# New Results for the Earth Radiation Environment

*Tsvetan DACHEV[1], Borislav TOMOV[1], Plamen DIMITROV[1]*
*Yury MATVIICHUK[1], Frantisek SPURNY[2]*

*[1]Solar-Terrestrial Influences Laboratory,*
*Bulgarian Academy of Sciences, Bulgaria, tdachev@bas.bg*

*[2]Nuclear Physics Institute,*
*Czech Academy of Sciences, Czech Republic, spurny@ujf.cas.cz*

# Outlook

- Liulin type instruments.
  Short Introduction
- Study of the Liulin MDU spectra and ambient equivalent dose distribution at different carriers and locations
- Future use of Bulgarian build spectrometers
- Conclusions

# Liulin type instruments.
# Short Introduction

# Internal and External view of some last modifications Liulin type instruments


Internal view of Internet based device, which create own WEB page with the obtained data.


External view of rechargeable battery device with LCD display, showing current absorbed and ambient dose equivalent and the accumulated dose since the beginning of the measurements.

# 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, 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

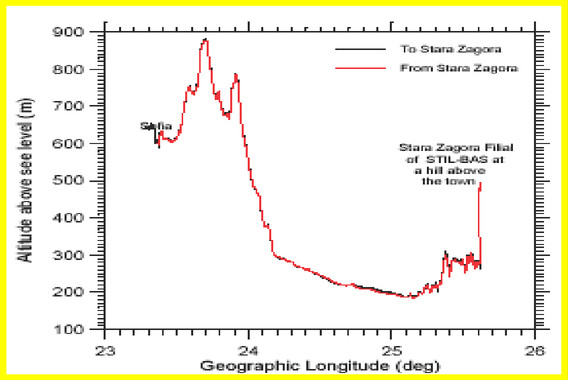

*Weight: 280 g**
*Size: 95x85x55 mm*

More than 4 days working time from Li-Ion accumulator

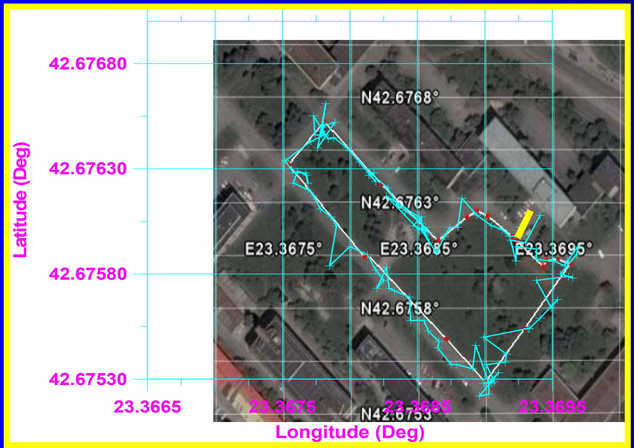

*Weight: 115 g**
*Size: 124x40x20 mm*

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

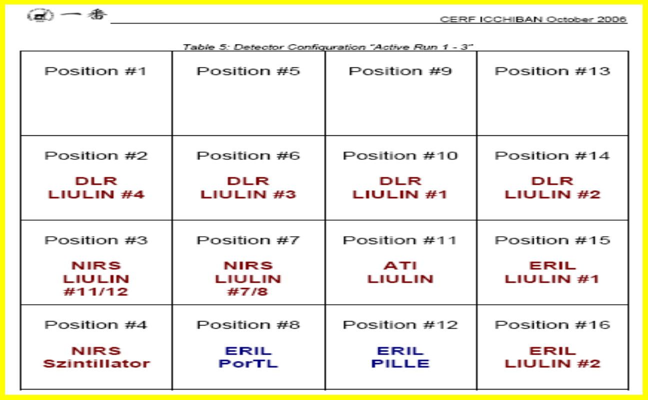

*Weight: 280 g*
*Size: 110x80x45 mm*




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.



CERF ICCHIBAN October 2006

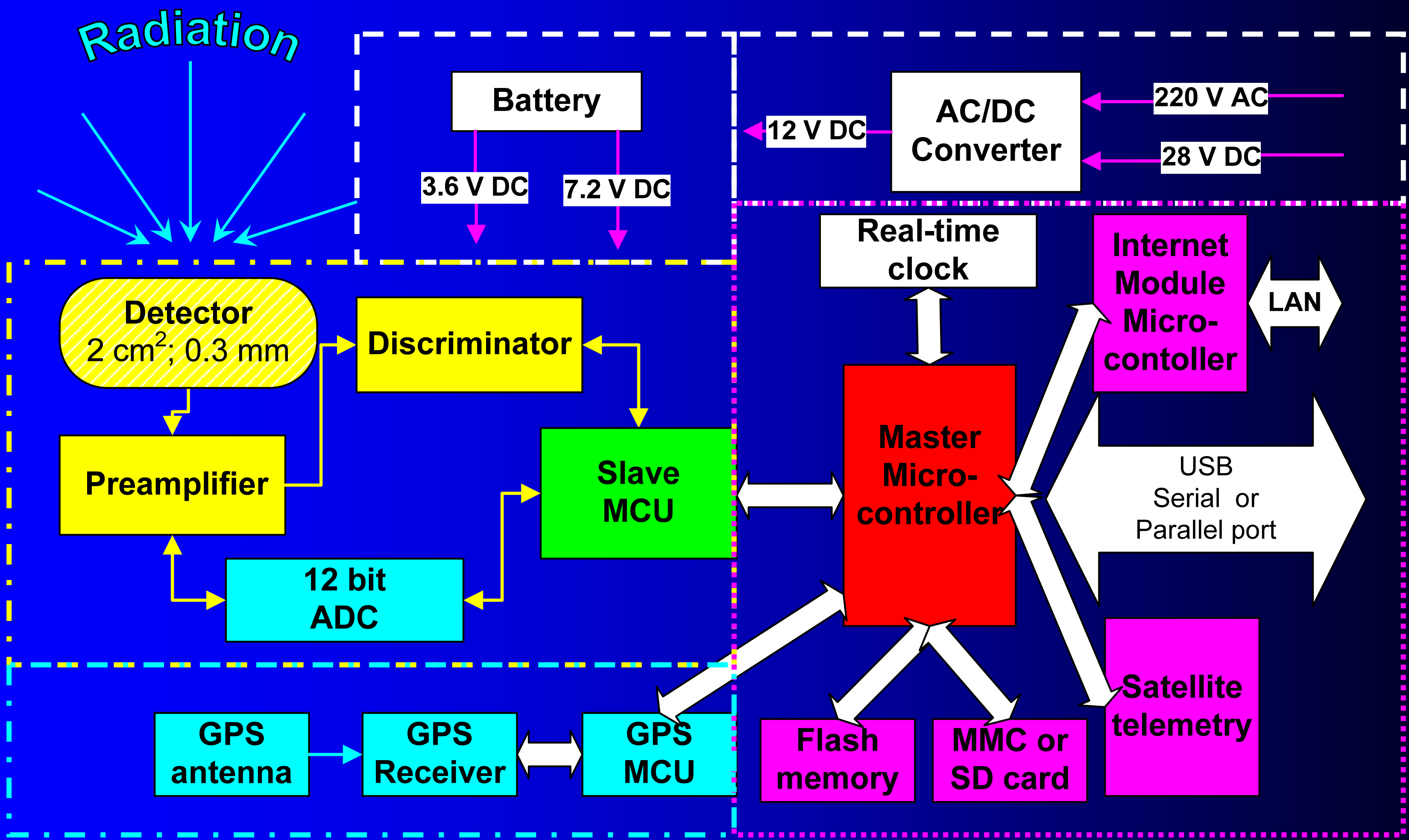
*Table 5: Detector Configuration "Active Run 1 - 3"*

| | | | |
|---|---|---|---|
| Position #1 | Position #5 | Position #9 | Position #13 |
| Position #2 DLR LIULIN #4 | Position #6 DLR LIULIN #3 | Position #10 DLR LIULIN #1 | Position #14 DLR LIULIN #2 |
| Position #3 NIRS LIULIN #11/12 | Position #7 NIRS LIULIN #7/8 | Position #11 ATI LIULIN | Position #15 ERIL LIULIN #1 |
| Position #4 NIRS Szintillator | Position #8 ERIL PorTL | Position #12 ERIL PILLE | Position #16 ERIL LIULIN #2 |

11 Liulin type spectrometers during calibrations in CERN, October 2007

*New results...*

# Integrated Block - diagram of the Liulin type devices



# MDU - Liulin aircraft dose interpretation procedure

## 1) Dose in Si is calculated as:

**$D = K * \sum(Ei \times Ai)*MD$, where**

**MD – mass of the detector;**

**Ei – energy loss in the channel i;**

**Ai – events number in the channel i;**

**K – coefficient based on $W_e$ in Si**

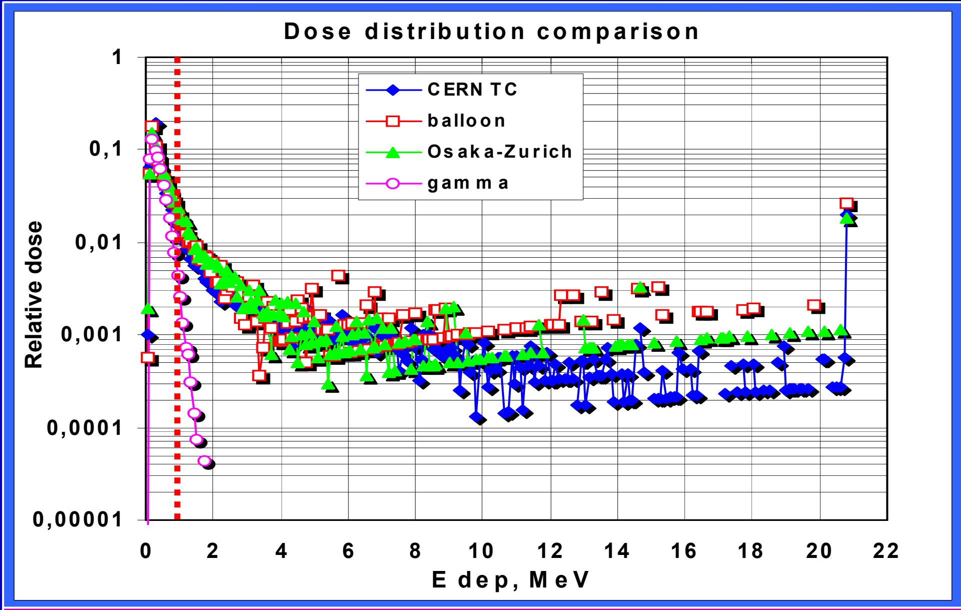
## 2) Apparent dose equivalent Happ (Ambient dose equivalent - H*(10)) is calculated as:

