of Supernova 1987

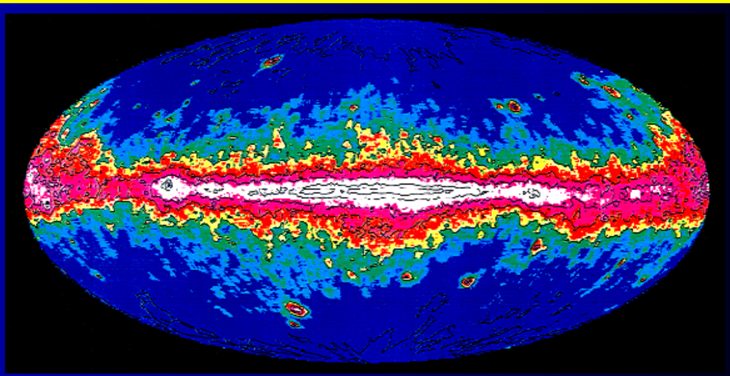
Galactic cosmic rays (GCRs) come from outside the solar system but generally from within our Milky Way galaxy. GCRs are atomic nuclei from which all of the surrounding electrons have been stripped away during their high-speed passage through the galaxy. They have been accelerated within the last few million years, and have travelled many times across the galaxy, trapped by the galactic magnetic field. GCRs have been accelerated to nearly the speed of light, probably by supernova remnants.

Crab Nebula

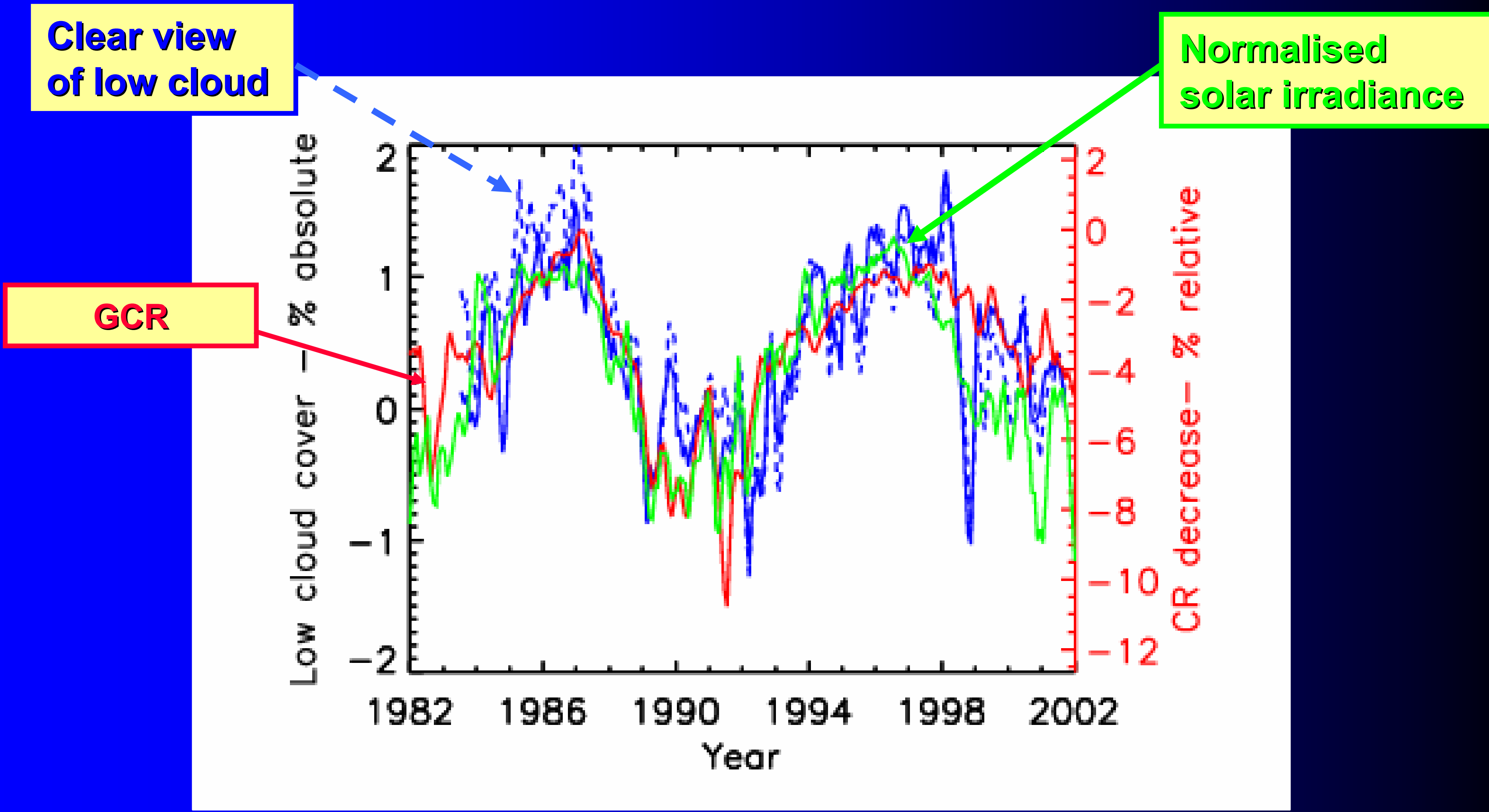




The image on the right is the EGRET gamma ray all-sky survey. Some GCRs interact with the interstellar medium and produce gamma rays.



Globally averaged adjusted low cloud cover and Solar activity



Marsh and Svensmark, 2003

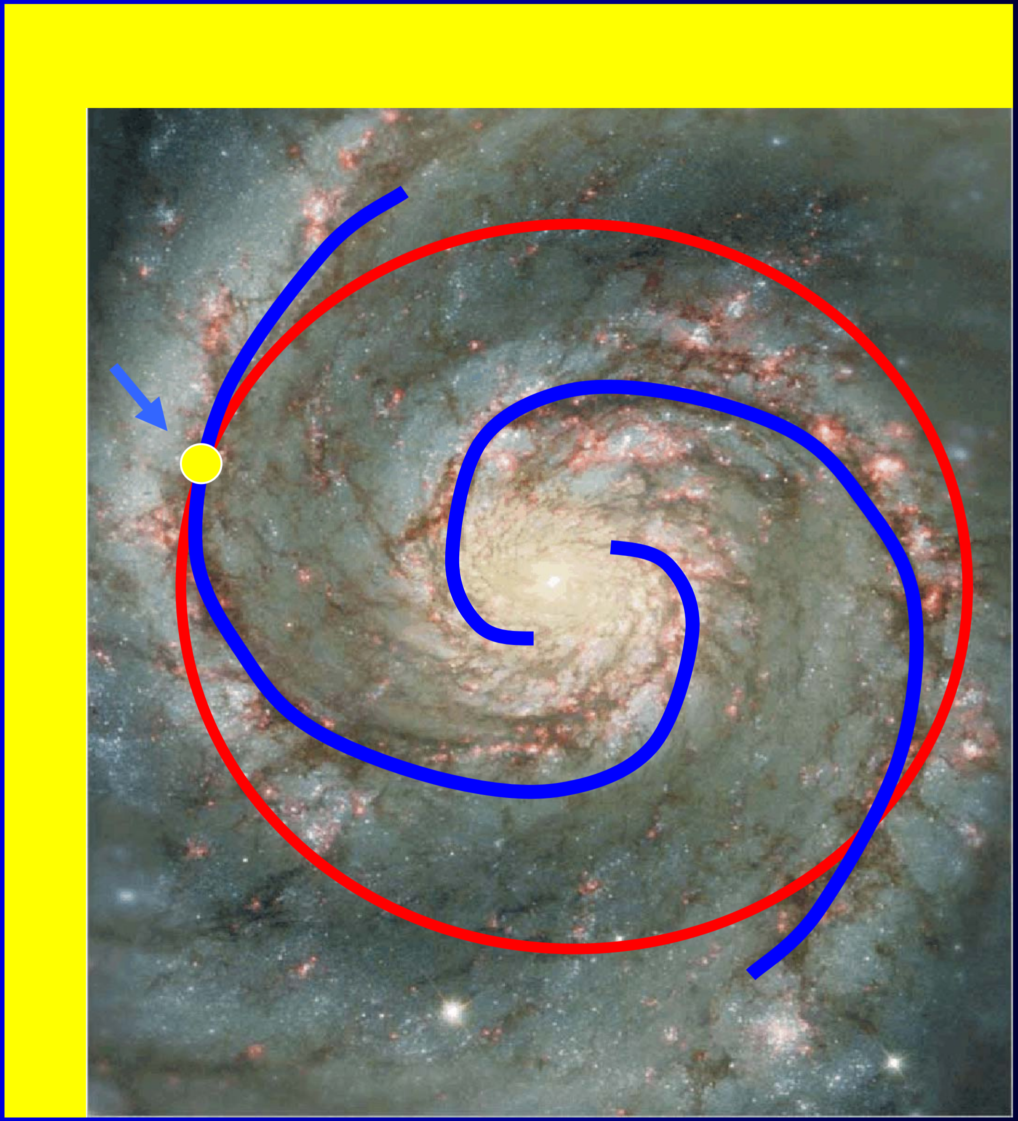
Cosmic rays and Spriral Arm Crossings*

Cosmic ray intensity
Largest in spiral arms

Galaxtic year -
Ca. 240 Mill. Years

Spiral Arm crossing –
140 Mill Years

*Shaviv (2002)



Svensmark, 2004

Particles from space *seems* to influence Earths climate, ranging from years to 10^9 years.

As result the history of the whole Milky Way could be of importance in the evolution of the Earth

It is not suggested that it is the only cause of climate change.

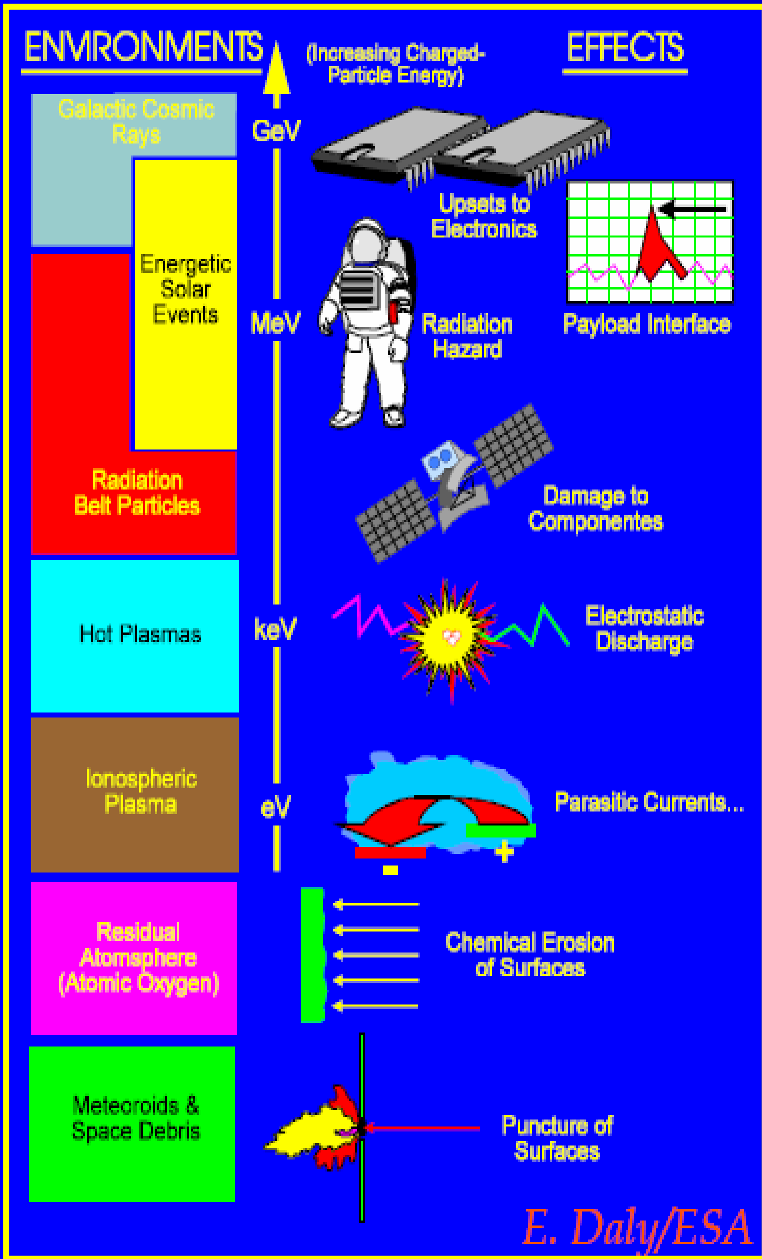
How can such a minute energy input affect the atmosphere?

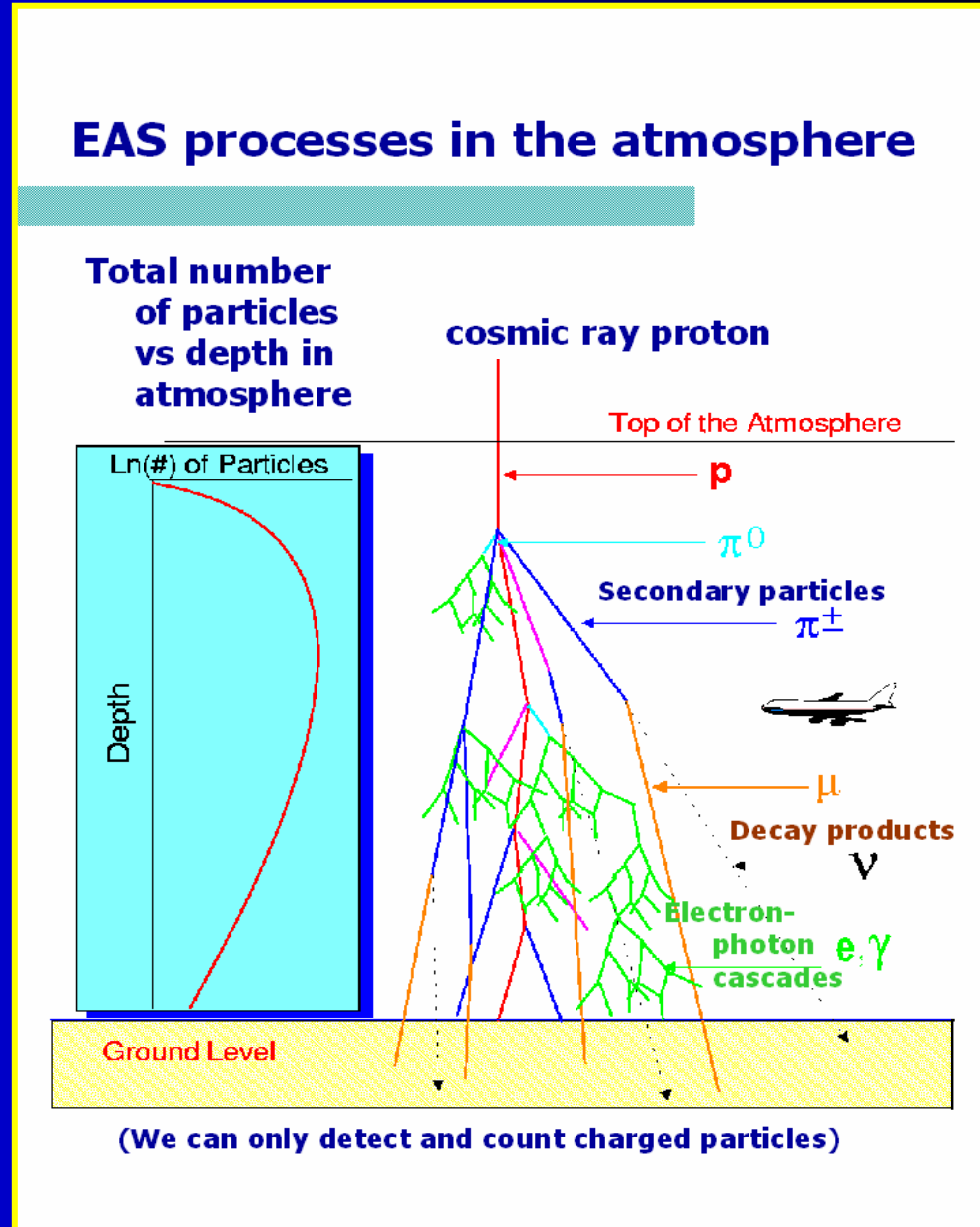
What is needed is a physical mechanism
• A link could be via clouds?
• A microphysical mechanism involving aerosol formation?

Understanding the cosmic ray climate link could have large implications in our understanding of climate changes.

Svensmark, 2004

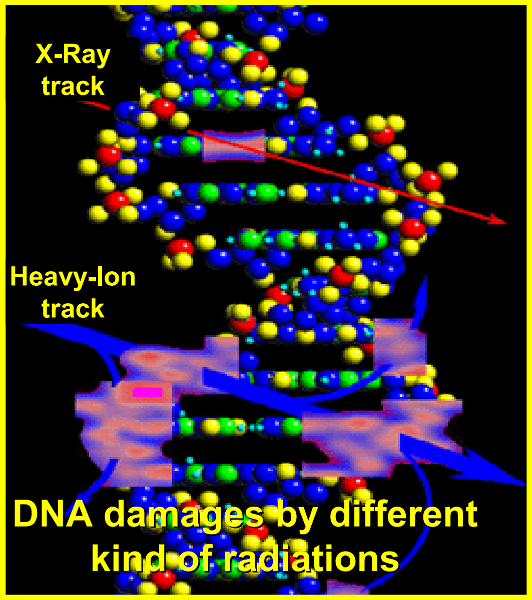
What Galactic and Solar Cosmic Rays are producing?





Why space radiation monitoring on near Earth orbits and on aircraft altitudes is important?

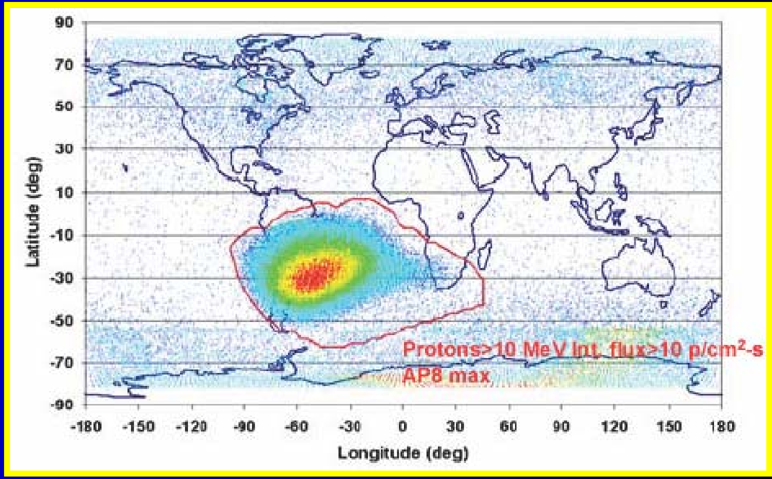
Human body damages



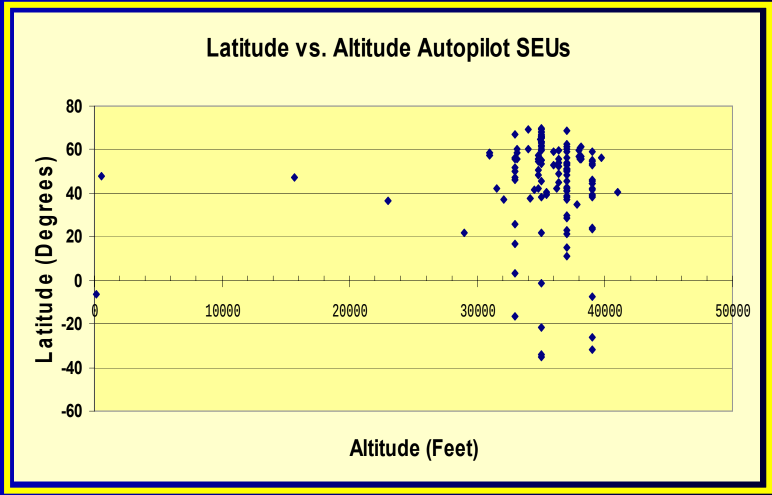
DNA damages by different kind of radiations

Bone marrow cells are damaged by radiation and stop to produce erythrocytes

Electronics damages



Single Event Upsets on the SEASTAR flight data recorder at 705 km altitude clearly show the location of trapped protons in the South Atlantic Anomaly, by Janet L. Barth



Single Event Upsets Observed in Autopilot in Boeing Commercial Aircraft

Liulin type spectrometers

First Liulin dosimeter-radiometer was successfully flown on Mir space station between 1988 and 1994

Detector Block:
Size: 40x100x160mm
Weight: 0.49 kg

Control Block:
Size: 300x220x170 mm
Weight: 10.5 kg

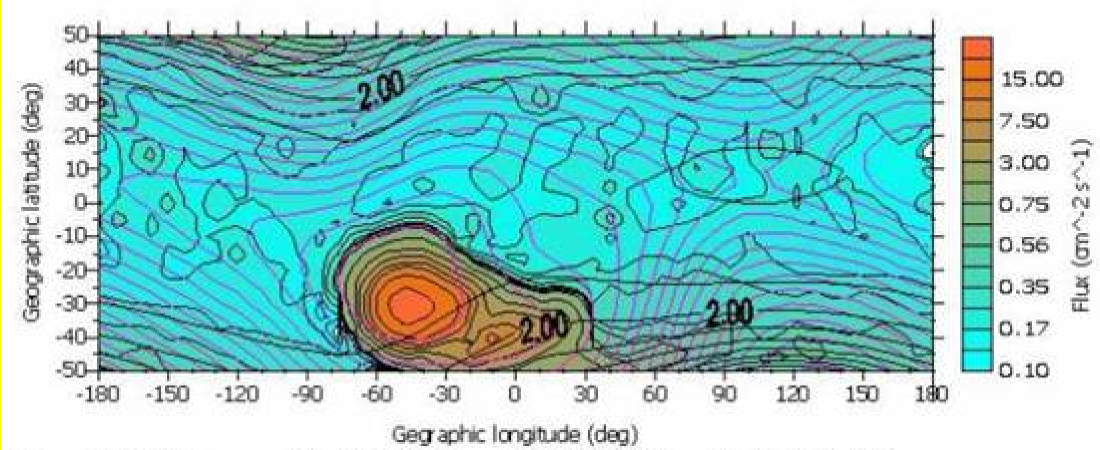
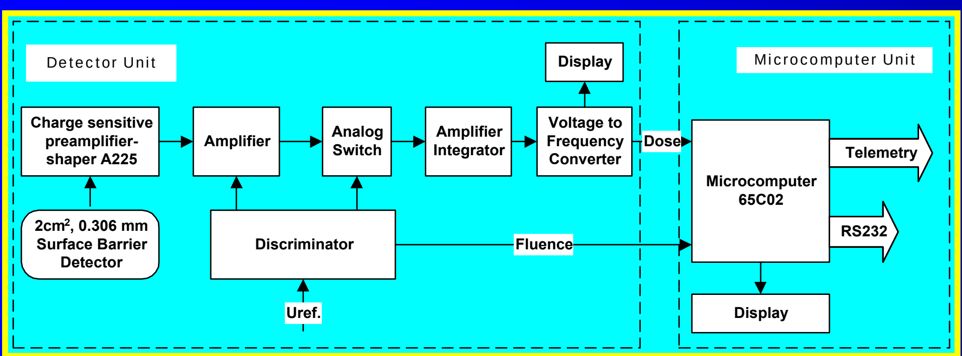


Figure 3. Global geographical distribution of the LIULIN flux data for July 1991.



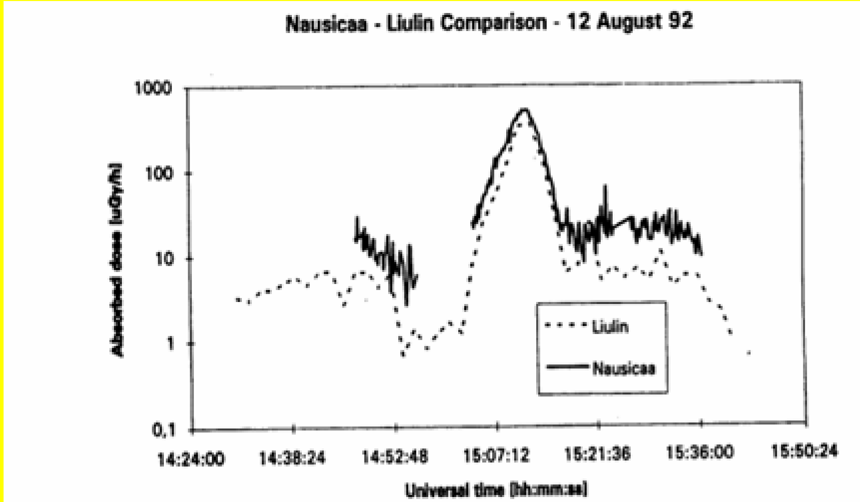
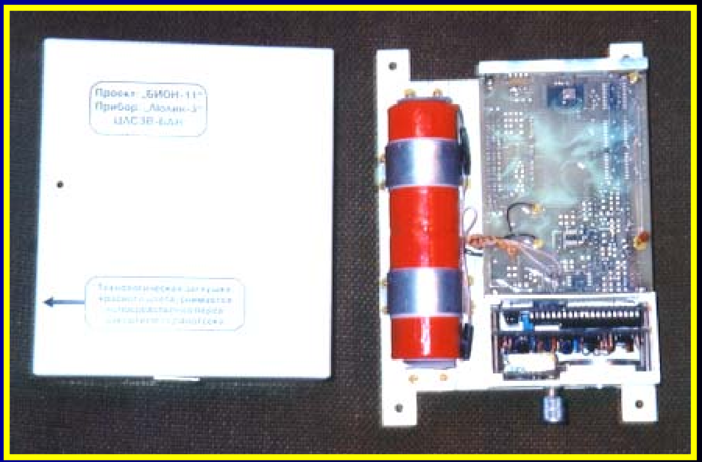


Figure2. Intercomparison of Liulin and NAUSICAA data obtained on MIR on August 12, 1992.

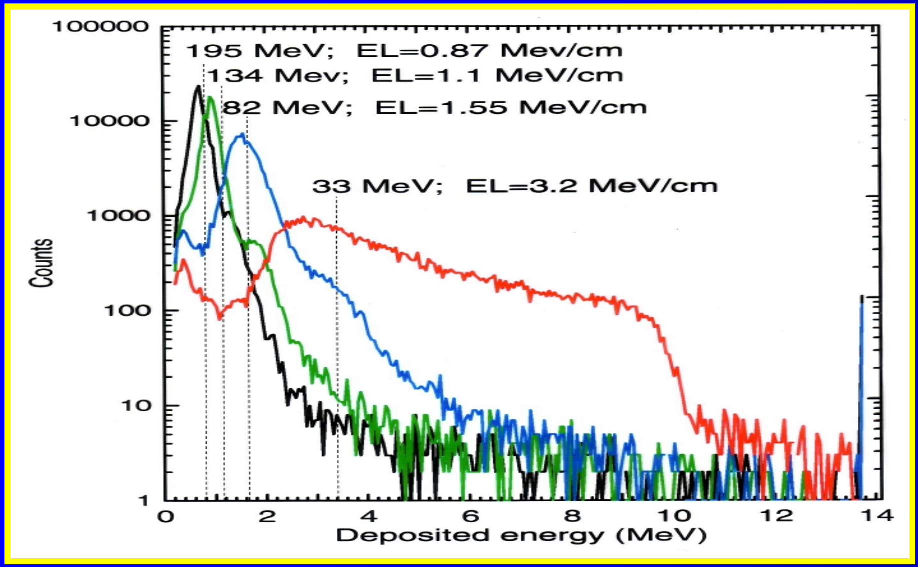
Liulin-3 and Liulin-3M instruments

Liulin-3 – 2 detector telescope (1995)

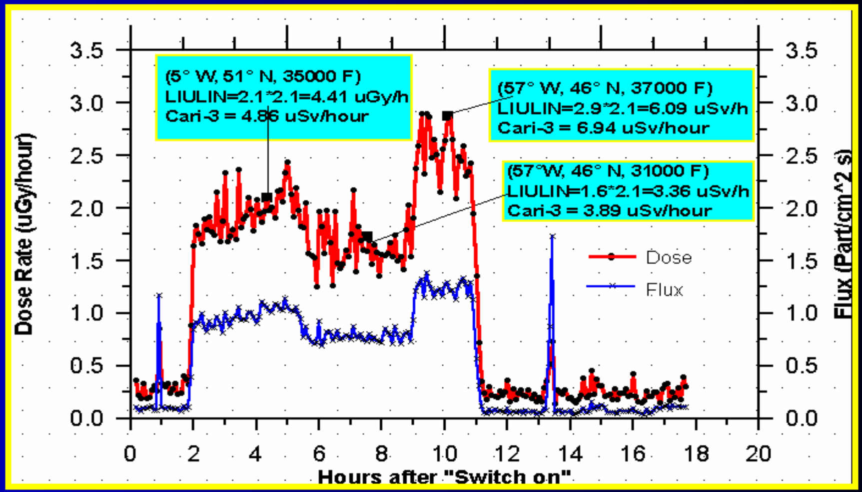
Liulin-3
DIMENSIONS:
Weight: 480 g
Size: 150x80x50 mm



Liulin-3M, prepared with
GSFC-NASA, 1997
Flown on aircrafts and Antarctida balloon



Proton tests at Indiana University
cyclotron facility, 1995



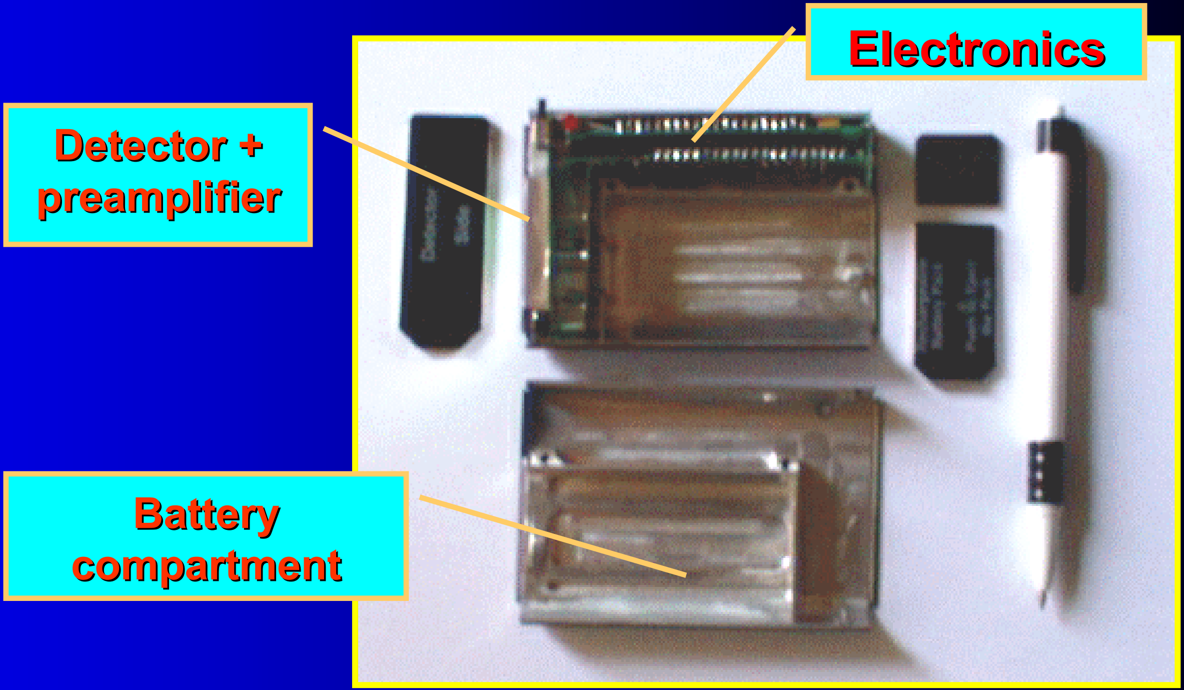
Sofia-NY flight data by Liulin-3M, June 16, 1997

Liulin-4 Mobile Dosimetry Unit (MDU) flown on ISS, 2001

External view of MDU

-*Size 100x64x24 mm;*
-*Total mass (including 0.08 kg battery pack): 0.23 kg.*
- *Operation time 5 days*

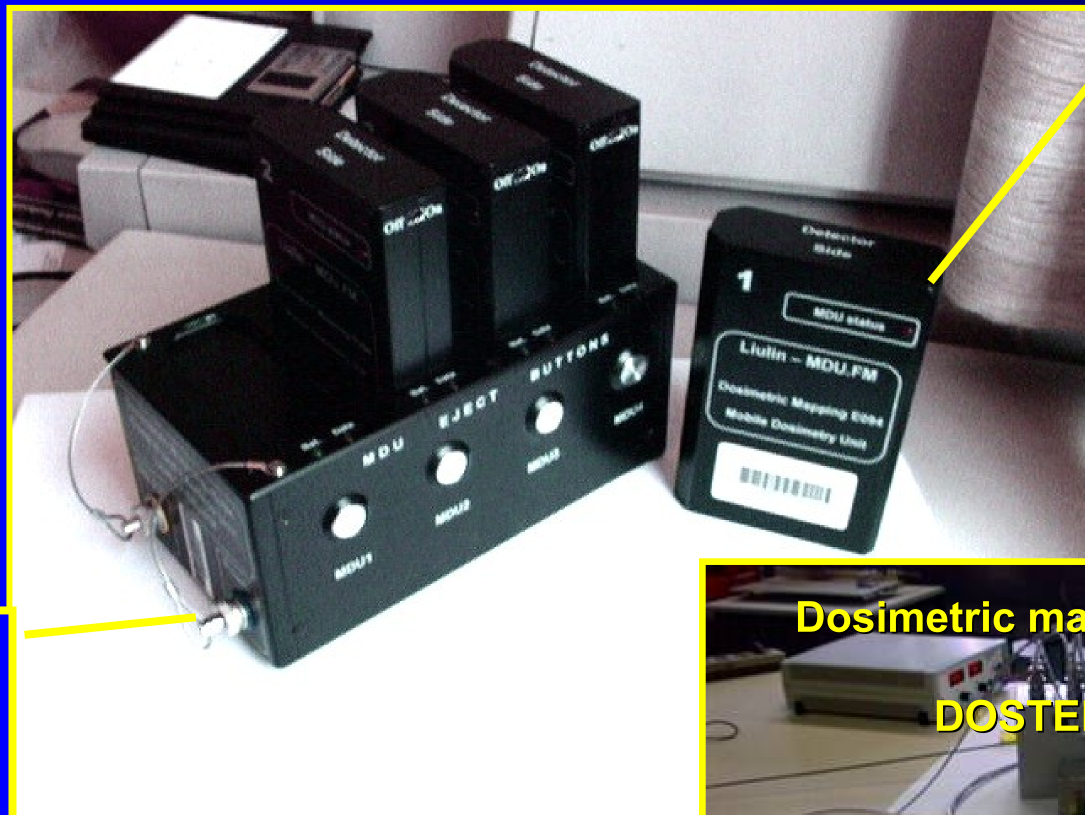
Internal view of MDU



SPECIFICATIONS OF MDU

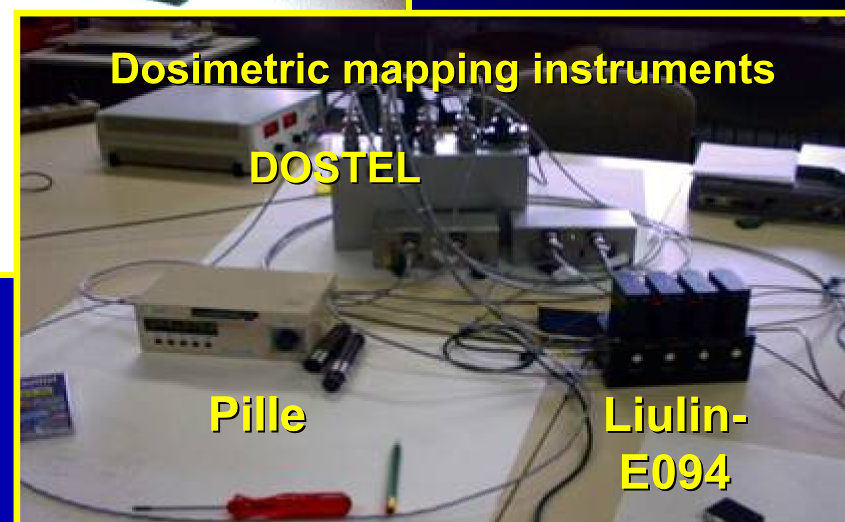
- *Dose range: 0.093 nGy – 1.56 mGy;*
- *Flux range: - 0.01 - 1250 part/cm^{2}s;*
- *Energy loss range: - 0.0407 – 20.83 MeV;*
- *Pulse height analysis range: - 19.5 mV – 5.0 V;*
- *LET range: 0.27- 69.4 keV/μ;*
- *Temperature range: 0°C - +40°C;*
- *Power consumption: typically 72 mW;*

Liulin-E094 instrument, flown successfully on American Laboratory module May-August 2001 as a part of German lead Dosimetric mapping experiment

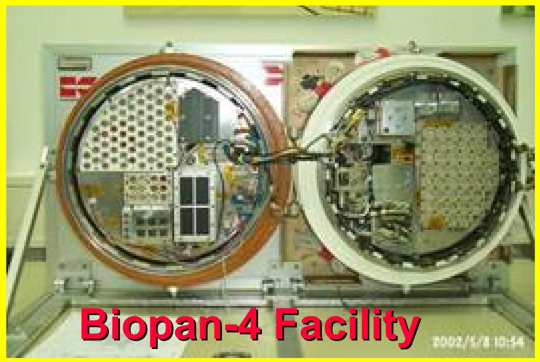


Liulin Mobile Dosimetry Unit (MDU)

Liulin Control And Interface Unit (CIU)



R3D-B1 instrument for ESA Biopan-4 facility outside of Foton M1 satellite. On 16 October 2002 it was unsuccessfully launched. The mission was repeated in June 2005. The spectrometer is mutually developed with the University in Erlangen, Germany



