The MATOSHKA Experiment: Results of Passive Dosimeters

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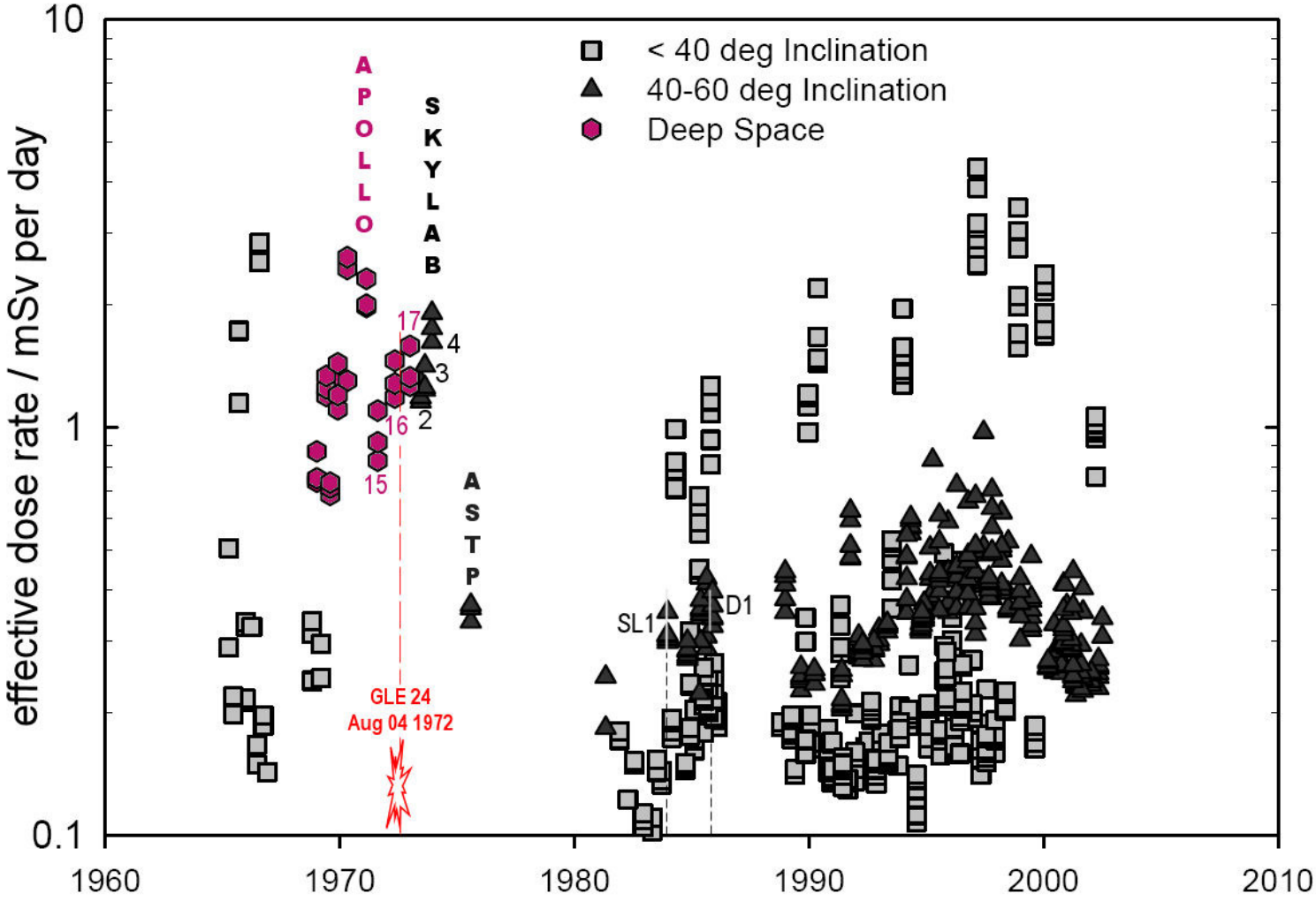
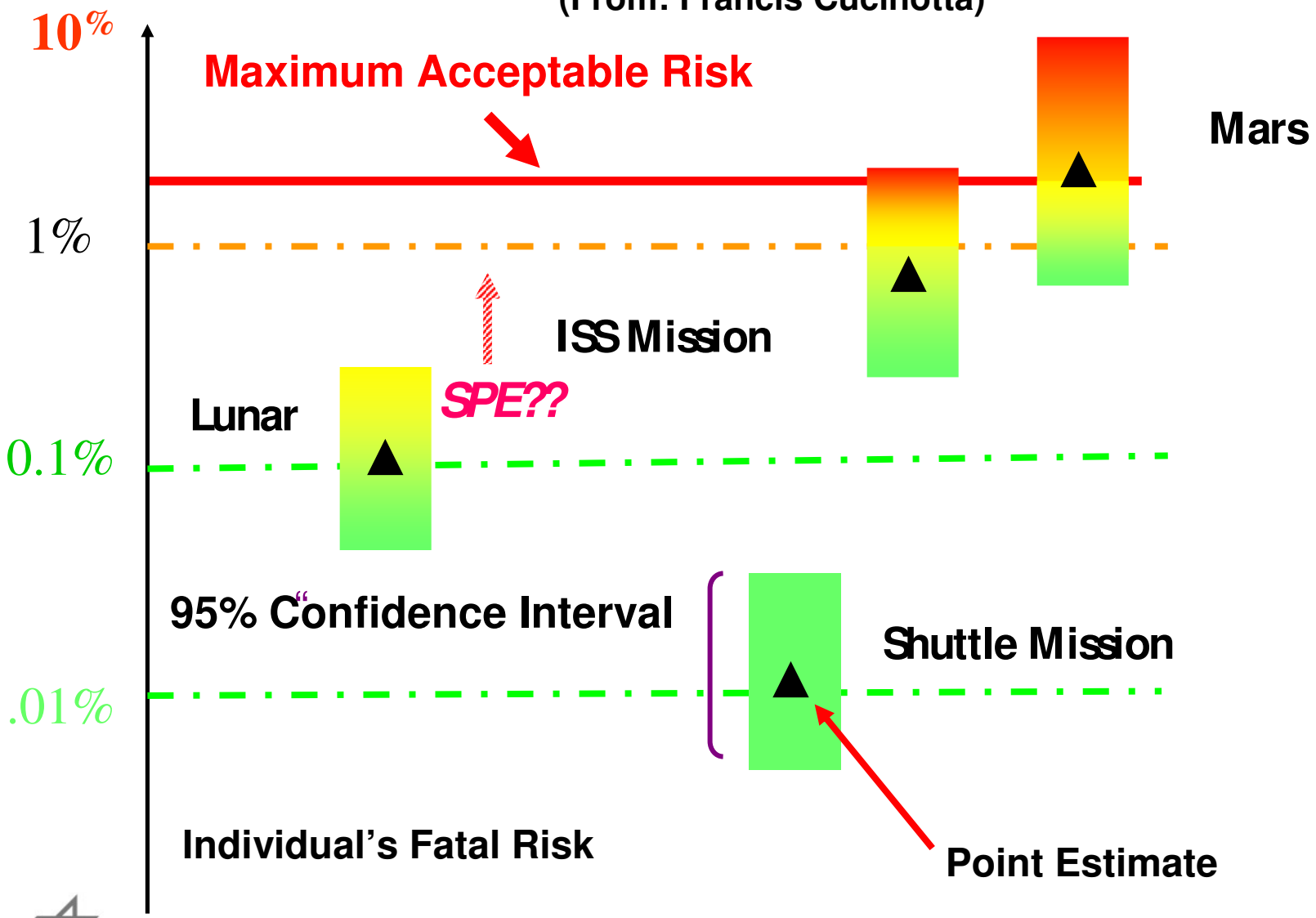
Institute of Aerospace Medicine, Cologne

Effective Doses in Low Earth Orbit Missions and Missions to the Moon



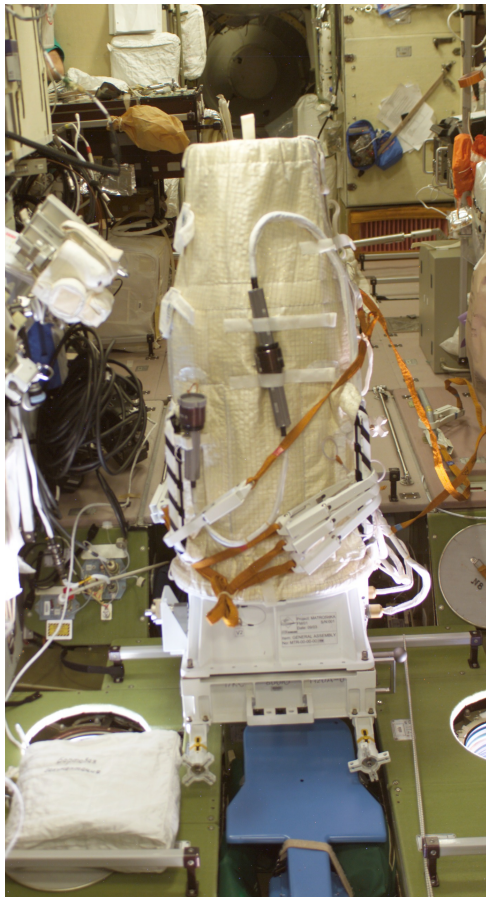
Uncertainties in Radiation Risk Projections

(From: Francis Cucinotta)



MATROSHKA Scientific Objectives (1)

- Exposures in long-term missions approach or even exceed radiation protection limits
- More accurate risk assessments are required
- Risks are based on organ doses
- Organ doses are determined by the use of anthromorphocal phantoms
- MATROSHKA is designed to determine the required exposure of an astronaut/ cosmonaut using a human phantom torso equipped with active and passive radiation sensors
  - during an extravehicluar activity (EVA)
  - inside the ISS Modules



