

MATROSHKA – Results from the exposure inside the Japanese KIBO Module – and comparison with previous missions

Thomas Berger on behalf of the MATROSHKA Team

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Knowledge for Tomorrow



MATROSHKA Team

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2 Institute of Atomic and Subatomic Physics, (ATI), Technical University Vienna, Austria

3 Institute of Nuclear Physic, (IFJ), Krakow, Poland

4 Oklahoma State University, (OSU), Stillwater, USA

5 NASA Johnson Space Center, (NASA), Houston USA

6 Centre for Energy Research of the Hungarian Academy of Sciences (formerly AERI), Budapest, Hungary

7 Health Protection Agency (HPA), Chilton, United Kingdom

8 National Institute for Radiological Sciences, (NIRS), Chiba, Japan

9 Japan Aerospace Exploration Agency, (JAXA), Japan

10 Institute for Biomedical Problems, (IBMP), Moscow, Russia

11 Christian Albrechts Universität zu Kiel, (CAU), Kiel, Germany

12 Chalmers University of Technology, (CHALMERS), Gothenburg, Sweden



CONTENT

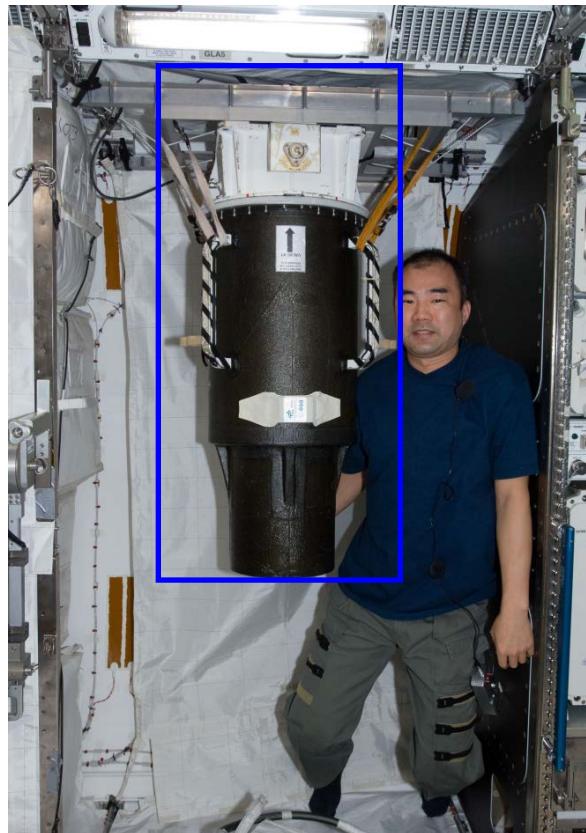
- Overview of the MATROSHKA Experiments
- Results : MATROSHKA in KIBO : **MTR-2 KIBO**
- Comparison with other MATROSHKA Experiment Phases :
 - MTR-1**
 - MTR-2A**
 - MTR-2B**



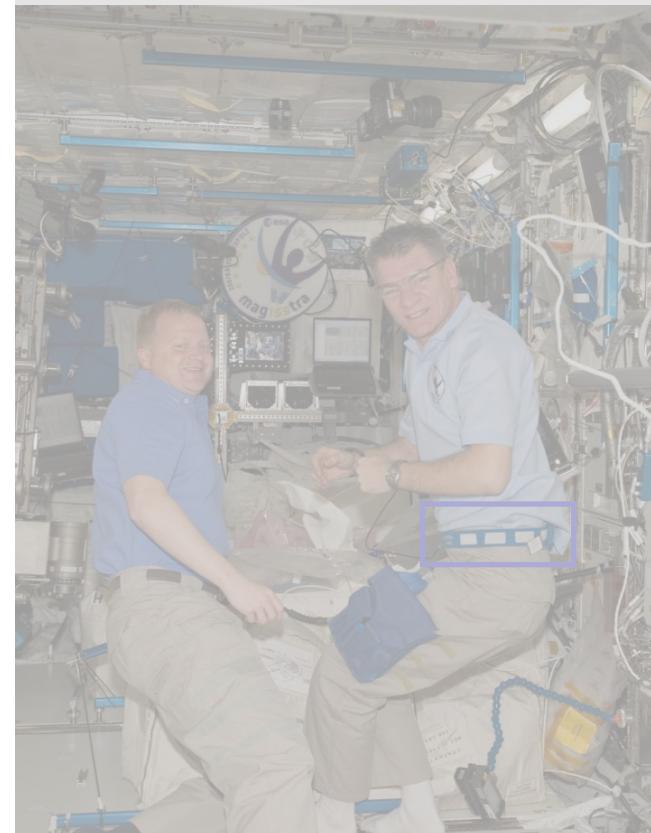
Radiation Measurements



Area monitoring
(DOSIS-3D)



Phantom experiments
(MATROSHKA)



Personal dosimetry
(EuCPD)



The MATROSHKA Experiment Facility



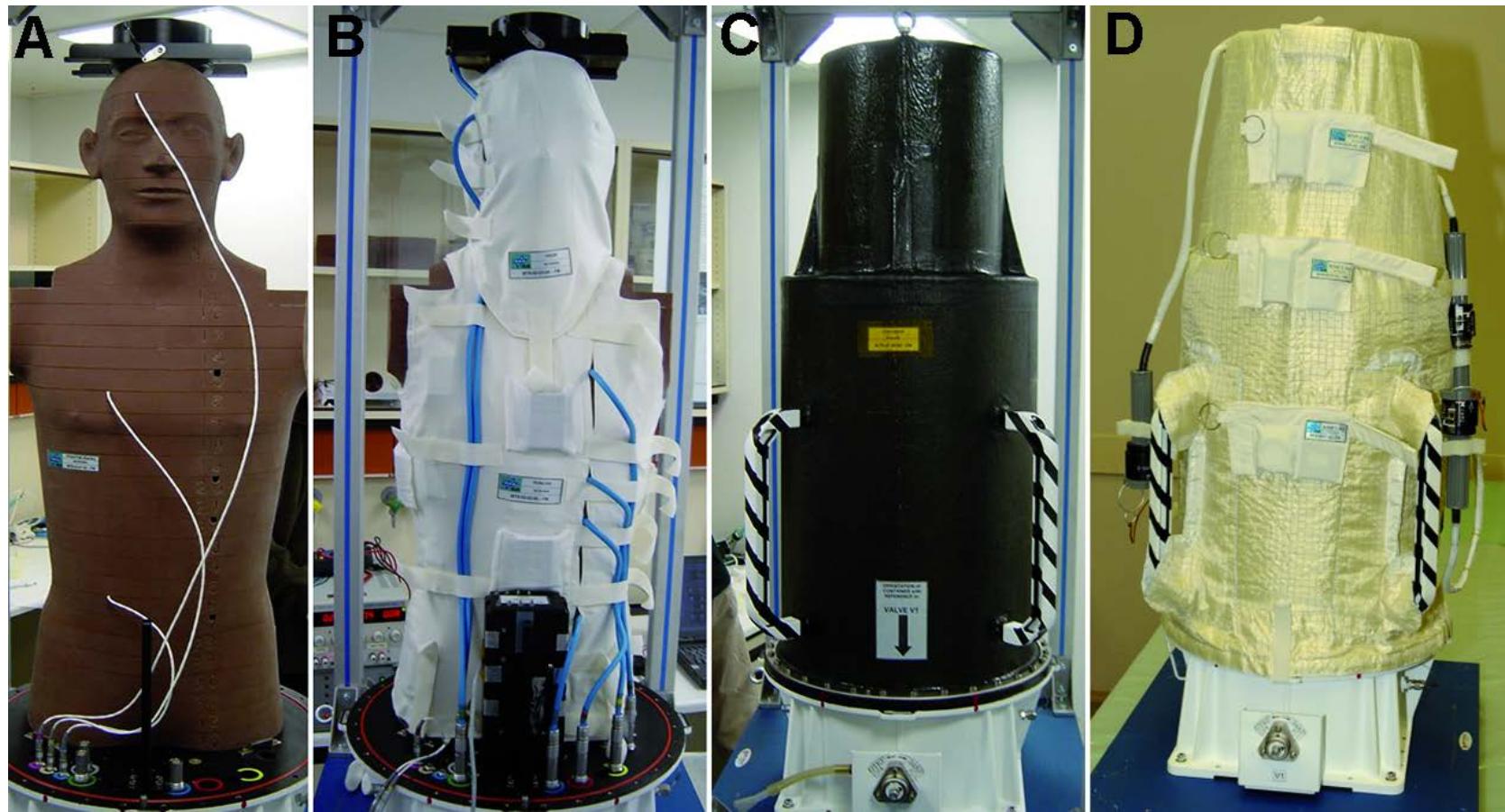
More than 6,000 passive
radiation detectors



Over 1,600 measurements sites
in a regular 2.5 cm x/y/z grid

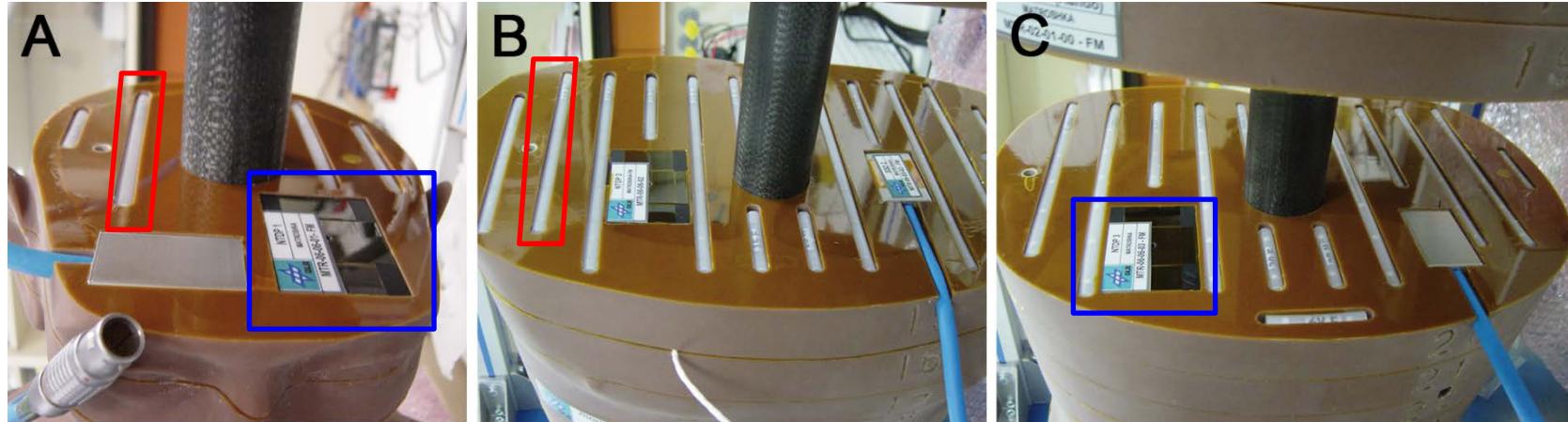
Seven active radiation
detectors





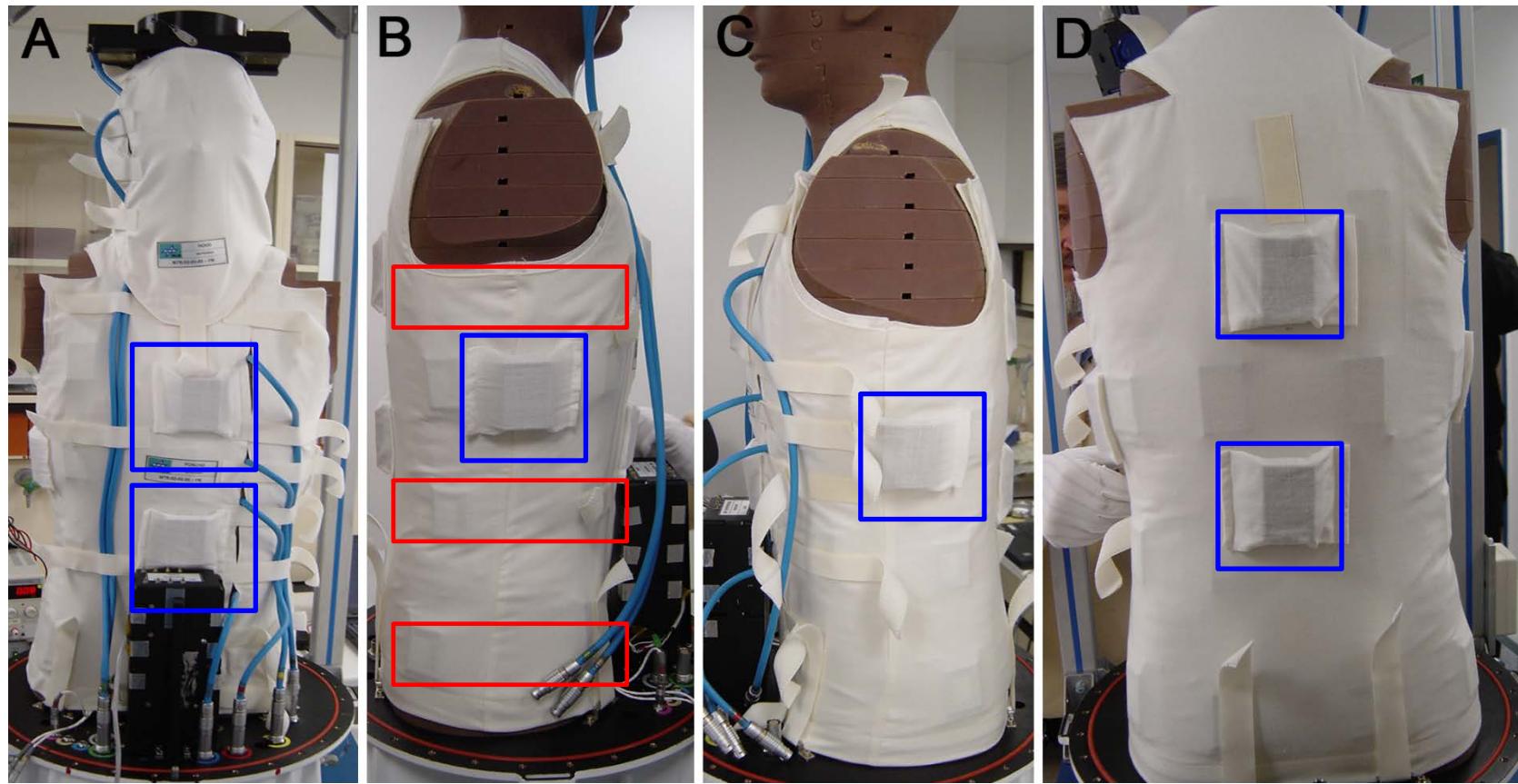
(A): The urethane-based phantom body of the MATROSHKA facility; (B): dressed with a Nomex® skin substitute, aka hood and poncho; (C): A carbon fibre container thermally protected by a multilayer insulation (D), resembles the shielding properties of an EVA spacesuit.





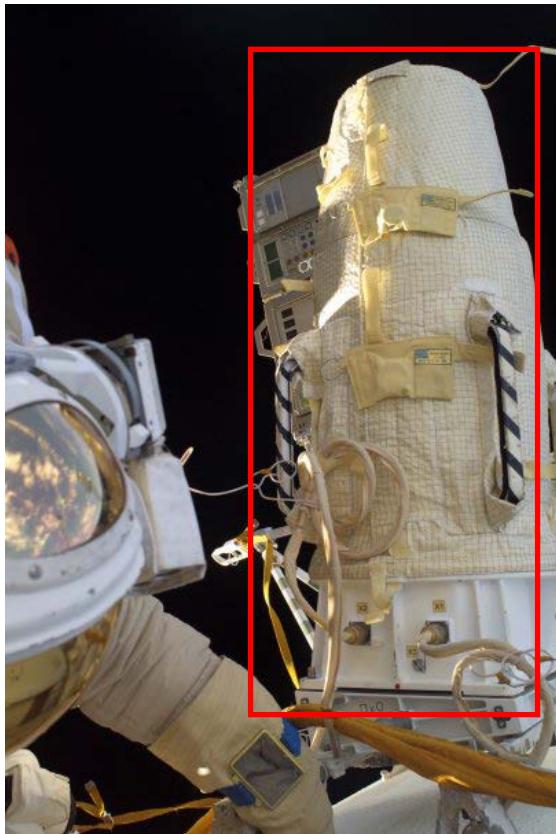
Polyethylene tubes containing luminescence detectors are accommodated in a regular grid throughout the phantom body. Organ detector boxes and silicon scintillation detectors monitor the doses at the sites of selected organs, as shown for (A) the eye; (B) the lung and (C) the stomach.

NTDP #	Slice #	Organ
1	3	Eye
2	15	Lungs
3	20	Stomach
4	22	Kidney
5	27	Intestine
6	–	Top of head



Skin doses are measured on the phantom's surface by means of **sewn-in dosimeter strips** and dedicated **poncho detector boxes** (A): mid thorax, upper abdomen; (B): lateral left; (C): lateral right; (D): mid dorsal and lumbar

MTR-1: 2004 - 2005



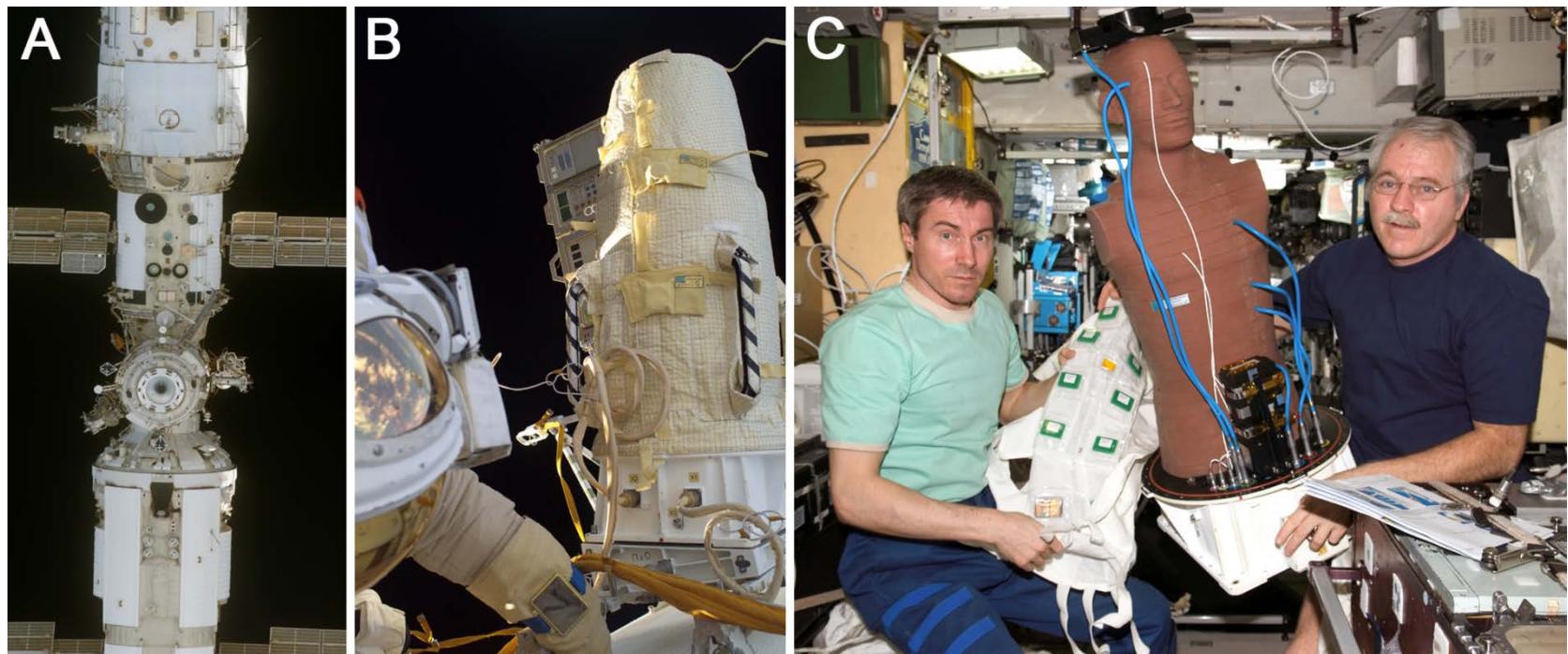
MTR-1 (2004–05)
539 days

Experiment phase	Event	Date
MTR-1 (2004-2005)	Launch of MTR with Progress 13P	29 January 2004
	Docking with ISS	31 January 2004
	EVA	26 February 2004
	Activation of active instruments	April 2004
	Outside exposure: 539 Days	26 February 2004 – 18 August 2005
	EVA	18 August 2005
	Dismounting of passive detectors	14 September 2005
	Detector download with Soyuz	11 October 2005 (landing)

Experiment phase	Timeline	Days
MTR 1 (2004–2005)	Total Time of the experiment	616
	EVA Time	539
	Detectors inside the ISS	77



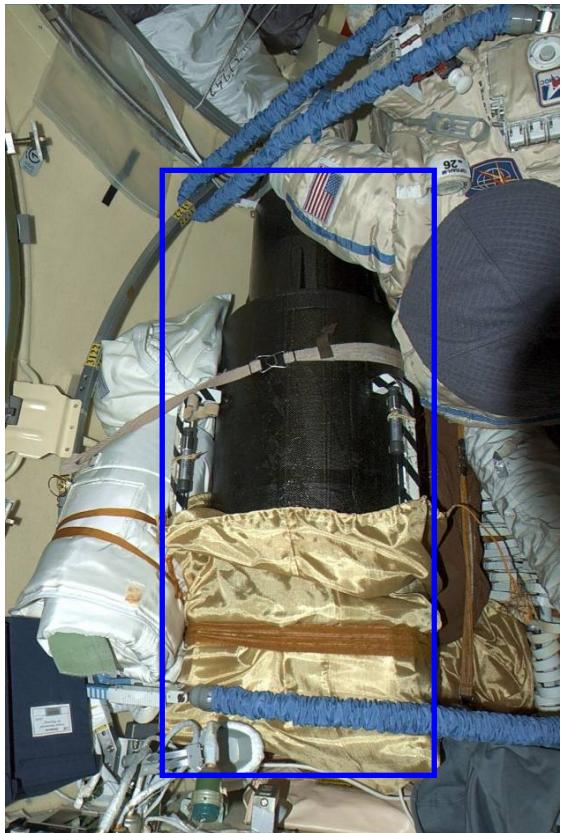
MTR-1: 2004 - 2005



(A): MTR-1 extravehicular exposure at the outer surface of the ISS Russian Service Module (Zvezda); (B): EVA for phantom removal; (C): Detector disintegration by Expedition 11 Commander Sergei K. Krikalev (left) and Flight Engineer John L. Phillips



MTR-2A: 2006

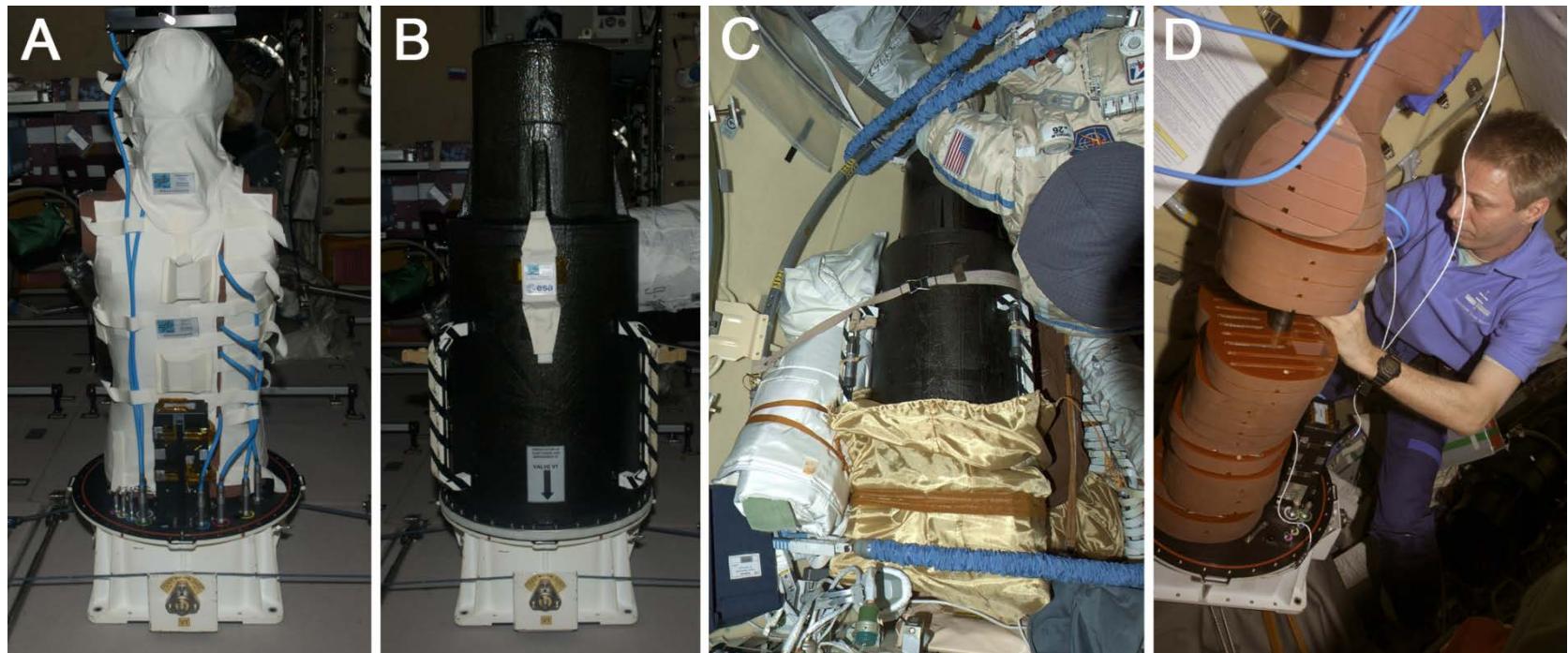


MTR-2A (2006)
337 days

Experiment phase	Event	Date
MTR-2A (2006)	Passive detector upload (Progress 20P)	21 December 2005
	Integration of passive detectors	5 January 2006
	Inside exposure: 337 Days	5 January 2006 – 7 December 2006
	Dismounting of passive detectors	7 December 2006
	Passive detector download (STS-116)	22 December 2006
Experiment phase	Timeline	Days
MTR-2A (2006)	Total exposure time	367
	Inside exposure I = Detectors inside or mounted on the MTR facility	337
	Inside exposure II = Detectors inside, but not mounted on the MTR facility	30



MTR-2A: 2006



(A) and (B): detector integration for MTR-2A; (C): MTR-2A intravehicular exposure in the ISS Russian Docking Compartment (Pirs); (D): Detector removal by Expedition 14 Flight Engineer, ESA astronaut Thomas Reiter



MTR-2B: 2007 - 2009



MTR-2B (2007–09)
518 days

Experiment phase	Event	Date
MTR-2B (2007–2009)	Passive detector upload (Soyuz TMA-11)	Oct. 10, 2007
	Integration of passive detectors	Oct. 18, 2007
	Inside exposure (active, passive detectors)	Oct. 18, 2007–March 18, 2009
	Dismounting of passive detectors I	Nov. 25, 2008
	Passive detector download I (STS-126)	Nov. 30 2008
	Dismounting of passive detectors II	March 18, 2009
	Passive detector download I (STS-119)	March 30, 2009

Experiment phase	Timeline	Days (I)	Days (II)
MTR-2B (2007–2009)	Total exposure time	417	536
	Inside exposure I = Detectors inside or mounted on the MTR facility	402	518
	Inside exposure II = Detectors inside, but not mounted on the MTR facility	12	18



