RADIATION PROTECTION PROPERTIES OF ADDITIONAL SHIELDING «PROTECTIVE CURTAIN» INSTALLED IN CREW CABIN OF RUSSIAN SEGMENT OF ISS

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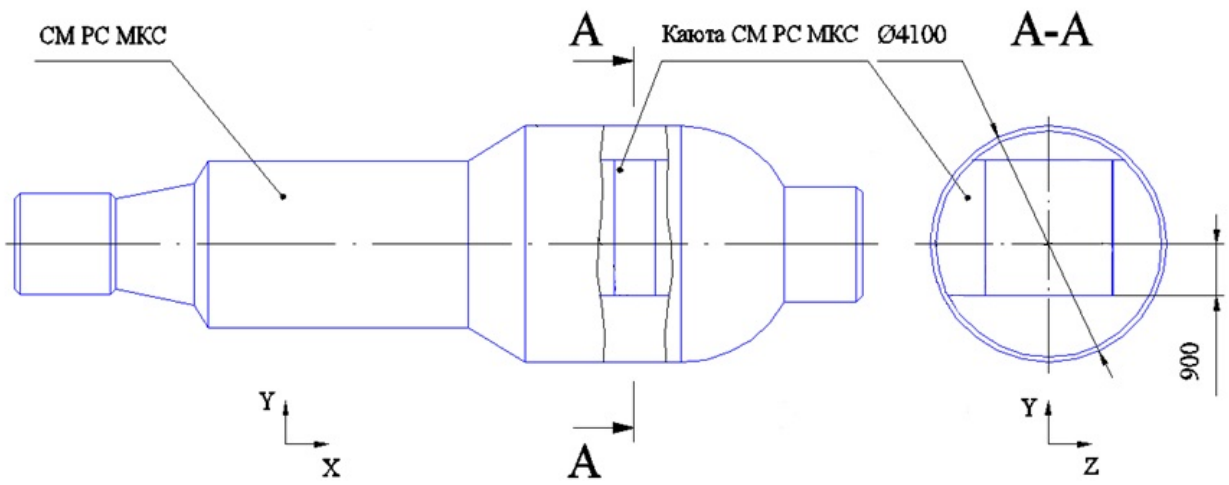
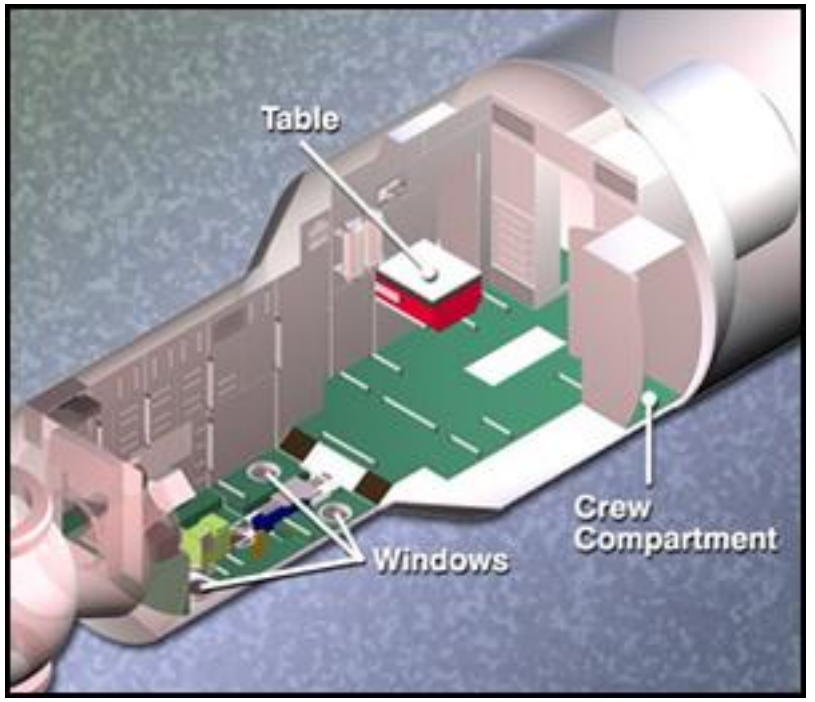
Participants of the current project

- IBMP, Russia (TLD)
- NPI, Czech republic (TLD, SSNTD)
- NIRS, Japan (TLD, SSNTD)
- CER HAS, Hungary (Pille-ISS)
- BTI, Canada (BUBBLE detectors)