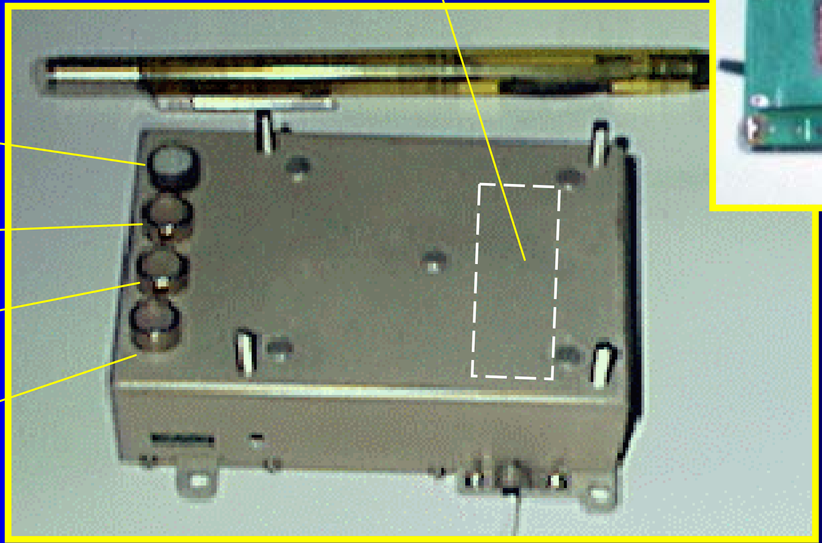
256 Channels
LET spectrometer

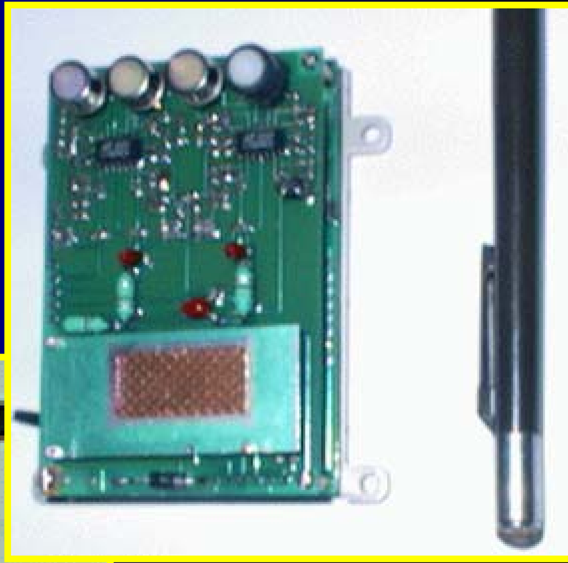
UV-C channel

UV-B channel

UV-A channel

PAR channel

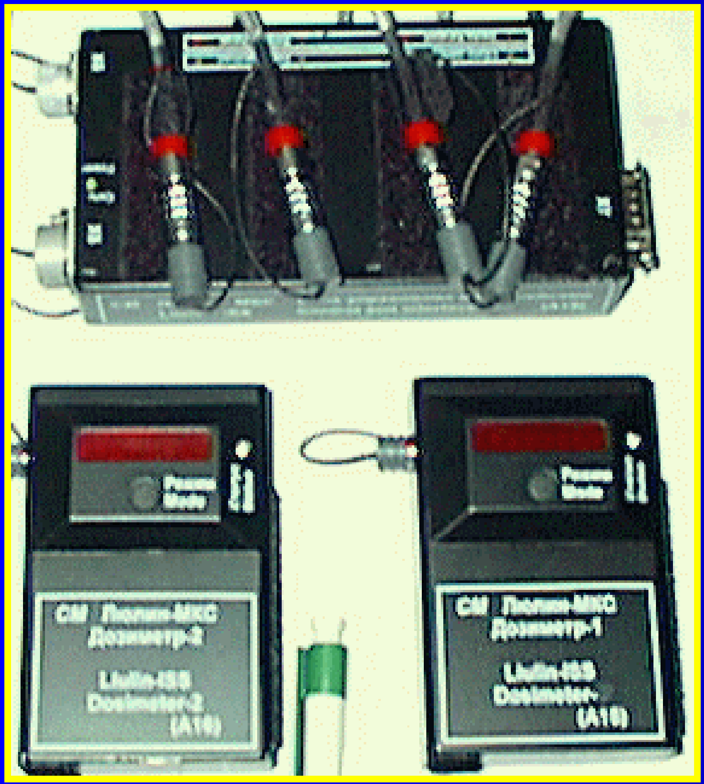


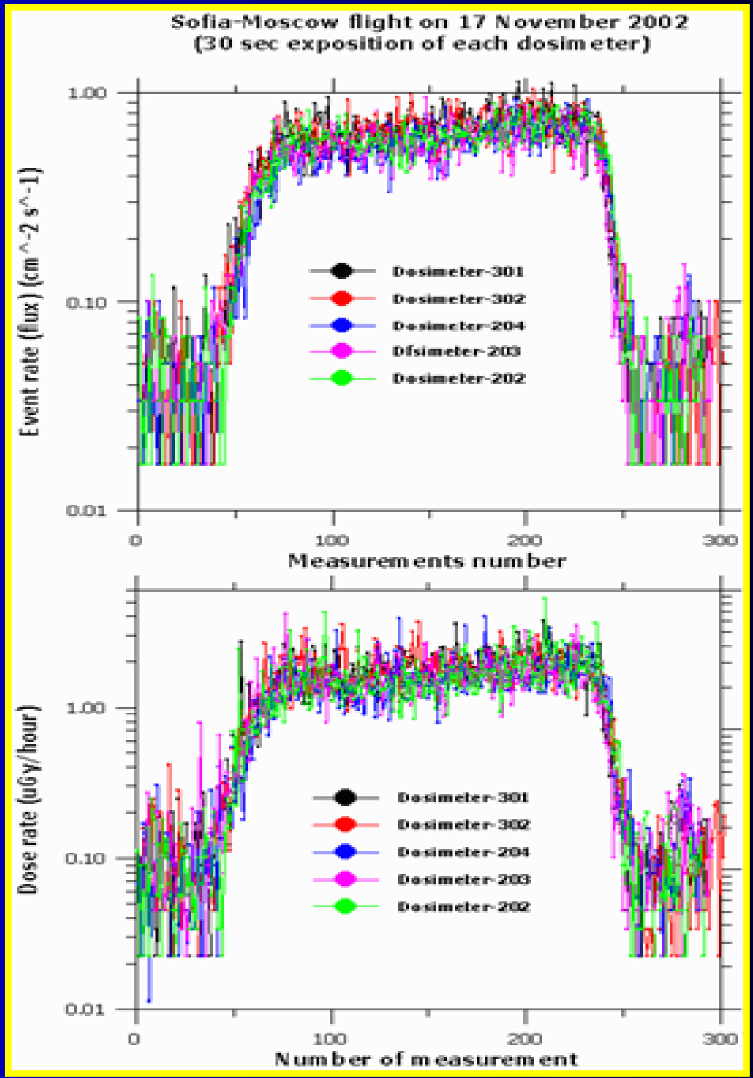


R3D-B DIMENSIONS:

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

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 will be activated by the current crew in the beginning of 2006



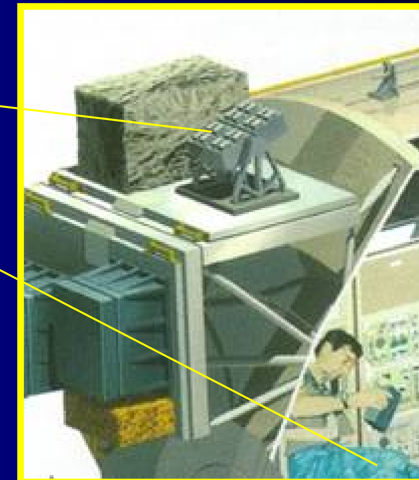


MDU Liulin-ISS dimensions:
Weight: 229 g incl. 80 g battery
Size: 110x80x25 mm
Consumption: 84 mW

The R3D spectrometer is mutually developed with the University in Erlangen, Germany and is expected to be launched first to Russian segment of ISS in 2006 and next to ESA Columbus module in 2008

EXPOSE

Columbus



256 Channels
LET spectrometer

Flight unit mounted in the EXPOSE facility (May 2003)

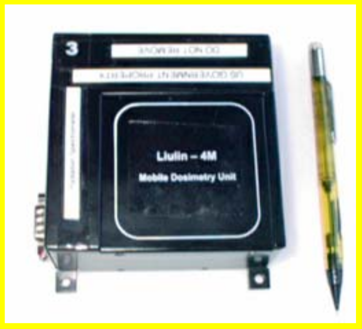
R3D DIMENSIONS:

Weight: 189 g
Size: 76x76x36 mm
Consumption: 120 mW

Vibration tests in ESA
May, 2003

Liulin-spectrometers for monitoring of the space radiation at aircraft altitudes

More than 100 days independent use on commercial aircrafts with Li-Ion primary batteries



*Weight: 320 g**
Size: 100x100x50 mm

More than 30 days independent multi session use on commercial aircrafts with rechargeable batteries

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

More than 50 hours independent multi session use on commercial aircrafts with rechargeable batteries

*Weight: 120 g**
Size: 104x40x20 mm

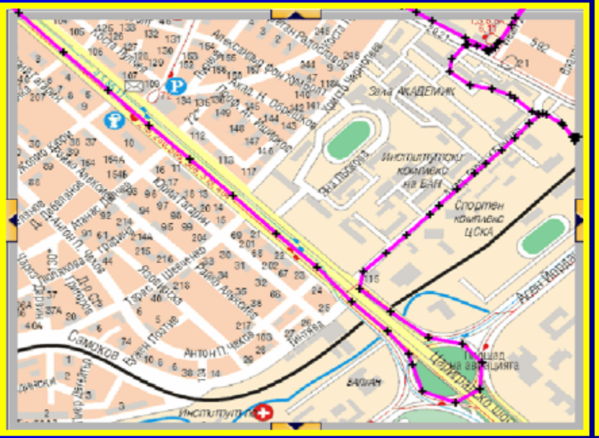
Liulin spectrometer with GPS receiver for 3D and time positioning on aircrafts with 28 DC power supply

Weight: 110 g
Size: 85x52x35 mm

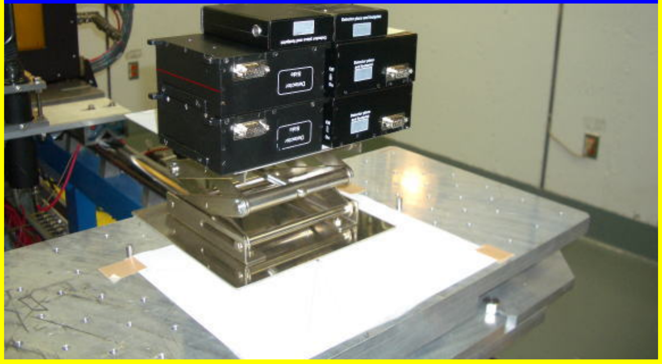
**With the batteries inside*

SPECIFICATIONS:

- *Dose rate: 0.093 nGy – 1.56 mGy;*
- *Flux range: 0.01 - 1250 part/cm^{2}s;*
- *Temperature range: 0°C - +40°C;*
- *Power consumption: typically 52 mW*

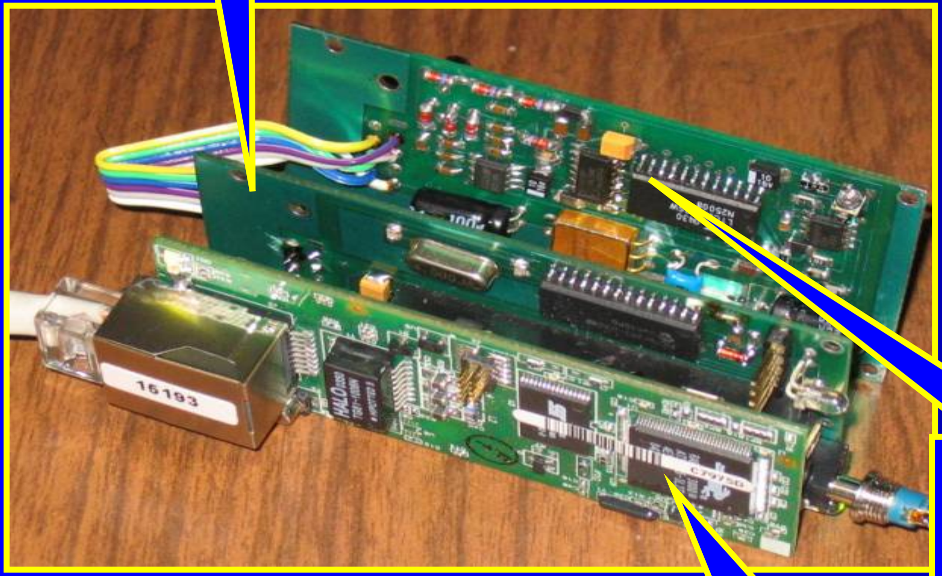


6 Liulin instruments at the NASA Space Radiation Laboratory tests held on 25-28 September 2004



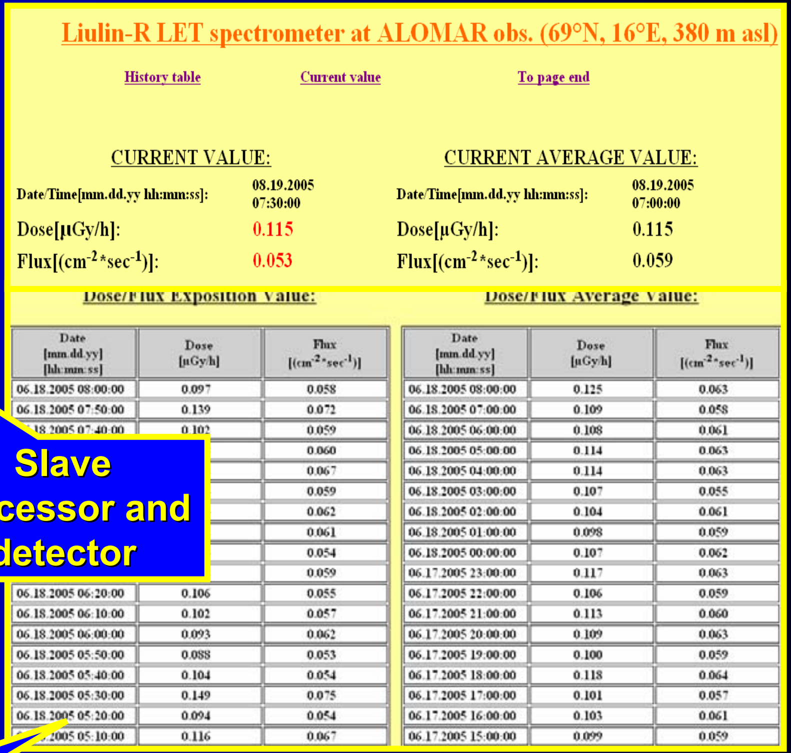
2 WEB based Liulin spectrometers was delivered and now are working at ALOMAR observatory, Norway (69^0N) and at Jungfraujoch (3475 m asl), Swtzerland

Master processor



Slave processor and detector

Internet module



Liulin-R LET spectrometer at ALOMAR obs. (69°N, 16°E, 380 m asl)

History table | Current value | To page end

CURRENT VALUE:

Date/Time[mm.dd.yy hh:mm:ss]:	08.19.2005 07:30:00
Dose[µGy/h]:	0.115
Flux[(cm^{-2}*sec^{-1})]:	0.053

CURRENT AVERAGE VALUE:

Date/Time[mm.dd.yy hh:mm:ss]:	08.19.2005 07:00:00
Dose[µGy/h]:	0.115
Flux[(cm^{-2}*sec^{-1})]:	0.059

Dose/Flux Exposition Value:

Date [mm.dd.yy] [hh:mm:ss]	Dose [µGy/h]	Flux [(cm^{-2}*sec^{-1})]
06.18.2005 08:00:00	0.097	0.058
06.18.2005 07:50:00	0.139	0.072
[illegible].18.2005 07:40:00	0.102	0.059
[illegible]	[illegible]	0.060
[illegible]	[illegible]	0.067
[illegible]	[illegible]	0.059
[illegible]	[illegible]	0.062
[illegible]	[illegible]	0.061
[illegible]	[illegible]	0.054
[illegible]	[illegible]	0.059
06.18.2005 06:20:00	0.106	0.055
06.18.2005 06:10:00	0.102	0.057
06.18.2005 06:00:00	0.093	0.062
06.18.2005 05:50:00	0.088	0.053
06.18.2005 05:40:00	0.104	0.054
06.18.2005 05:30:00	0.149	0.075
06.18.2005 05:20:00	0.094	0.054
[illegible].2005 05:10:00	0.116	0.067

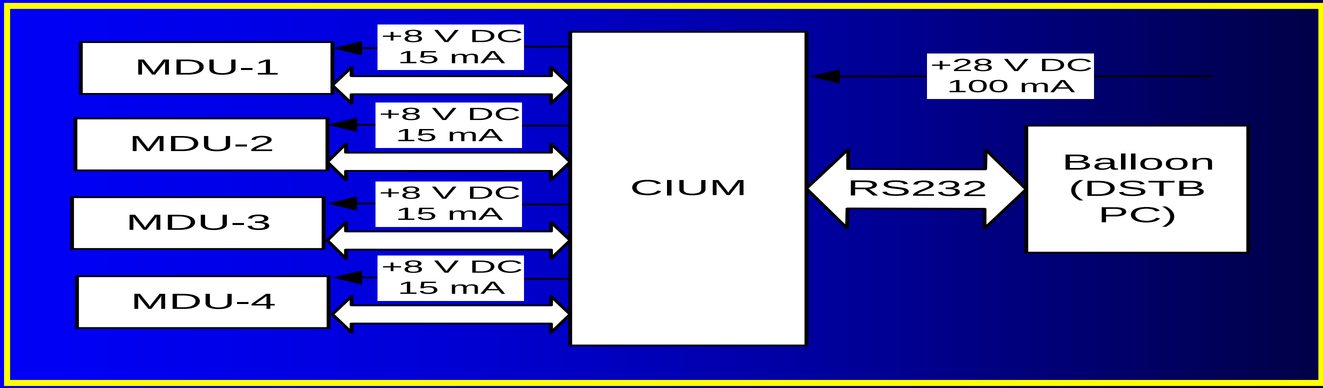
Dose/Flux Average Value:

Date [mm.dd.yy] [hh:mm:ss]	Dose [µGy/h]	Flux [(cm^{-2}*sec^{-1})]
06.18.2005 08:00:00	0.125	0.063
06.18.2005 07:00:00	0.109	0.058
06.18.2005 06:00:00	0.108	0.061
06.18.2005 05:00:00	0.114	0.063
06.18.2005 04:00:00	0.114	0.063
06.18.2005 03:00:00	0.107	0.055
06.18.2005 02:00:00	0.104	0.061
06.18.2005 01:00:00	0.098	0.059
06.18.2005 00:00:00	0.107	0.062
06.17.2005 23:00:00	0.117	0.063
06.17.2005 22:00:00	0.106	0.059
06.17.2005 21:00:00	0.113	0.060
06.17.2005 20:00:00	0.109	0.063
06.17.2005 19:00:00	0.100	0.059
06.17.2005 18:00:00	0.118	0.064
06.17.2005 17:00:00	0.101	0.057
06.17.2005 16:00:00	0.103	0.061
06.17.2005 15:00:00	0.099	0.059

Weight: 140 g
Size: 84x40x40 mm
Cons.: 200 mA, 12 VDC

Internet page view

Liulin-6U instrument for NASA DSTB mission



DU DIMENSIONS:

Weight: 65 g
Size: 90x40x20 mm
Consumption: 50 mW

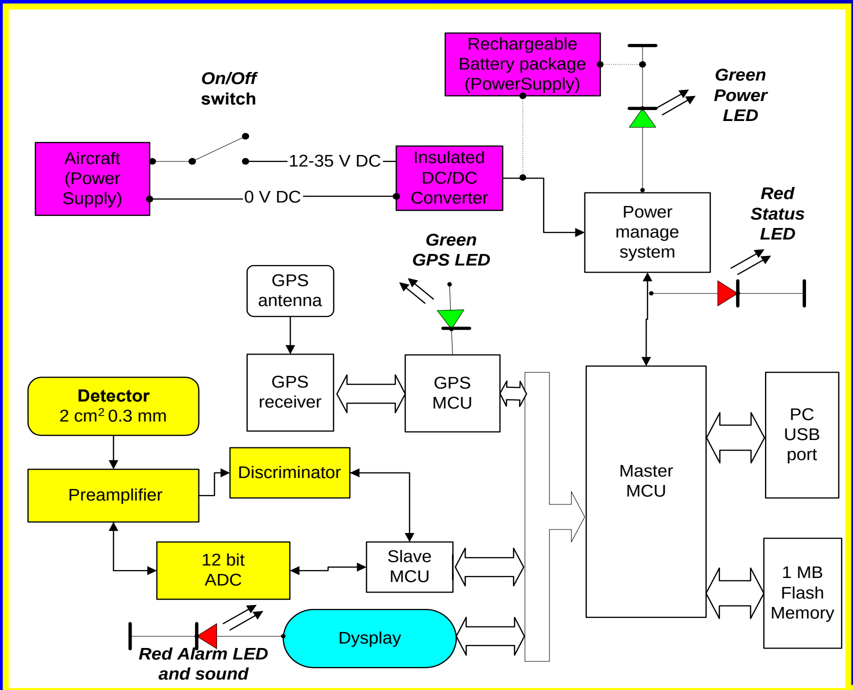
CIUM DIMENSIONS:

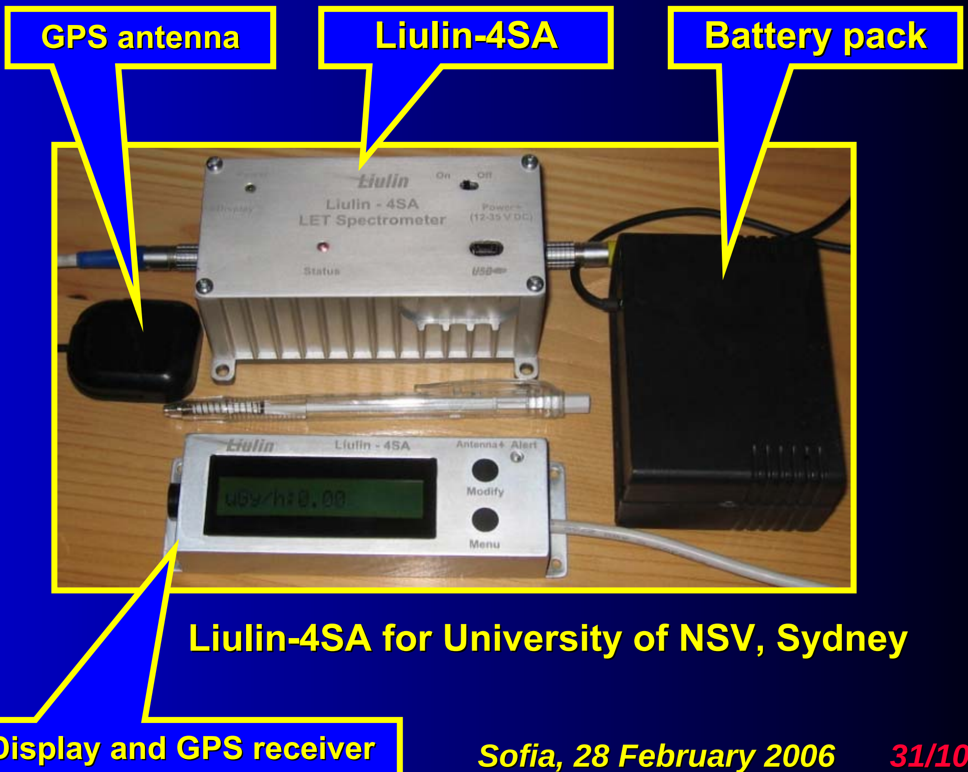
Weight: 210 g
Size: 155x60x20 mm
Consumption: 90 mW

Last modifications

Liulin-6SP for the fleet of IBERIA airlines

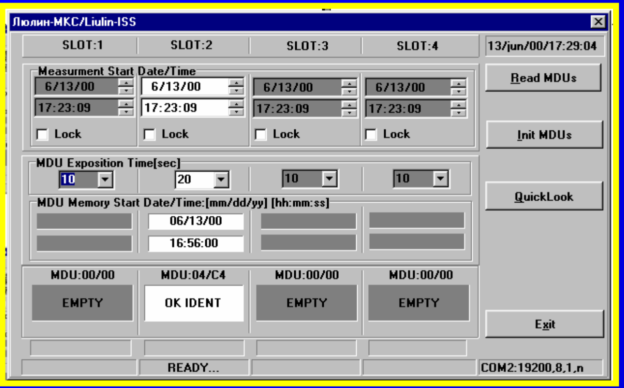
Liulin-6MB for BEOBAL project



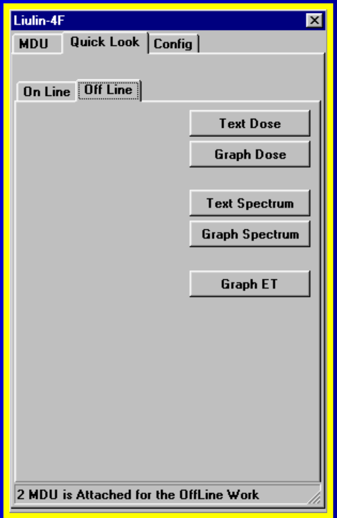


Liulin-4SA for University of NSV, Sydney

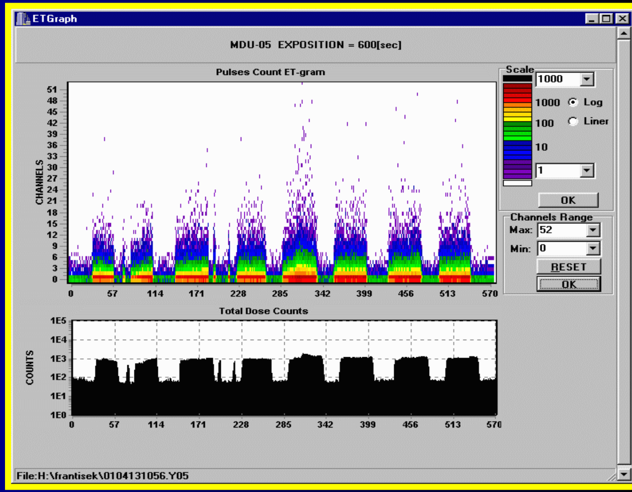
Examples of Windows Environment Software



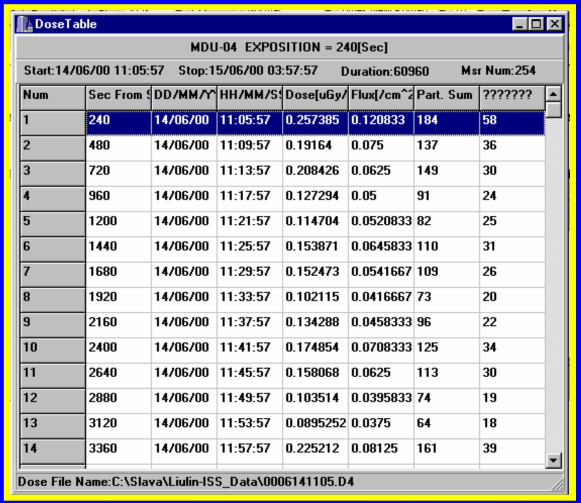
Initialization screenshot of 4 slot CIU with 4 MDUs



Initialization screenshot



Quick look graph of ET spectrogram


DoseTable

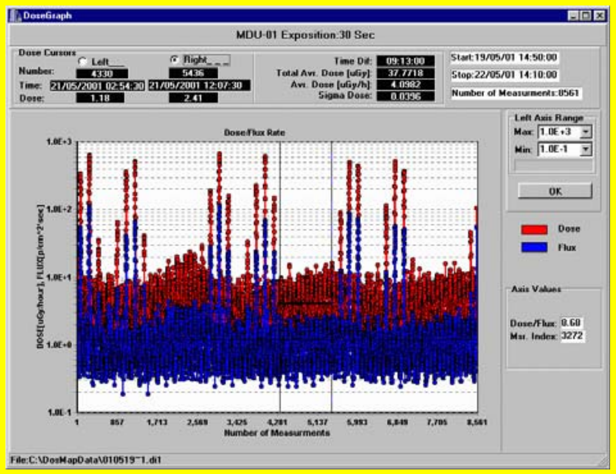
MDU-04 EXPOSITION = 240[Sec]

Start:14/06/00 11:05:57 Stop:15/06/00 03:57:57 Duration:60960 Msr Num:254

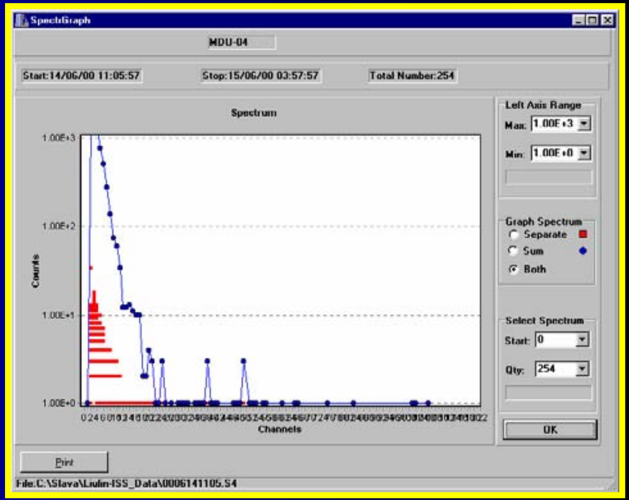
Num	Sec From S	DD/MM/YY	HH/MM/SS	Dose[uGy/	Flux[/cm^2	Part. Sum	???????
1	240	14/06/00	11:05:57	0.257385	0.120833	184	58
2	480	14/06/00	11:09:57	0.19164	0.075	137	36
3	720	14/06/00	11:13:57	0.208426	0.0625	149	30
4	960	14/06/00	11:17:57	0.127294	0.05	91	24
5	1200	14/06/00	11:21:57	0.114704	0.0520833	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

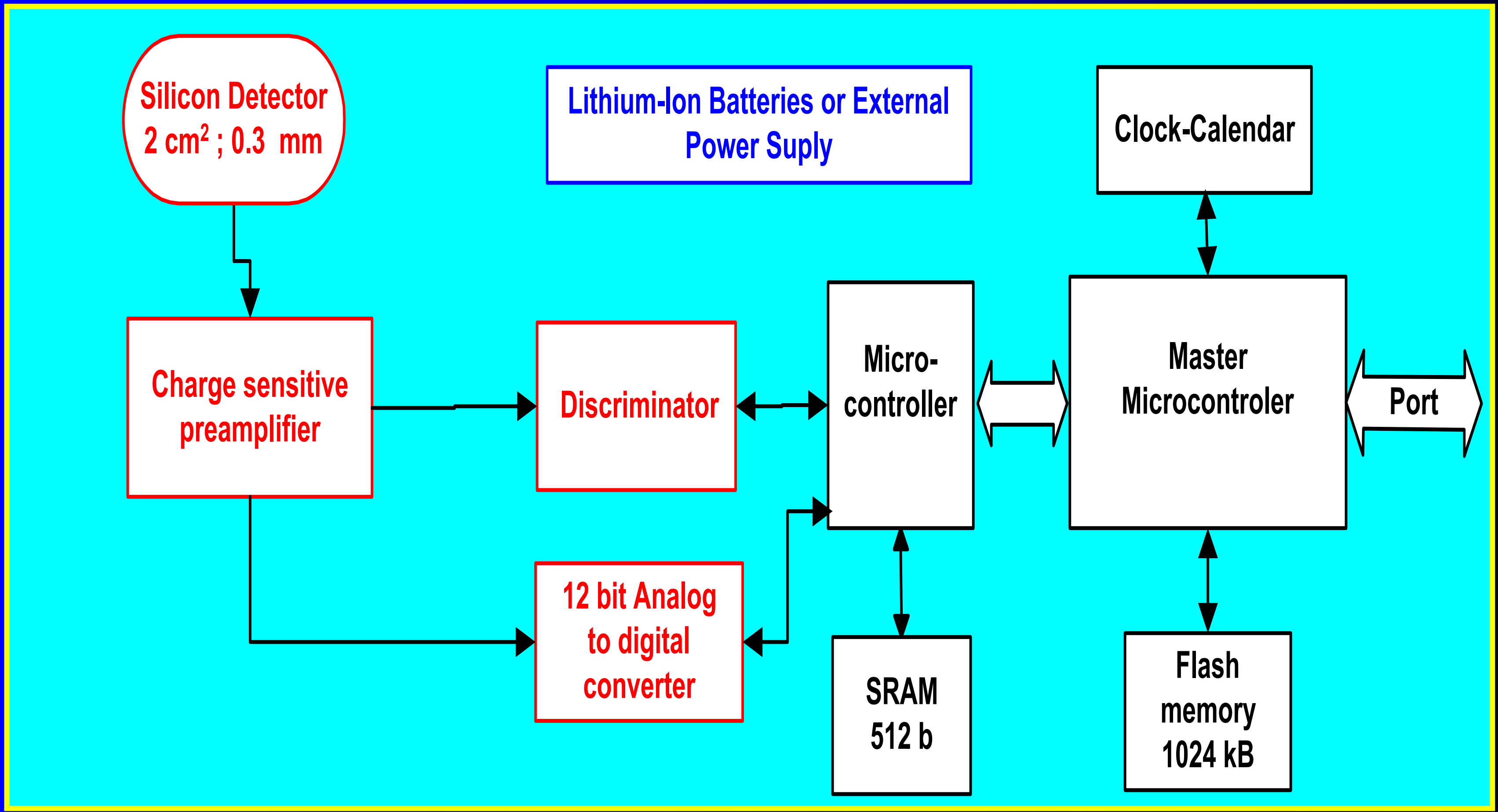


Quick look graph of dose and flux data

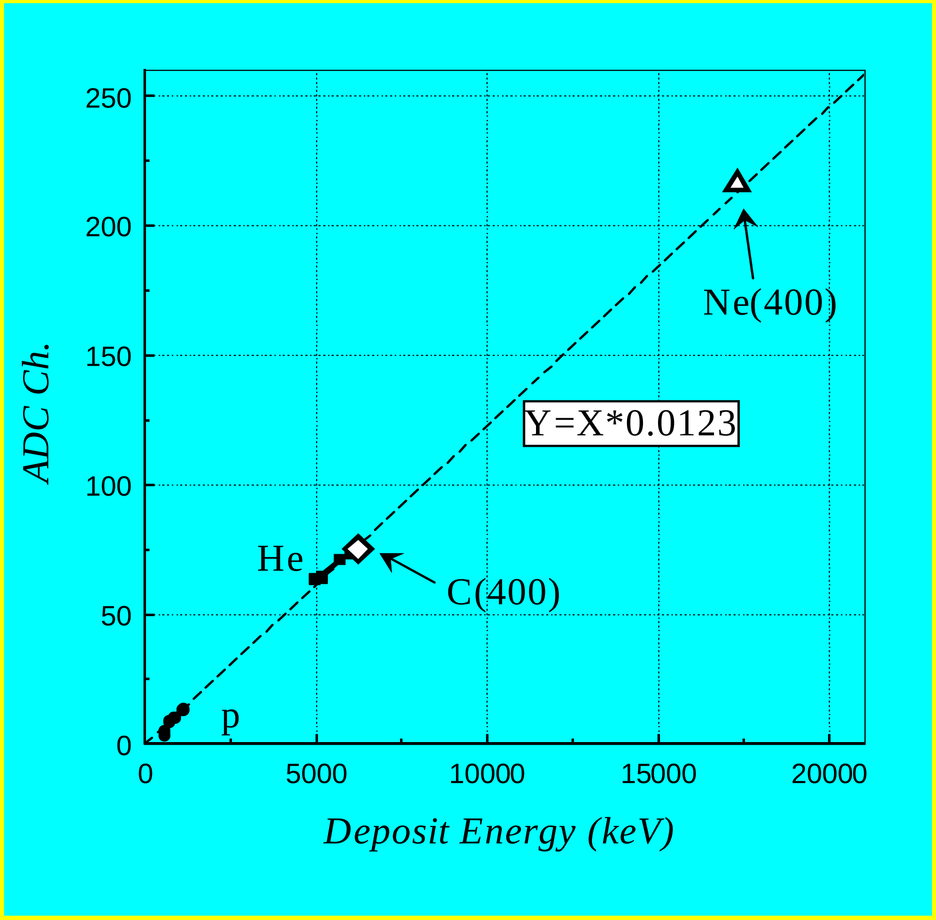


Quick look graph of spectra

Usual block-diagram of the Dosimetry Unit



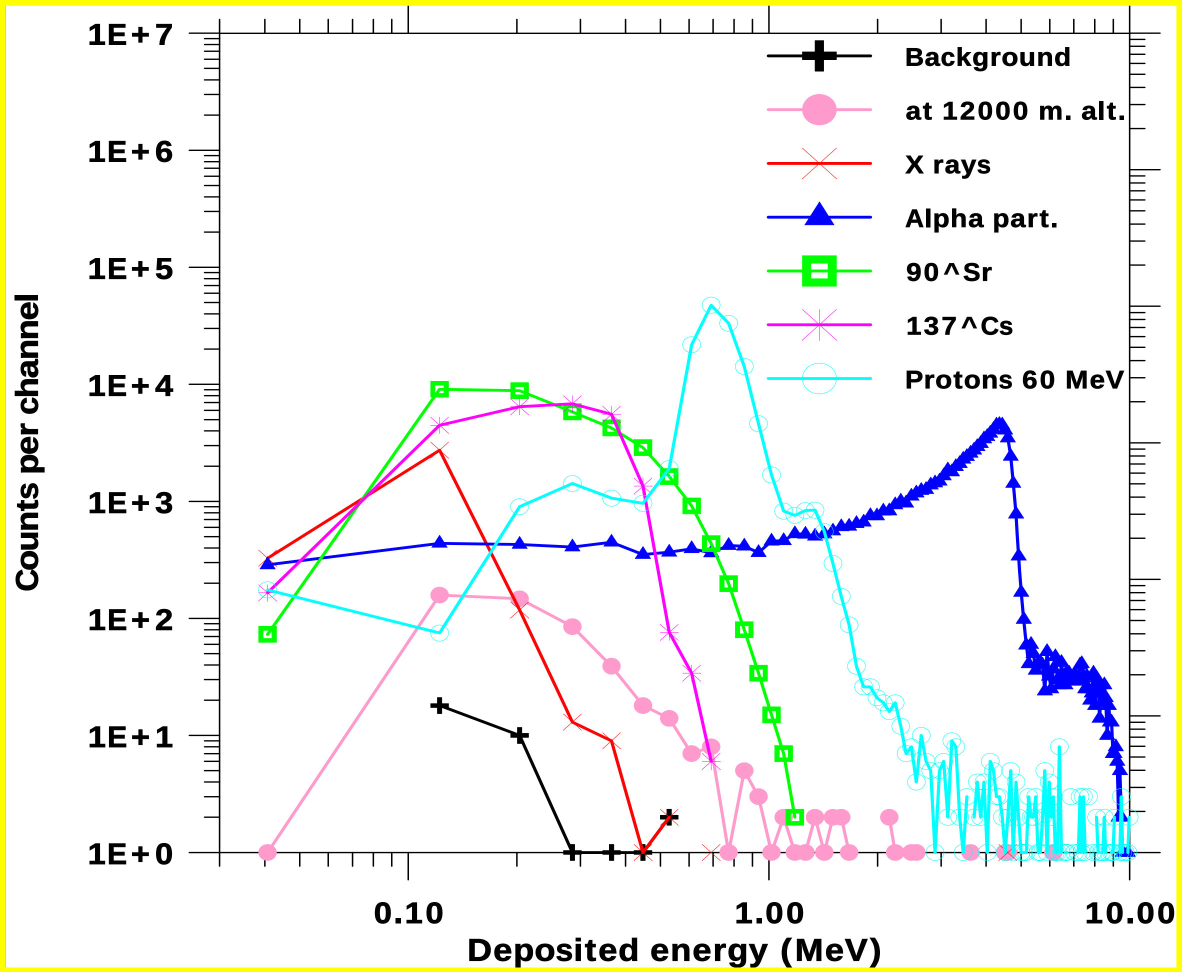
MDU calibration curves obtained by Dr. Uchihori at different NIRS sources



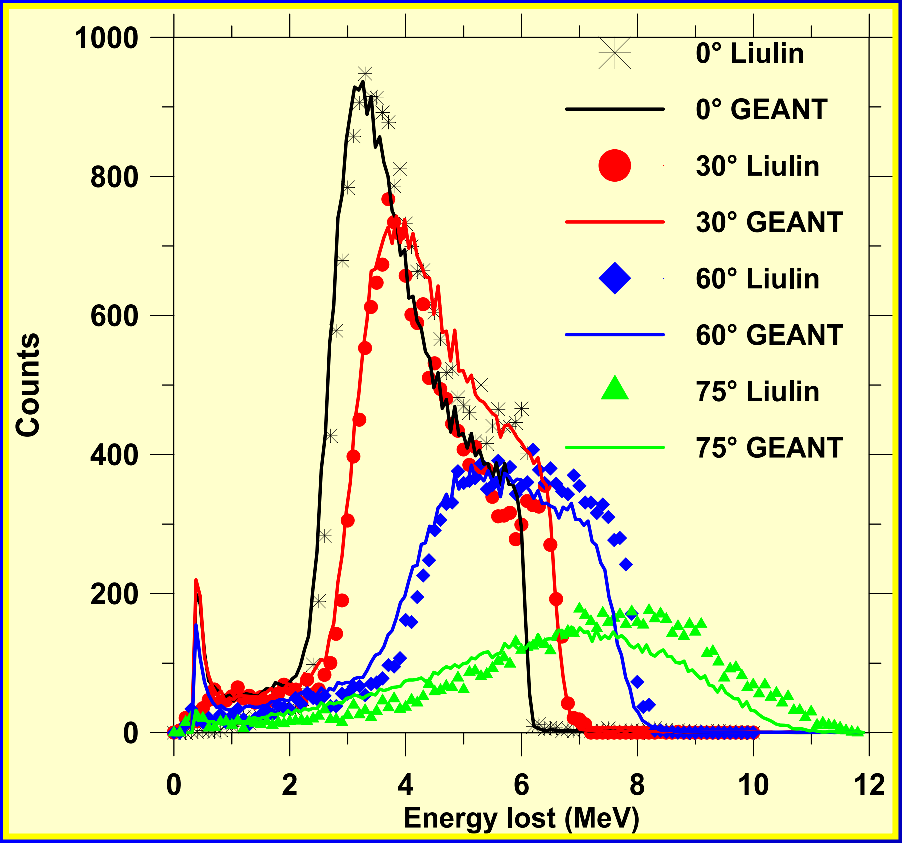
Comparison between predicted (dotted line) and obtained (points) deposited energies