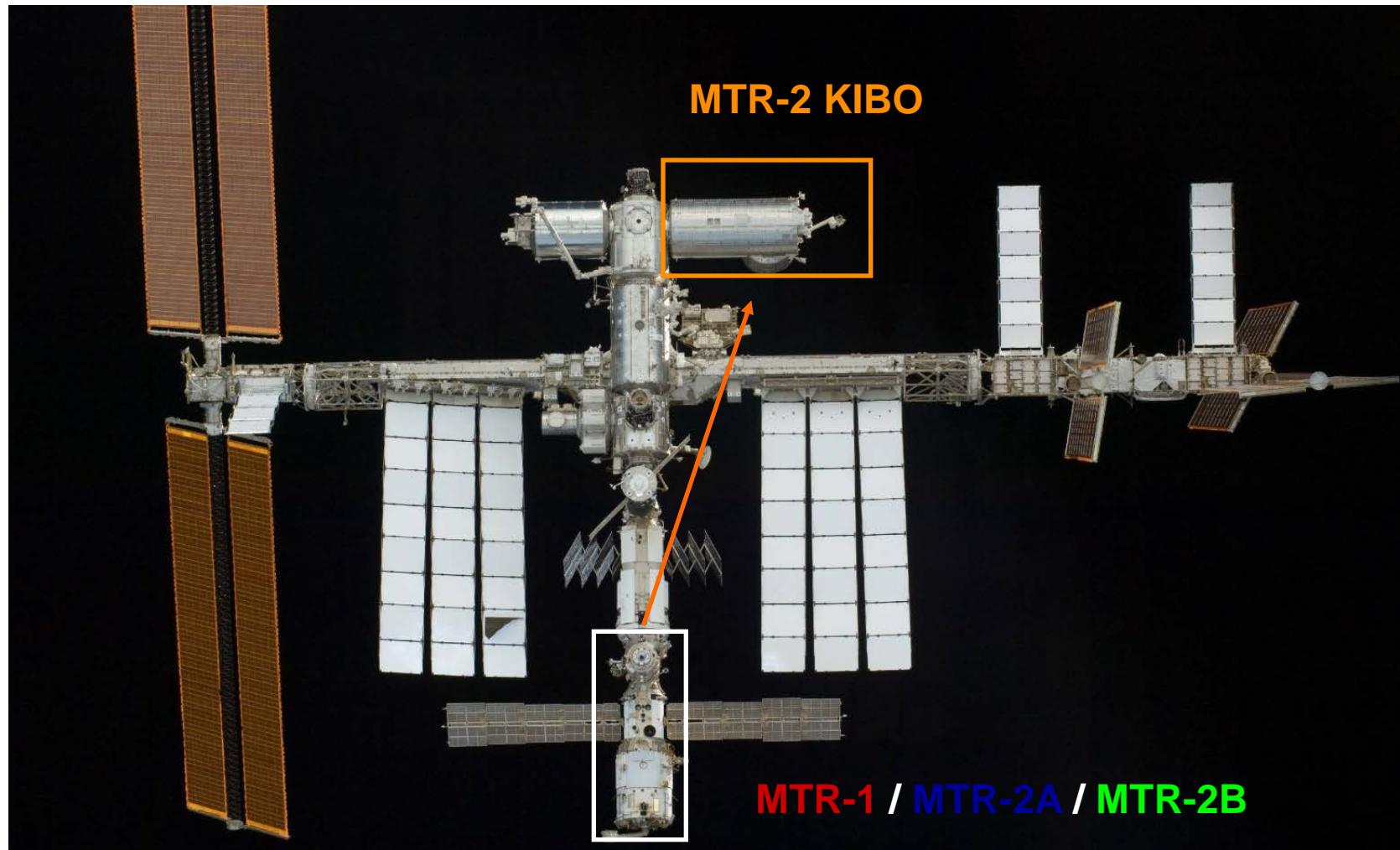
MTR-2B: 2007 - 2009



(A) and (B): MTR-2B intravehicular exposure in the ISS Russian Service Module (Zvezda); (C): Detector disintegration by Expedition 18 Flight Engineer Yury V. Lonchakov



MATROSHKA: From „Russia“ to „Japan“



MTR-2 KIBO: 2010 - 2011



The MATROSHKA 2 KIBO space experiment was conducted under

*'ESA/ROSCOSMOS and JAXA
Payload Integration Agreement
(PIA) for MATROSHKA'*

approved on 19 August 2009 and revised on 2 September 2010, as part of Kibo utilization framework.



MTR-2 KIBO: 2010 - 2011



**MTR-2 KIBO
(2010–11)
310 days**

Experiment phase	Event	Date
MTR-2 KIBO (2010 - 2011)	Passive detector upload (Progress 37P)	April 28, 2010
	Integration of passive detectors	May 04, 2010
	Inside exposure (passive detectors)	May 04, 2010 – March 10, 2011
	Dismounting of passive detectors	March 10, 2011
	Passive detector download (Soyuz 24S)	March 16, 2011

Experiment phase	Timeline	Days
MTR 2 KIBO (2010–2011)	Total Time of the experiment	322
	Detectors inside the MATROSHKA	310
	Detectors inside the ISS	12



MTR-2 KIBO: 2010 - 2011



(A): MTR-2 KIBO detector integration (May 2010); (B): MATROSHKA exposure inside the KIBO module; (C): MTR-2 KIBO detector disintegration (March 2011)



MTR-2 KIBO: Results



Thermoluminescence detector (TLD) data from:

- Institute of Nuclear Physics, **IFJ**, Krakow, Poland;
- Institute of Atomic and Subatomic Physics, **ATI**, Vienna, Austria
- German Aerospace Center, **DLR**, Cologne, Germany
- Japan Aerospace Exploration Agency, **JAXA**, Tsukuba, Japan

Nuclear Track Etch Detectors (CR-39) data from:

- German Aerospace Center, **DLR**, Cologne, Germany
- Centre for Energy Research, **EK**, Budapest, Hungary



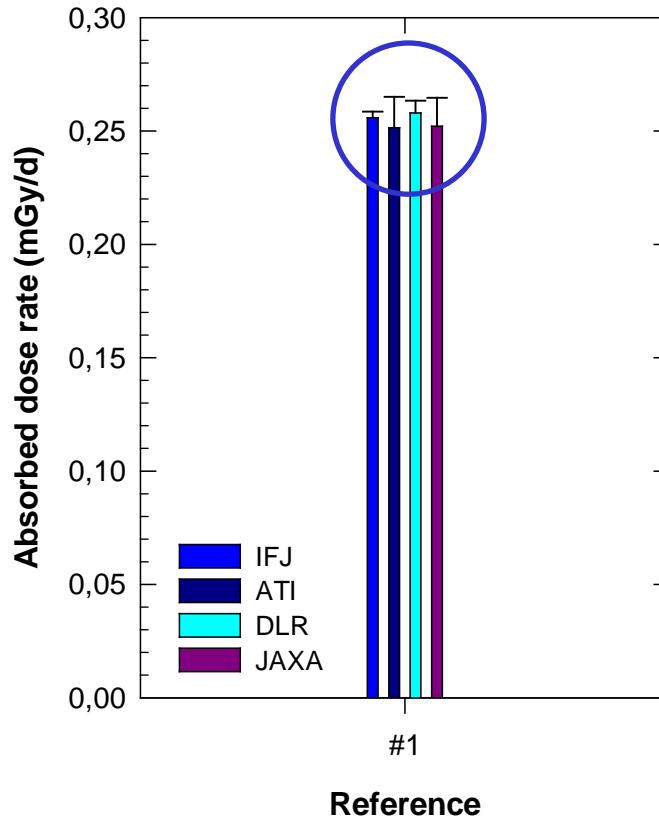
MTR-2 KIBO: Results



Thermoluminescence Detectors



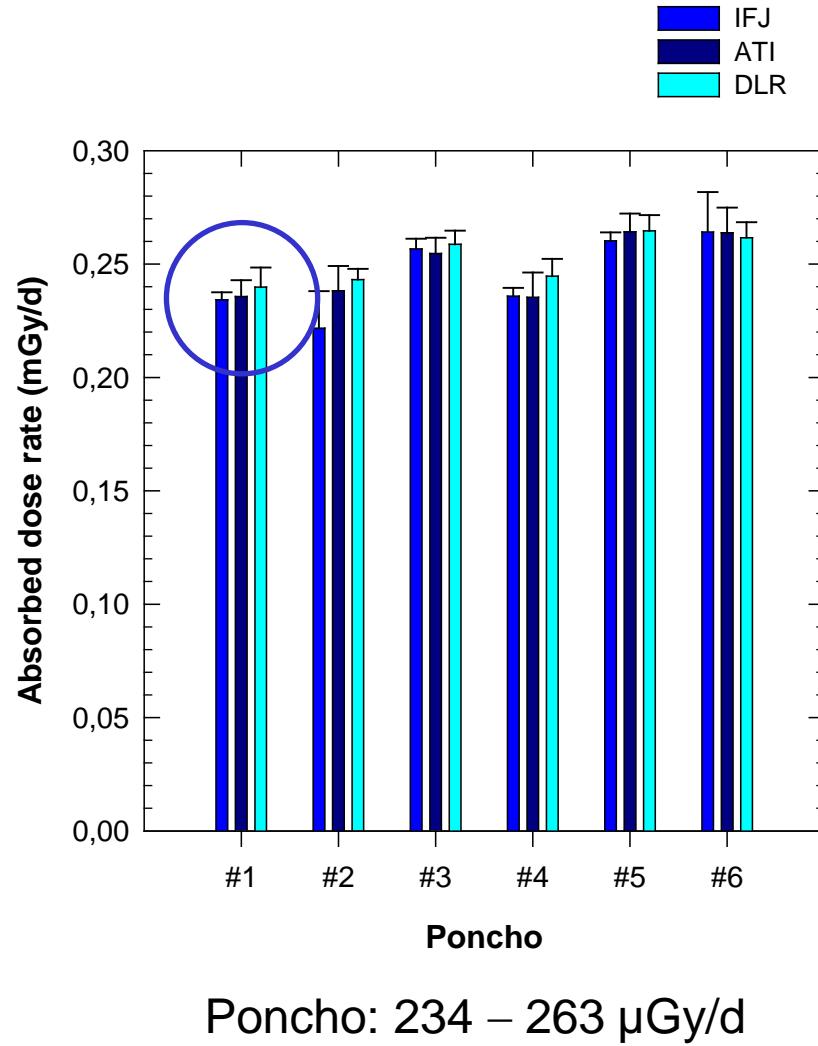
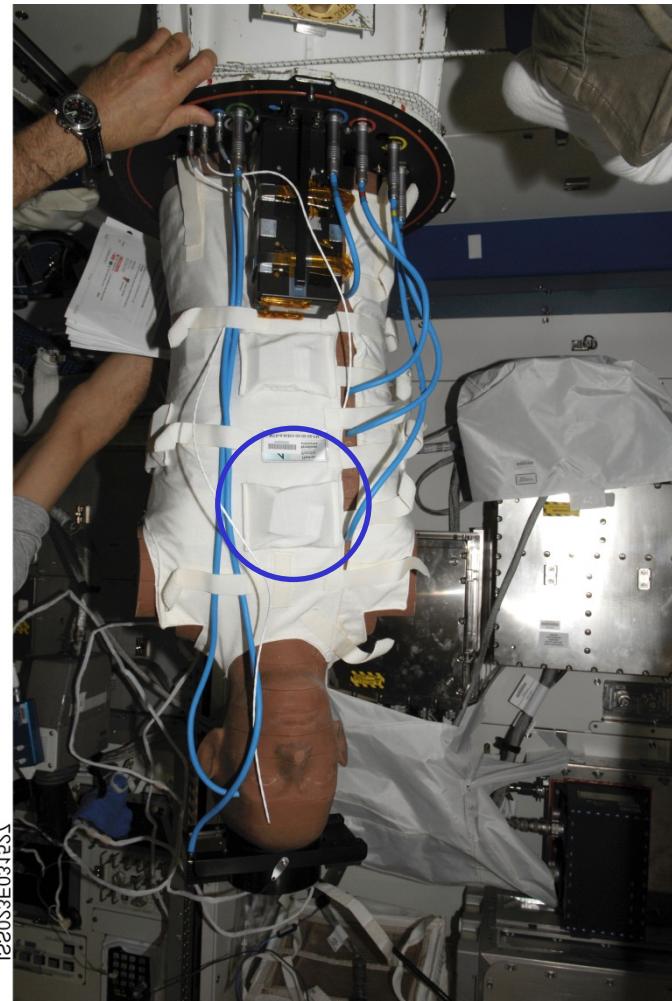
MTR-2 KIBO: Results / Reference (IFJ, ATI, DLR, JAXA)



Reference: $254 \pm 8 \mu\text{Gy}$



MTR-2 KIBO: Results / Poncho (IFJ, ATI, DLR)



MTR-2 KIBO: Results / Poncho (JAXA)



FRONT



BACK

MTR-2 KIBO: Results / Poncho (JAXA)

242 ± 19			
		240 ± 11	
211 ± 13			

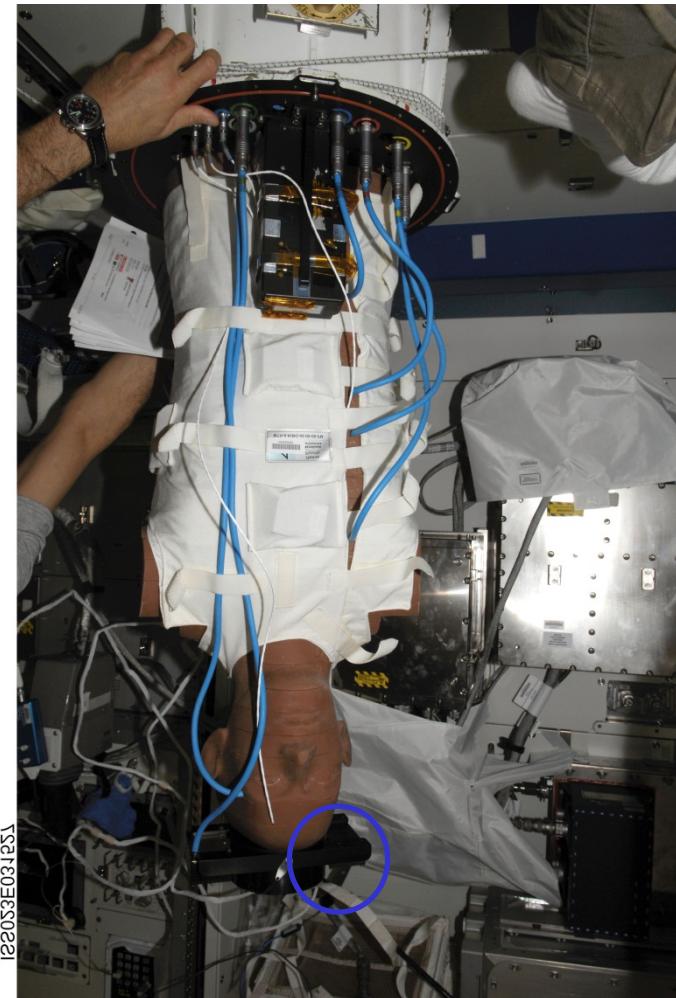
FRONT

	265 ± 21	265 ± 17	
	248 ± 12		275 ± 19
		292 ± 21	251 ± 18
	240 ± 18		249 ± 10

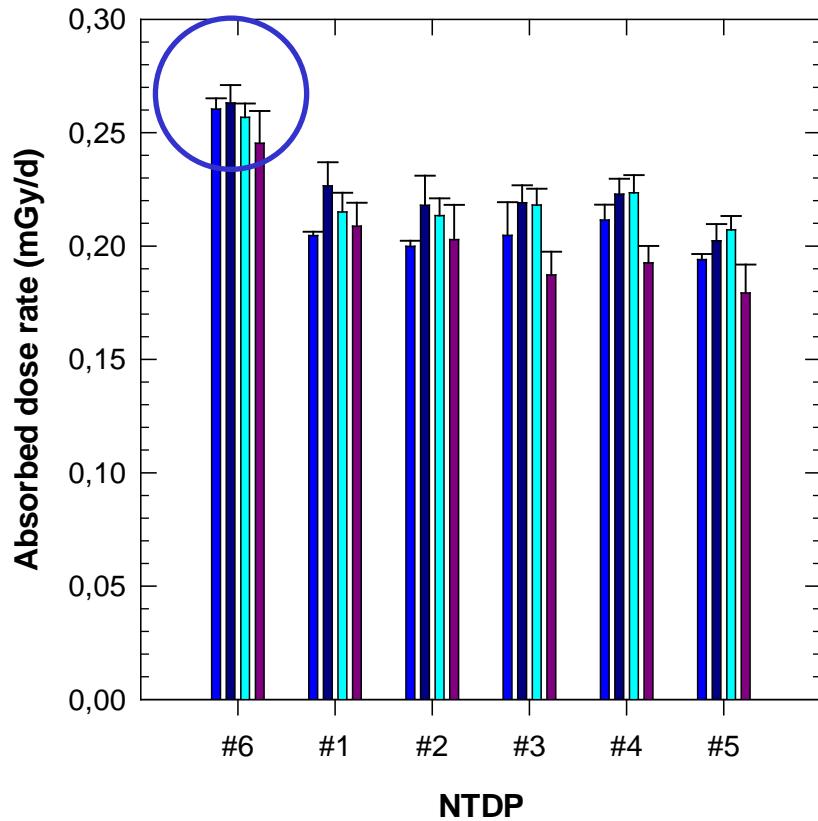
BACK



MTR-2 KIBO: Results / NTDP (IFJ, ATI, DLR, JAXA)



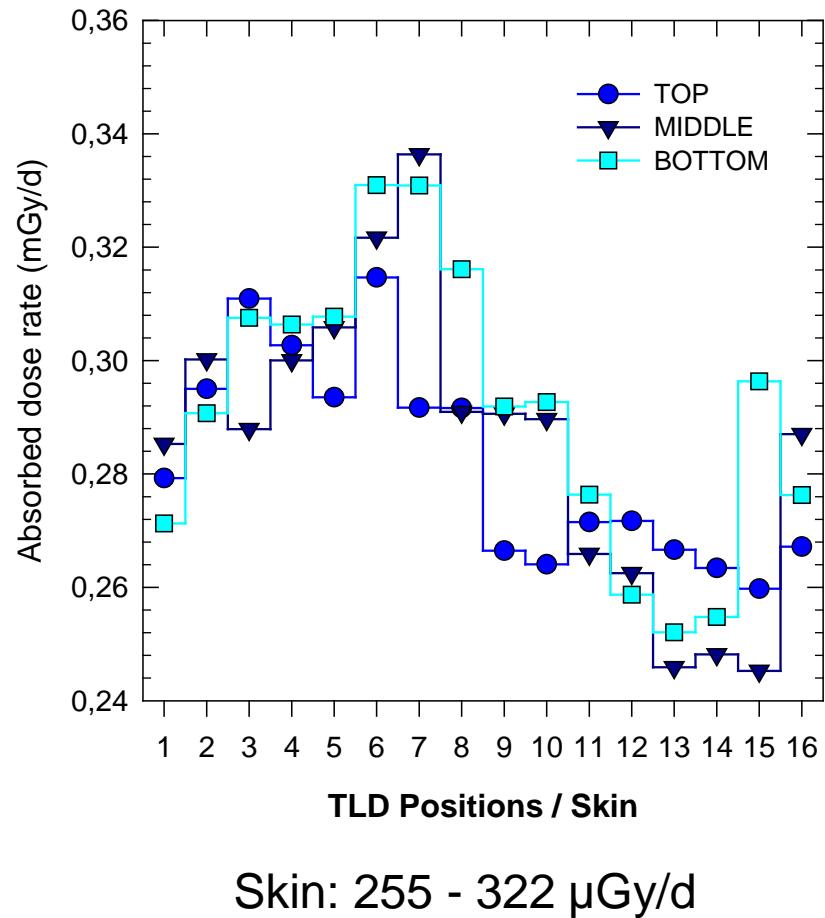
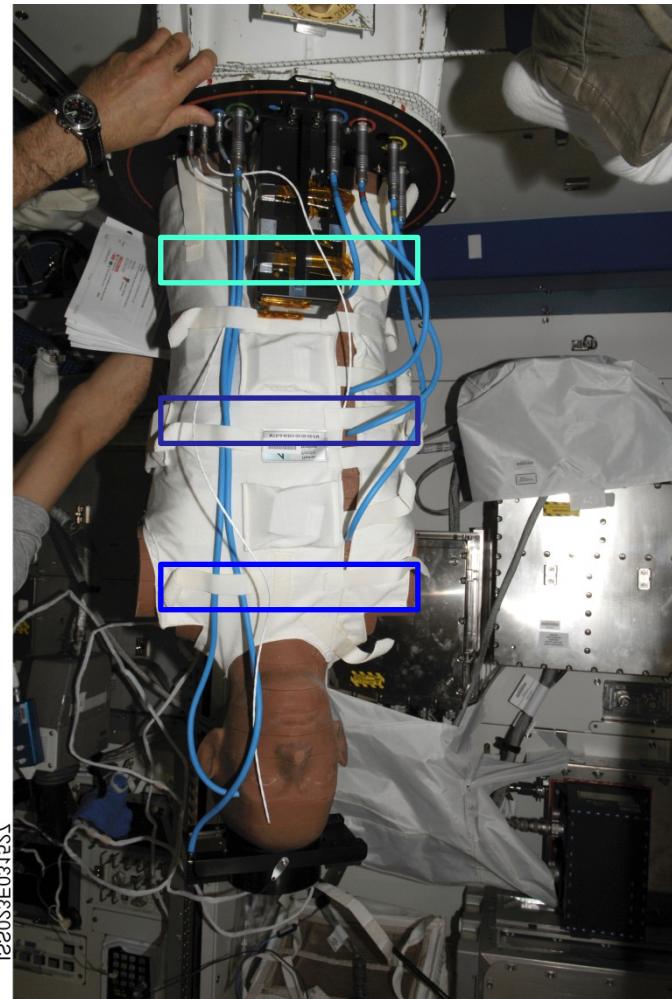
IFJ
ATI
DLR
JAXA



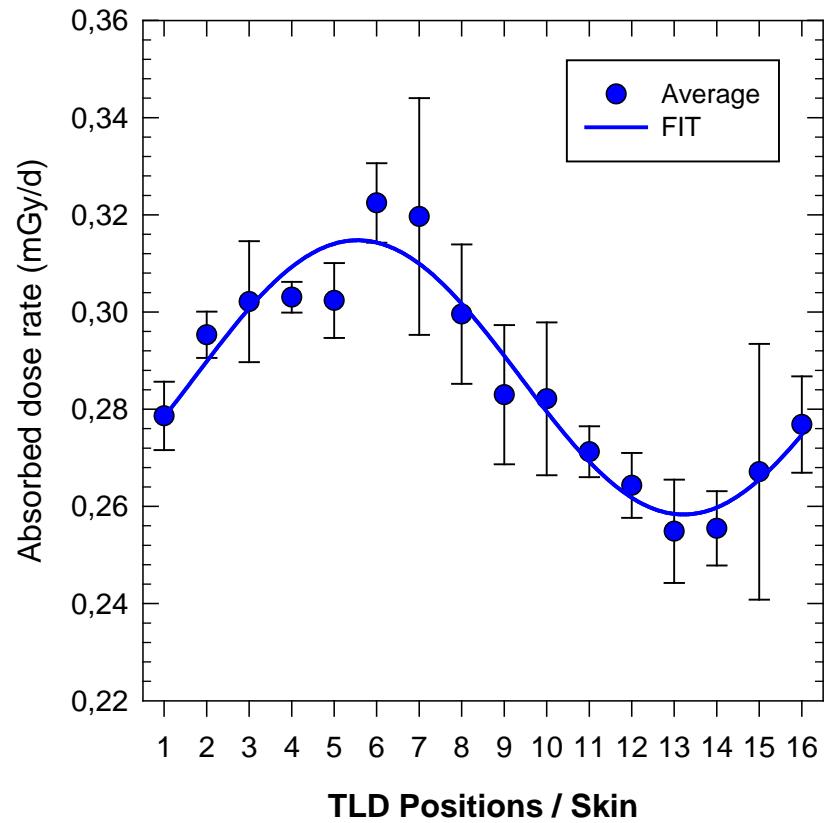
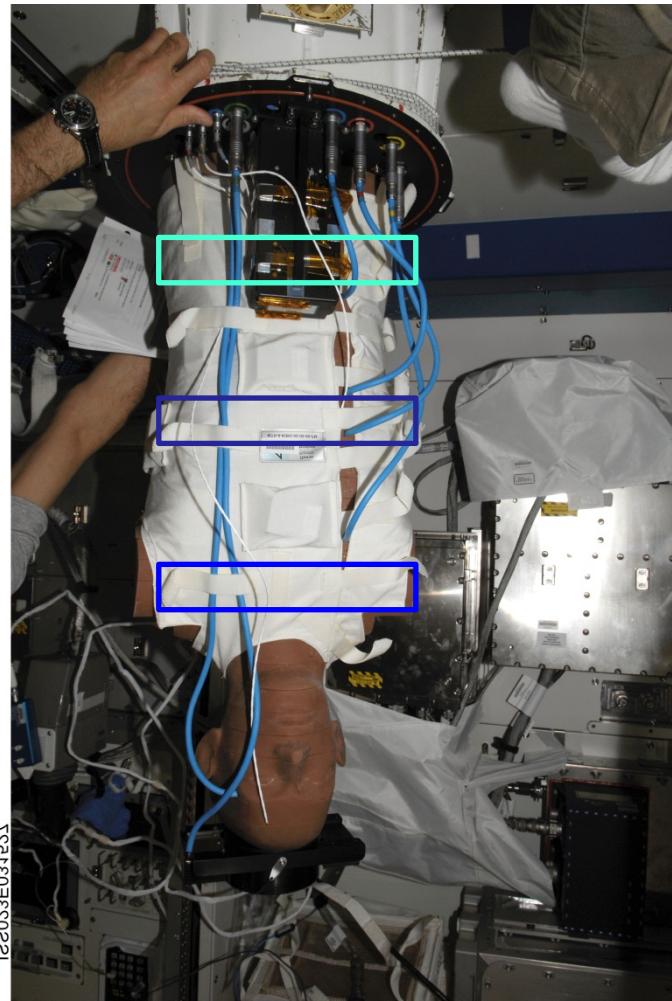
NTDP #1 - #5: 195 – 214 $\mu\text{Gy/d}$
NTDP #6 : 256 $\mu\text{Gy/d}$



