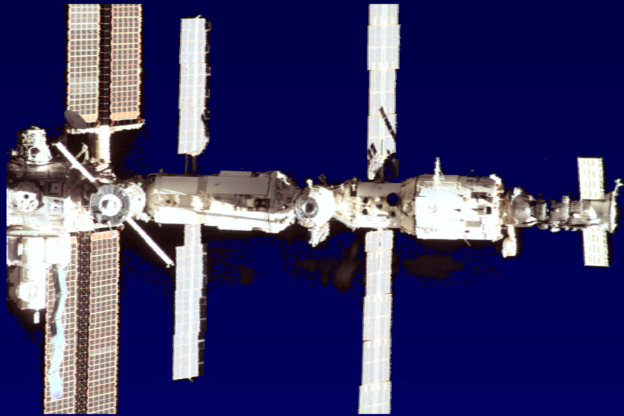

WRMISS 15

"Villa Mondragone Conference Center"

7-9th September 2010

OVERVIEW ON THE RADIATION QUANTITIES OBSERVED BY LIULIN-5 INSTRUMENT IN THE SPHERICAL TISSUE-EQUIVALENT PHANTOM ON ISS

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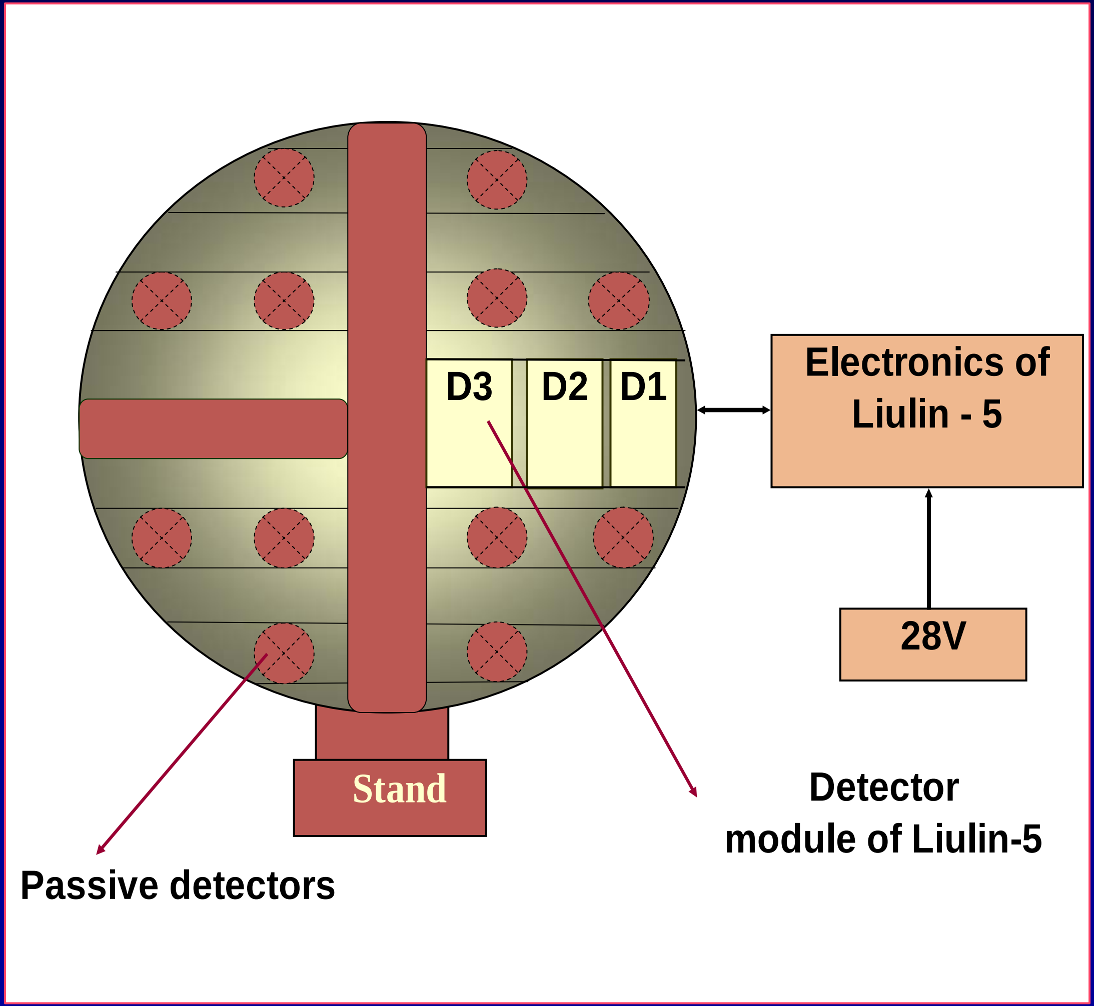
LIULIN – 5

- Experiment Liulin-5 for investigation of the radiation environment dynamics within the spherical tissue-equivalent phantom on ISS started in June 2007 on RS of ISS.
- Liulin-5 experiment is a part of the international project MATROSHKA-R.
- We present some results of analysis of the data obtained in 2007- 2009-minimum of 23 Solar Cycle.

