Variation of absorbed doses onboard of ISS Russian Service Module as measured with passive detectors

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Introduction

- cosmic radiation – risk for astronauts (dose equivalent rate in low-Earth orbit about 200 times higher than on the Earth surface)
- to estimate risk – dose distribution in the spacecraft compartments in real space flight conditions
- passive detectors – luminescent (low-LET component) + track etch detectors CR-39 (high-LET component (> 5 keV/μm))

Aim of the work

- to measure LET spectra of particle fluxes, absorbed dose, and dose equivalents at different locations inside the Russian Service Module (SM) of International Space Station (ISS)

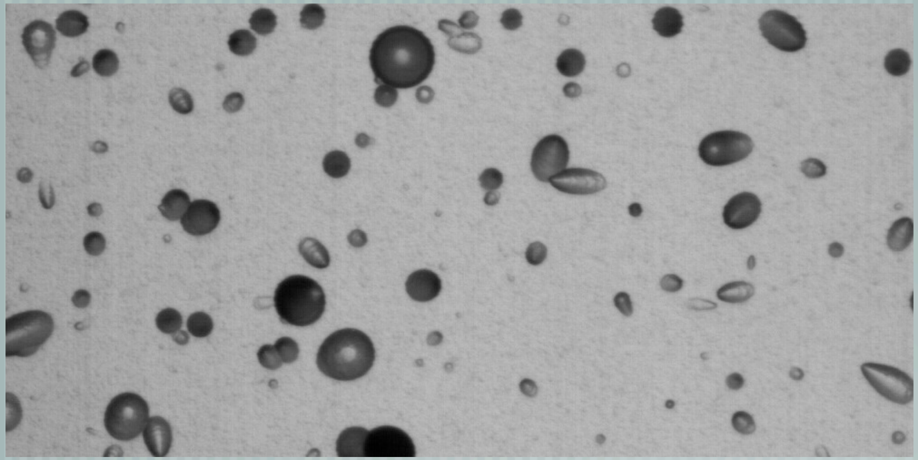
Luminescent detectors

- Thermoluminescent detector (TLD)
  - TLD-100 – LiF: Mg,Ti (Nagase Landauer Ltd)
- Radiophotoluminescent detector (RPLD)
  - FD-P8.5-7 – glass (Chiyoda Technol Corporation)
- standard processing methods (annealing, read-out luminescence and quality control) established by the companies
- decreased efficiency for high-LET radiation
- no information about LET spectra

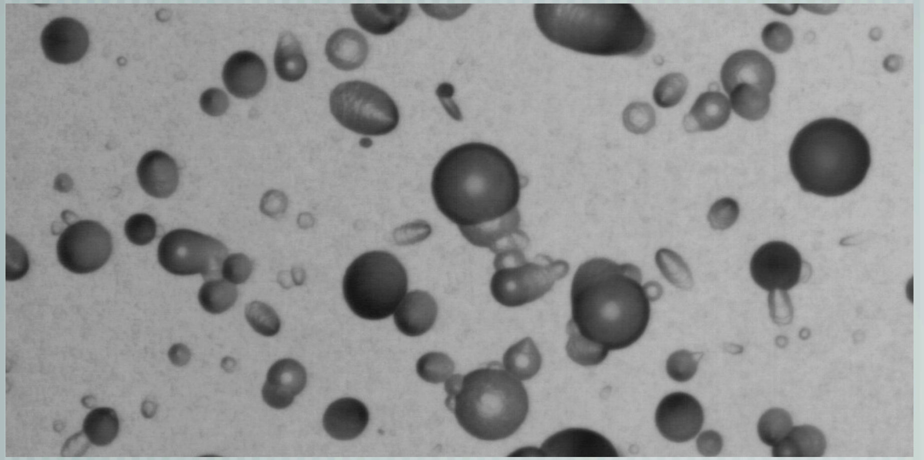
CR-39 Plastic Nuclear Track Detectors

- thermoset polymer sensitive to charged particles with $LET_{\infty}H_2O \sim 5 - 1500$ keV/μm
- HARZLAS TD-1 (Nagase Landauer Ltd, Japan), 0.9 mm thick
  - etching in 7N NaOH at 70°C
  - two different etching times (short etch – short-range, higher-LET target fragment tracks; long etch – lower-LET tracks)
  - bulk etch $B = 17$ μm and $B = 21$ μm
  - high-speed microscope (HSP-1000) and ellipse fitting software (PitFit) → major and minor axes of etch pits → LET of a particle