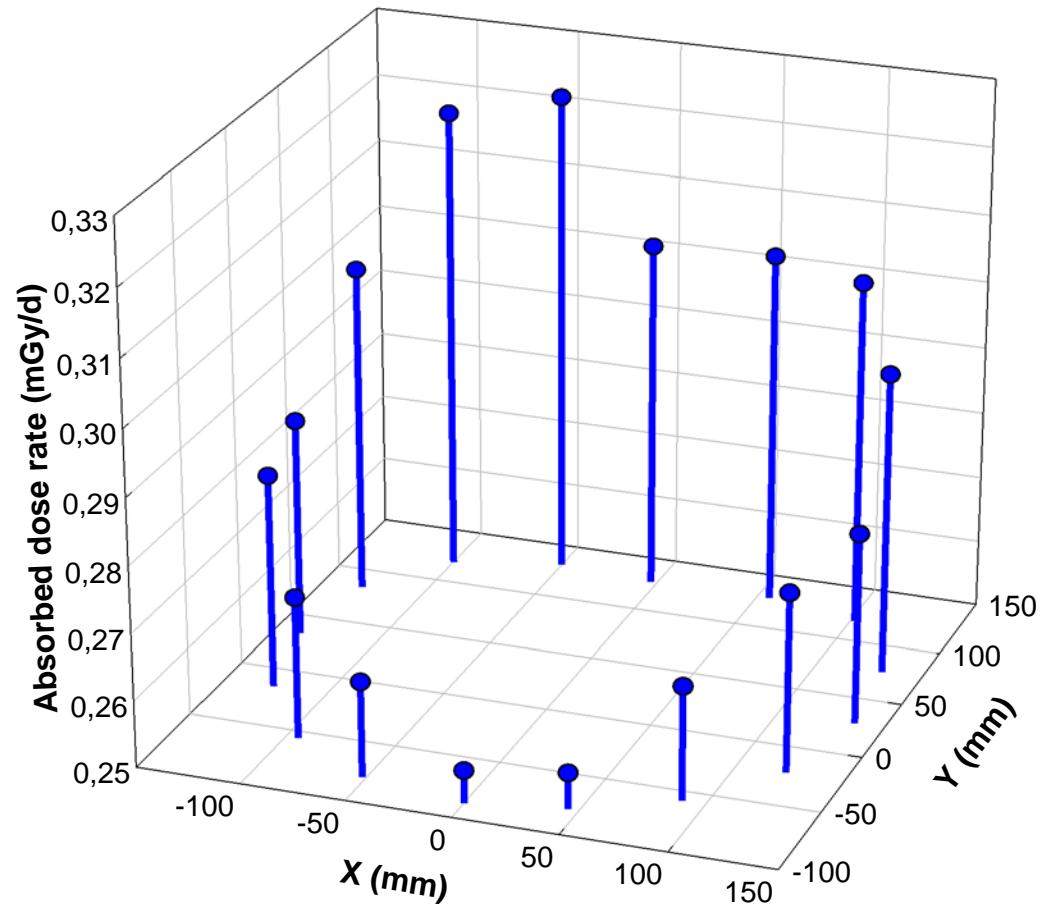
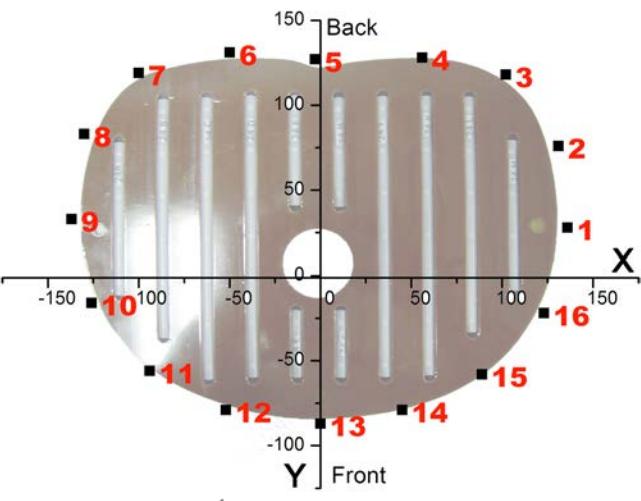
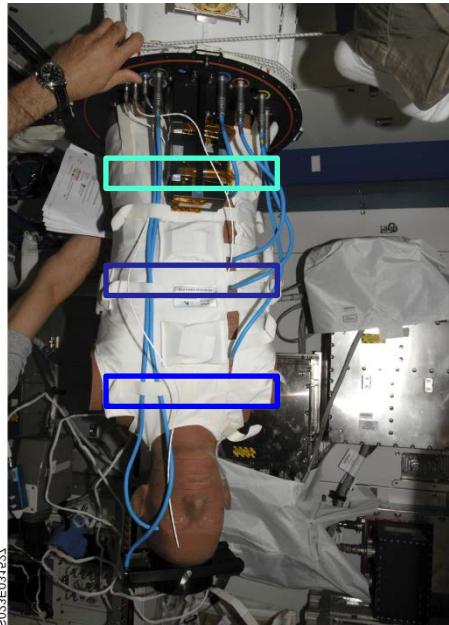
MTR-2 KIBO: Results / Skin (DLR)



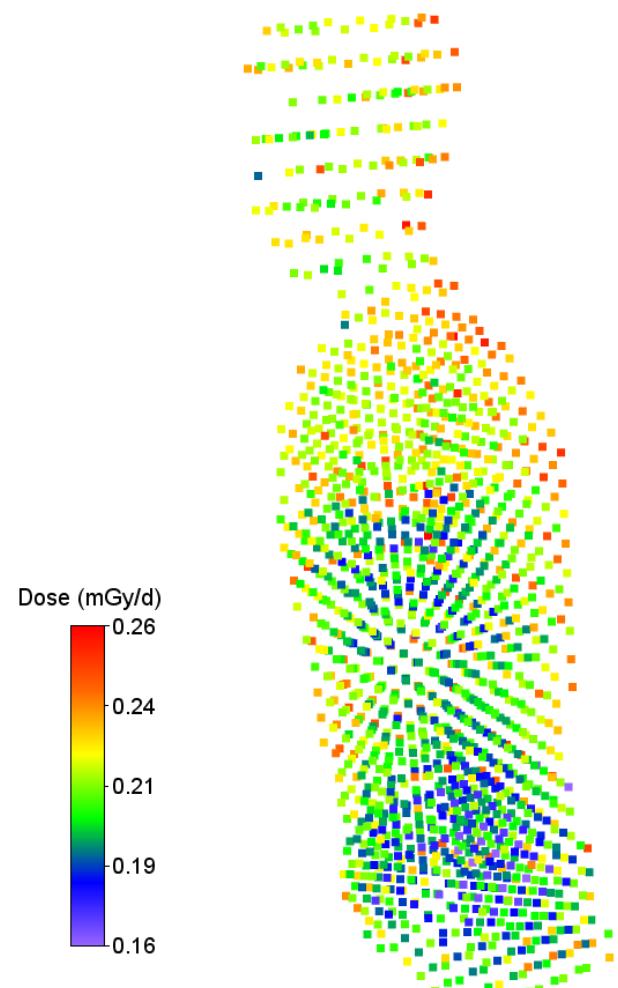
MTR-2 KIBO: Results / Skin (DLR)



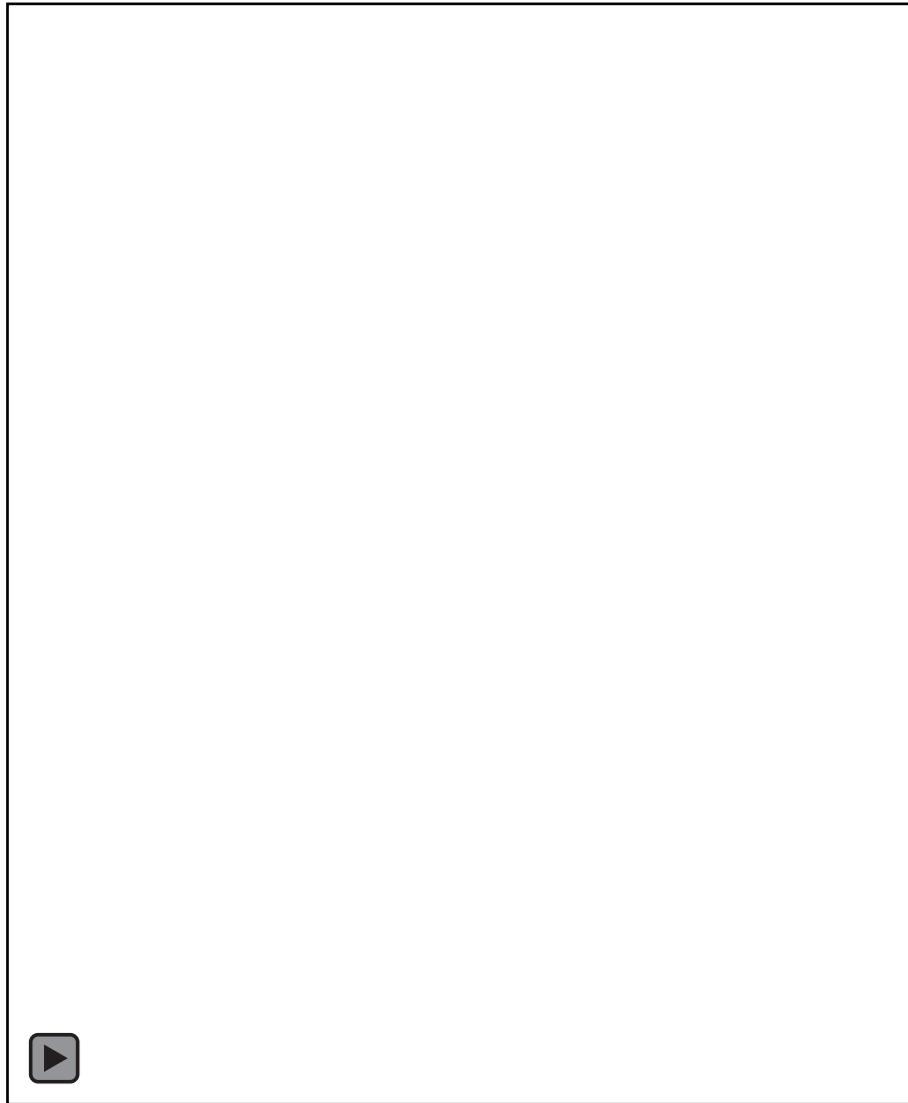
MTR-2 KIBO: Results / Skin (DLR)



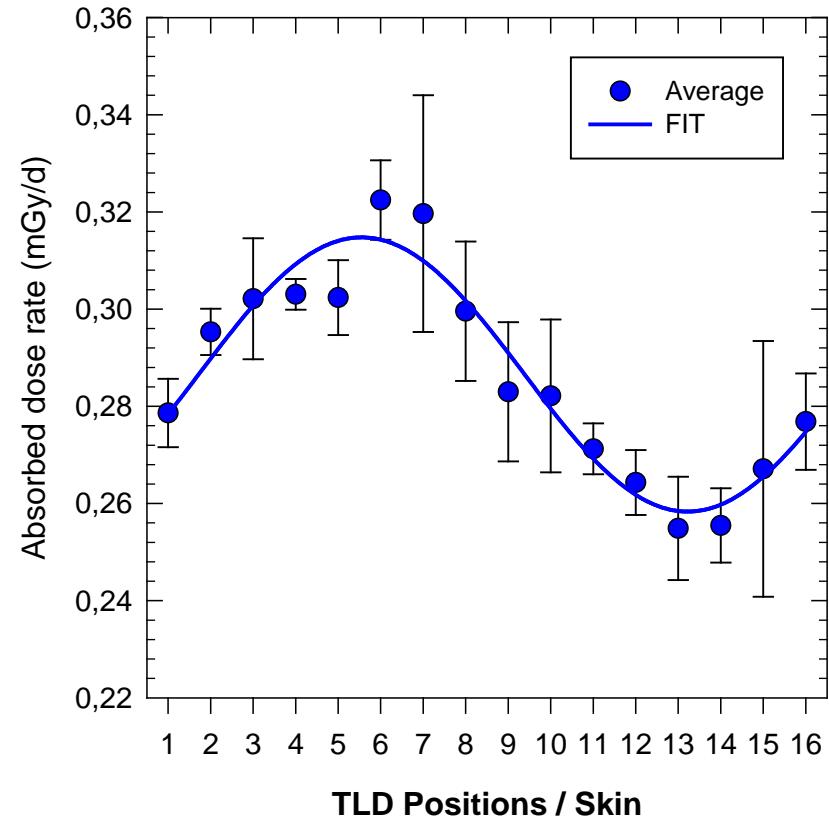
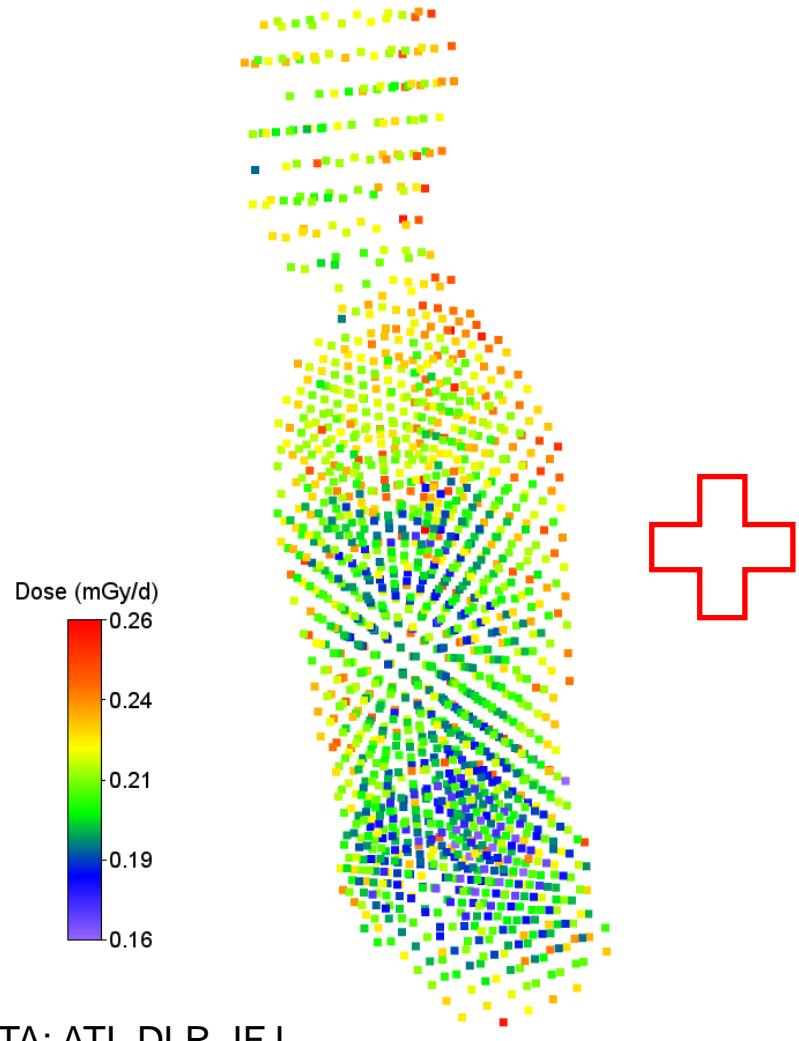
MTR-2 KIBO: Results / 3D Dose Distribution → Discrete



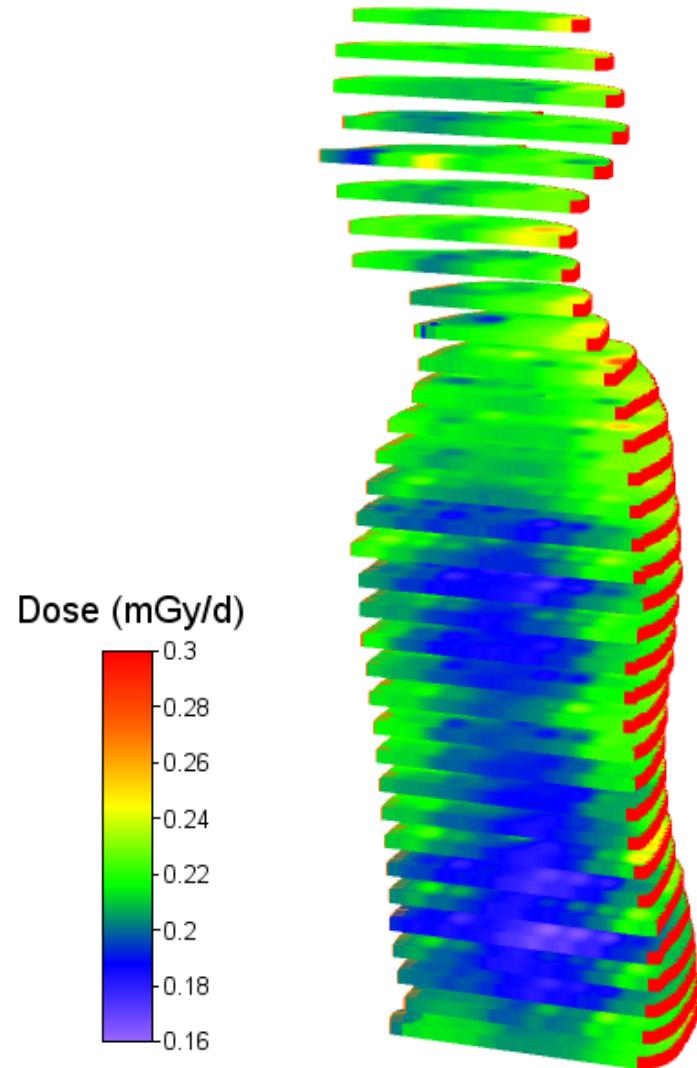
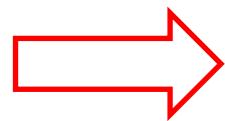
DATA: ATI, DLR, IFJ



MTR-2 KIBO: Results / 3D Dose Distribution → Continuous



MTR-2 KIBO: Results / 3D Dose Distribution → Continuous



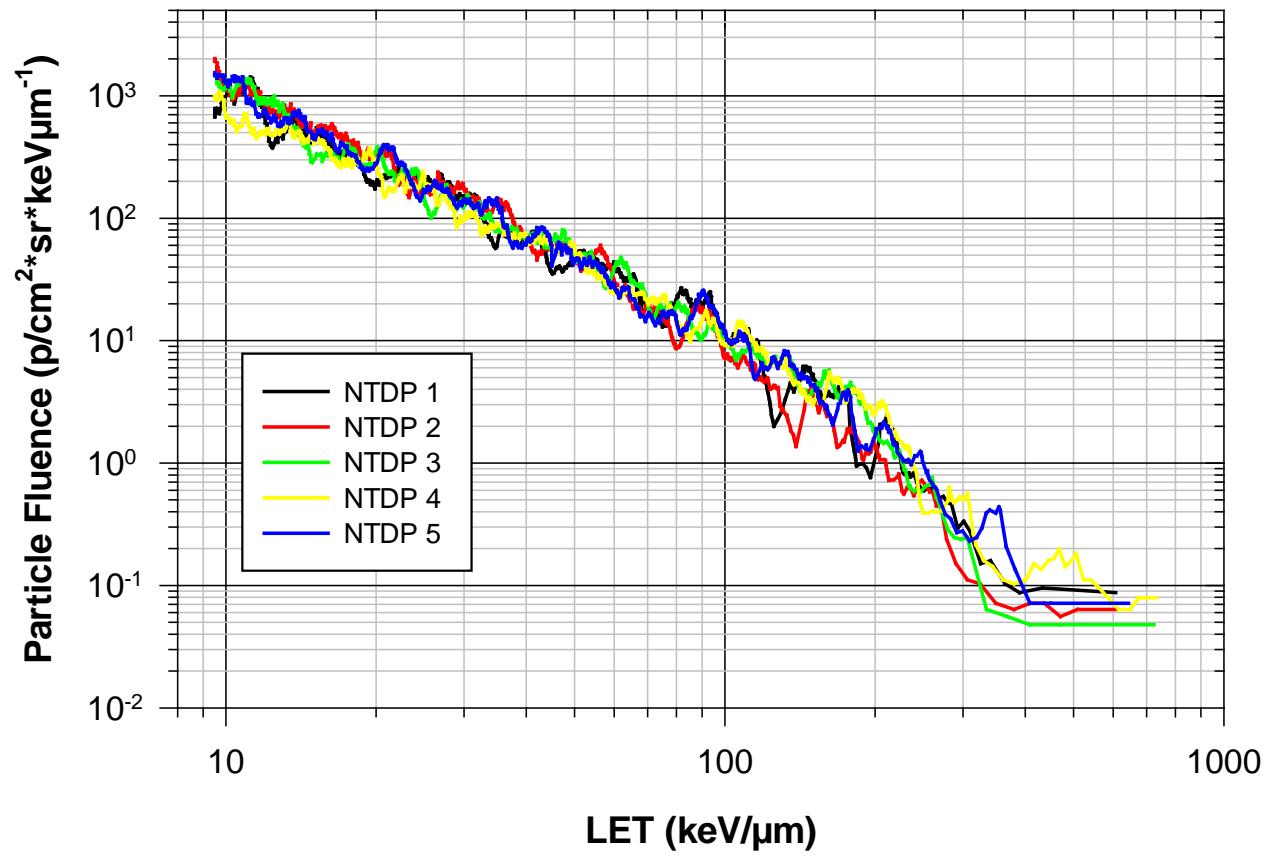
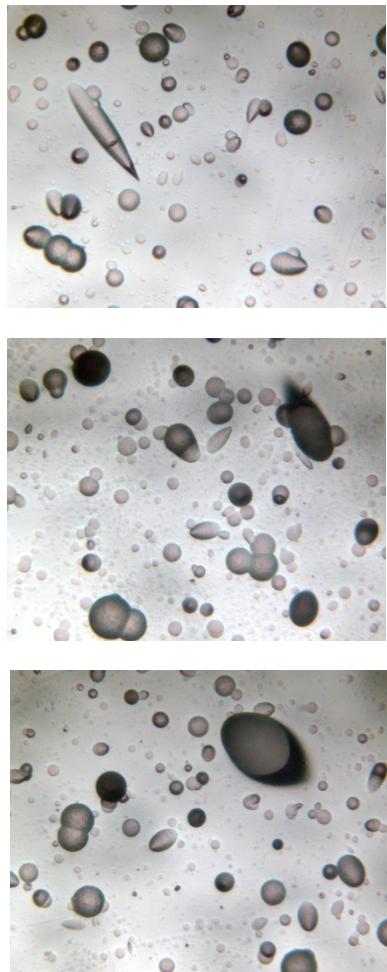
MTR-2 KIBO: Results



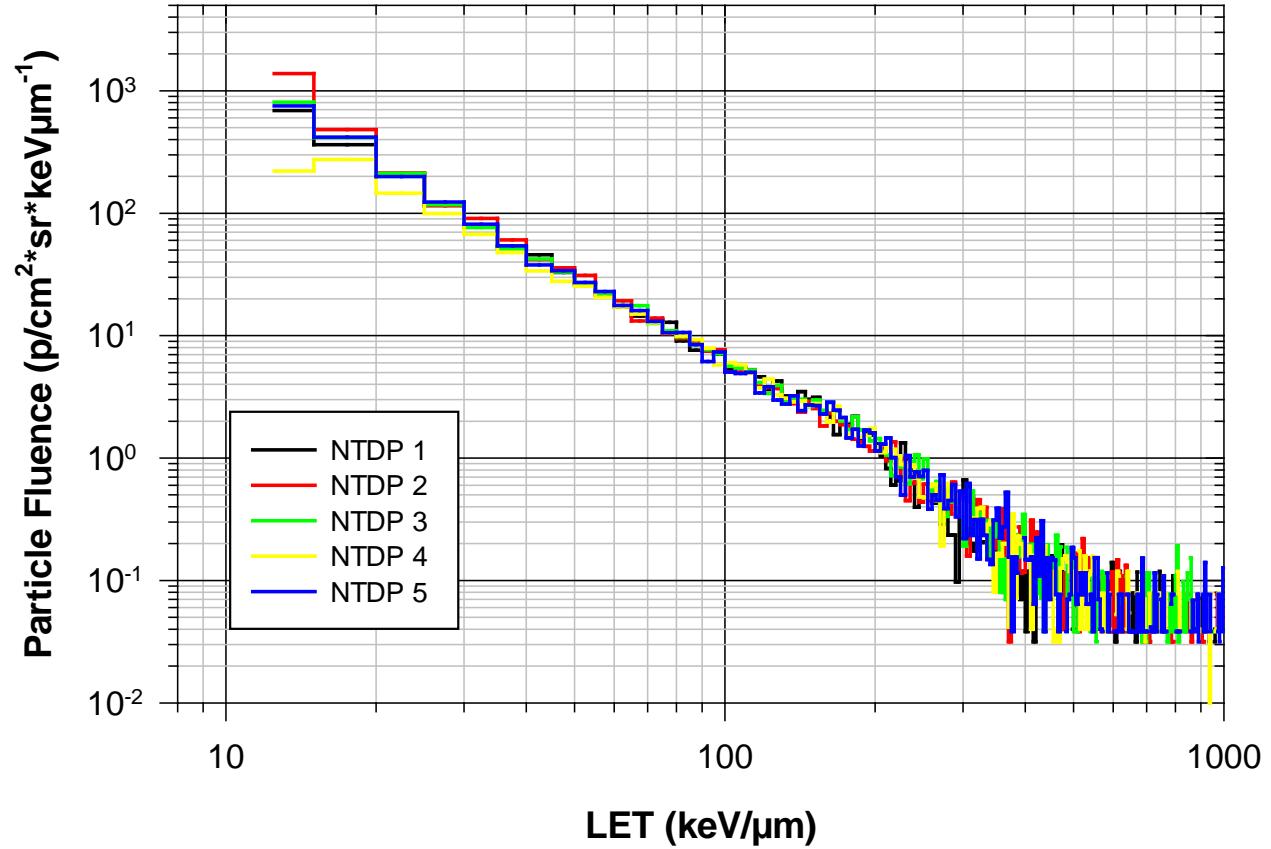
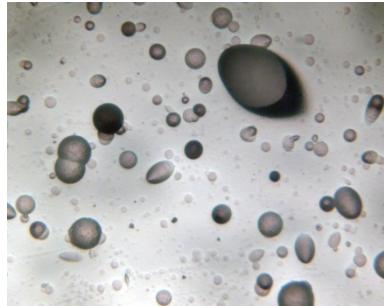
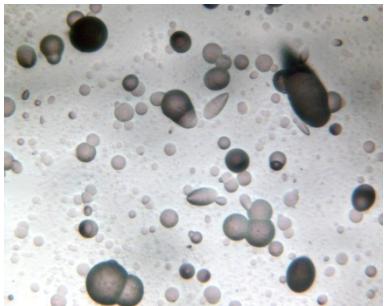
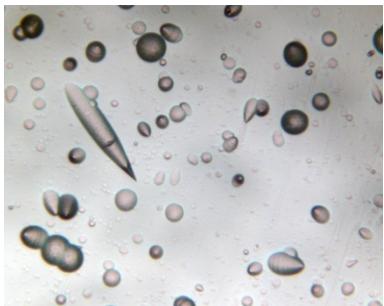
Nuclear Track Etch Detectors