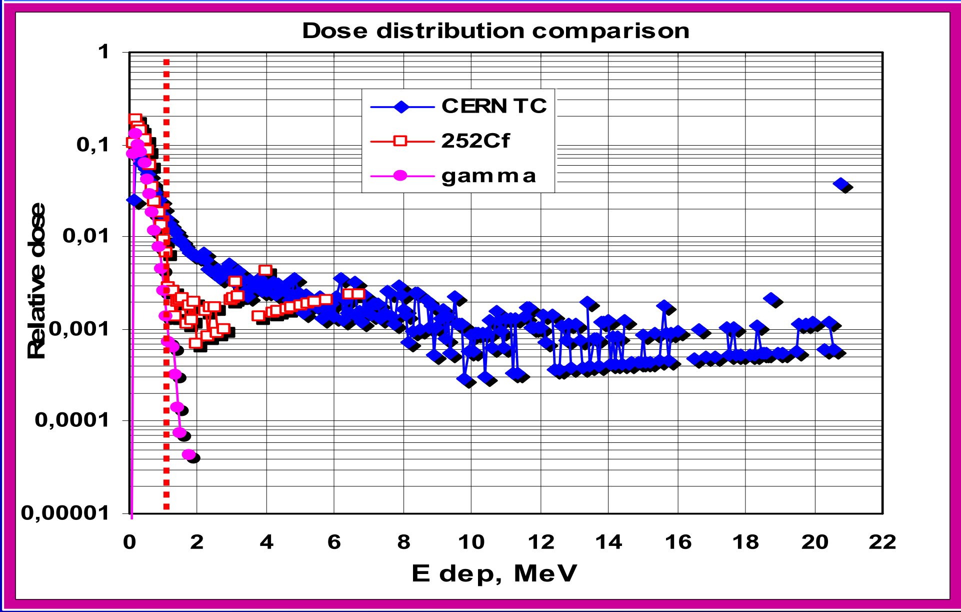
**D(Si) above ~ 1 MeV ($D_{high}$) neutron like component**

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

**Dlow and Dhigh – multiplied by a coefficient to get $H^*(10)_{high}$**

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



# MDU – Liulin spacecraft dose interpretation procedure

## GCR

Supposed that:

$E_{dep}$ bellow ~ 1 MeV  low LET component

$E_{dep}$ above ~ 1 MeV high LET component composed of:

neutron component, with similar spectra as onboard aircraft, and contribution of HECP of GCR

Interpreted as:

Low LET component: D(Si)→D(tissue)→"H*(10)";

High LET or Neutron component: as onboard aircraft;

GCR component: D(Si)x5→D(tissue)="H*(10)";

To get as good statistical reliability as possible to distinguish neutron and GCR contribution - for energy deposition spectra above ~ 1 MeV – all aircraft spectra (~ 6000 hours; ~ 30 mSv) summed up and regressed

## SAA

Supposed that all events are due to protons of SAA

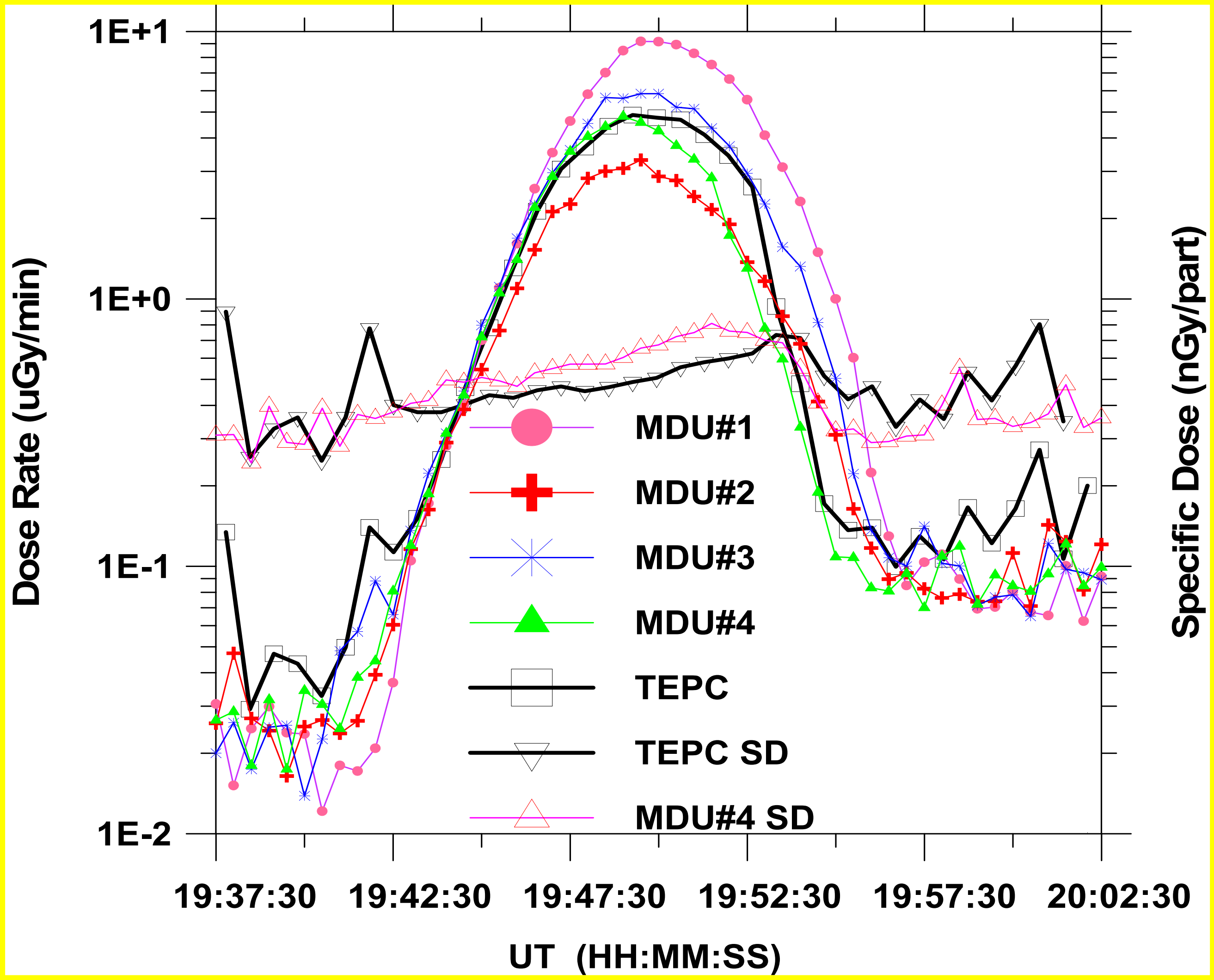
Interpretation:

D(Si)→D(tissue), and

D(tissue) x $QF_{average}$ calculated from energy distribution spectra (~1.3) = "H*(10)"

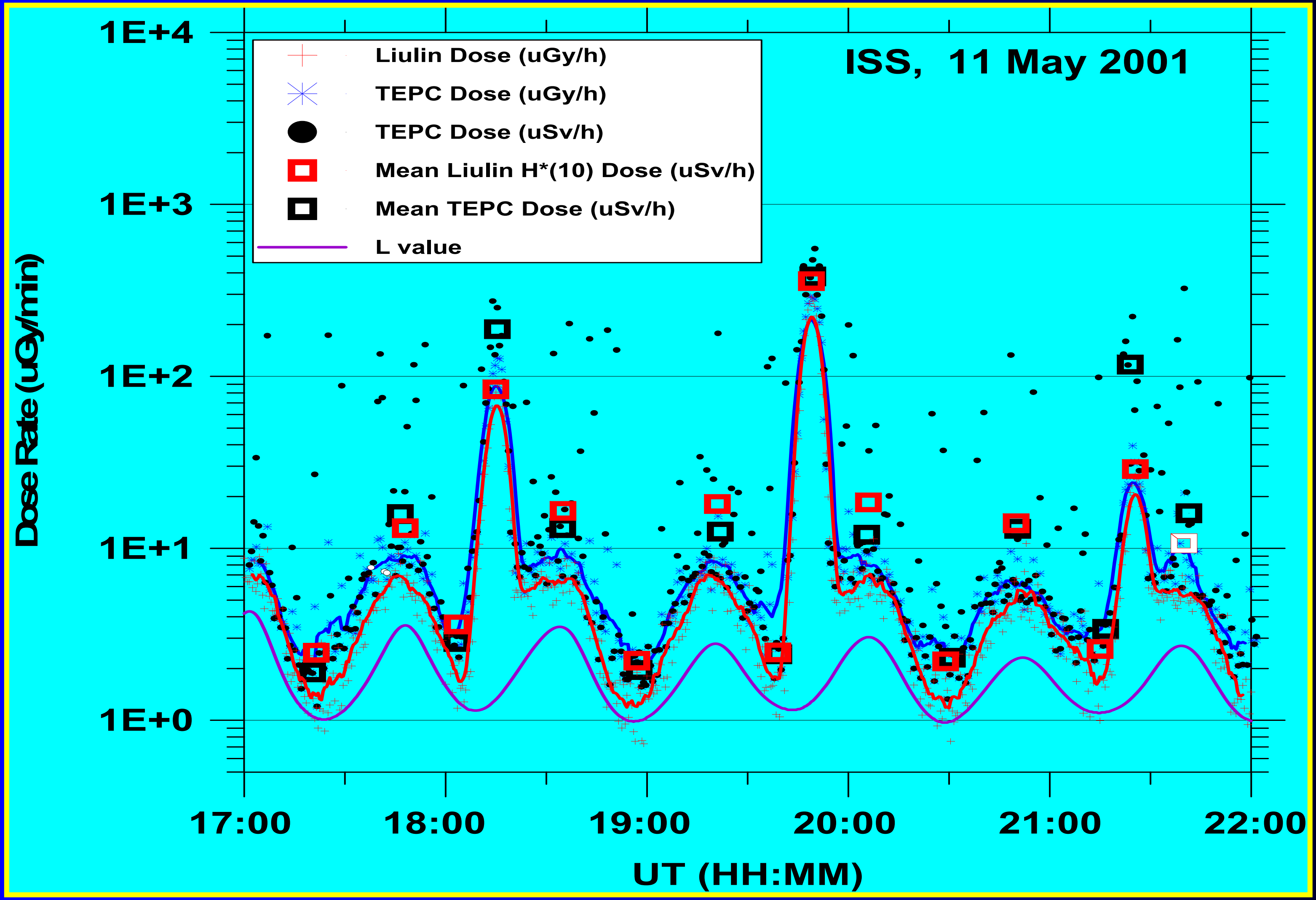
# Study of the Liulin MDU spectra and ambient equivalent dose distribution at different carriers and locations

# Comparison of absorbed dose data obtained by Liulin MDUs and NASA TEPC at ISS*




*Dachev, T., Atwell, W. Semones, E.; Tomov, B., Reddell, ISS Observations of SAA radiation distribution by Liulin-E094 instrument on ISS, Adv. Space Res., V 37, 1672-1677, 2006.