MATROSHKA inside ISS in Jan 2004 during EVA preparation

MATROSHKA Scientific Objectives (2)

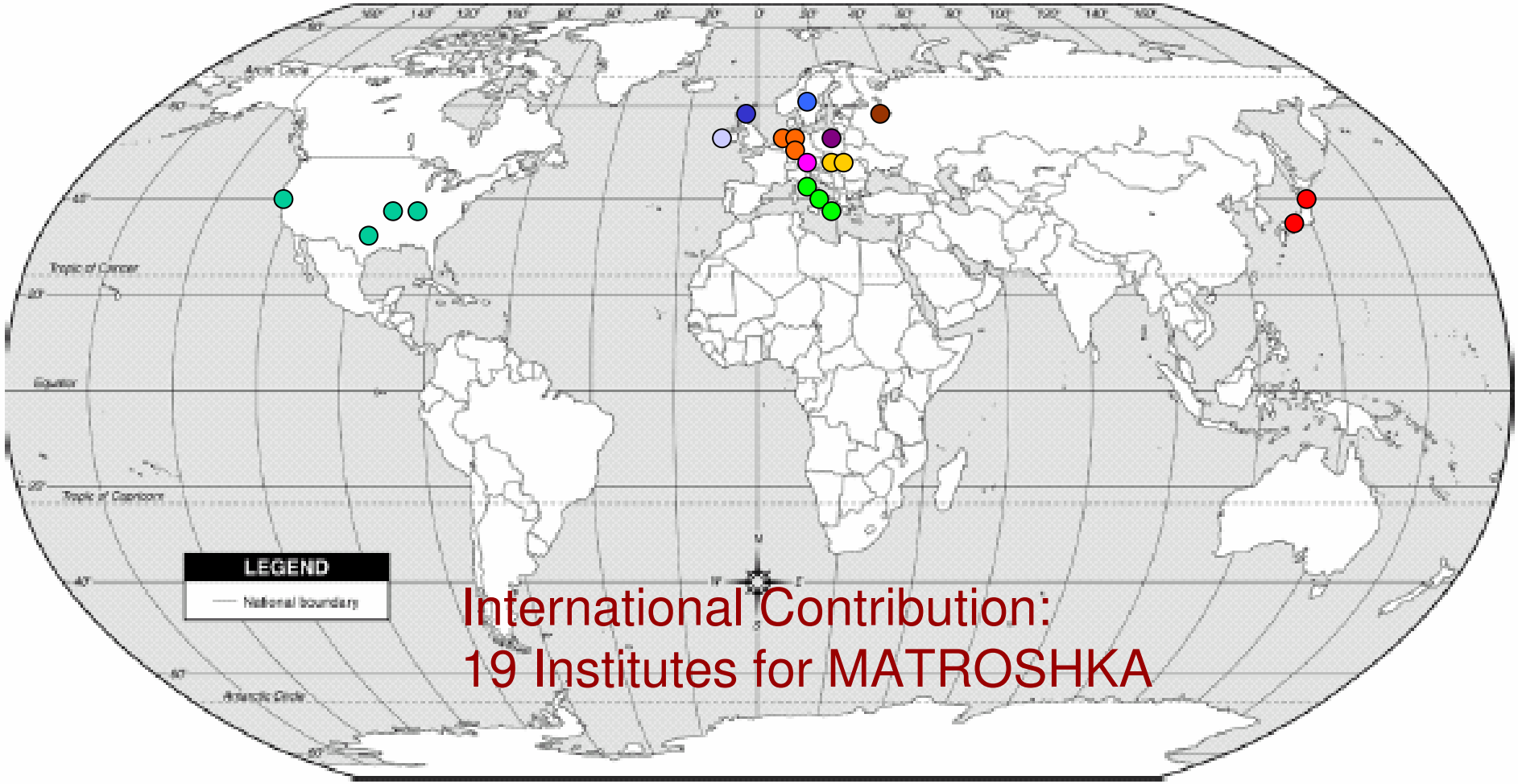
- MATROSHKA provides for

  - Skin dose measurements
  - Measurement of depth dose distributions inside the phantom
  - Measurements at sepositions of selected organs
  - Assessment of organ doses
  - Benchmarking for model calculations
  - Improved radiation risk estmates for long duration spaceflights

MATROSHKA-1 EVA February 2004

ESA Project

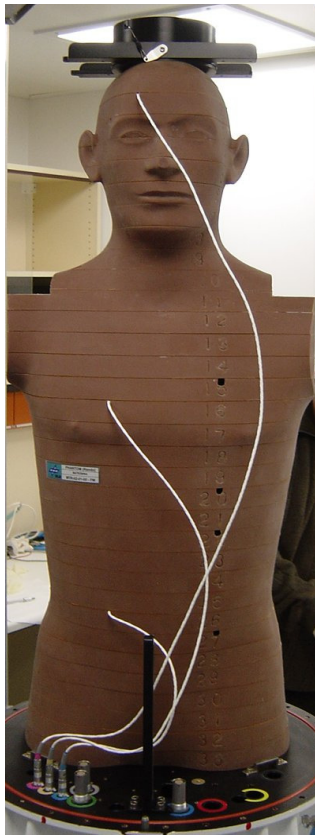
Science and Project Lead: G. Reitz, DLR



International Contribution:
19 Institutes for MATROSHKA

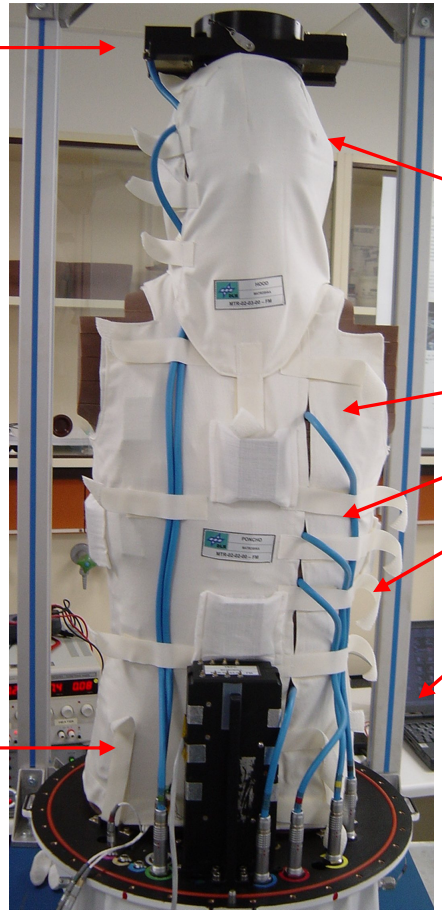
The MATROSHKA Facility

Phantom Torso + Poncho + Container + MLI (MTR-1)



The MATROSHKA Facility – Active radiation detectors

DOSTEL
(Dosimetric Telescope)

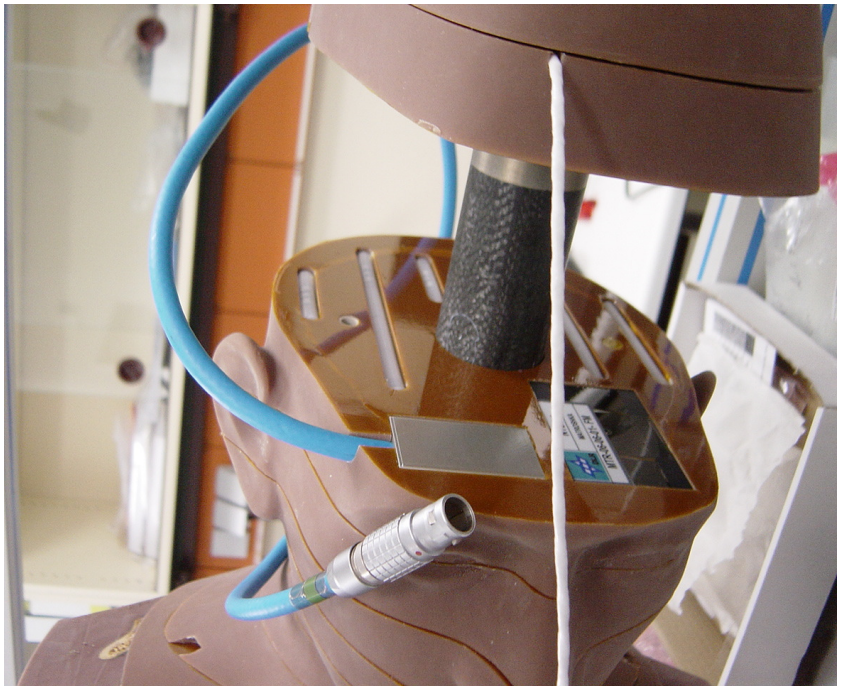


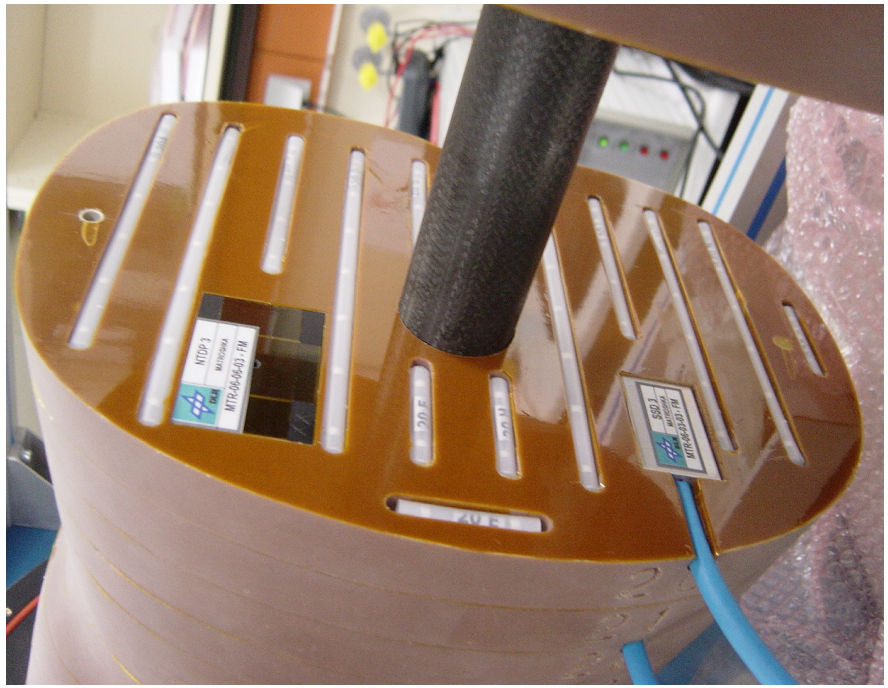
SSD
(Silicon Scintillator Device)