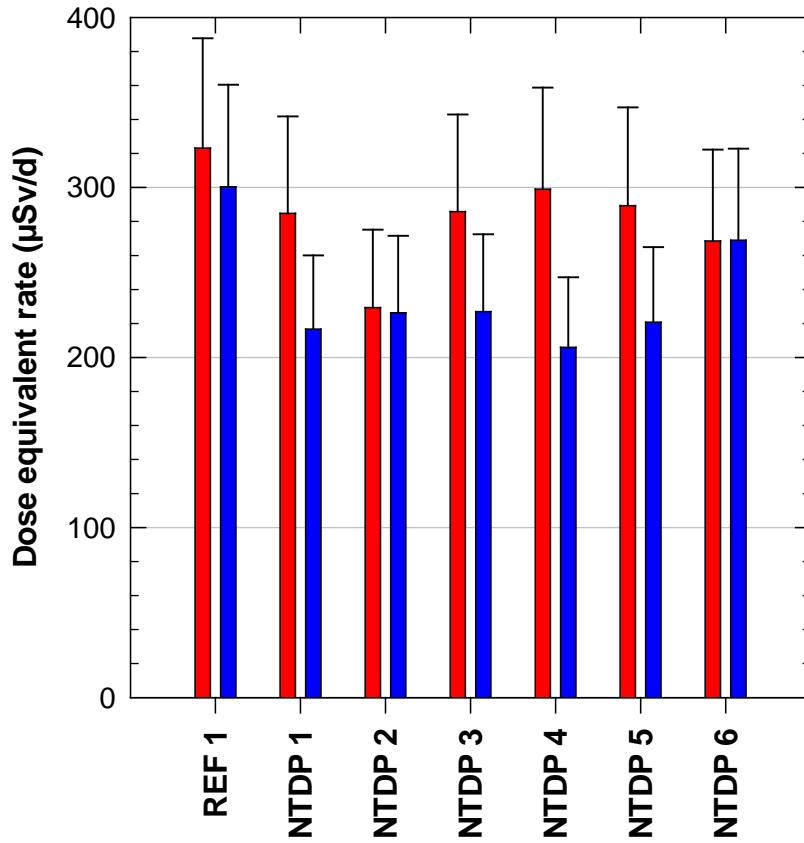
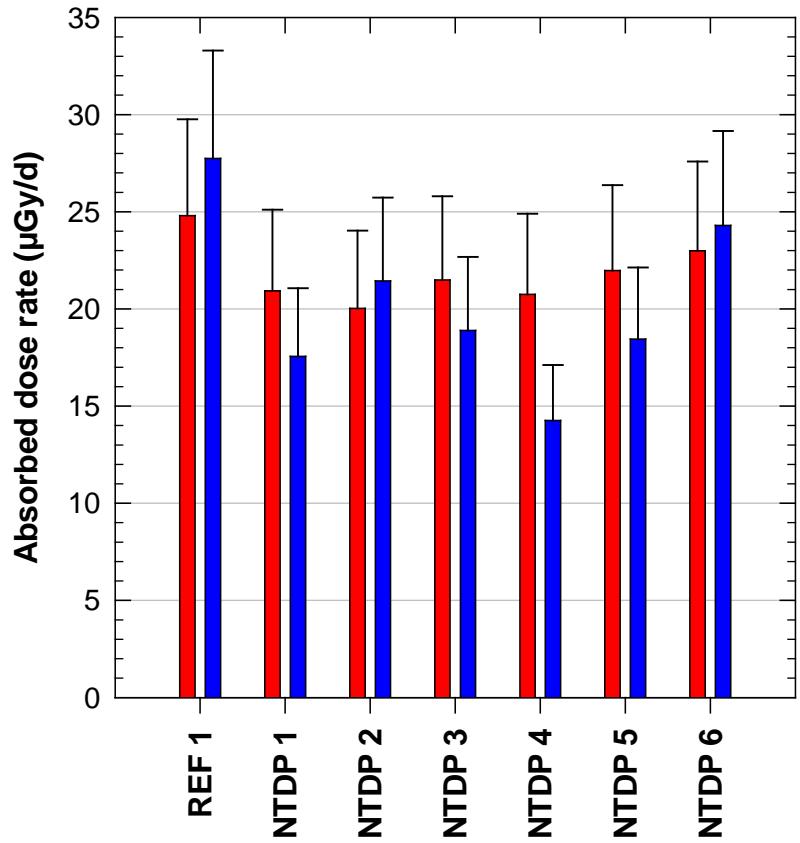
MTR-2 KIBO: CR-39 Results (DLR)



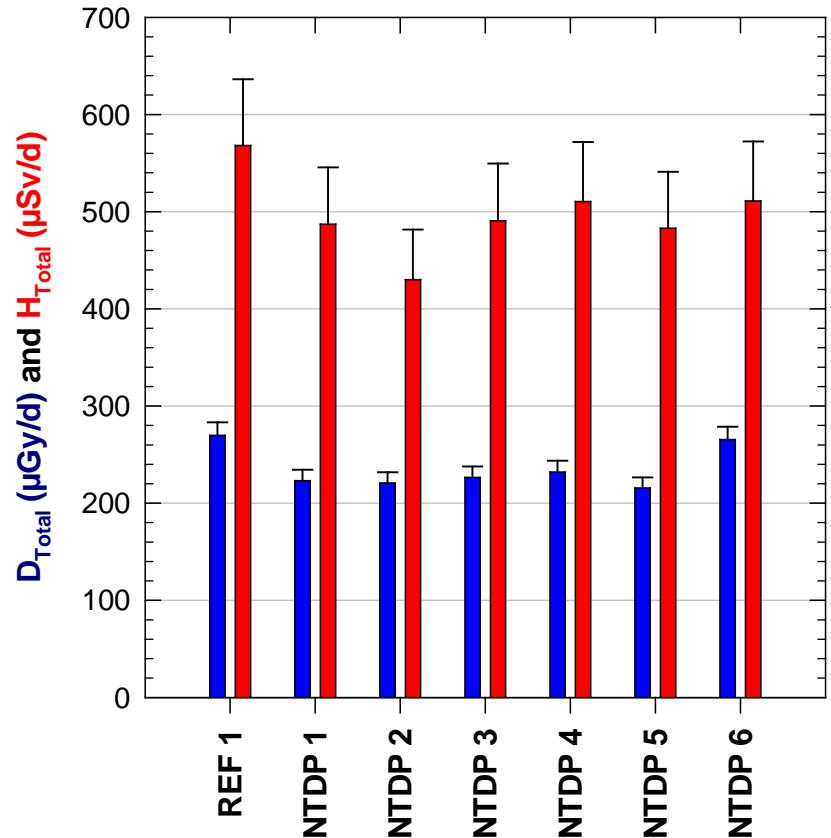
MTR-2 KIBO: CR-39 Results (EK)



MTR-2 KIBO: CR-39 Results (DLR / EK)

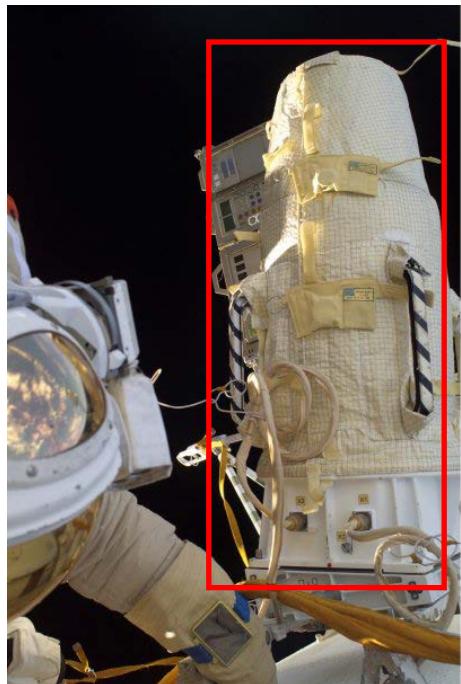


MTR-2 KIBO: TLD + CR-39 Results (DLR)



	D_{Total} ($\mu\text{Gy}/\text{d}$)	H_{Total} ($\mu\text{Sv}/\text{d}$)	Q
REF 1	270 ± 13	568 ± 68	2,1
NTDP 1	223 ± 11	487 ± 58	2,2
NTDP 2	221 ± 11	430 ± 52	1,9
NTDP 3	226 ± 11	491 ± 59	2,2
NTDP 4	232 ± 12	510 ± 61	2,2
NTDP 5	216 ± 11	483 ± 58	2,2
NTDP 6	265 ± 13	511 ± 61	1,9

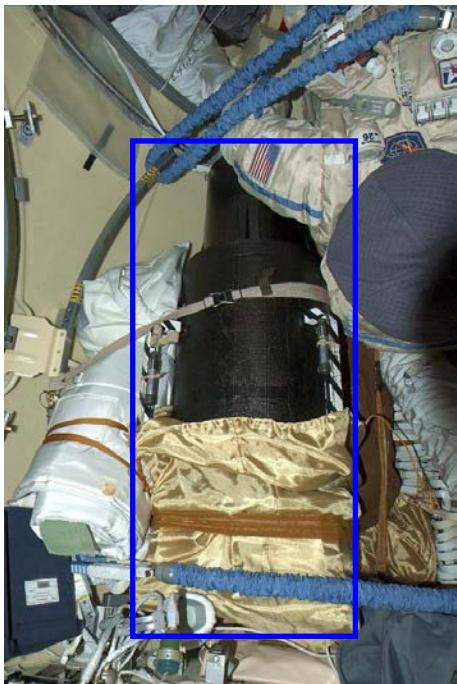
MATROSHKA: Comparison



MTR-1

(2004–05)

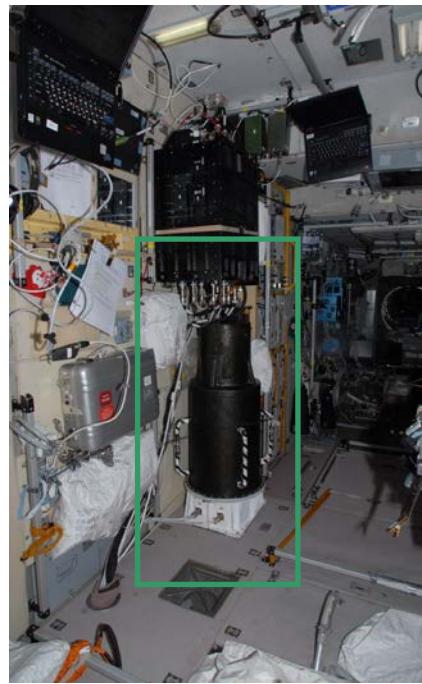
539 days



MTR-2A

(2006)

337 days



MTR-2B

(2007–09)

518 days

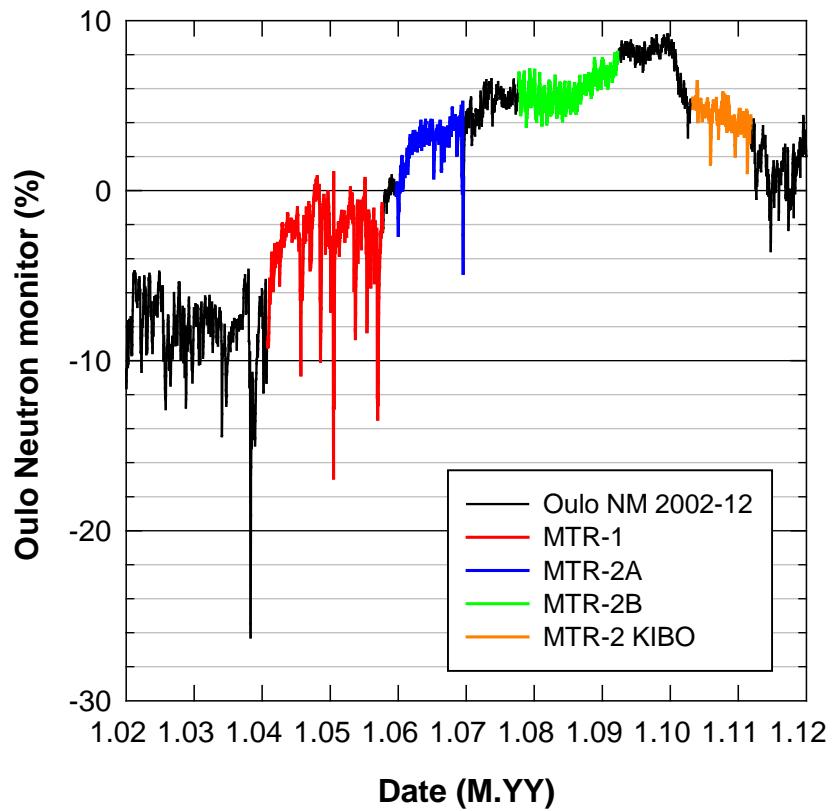


MTR-2 KIBO

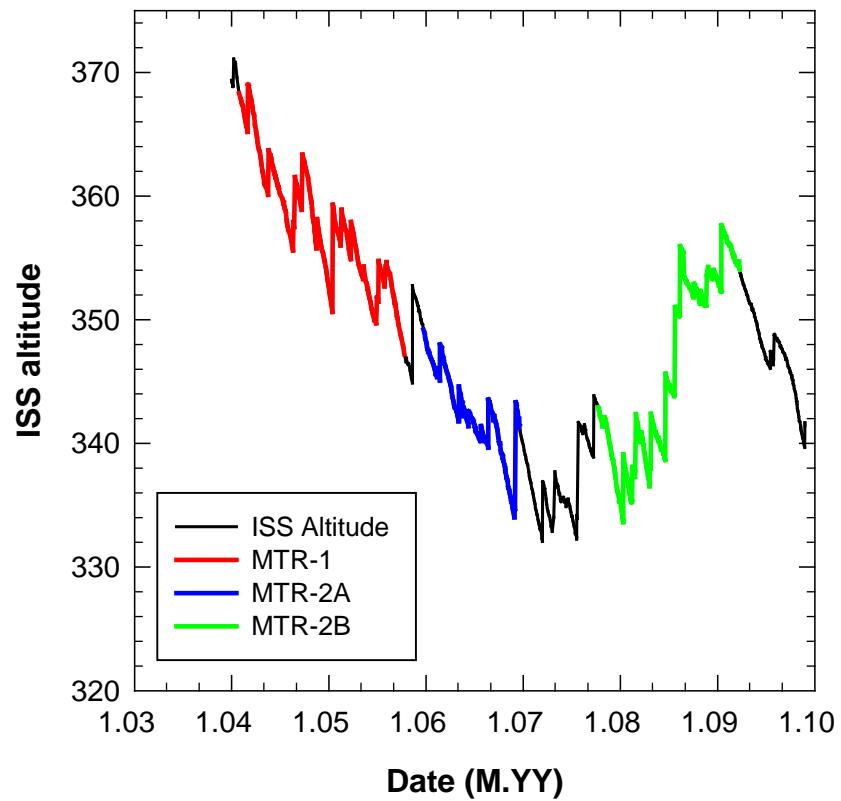
(2010–11)

310 days

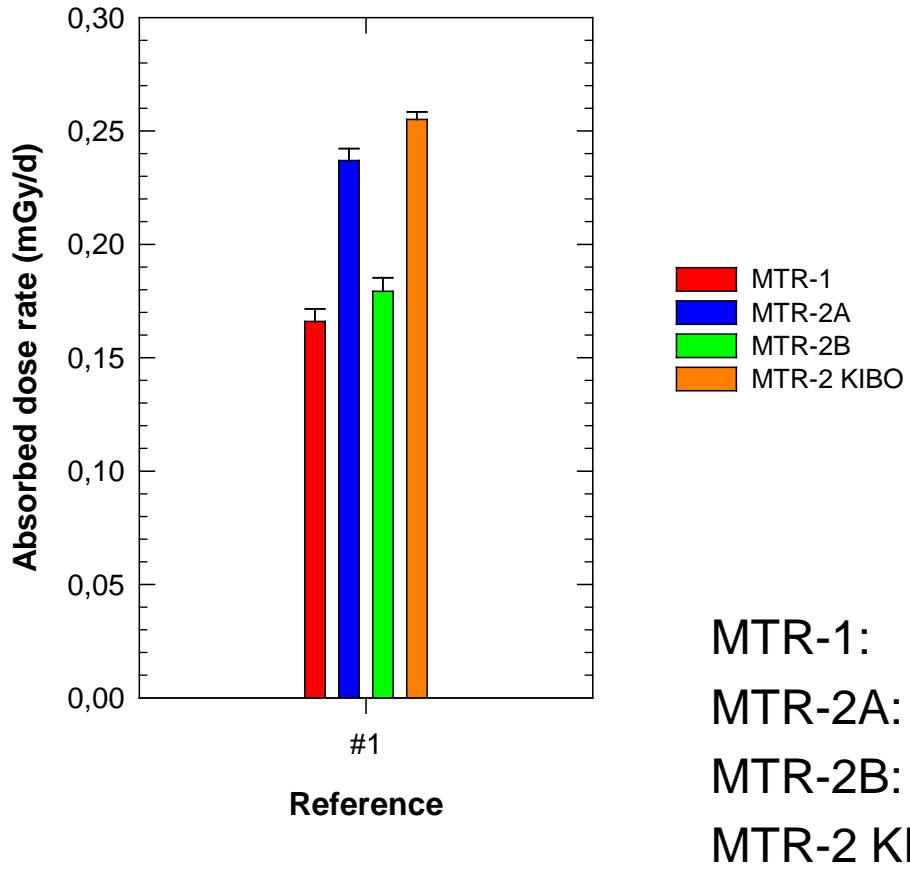
Oulo Neutron Monitor



ISS Altitude

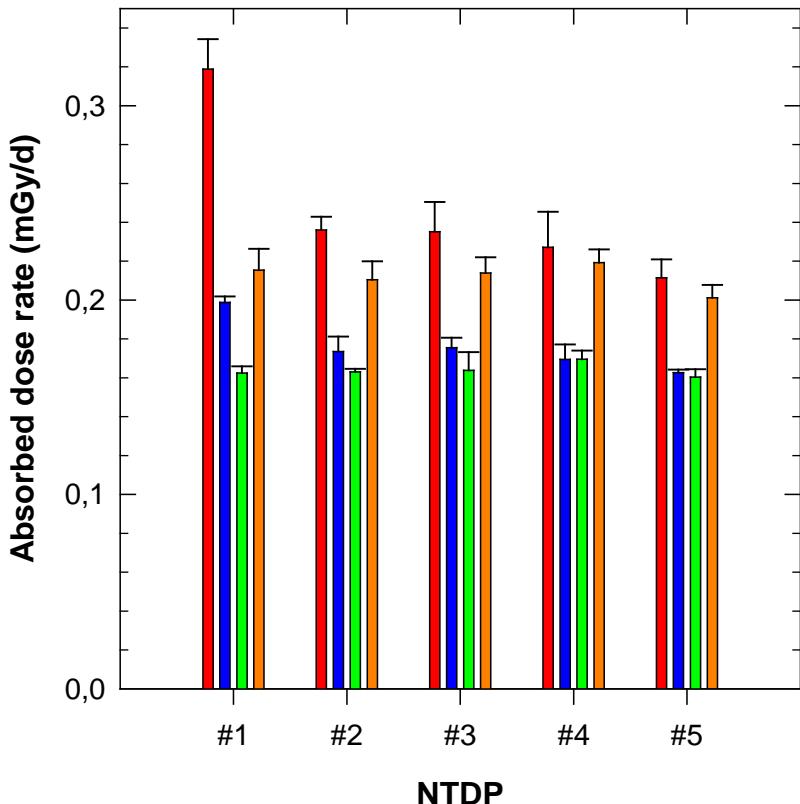
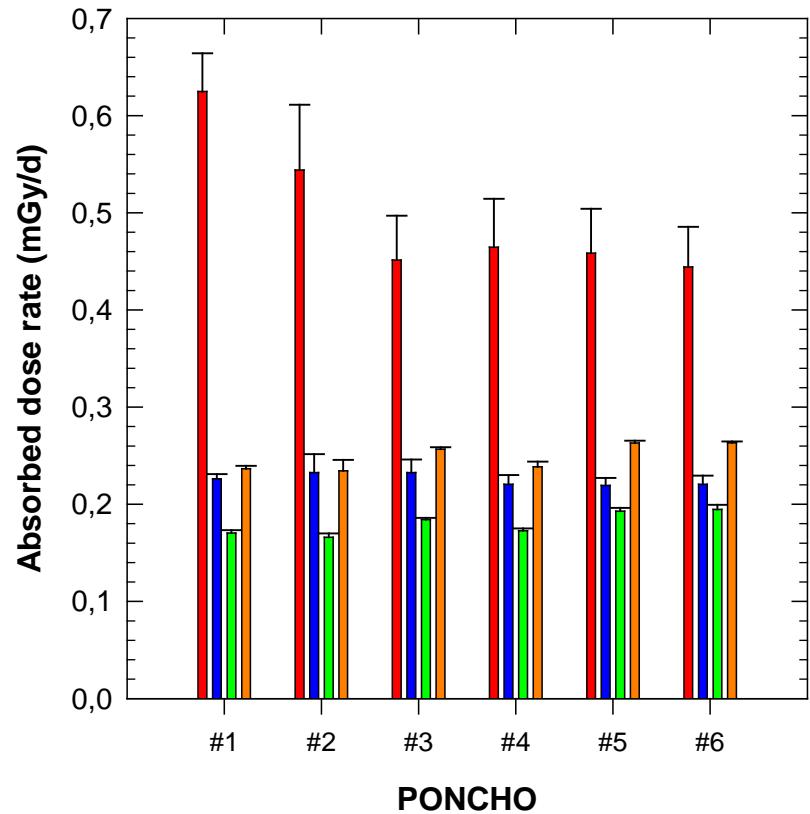


MATROSHKA: Comparison I → Reference



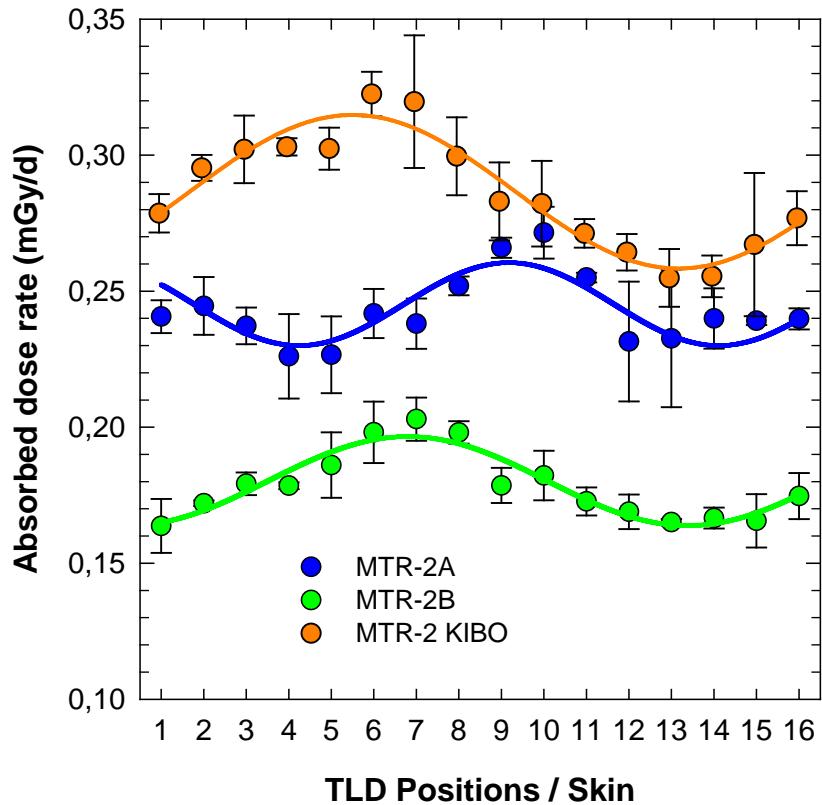
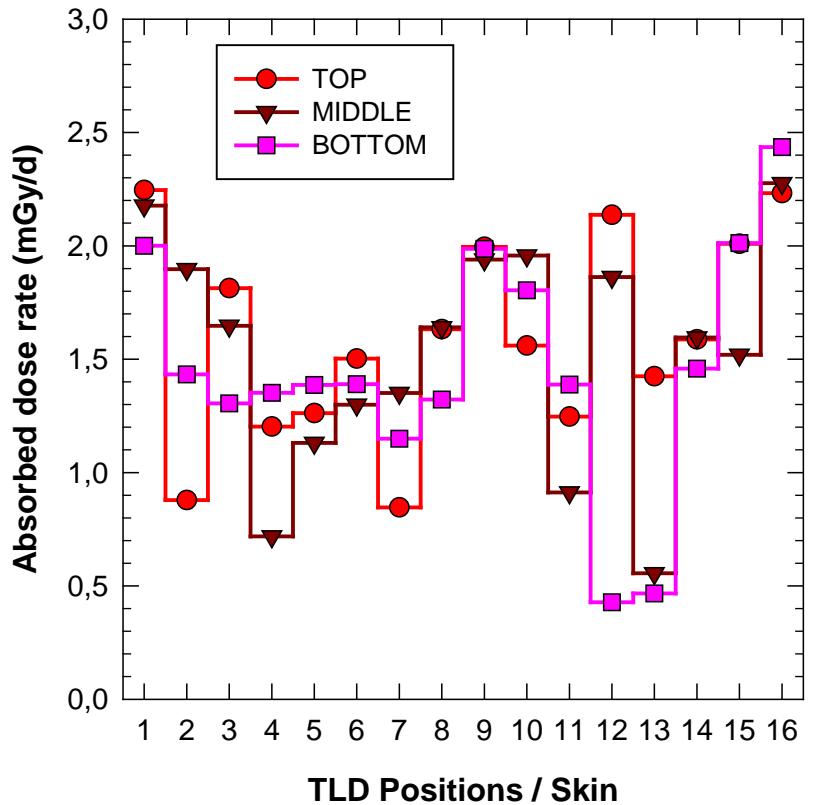
MATROSHKA: Comparison II → Poncho and NTDP

■ MTR-1
■ MTR-2A
■ MTR-2B
■ MTR-2 KIBO



MATROSHKA: Comparison III → Skin

MTR-1
MTR-2A
MTR-2B
MTR-2 KIBO

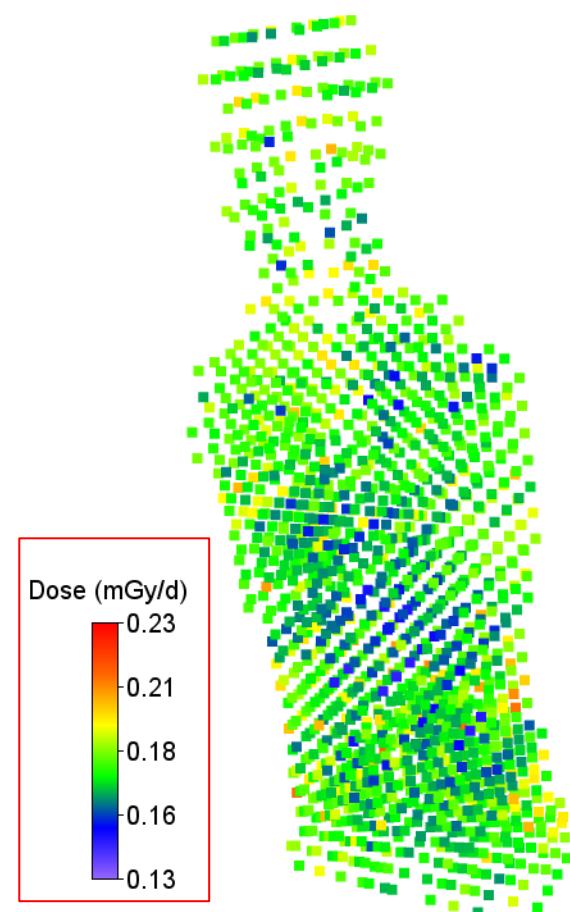
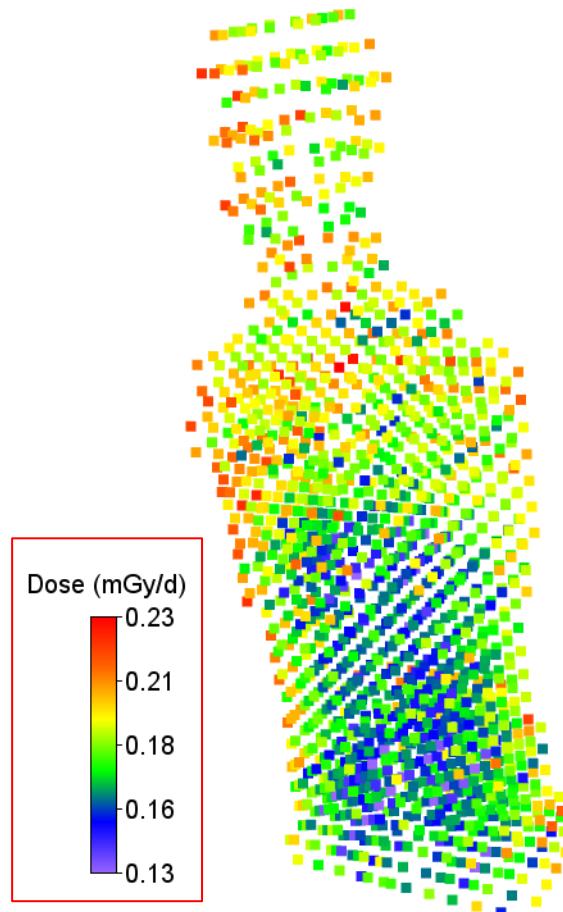
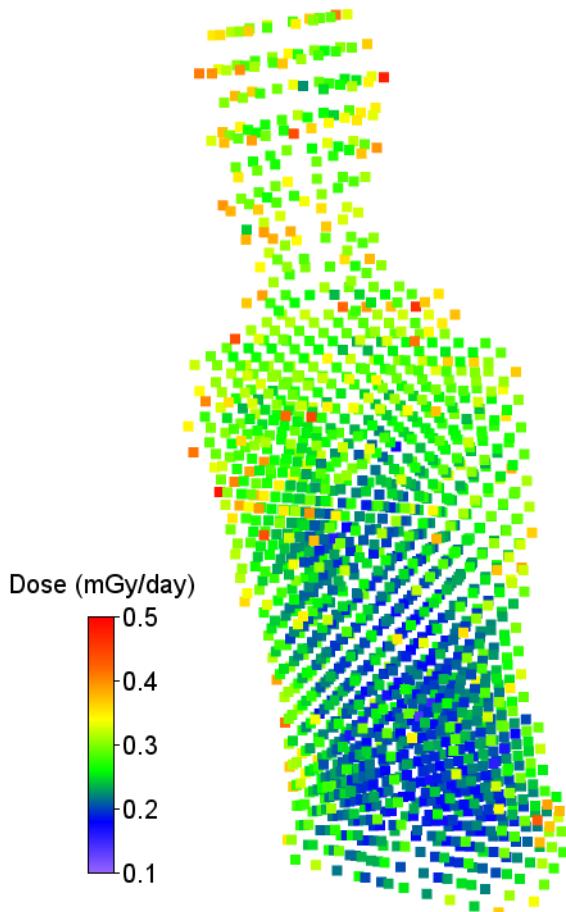