Examples of etched tracks



$B = 17\ \mu m$



$B = 21\ \mu m$

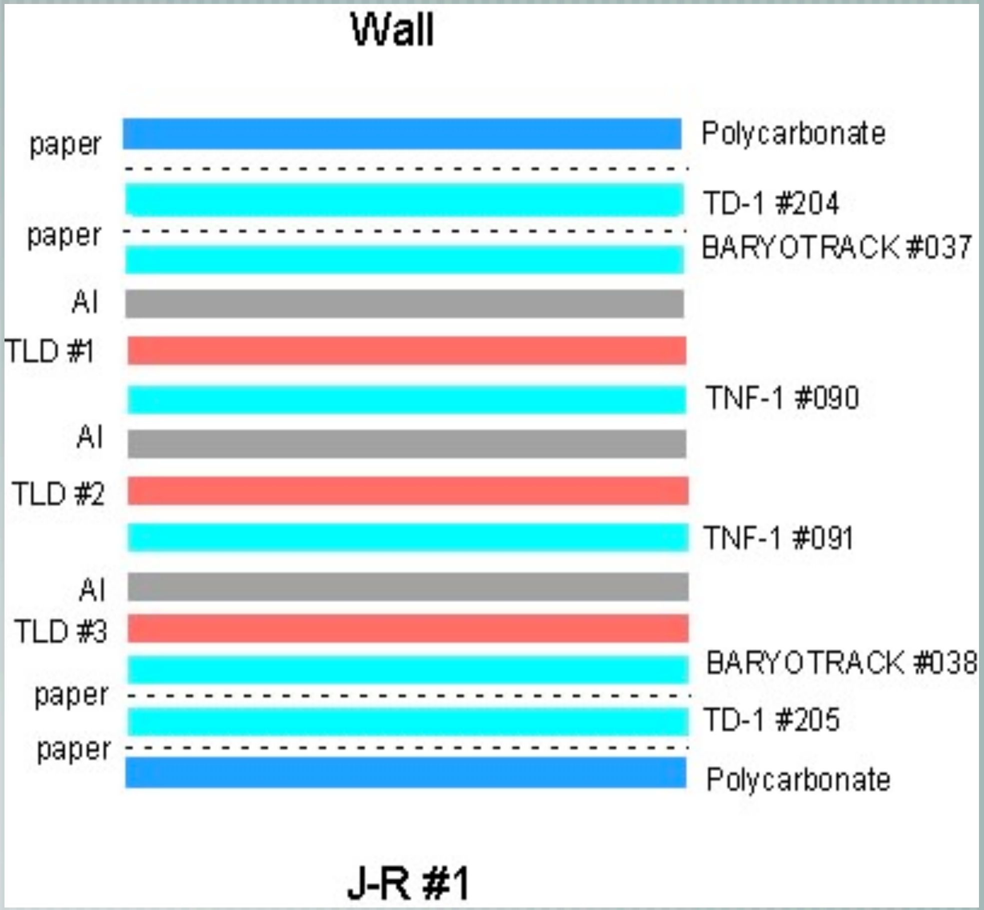
Exposure

- exposure onboard of Russian Service Module on ISS in the frame of MATROSHKA-R experiment
- 425 days (Aug. 2004 – Oct. 2005)
- the passive detectors were placed in SPD boxes at 6 different locations of the ISS SM
- top and bottom detectors