Block - diagram of Liulin - 5 connections in the phantom



Goals

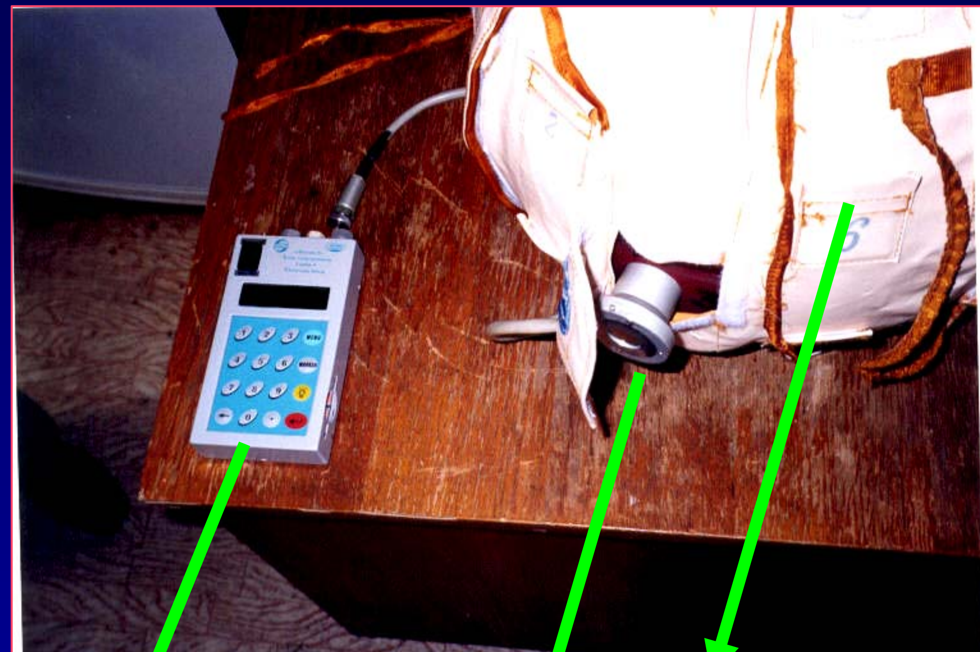
- Liulin-5 measures simultaneously at 3 different depths of the radial channel of the spherical phantom:
  Energy Deposition Spectra, Dose Rate & Particle flux - then Absorbed Dose D;

- Measurement of the Linear Energy Transfer (LET) spectra in silicon – then assessment of LET(H_2O), Q=f(LET), given in ICRP-60 and Dose Equivalent H; H=DxQave.

External view of <u>Liulin-5</u>

Two units: a **detector module** and an **electronic block**.

Liulin-5 in the <u>spherical phantom</u>

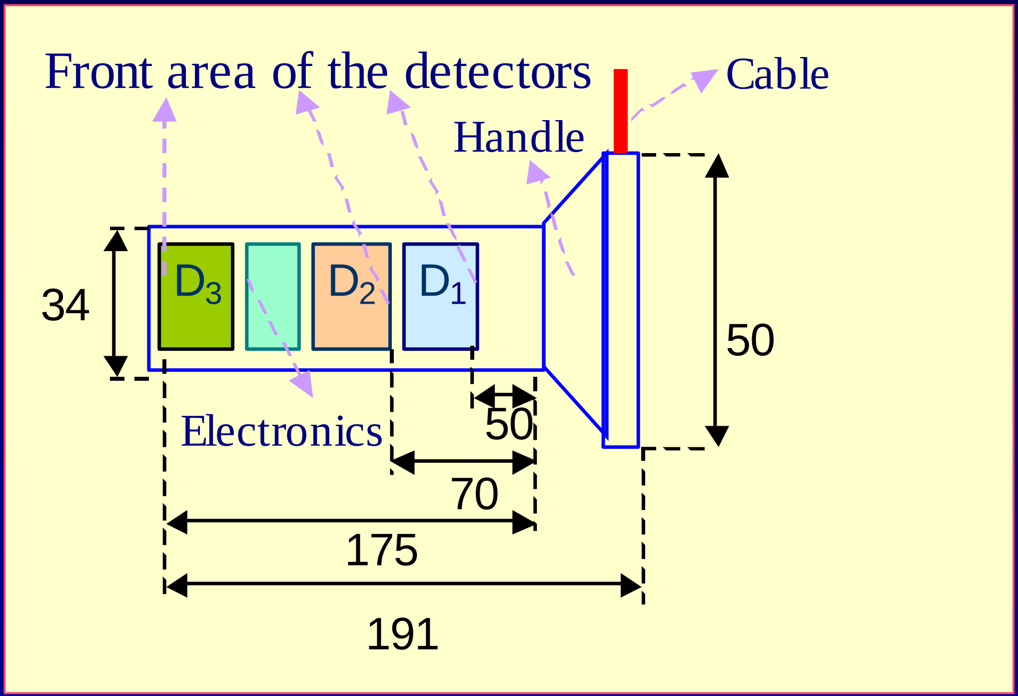


Phantom

Electronic Block

Detector Module

Lay-out of detectors and electronics in the detector module



- D1 and D2 operate in coincidence mode to obtain LET. FOV is 81.4 degrees;
- Distances: D1-D2=20 mm, D1-D3 = 125 mm, D2-D3 = 105 mm. Detector's thickness 370 µm. Detector's diameter 17.2 mm.
- Geometry factor for a single detector – 14.6 cm^2.sr.
- Geometry factor for the D1-D2 telescope coincidence events number is 2.01 cm^2.sr .
- Positions of D1 and D2 correspond to the depth of BFO.

Parameters provided

- Absorbed dose rate in the range 0.04 $x10^{-6}$ Gy/h - 0.04 Gy/h;
- Particle flux in the range 0 - $4x10^2$ particle/(cm^2.sec);
- Energy deposition spectra in 512 spectral channels:
- In 1-st and 2-nd detectors in the range 0.45 – 63 MeV;
- in 3-rd detector in the range 0.2 –10 MeV;
- LET(H_2O) spectra in the range 0.65 –90 keV/µm.
- All events, exceeding the upper energy deposition and/or LET limit, are recorded in the last spectral channel of the respective spectrum.

Measurement modes

Two measurement modes are pre - programmed:

- Standard - dose and flux rates have a time resolution of 90s, the cycle of measurement of energy deposition spectra and LET spectra is 85 minutes, but may be interrupted by switching to fast mode.
- Fast - dose and flux rates have a time resolution of 20 s, the cycle of energy deposition and LET spectra measurement is 15 min. This mode is used for measurements in the SAA or during SPE. Switching from standard to fast mode is made automatically. Because of the fixed length of cycle, measurements in fast mode may continue few minutes after ISS has already passed SAA.