MATROSHKA: Comparison IV → 3D Discrete Dose Distribution

MTR-1 (2004-05)

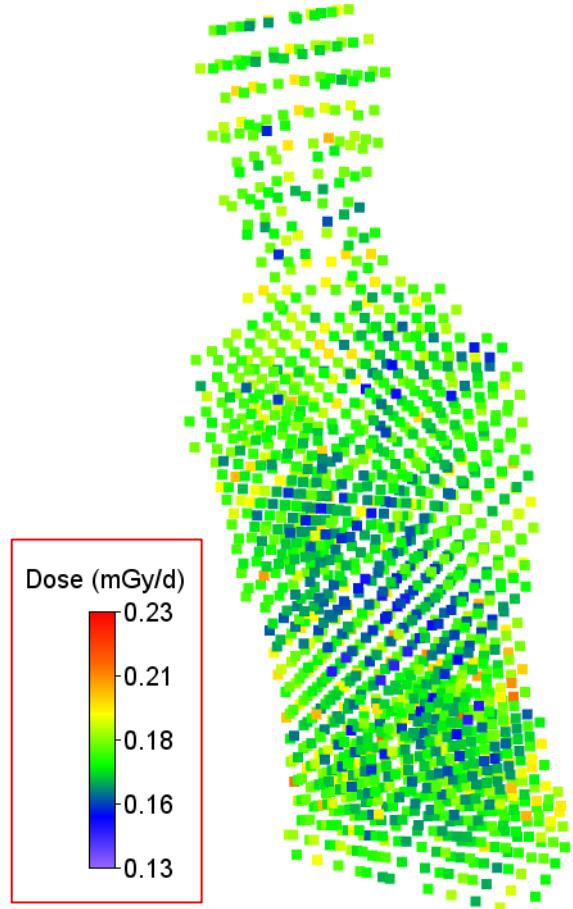
MTR-2A (2006)

MTR-2B (2007-09)

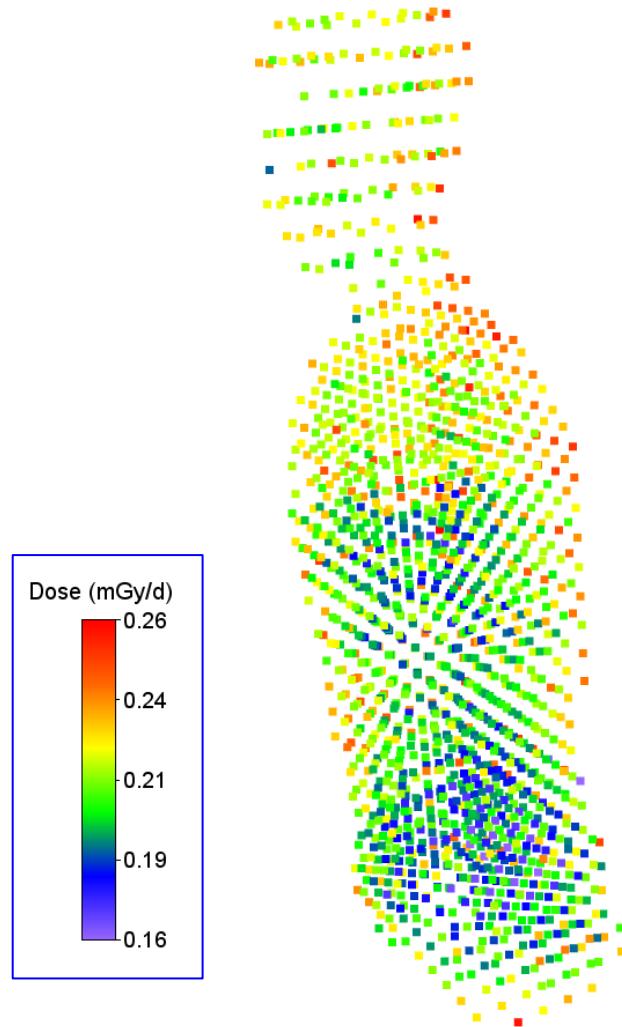


MATROSHKA: Comparison IV → 3D Discrete Dose Distribution

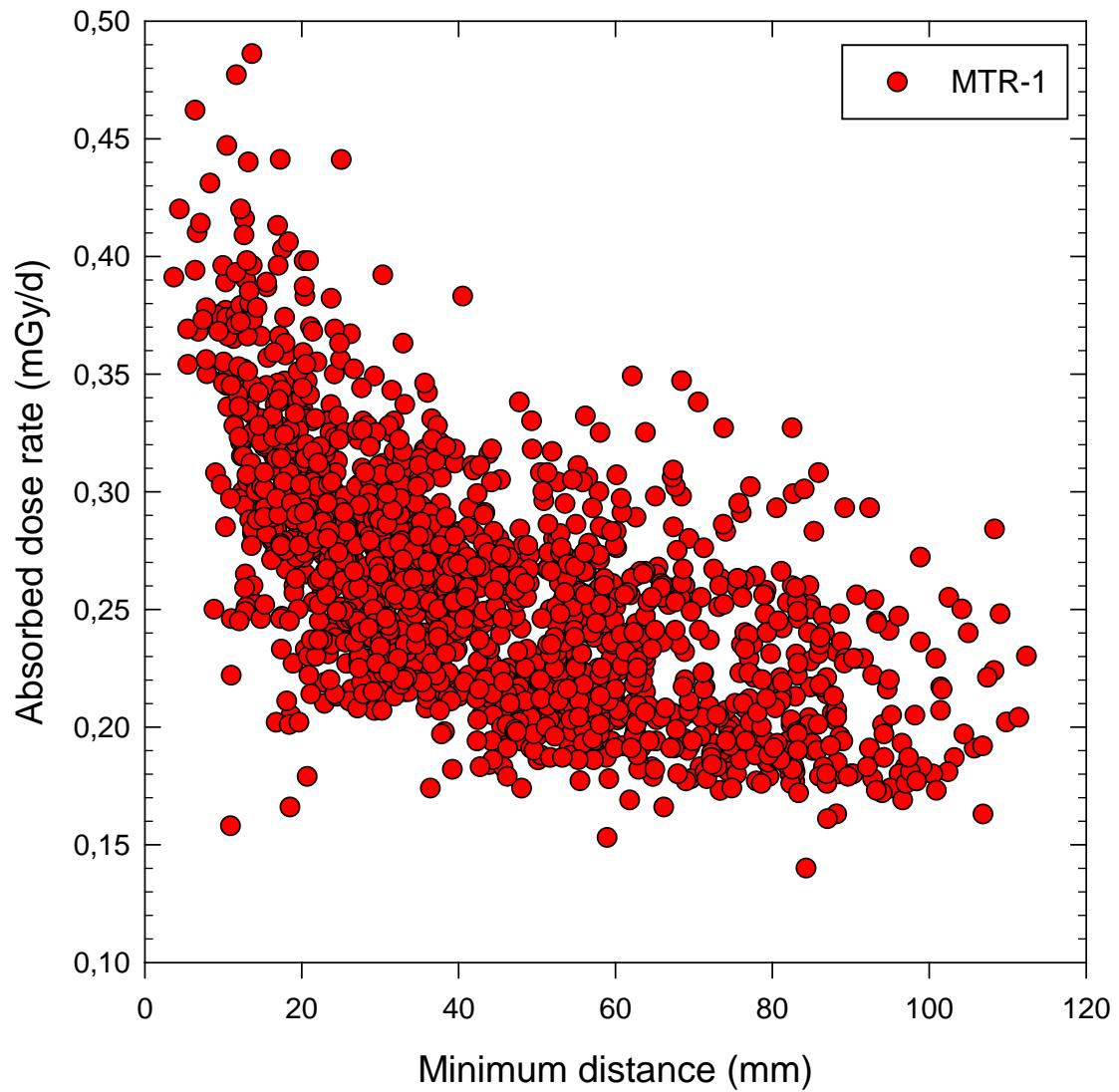
MTR-2B (2007-09)



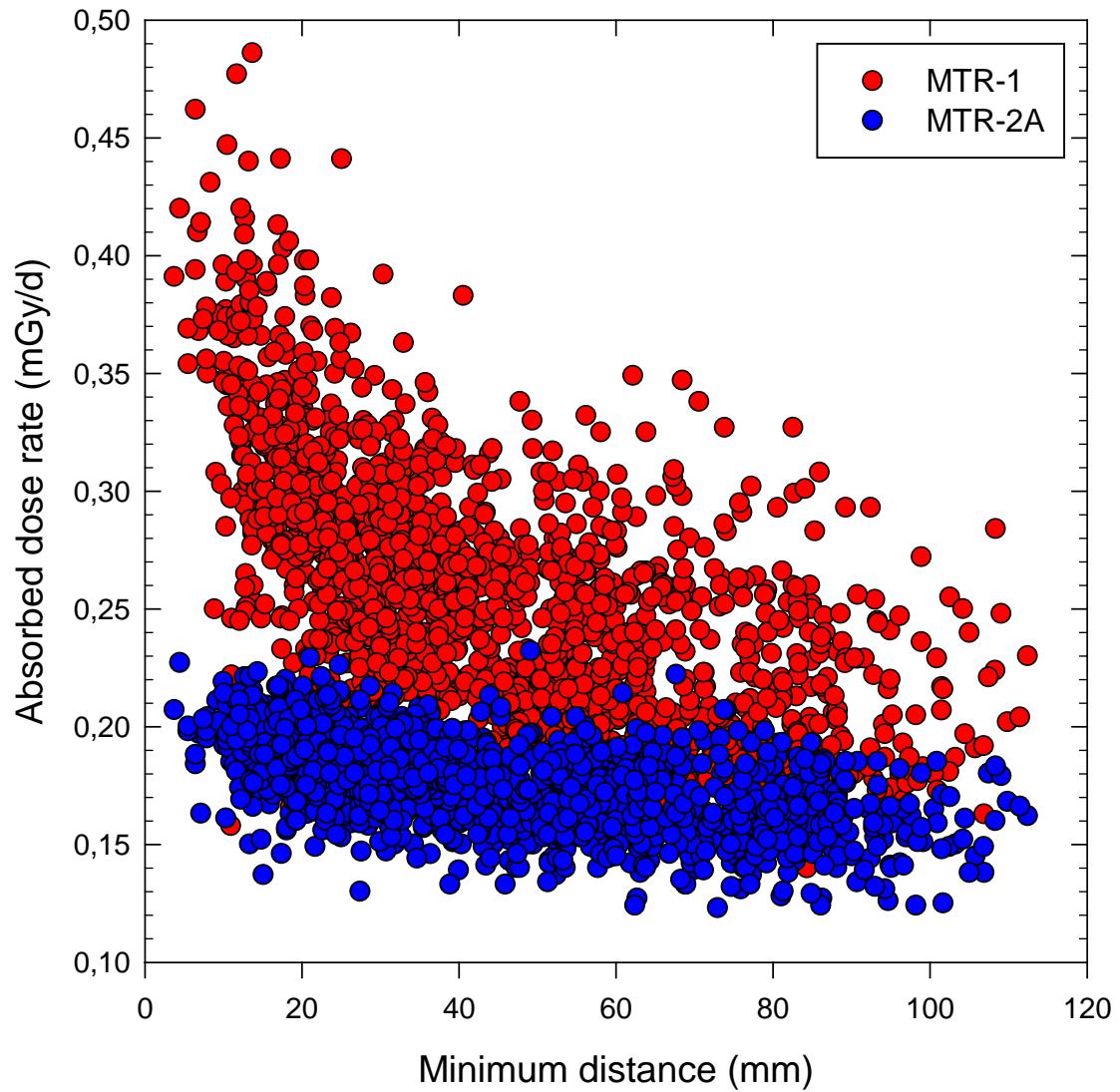
MTR-2 KIBO (2010-11)



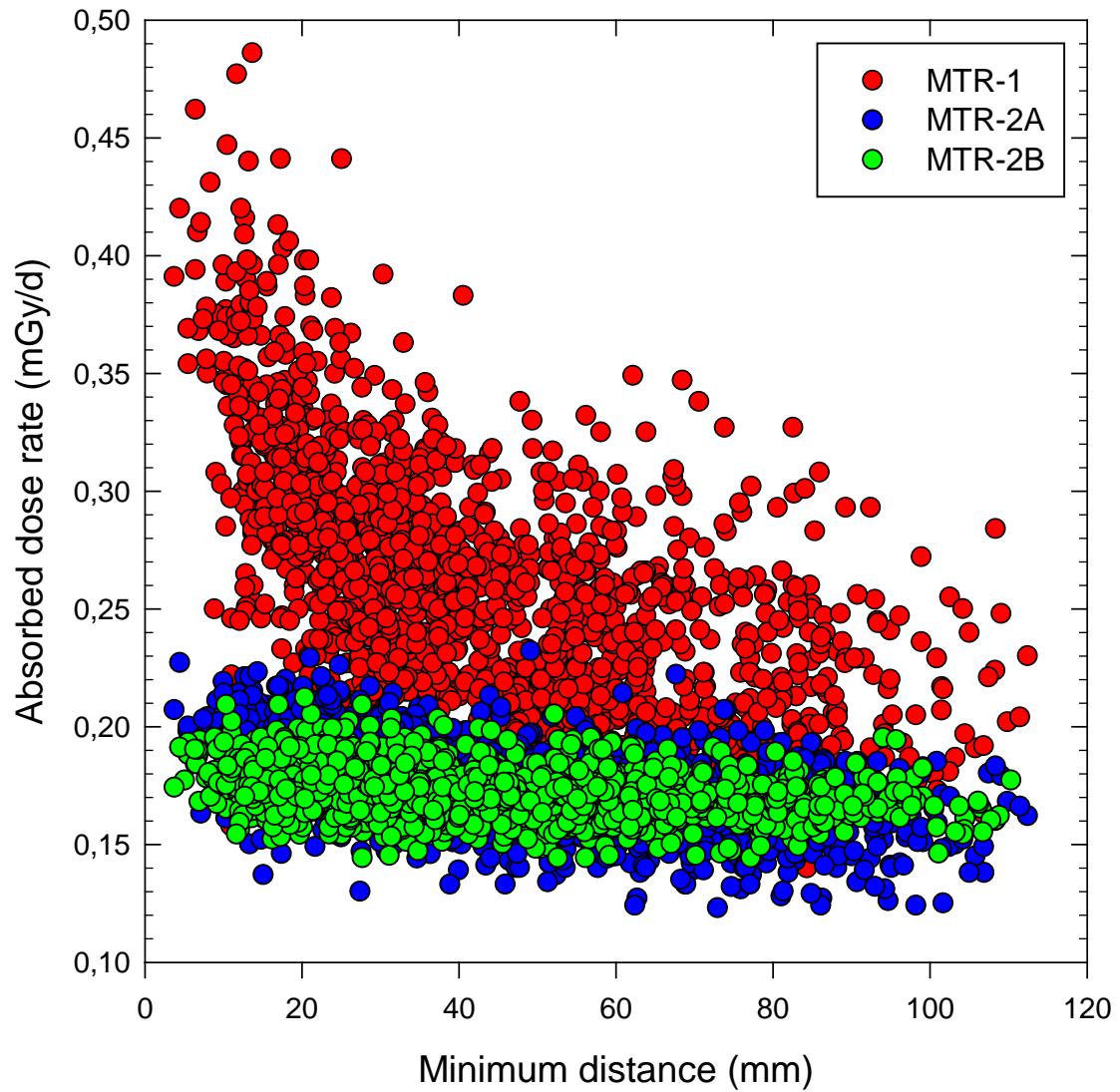
MATROSHKA: Comparison V → Minimum distance (mm)



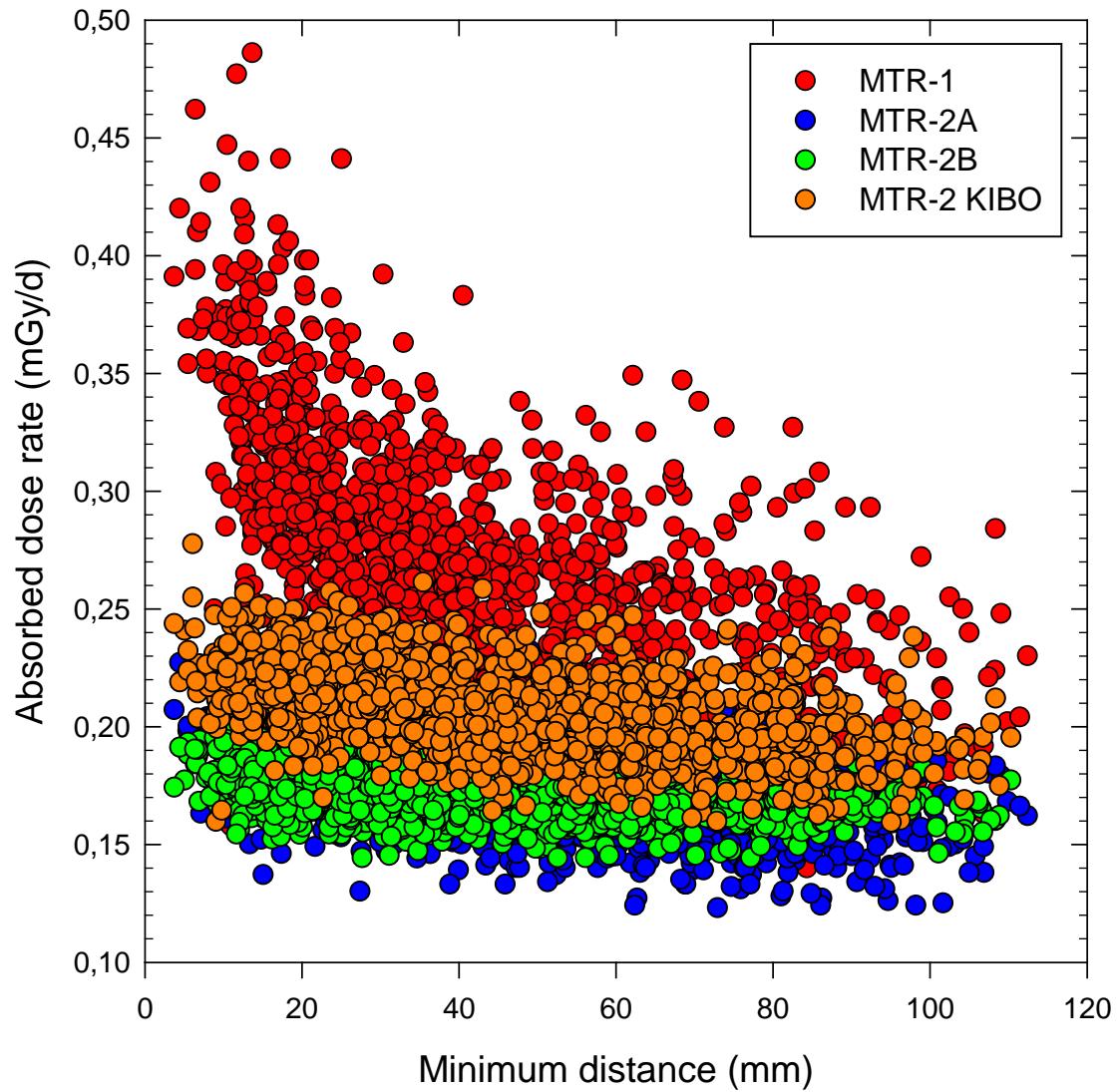
MATROSHKA: Comparison V → Minimum distance (mm)



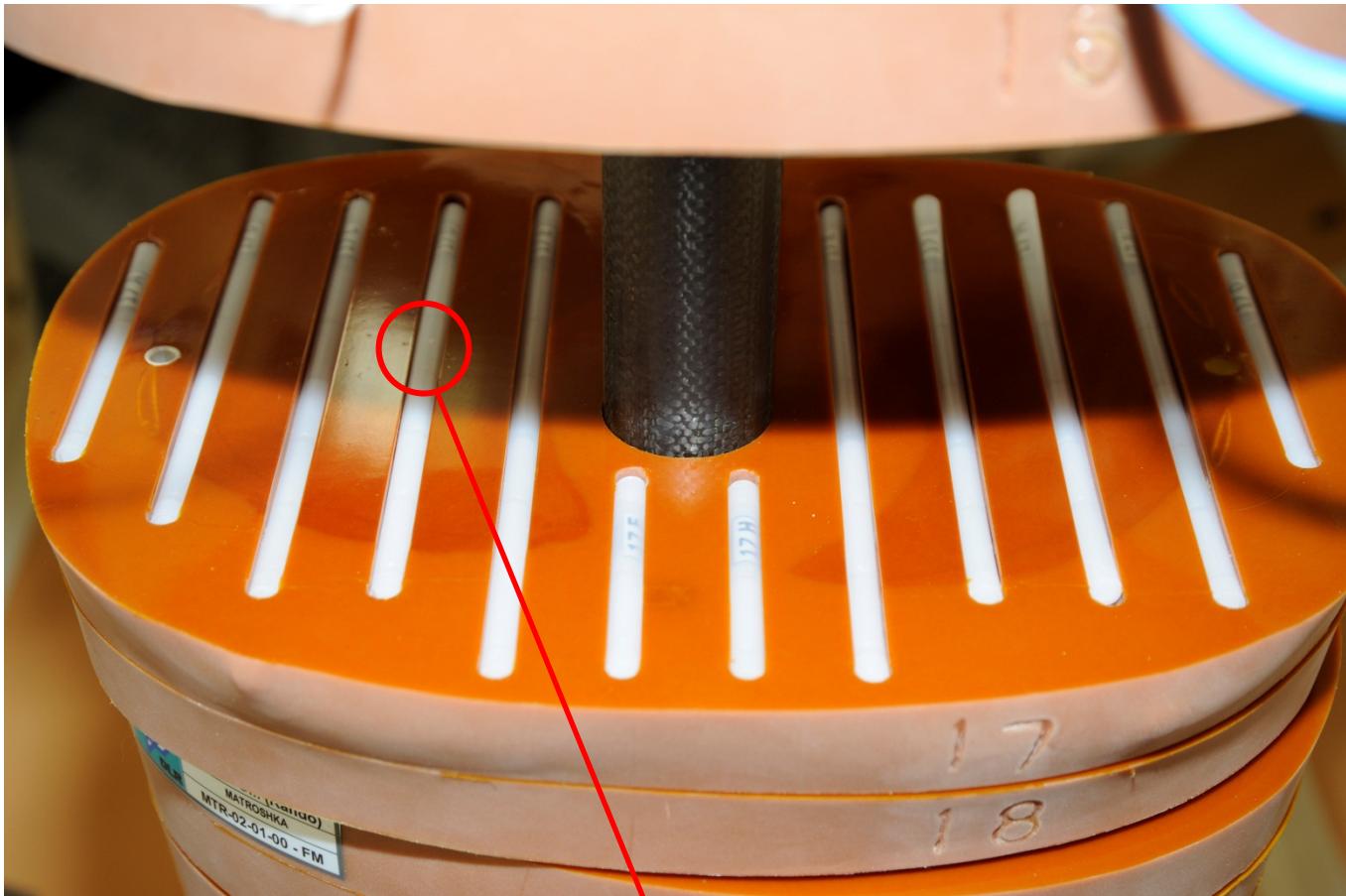
MATROSHKA: Comparison V → Minimum distance (mm)



MATROSHKA: Comparison V → Minimum distance (mm)



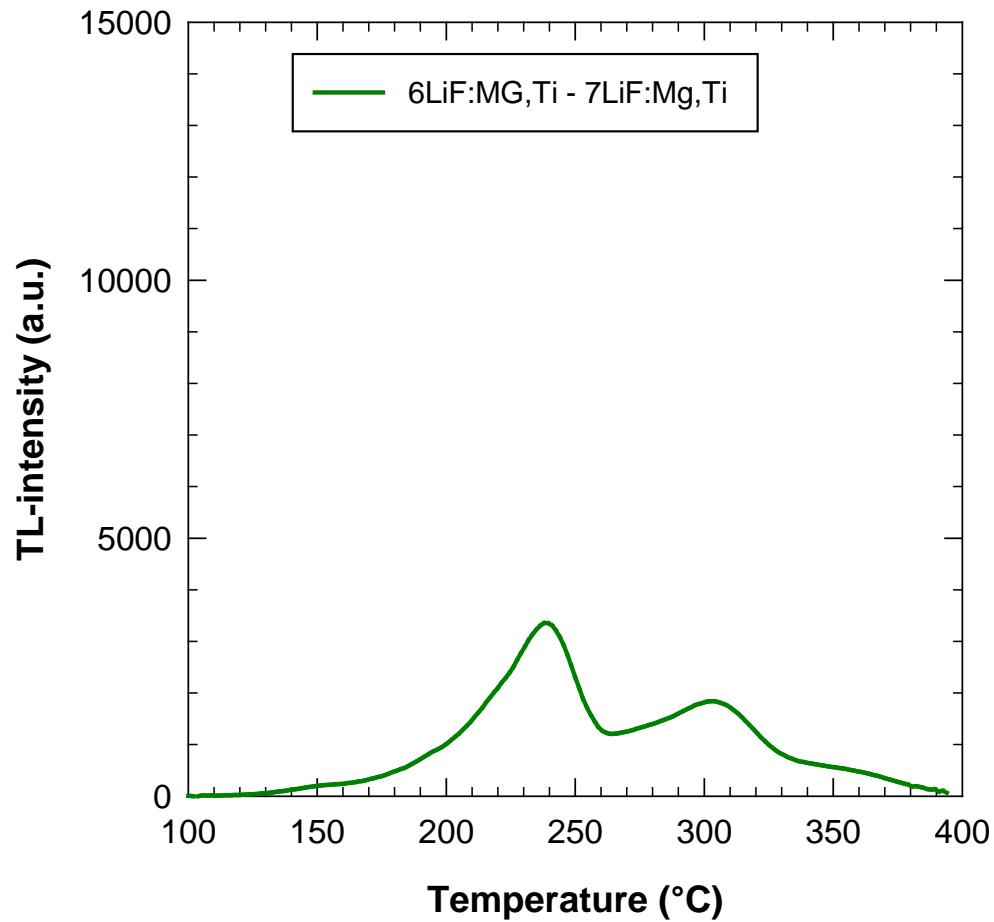
MATROSHKA: 6LiF:Mg,Ti \leftrightarrow 7LiF:Mg,Ti