Calibration results

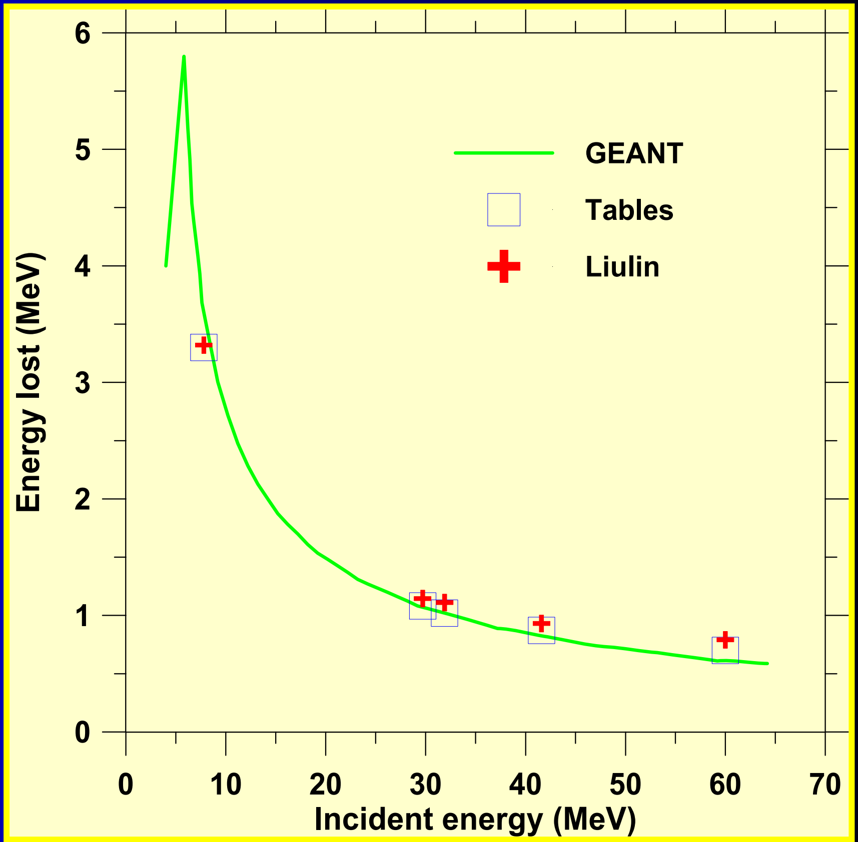
MDU spectra from different sources and conditions



Some Louvain-la-Neuve, Belgium cyclotron facility proton calibration results (1999-2000) 2

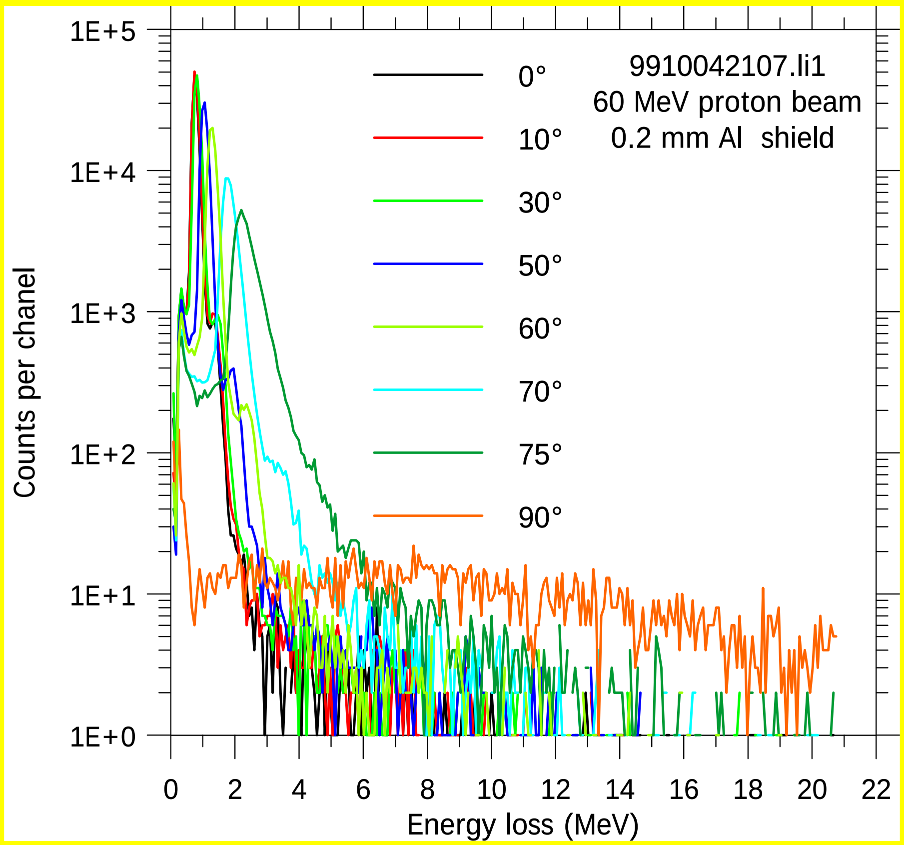


Theoretical and experimental deposited energy spectra recorded by Liulin spectrometer for 7.8 MeV proton irradiation at different incidence angles

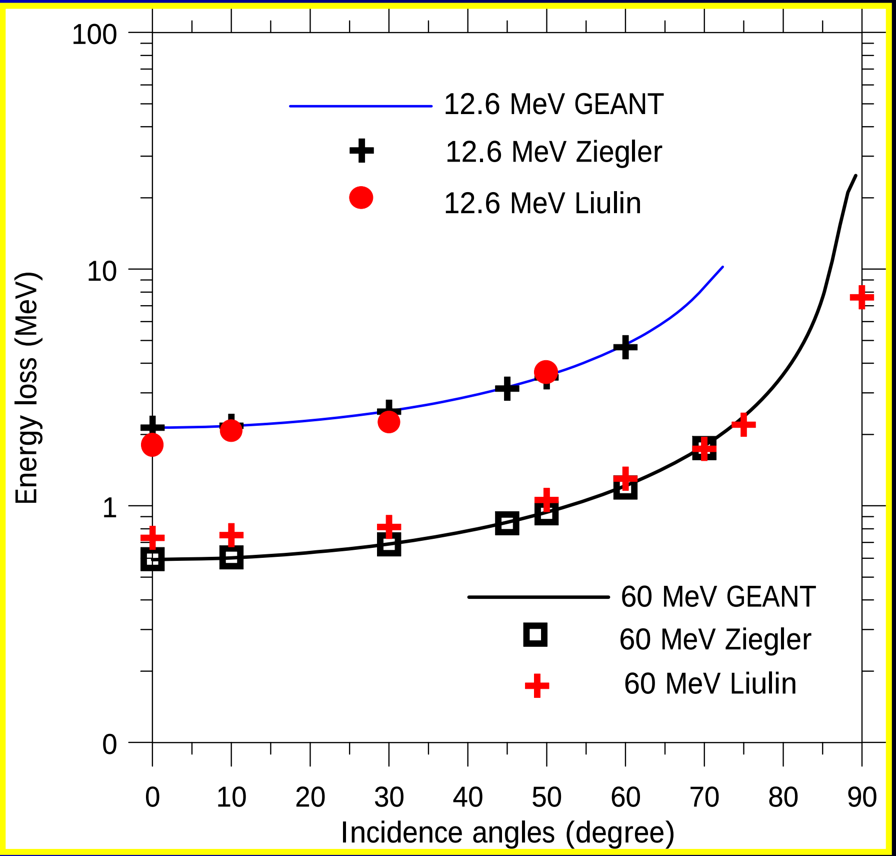


"Bethe-Bloch" behavior of Liulin experimental data at normal incidence (red crosses) versus energy. The blue squares refer to Ziegler and Williamson estimations while the continuous green line is the prediction of GEANT 3.21.

Some Louvain-la-Neuve, Belgium cyclotron facility proton calibration results (1999-2000)

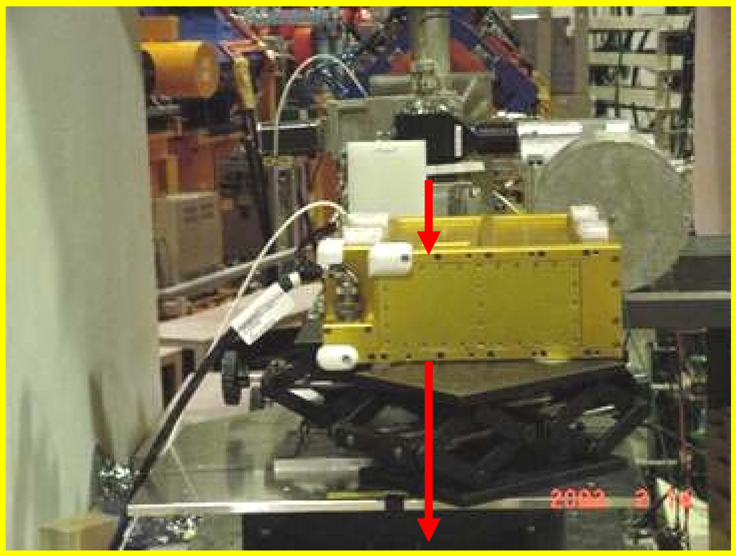


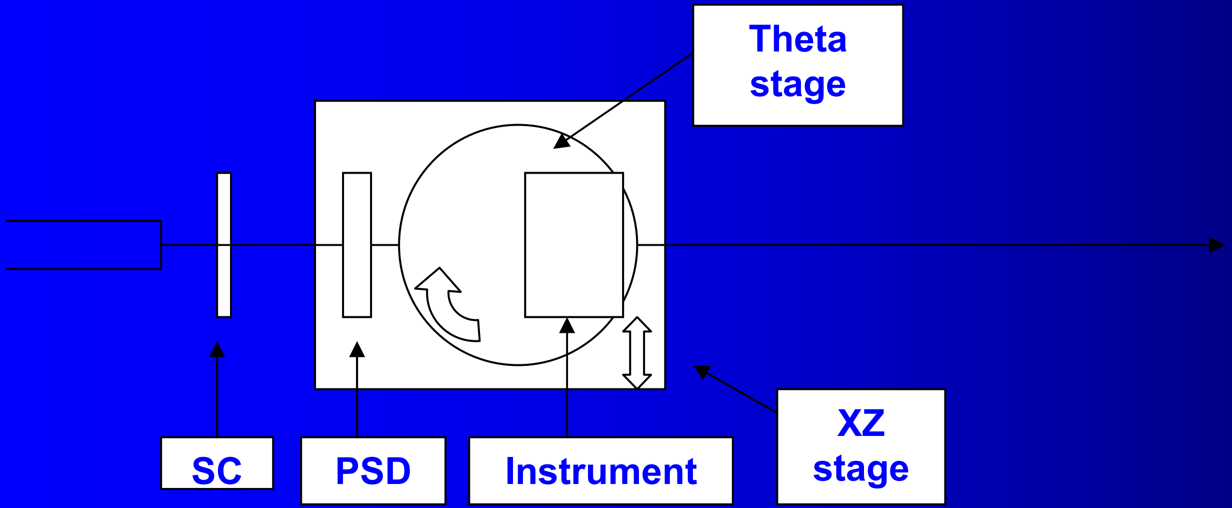
Experimentally obtained energy spectra recorded by Liulin spectrometer for 60 MeV proton irradiation at different incidence angles

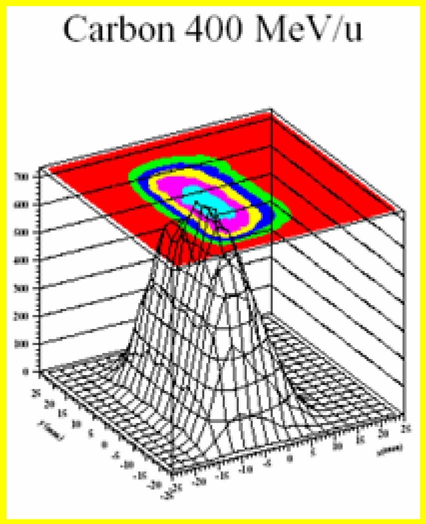


Comparison between theoretical and experimental places of the maxima of the deposited energies recorded by Liulin spectrometer for 12.6 and 60 MeV proton irradiation at different incidence angles

HIMAC experiment setup

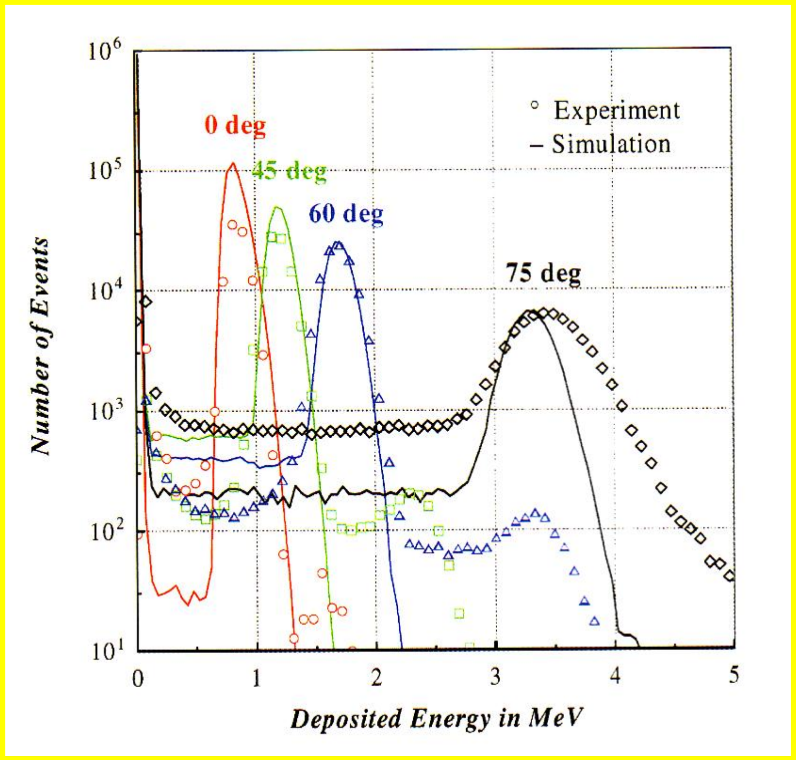


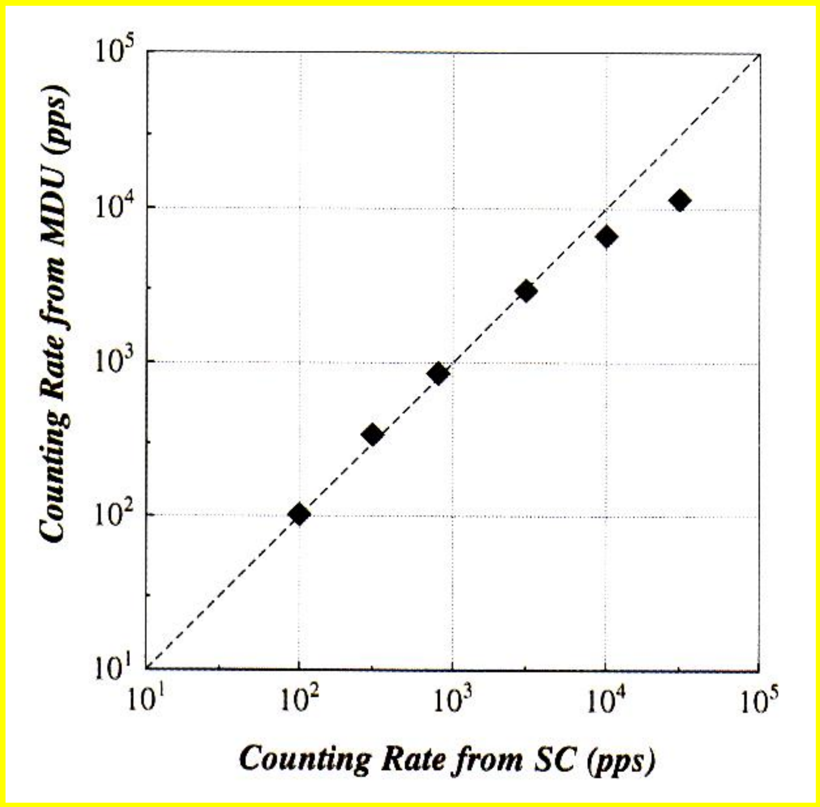




NIRS cyclotron experimental results*

Protons 40 MeV

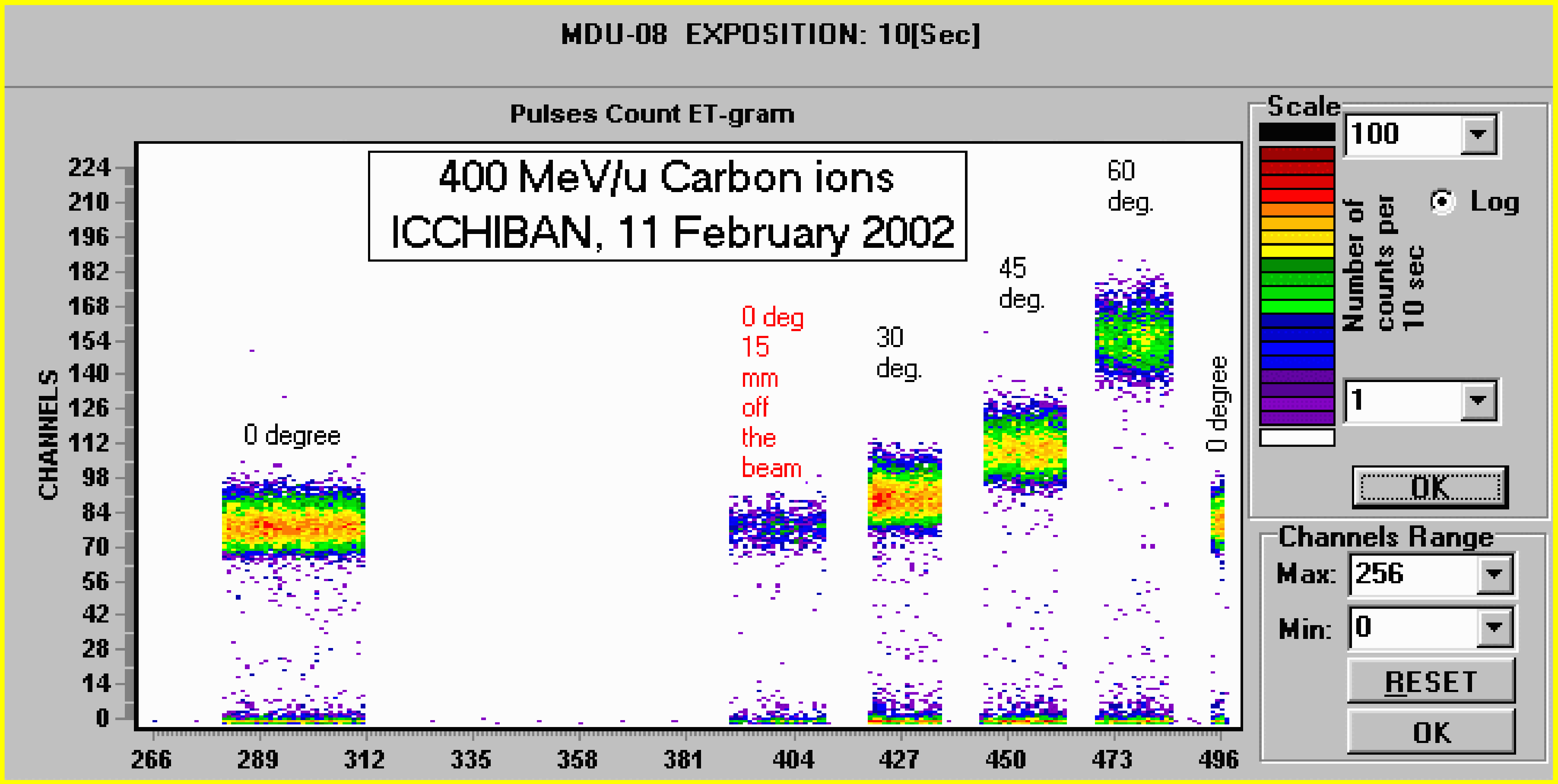




MDU data acquisition system efficiency

Uchihori, Y., et all, Analysis of the calibration results obtained with Liulin-4J spectrometer-dosimeter on protons and heavy ions, Radiation Measurements, 35, 127-134, 2002.

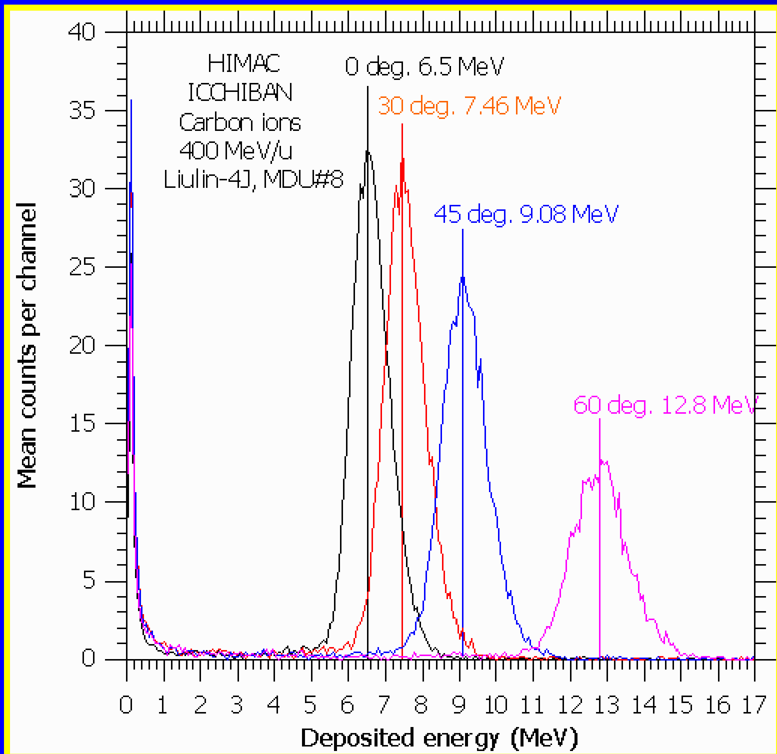
HIMAC experimental results

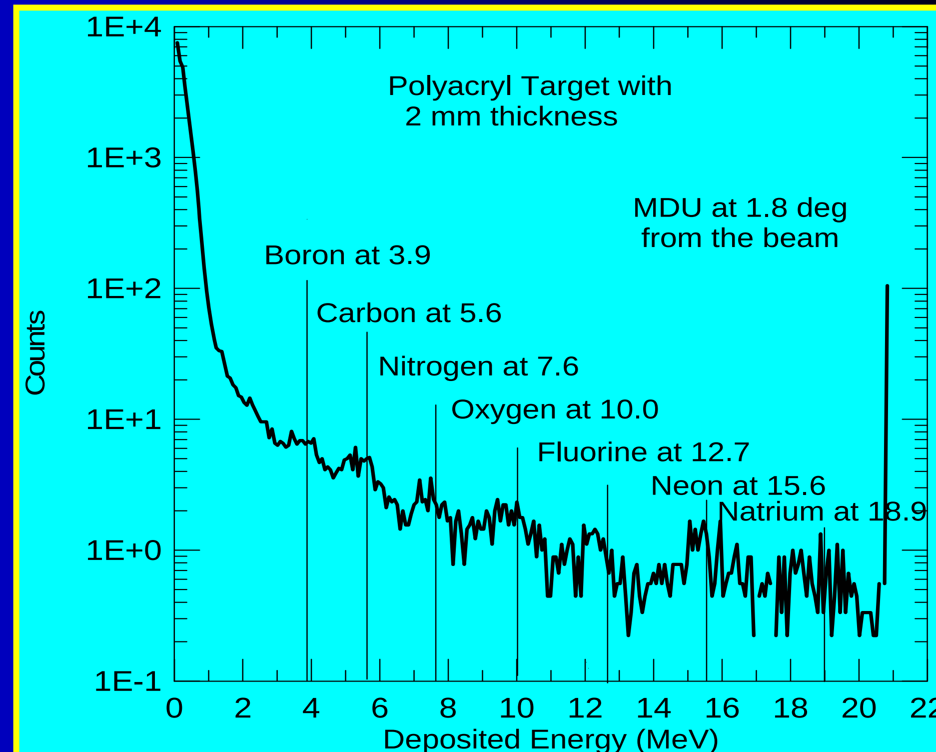


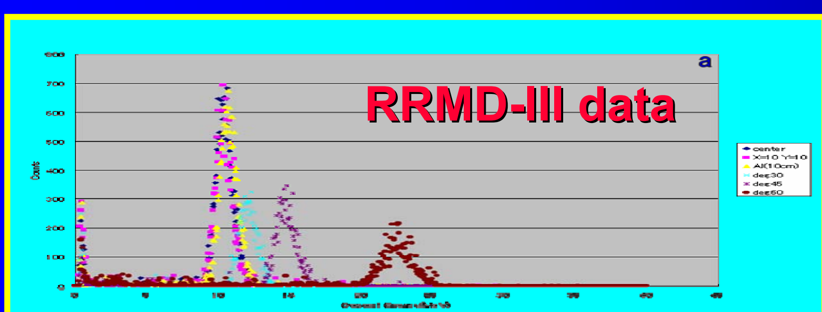
History of the irradiation of the MDU#8 with Carbon ions with different angles

HIMAC experimental results 2

Carbon ions 400 MeV

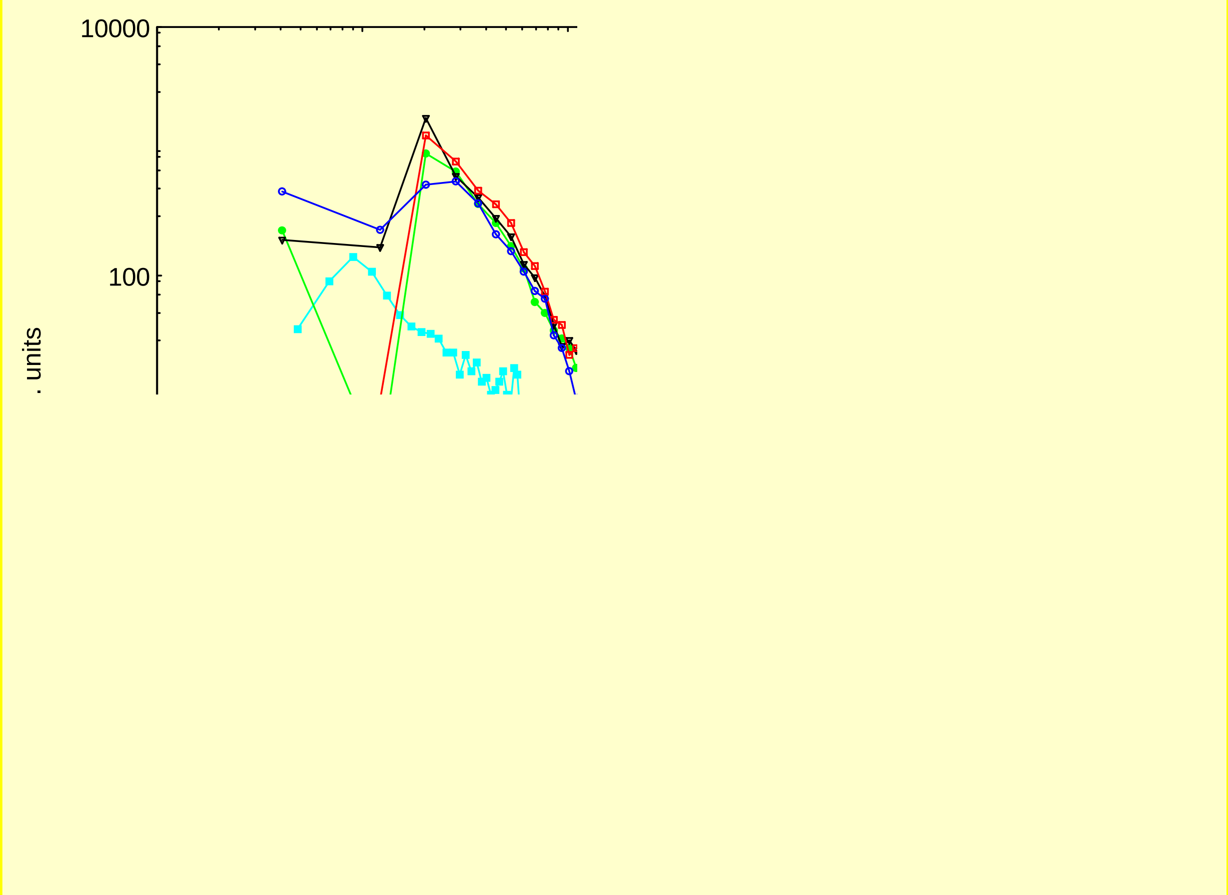






Fragmentation of Acryl target by 500 MeV/u Iron ions beam. The MDU is at 1.5 degree from the beam line direction

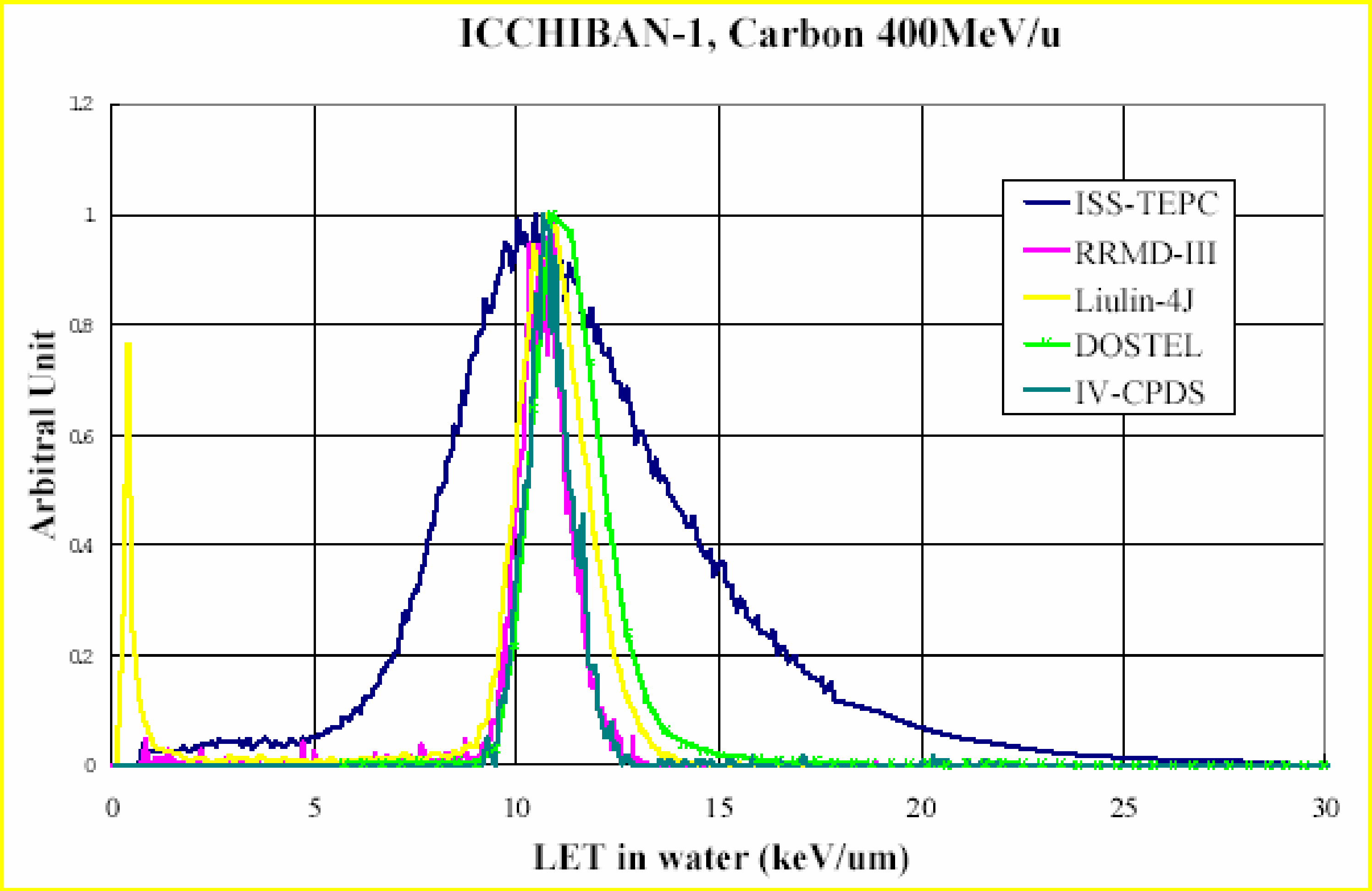
Comparison of the spectra obtained during the calibrations at Chiba, Japan (February, 2002) with 400 MeV/u Carbon ions by the 4 MDUs of Liulin-E094 and DOSTEL-1 instrument build by Kiel University, Germany



The deposited energies in 300 µm thick silicon detector from 400 MeV carbon ions were estimated using a computer calculation (Salamon, 1980), to be ~6.1 MeV in the silicon detector (Uchihori et al, 2002)

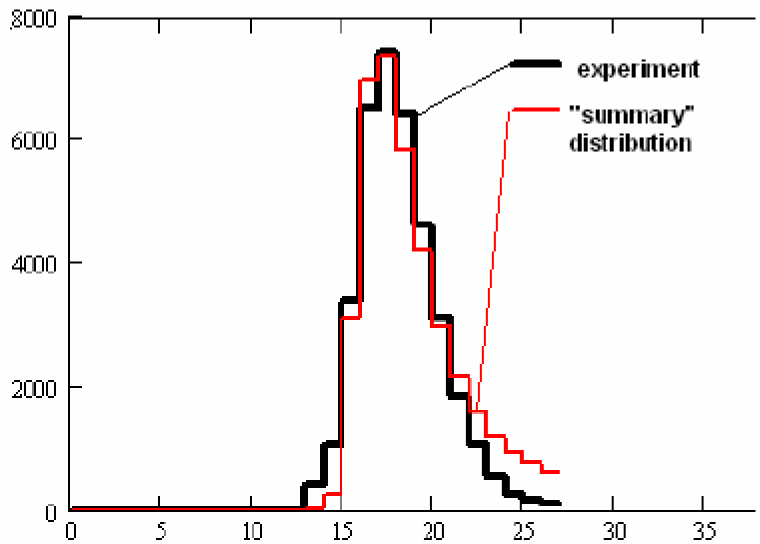
Comparisons with more instruments

(Uchihori, Y., WRMISS, Vienna, September 2004)

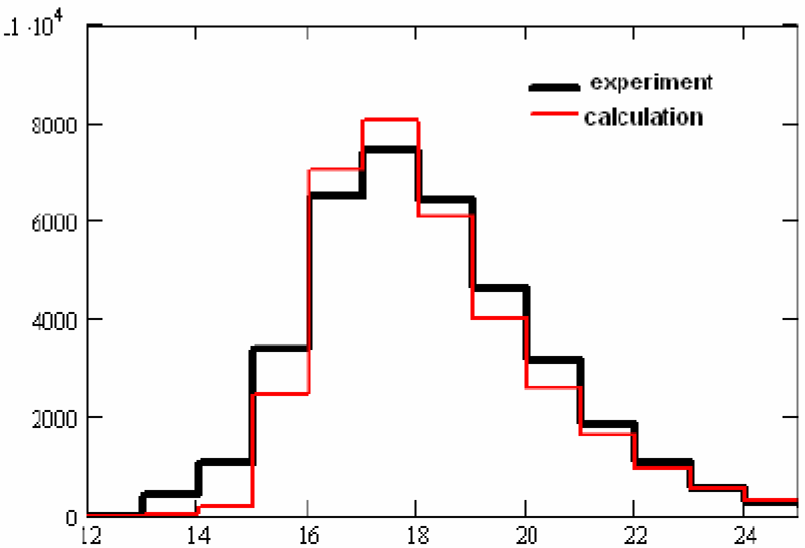


Comparison of experimentally measured energy deposition spectrum with Landau and Vavilov theoretical distributions

MDU-301
Landau distribution,
Helium 150 MeV/n
16.02.2004

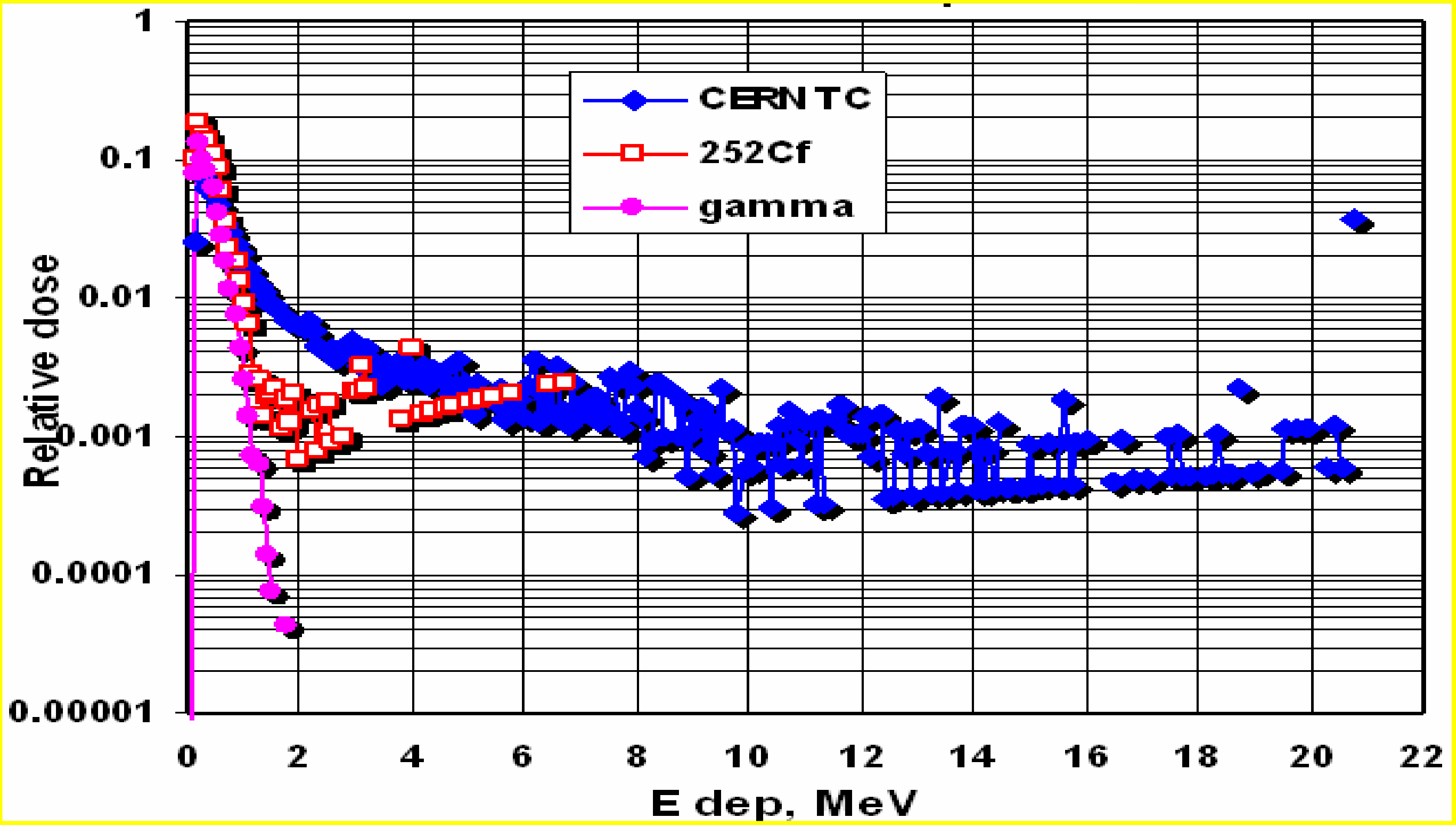


MDU-301
Vavilov distribution,
Helium 150 MeV/n
16.02.2004

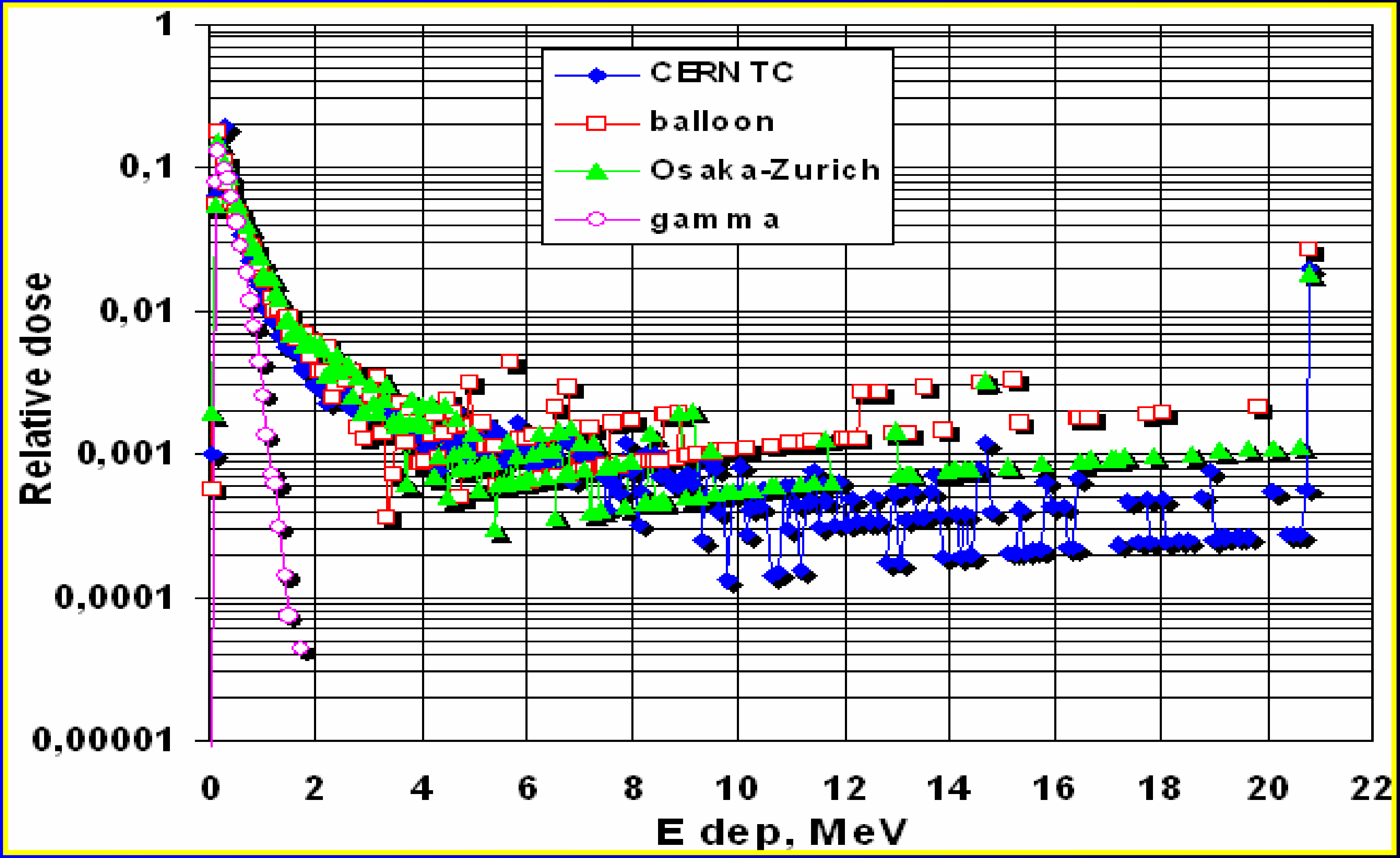


The calculations indicated that the difference doesn't exceed 3%
(Benghin, V., et all, WRMISS, Vienna, September 2004.)