Llulin -5 in the Spherical Phantom on ISS

Detector module

LIULIN-5 in the Phantom in Piers-1 module of ISS –activated 28 June 2007.

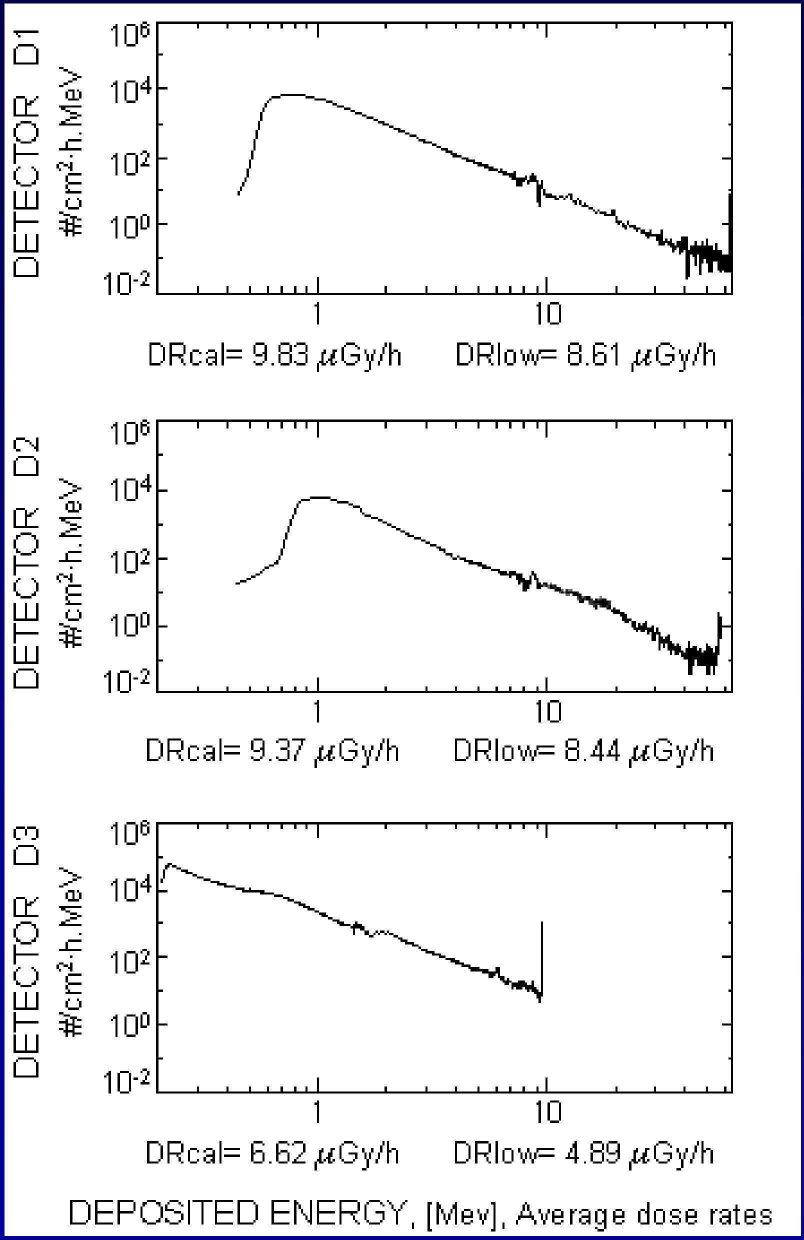
RESULTS

- Absorbed energy spectra, LET spectra.
- Dose and flux distribution in the radial channel of the phantom.
- Dosemetric quantities from the different components of the radiation environment in ISS.

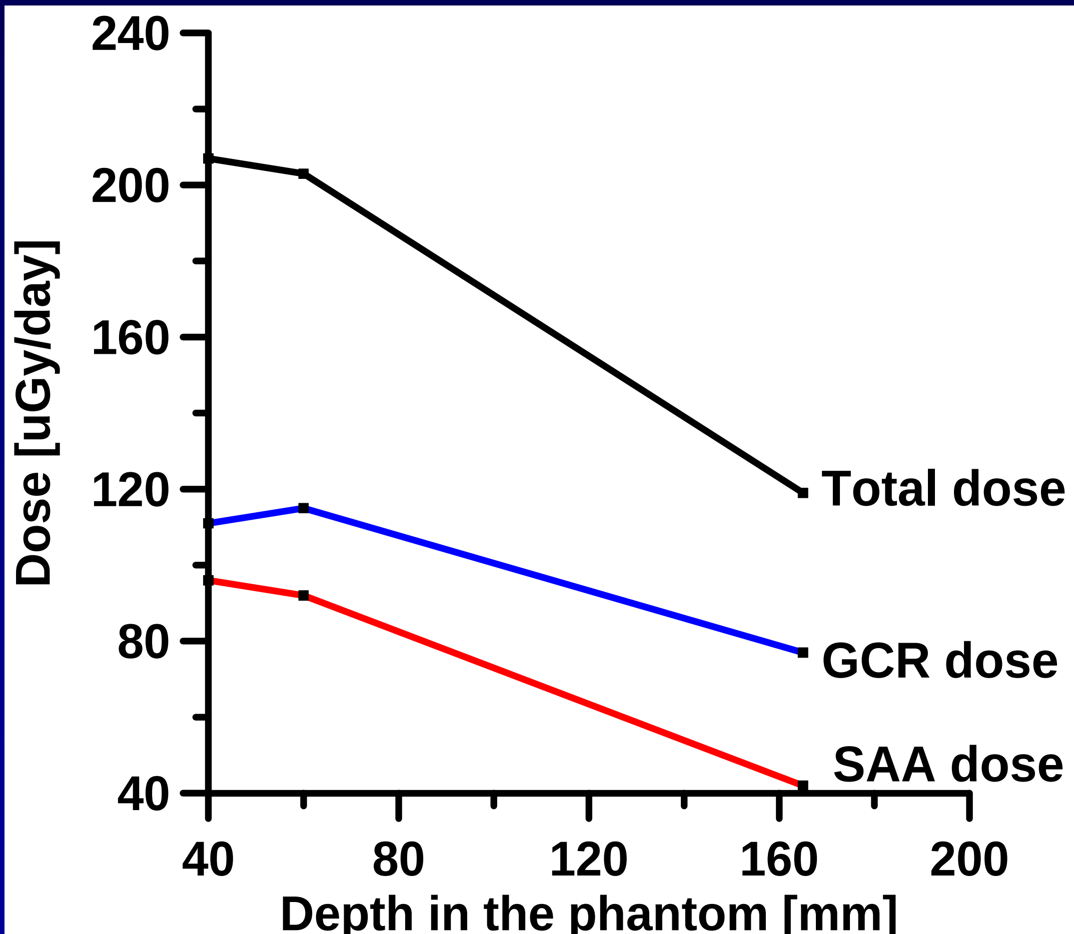
Energy deposition spectra and dose rates at 40, 60 and 165 mm depth in the radial channel