MTR-2 KIBO: Slice #17 Position #10



MATROSHKA: 6LiF:Mg,Ti \leftrightarrow 7LiF:Mg,Ti



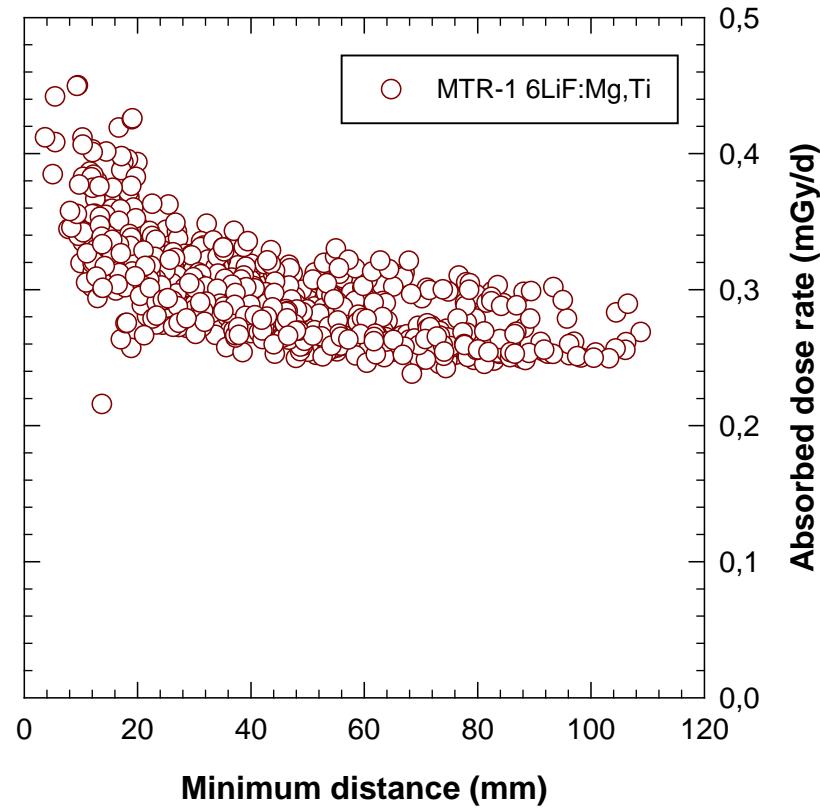
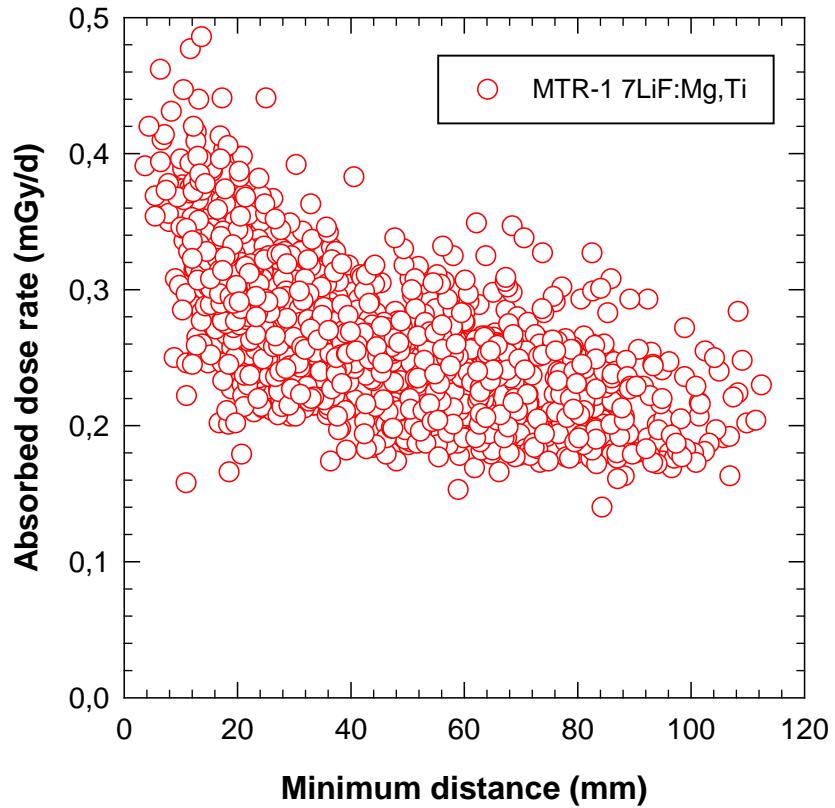
7LiF:Mg,Ti:
243 μ Gy/d

6LiF:Mg,Ti:
321 μ Gy/d

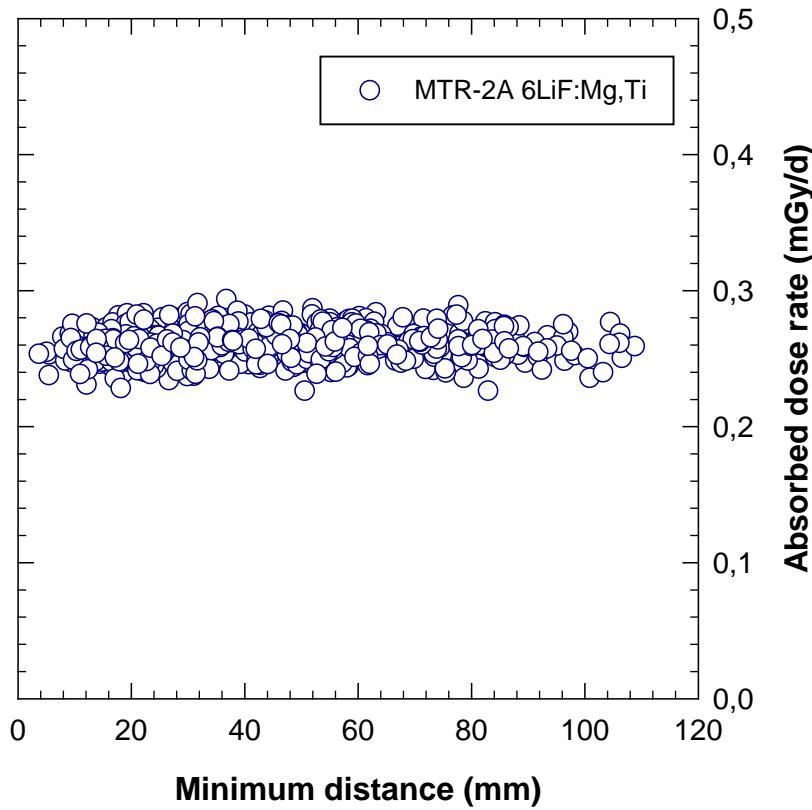
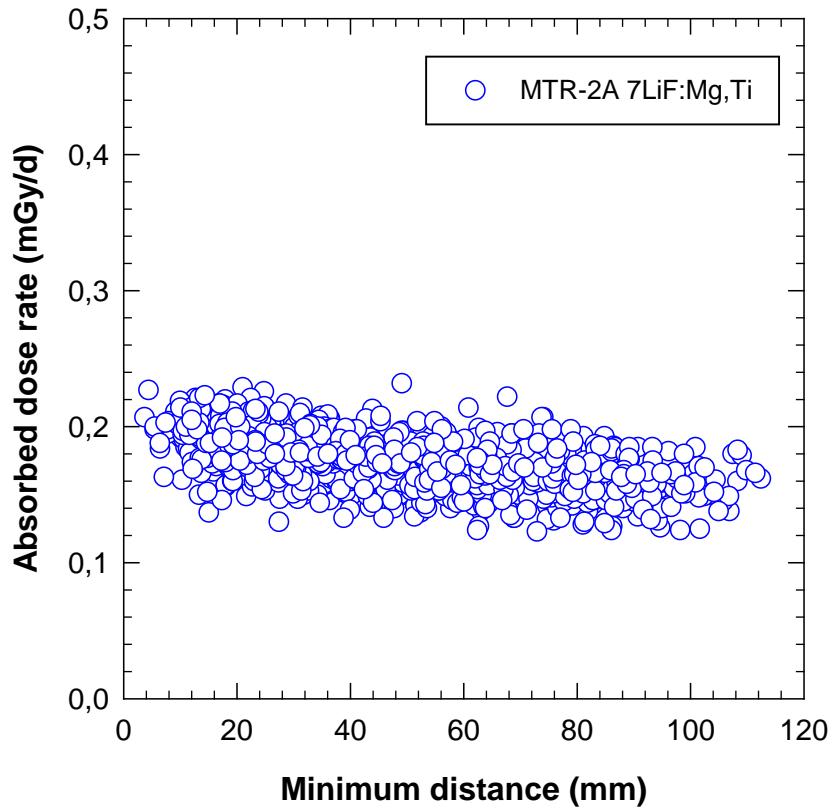
6LiF:Mg,Ti – 7LiF:Mg,Ti
78 μ Gy/d



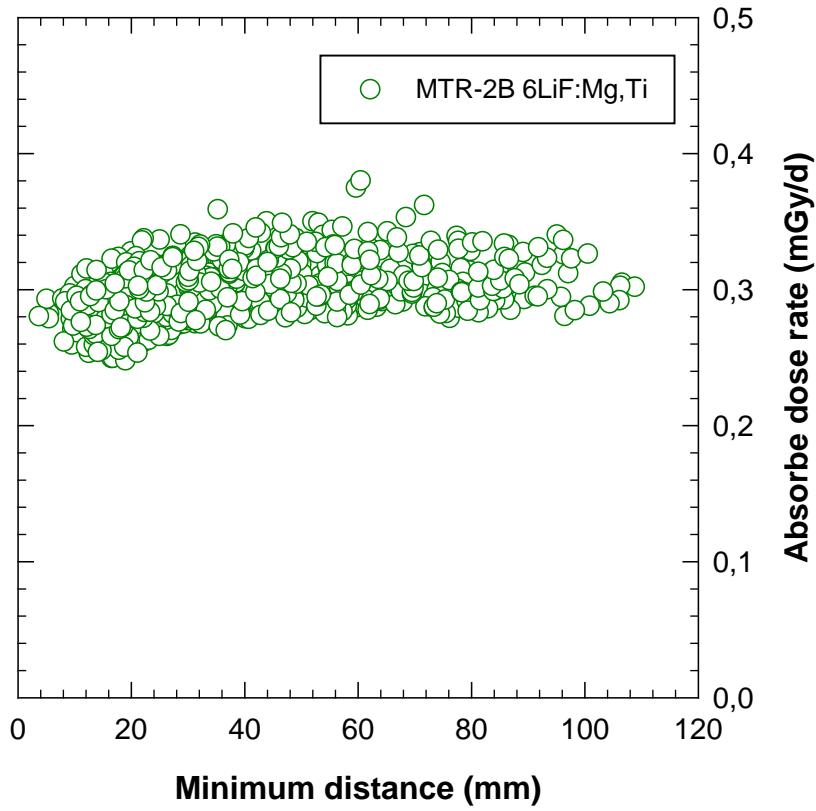
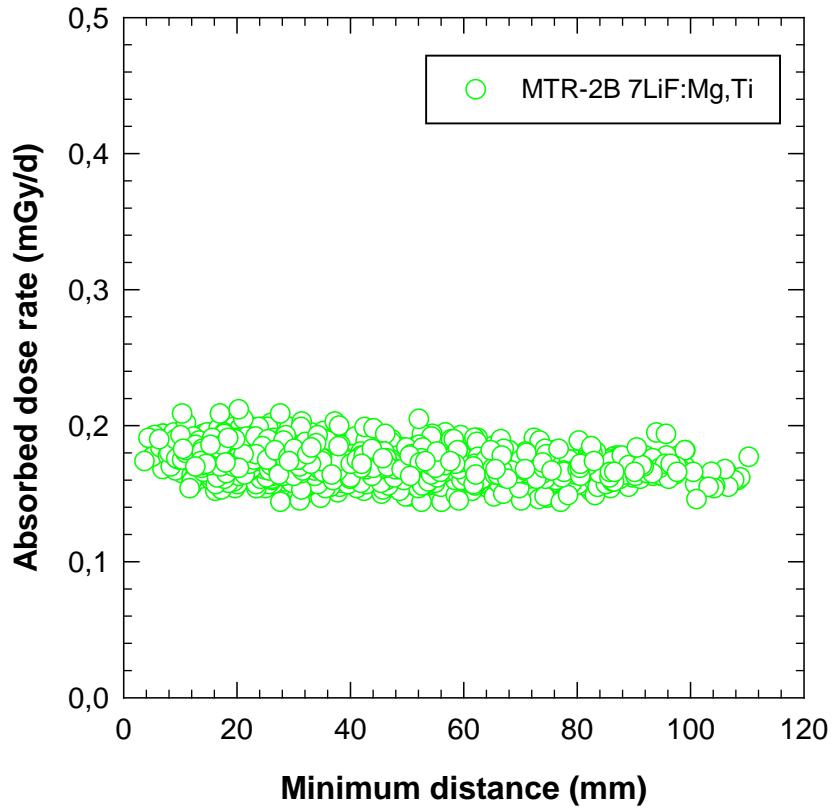
MATROSHKA: Comparison → Minimum Distance



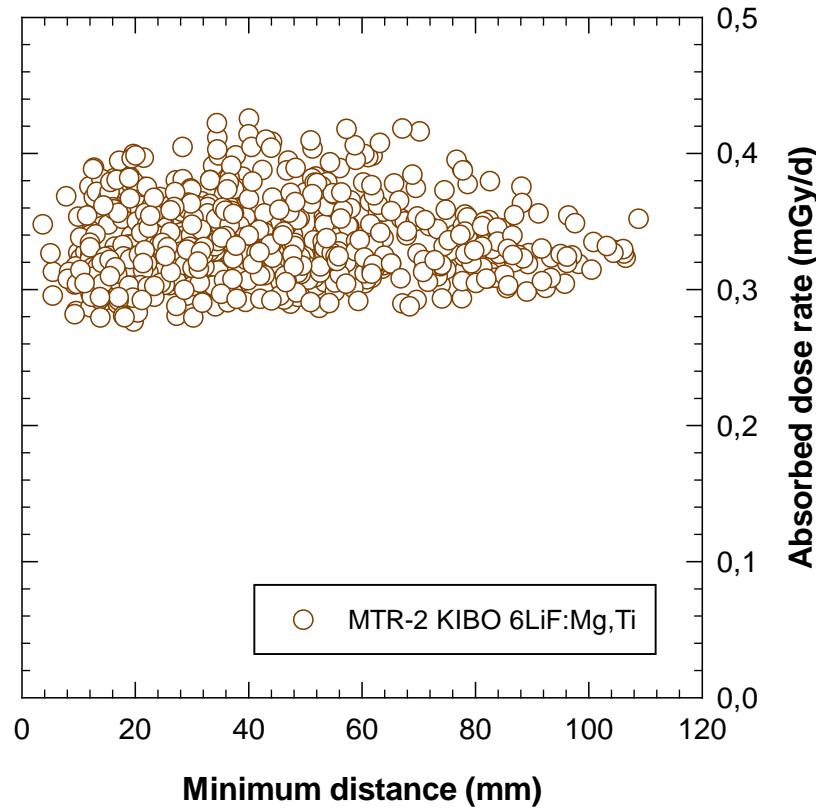
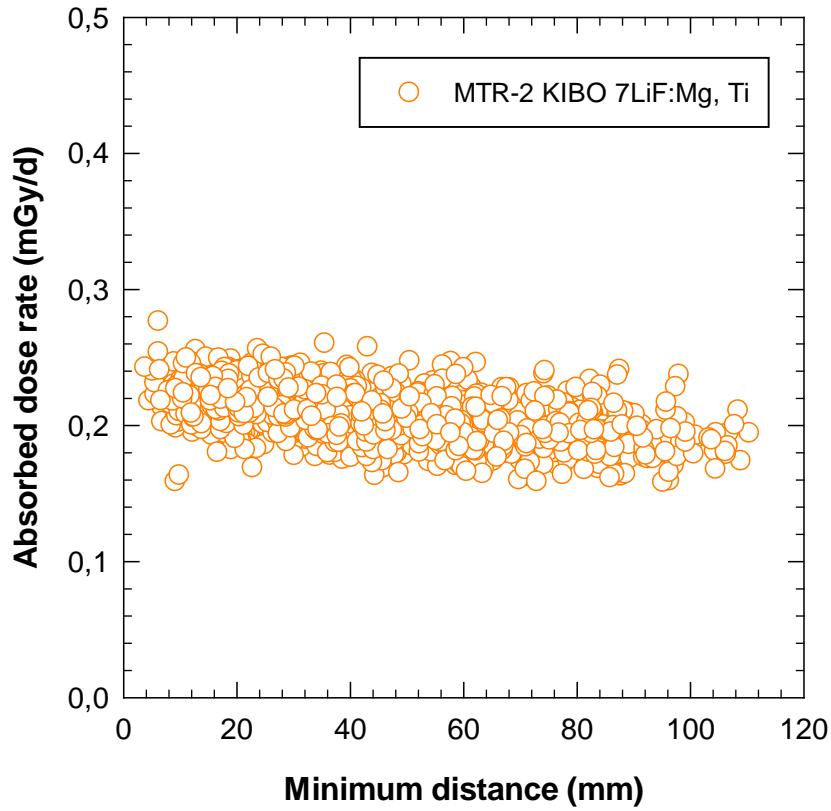
MATROSHKA: Comparison → Minimum Distance



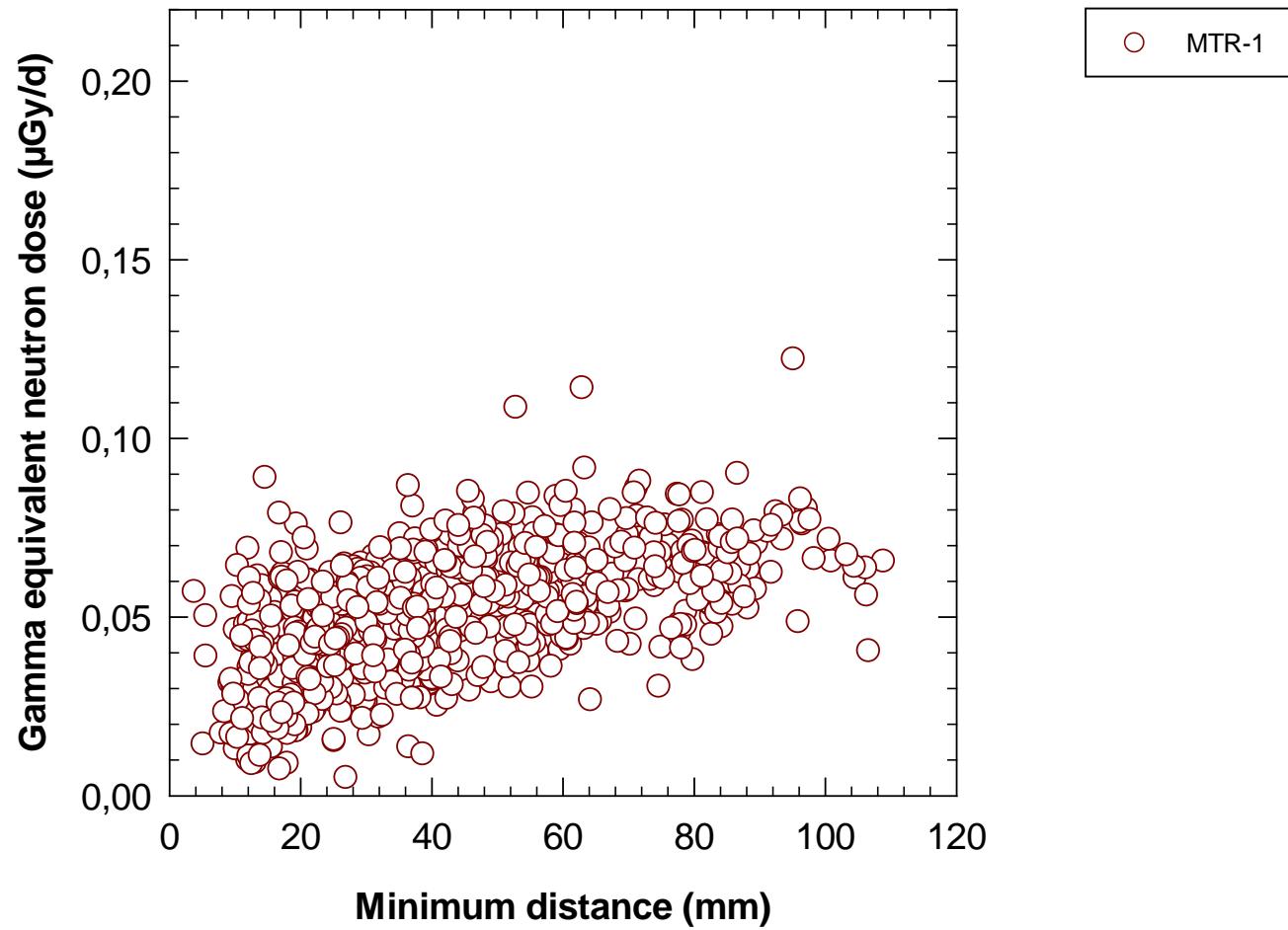
MATROSHKA: Comparison → Minimum Distance



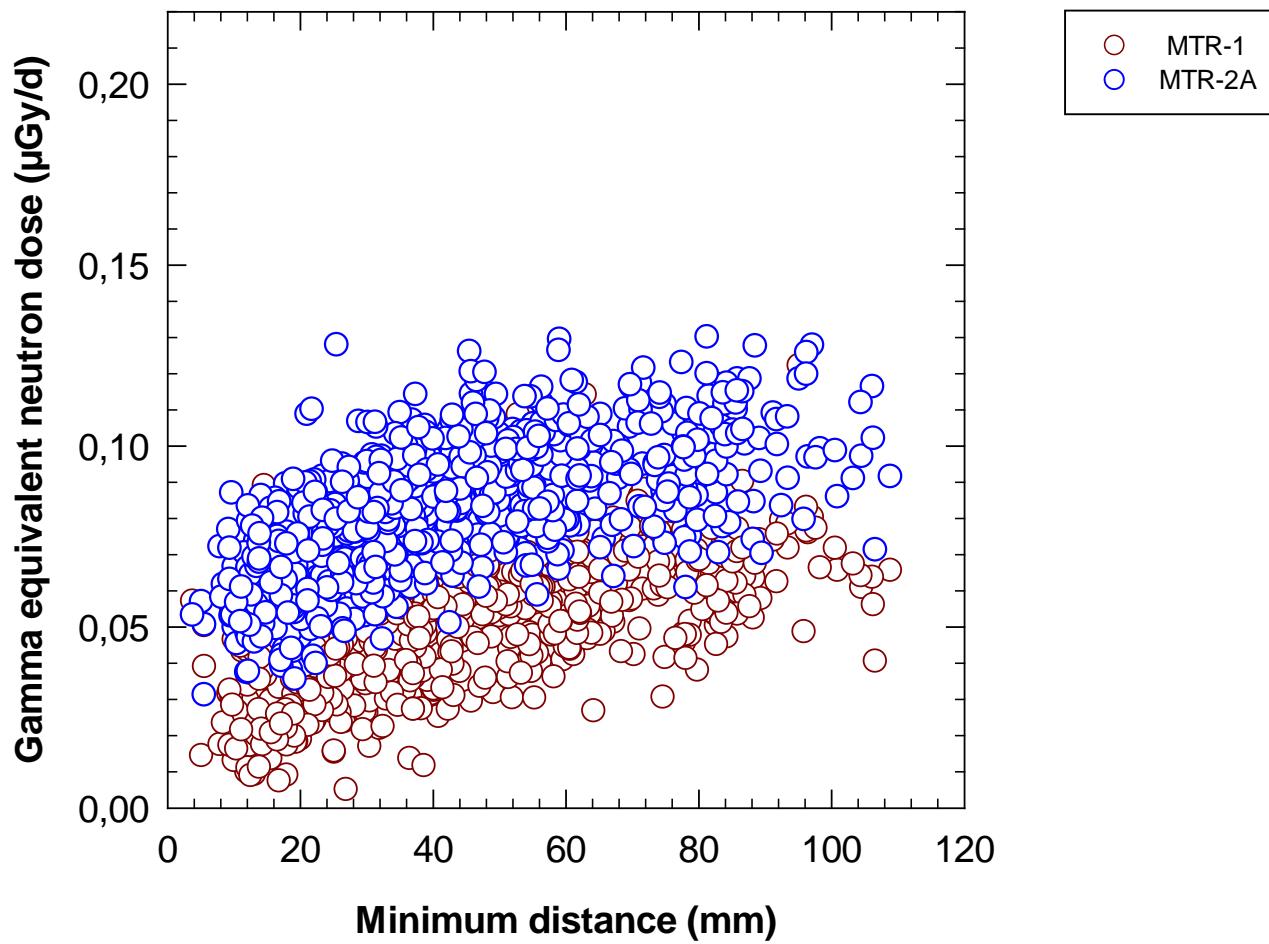
MATROSHKA: Comparison → Minimum Distance



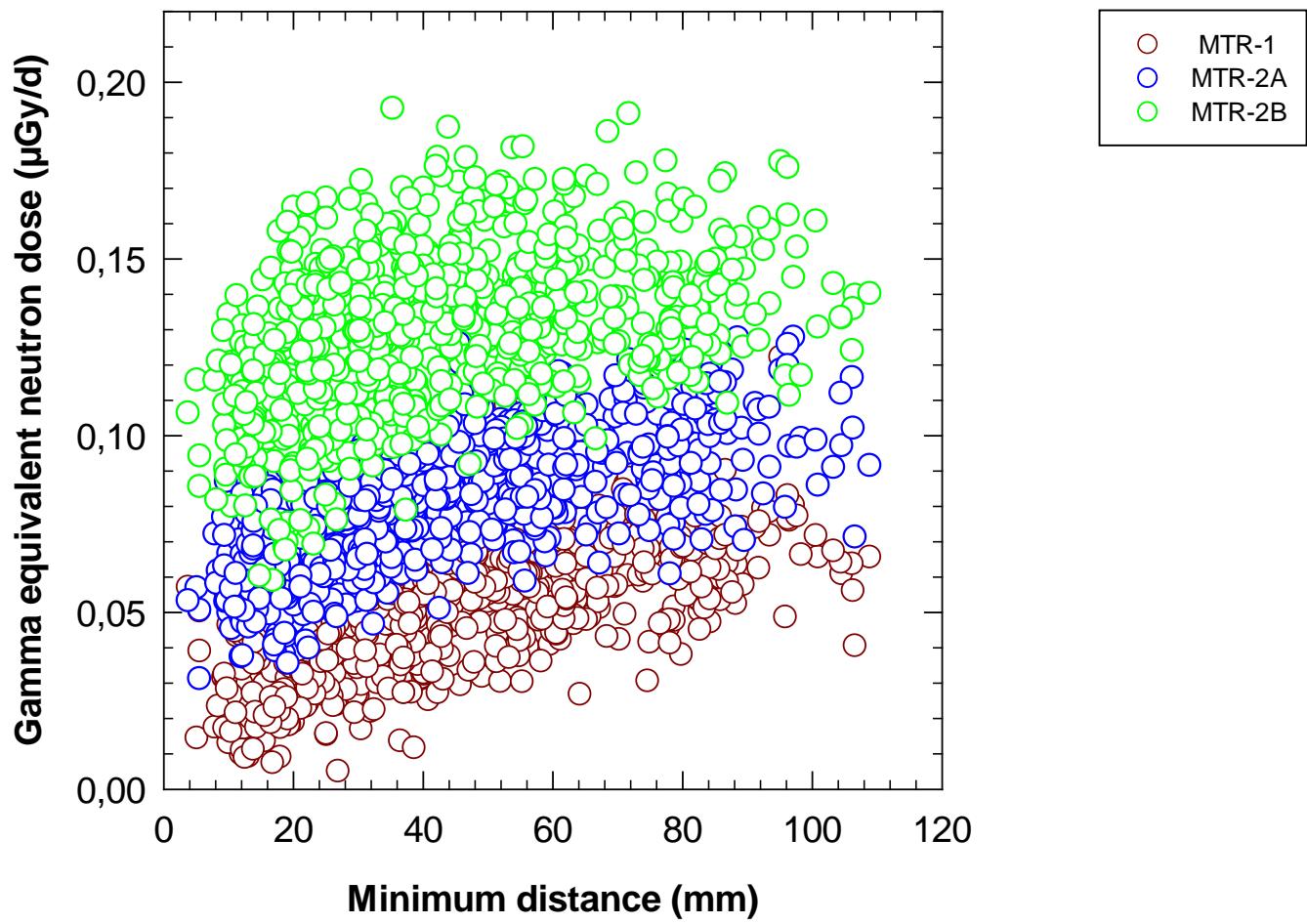
MATROSHKA: Comparison → Minimum Distance