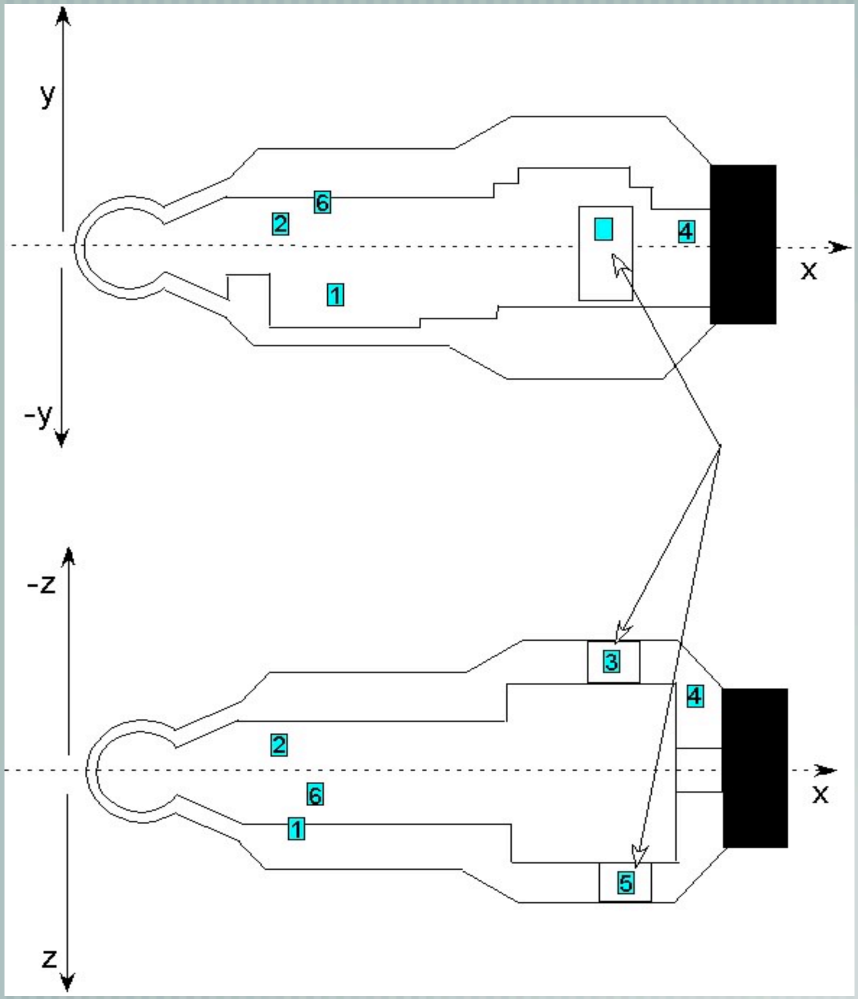
SPD boxes

size: 118 × 63 × 43 mm

mass: less than 0.45 kg



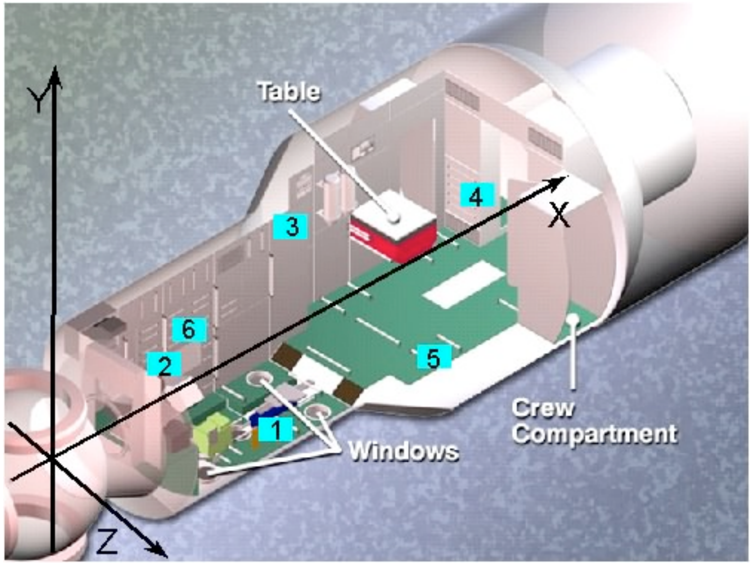
Detectors location

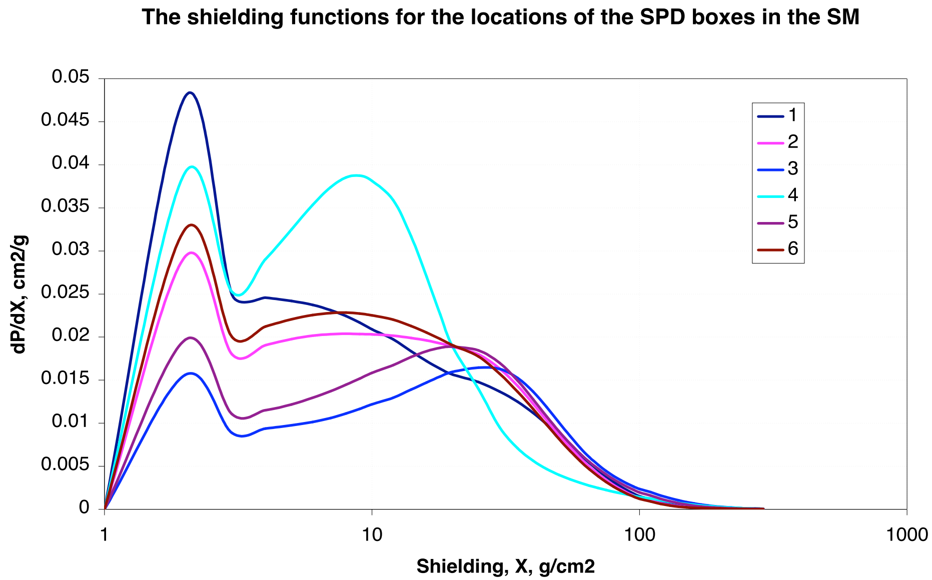


SPD box #	Coordinates [cm] (x, y, z)	Panel #	Averaged shielding [g/cm^2]	Standard deviation [g/cm^2]
SPD-1	(327, -54, 48)	102 Piers Module 1, floor	35	34
SPD-2	(301, 37, -43)	401 Piers Module 1, the star board	35	32
SPD-3	(786, 135, -108)	325 SM, cone, ceiling, close to R-16	48	42
SPD-4	(1216, 22, -81)	461 SM, the star board	32	42
SPD-5	(786, 129, 97)	323 SM, cone, ceiling, close to R-16	41	37
SPD-6	(317, 54, 27)	305 SM, ceiling, small diameter	33	31