<u>5-10 September 2007</u>

- **Differential fluxes of the energy deposition spectra in 3 detectors;**
- **Dose rate in every detector and dose rates in the equal for all detectors energy deposition range 0.45-10 MeV (0.65 < LET <14 keV/μm).**

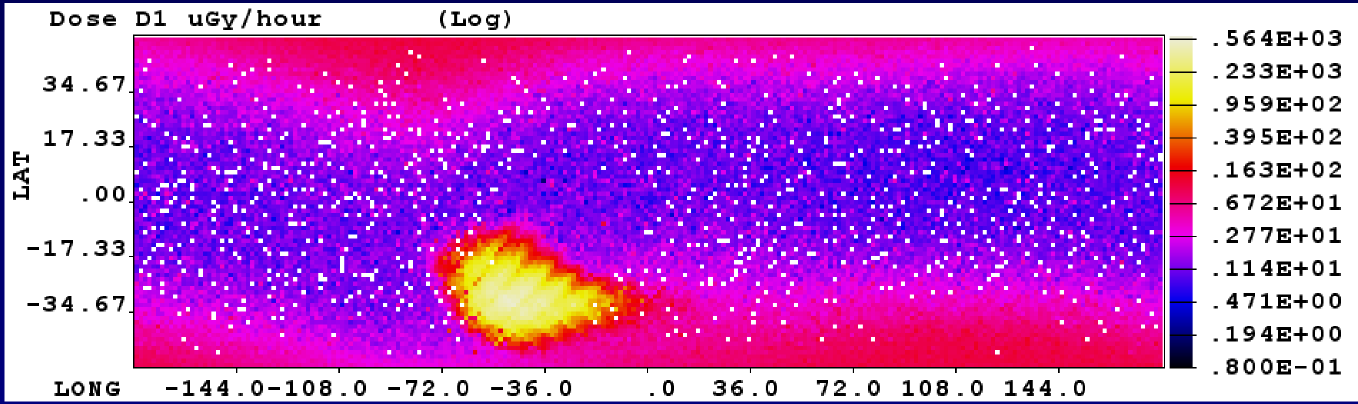


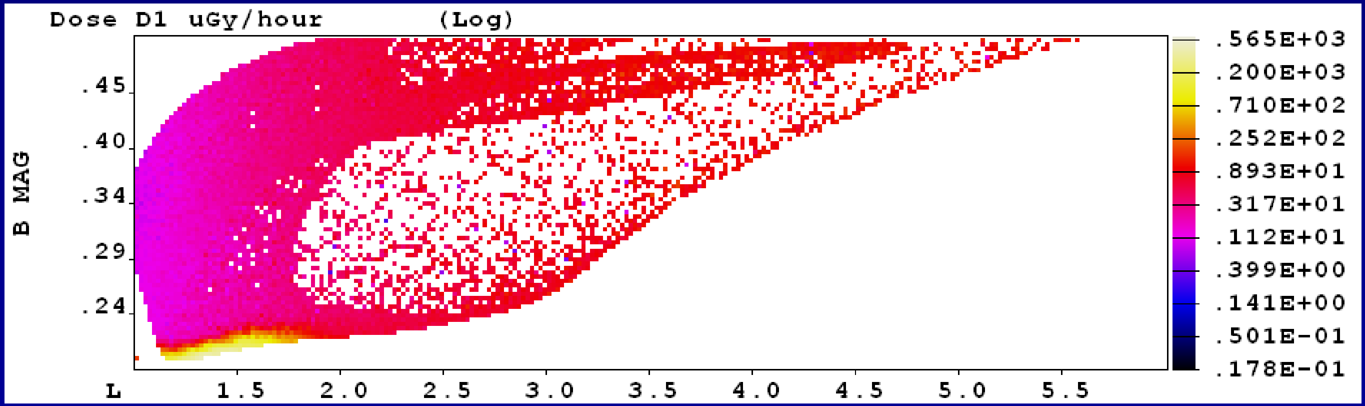
Absorbed dose depth distribution
5-10 September 2007



- Absorbed doses from particles of 0.65 < LET <14 keV/µm measured at 40, 60 and 165 mm depth .
- The total dose at the centre of the phantom is 1.7 times less than at BFO depth. In SAA this decreasing is 2.3.
- SAA data-from fast mode, GCR –from standard mode measurements.