Relative dose distributions in different on-Earth fields as obtained by F. Spurny

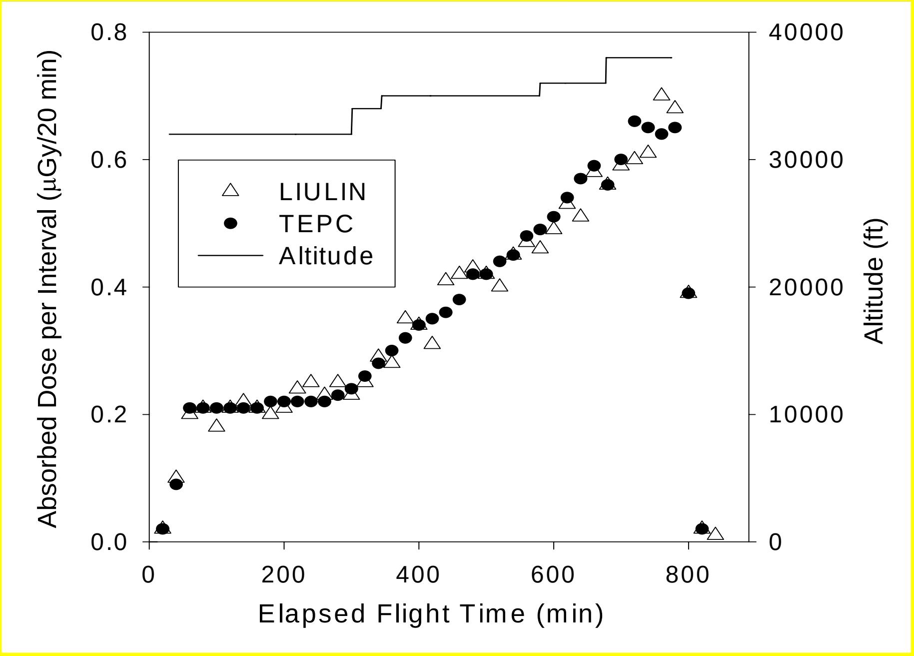


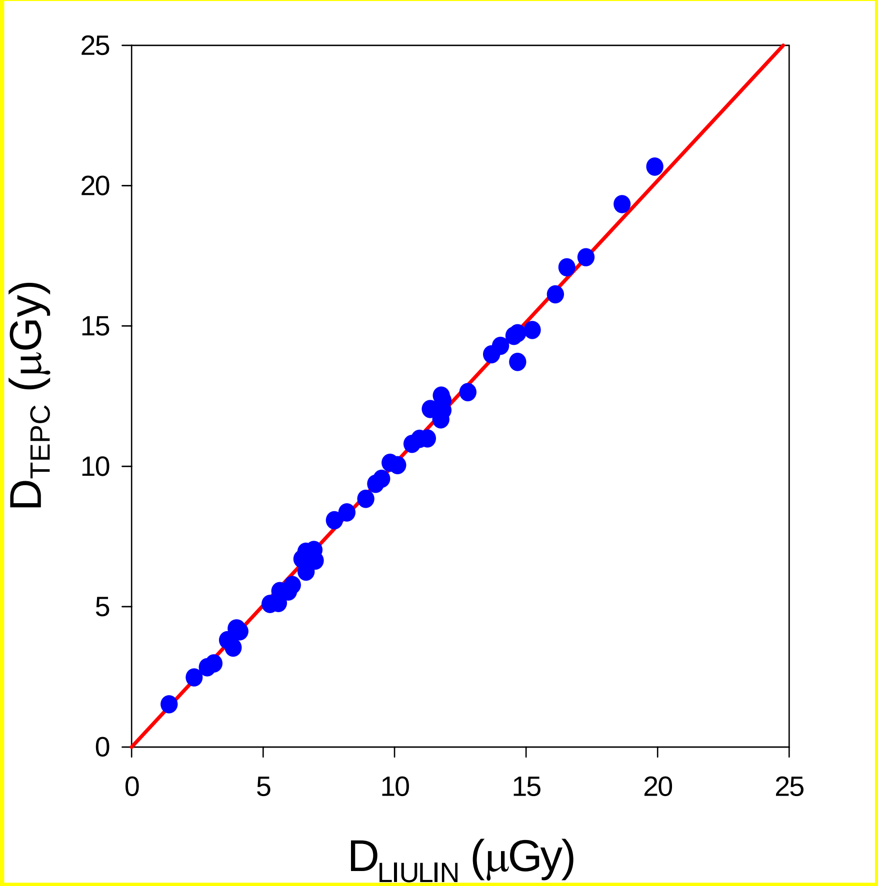
Relative dose distributions in different on-Earth fields and on balloons and aircrafts as obtained by F. Spurny



In-flight Inter-calibrations with other instruments

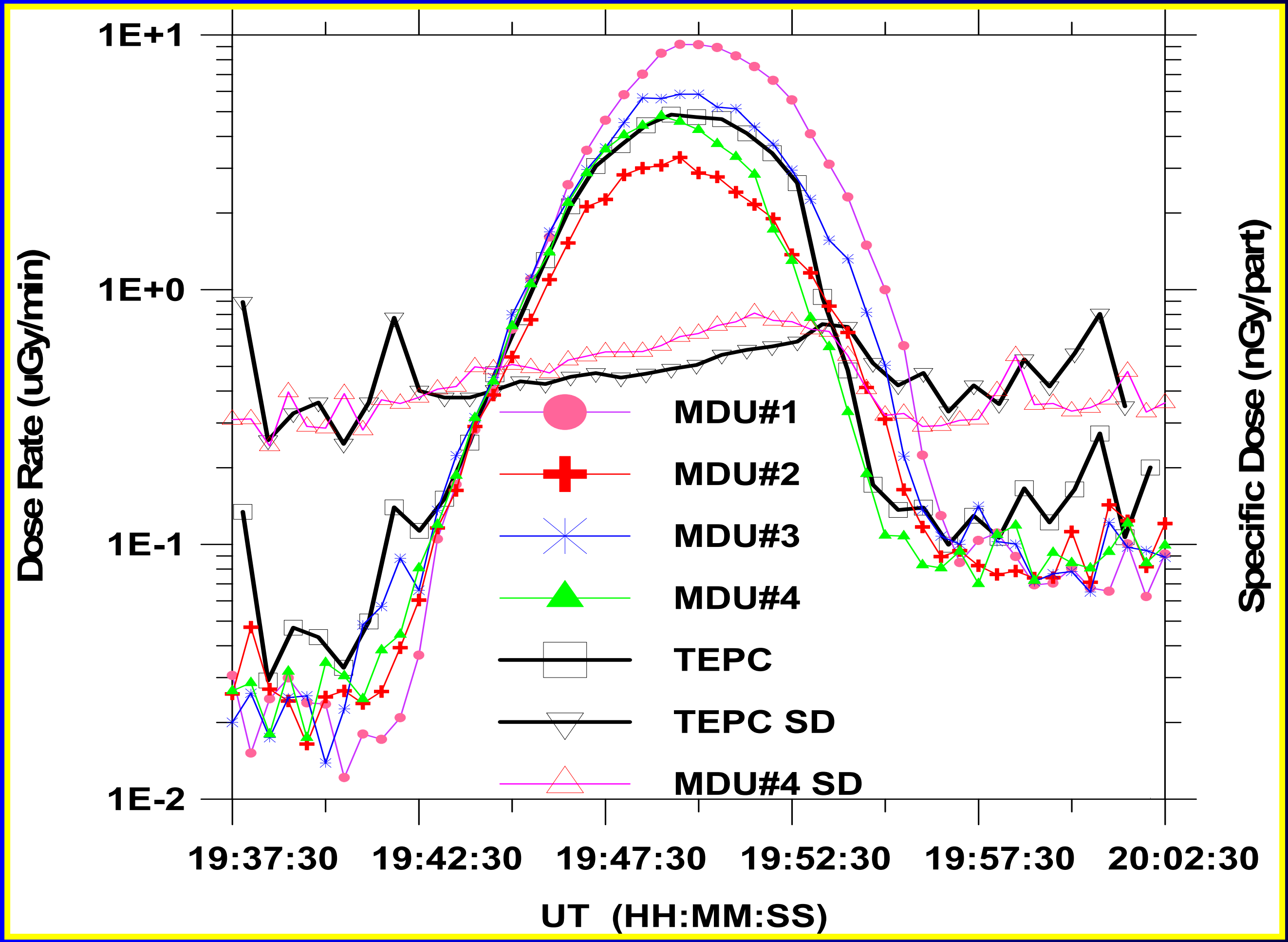
Liulin-4SN comparisons with TEPC data during aircraft experiments performed by Royal College, Canada*





*Bennett, L.G.I; Lewis, B.J.; Kitching, F.; Green, A.R.; Butler, A., An Empirical Approach to the Measurement of the Cosmic Radiation Field at Jet Aircraft Altitudes, COSPAR04-A-01135, Presented at 35th COSPAR Assembly, Paris, July 2004.

Comparison between Liulin MDUs and NASA TEPC at ISS*



*Dachev, T.; Atwell, W.; Semones, E.; Tomov, B.; Reddell, B. ISS Observations of the Trapped Proton Anisotropic Effect: A Comparison with Model Calculations, paper F2.6-0022-04, presented at 35th COSPAR Scientific Assembly, Paris, France July 2004. (will be published in ASR, 2005)

Space experiments

First Liulin dosimeter-radiometer was successfully flown on Mir space station between 1988 and 1994

Detector Block:
Size: 40x100x160mm
Weight: 0.49 kg

Control Block:
Size: 300x220x170 mm
Weight: 10.5 kg

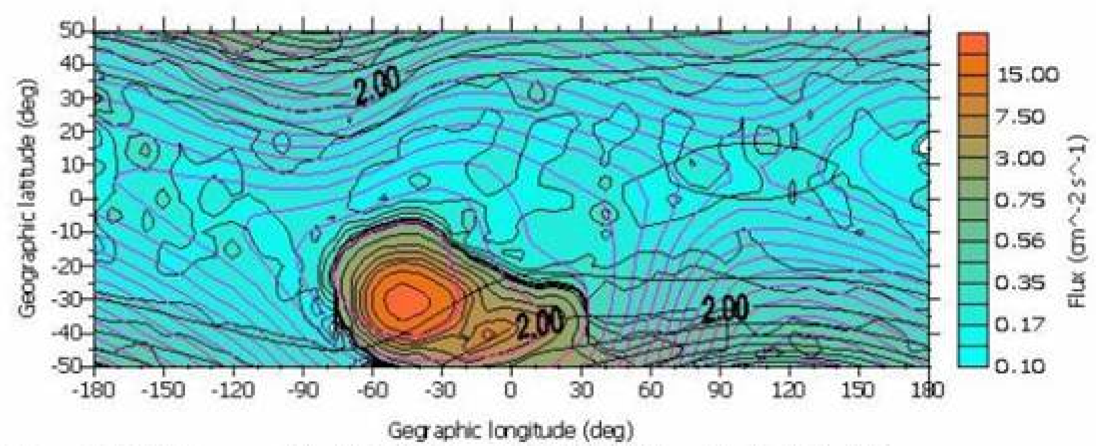


Figure 3. Global geographical distribution of the LIULIN flux data for July 1991.

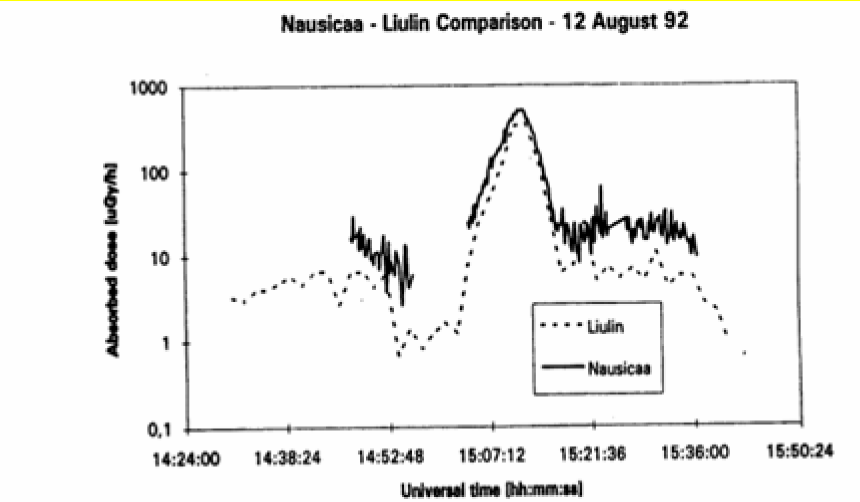
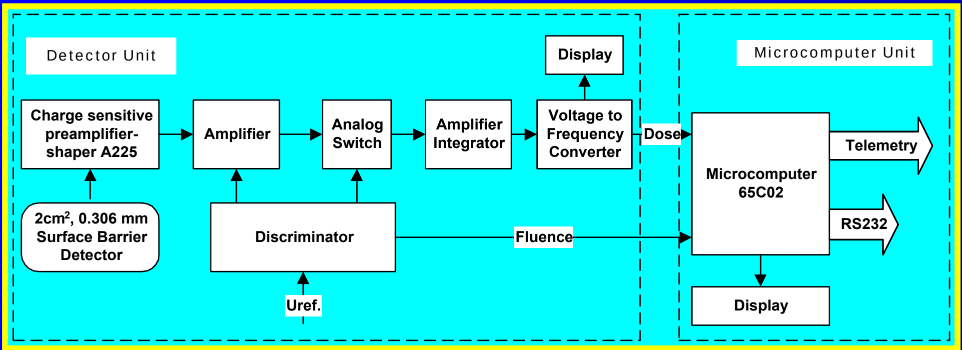
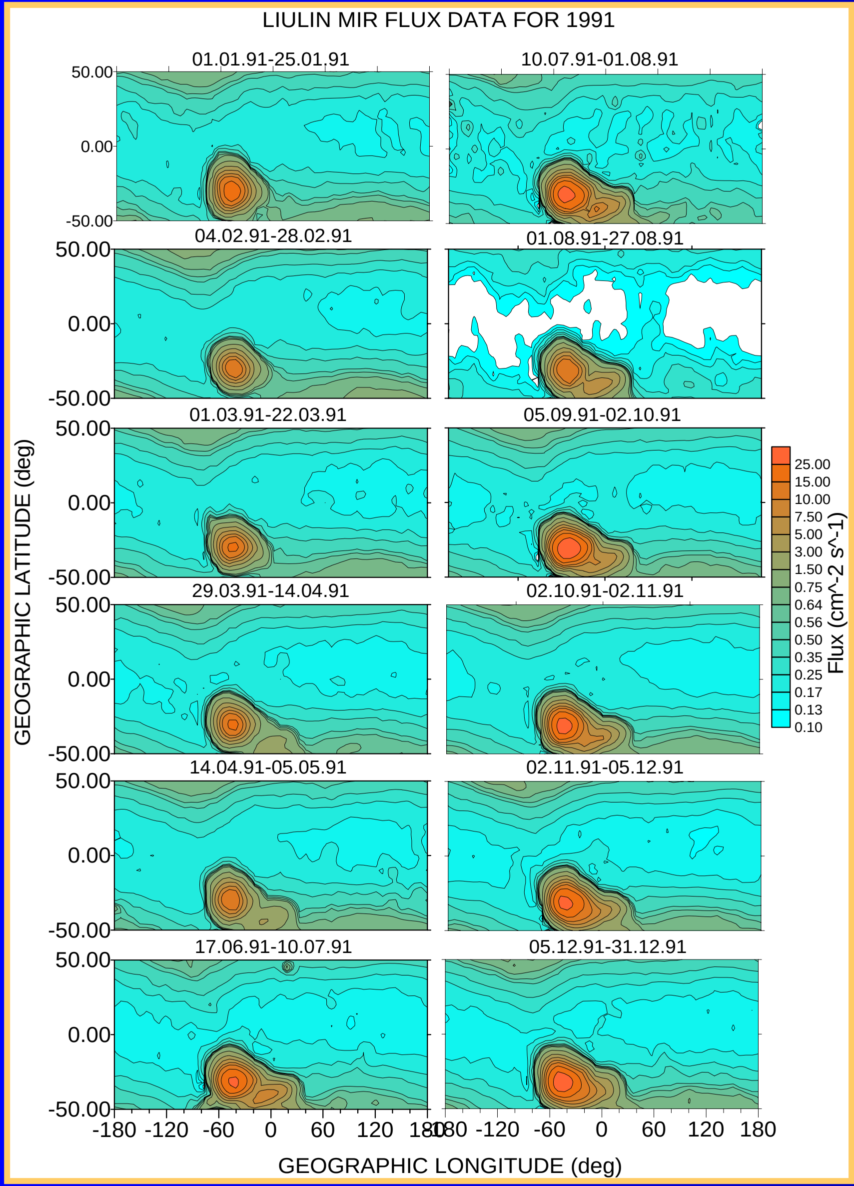
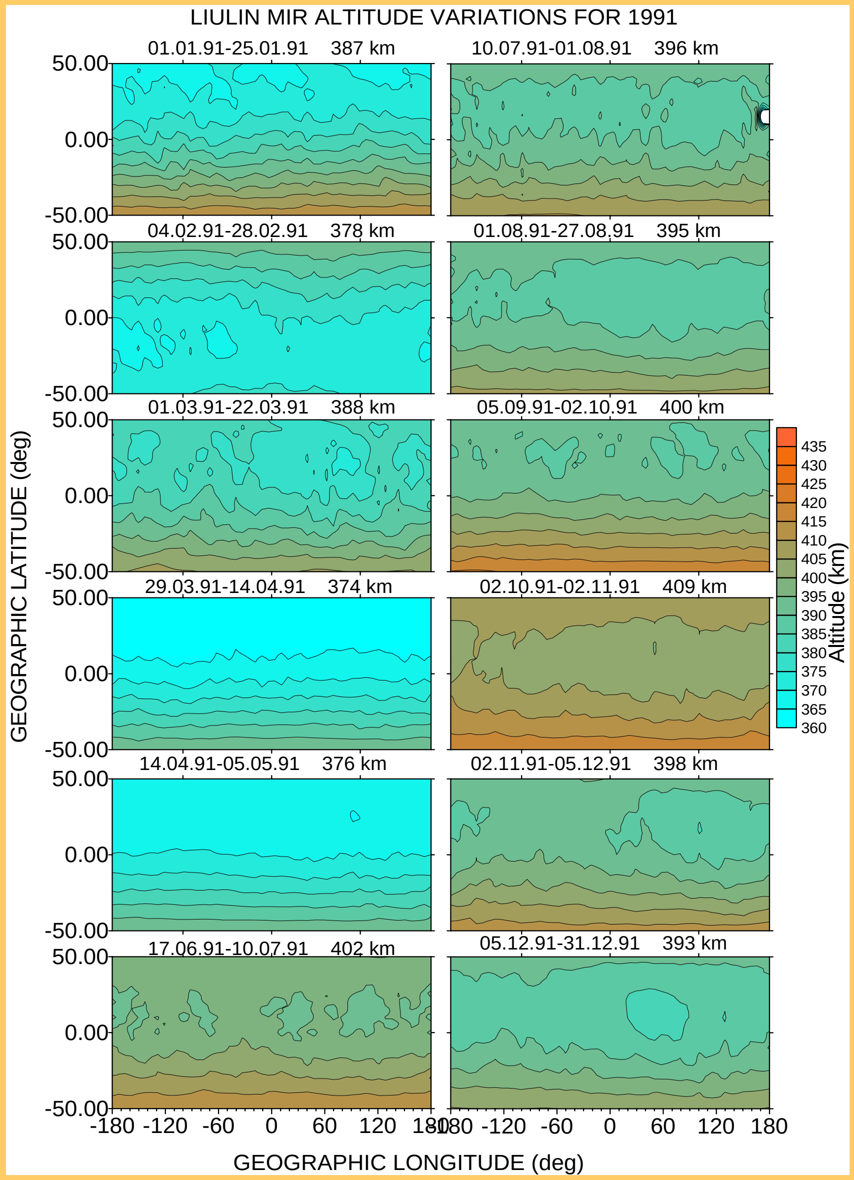


Figure2. Intercomparison of Liulin and NAUSICAA data obtained on MIR on August 12, 1992.

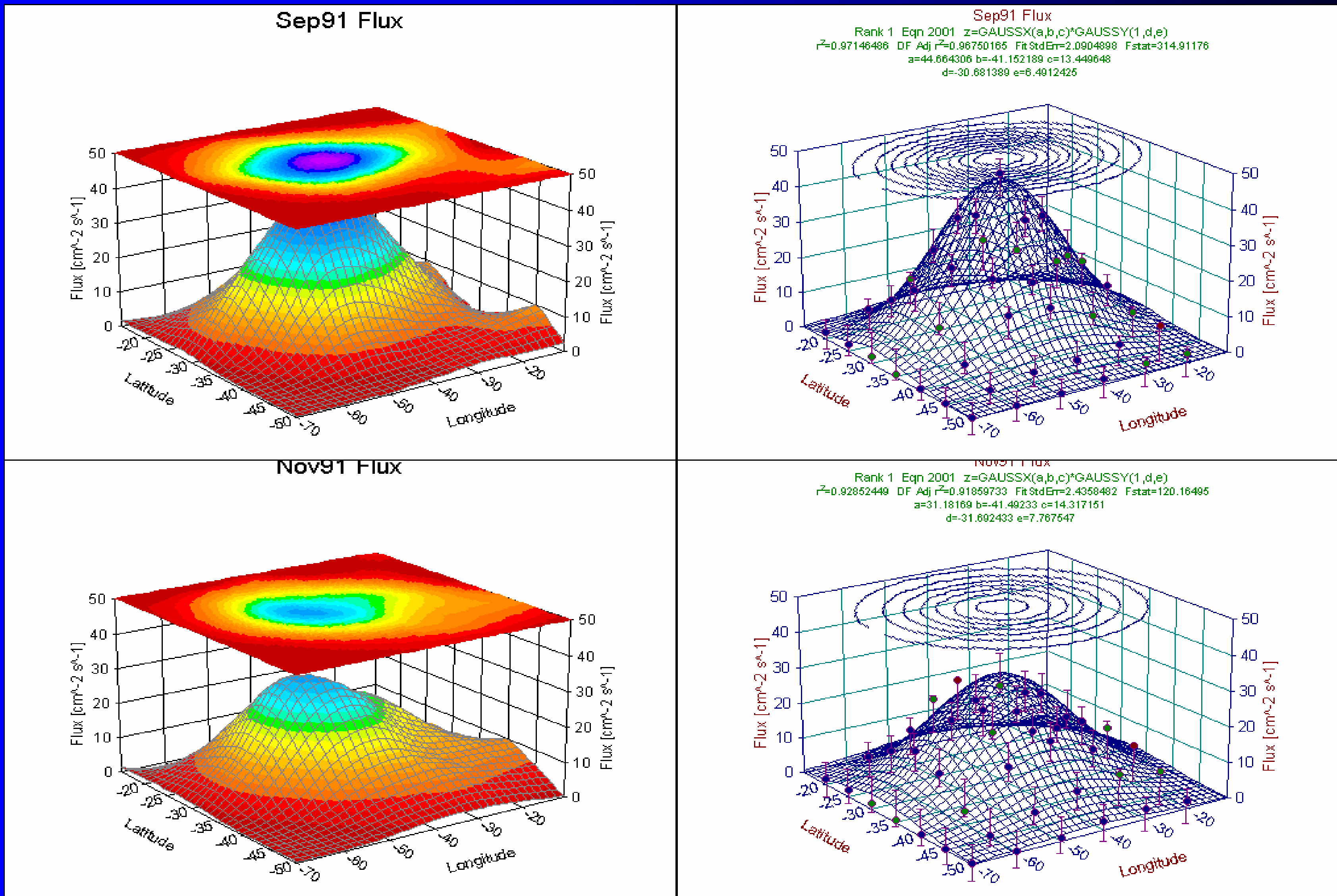


Global variations of the LIULIN flux data for 1991 in comparison with the altitude of MIR space station

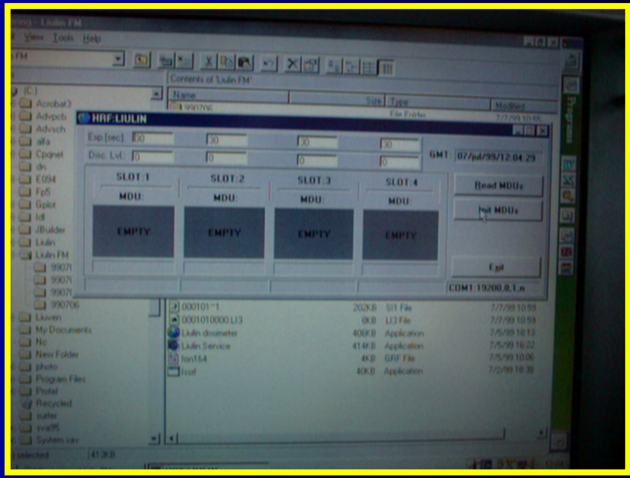




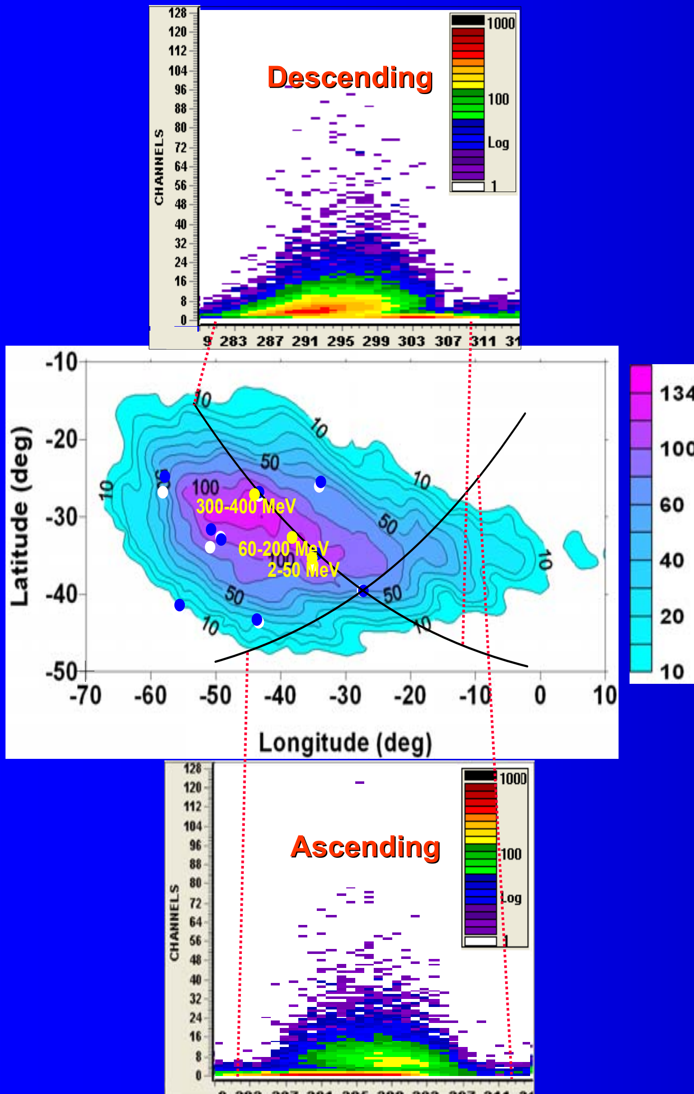
3D Curve fitting of the SAA region for September (415-425 km) and November (410-420 km) 1991

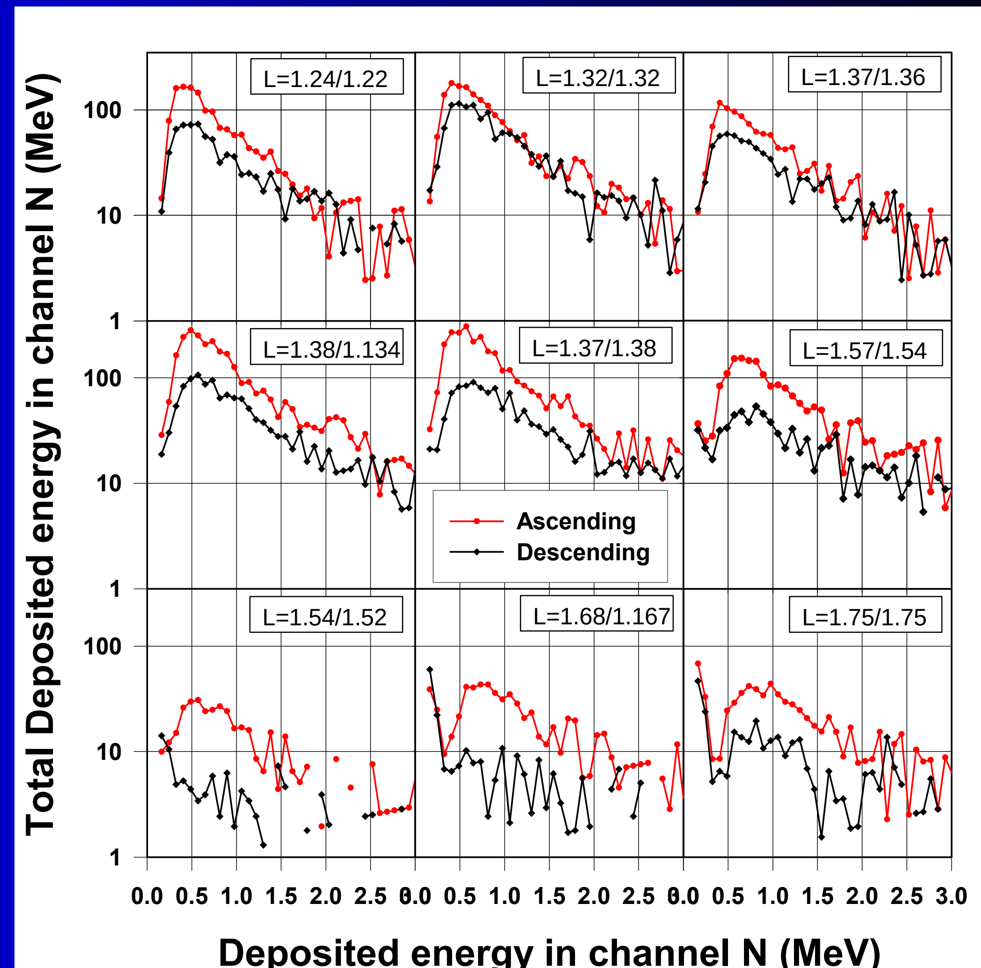


Liulin-E094 instrument, flown successfully on American Laboratory module May-August 2001 as a part of German lead Dosimetric mapping experiment

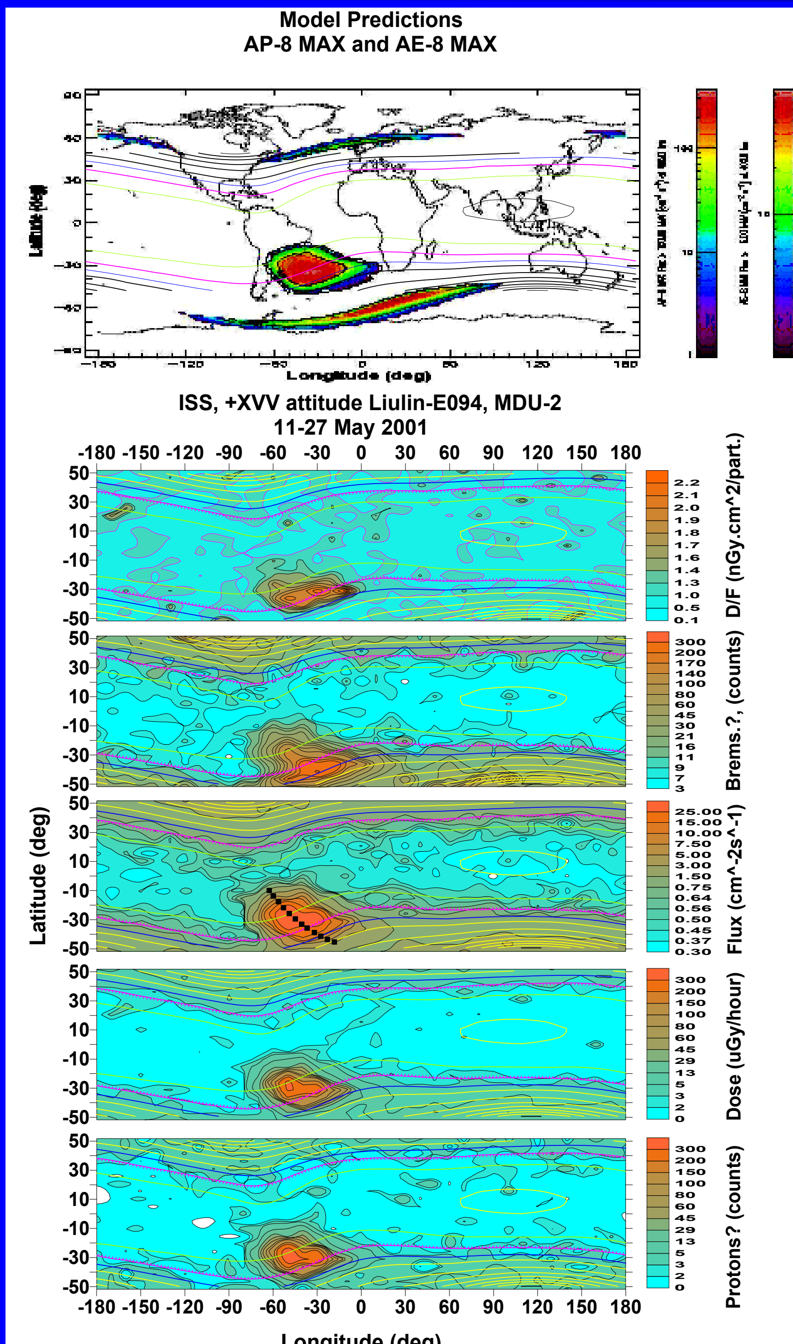


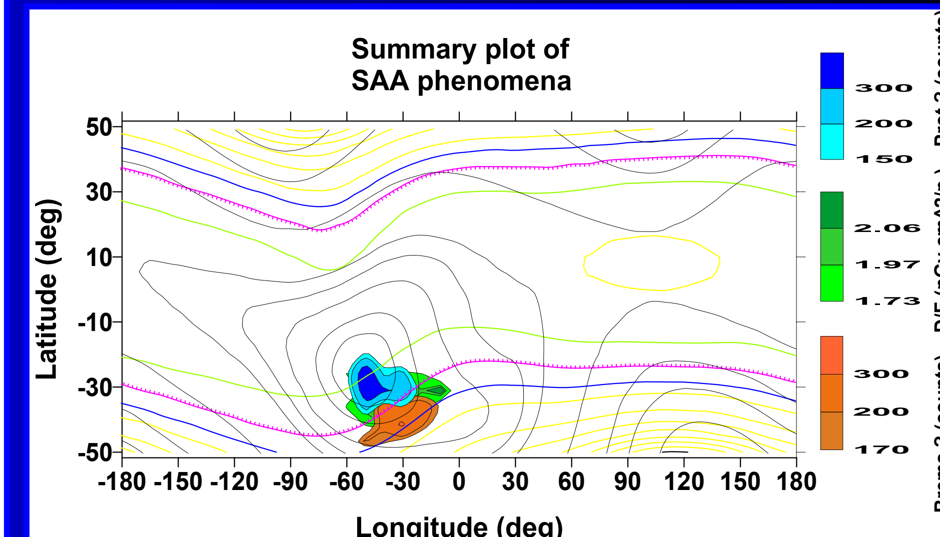
Ascending/descending spectra comparison for MDU#2 on ISS in 11-19 May 2001 time interval





Summary of SAA observations on ISS in 2001

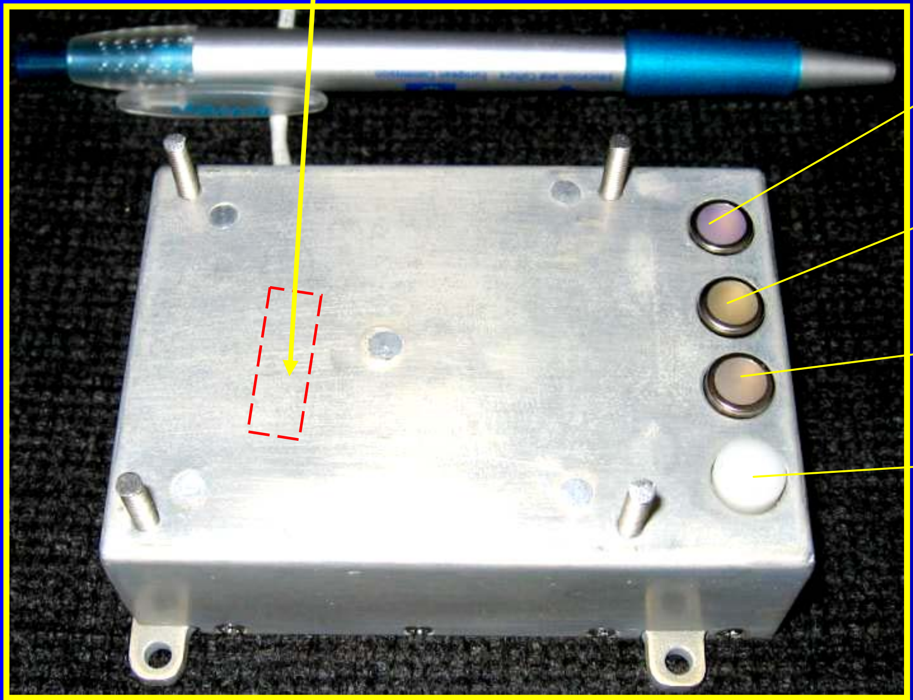




R3D-B2 instrument for ESA Biopan-5 facility outside of Foton M2 satellite. On June 16 2005 it was successfully returned after 2 weeks in space. The mission will be repeated in 2007. The spectrometer is mutually developed with the University in Erlangen, Germany