# Comparison between NASA TEPC and MDU doses. H*(10) MDU doses are calculated as shown on next slide




Authors are thankful to Dr. E. Semones for the Phantom TORSO NASA TEPC data

*New results...*

# Tabulated results from previous slide

$$H_{GCR}*(10) = K\{\sum_{i=1}^{14} k_i A_i + 5\sum_{i=15}^{256} k_i A_i\}/MD$$

$$H_{SAA}*(10) = K\{1.3\sum_{i=1}^{14} k_i A_i + 1.3\sum_{i=15}^{256} k_i A_i\}/MD$$

| Dose/Instrument Position | H*(10)low µSv/h | H*(10)high µSv/h | H*(10)tot µSv/h | D µGy/h |
|---|---|---|---|---|
| Liulin MDU#4 Equator (GCR) (mean value over 81 spectra) | 1.2 | 1.37 | 2.58 | 1.48 |
| Liulin MDU#4 Equator (GCR) (%) | 47 | 53 | | |
| Phantom TORSO NASA TEPC (GCR) (%) | 29 | 71 | | |
| Liulin MDU#4 L~3 (GCR) (mean value over 63 spectra) | 4.29 | 10.6 | 14.89 | 6.41 |
| Liulin MDU#4 L~3 (GCR) (%) | 29 | 71 | | |
| Phantom TORSO NASA TEPC (GCR) (%) | 29 | 71 | | |
| Liulin MDU#4 SAA (Trapped) (mean value over 33 spectra) | 85.1 | 53.4 | 138.5 | 106.7 |
| Liulin MDU#4 SAA (Trapped) (%) | 61 | 39 | | |
| Phantom TORSO NASA TEPC (Trapped) (%) | 71 | 29 | | |

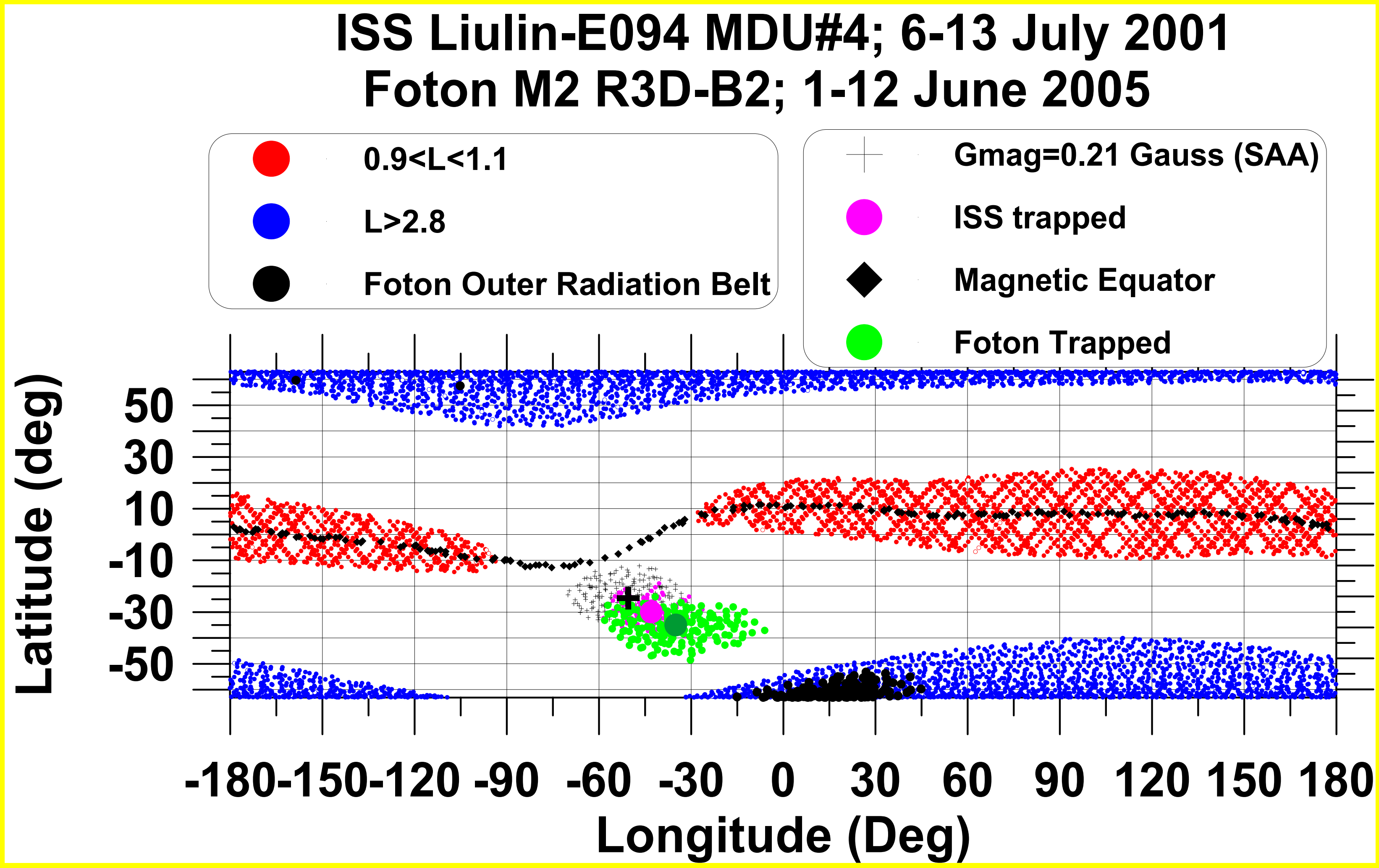
► Best results from the comparison are obtained for GCR component at L~3;

► The results for GCR component in equatorial region are fair;

► Trapped radiation comparison is relatively good.

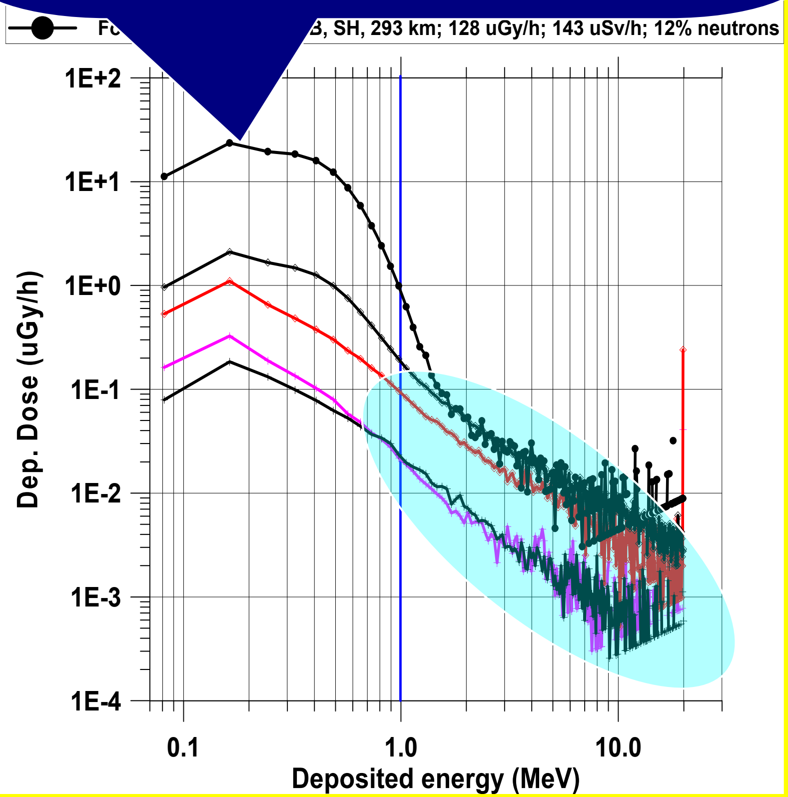
*New results...*

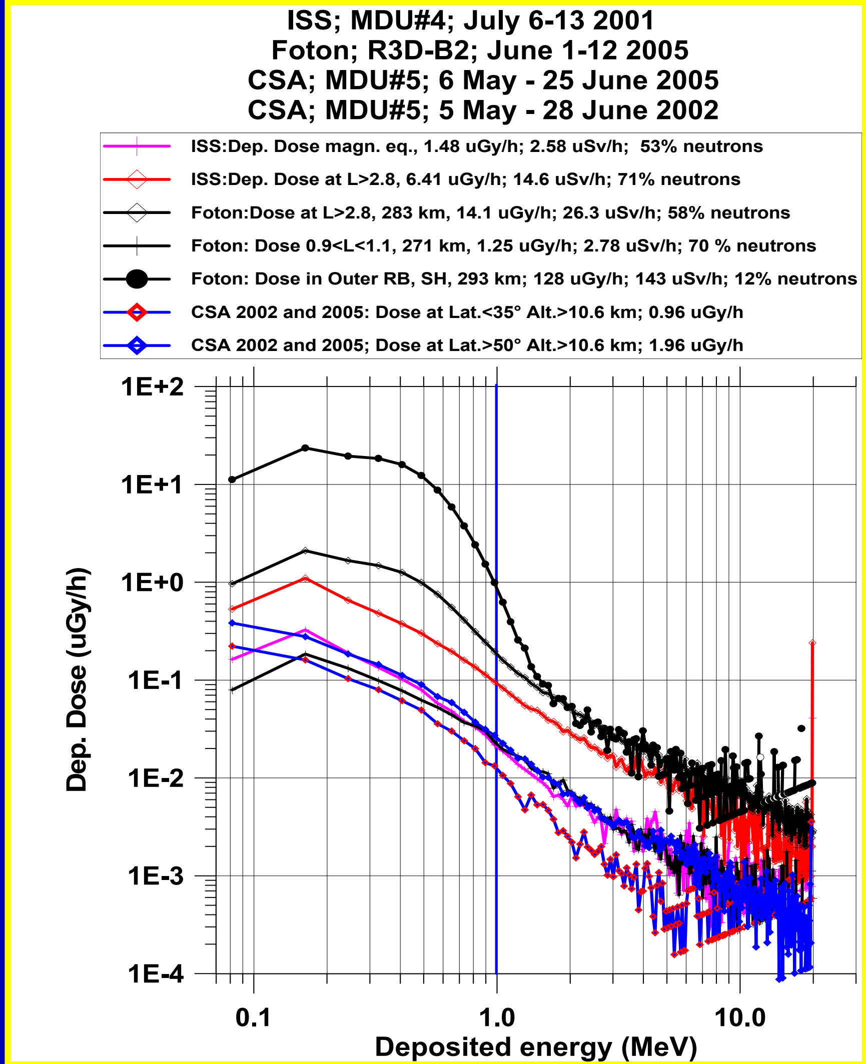
# Selection procedures and data positions