Shielding function

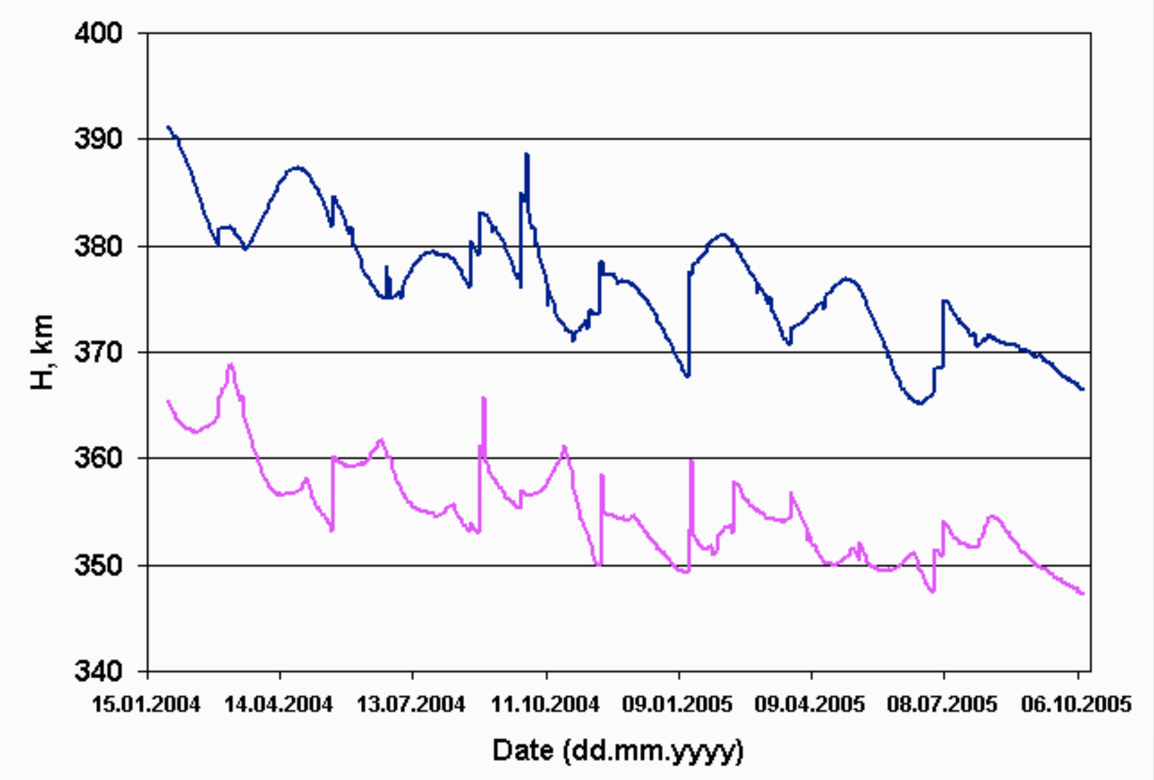
- SM construction – set of geometrical figures formed with 73 surfaces (1st and 2nd power) and filled with different matters
- shielding model allows to calculate the probability p(ξ)dξ to get the shielding thickness within the interval from ξ to ξ+dξ for any point inside the module given in (X, Y, Z) coordinate system





ISS orbit parameters

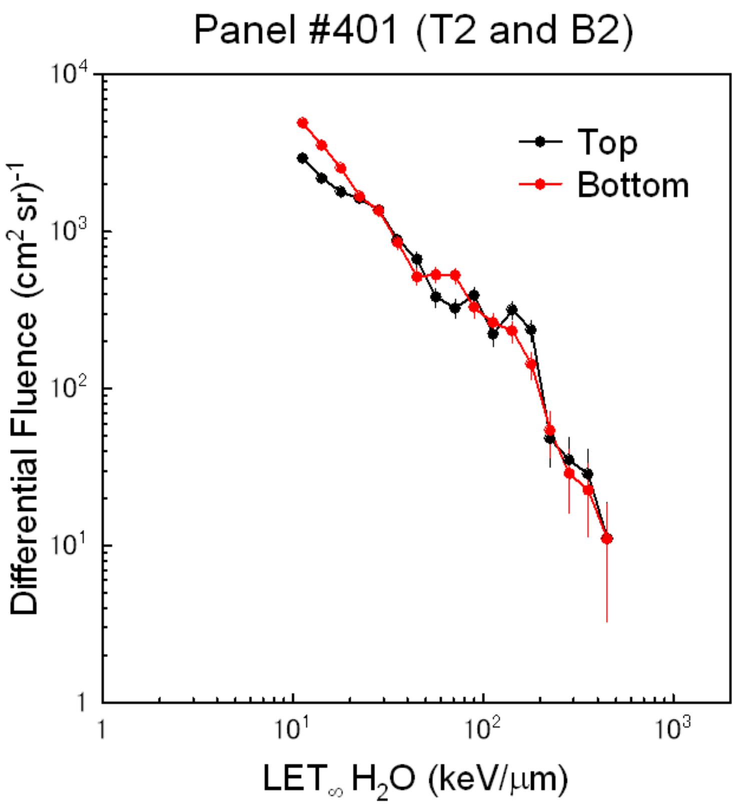
- inclination: 51.65°; orbit period ~ 90 min, 16 orbits/day
- apogee altitude: 374 km
- perigee altitude: 353 km