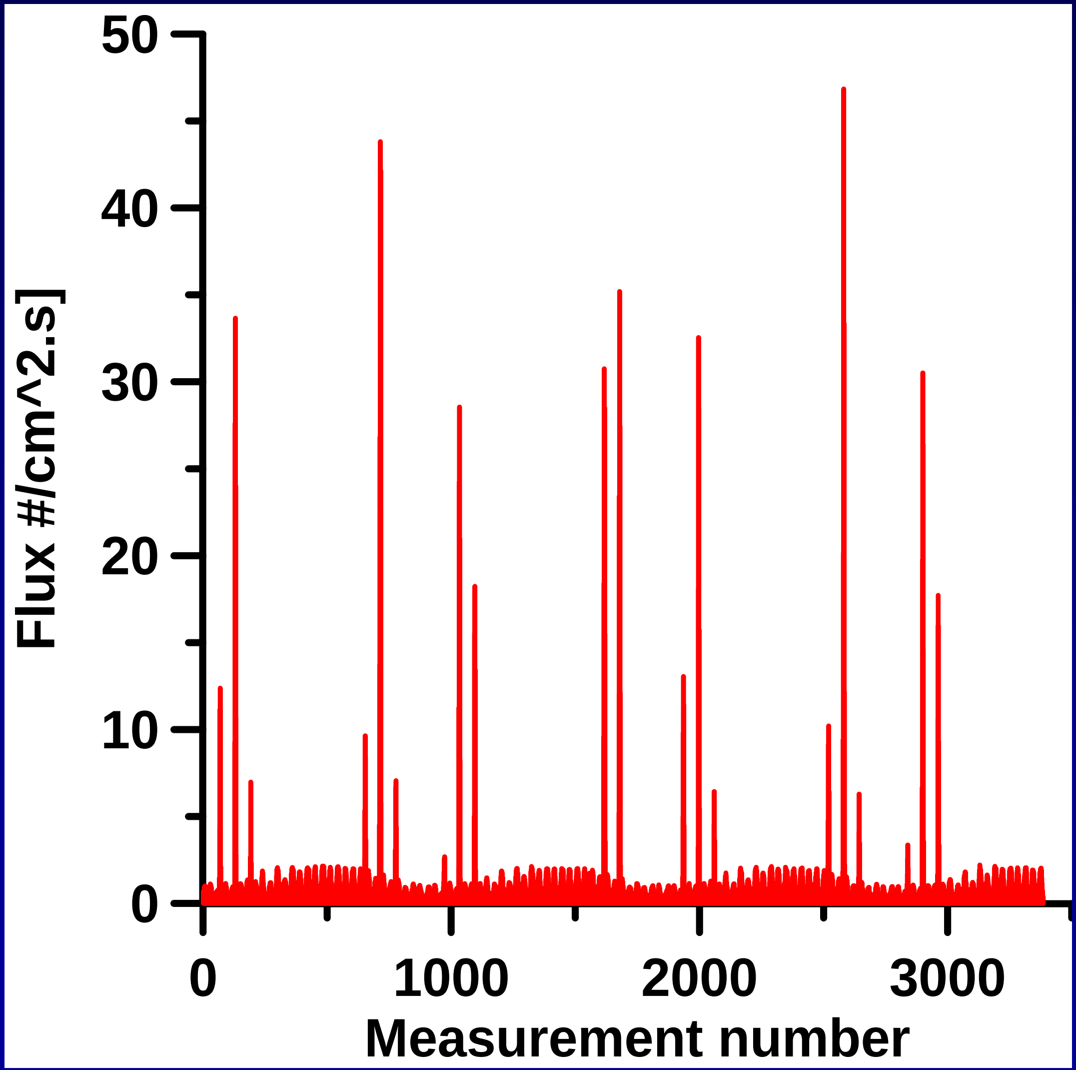
Distribution of dose rate in D1 in geographic and L-B coordinates (5 February - 8 April 2008)





Dose rates distribution at 40 mm depth: D1 ≤ 565 μGy/h. Time resolution 20s in SAA, 90s outside it.