- Eye
- Lung
- Stomach
- Kidney
- Intestine

TEPC
(Tissue equivalent proportional counter)

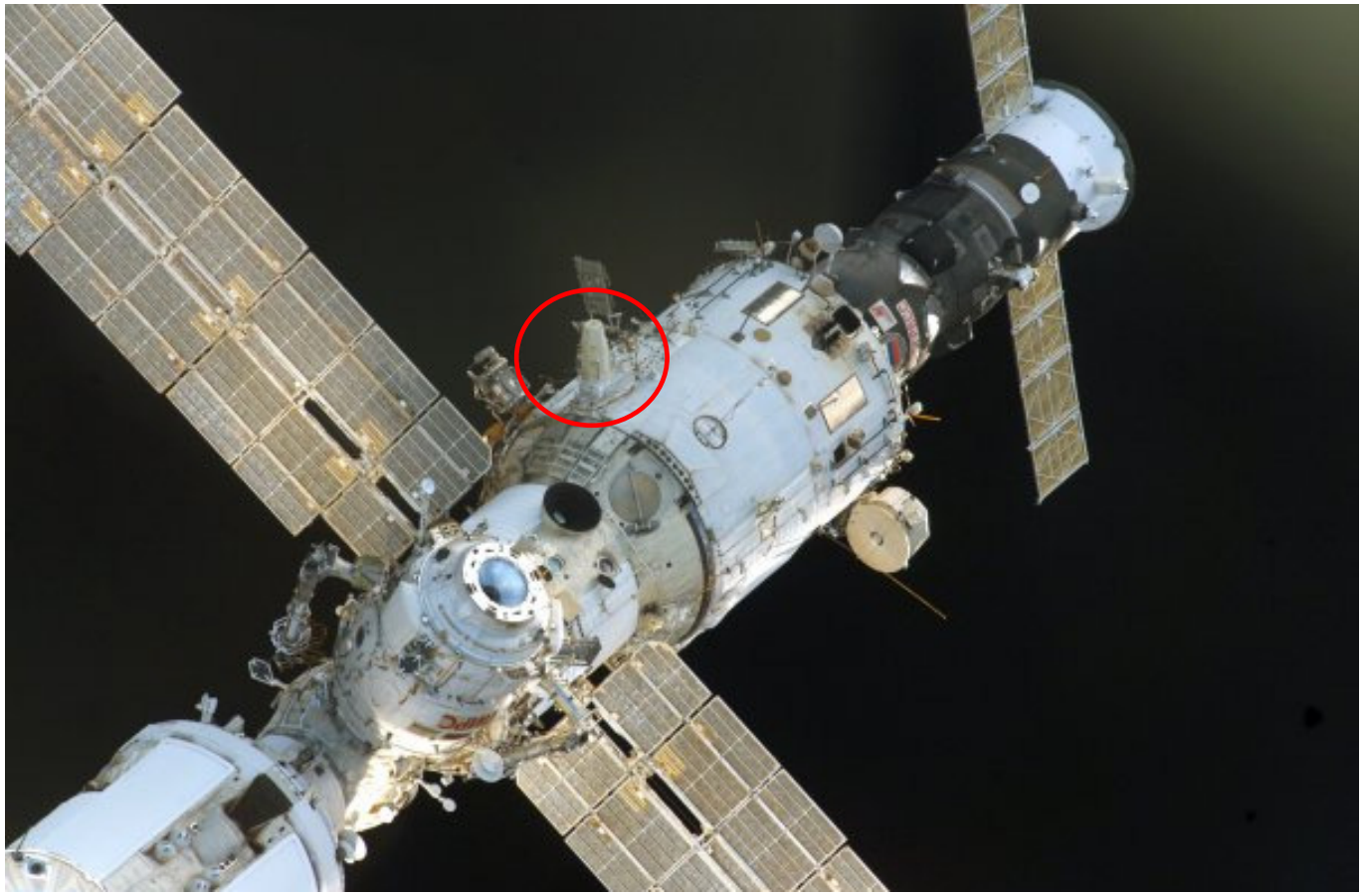
The MATROSHKA Facility – Passive radiation detectors



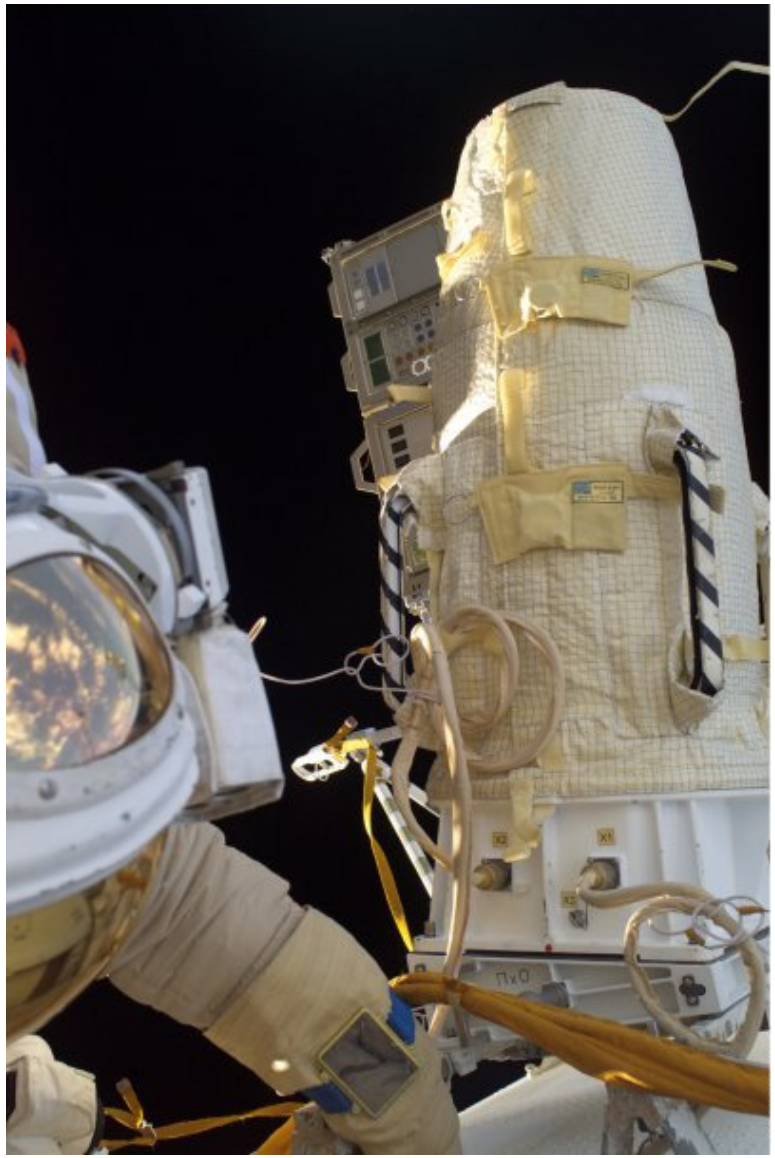


Thermoluminescence detectors (TLDs) and Nuclear Track Etch detectors
Total Number : ~ 6000