Results

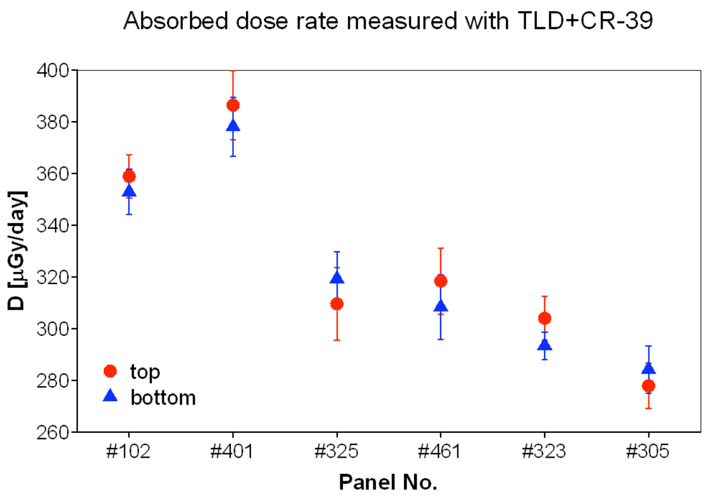
- particle flux measured with CR-39
- absorbed doses, dose equivalents, and quality factors measured with TLD, RPLD, and CR-39 for different locations of SPD boxes
- shielding effect

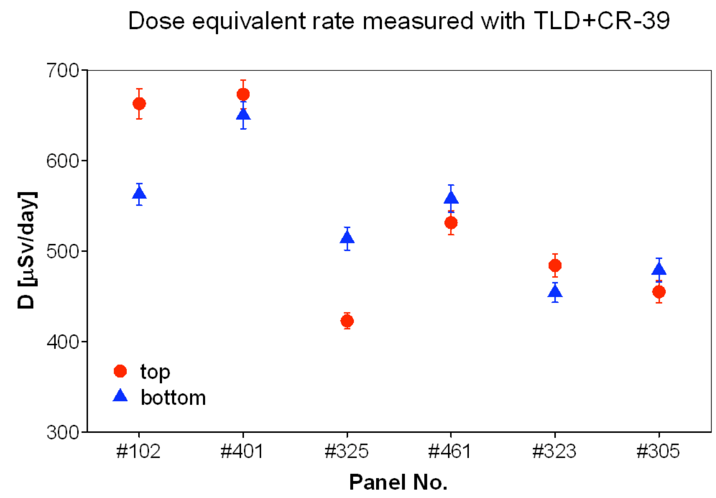
Particle flux

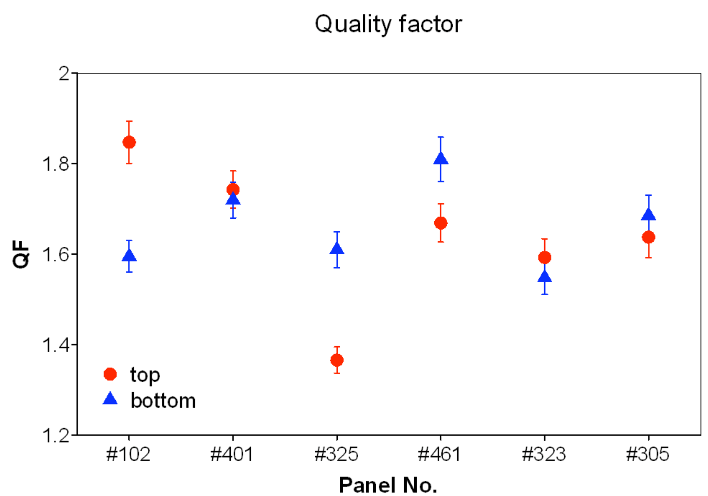


- quite similar shapes of differential LET spectra
- small peak between 100 and 200 keV/μm – likely from a combination of relativistic Fe in the galactic cosmic radiation spectrum and knock-out secondary particles in the form of stopping α-particles
- for LET ≥ 200 keV/μm rather large uncertainty bars (~ 100 %) due to small number of high-LET particles detected and corresponding poor statistics