# GCR component as seen by ISS Liulin MDU#4, Foton M3 R3D-B3 and CSA MDU-5 instruments

- The Outer RB spectra, which is created mainly by electrons have very high count rate in low LET region;
- The neutron component is less than 12%;
- At energies above 1.6 MeV it coincide with the usual GCR spectra for these latitudes



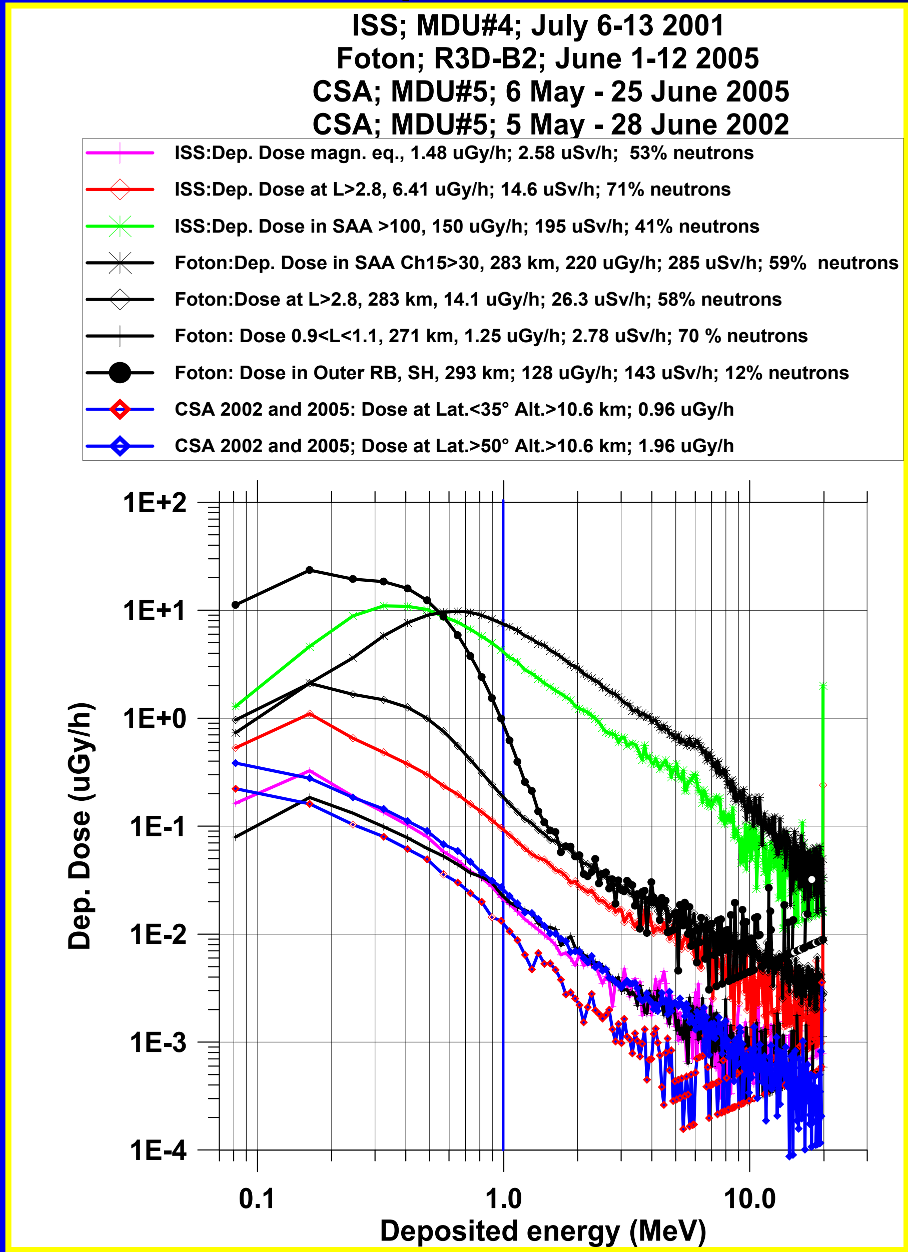




- ► All spectra with GCR component are with equal slope in high LET region;
- ► Higher doses bring higher Y axes values;
- ► The neutron component is higher than 60%

- ► The aircraft spectra at latitudes above 50 are with same slope as GCR spectra at spacecrafts;
- ► At Latitudes below 35 the whole spectra is with less count rate, but with same slope

*New results...*

# All deposited dose spectra observed at different locations at aircrafts, Foton M2 spacecraft and ISS



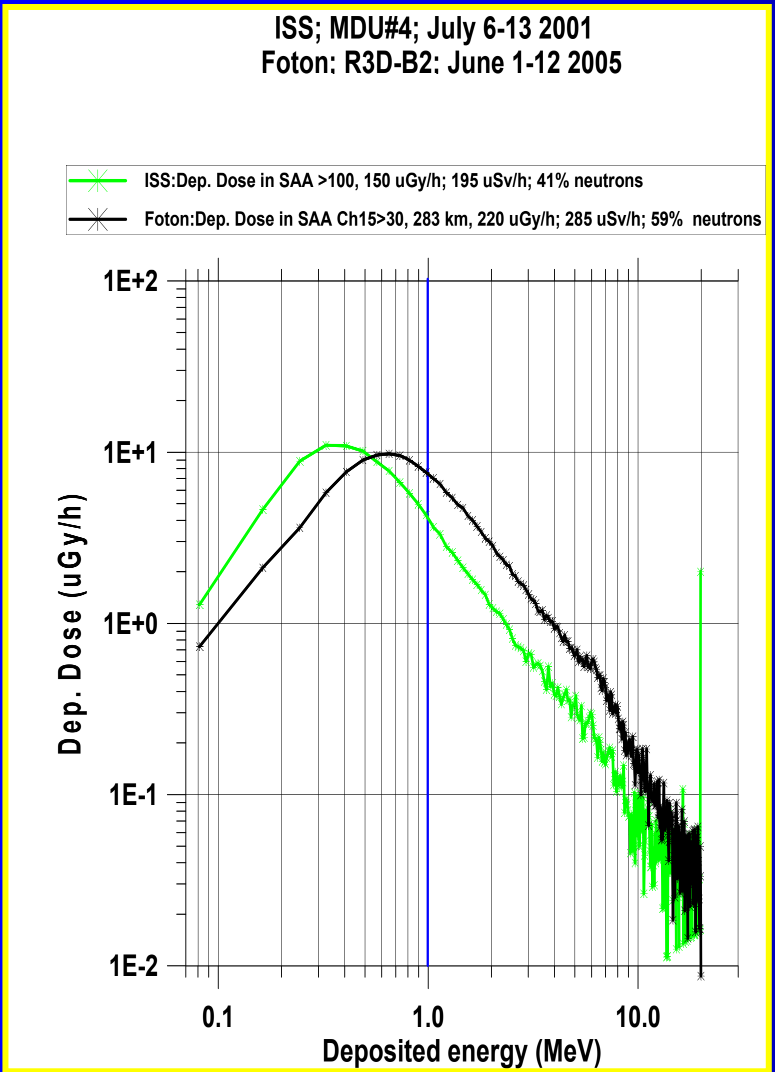
# Tabulated results from previous slides

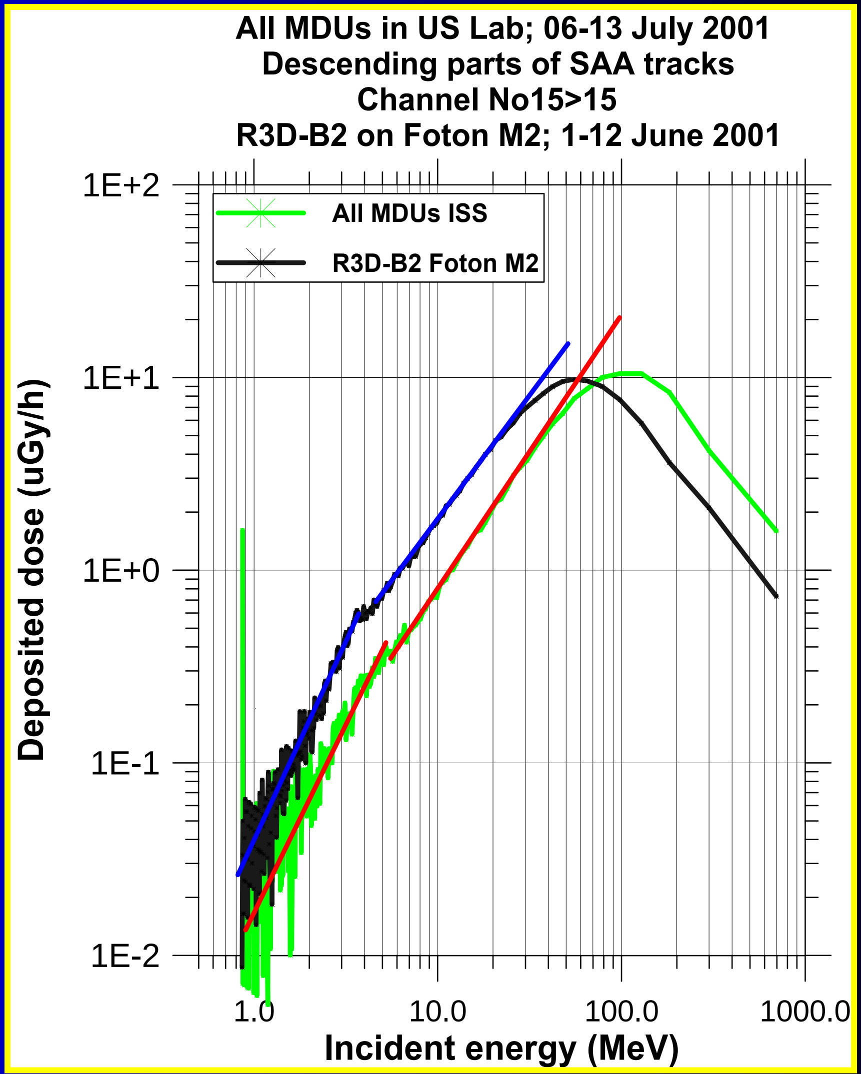
| Dose/Carrier/Instrument Position | H*(10) mSv/h | Abs. Dose mGy/h | % Neutrons |
|---|---|---|---|
| ISS Liulin MDU#4; >10 g/cm$^2$ Equator (GCR) (mean value over 2414 spectra) | 2.58 | 1.48 | 53 |
| Foton M3 R3D-B2; < 2 g/cm$^2$ Equator (GCR) (mean value over 2434 spectra) | 2.78 | 1.25 | 70 |
| GCR Phantom TORSO NASA TEPC (%) | | | 71 |
| GCR DOSTEL | | | 78 |
| ISS Liulin MDU#4 >10 g/cm$^2$ L>2.8 (GCR) (mean value over 2098 spectra) | 14.6 | 6.41 | 71 |
| Foton M3 R3D-B2; < 2 g/cm$^2$ L>2.8 (GCR) (mean value over 4454 spectra) | 26.3 | 14.1 | 58 |
| GCR Phantom TORSO NASA TEPC (%) | | | 71 |
| GCR DOSTEL | | | 78 |
| ISS Liulin MDU#4 >10 g/cm$^2$ SAA (Trapped) (mean value over 129 spectra) | 195 | 150 | 41 |
| Foton M3 R3D-B2; < 2 g/cm$^2$ SAA (Trapped) (mean value over 164 spectra) | 285 | 220 | 59 |
| GCR Phantom TORSO NASA TEPC (%) | | | 29 |
| GCR DOSTEL | | | 19 |
| Foton M3 R3D-B2; < 2 g/cm$^2$ L>2.8 (GCR) Outer radiation belt (mean value over 164 spectra) | 143 | 128 | 12 |

- ►Liulin MDU H*(10) calculations in general underestimate the neutron component.
- ► Best results of the comparison with TEPC and DOSTEL are obtained at L>2.8.
- ► Worst are the comparison in SAA region, because neutrons coming from GCR are masked by bulk of protons.