MATROSHKA-1 Location



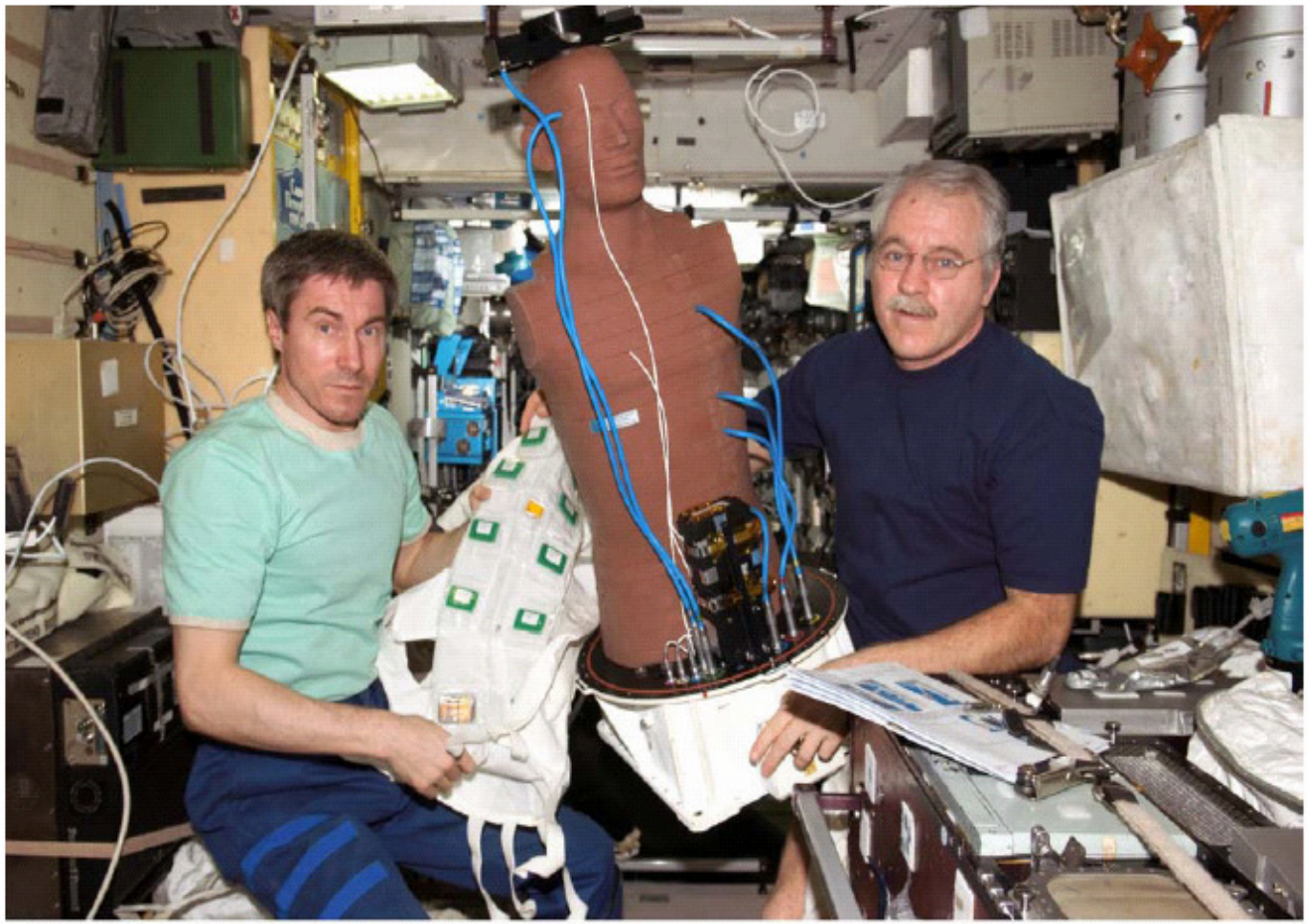
MATROSHKA mounted outside the ISS February 2004 – August 2005



MATROSHKA

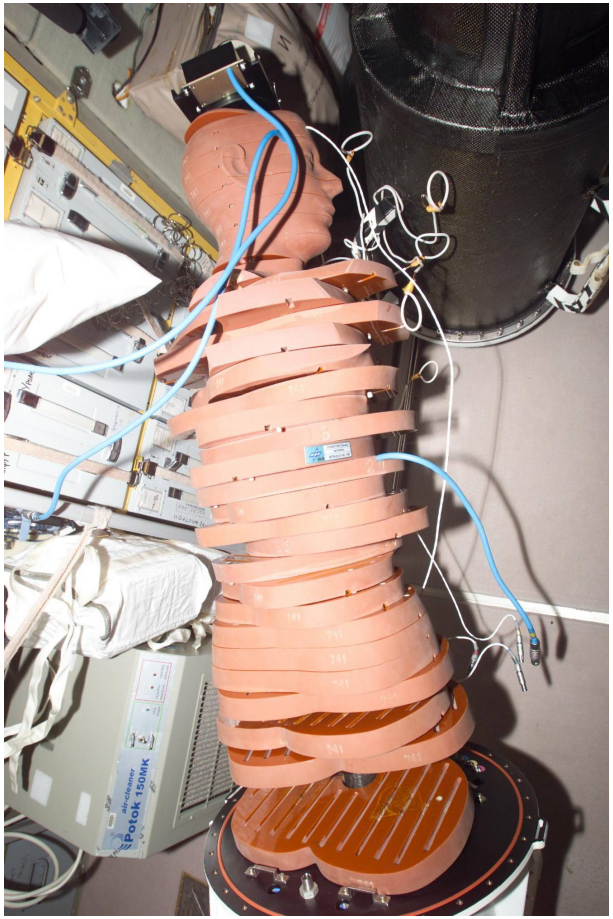
Retrieval

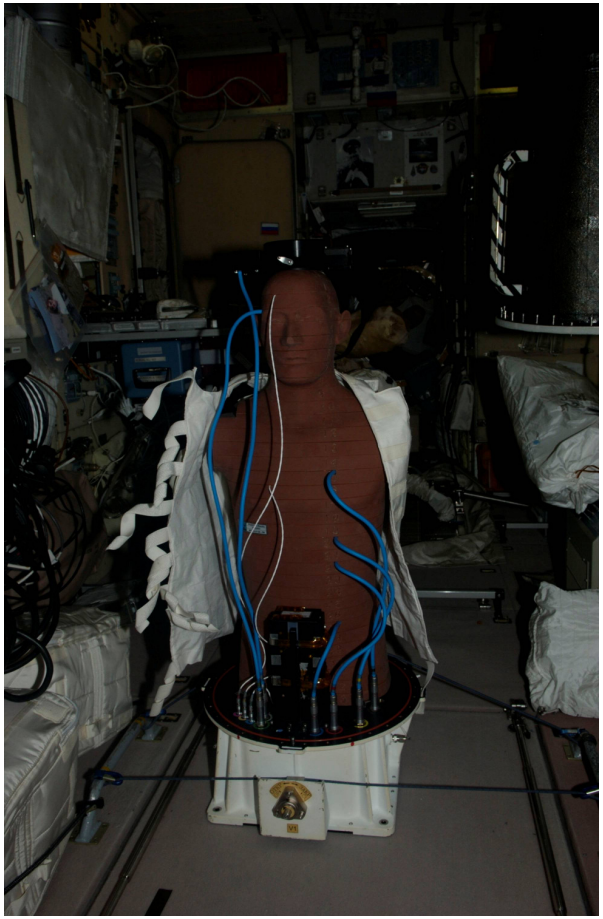
ISS Commander Sergei Krik NASA Scientist John Phillips disassembling the MATROSHKA detectors in Sept 14, 2005

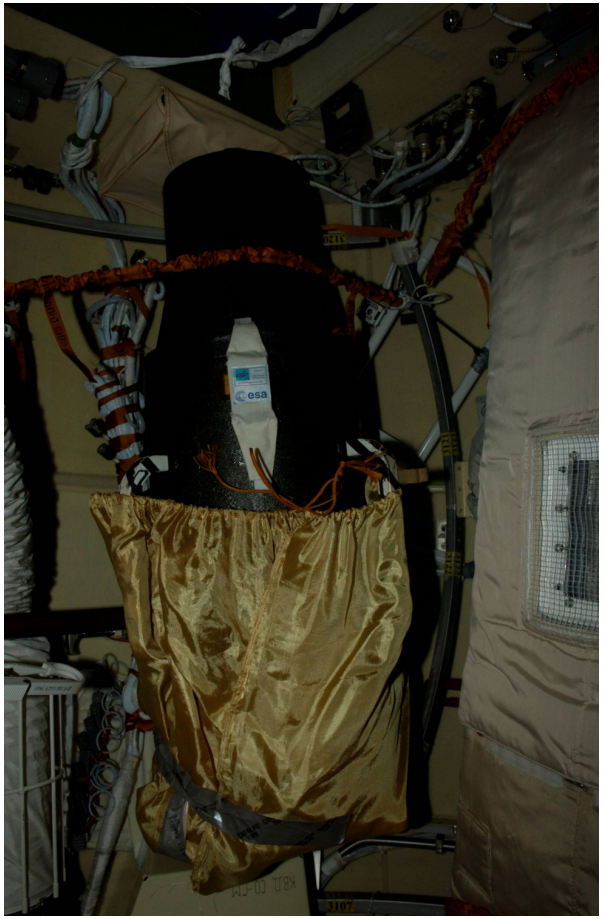


ISS011E13025

MATROSHKA Disassembly,Assembly and Stowage in Compartment DC-1







EVA Doses

Sensor #	Purpose	Start of Measurement before EVA	Exposure at EVA	Time of Measure-ment after EVA	Dose, µGy
307	Control inside the station	25.02.2004 16:00	Inside the station	27.02.04 11:00	340
309	Dose of the Commander	25.02.2004 16:02	In the spacesuit pocket during EVA 27.02.2004 from 00:00 to 04:00 (4 hours)	27.02.04 11:02	550* (550-340 = **210**)
310	Dose of the flight engineer	25.02.2004 16:04	In the spacesuit pocket during EVA 27.02.2004 from 00:00 to 04:00 (4 hours)	27.02.04 11:04	494* (494-340 = **154**)