Flux distribution at the centre of the phantom-August 2009

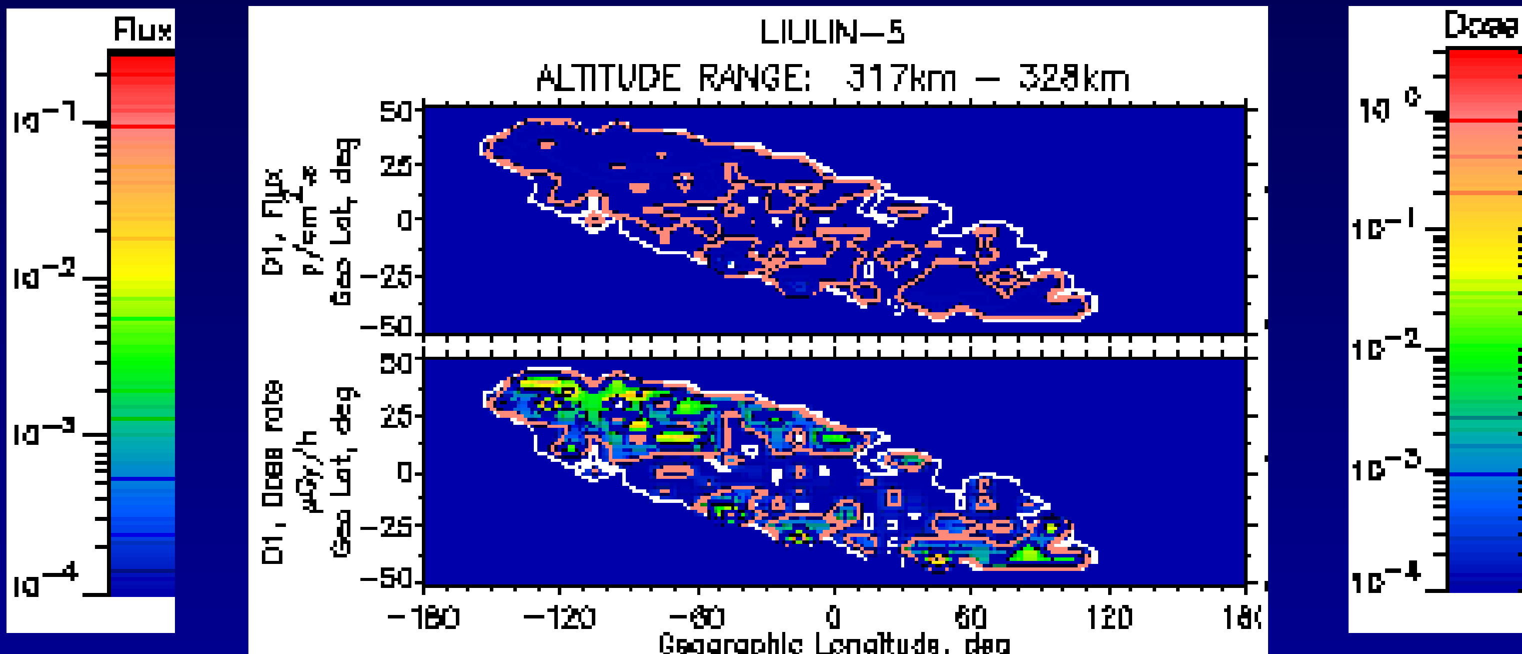


Data for 26-28.08.2009.

The maximum flux at the the centre of the phantom in SAA is ~ 45 part/cm^2.s.

Outside SAA 0.2÷2.1 part/cm^2.s.

Dependence of flux and dose rate on ISS altitude



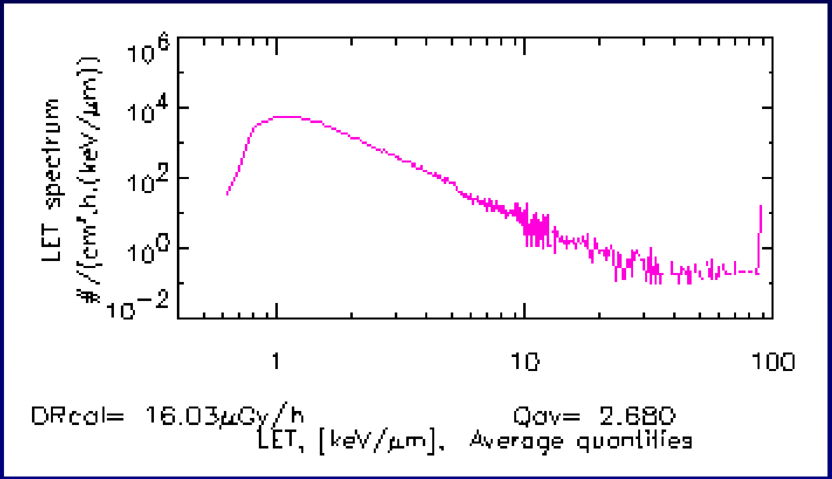
At 317-328 km altitude the biggest flux and dose rate at the depth of blood-forming organs of human body are from GCR at high geographic latitudes. The inner radiation belt protons do not penetrate at these depths.

Absorbed dose in the range 0.65 ≤ LET ≤ 90 keV/μm, measured by D1

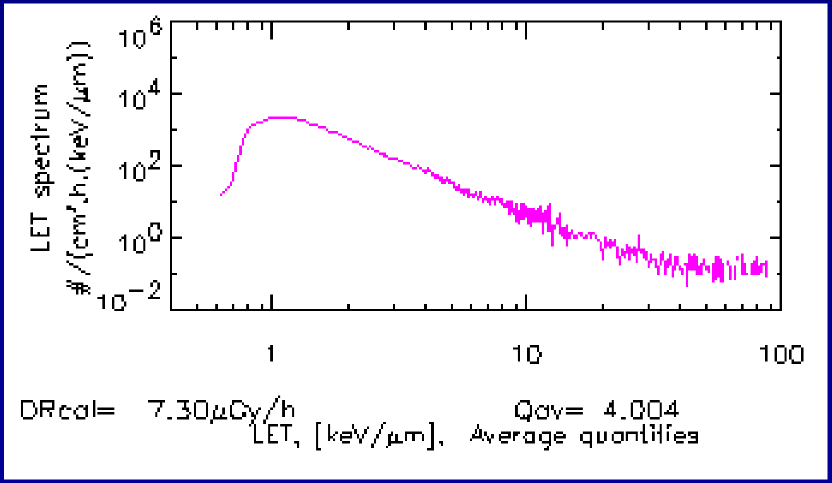
Date	SAA [μGy/day]	GCR [μGy/day]	Total [μGy/day]
3-10.07. 07	91.8	122.9	214.7
5-10.09. 07	101.4	128	229.4
3-13.05.08	67.8	123.8	191.6
24.10-01.11.08	84.8	130.1	214.9

Absorbed doses at depths of BFO are 35-45% from SAA and 55-65% from GCR .