Detector of 256 Channels LET spectrometer

4 Channels UV spectrometer

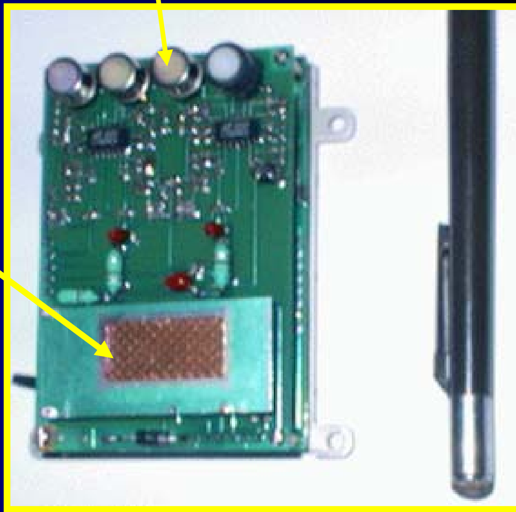


UV-C channel

UV-B channel

UV-A channel

PAR channel

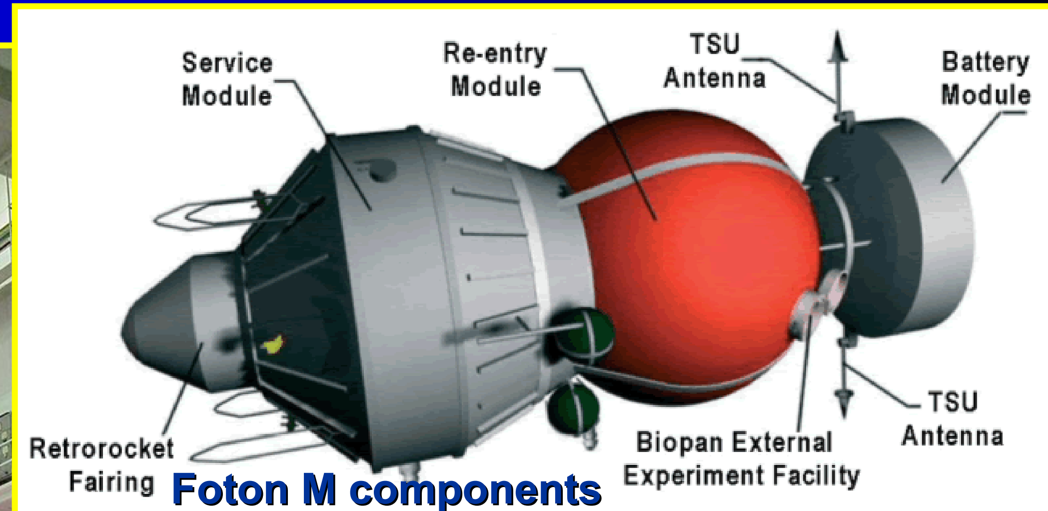


Size: 82x57x25 mm
Weight: 129 g
Consumption: 84 mW

Soyuz-U launcher and Foton M spacecraft

Soyuz-U

Foton M1



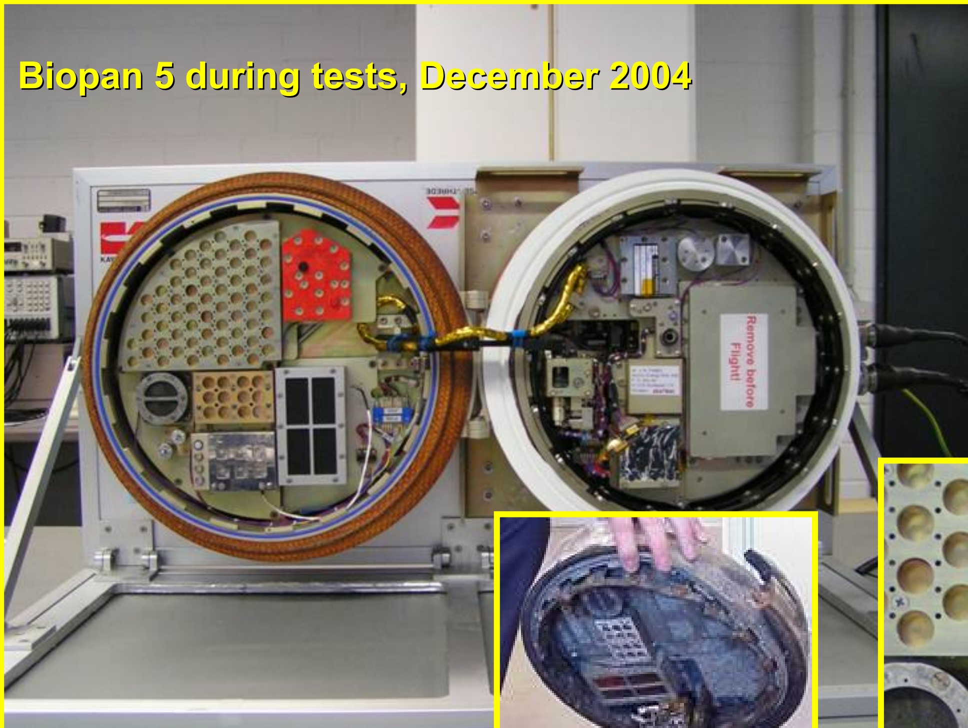
Foton M components

Launch of Foton M2, 31 May 2005

Re-entry Module of Foton M2, 16 June 2005

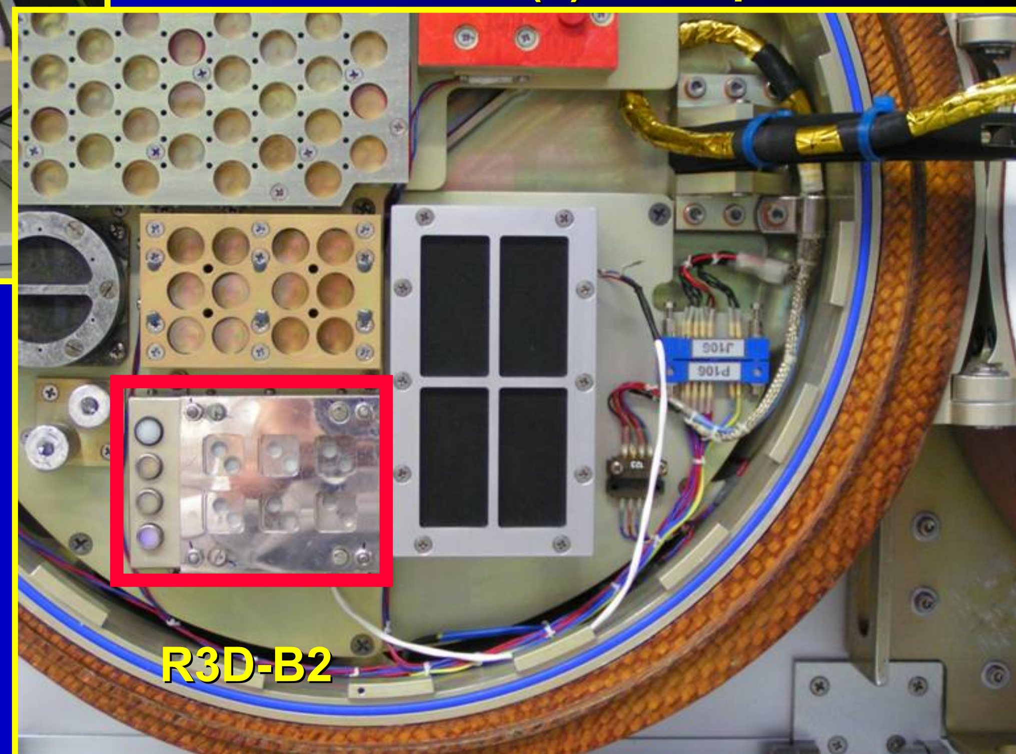
Biopan 5

Biopan 5 platform on Foton M2



Biopan 5 during tests, December 2004

R3D-B(1) in Biopan 4



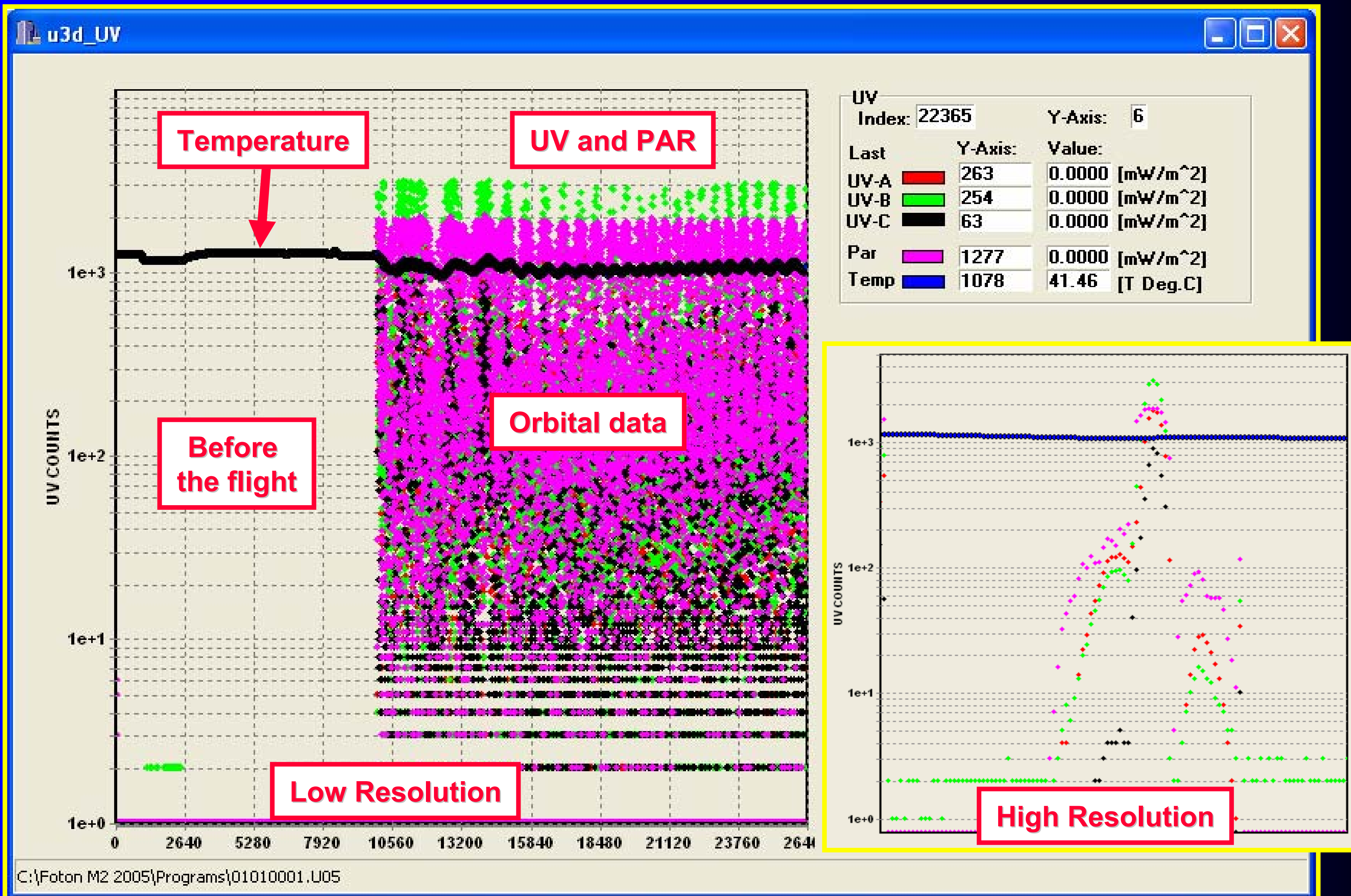
R3D-B2

Biopan 4 after the crash

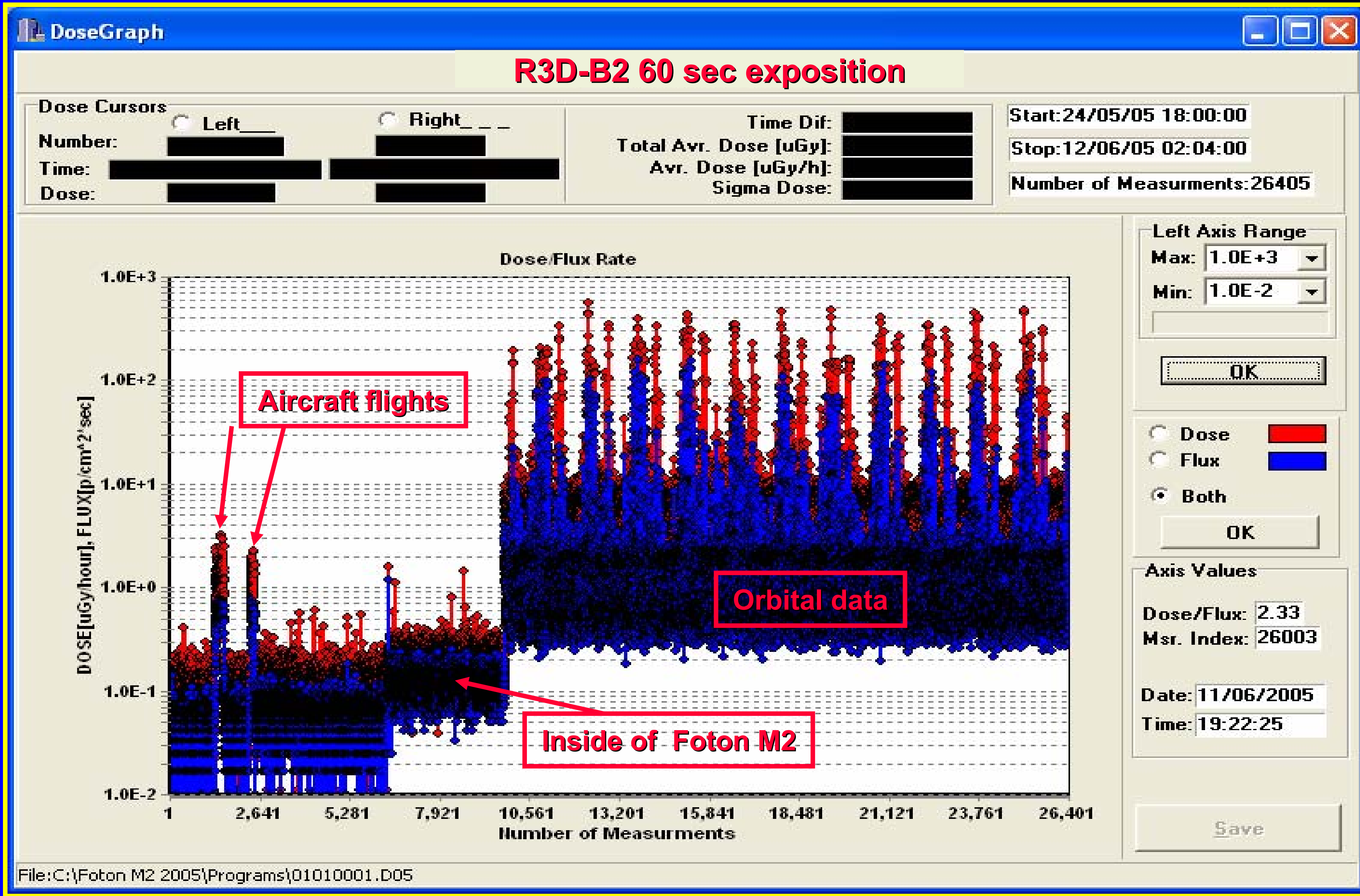
Biopan 3 before the flight

Biopan 3 after the flight

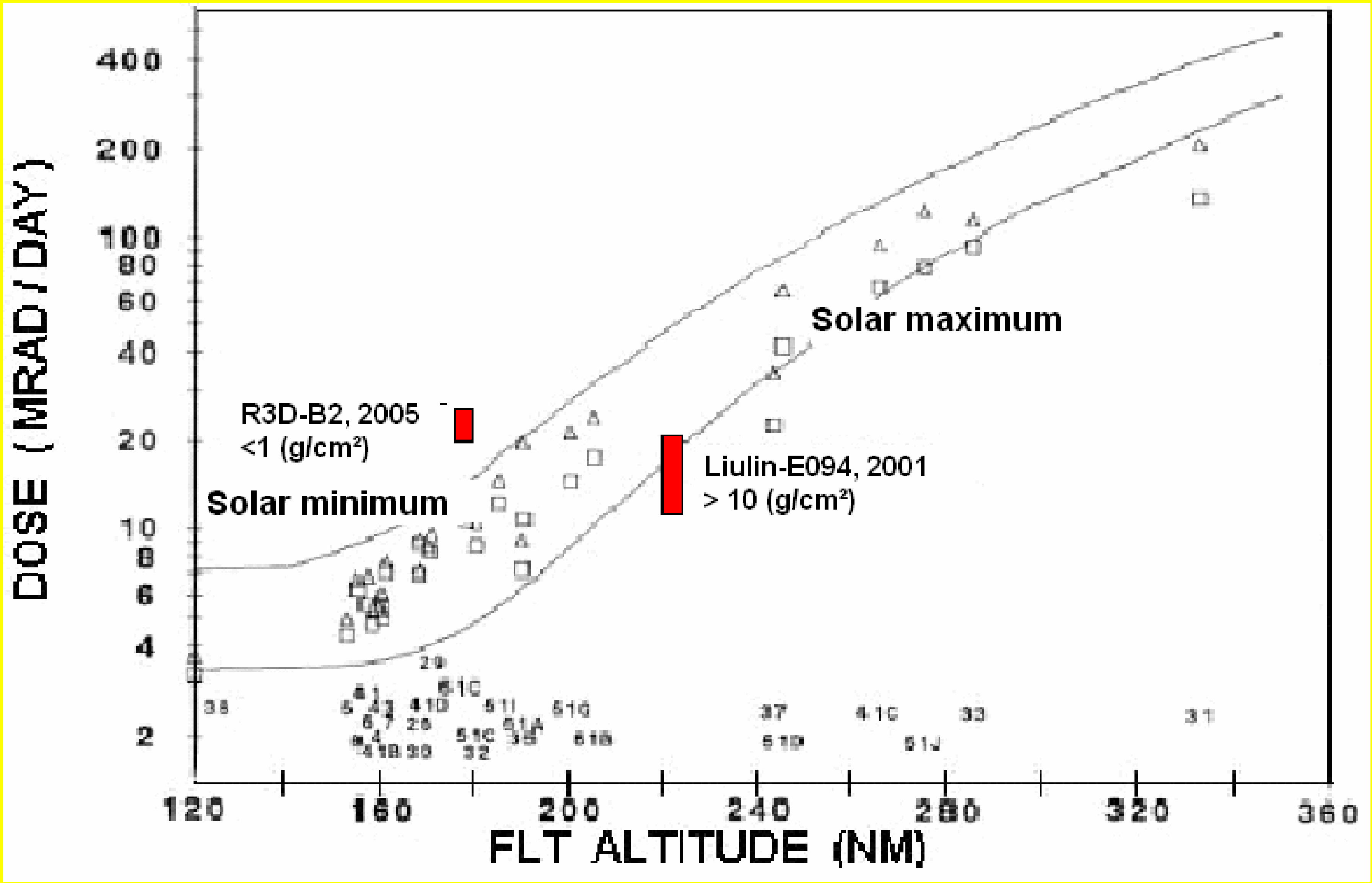
All available UV and temperature data in the flash memory of R3D-B2



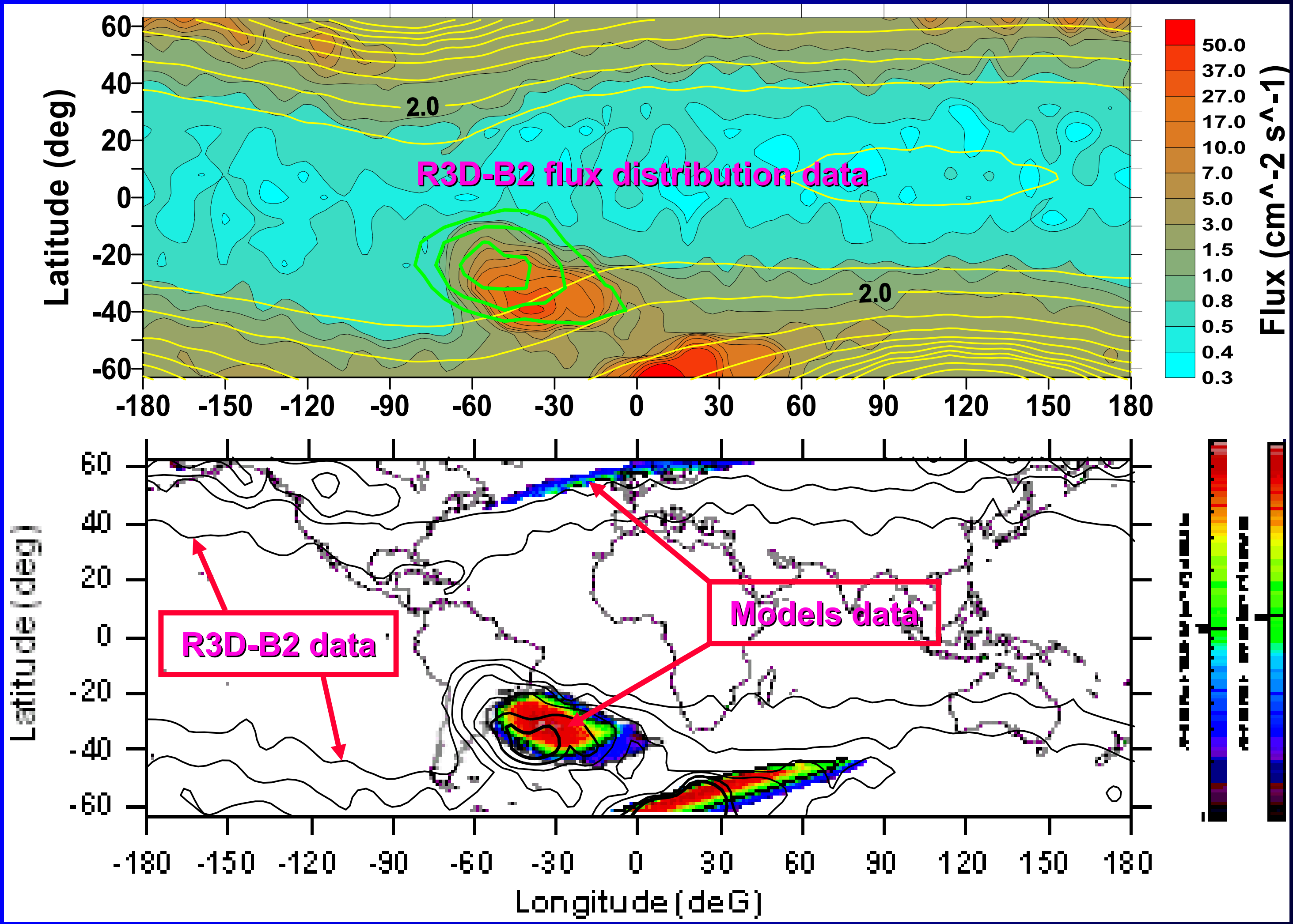
All available ionization radiation (doses and fluxes) data in the flash memory of R3D-B2



Comparison of the R3D-B2 and Liulin-E094 mean daily doses with (Johnson et al, 1993)



Comparison of R3D-B2 global data distribution with AE-8 Min and AP-8 Min models



About 10 degree westward movement of the SAA center R3D-B2 data toward the models is seen, because of the century drift of the magnetic poles (Models are based on 1960-1970 data)

3 more experiments are under development

Liulin-R instrument for ESA-Norwegian rocket Launch in February 2007

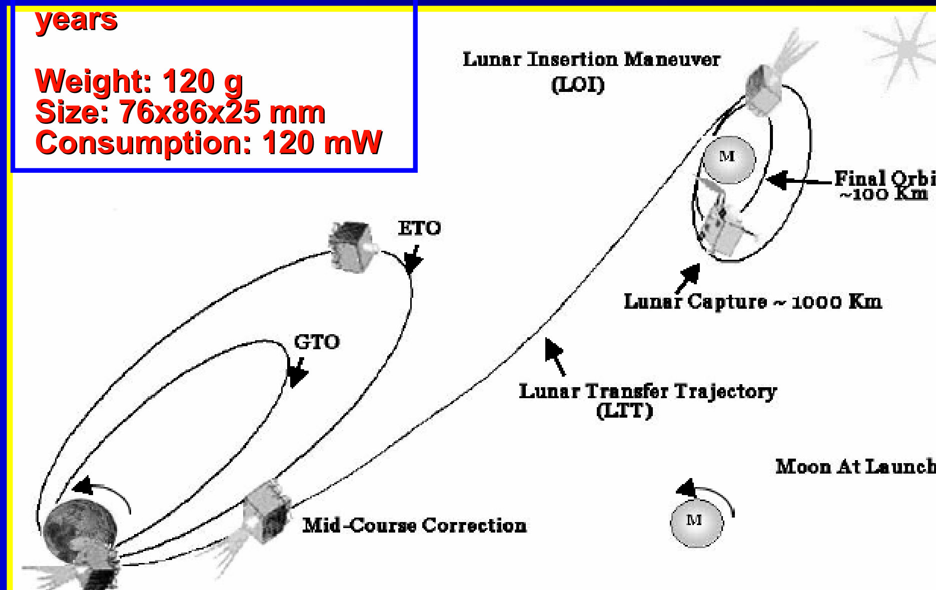
Rocket launch up to 280 km from Andoya, Norway (69.3° N)

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

RADOM instrument for Indian Chandrayaan-1 satellite
2007/2008

Satellite at 100 km over the Moon surface for 2 years

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



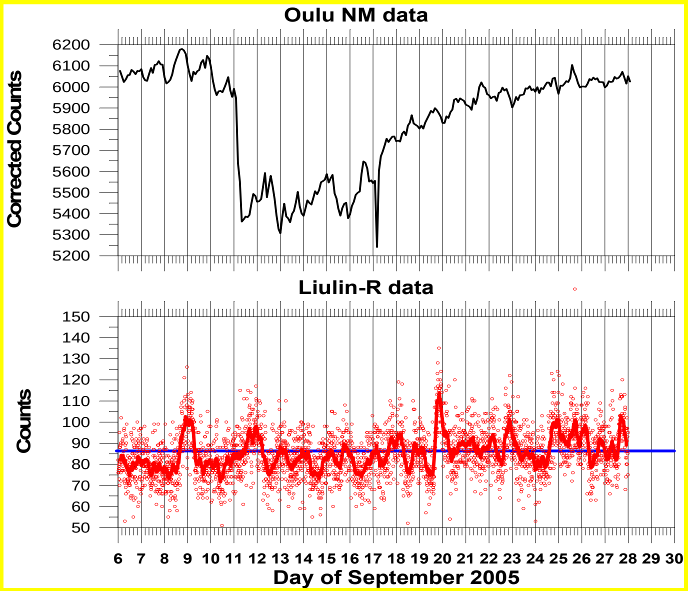
Liulin-F instrument for Russian Phobos-Ground satellite
2009/2011

Satellite at 100 km over the Phobos surface for 2 years

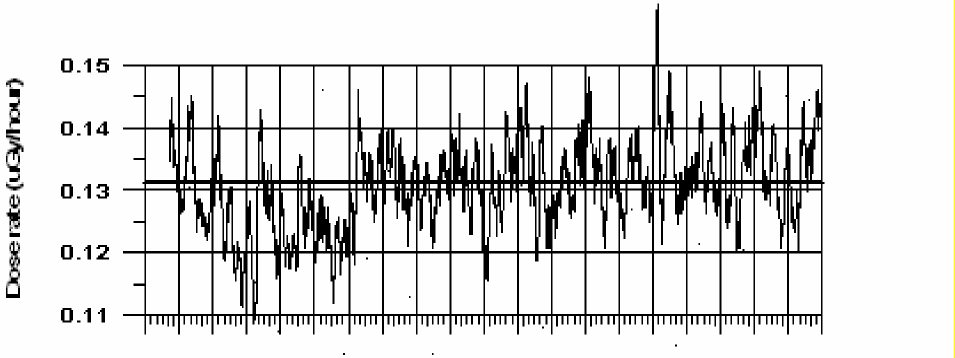
Weight: 400 g
Size: 100x100x50 mm
Consumption: 520 mW

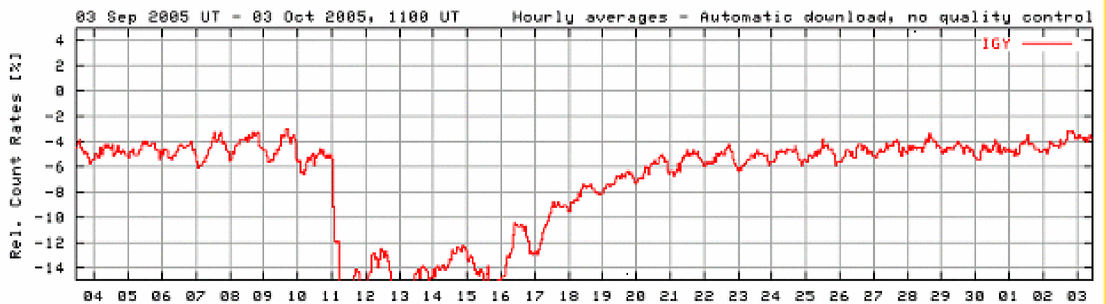
Results from aircraft and groundbased Liulin type spectrometers

Comparison of Liulin-R and Liulin-6I data with Neutron monitors data during the Forbush decrease in September 2005

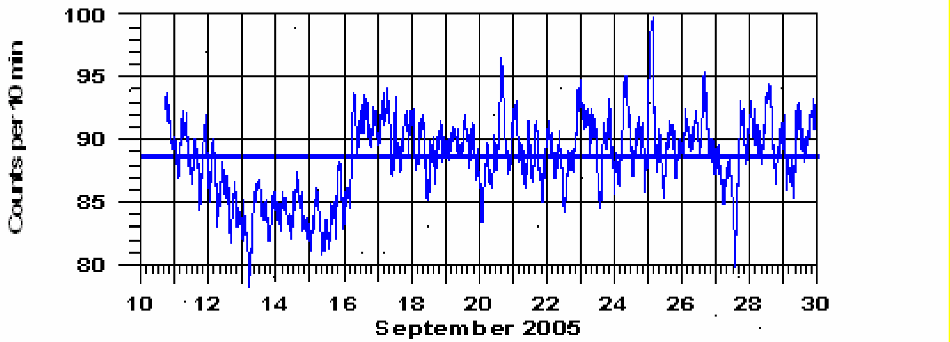


ALOMAR observatory (http://128.39.135.6)





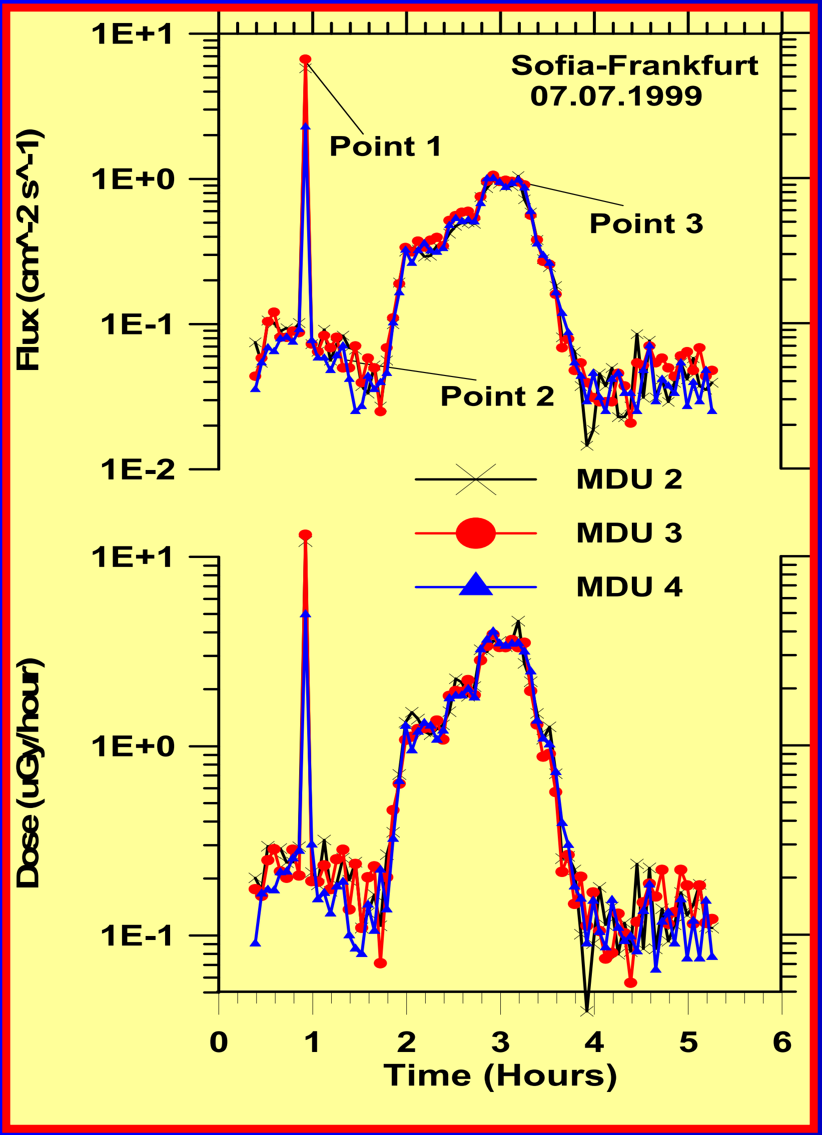
(Jungfraujoch data are obtained by Prof. E. Flueckiger, Switzerland)

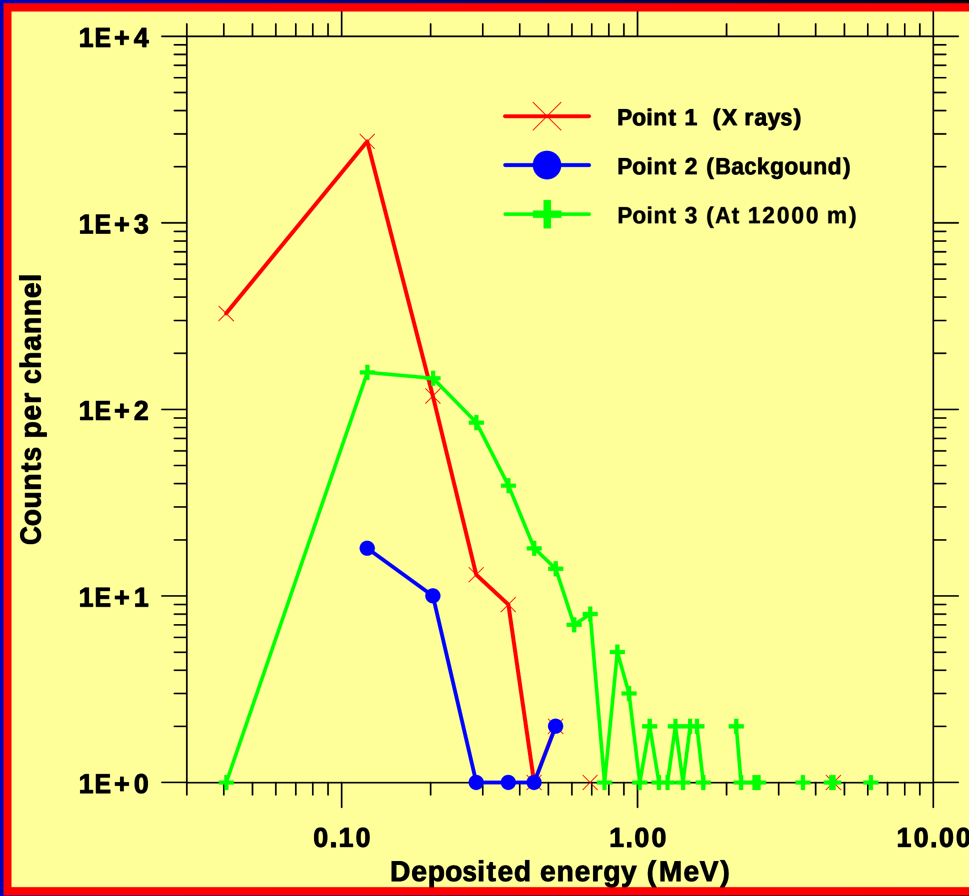


Jungfraujoch (http://130.92.231.184/)

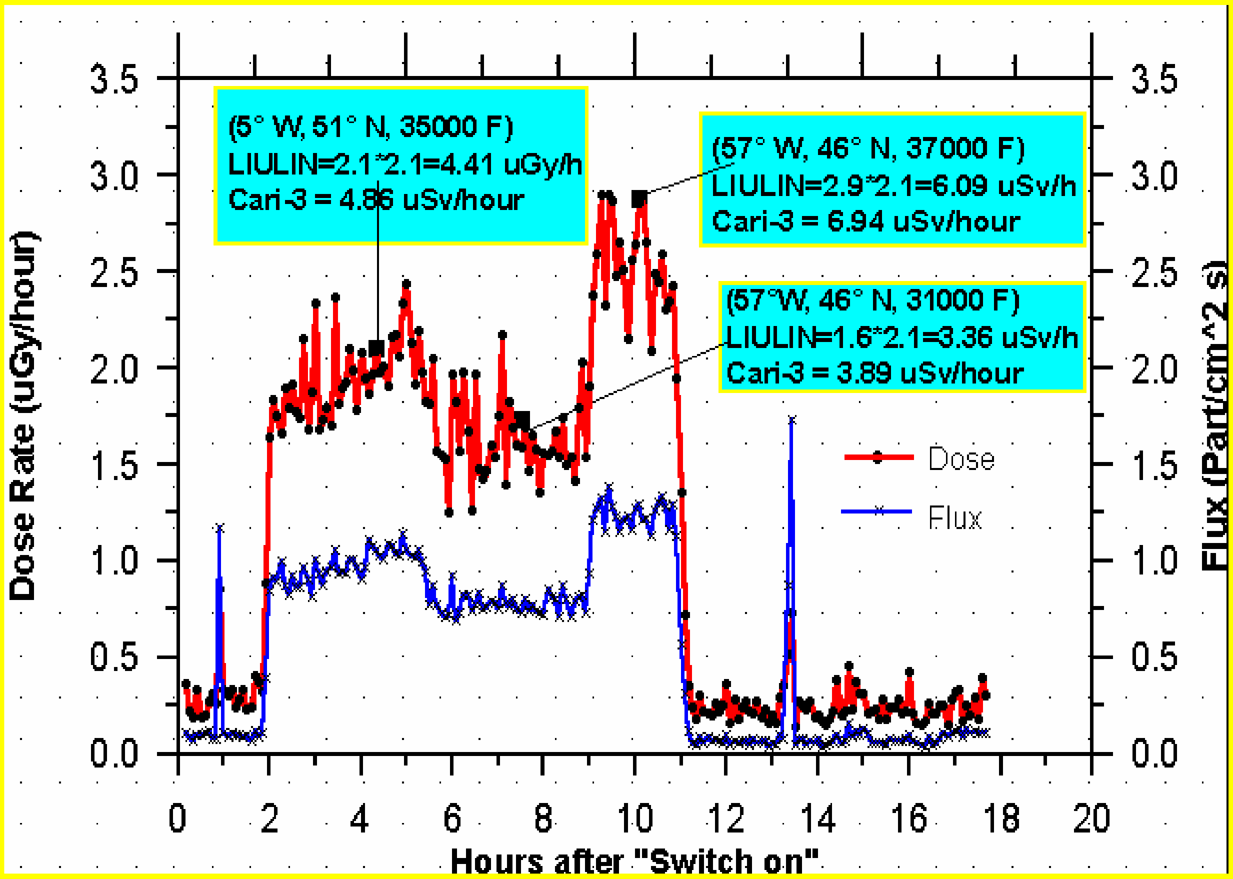
Short term and unique In-flight results

Flight time dose and flux dynamics



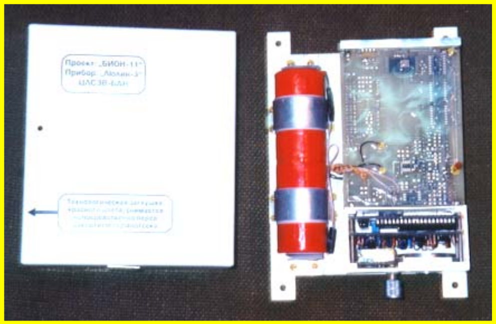


First aircraft results*



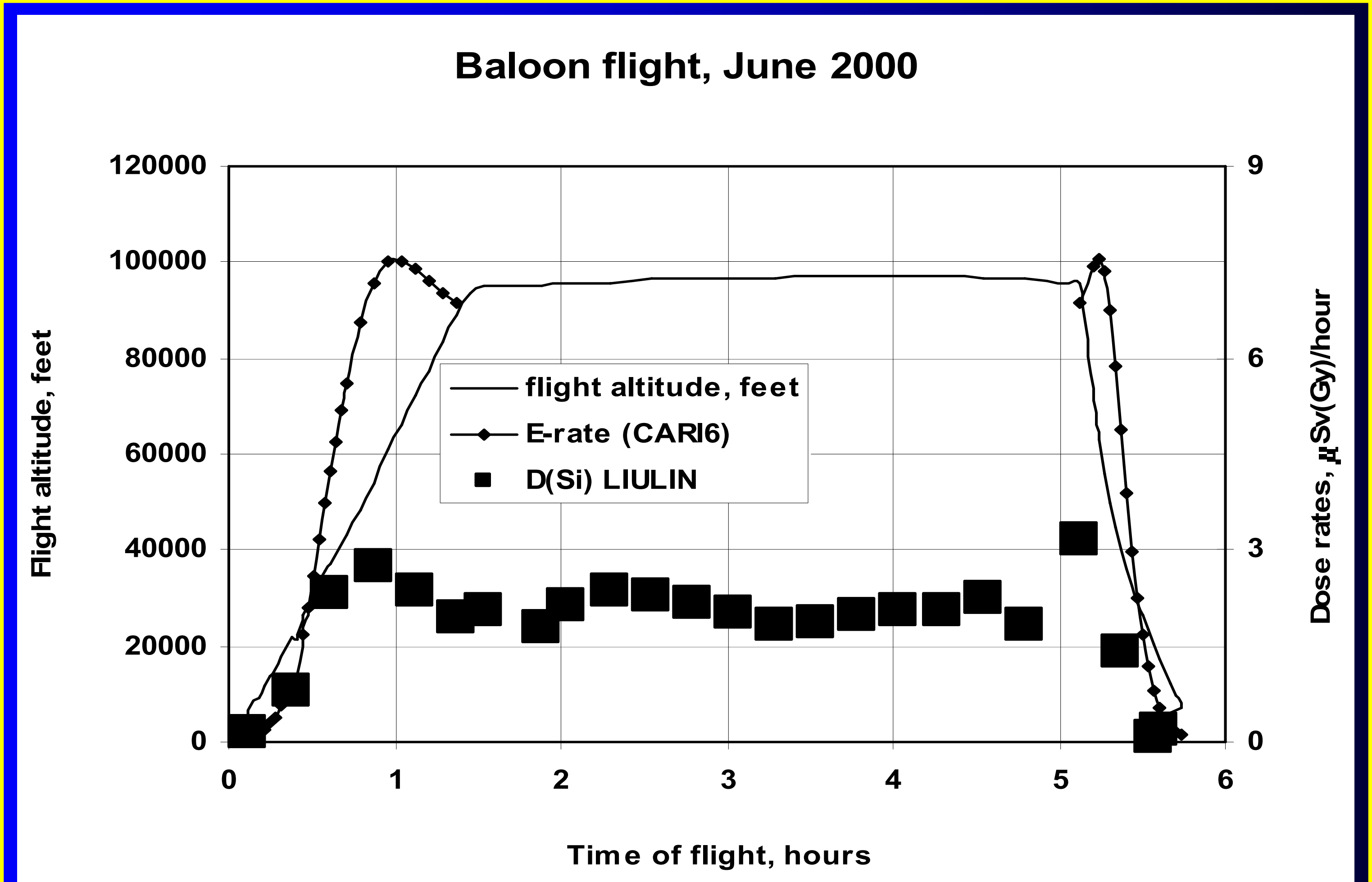
Sofia-NY flight data by Liulin-3M, June 16, 1997

Liulin-3M, prepared for GSFC-NASA, 1997
Flown on Antarctida balloon



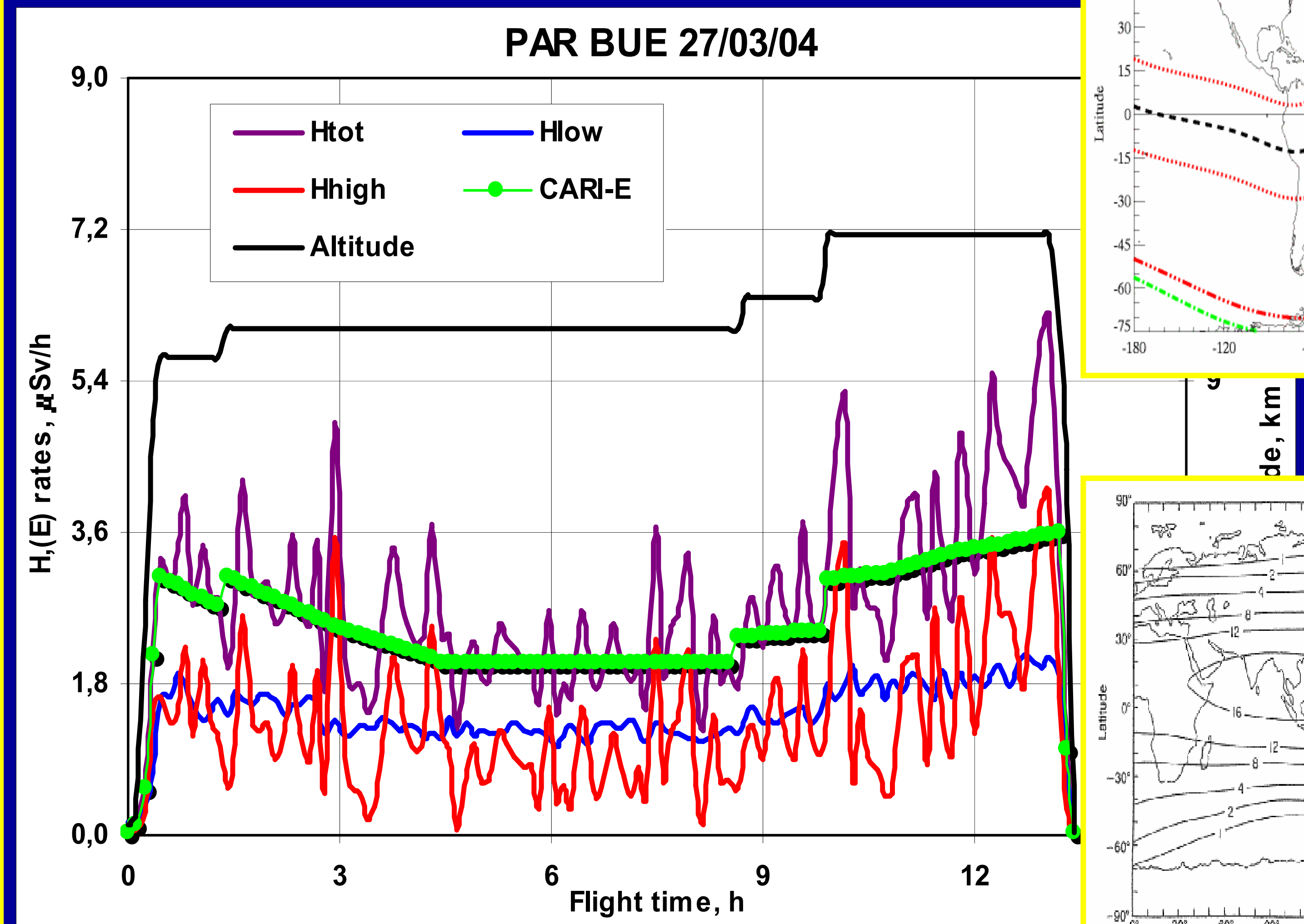
Dachev, Ts.P., E.G. Stassinopoulos, B.T. Tomov, Pl.G. Dimitrov, Yu.N. Matviichuk, V.A. Shurshakov, V.M. Petrov, Analysis Of The Cyclotron Facility Calibration And Aircraft Results Obtained By LIULIN-3M Instrument, Adv. Space Res., vol. 32, No 1, pp. 67-71, 2003.