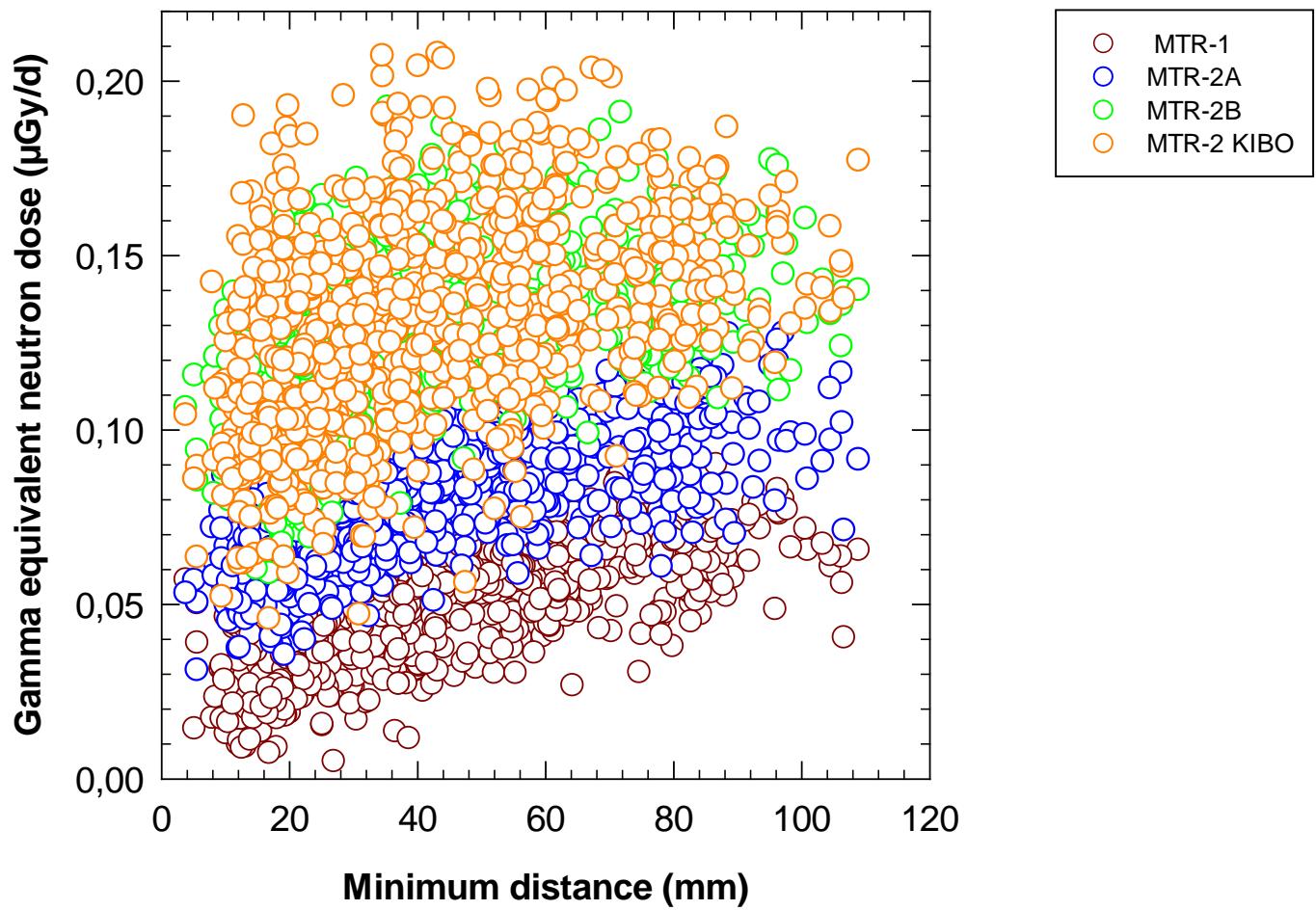
MATROSHKA: Comparison → Minimum Distance



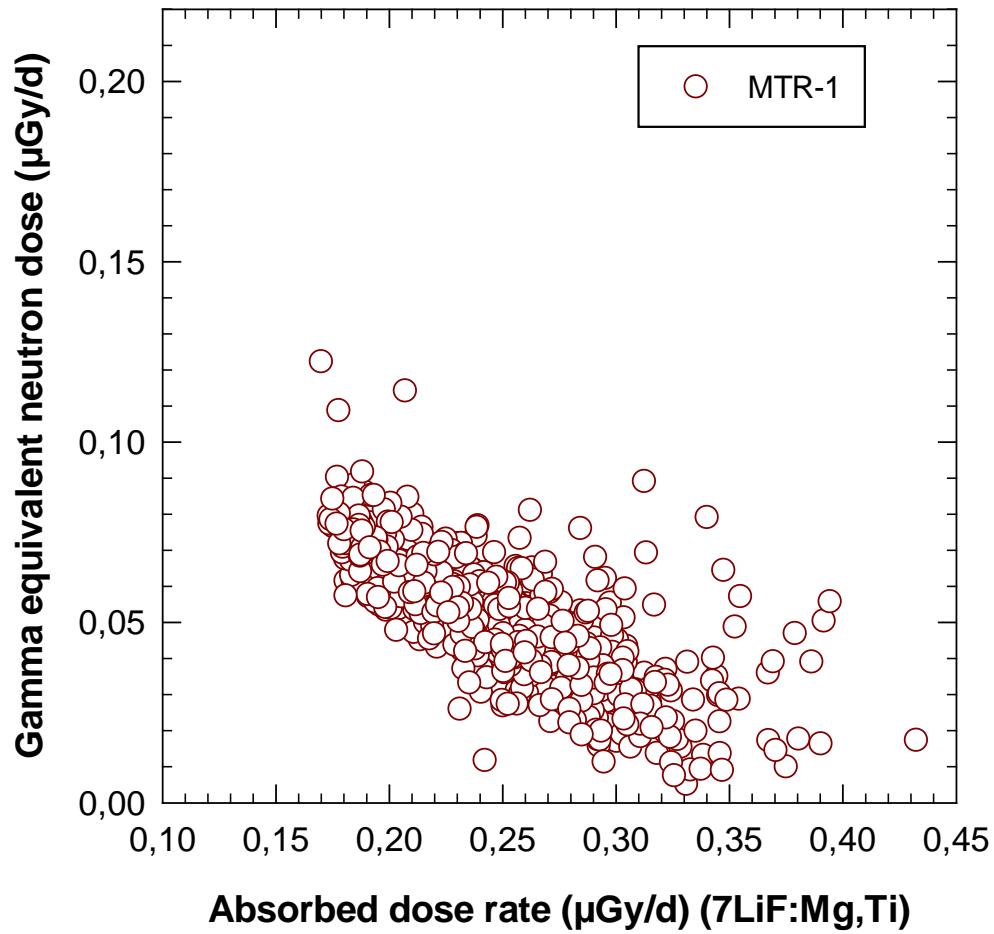
MATROSHKA: Comparison → Minimum Distance



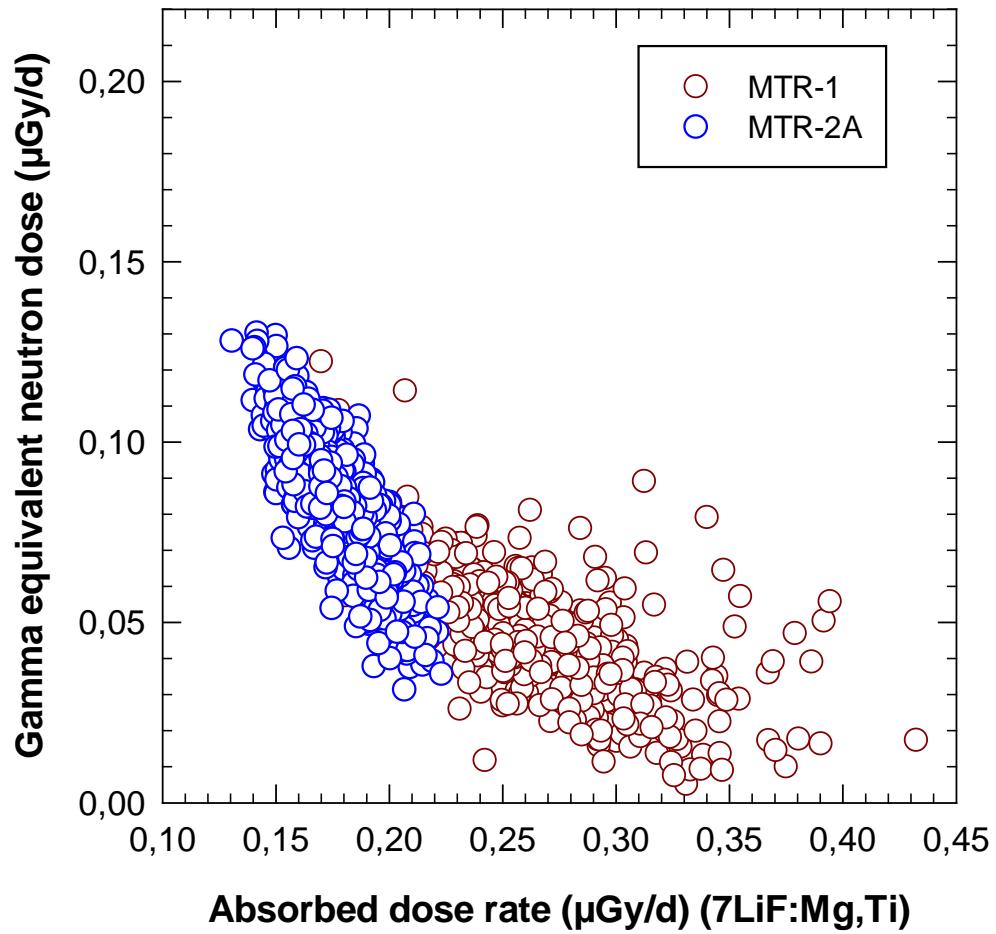
MATROSHKA: Comparison → Minimum Distance



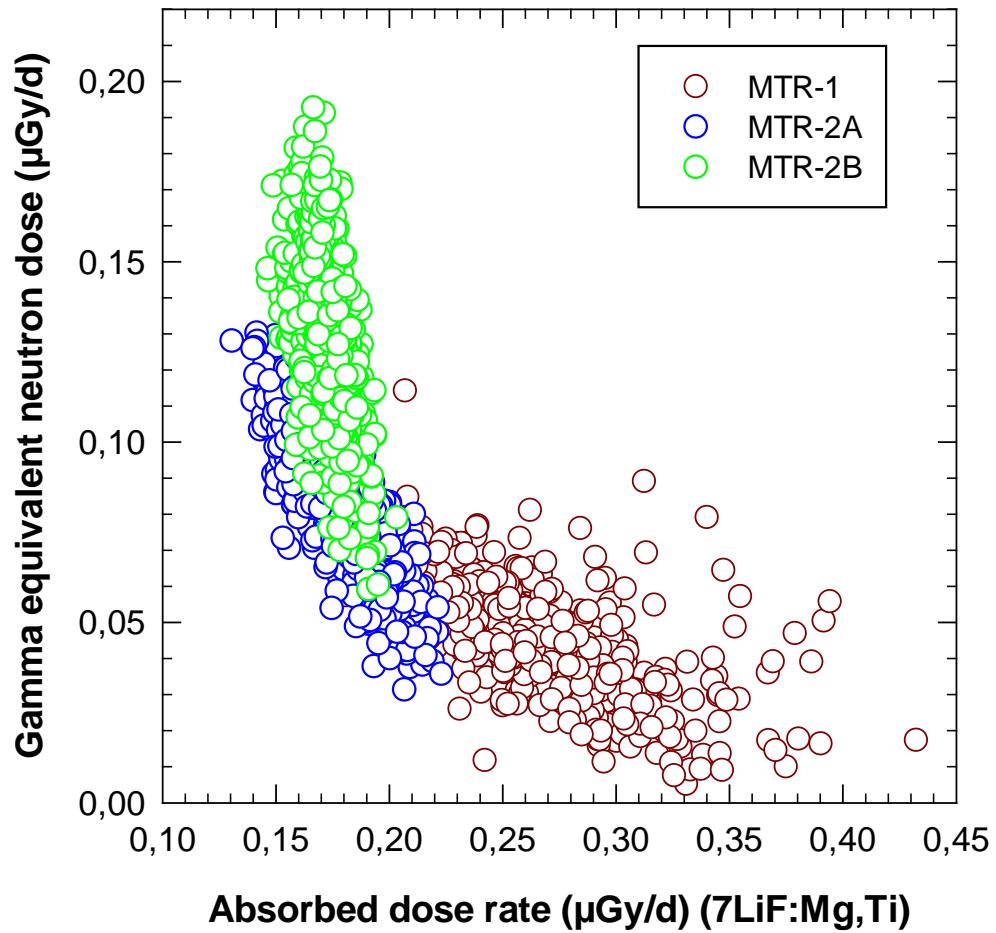
MATROSHKA: Comparison → Minimum Distance



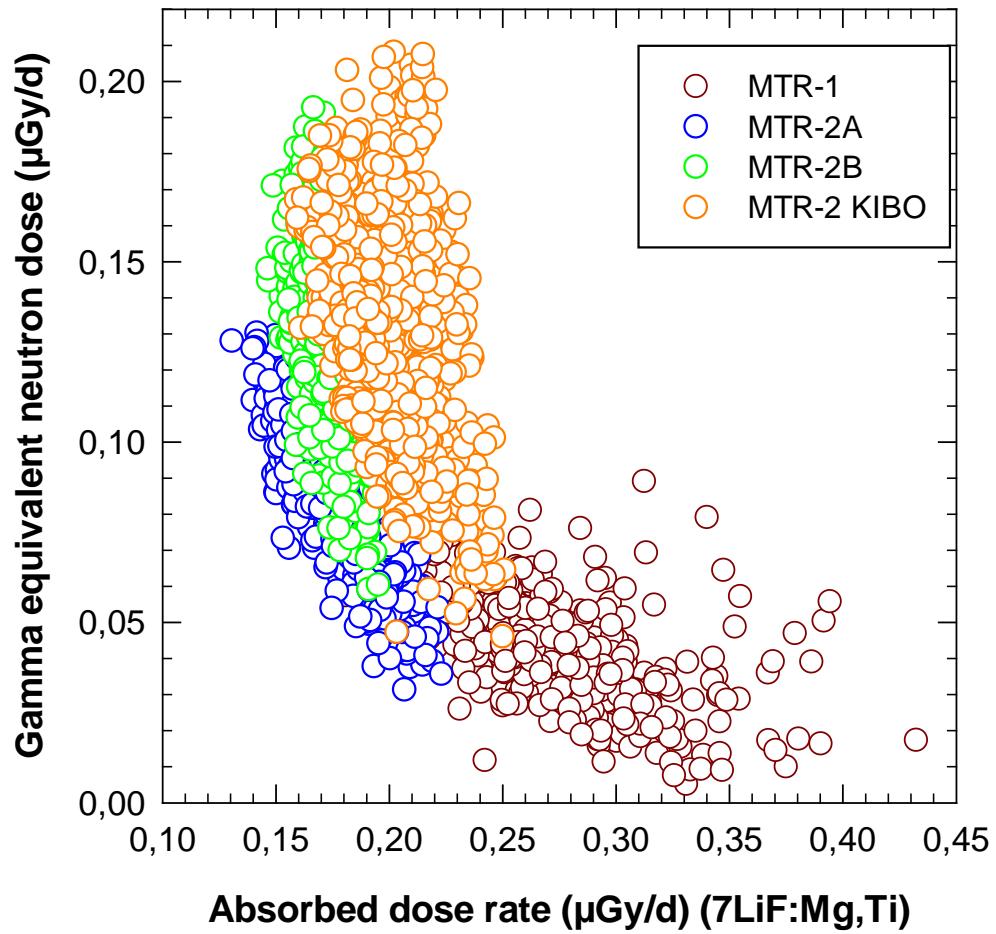
MATROSHKA: Comparison → Minimum Distance



MATROSHKA: Comparison → Minimum Distance



MATROSHKA: Comparison → Minimum Distance



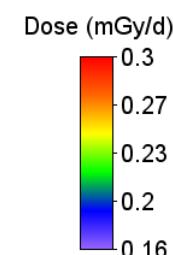
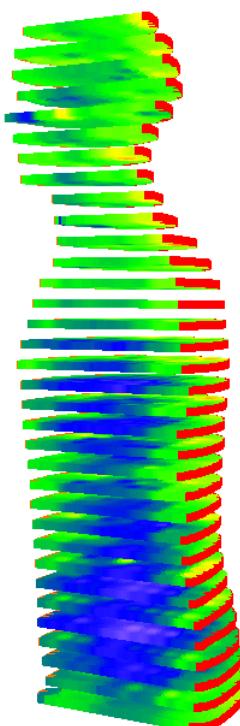
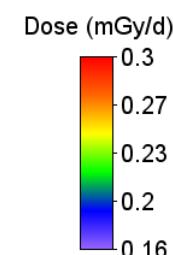
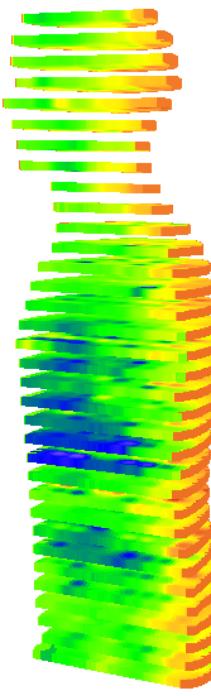
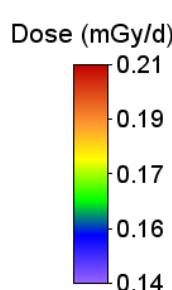
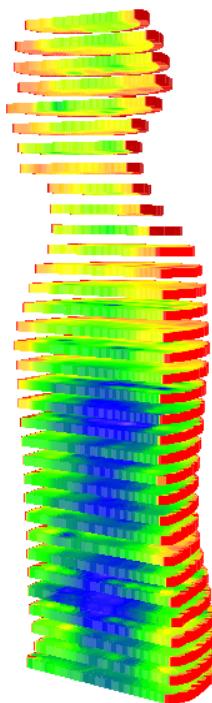
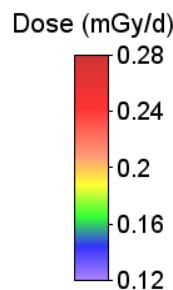
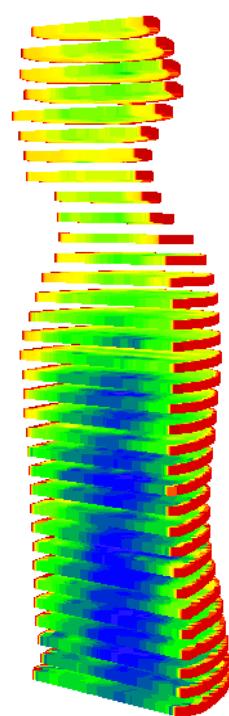
MATROSHKA: Comparison VI →3D Dose Distribution (continuous)

MTR-1
(2004-05)

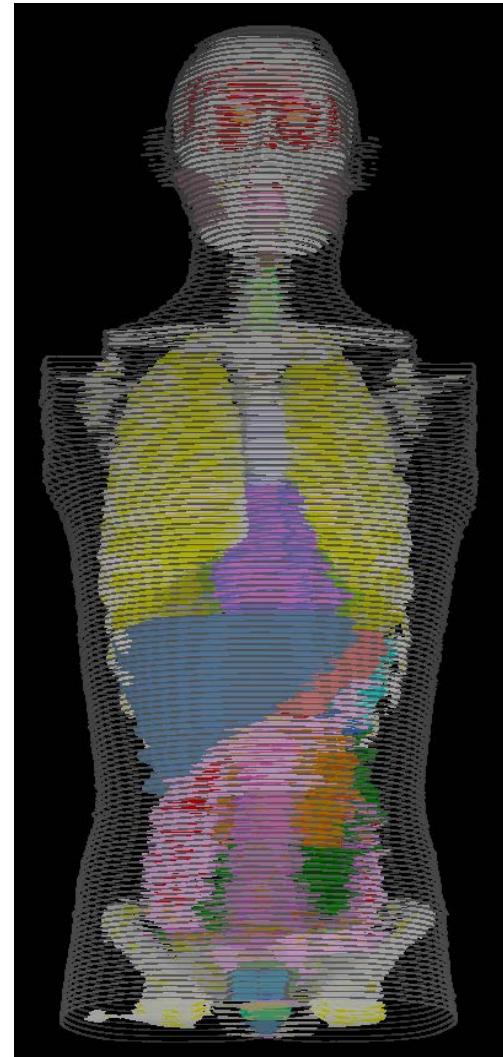
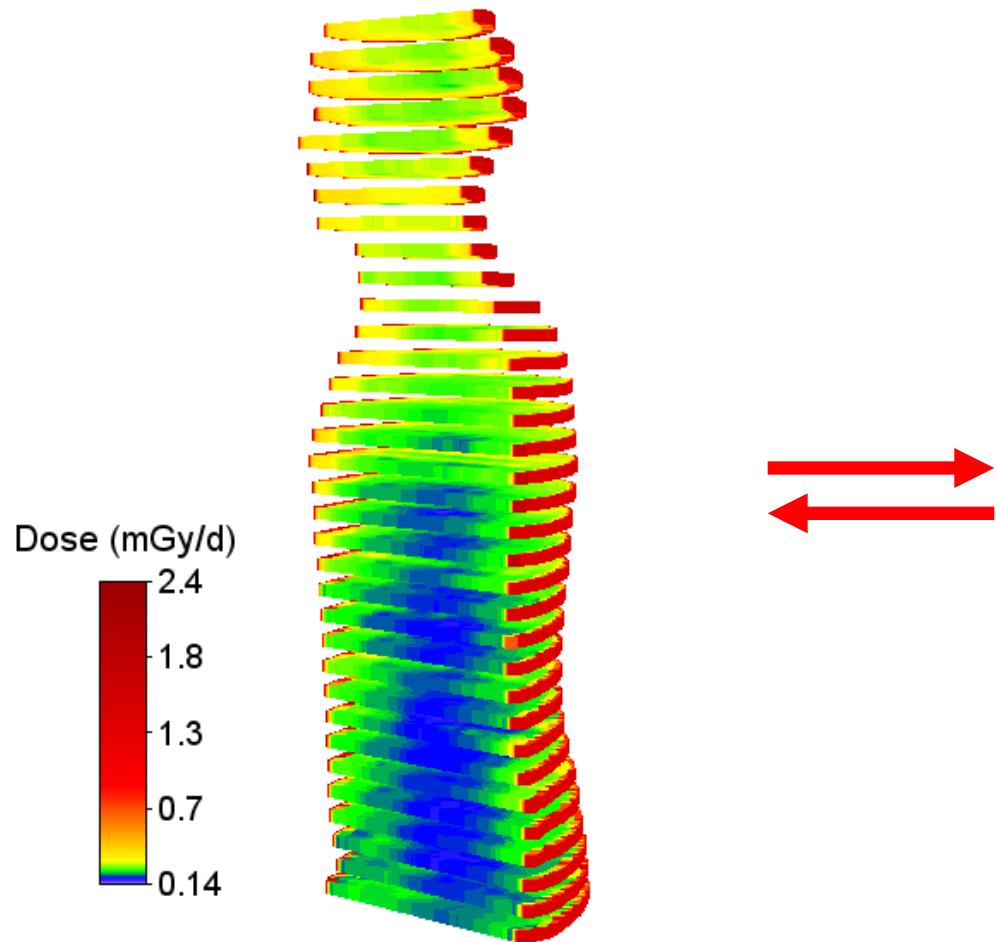
MTR-2A
(2006)

MTR-2B
(2007-09)

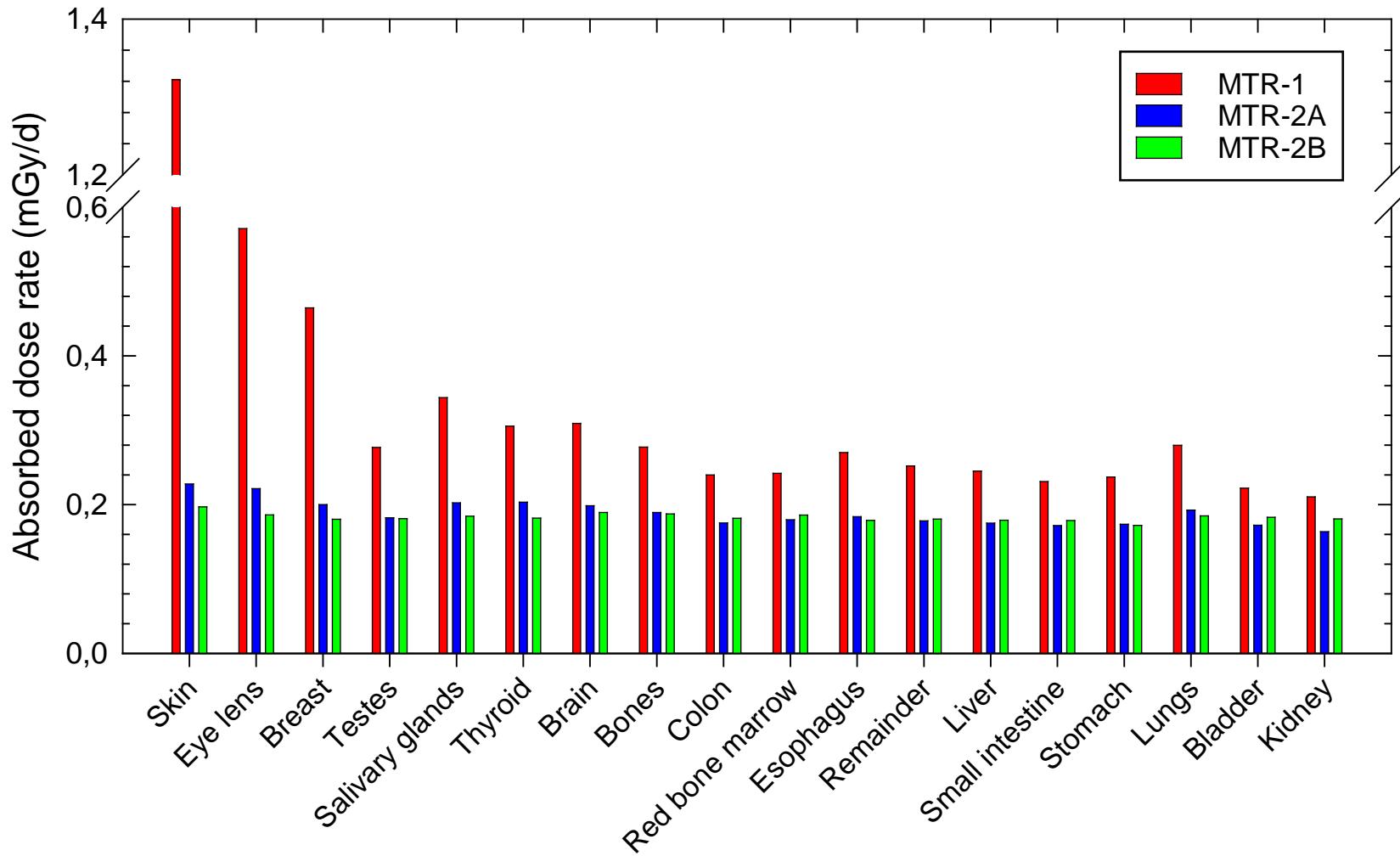
MTR-2 KIBO
(2010-11)