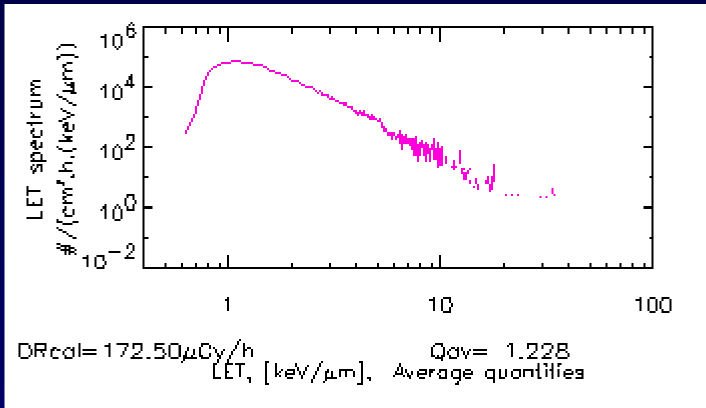
LET spectra

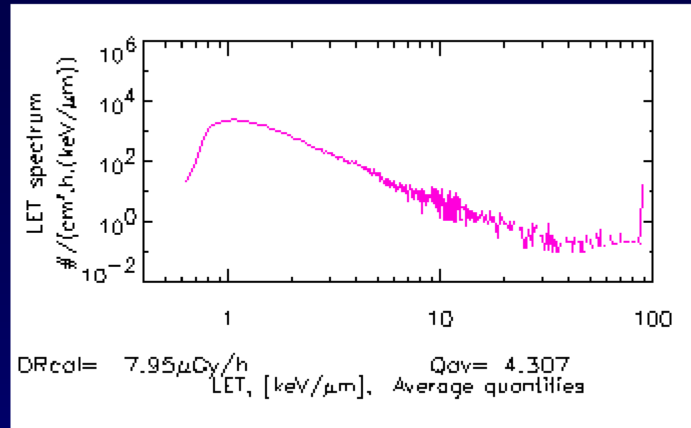


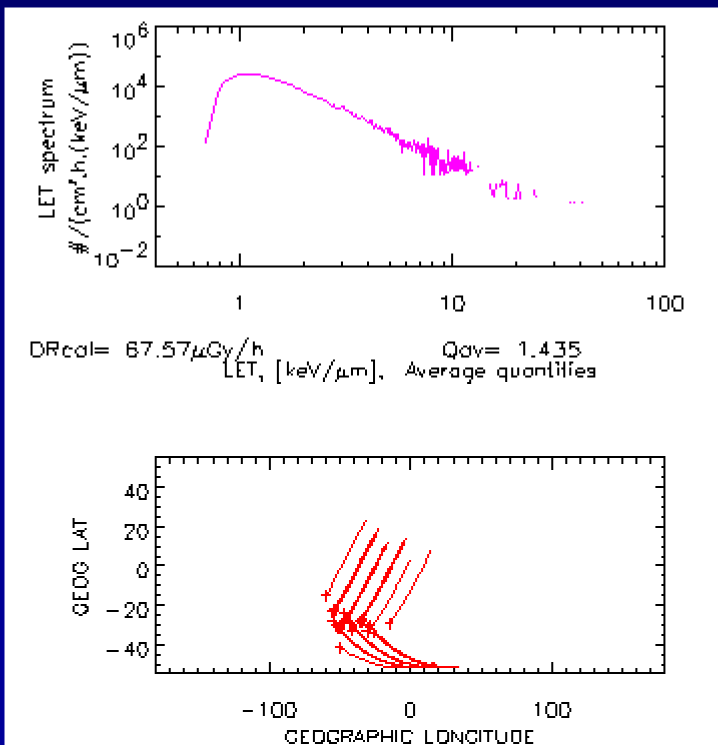
Total LET spectrum for 5-10.09.2007

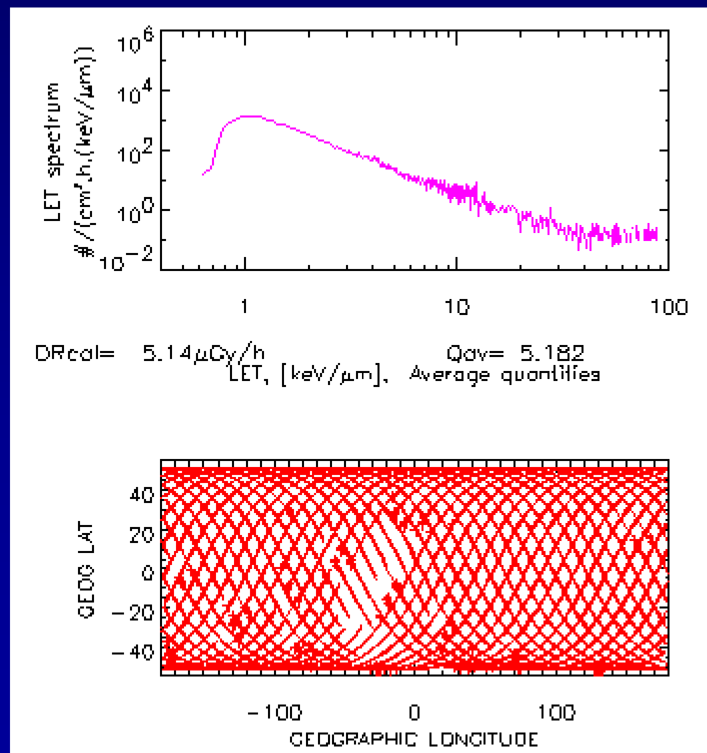


Total LET spectrum for 3-13.05.2008









On the left – LET spectrum in SAA, on right- LET spectrum of GCR.
Upper -data for 05-10.09.2007
middle -data 03-13.05.2008
Bottom –ISS orbits

Q defined by LET spectrum

Date	SAA		GCR		Total	
	Qav 0.65 ≤ LET ≤ 90 keV/µm	Qav 0.65≤LET ≤ 88.1 keV/µm	Qav 0.65 ≤ LET ≤ 90 keV/µm	Qav 0.65≤LET ≤ 88.1 keV/µm	Qav 0.65 ≤ LET ≤ 90 keV/µm	Qav 0.65≤LET ≤ 88.1 keV/µm
3-10.07. 07	1.3	1.22	4.76	2.75	3.2	2.03
5-10.09. 07	1.23	1.15	4.31	2.42	2.68	1.77
3-13.05.08	1.43	1.35	5.18	3.17	4	2.54
24.10-1.11.08	1.3	1.19	4.14	2.59	2.83	1.9
23-28.02. 09	1.33	1.33	4.89	2.9	4.23	2.59

Events in the last spectral channel LET ≥90 keV/µm are between 0.08-0.17% of all events in the LET spectrum, but they contribute significantly to Qave.

Dose rate of radiation with low and high LET, measured in D1-D2 telescope for the period <u>6 February - 8 April 2008.</u>

LET range	Absorbed dose [μGy/h]	Qav	Dose equivalent [μSv/h]
LET <10 keV/μm	6.50	1.0	6.50
90keV/μm≥ LET >10 keV/μm	1.86	15.19	28.28
90keV/μm≥ LET > 0.65 keV/μm	8.36	4.15	34.78

The radiation with low LET presents about 85% of total absorbed dose at the depth of blood forming organs of human body, but its contribution to the dose equivalent is only about 20%. The main part of the dose equivalent (80%) is from high LET particles. For the period 5-10 September 2007 the dose equivalent from particles of LET>10 keV/μm comprises 66% of total dose equivalent at the depth of blood forming organs.