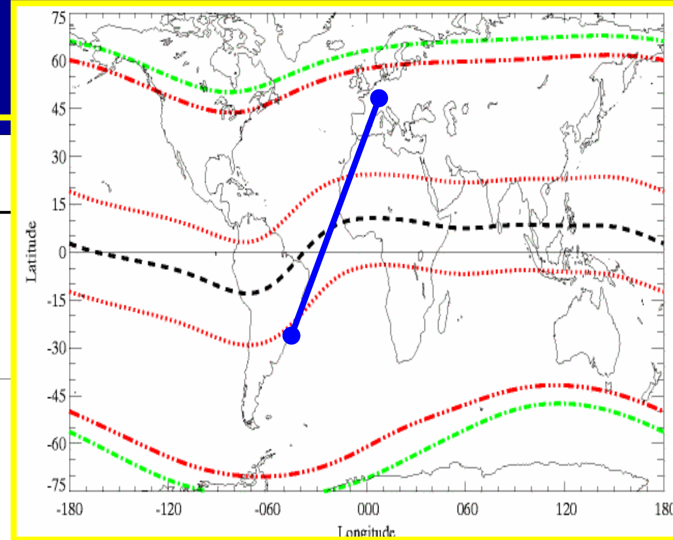
Balloon results obtained on 14th June 2000. Balloon was launched from Gap (France). *

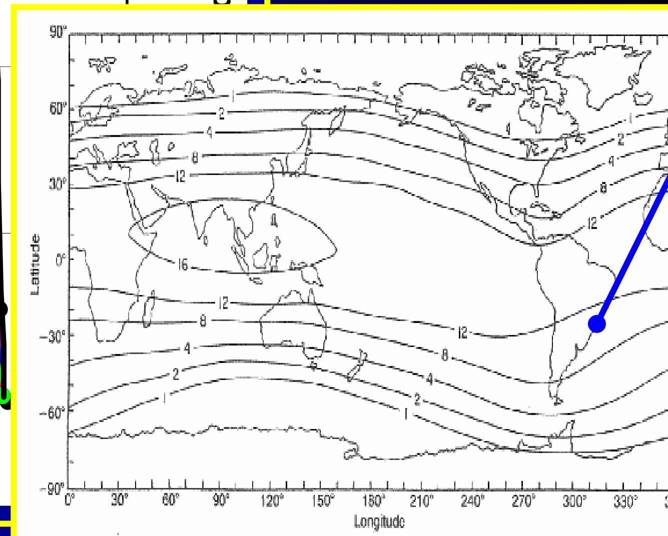


*F. Spurny, Ts. Dachev, B. Tomov, Yu. Matviichuk, Pl. Dimitrov, K. Fujitaka, Y. Uchihori, H. Kitamura, Dosimetry Measurements During a Balloon and Aircraft Flights Proceedings of 7th STIL-BAS conference, 169-173, Sofia, November, 2000.

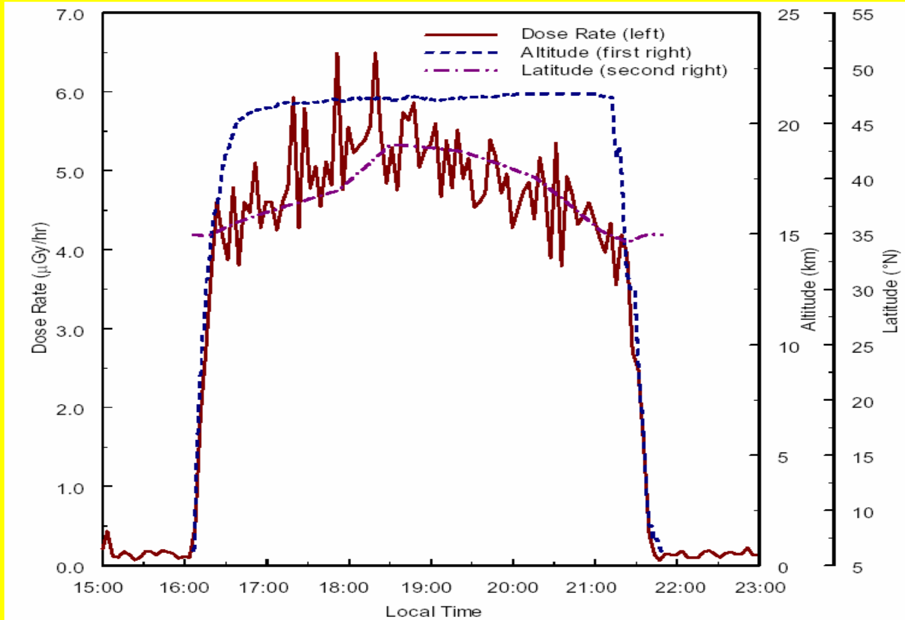
Flight over the magnetic equator - Paris-Buenos-Aires

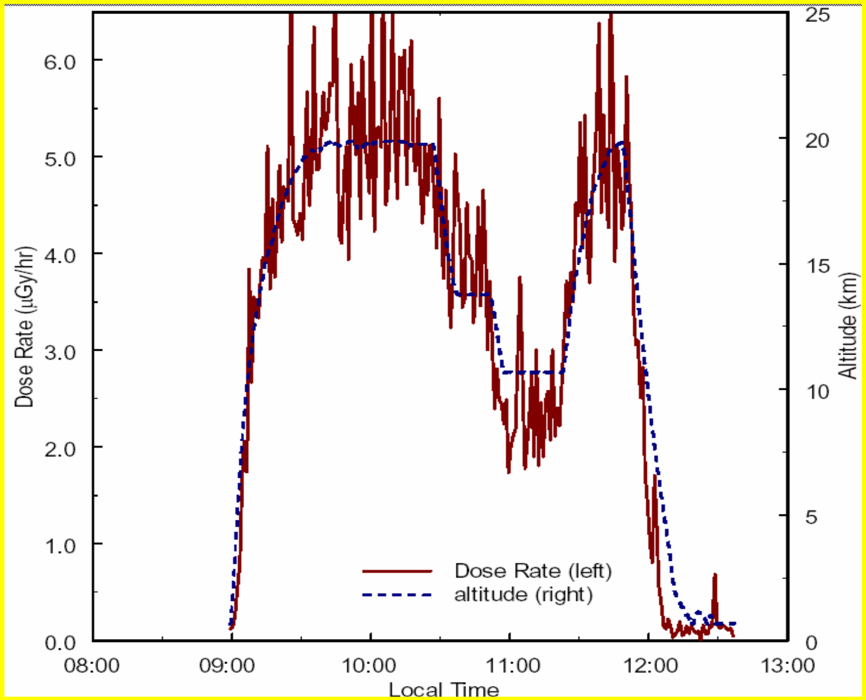


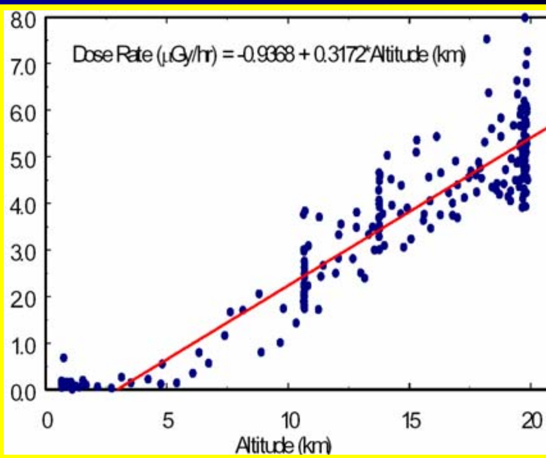




Results from NASA ER-2 high altitude aircraft flights obtained by Uchihori et all*

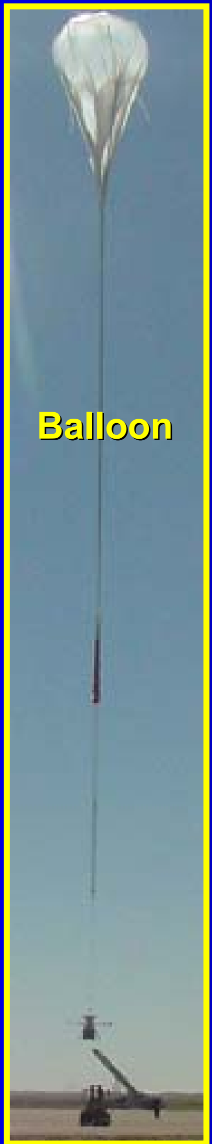


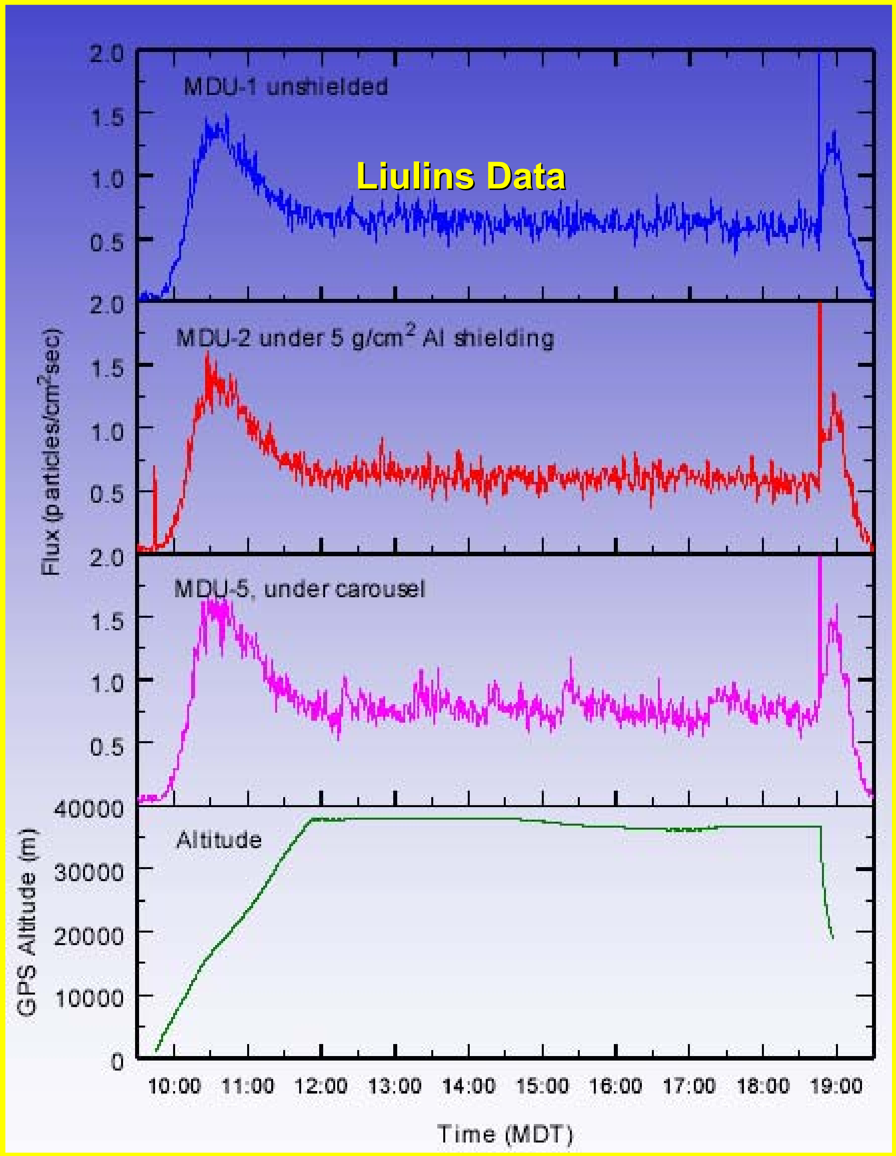




*Uchihori Y, Benton E, Moeller J, Bendrick G., Radiation measurements aboard NASA ER-2 high altitude aircraft with the Liulin-4J portable spectrometer, Adv Space Res., 32(1), 41-6. 2003.

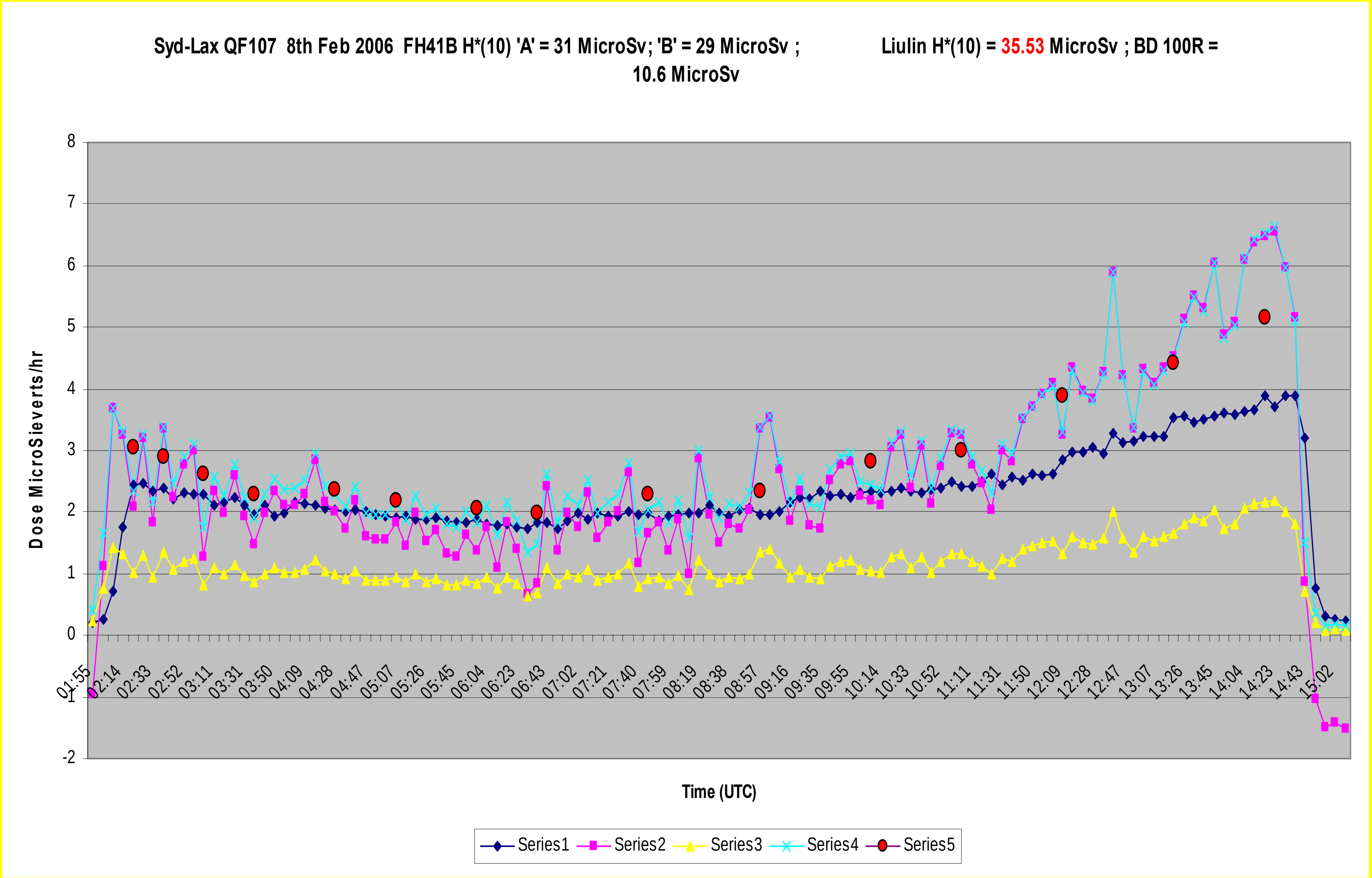
NASA Deep Space Test Bed (DSTB) balloon certification flight on June 11 2005, New Mexico, USA



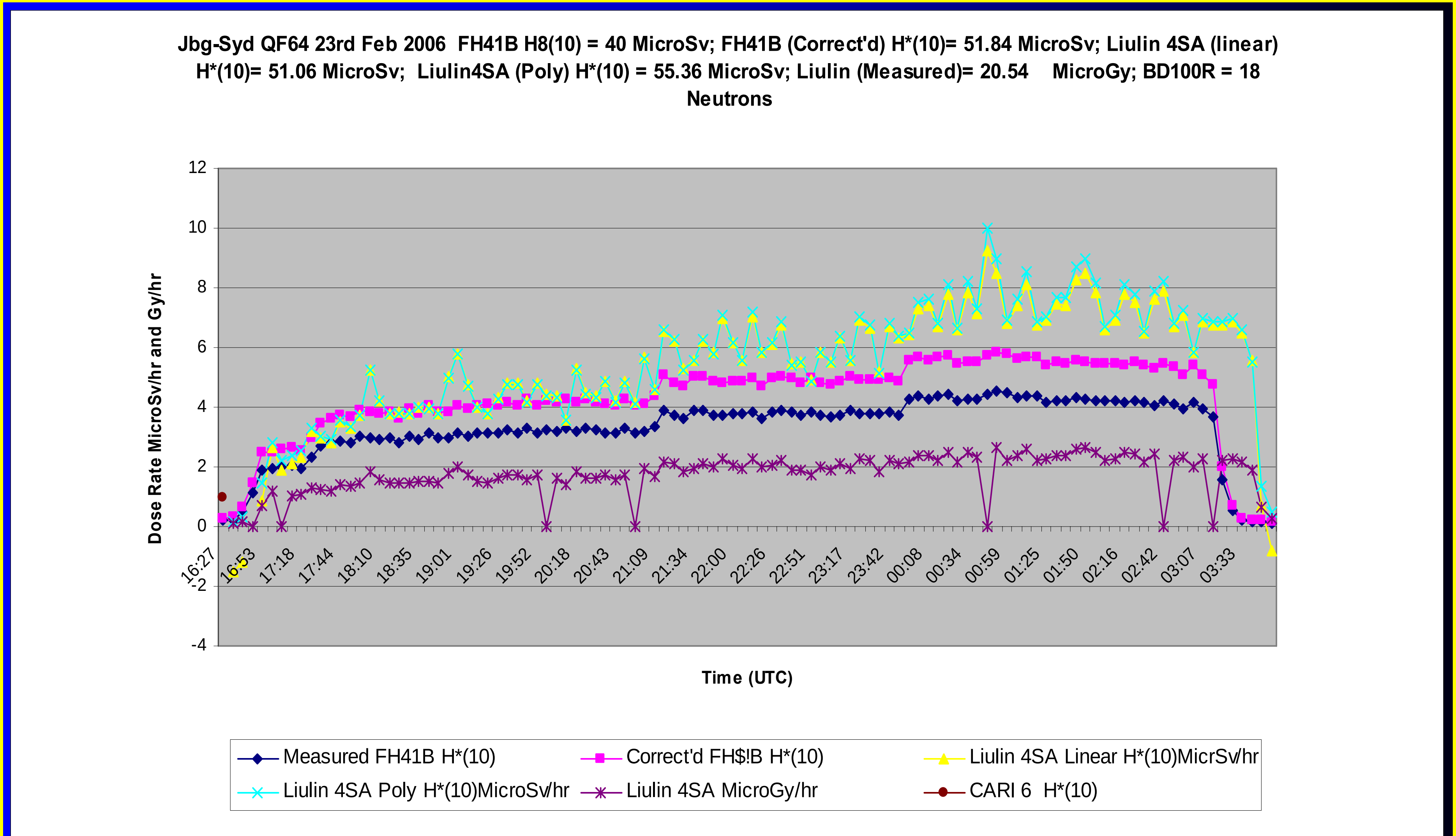


(Liulin data were obtained by Dr. E. Benton, USA and presented at 10th WRMISS meeting, Chiba, Japan, September 2005.)

Last results 1: Sydney-Los Angelis
February 8 2006

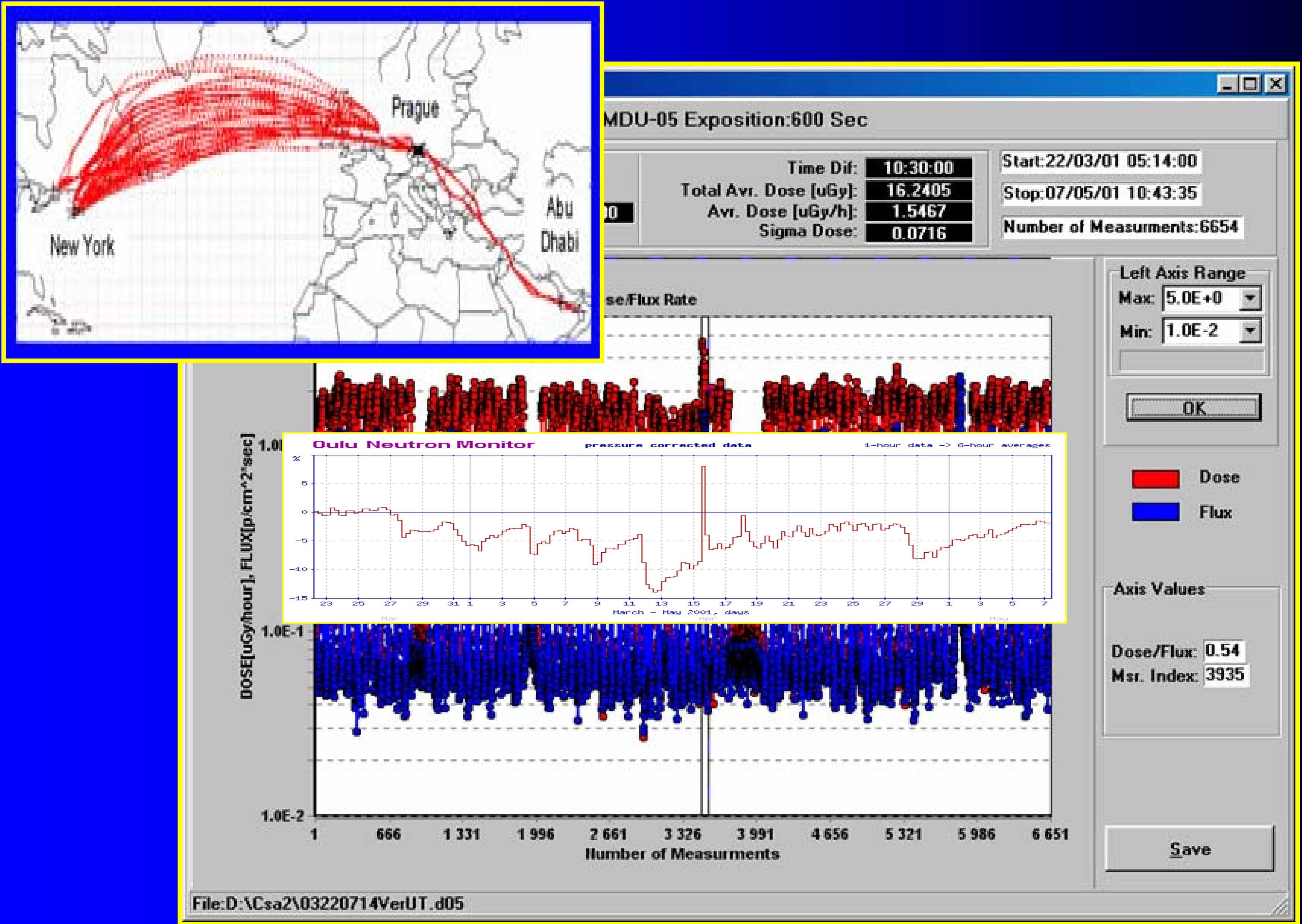


Last results 2: Johannesburg-Sydney February 23 2006

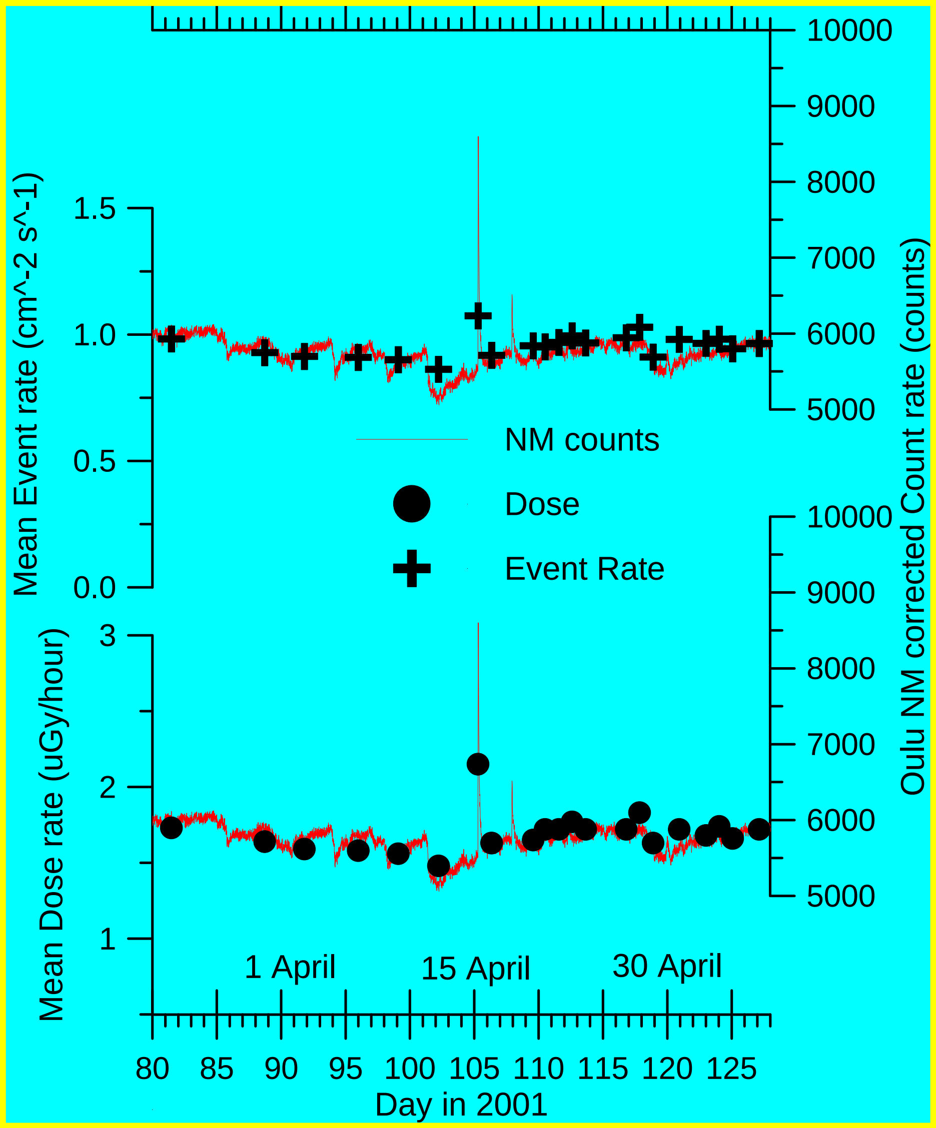


Long term flights on CSA airline Boeing A310-300 aircraft

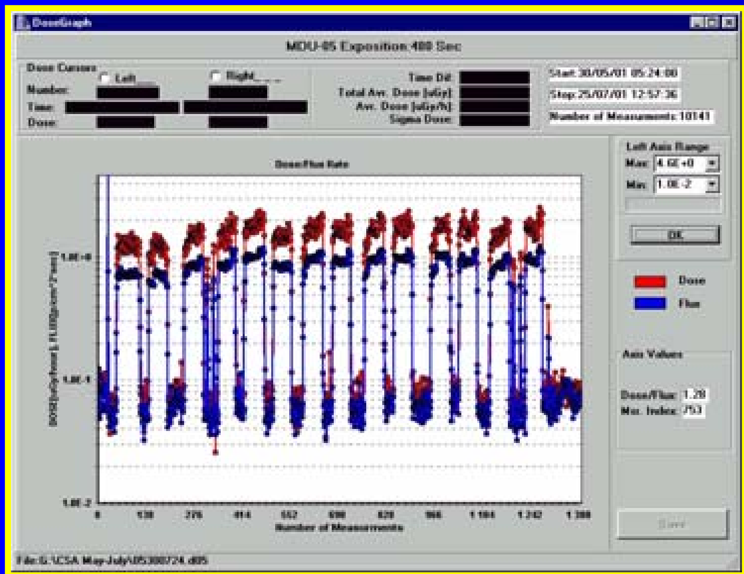
Flight doses and fluxes on CSA aircraft between 22 March and 7 May 2001 compared with Oulu NM data

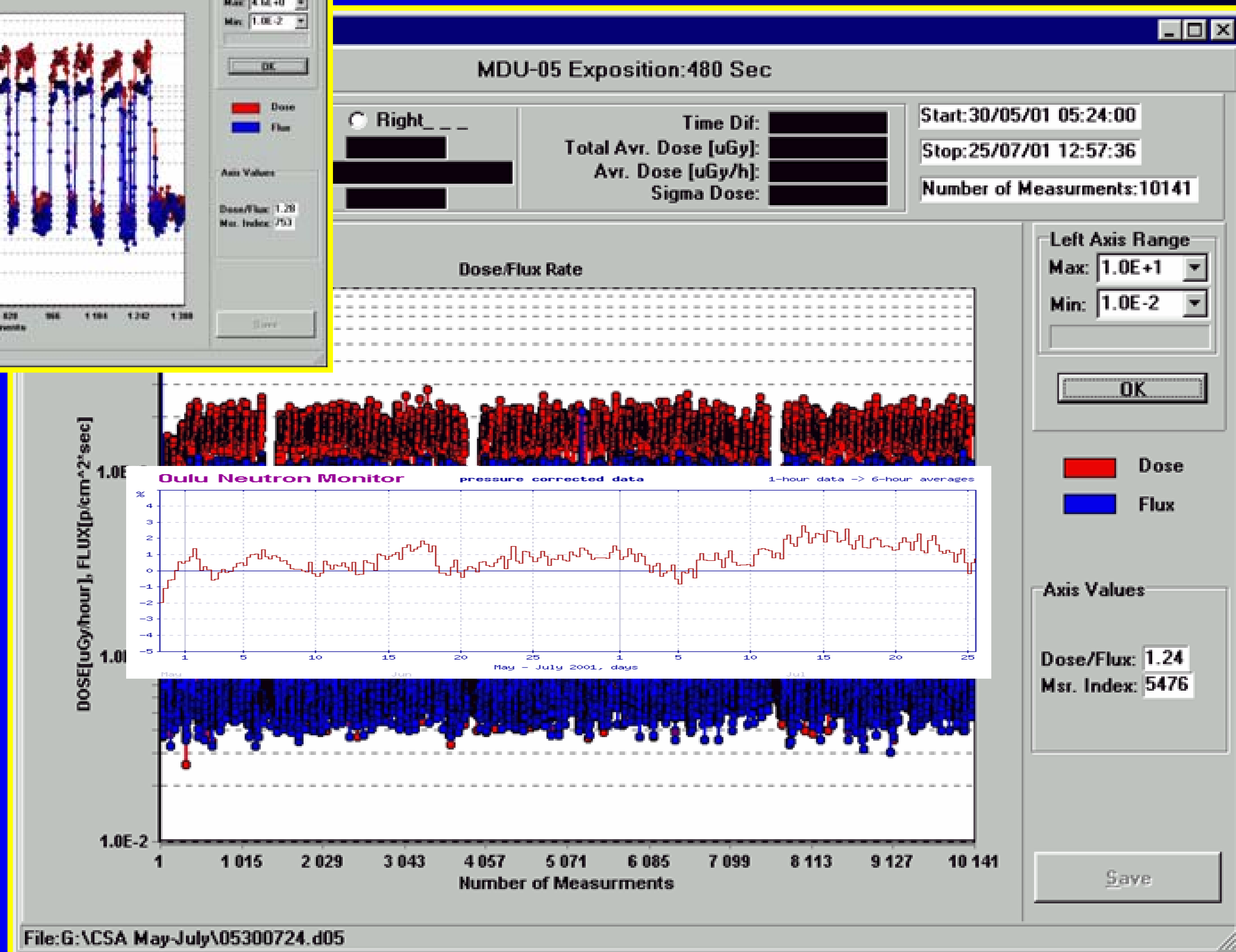


Mean doses and fluxes long term variations including Forbush decreases and GLE#60 as seen by Liulin data on CSA aircraft Prague New-York routes, 22 March – 7 May 2001

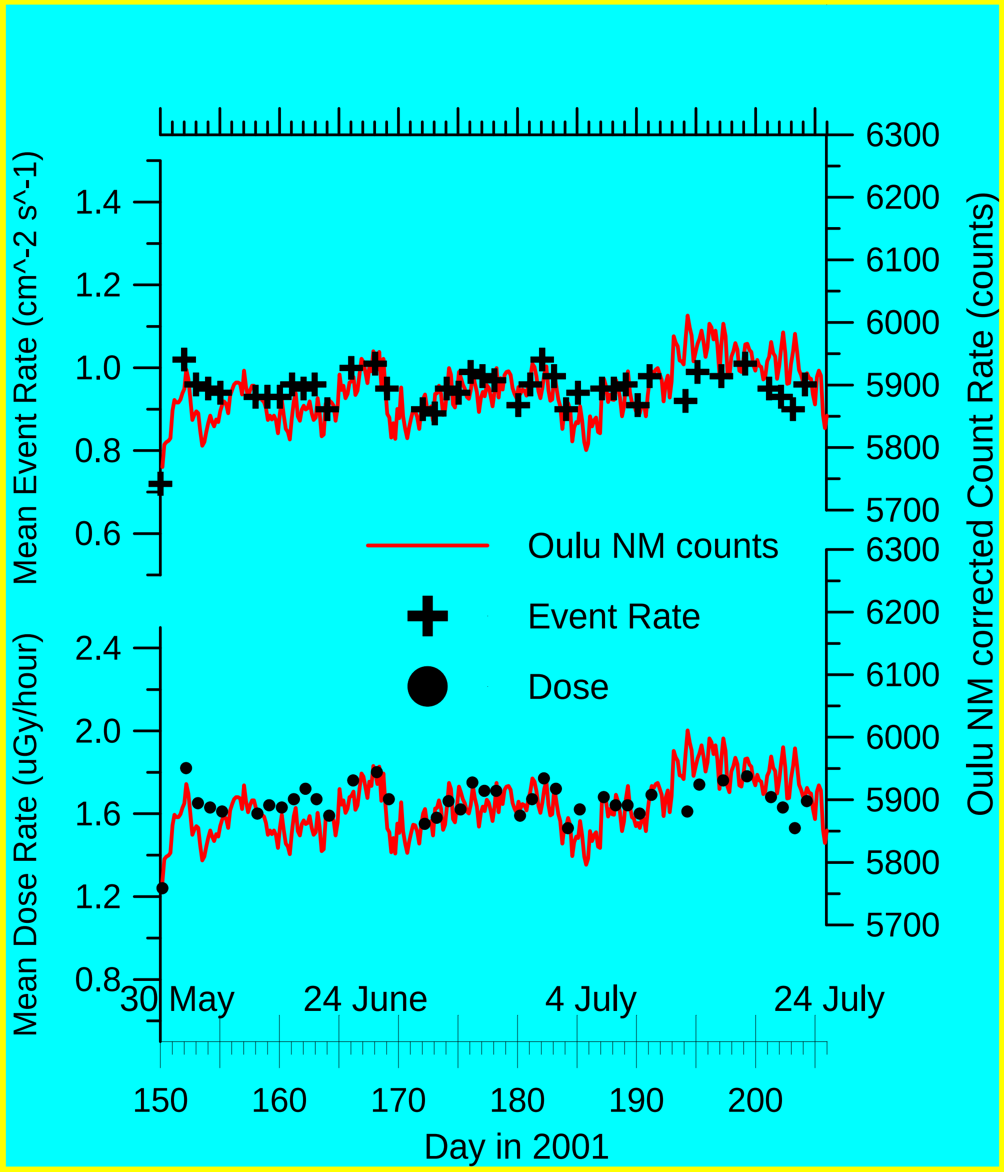


Flight doses and fluxes on CSA aircraft between 30 May and 24 July 2001 compared with Oulu NM data