*New results...*

# SAA (trapped radiation) spectra as seen by ISS Liulin MDU#4 and Foton M3 R3D-B3 instruments



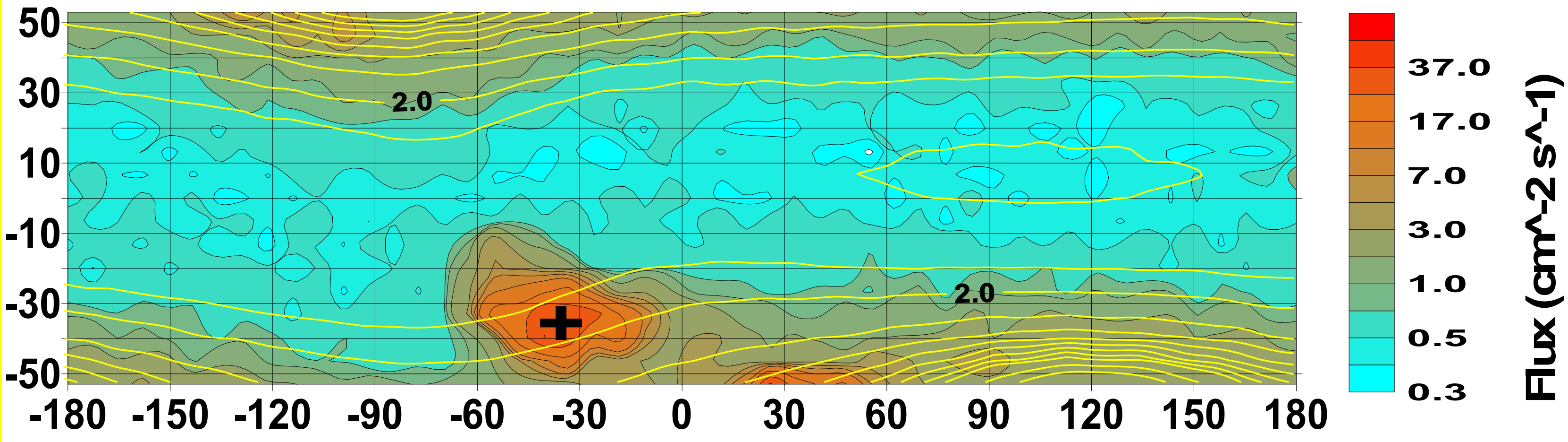

► SAA spectra are with double slope;

► The SAA maximum energy on ISS of 100-110 MeV is moved at Foton M2 to lower energy of 40-50 MeV because of lover altitude

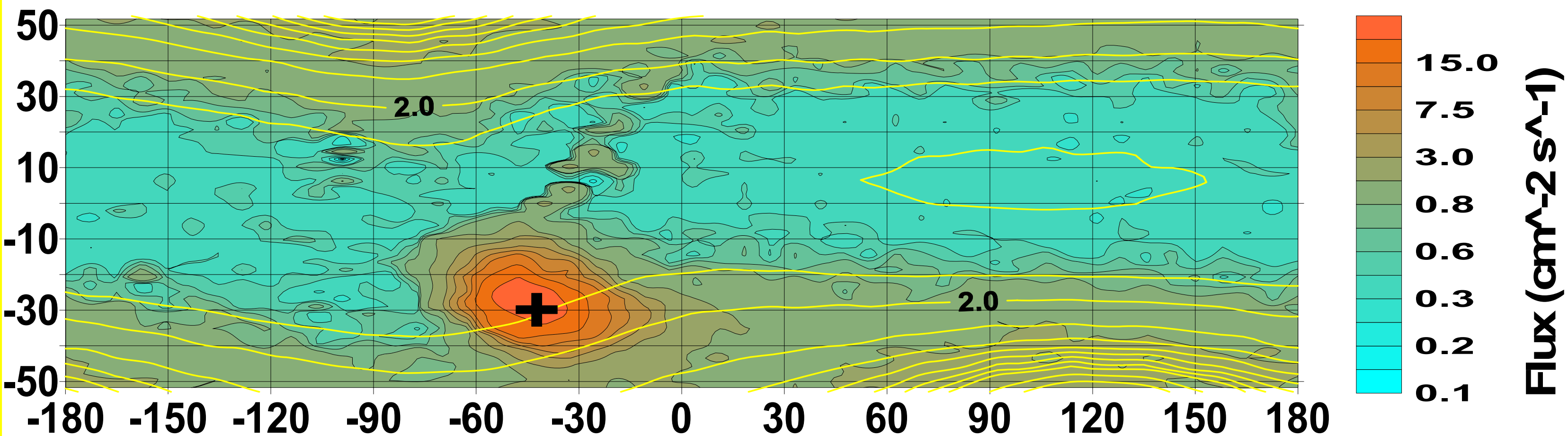
*New results...*

# Move of the SAA central location by altitude

R3D-B2 on Foton M2 data; 1-12 June 2005, 250-306 km

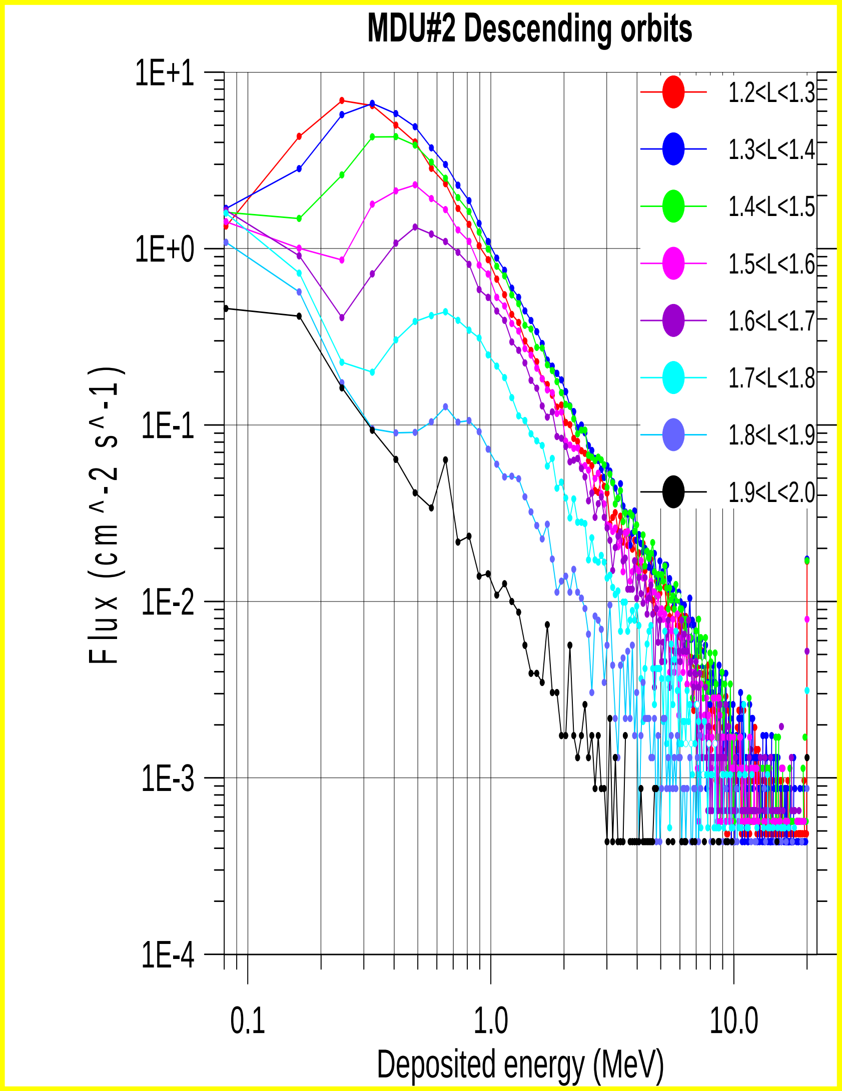


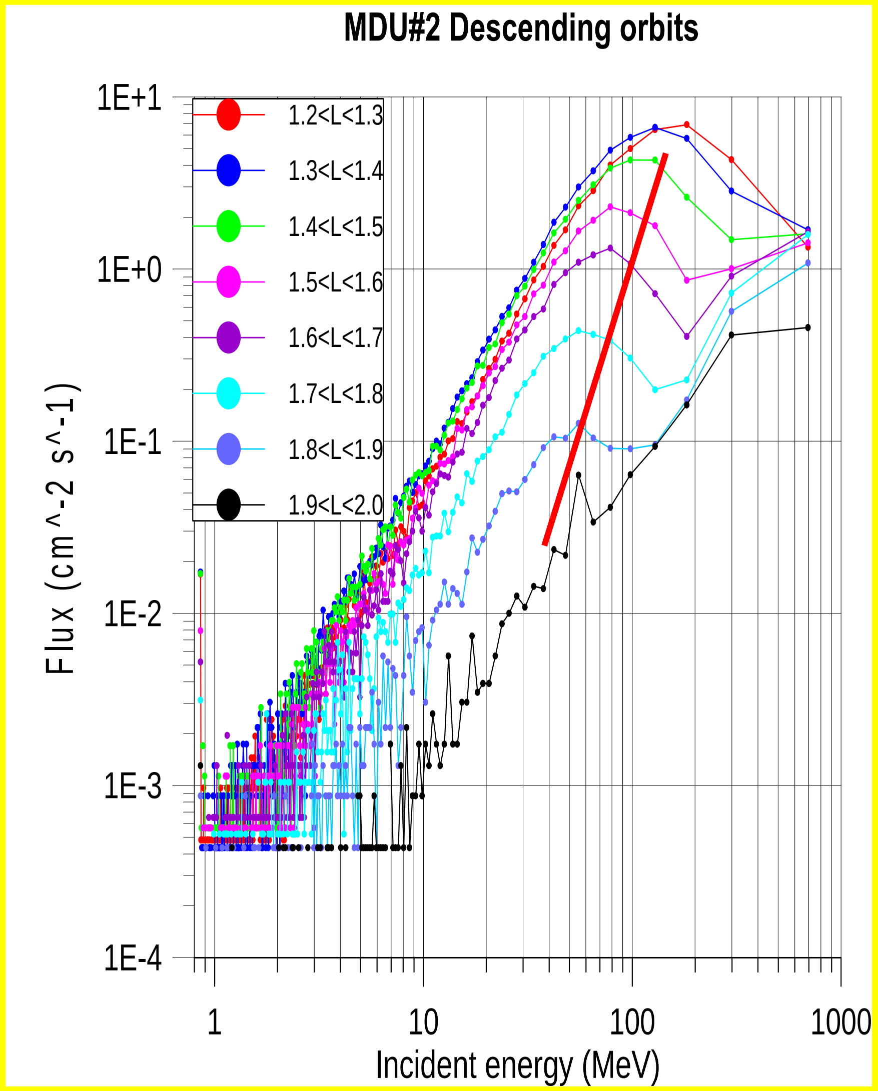

Liulin-E094 MDU#3 on ISS data; June-July 2001, 380-410 km




The Foton M2 SAA central location moves at southeast direction at lower altitudes, because of lower proton incident energy.