MATROSHKA-1 Exposure Times

MTR 1: Space Exposure (total)
31.01. 2004 – 08. 10. 2005 **616 days**

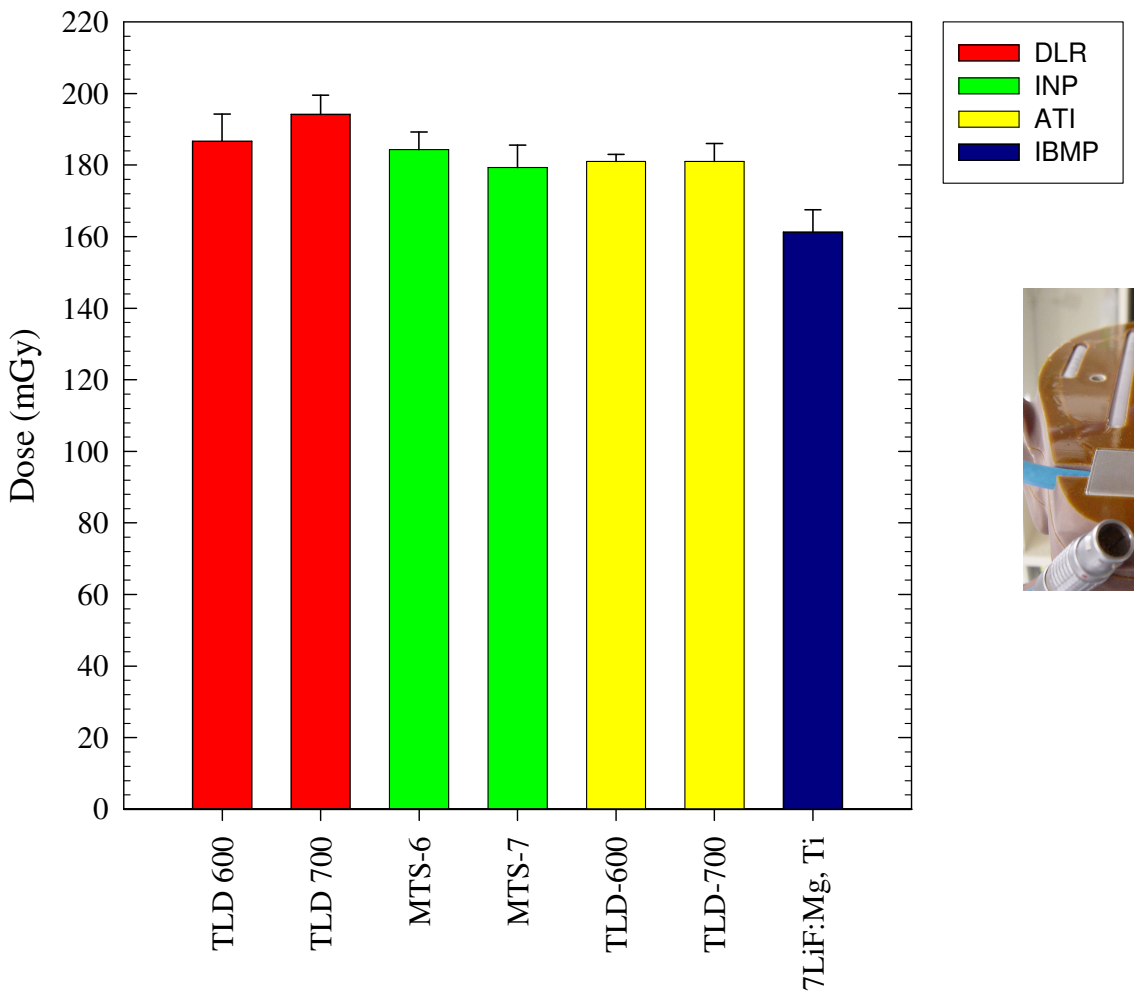
MTR 1: Outside Exposure (total)
26. 02. 2004 – 18. 08. 2005 **539 days**

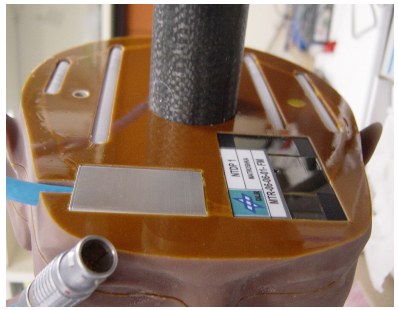
MTR 1: Inside Exposure (total = 77 days)

31. 01. 2004 – 26. 02. 2004 (Detectors inside 26 days)
18. 08. 2005 – 14. 09. 2005 (Detectors inside 27 days)
14. 09. 2005 – 08. 10.2005 (Detectors outside 24 days)

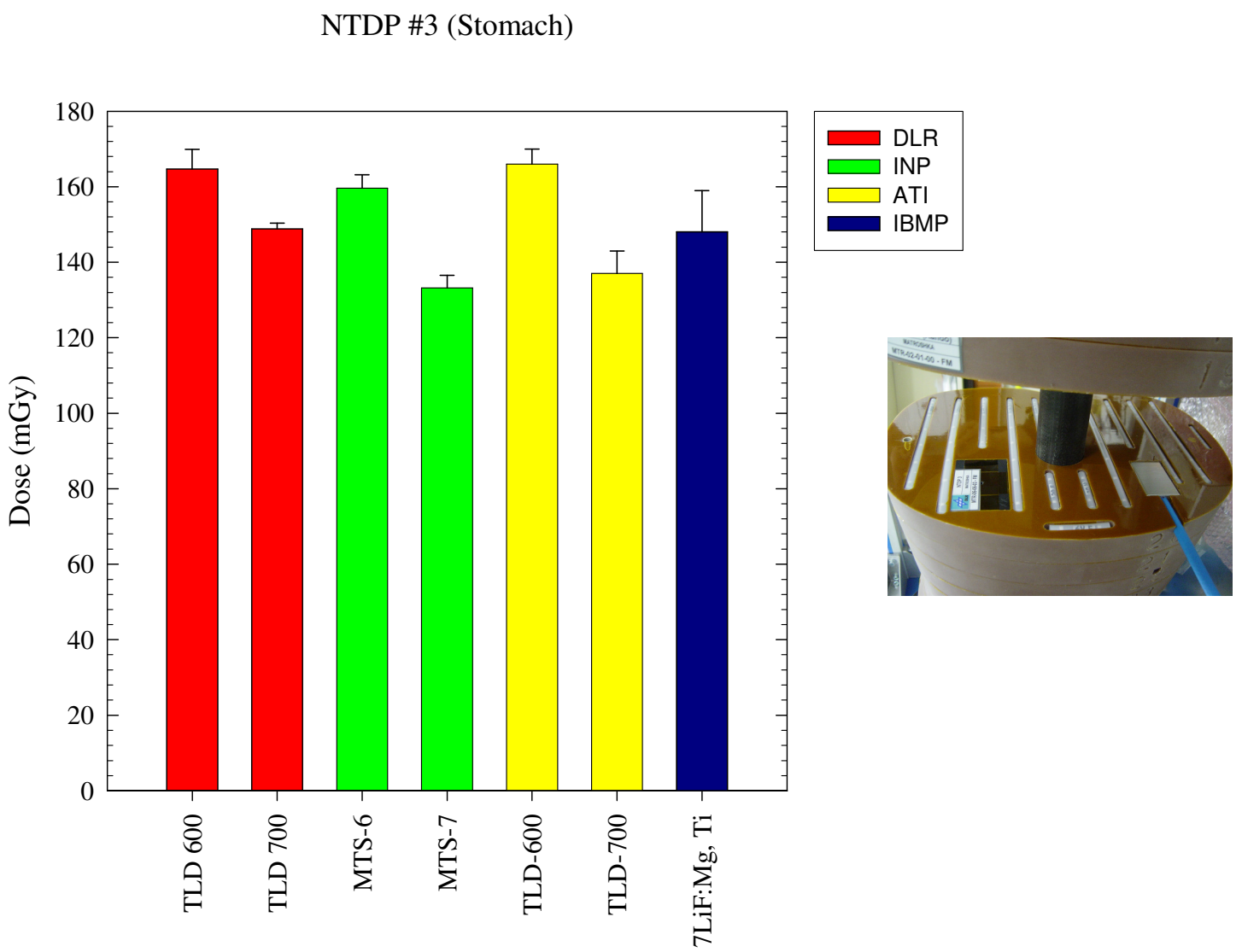
Inside Background: 53 days detectors inside MTR
24 days detectors outside MTR

MTR – NTDP #1 (Eye)