CONCLUSION (1)

- Data obtained in July, 2007-August, 2009 show that the dose rates and fluxes measured in the inner radiation belt in SAA strongly depend on the shielding of detectors in the phantom and ISS orbital parameters.
- The trapped radiation contributes 35-45% and GCR contribute 55-65% to the total absorbed doses at the depths of blood forming organs in the phantom.
- The total absorbed dose at the centre of the phantom is at least 1.6 lower than at the depth of blood forming organs and the decreasing of the doses in the radial depth is due to self-shielding of the phantom against trapped protons.

CONCLUSION (2)

- At the minimum of the 23rd solar cycle the dose equivalent of GCR and their secondary particles represents ≥ 75% of total dose equivalent at the depths of BFO and ≥ 65% of the total dose equivalent is from particles with LET > 10 keV/μm.

This shows the importance of measurements of high LET particles and LET spectrum on ISS with active radiation detectors .

Such measurements should be planned for the upcoming flights to Mars and Moon to obtain data for radiation doses to future interplanetary missions crew.

Future plans (1)

➢ A new experiment with the charged particle telescope Liulin-F will be flown on Phobos-Grunt interplanetary mission. Expected launch –end 2011.

➢ Measurements during the cruise phase, on Mars's orbit and on the surface of Phobos.

➢ Two dosemetric telescopes in perpendicular directions.

Single detectors

- Absorbed dose rate $\Rightarrow$ 0.04 x 10^{-6} - 0.1 Gy/h.
- Particle flux $\Rightarrow$ 0 - 10^4 particle/(cm^2.s).
- Energy deposition spectrum.

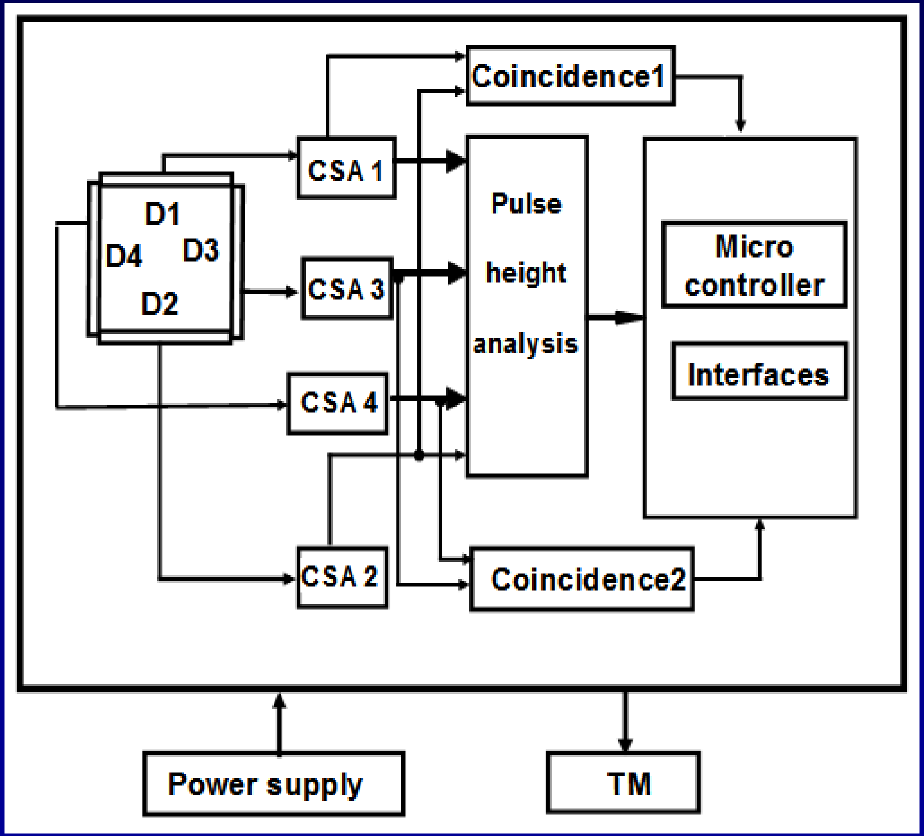
Dosemetric telescopes

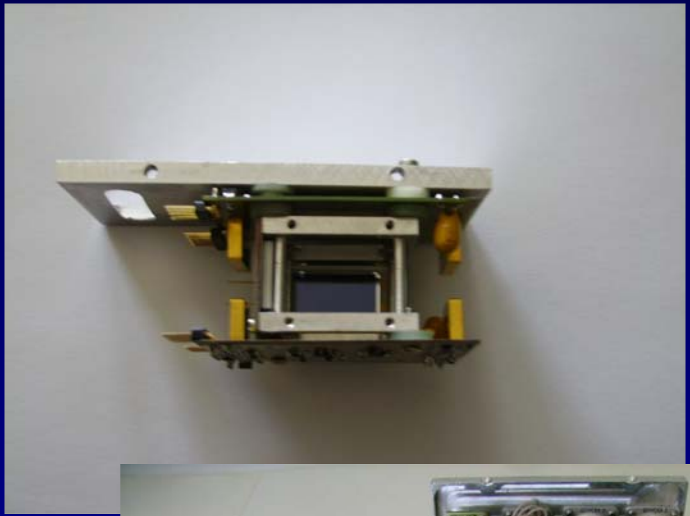
- LET spectrum (in H2O) $\Rightarrow$ 0.5–120 keV/μm.

Colaboration

➢ STIL-BAS, IMBP-Russia, NIRS

Liulin-F bloc diagram and internal view





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- NIRS - Japan.

Thank you for attention!