# ISS descending orbits SAA crossing variations

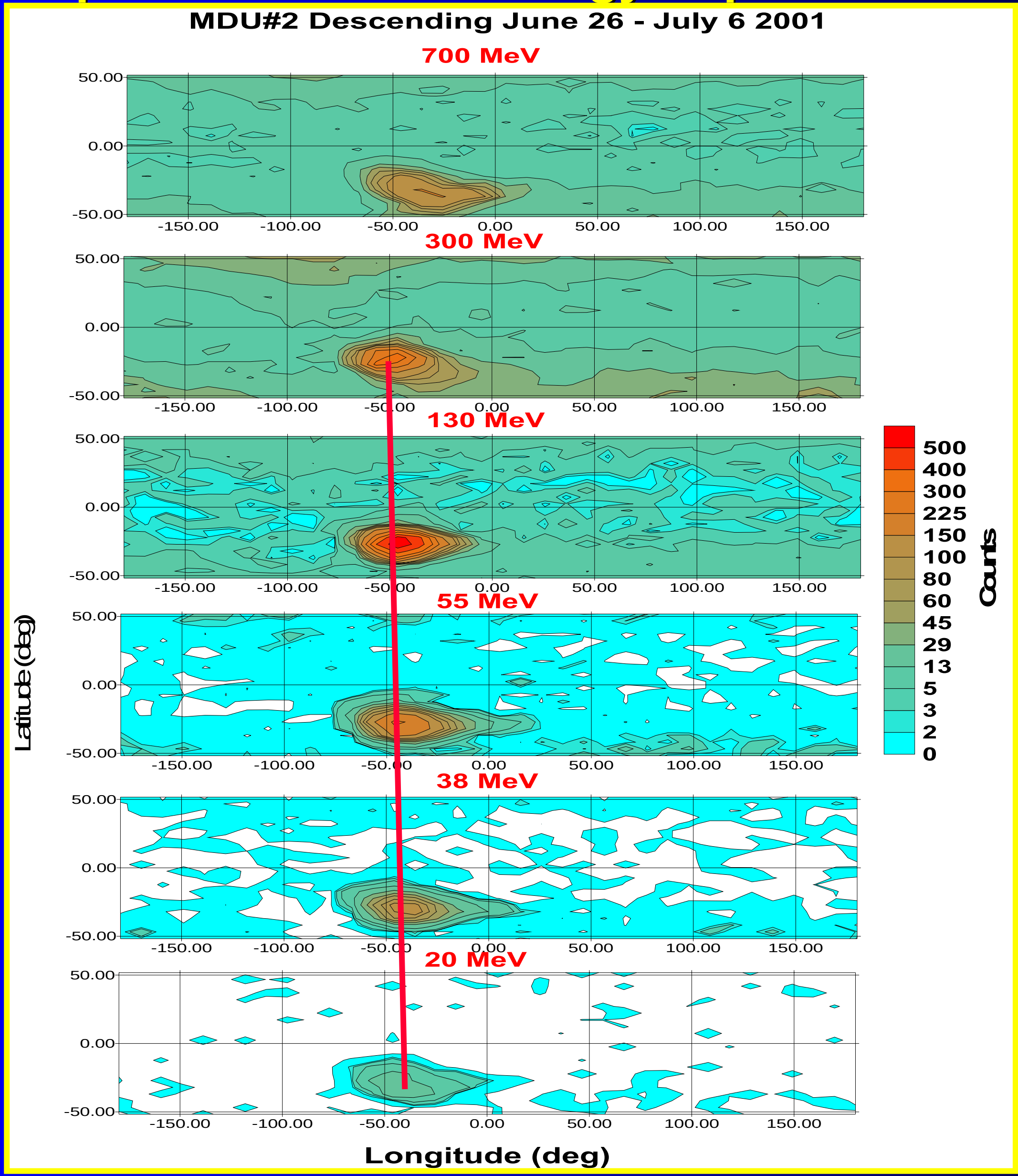


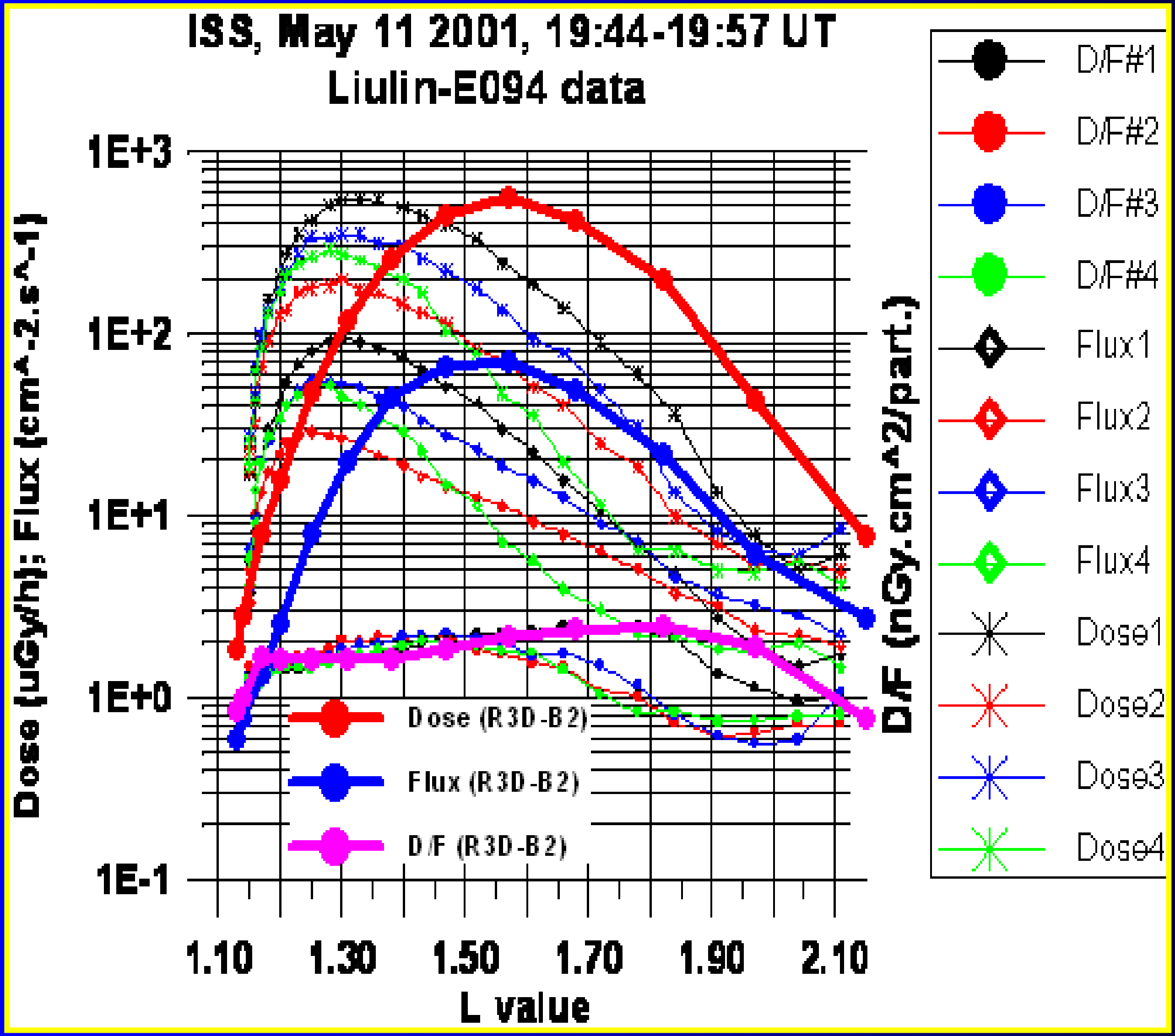

➢The SAA maximum energy on ISS from 100-110 MeV at L=1.25 is moved to lower energy of 40-50 MeV at L=1.85 because of lover magnetic field strength