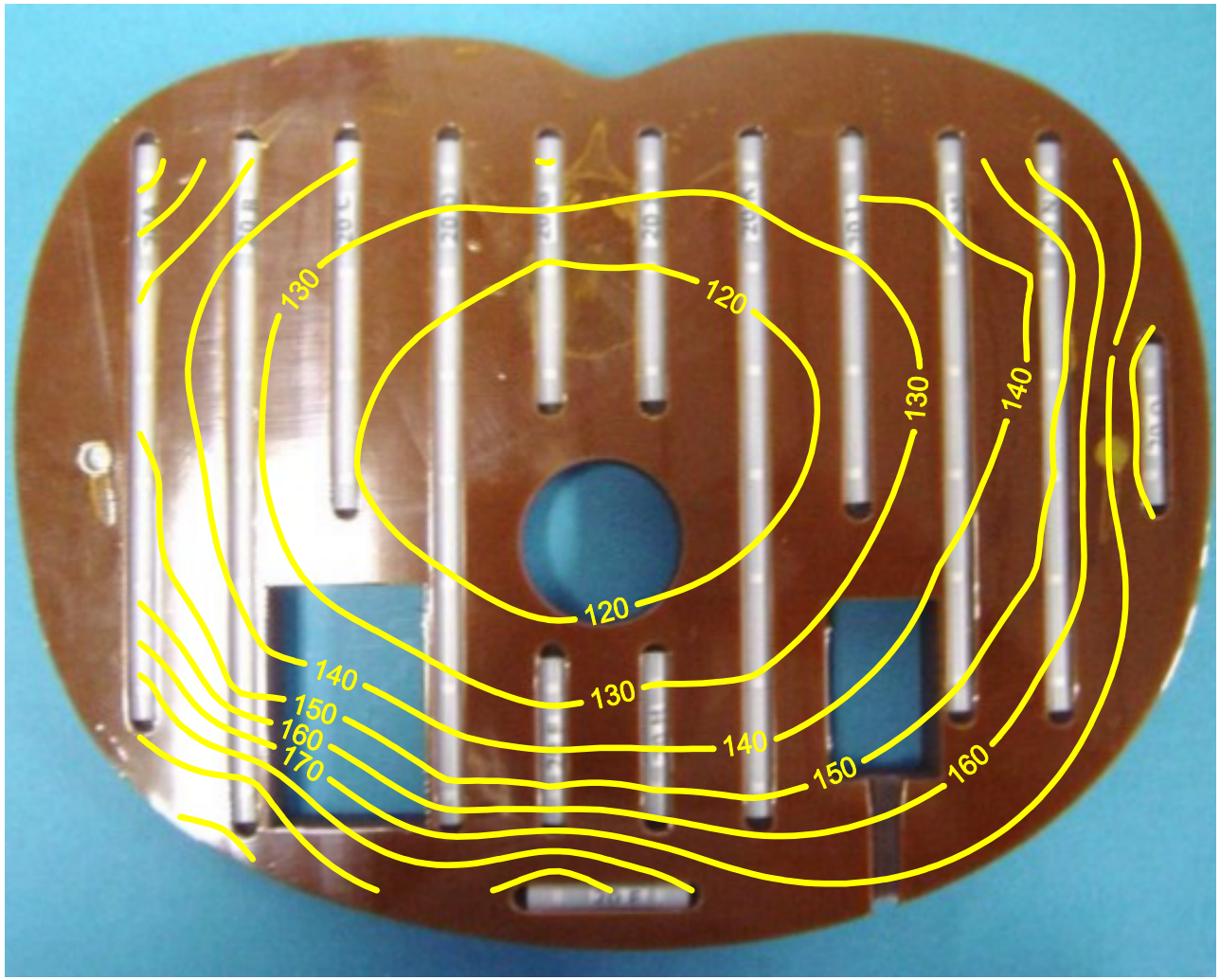


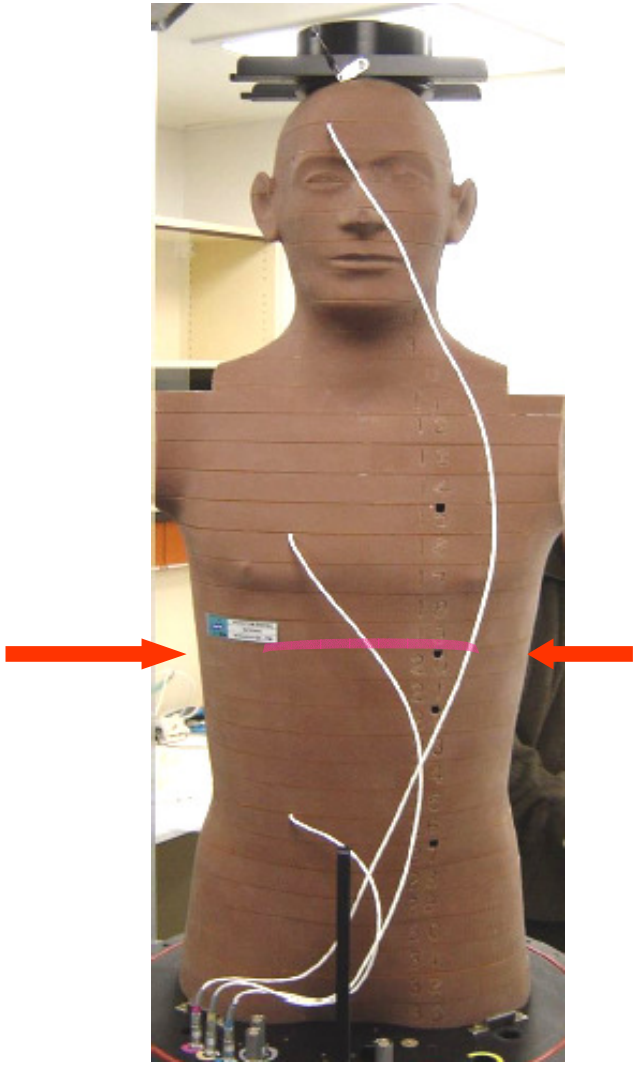


MTR – NTDP #3 (Stomach)

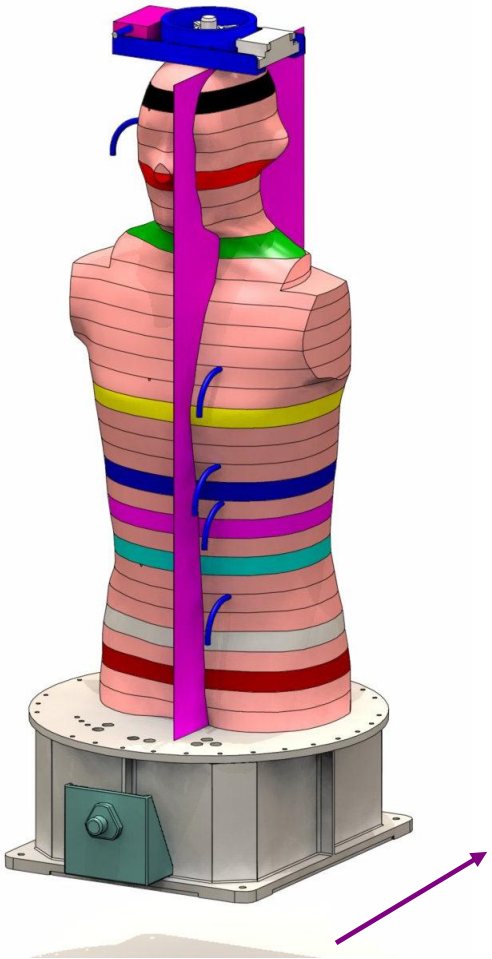


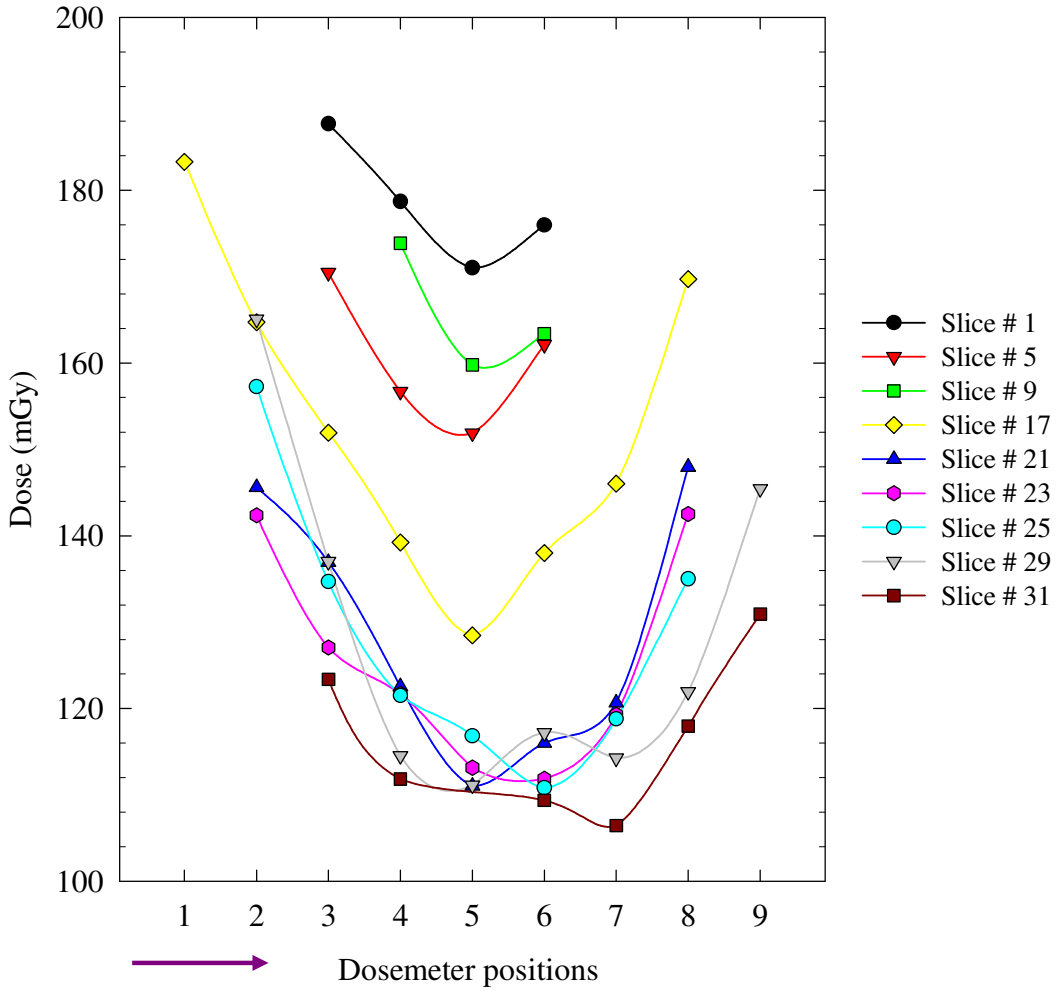
MATROSHKA iso doses [mGy]