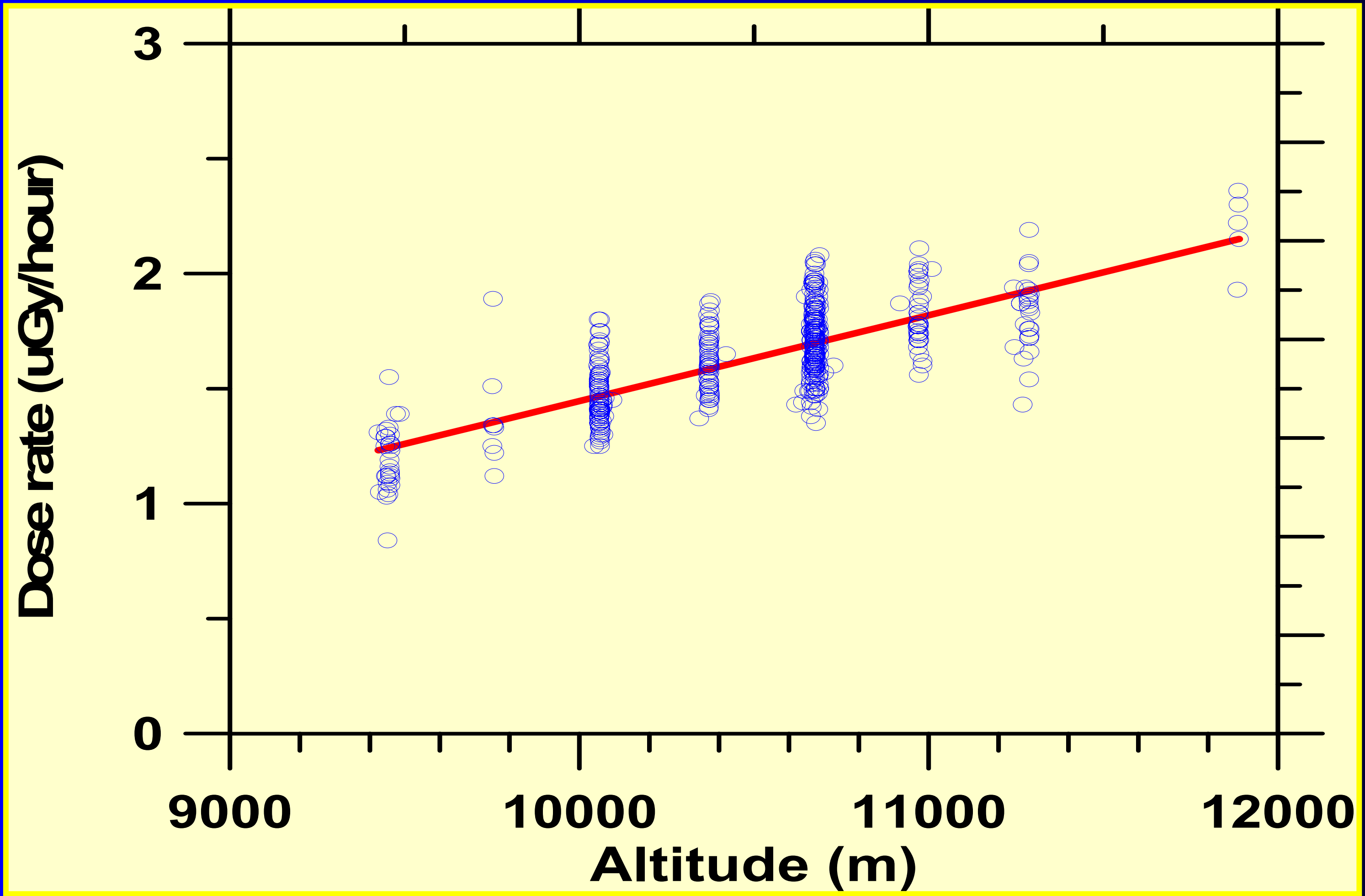




Mean doses and fluxes long term variations including end of 27.05.2001 Forbush decrease as seen by Liulin data on CSA aircraft Prague New-York routes, 30 May – 24 July 2001



Altitudinal dependence by aircraft data



MDU – interpretation procedure

1) Dose in Si is calculated as:

D = K * ∑(Ei x Ai)/MD, where

MD – mass of the detector;

Ei – energy loss in the channel i;

Ai – events number in the channel i;

K – coefficient

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

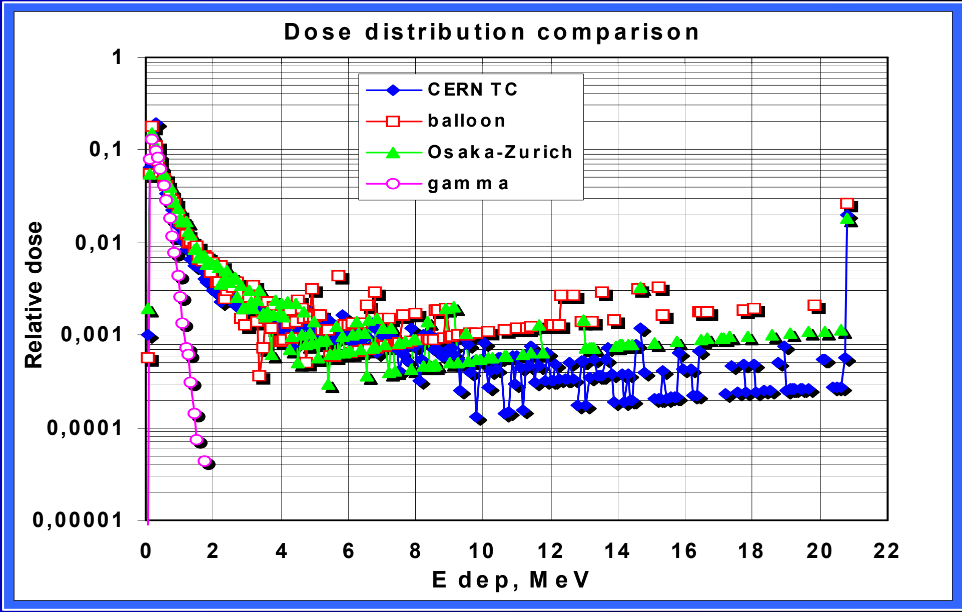
D(Si) above ~ 1 MeV (Dhigh) - neutron component

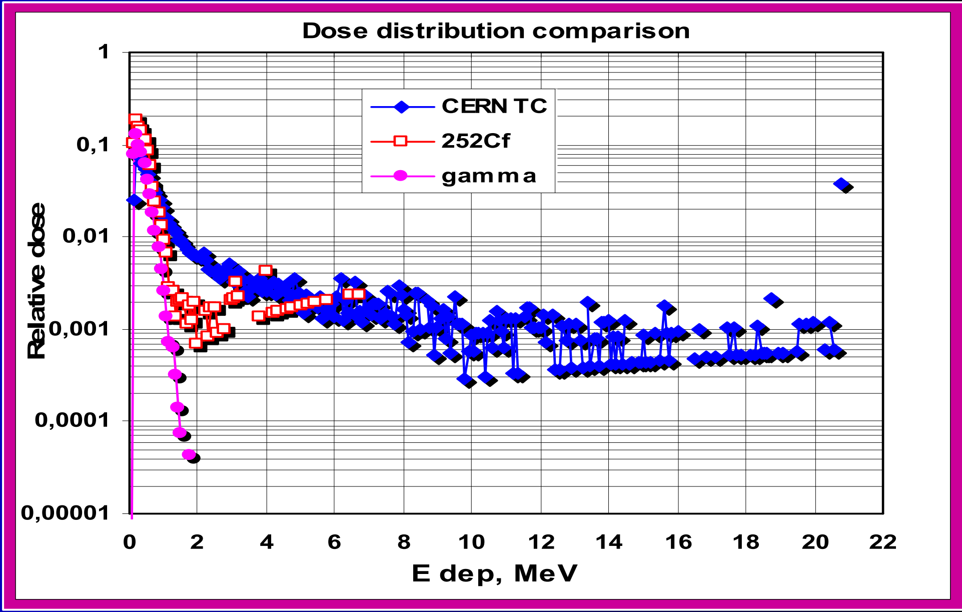
D(Si) below ~ 1 MeV - (Dlow) non-neutron component

Dlow and Dhigh – multiplied by a coefficient to get H*(10)high

Coefficients – established in CERN Reference fields and/or on the base of comparison with TEPC results

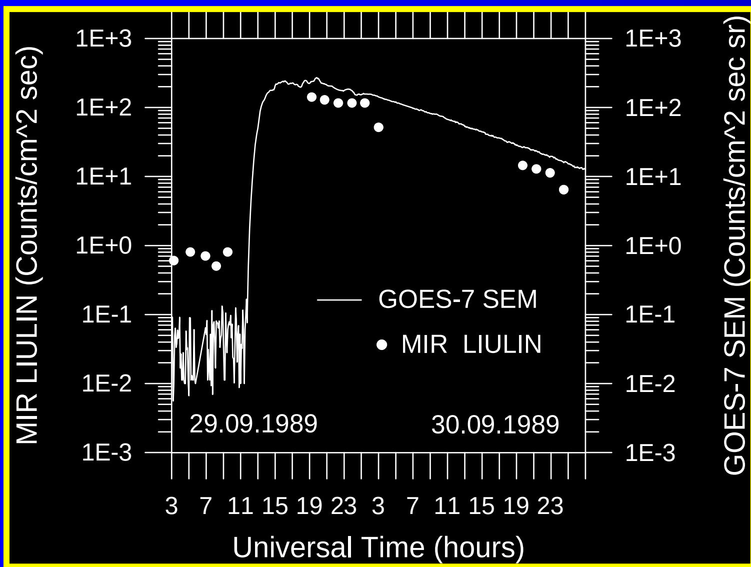
*Procedure is developed by Prof. F. Spurny on the base of results from 5 CERN calibration sessions

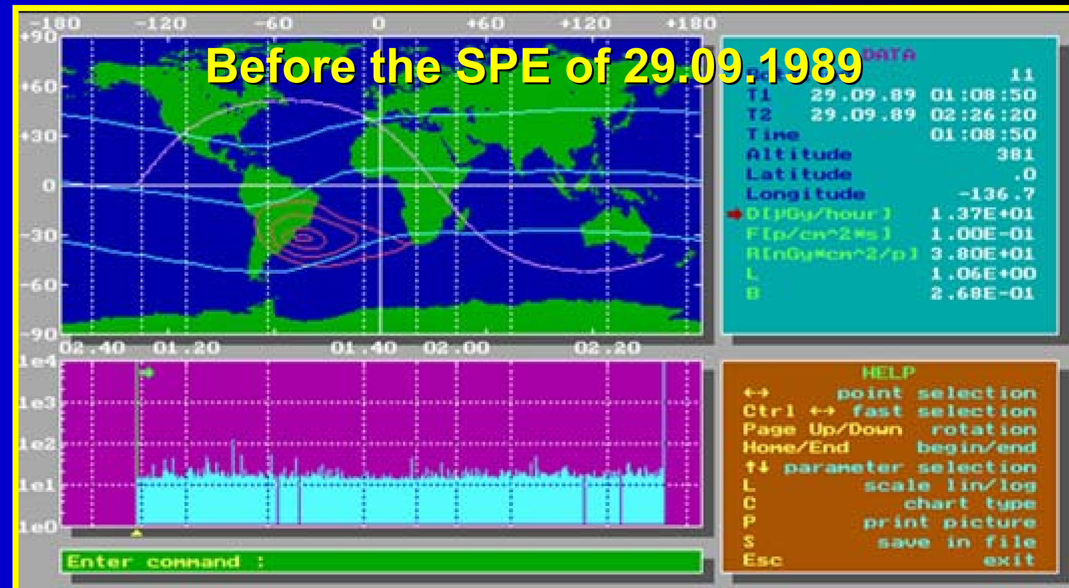


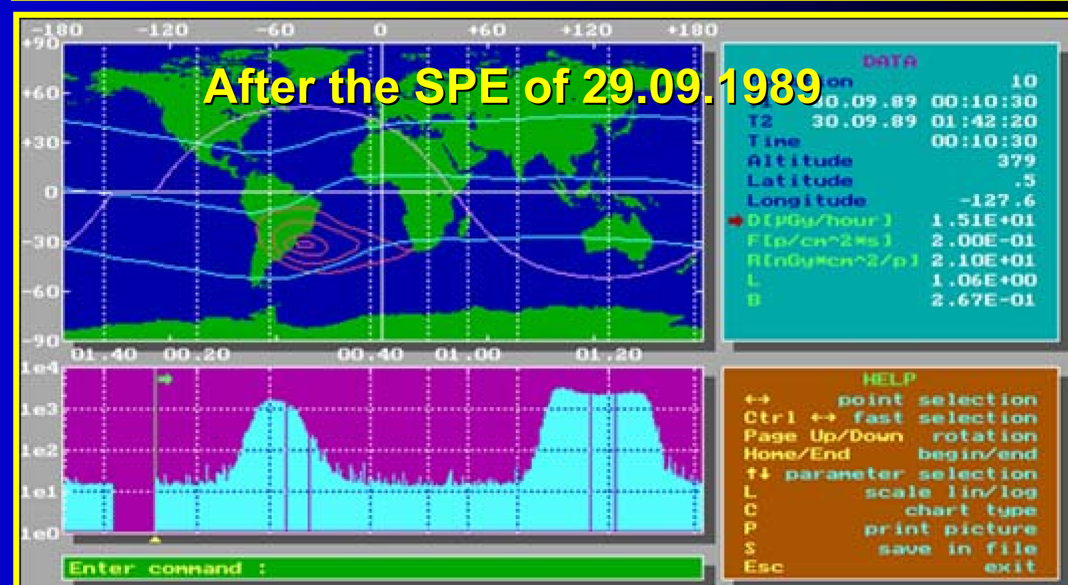


Ground-level event (GLE60) on 15.04.2001 in-flight results

Solar Proton Event observation by Liulin on Mir



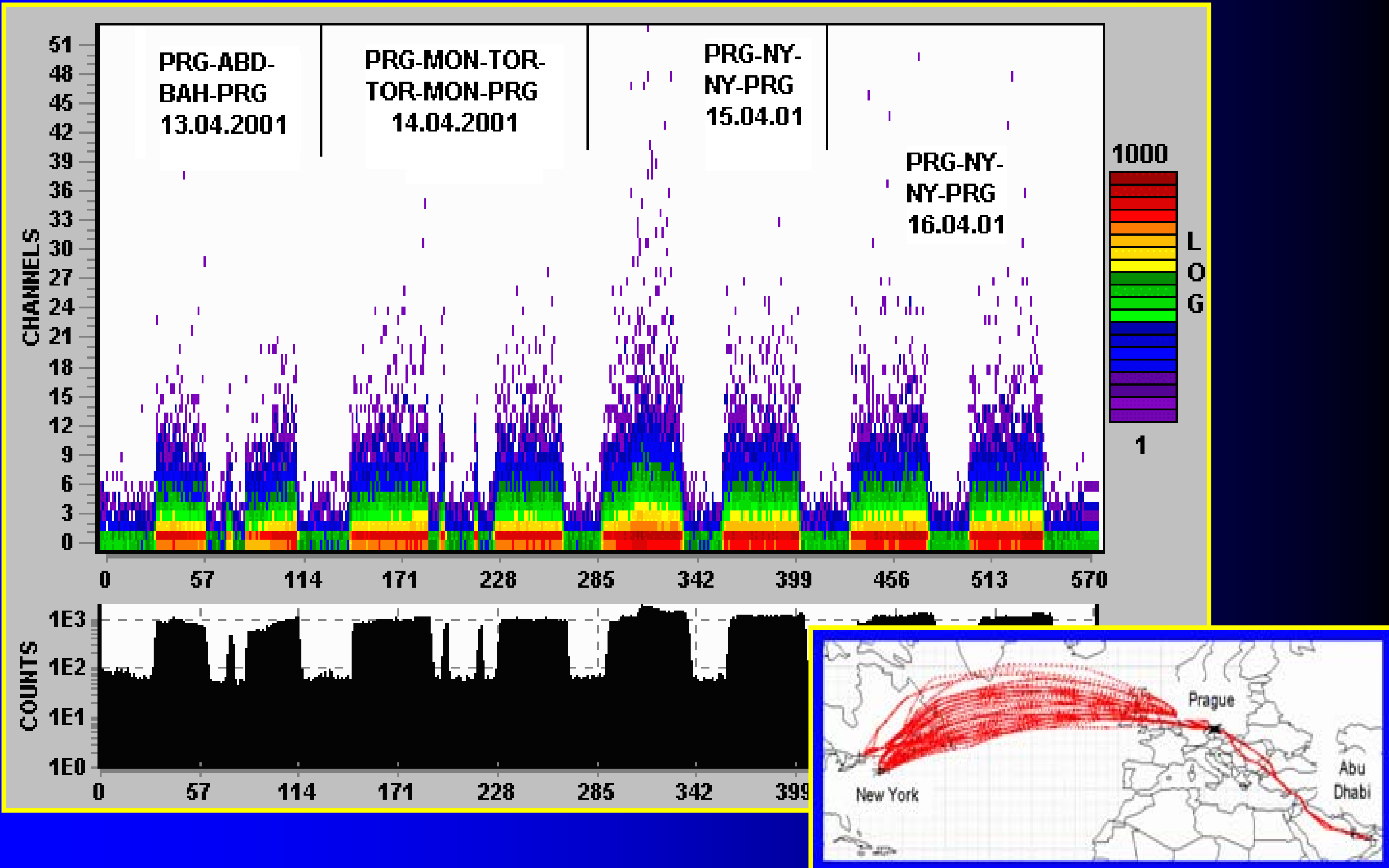




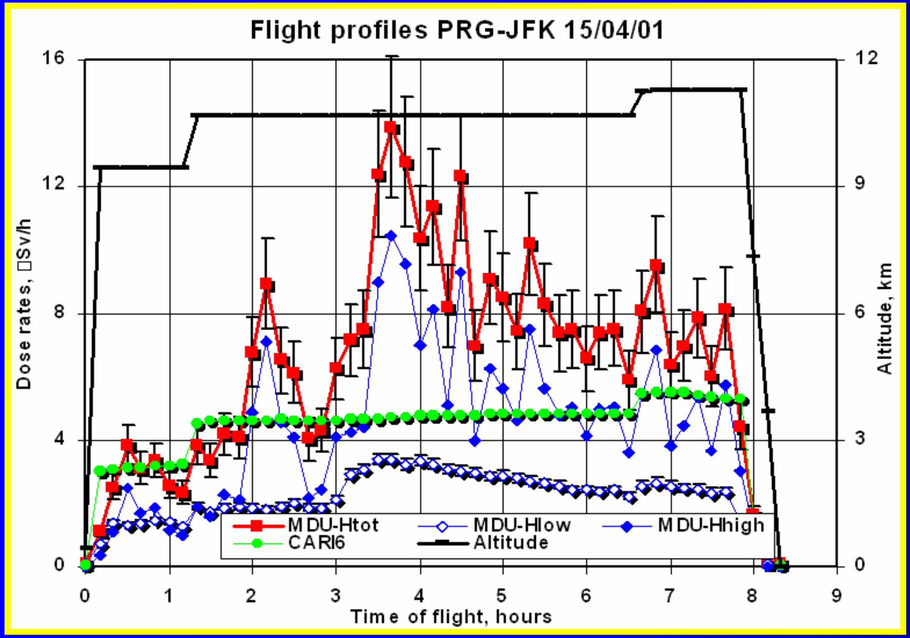
Flux Max = 250 p/cm^2 s

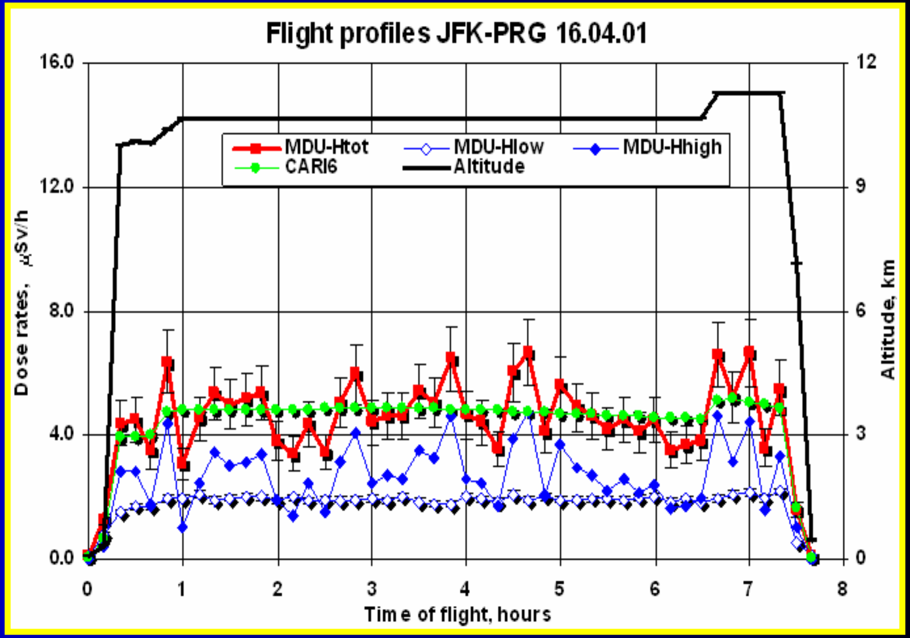
Dose max = 3000 mGy/h

Flight data dynamics close to the Ground level event number 60 on 15.04.2001

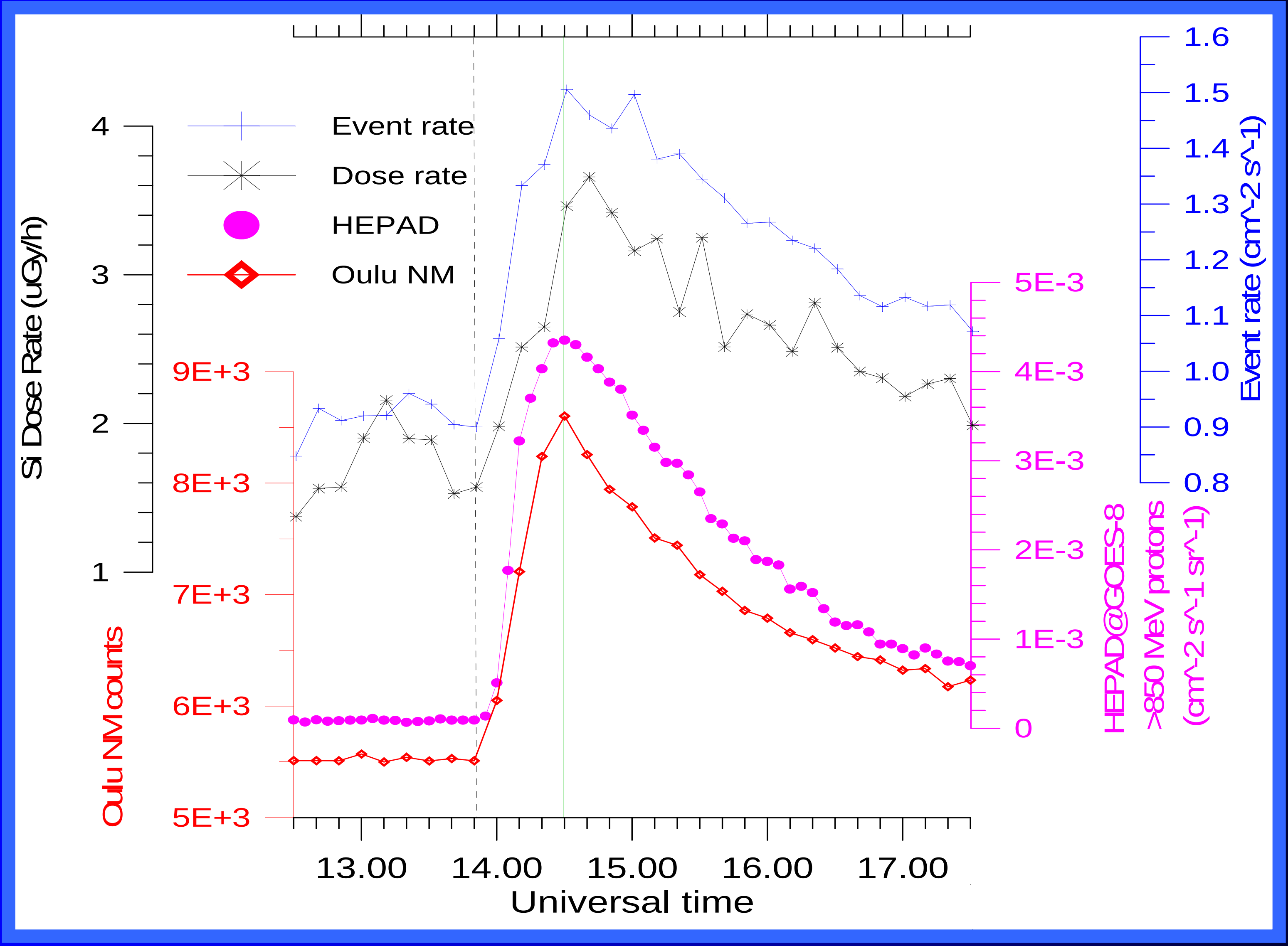


Flight profiles during and after GLE



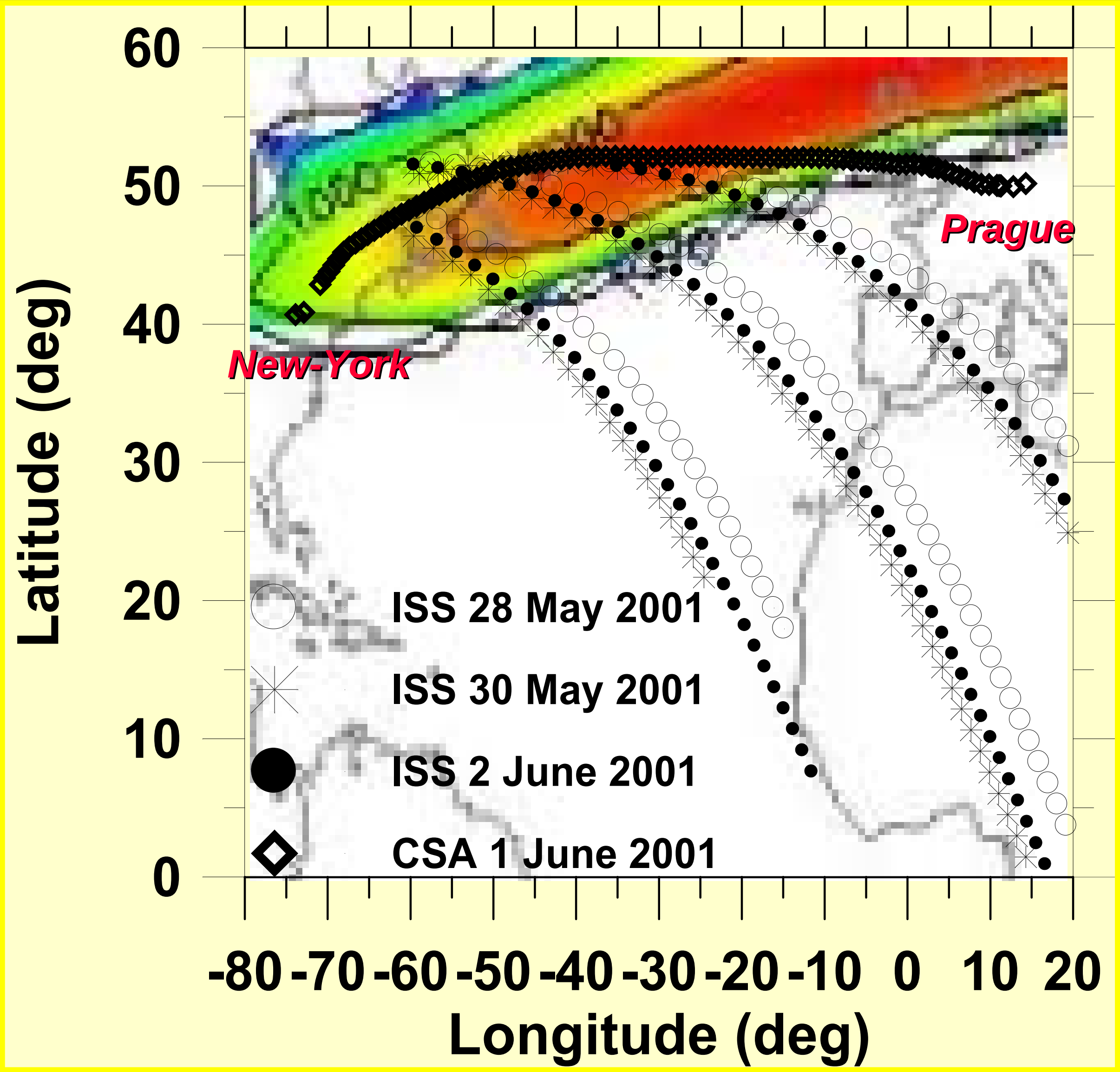


Comparisons of the Liulin data with Oulu NM and HEPAD (GOES-8) protons close to Ground level event number 60 on 15.04.2001

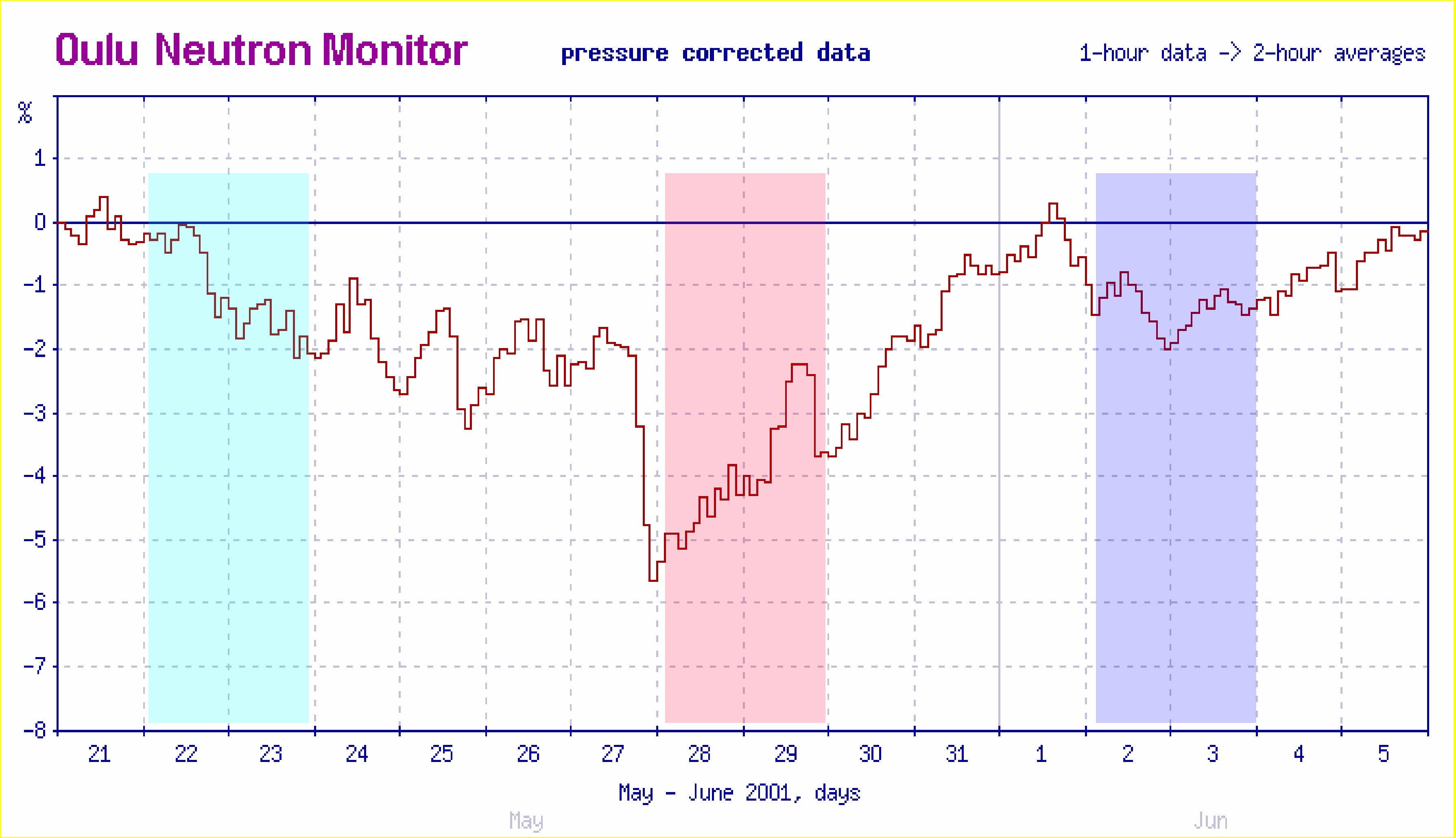


Comparison of data from aircrafts and ISS & Forbush decrease study

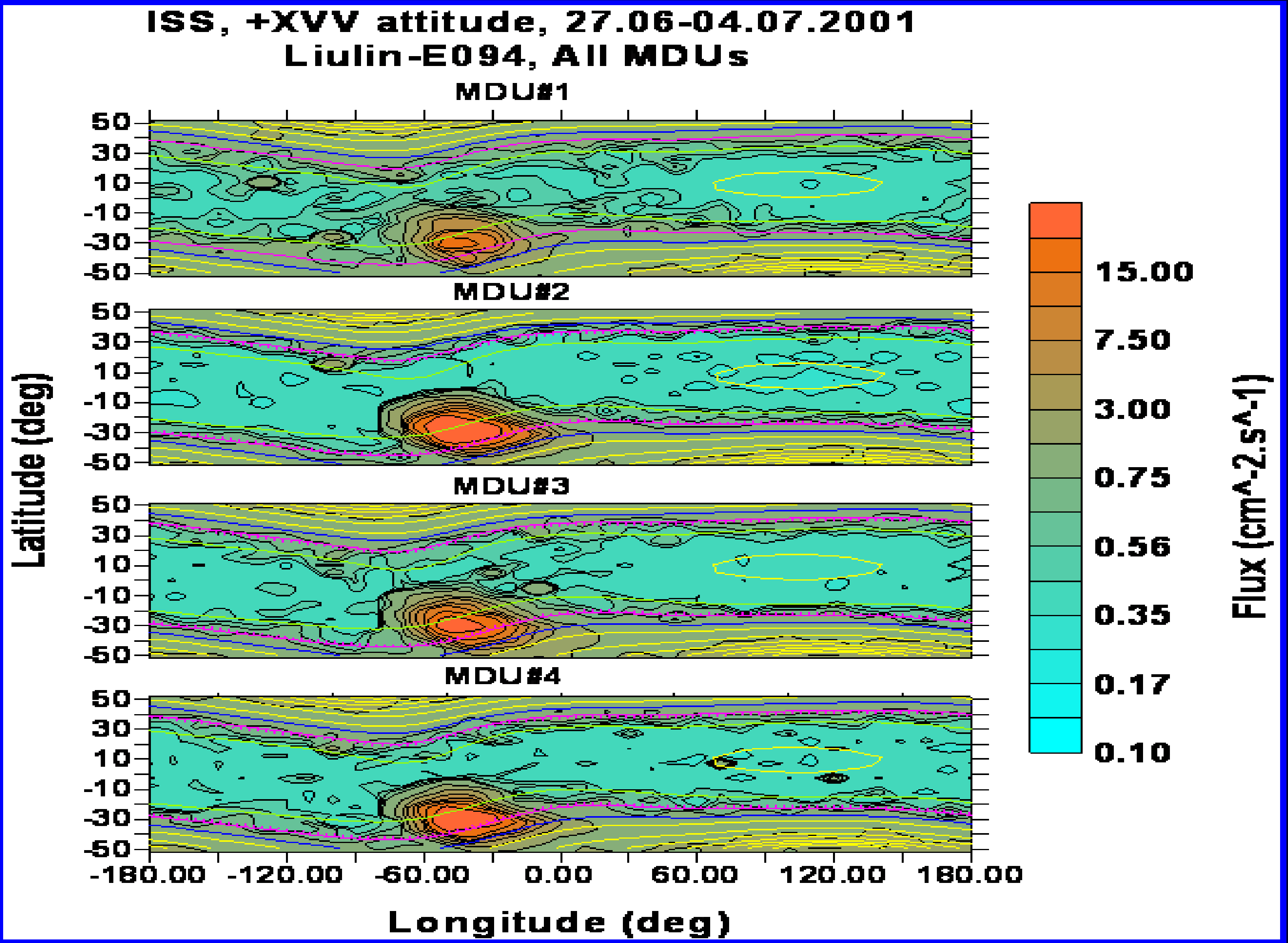
Configuration of ISS and CSA aircraft orbits