*New results...*

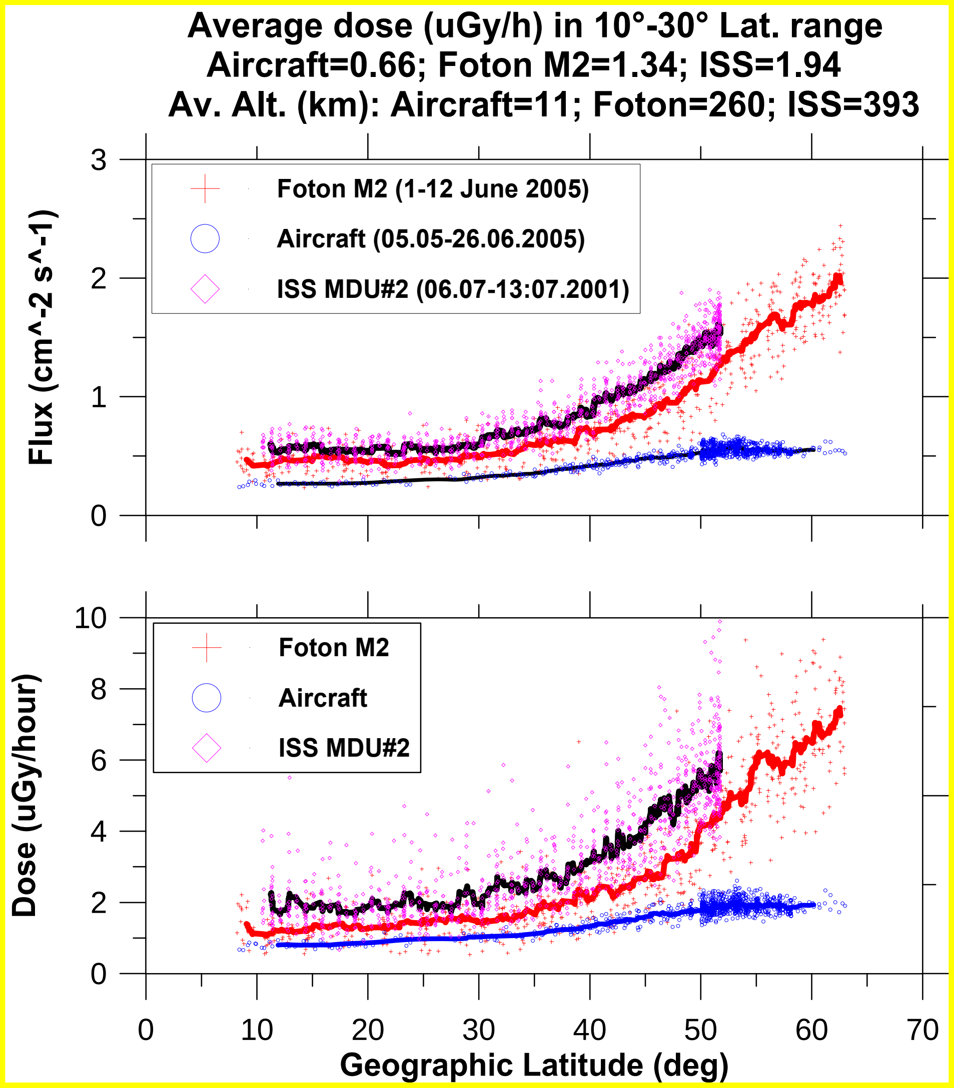
# Movement of the SAA maximum location on ISS in dependence of the energy of protons



# The specific doses are very similar at ISS and Foton M2 in the 1.15<L<1.6



# Averaged doses and fluxes in Northern hemisphere observed on aircrafts, Foton M2 satellite and ISS



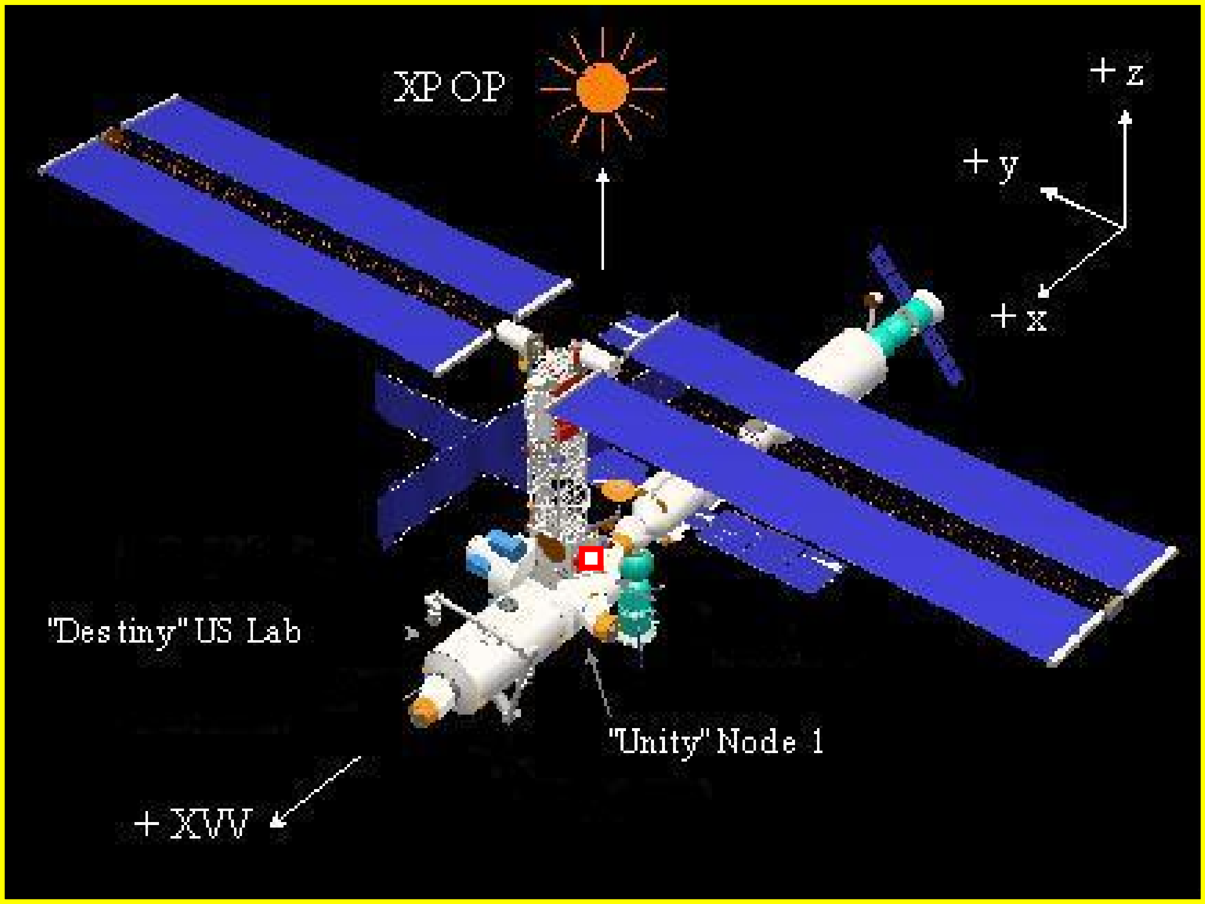

►The relations between the dose and flux values do not changes in the latitude range 10-30 degree and are relatat as 1:2:3.

# Orientation of ISS

ISS was in one of two attitudes:

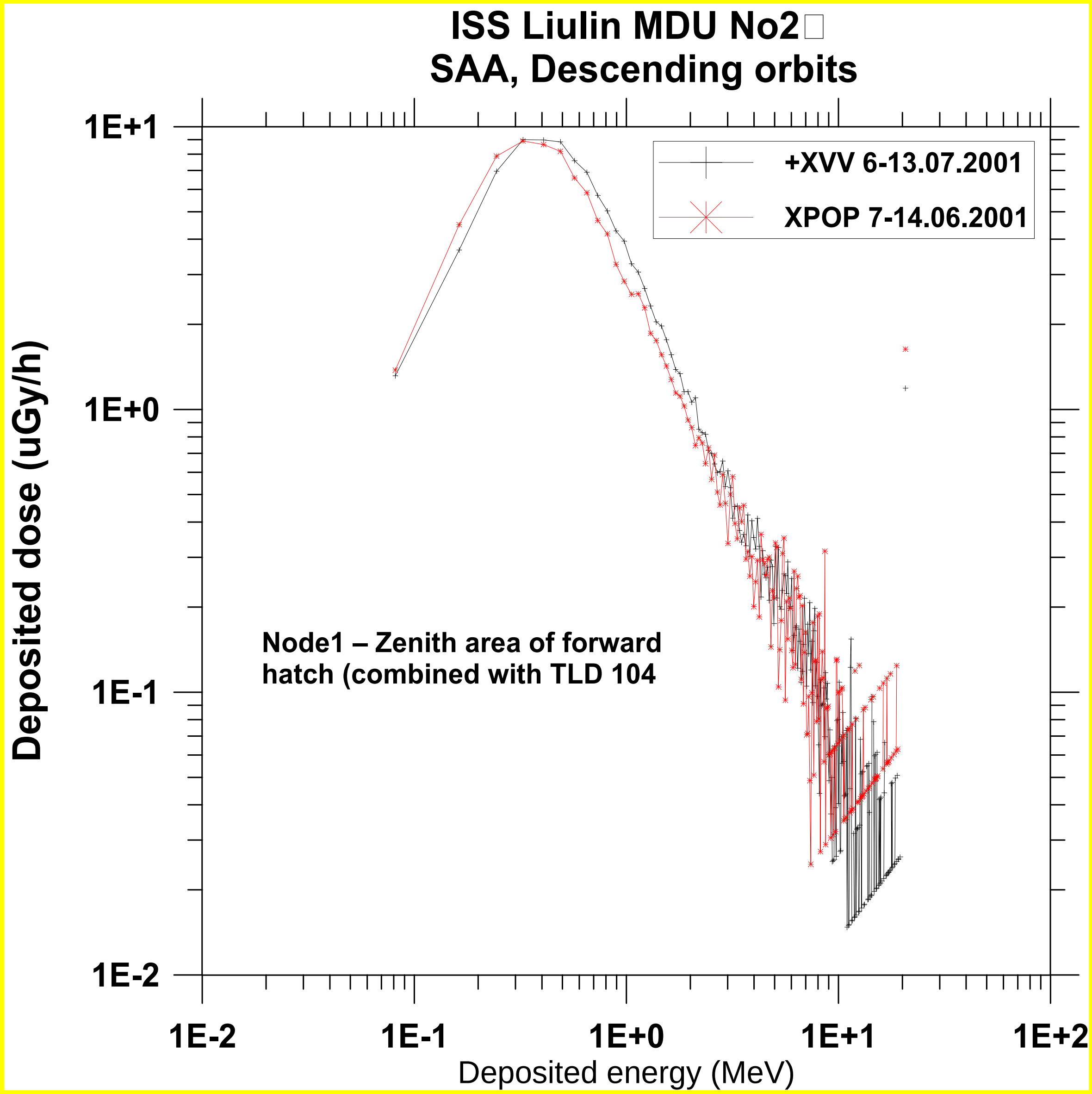
+XVV with the +x-axis parallel to the velocity vector

XPOP (x-axis perpendicular to plane of orbit) with +z-axis constantly pointing toward the Sun & no fixed leading edge




Node1 – zenith area of forward hatch (combined with TLD104)