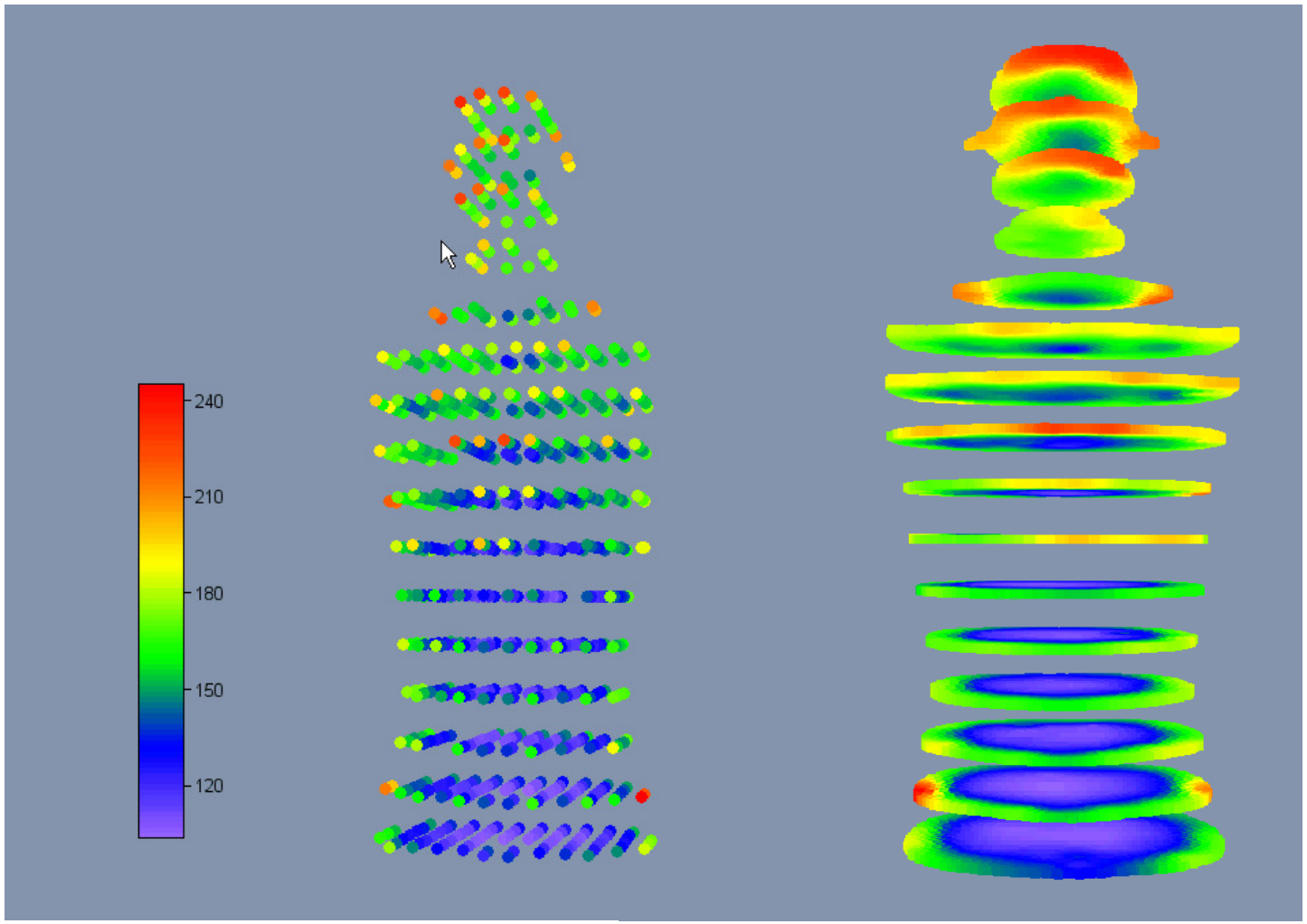


MATROSHKA-1 Science (TLDs)

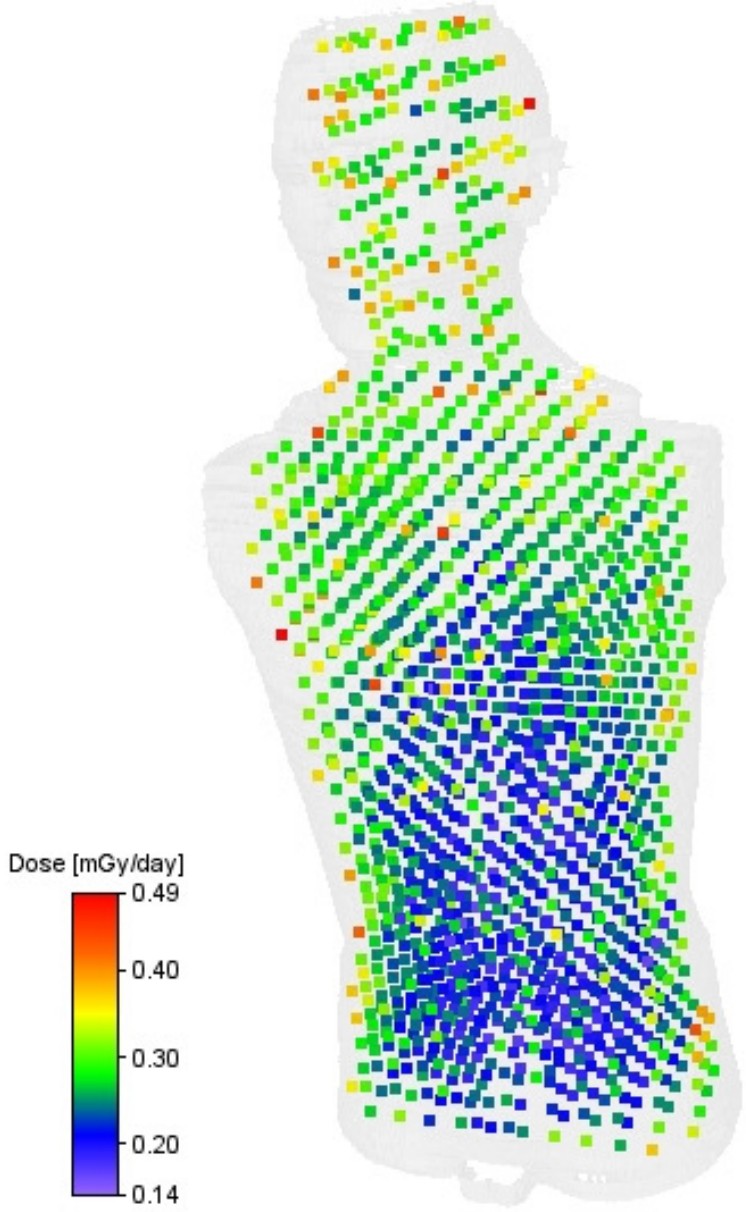




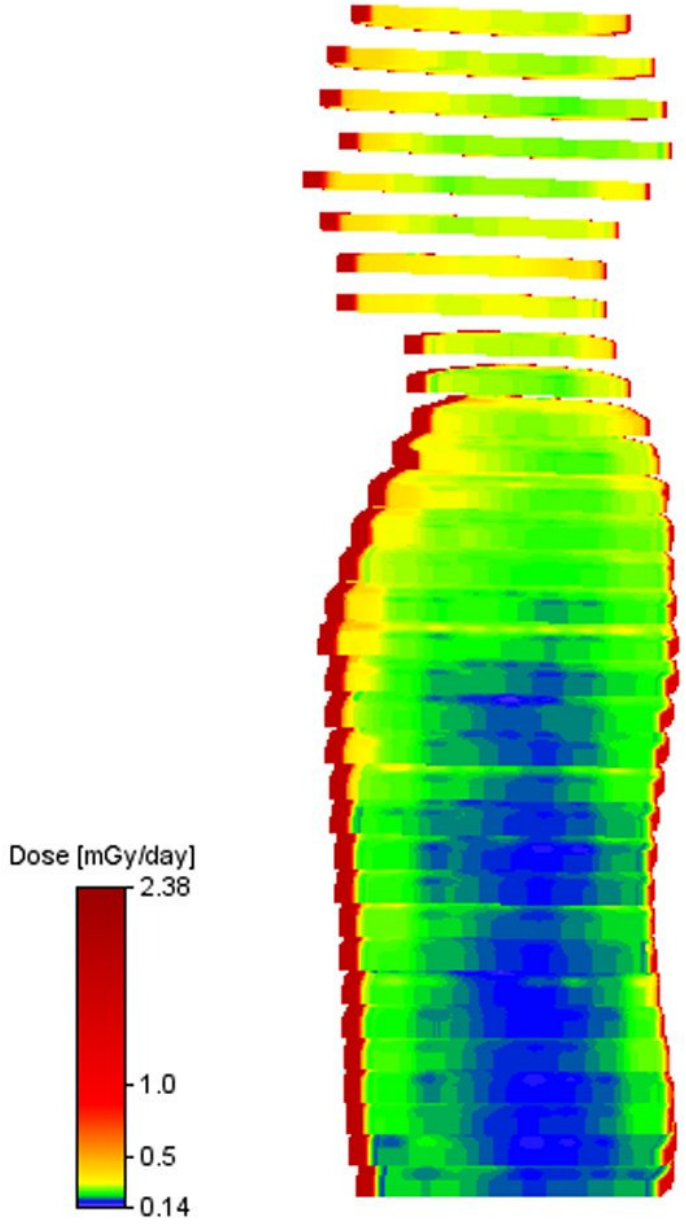
MATROSHKA Science Data 2 (TLDs)