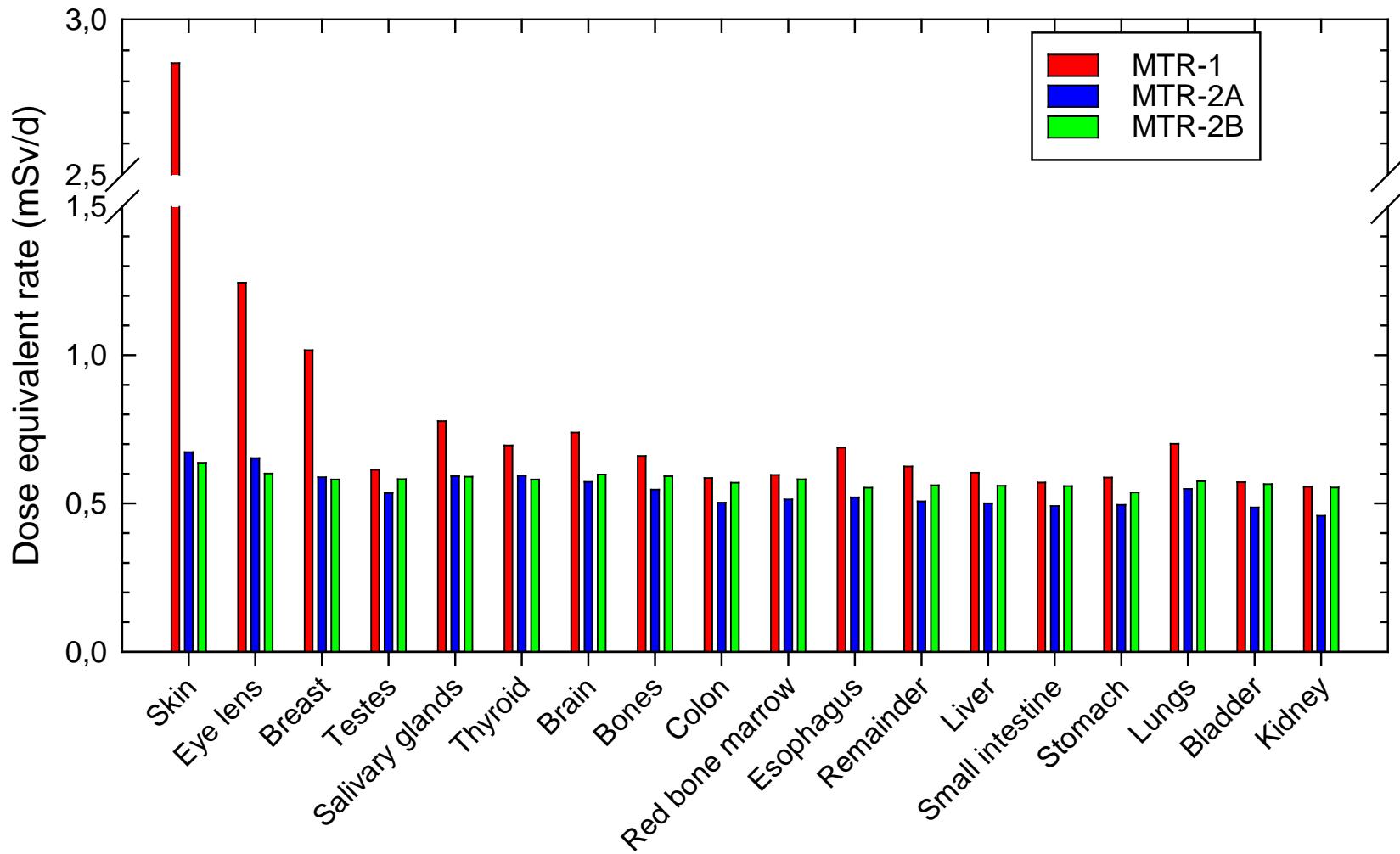
MATROSHKA: Effective Dose



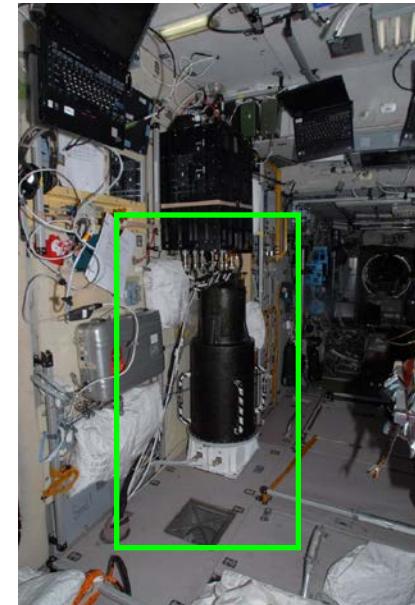
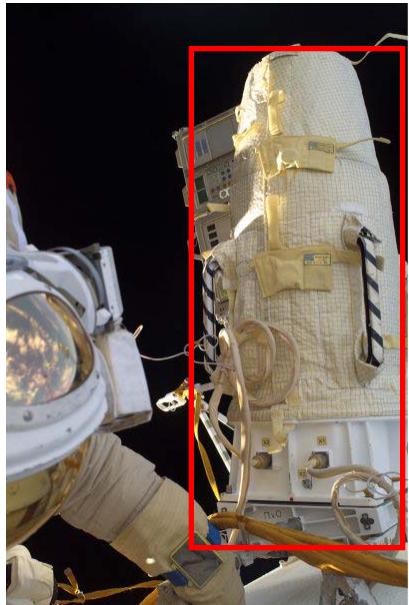
MATROSHKA: Effective Dose



MATROSHKA: Effective Dose



MATROSHKA: Effective Dose



MTR-1

0.695 mSv/d

MTR-2A

0.529 mSv/d

MTR-2B

0.569 mSv/d

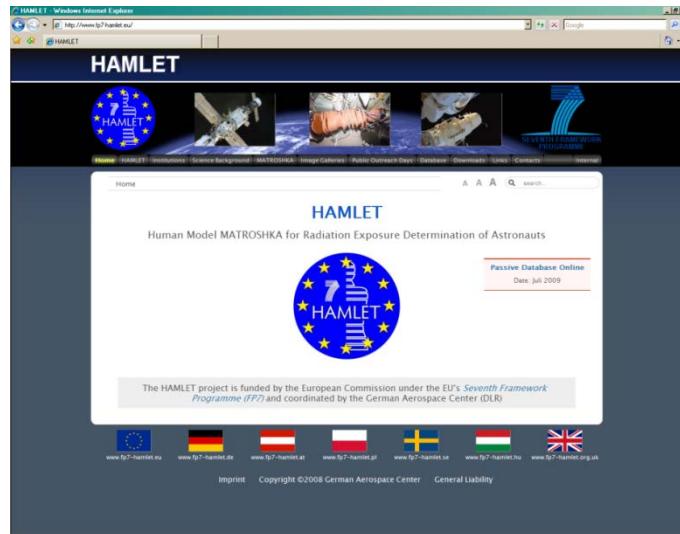
Summary

- 3D Dose Distributions have been accomplished at four different places in- and outside the ISS (Russian and Japanese Modules)
- Clear distinction between the exposure places in the depth dose distribution in connection with the various shielding locations
- Clear distinction also in the readings of the 6LiF:Mg, Ti and 7LiF:Mg, Ti detectors – based on the different local shielding environments
- Highest dose inside the ISS for the exposure in the Japanese KIBO Module
- **Comprehensive database as input for radiation transport calculations / benchmarking of radiation transport codes**
- Organ dose and organ dose equivalent results resulting in effective dose values of:
MTR-1: 0.7 mSv/day (outside ISS) and **MTR-2A: 0.53 mSv/day** and
MTR-2B: 0.57 mSv/day (inside ISS)



Acknowledgements

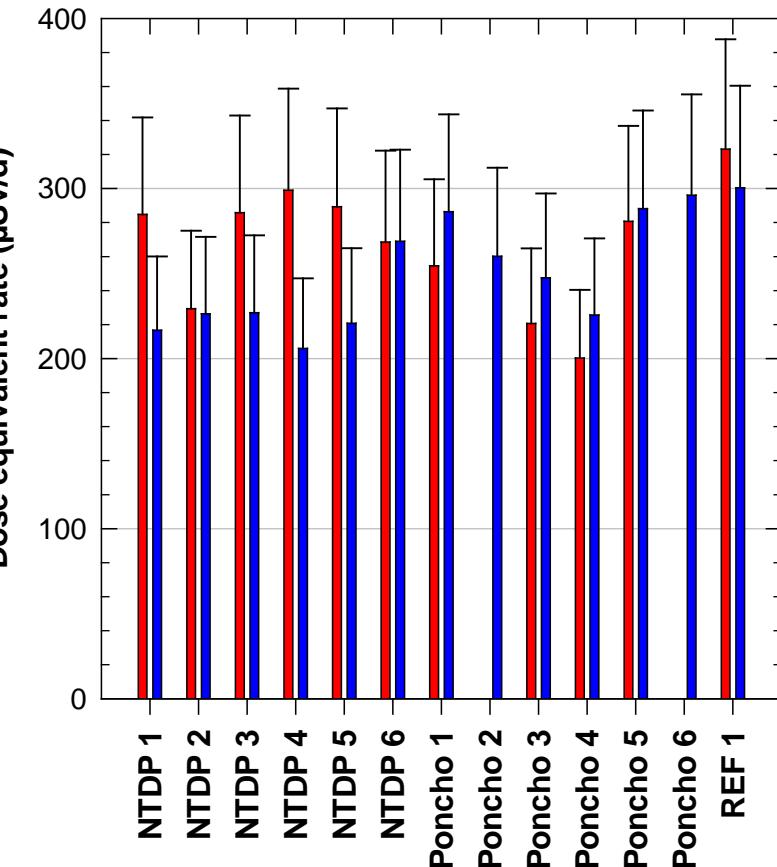
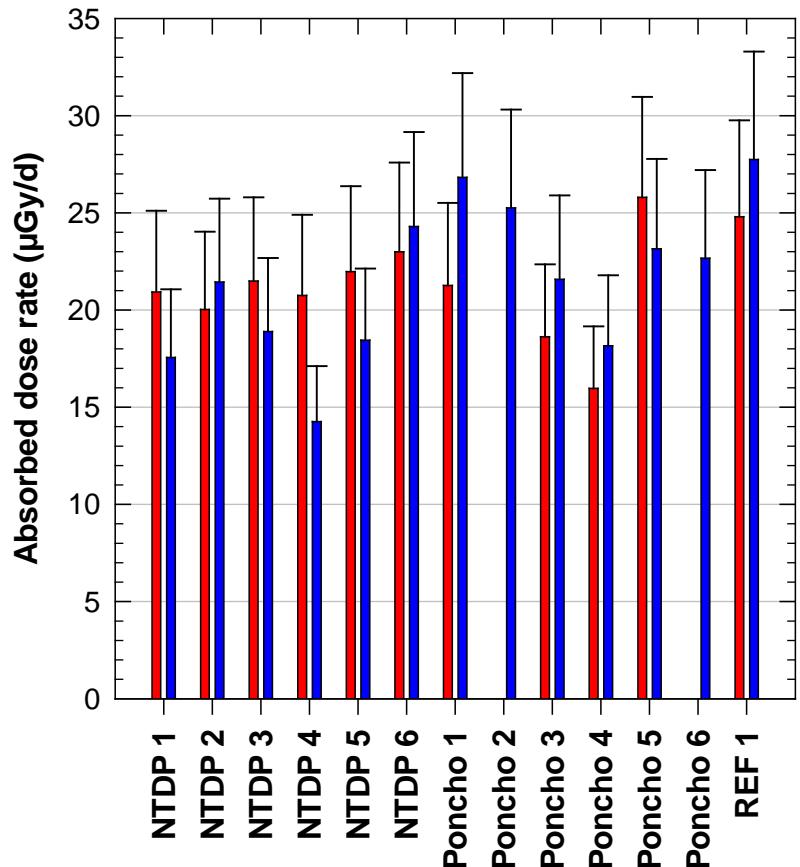
- All the astro- and cosmonauts working with the MATROSHKA experiment
- Extensive scientific exploitation of data was made possible through the funding by the European Community's 7th Framework Programme (FP7) under Contract No. 218817 HAMLET <http://www.fp7-hamlet.eu>



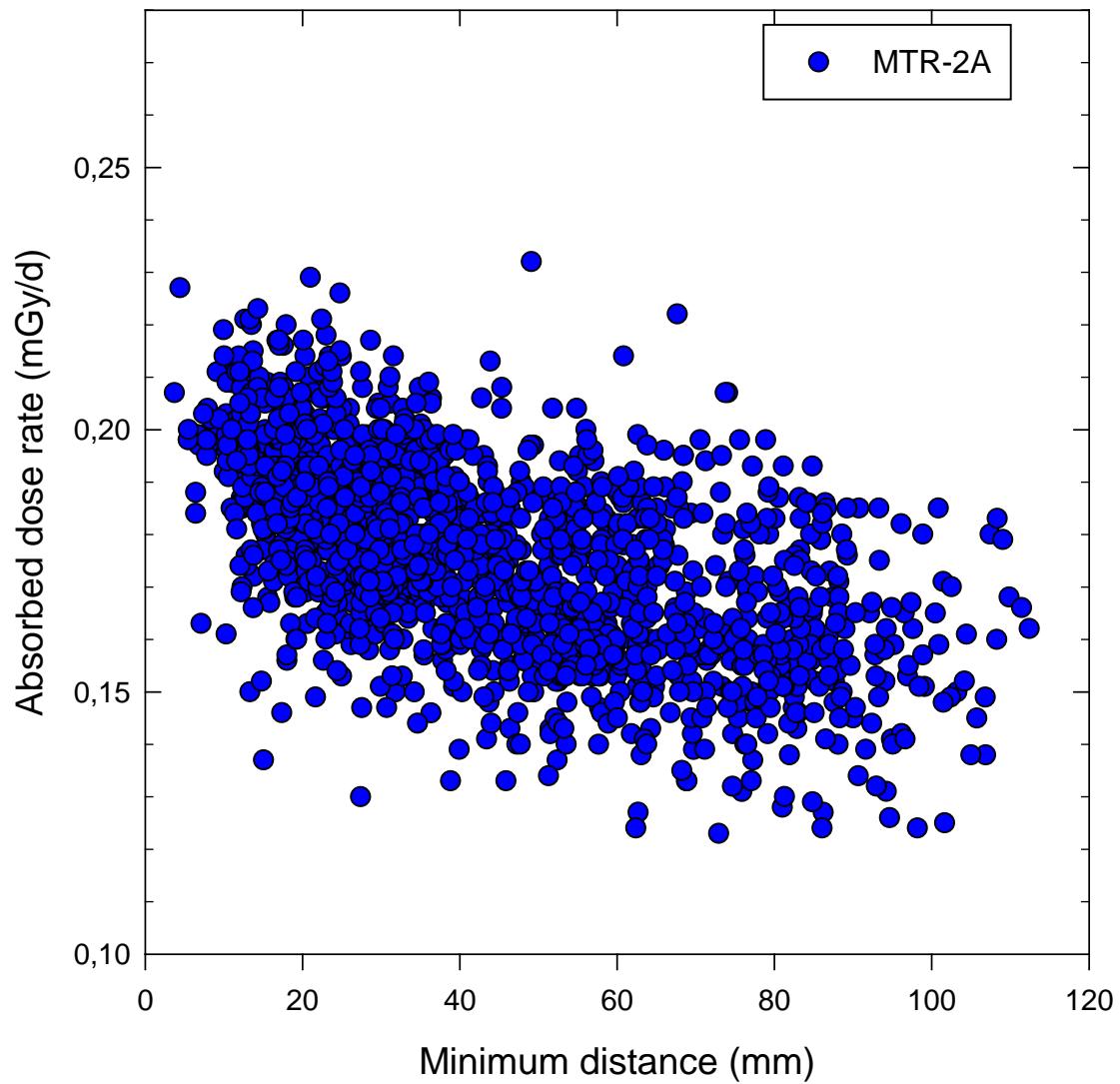
Backup



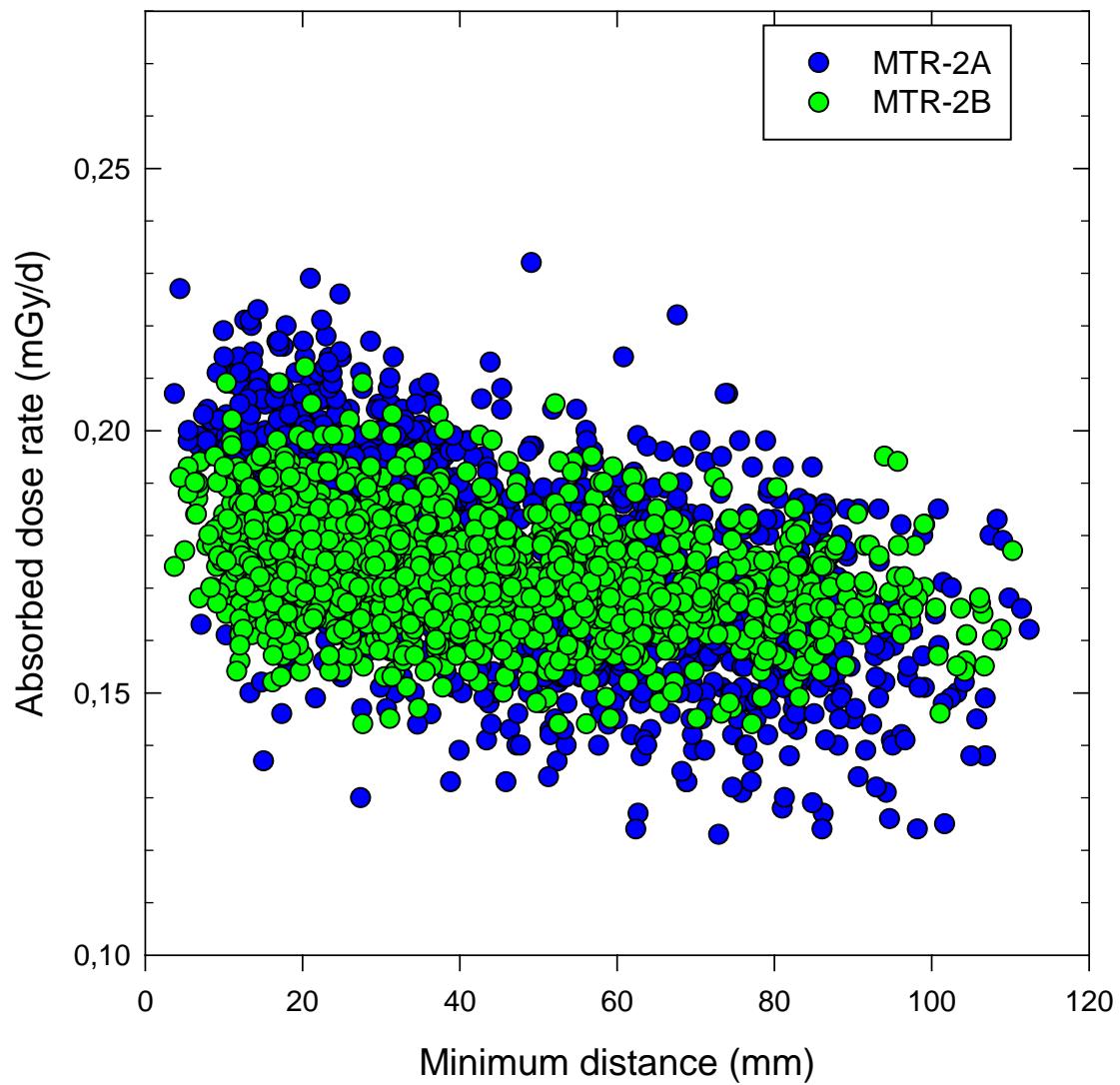
MTR-2 KIBO: CR-39 Results (DLR / EK)



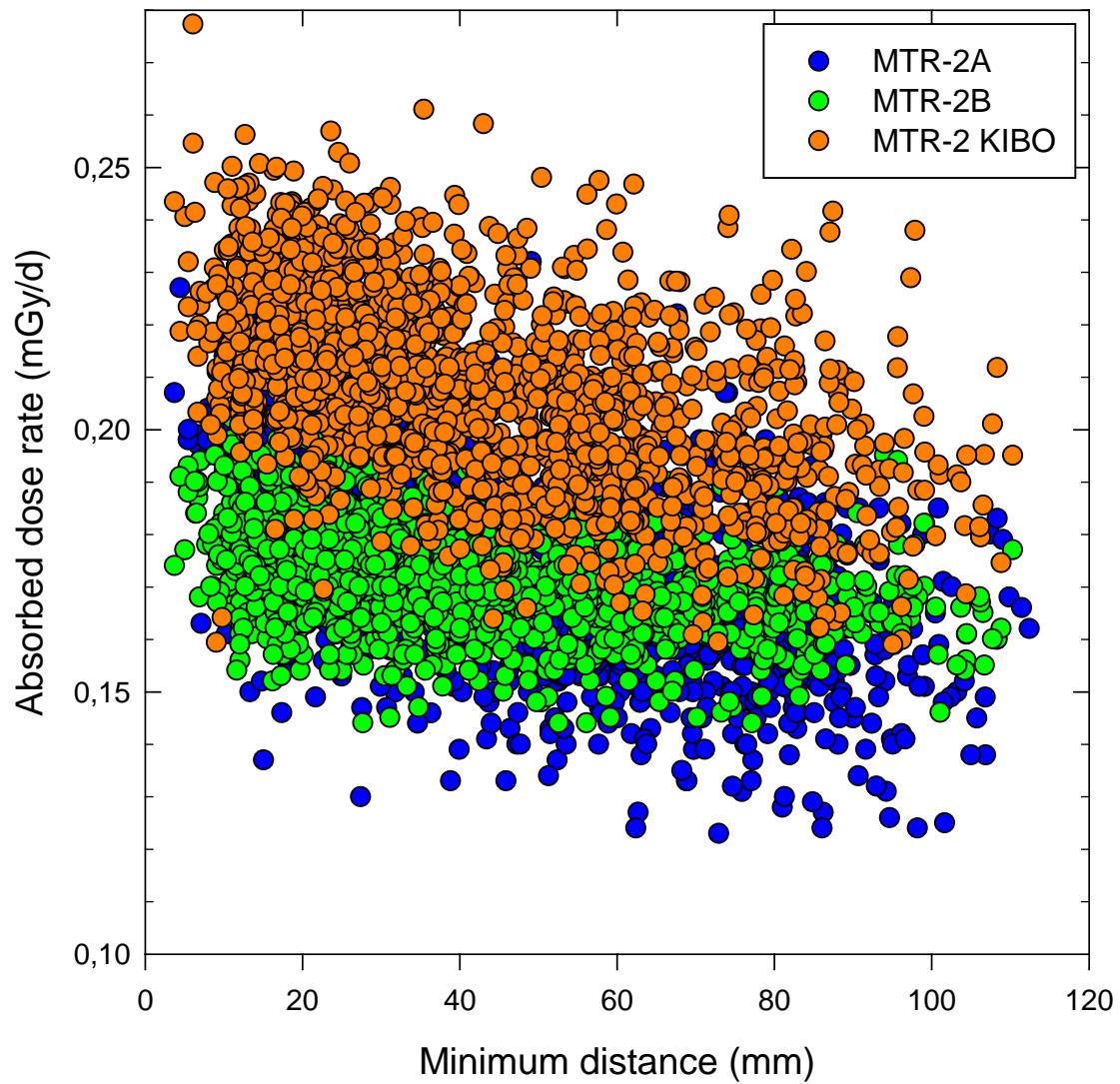
MATROSHKA: Comparison → Minimum Distance (MTR-2A)



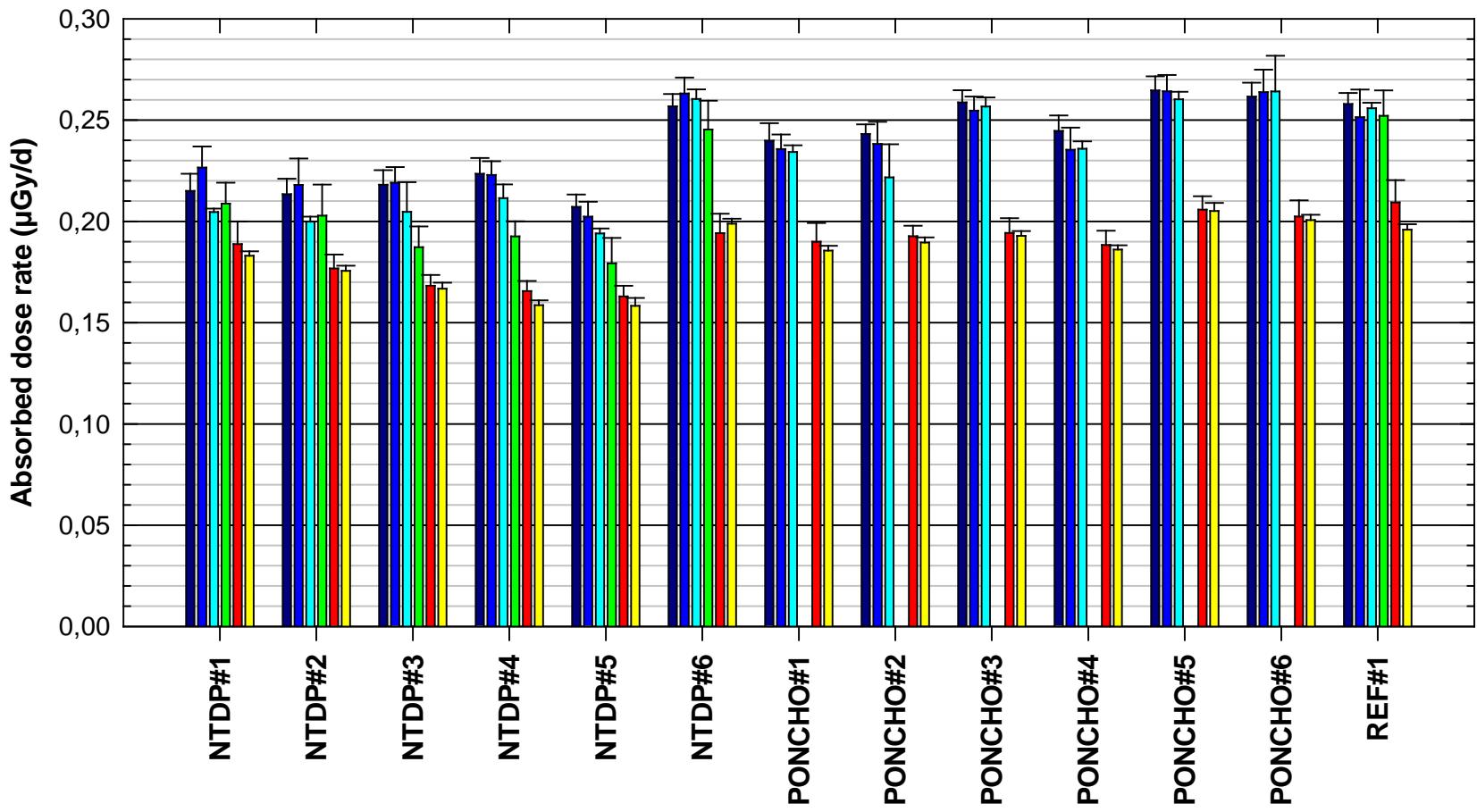
MATROSHKA: Comparison → Minimum Distance (MTR-2A /-2B)



MATROSHKA: Comparison → Minimum Distance (MTR-2A /-2B /2 KIBO)



MATROSHKA-2 KIBO: TLD



MATROSHKA-2 KIBO: TLD