Absorbed dose, dose equivalent, and QF measured with CR-39 and TLD

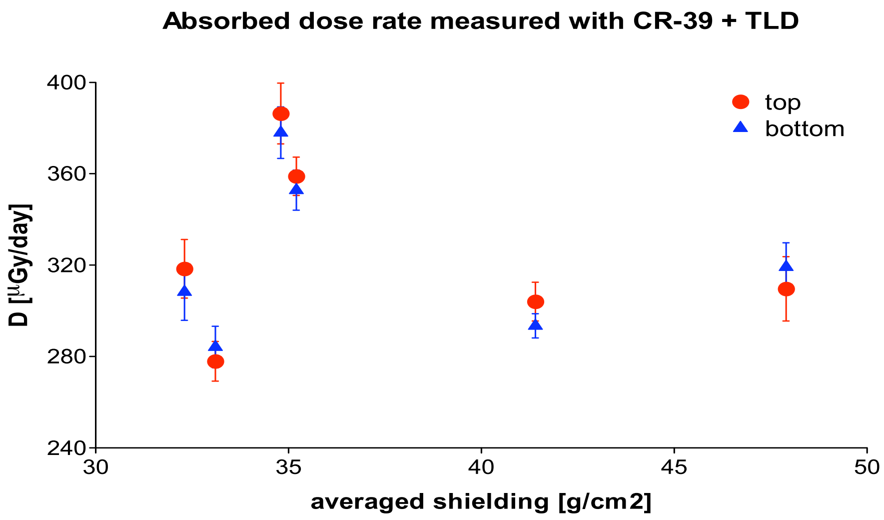


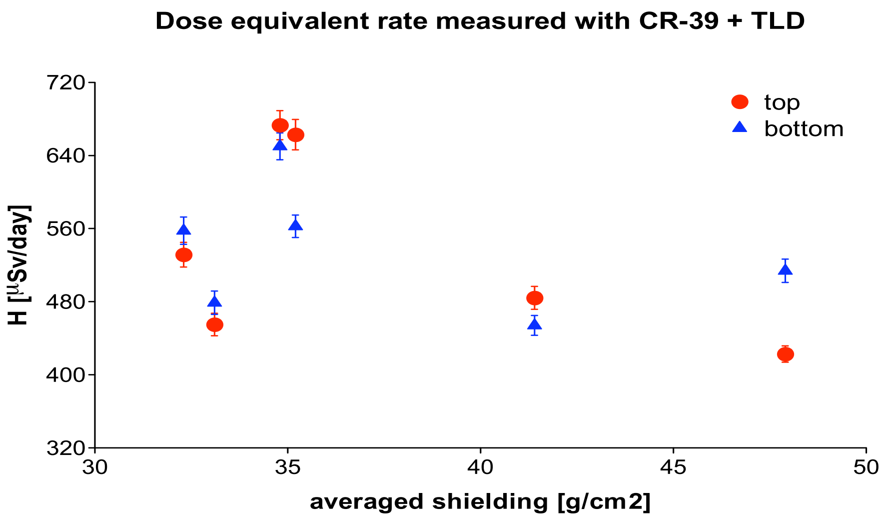




Detector	D av. [µGy/day]	H av. [µSv/day]	D range [µGy/day]	H range [µSv/day]
TLD	316 ± 34	—	271 – 376	—
RPLD	313 ± 43	—	255 – 378	—
CR-39	17 ± 4	230 ± 60	11 – 24	124 – 327
Total	324 ± 40	537 ± 85	263 – 393	423 – 675

Shielding effect





- the values of absorbed dose and dose equivalent in most cases little higher for bottom detectors that were closer to the outside wall of ISS (with the exception of SPD box 1, located on the floor)
- the influence of average shield thickness is not particularly pronounced for any of quantities studied; however, for higher shielding thickness the values of absorbed dose and dose equivalents seem to be lower than for the shielding about 35 g/cm^2

Conclusions

- variation of absorbed doses and dose equivalents with detectors position (shielding thickness)
- practically no differences between top and bottom
- the total dose rate values vary between 263 and 393 µGy/day, that of dose equivalent rates between 423 and 675 µSv/day, the quality factor 1.4 – 1.9.

Acknowledgement

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