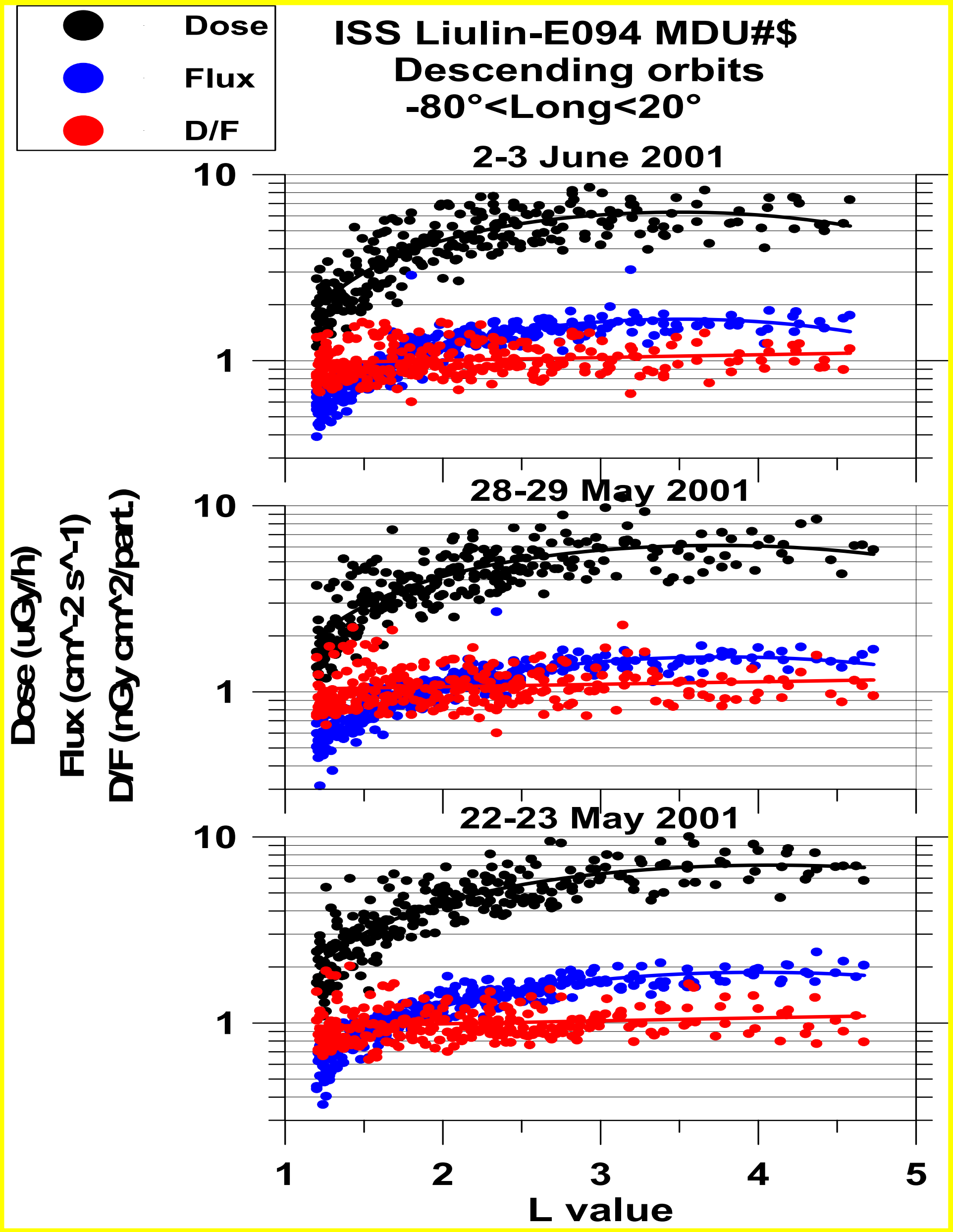
Oulu Neutron Monitor Data



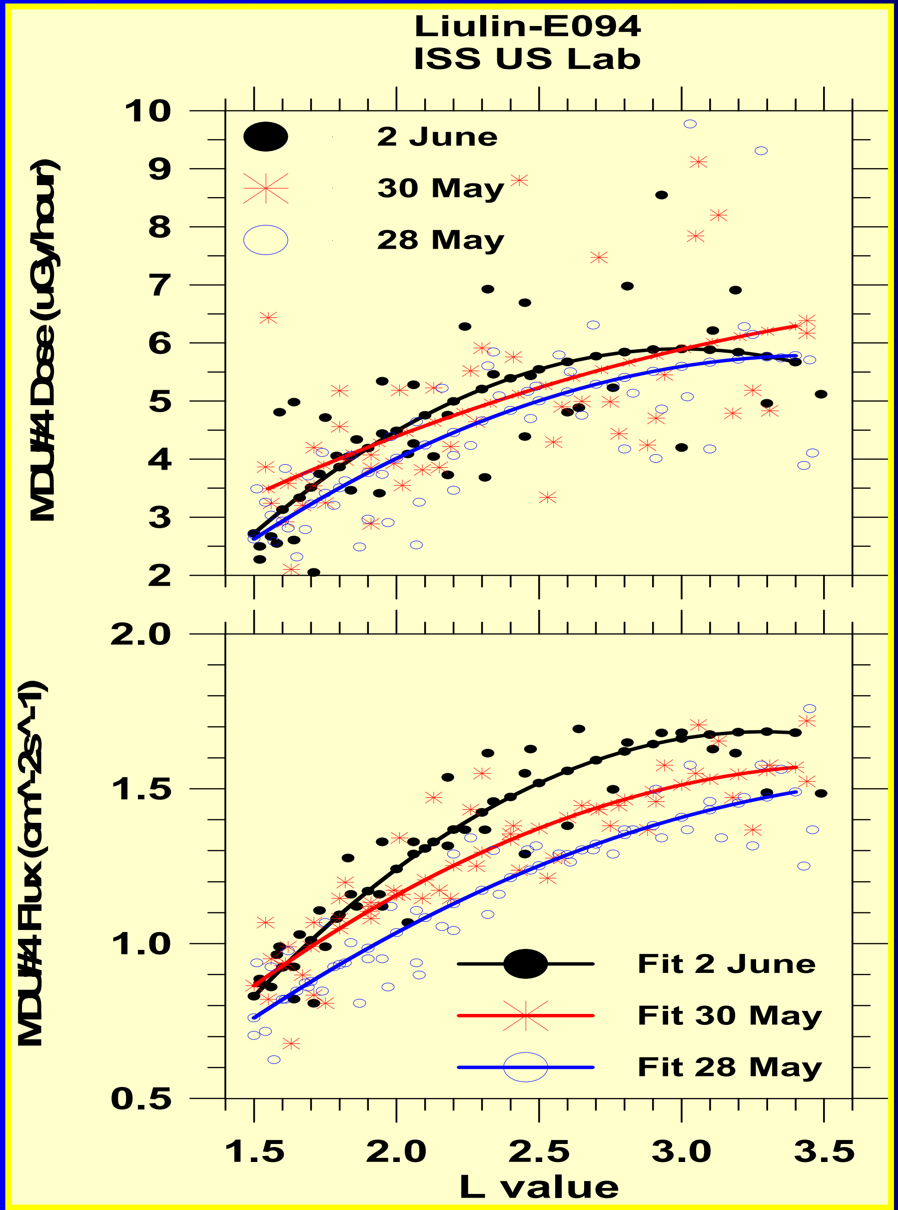
Global view of ISS MDUs data



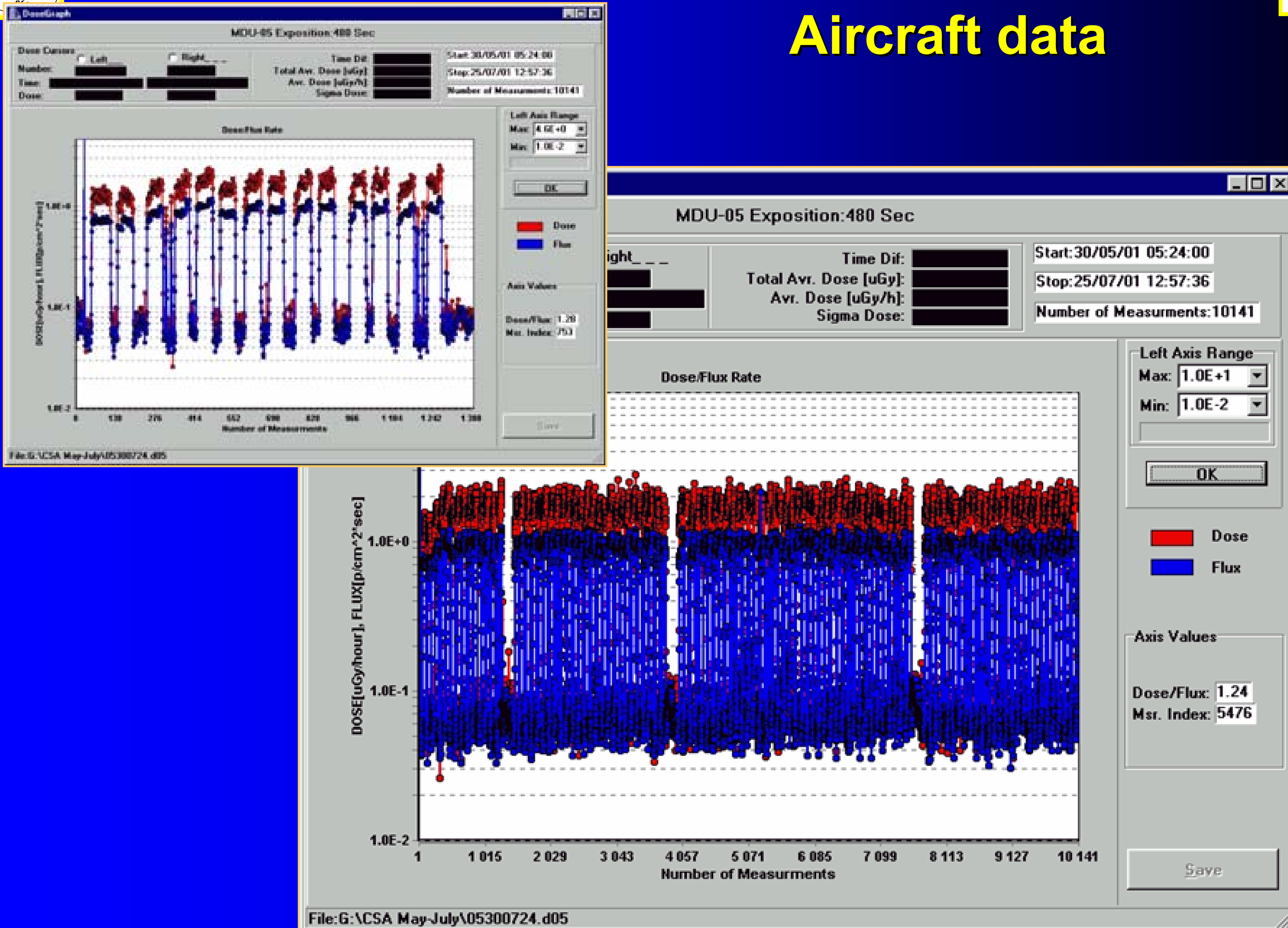
Presentation of the ISS data



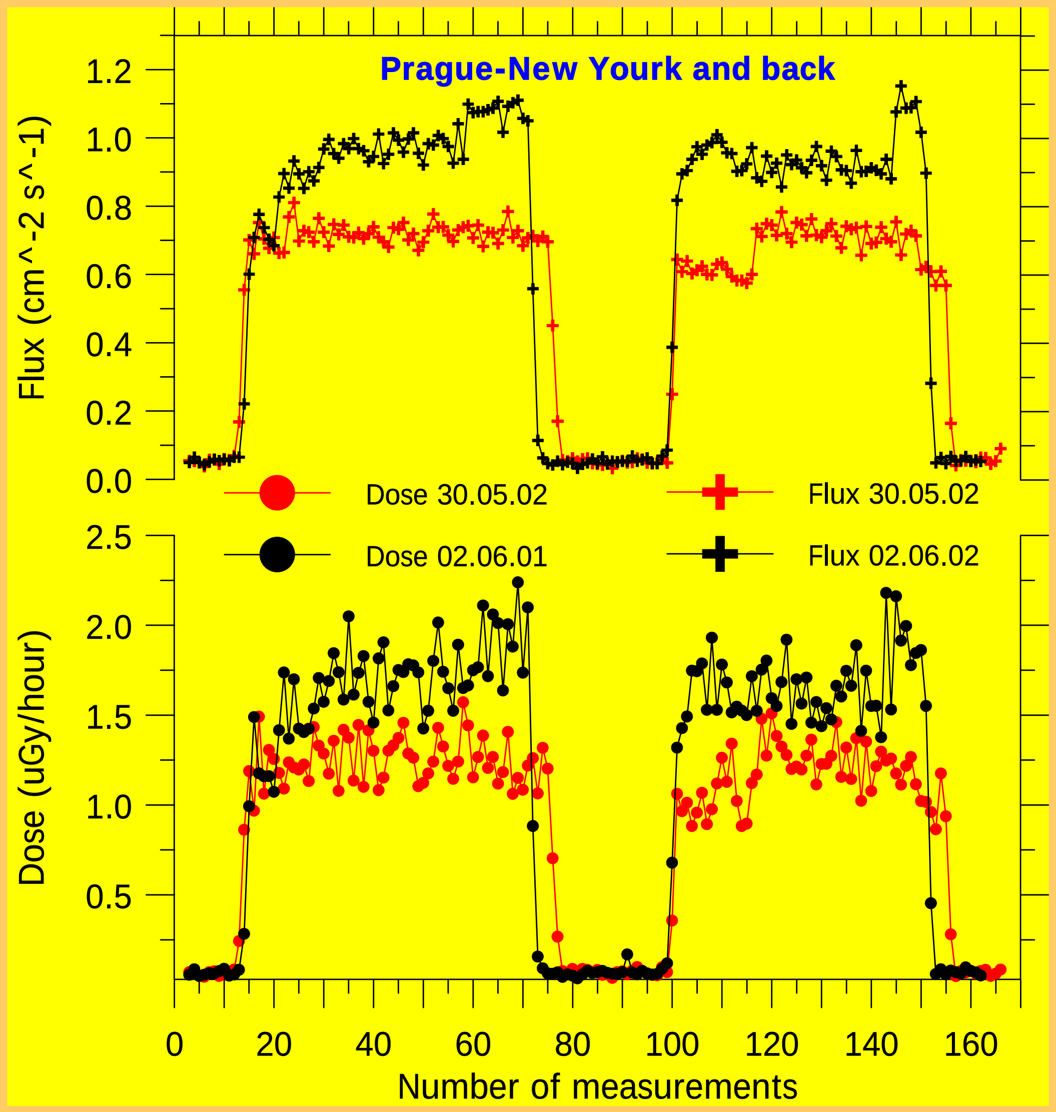
Variations of the GCR in dependence of L value as observed by MDU#4 on ISS.



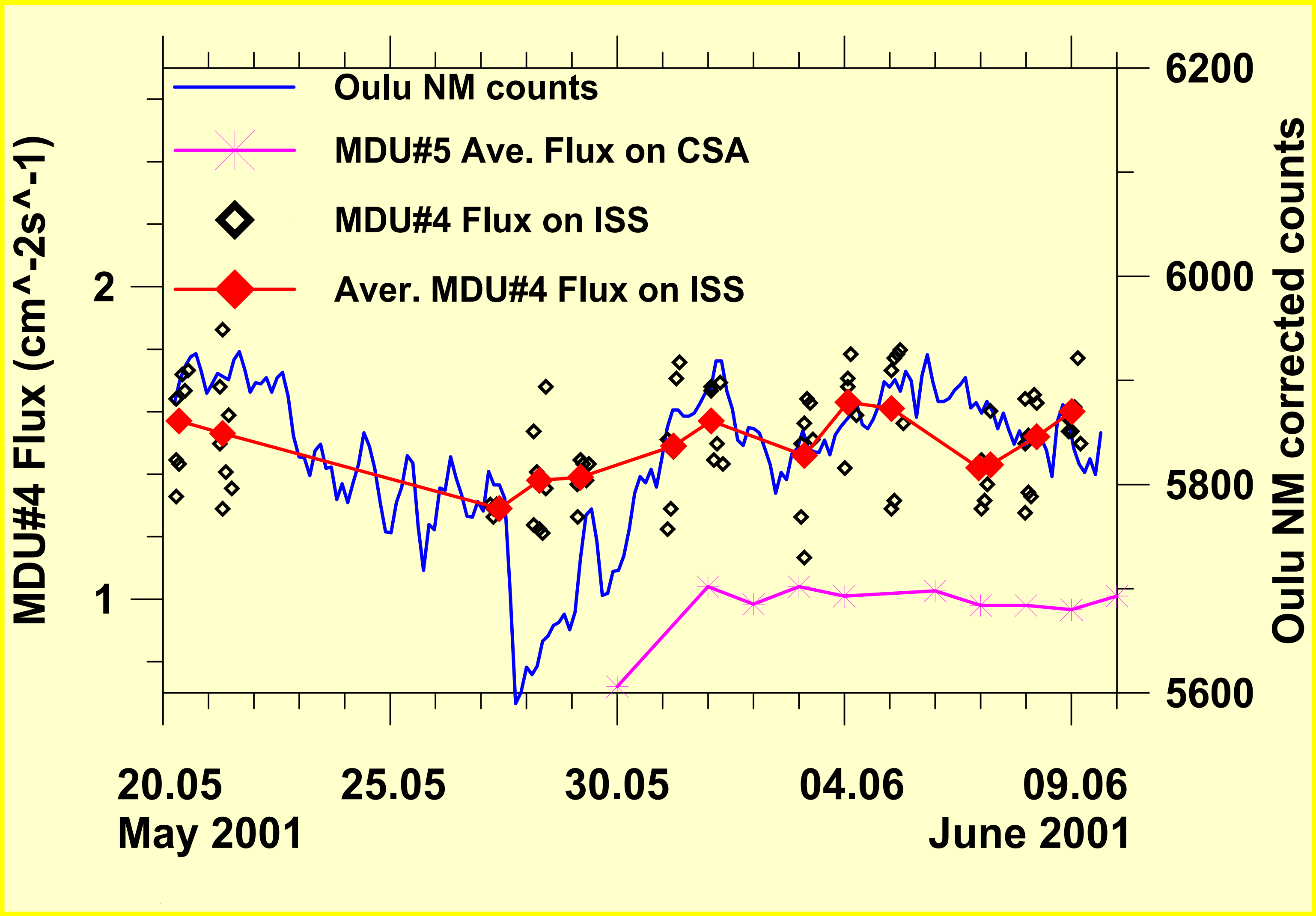
Aircraft data



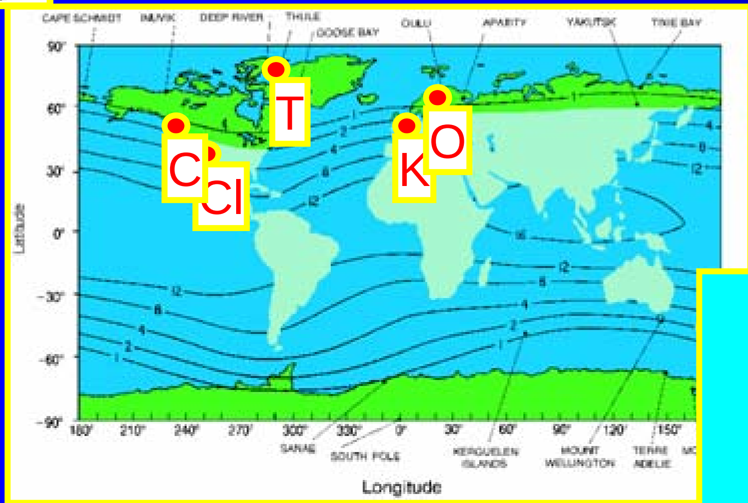
Variations of the CSA aircraft dose and flux data for 30 May and 2 June 2001 on the route Prague-New York and back



Simultaneously plotted Flux data from MDUs on CSA and on ISS from 21 May to 10 June 2001



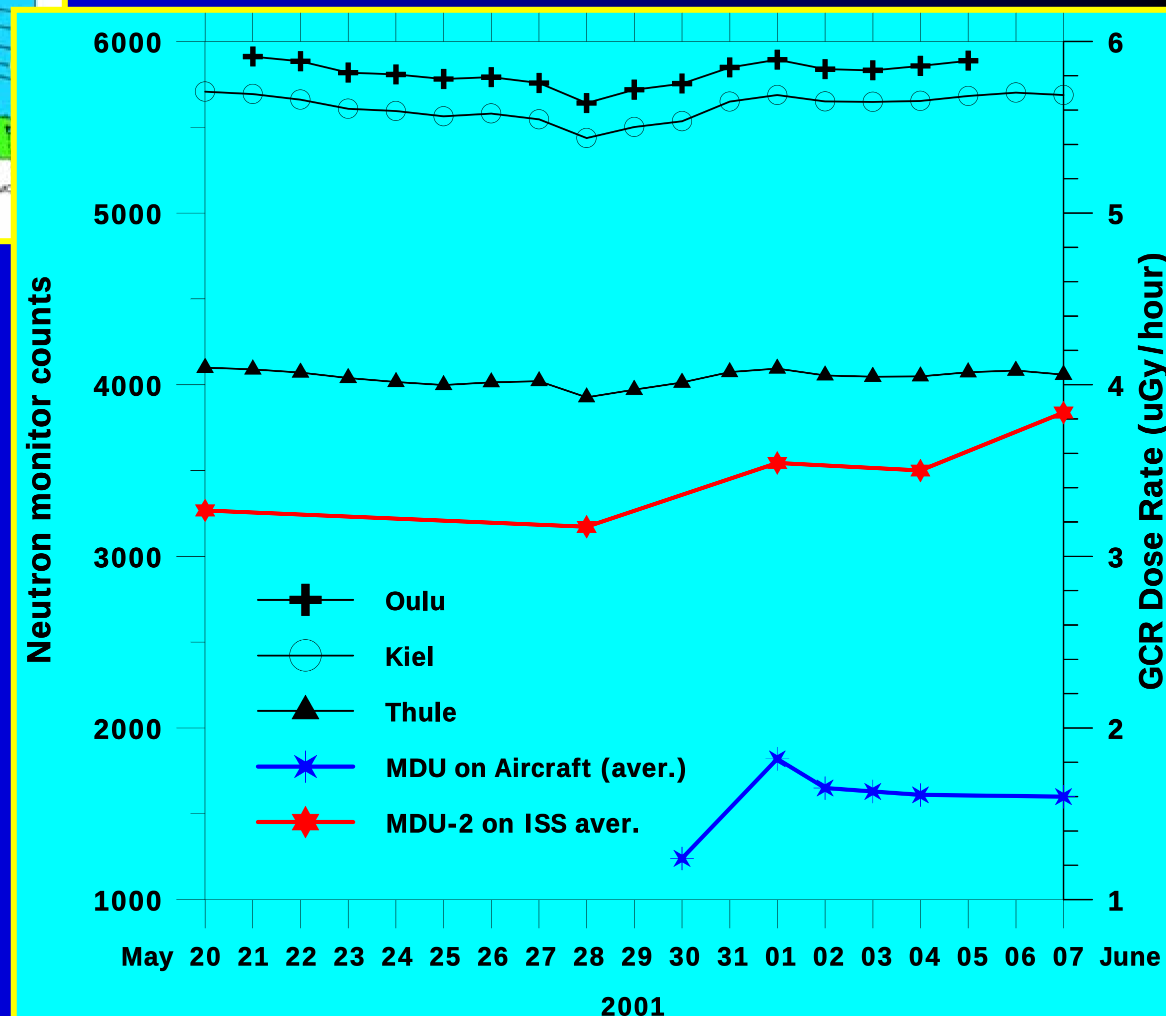
Comparison of ISS and aircraft dose and NM data



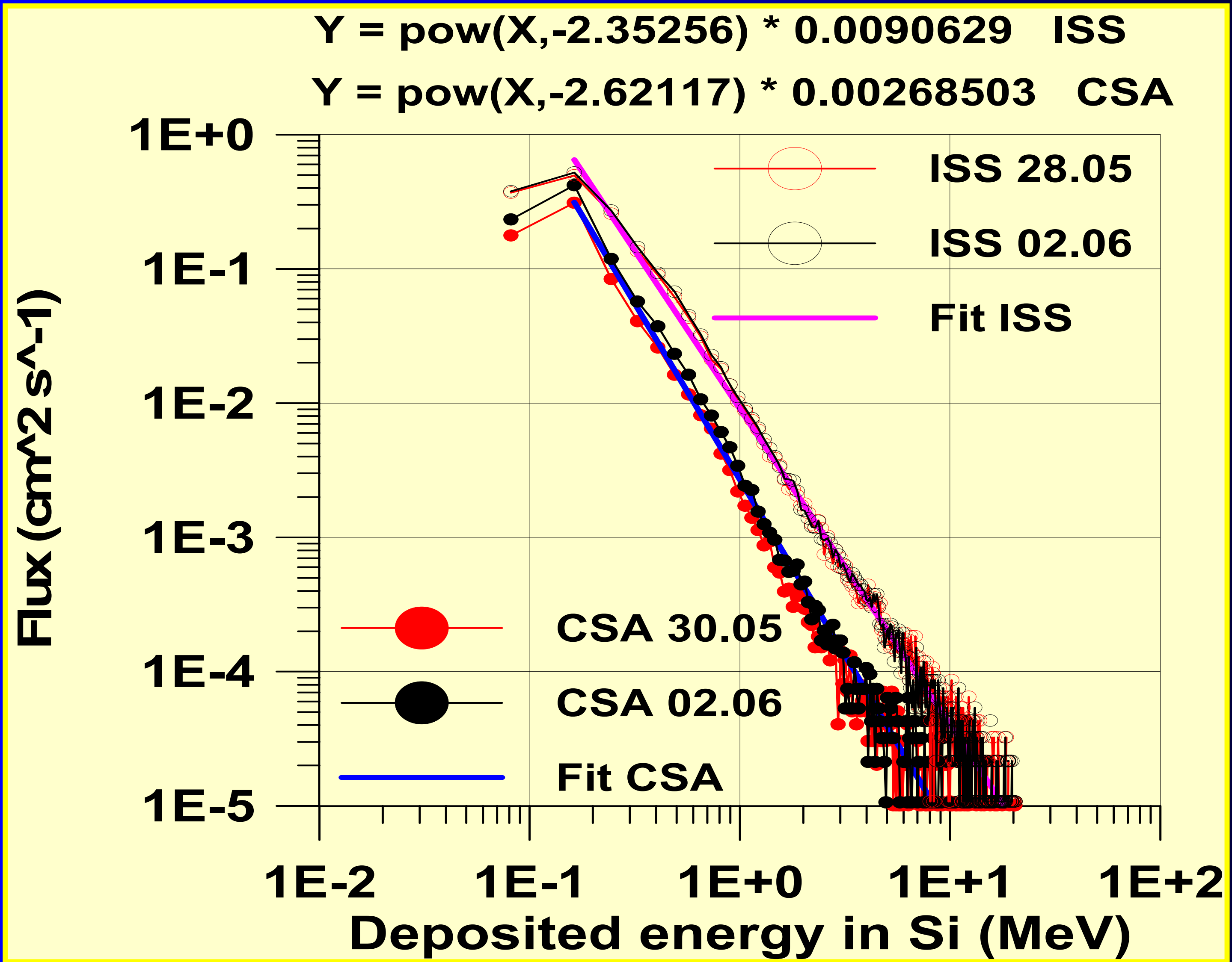
Normal to Forbush Ratios

On CSA aircraft: N/F=1.29

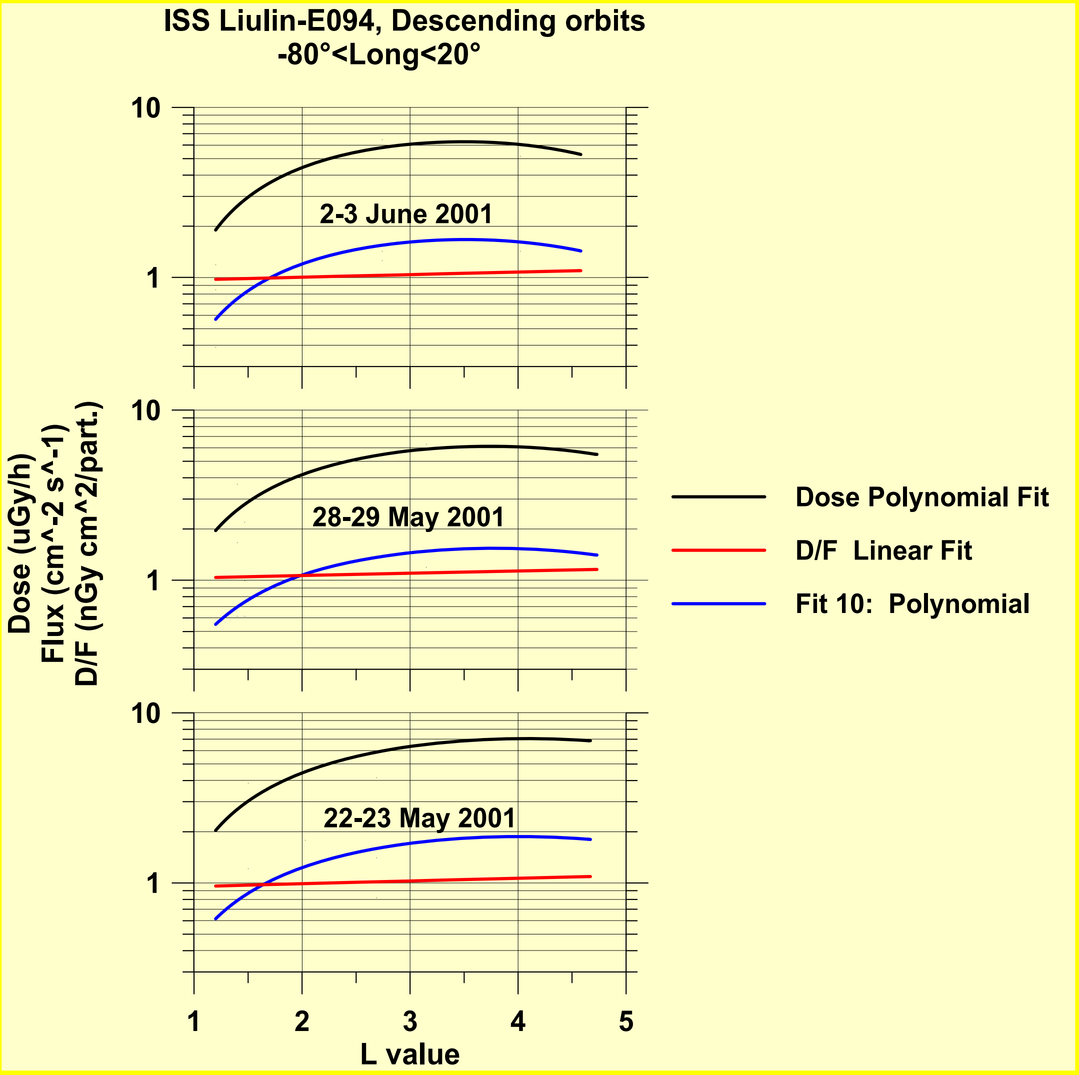
On ISS: N/F=1.21



Comparison of the spectra obtained on ISS and on CSA aircraft for the time before and after Forbush Decrease



Fitting curves of the Dose, Flux and dose to flux ratio from MDU#4 on ISS for 3 different periods before, during and after the Forbush decrease on 27 May 2001



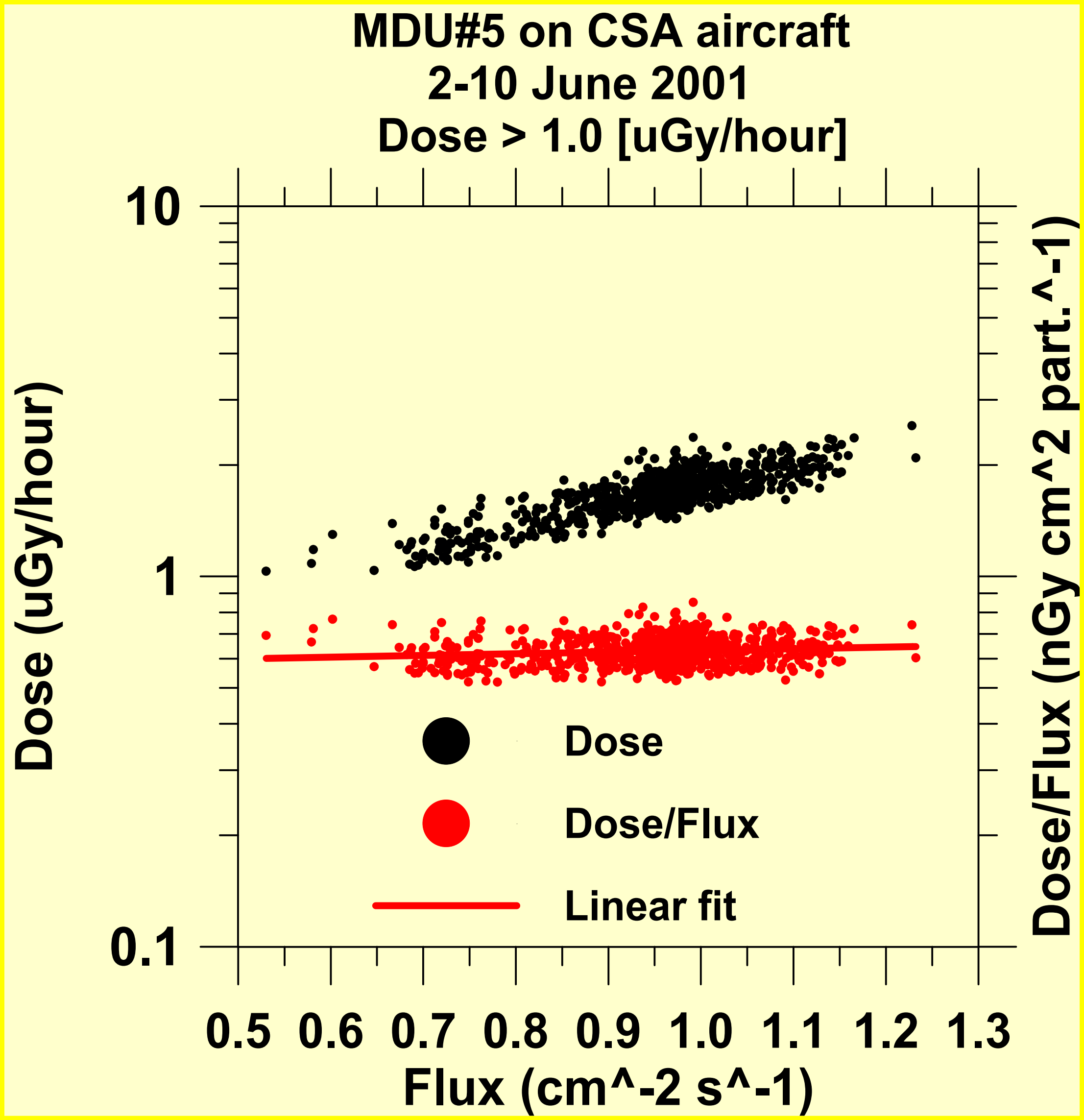
Note:

- Dose/Flux ratio being almost constant about 1.08 [mGy cm^2 p^{-1}];

- Average Dose L>2,5 is 5.28 [μGy/h];

-Average Flux is 1.62 [cm^{-2} s^{-1}]

Dose and dose to flux ratio from MDU#5 on CSA for 2-10 June 2001



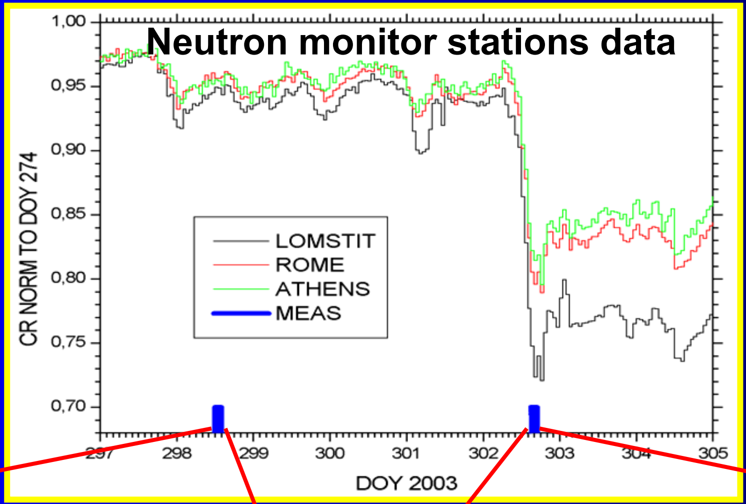
Note:

- Dose/Flux ratio being almost constant about 0.63 [mGy cm^2 p^{-1}];

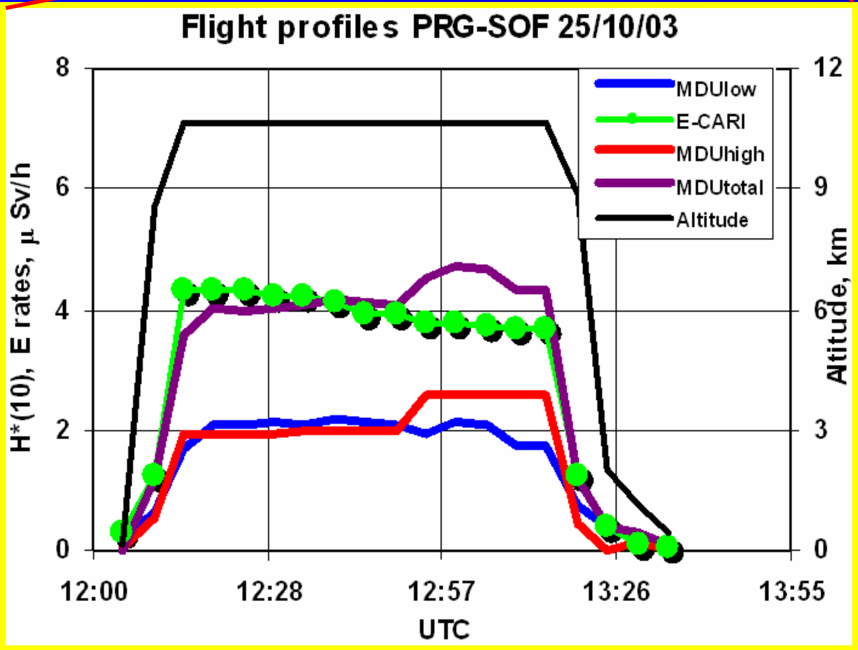
- Average Dose is 1.68 [μGy/h];

-Average Flux is 0.95 [cm^{-2} s^{-1}]

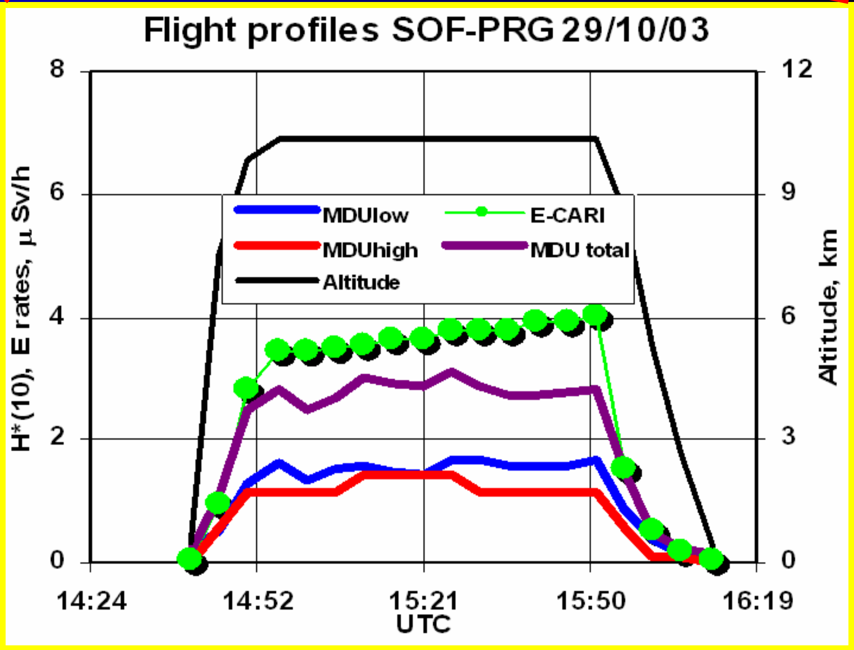
Halloween magnetic storm data by Liulin MDU on CSA



Liulin/EPCARD3.2=0.98



Liulin/EPCARD3.2=0.74



Ratios of ambient dose equivalent values for total flights estimated from MDU-Liulin measurements and calculated by means of EPCARD3.2 code

Date	Event	For low E_{dep}	For high E_{dep}	Total H
12/04/01	Forbush (LŠ: - 13 %)	0,92	0,78	0,84
15/04/01	GLE 60 (LŠ: + 10 %)	1,24	1,68	1,45
16/04/01	normal	1,01	1,00	1,01
25/10/03	normal	0,95	1,00	0,98
29/10/03	Forbush (LŠ: - 26 %)	0,88	0,62	0,74

Remarks:

1) LŠ: difference of counts at Lomnický Štít cosmic ray neutron monitor
2) April 2001: PRG-JFK flights; October 2003: PRG-SOF (25/10); SOF-PRG (29/10)

Who is using Liulin type spectrometers and where?

- Dr. G. Reitz, DLR, Institute fuer Luft-und Raumfahrtmedizin, Cologne, Germany - Cigarettes box size LSs and CIU used in the Experiment “Dosimetric Mapping”, May-August, 2001 on the International Space Station;
- Dr. E.G. Stassinopoulos, Goddard Space Flight Center, NASA, USA - large LSs used for characterization of radiation field at Antarctic balloons;
- Dr. Y. Uchihori, National Institute of Radiological Sciences-STA, Chiba, Japan - Cigarettes box size LSs and large size LSs used for characterization of dose at HIMAC and for 23 ER-2 flights in period 2000-2002;
- Prof. F. Spurny, Nuclear Physics Institute, Czech AS, Praha, large MDUs and Cigarettes box size LSs used for about 9x2 months flights on CSA A310-300 aircraft in 2001-2005;
- Dr. V. Petrov and Dr. V. Shurshakov, Institute of Biomedical Problems, Moscow, Russia Cigarettes box size MDUs with displays will be used in the Service Radioprotection System on the Russian segment of the International Space Station for 15 years starting from 2006;
- Dr. J.-F. Bottollier, Institut de Protection es de Surete Nucleaire – CEA, Fontenay-Aux-Roses, France Cigarettes box size LS large LS are used on Air France aircrafts;
- Dr. P. Bilski, *Health Physics Laboratory, Institute of Nuclear Physics, Krakow, Poland -* large LS is used on aircrafts;
- Dr. Les Bennett, Royal Military Colleague, Ontario, Canada - spectrometers with GPS on aircrafts;
- Prof. D.-P. Haeder, University of Erlangen, Germany – R3D-B type and R3D spectrometers for ESA Biopan and EXPOSE facilities on Foton M satellites and ISS;
- Dr. Eric Benton, ERIL Research, USA, Cigarettes box size MDUs for NASA balloon mission;
- Prof. Erwin Flueckiger, University of Bern, Switzerland, Internet based spectrometer on Jungfraujoch (http://130.92.231.184/);
- Dr. Michael Gausa, Andoya Rocket Range, Norway, Internet based spectrometer on ALOMAR observatory ALOMAR (http://128.39.135.6);
- Dr. Peter Beck, Head Radiation Safety R&D, ARC Seibersdorf research, Austria – DU with RS232 port and external power supply 9-36 V for aircraft measurements;
- Dr. Jose Carlos Saez-Vergara, CIEMAT, and Dr. Dr. Ramón Domínguez-Mompell, IBERIA, Health Services, Aeropuerto de Barajas, Madrid – Liulin-4S LETS with GPSs for aircraft measurements;

Conclusions

- Different modifications of Liulin type spectrometers was developed and build by SRIG in STIL-BAS between 1985 and 2006. 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;
- Calibrations of Liulin type spectrometers on radiation sources and different type accelerators with electrons, protons and heavy ions was performed. The obtained results well coincide with the theoretical predictions;
- Liulin spectrometers proved their availability to qualify the different radiation fields in space, on aircraft and on ground;
- Comparison of Liulin type spectrometers with other high statistics instruments and TEPCs show that in many cases they are compatible;
- Future experiments in space are under development and will be performed up to 2019;

Thank you for your attention