# In some locations the orientation do not play important role for the dose values

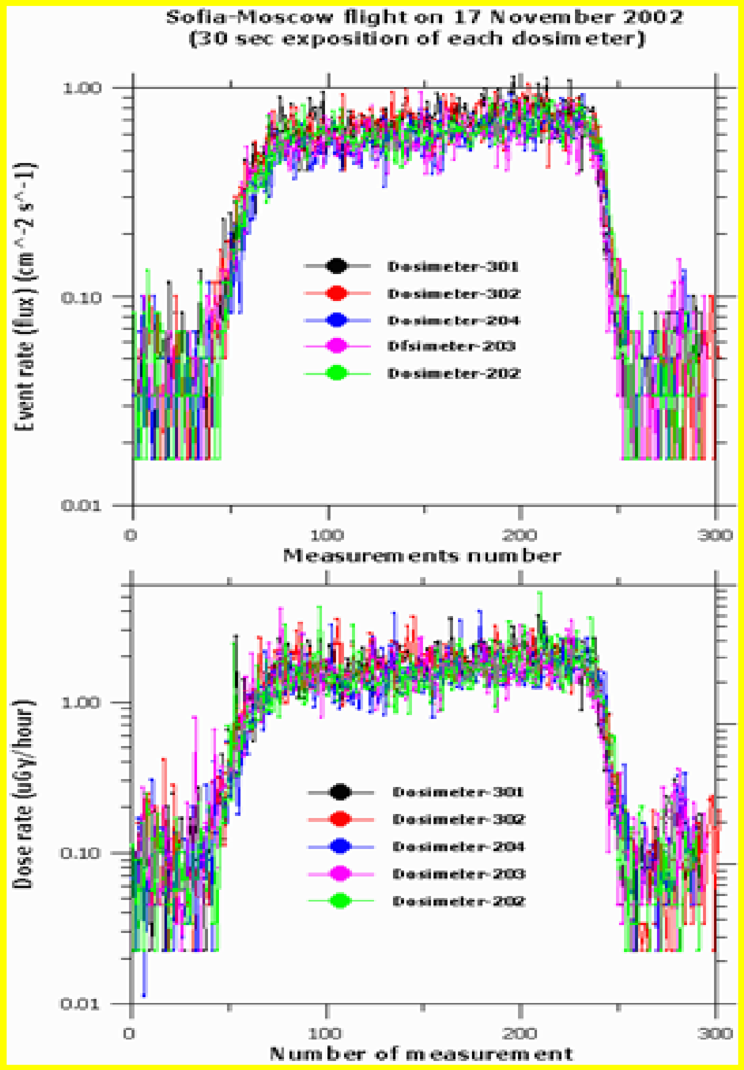


## Future use of Bulgarian build spectrometers

# Expected space and groundbased experiments in which we are involved

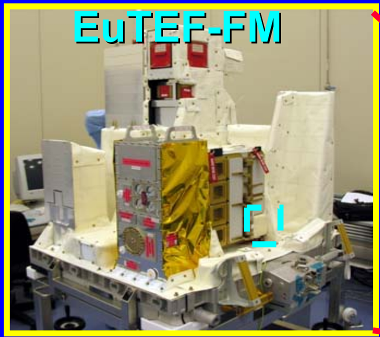
| Expected groundbased and in space experiments | Duration | | | | | |
|---|---|---|---|---|---|---|
| | Start 2007 End 2012 | | | | | |
| | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 |
| Liulin-ISS on RS of ISS | ?? | | | | | |
| Liulin-R rocket experiment | | | | | | |
| R3D-B3 on Biopan on Foton M3 | | | | | | |
| R3D1 on ISS ESA-Columbus EuTef | | ?? | ??? | | | |
| R3D2 on Russian Segment of ISS | | ?? | ??? | | | |
| RADOM on Chandrayaan-1 satellite in 100 km Moon orbit | | | | ??? | | |
| Liulin-F on Phobos-Grund | | | | | ??? | |
| Liulin-R, ALOMAR, Norway | | | | | | |
| Liulin-M on Mousala 2925 m | | | | | | |

# 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 in the end of 2007


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

## The R3D1/2 UV and space radiation spectrometers is expected to be launched inside of EXPOSE facility to Russian segment of ISS and to ESA COLUMBUS module in 2008. They are developed with the University in Erlangen, Germany







R3D/1 Flight unit mounted in the EXPOSE facility (May 2003)

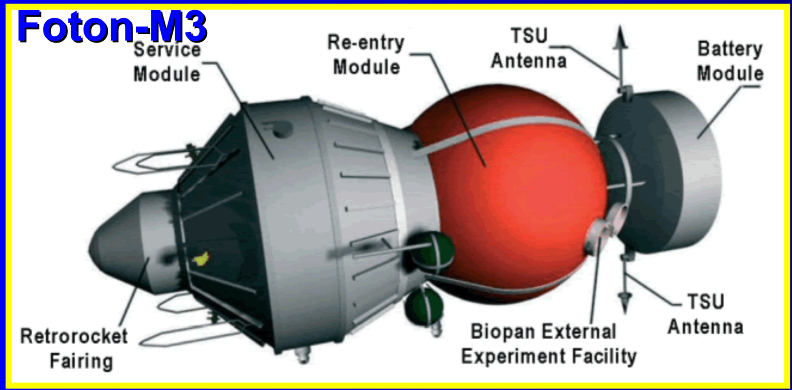

Vibration tests in ESA May, 2003

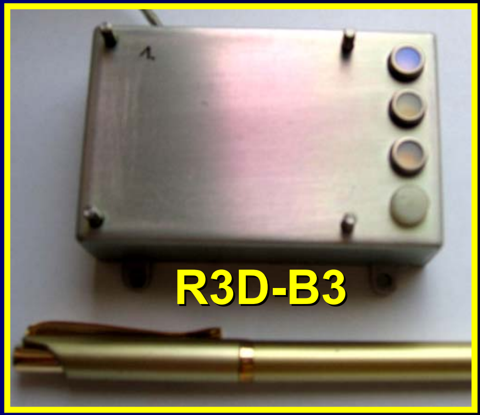
**R3D DIMENSIONS:**

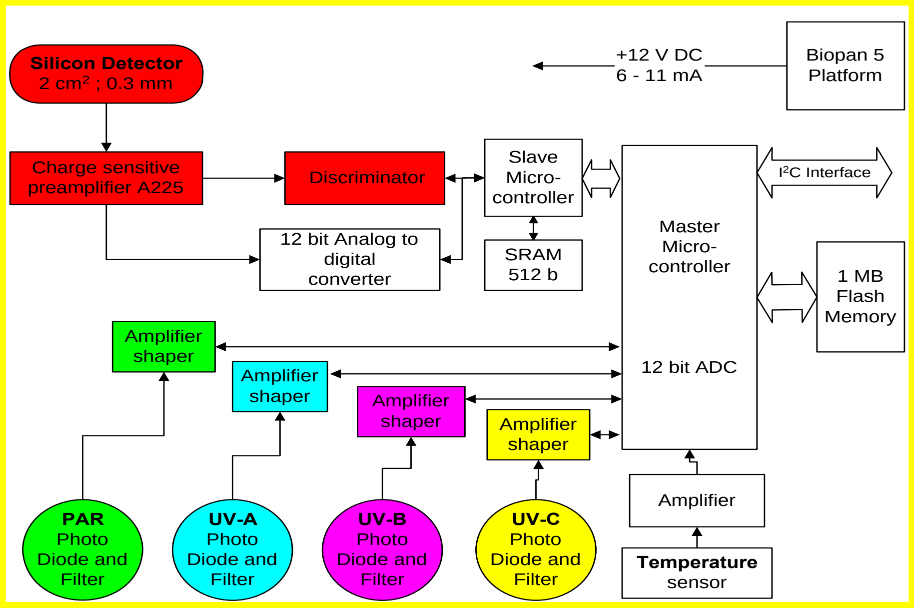
Weight: 189 g
Size: 76x76x36 mm
Consumption: 120 mW

*New results...*

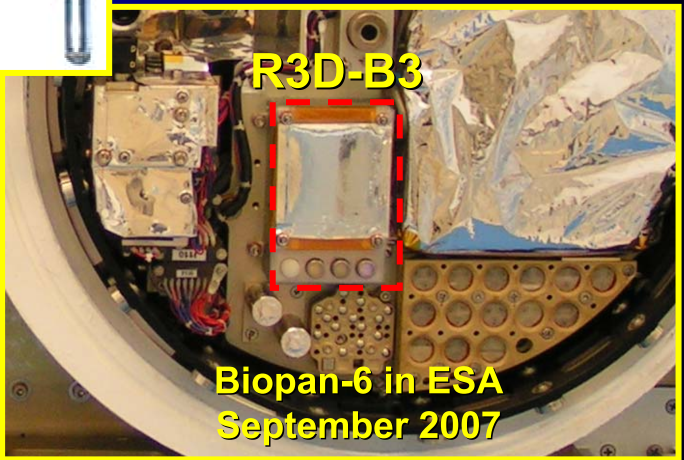
# R3D-B3 UV and space radiation spectrometer for ESA Biopan-6 facility outside of Foton M3 satellite will be launched on 14 September 2007. The spectrometer is mutually developed with the University in Erlangen, Germany




Block-Diagram of R3D-B3 instruments




*New results...*

# 3 more experiments are under development


**Liulin-R instrument for ESA-Norwegian rocket Launch in October 2007**

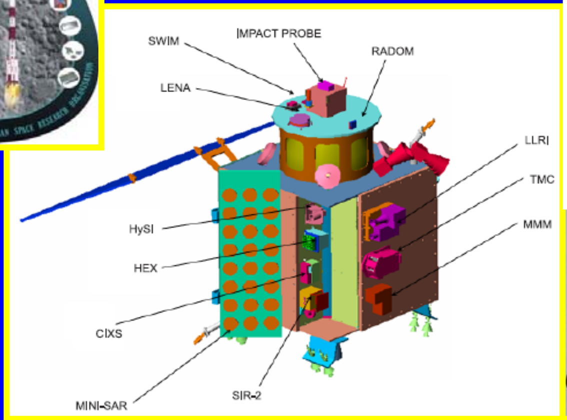
**Rocket launch up to 280 km from Andoya, Norway (69.3° N)**

**Weight: 105 g**
**Size: 104x40x20 mm**
**Consumption: 120 mW**

**Liulin-F instrument for Russian Phobos-Ground satellite Launch in 2010.**

**On the Phobos surface for 2 years**

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




**RADOM instrument for Indian Chandrayaan-1 satellite. Launch in April 2008. Lifetime 2008/20010**

**Satellite at 100 km over the Moon surface for 2 years**

**Weight: 98 g**
**Size: 104x40x20 mm**
**Consumption: 120 mW**

# Conclusions

- Data obtained by Liulin type instruments on ISS, Foton M2 satellite and aircrafts since 2001 are analyzed to try to evaluate the contribution of neutron component in the spectra of energy deposited in Si-detector. The dose in Si, D(Si), was converted to obtain an apparent dose equivalent Happ;
- The conversion coefficients used were obtained during calibrations of Liulin type instruments at the CERN (CERF) and on the base of intercomparison with TEPC during common measurements in dedicated aircraft flights;
- Liulin MDU values of Happ obtained in general underestimate a little the neutron component obtained by TEPC;
- Best agreement with the values results of the comparison with TEPC are obtained at L>2.8;
- As expected the other radiation belt spectra contains very low neutron component in the spectra.
- Expected new space experiments with Liulin type spectrometers on Foton M3 satellite, ISS and Indian Moon Chandrayaan-1 satellite are shortly presented

# Thank you for your attention

# All MDU all data on ISS for July 6-13 2001