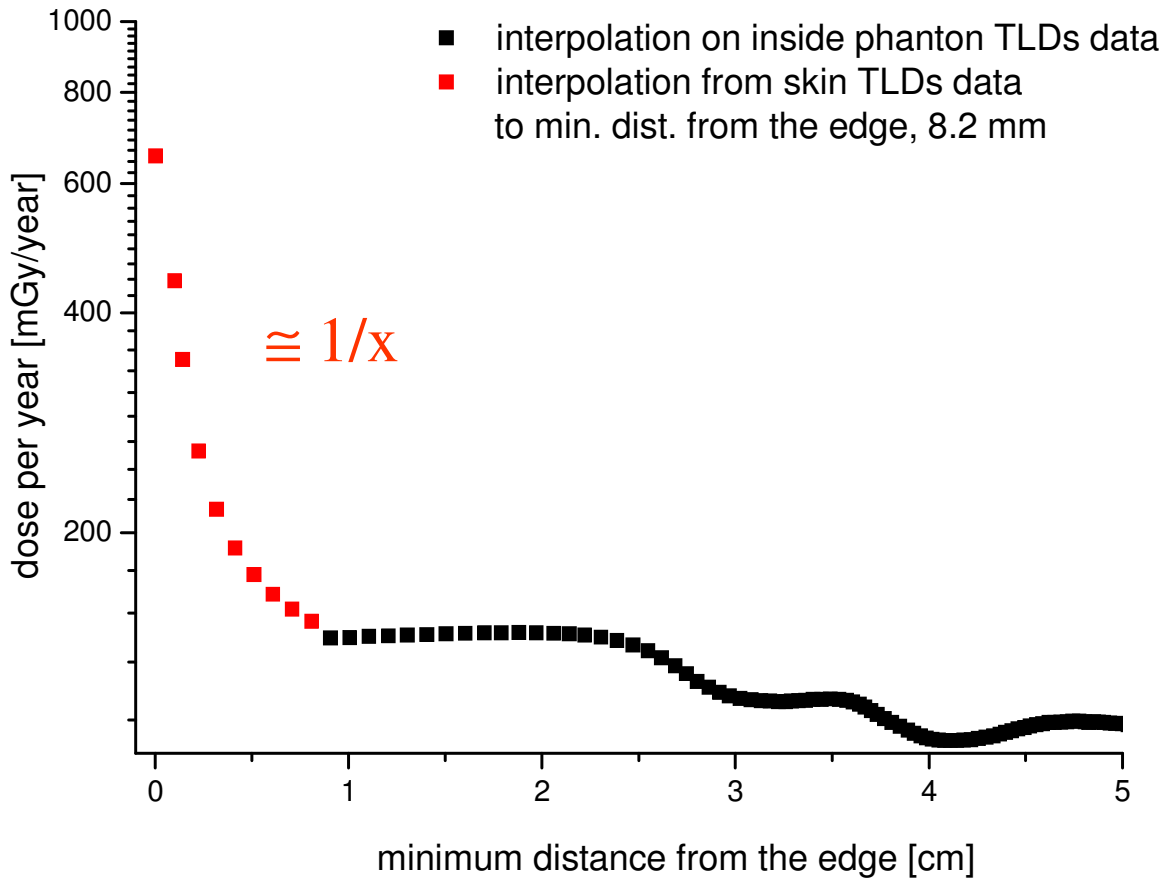
3D daily absorbed dose distribution for the MATROSHKA phantom



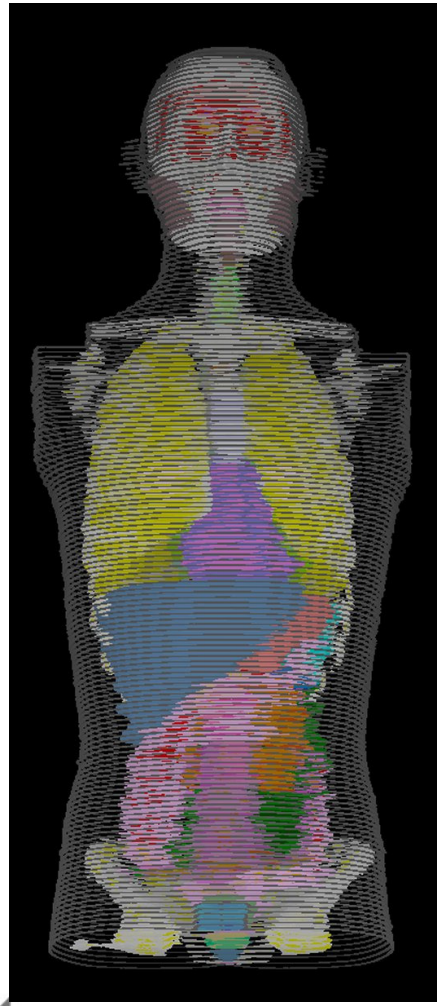
Median-sagittal plane of the 3D model of MATROSHKA including “skin dose” distribution



Depth Dose Distribution

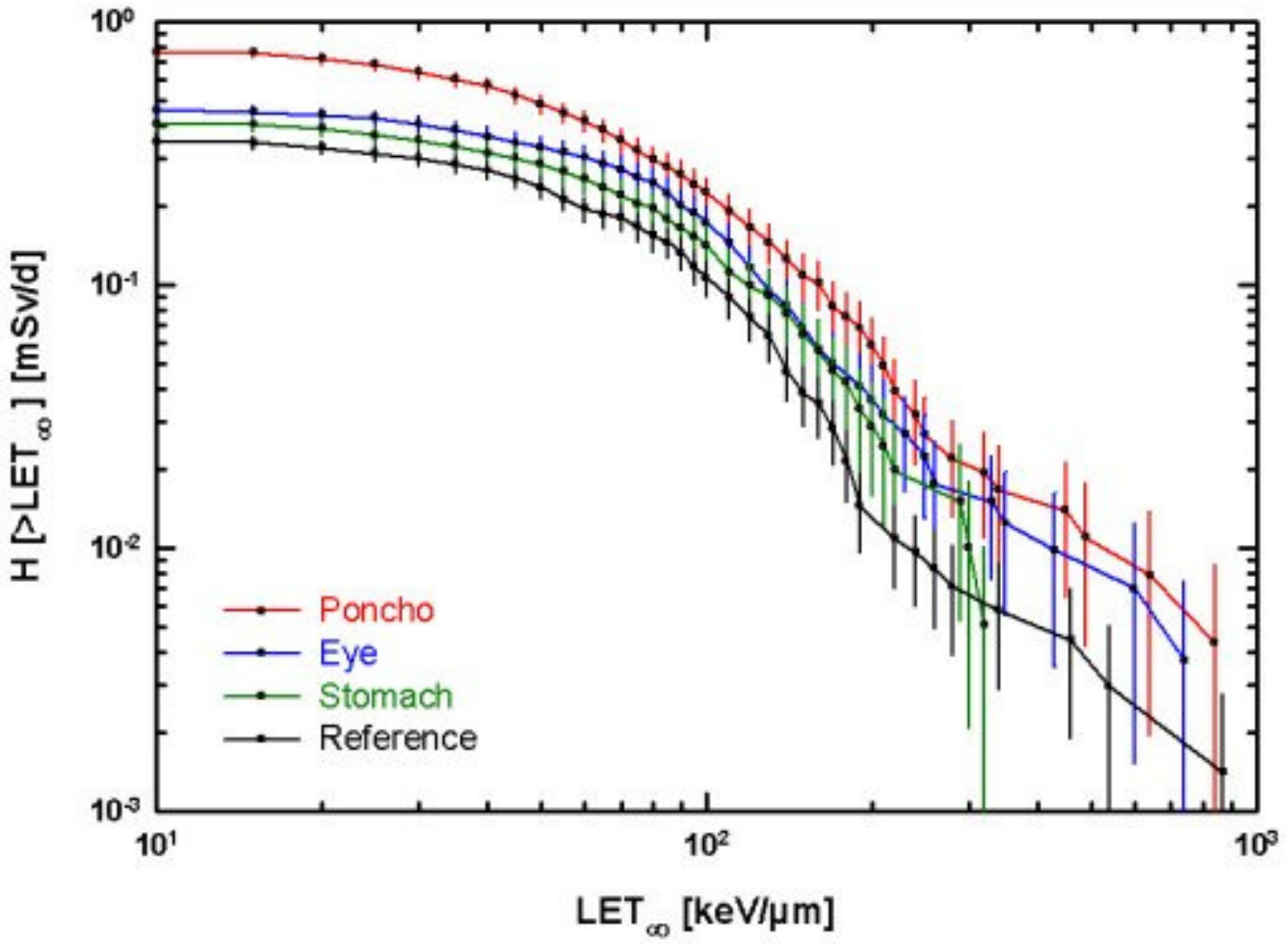


Organ dose rates calculated from TLD depth-dose distribution



Organ	Dose rate (mGy/d)
Skin	0.94 (8)
Eyeball, lens	0.54 (8), 0.58 (12)
Salivary glands, breast	0.33 (7) ; 0.39 (10)
Thymus, thyroid, trachea, brain	0.28 – 0.30 (6)
Lungs, bones	0.26 (6), 0.28 (6)
Esophagus, testes	0.24 (6), 0.26 (7)
Colon, stomach, liver, red bone marrow, heart	0.22 - 0.24 (6)
Kidneys, gall bladder , small intestine, spleen, pancreas , prostate	0.20 – 0.22 (6)

Integral dose equivalent spectra



Daily dose equivalent rate H_{Total} based on the combination of TLD measurements and CR 39 data

Dosimeter Location	D_{TLD-L} mGy/d	$D_{CR\ 39}$ mGy/d	D_{Total} mGy/d	$H_{CR\ 39}$ mSv/d	H_{Total} mSv/d	<Q>
Skin	0.879	0.065	0.944	0.763	1.642	1.74
Eye	0.505	0.036	0.541	0.461	0.966	1.78
Stomach	0.211	0.031	0.242	0.407	0.618	2.55
Poncho	0.536	0.065	0.600	0.762	1.298	2.16
Reference	0.141	0.028	0.170	0.350	0.491	2.89

MATROSHKA Status

- MATROSHKA allowed the measurement of the depth-dose distribution throughout a whole human phantom torso
- The substantial increase in radiation exposure for an astronaut performing an EVA predominantly affects tissues and organs close to the body surface.
- Due to self shielding of the body, exposure of interior organs is only slightly enhanced over the situation inside the ISS.
- These data can now be used to validate particle transport models which can calculate organ doses for the ISS orbit by allowing for the shielding model of the ISS and the self-shielding of MATROSHKA.
- The data from the active instruments – not presented in this talk- gathered at specific points can also be used to benchmark these models using the available external flux information.

MATROSHKA Next

- Analysis of the depth-dose distribution inside the same phantom when exposed inside the ISS
- Comparison of the depth-dose distributions inside the phantom inside and outside the ISS.
- HAMLET – Human Model MATROSHKA for Radiation Exposure Determination of Astronauts (EU FP7 Project)
- MATSIM-A: Mathematical Simulation of the Radiation Exposure in the Phantom using Monte Carlo transport codes
- Comparison of data with calculations using the full ISS geometry models for the transport of the different radiations

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