Introduction: Crew cabin shielding characteristic

Scheme of Service Module of Russian Segment of ISS



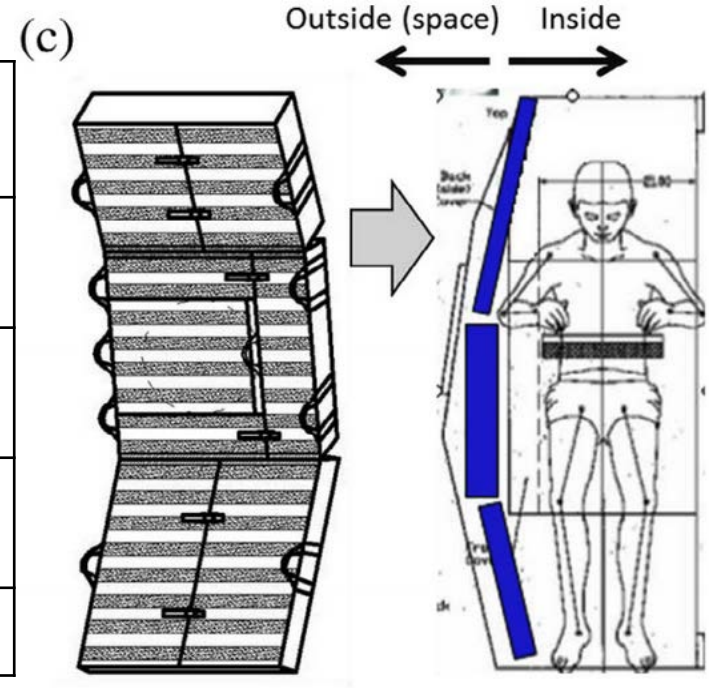


Protective curtain thickness is estimated to be **6.3** g/cm^2
Crew cabin outer wall thickness is estimated as ~ **1.5** g/cm^2
(2 Al layers with 2 mm thickness (0.4 cm * 2.7 g/cm^3 = 1.08 g/cm^2)
+ also an additional shielding of the anti-meteorite protection (outside)
and the cabin interior cover (inside))


CREW CABINS IN ZVEZDA MODULE
ISS FOOD WARMER
photo by NASA

Protective curtain design

	Thickness, cm	Mass, kg
Upper part	7,5	14,600
Middle part	13	25,600
Bottom part	12	24,000
All		64,200



Hygenic wipes and towels

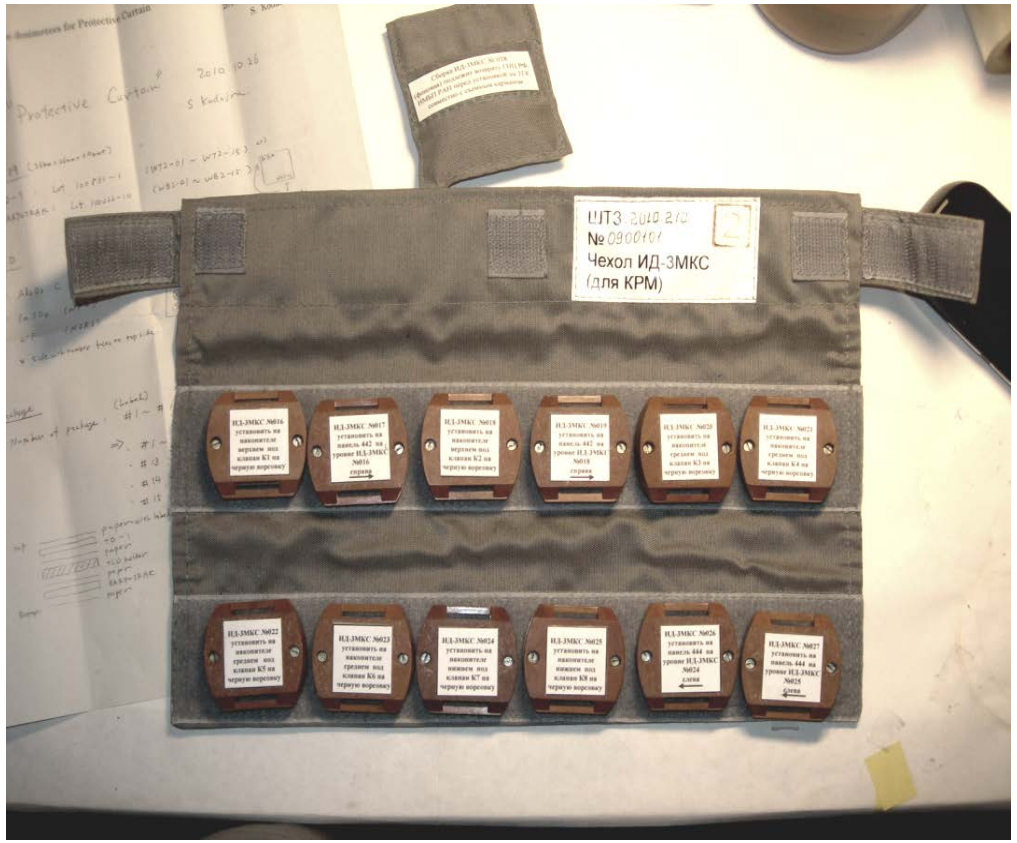
Estimated thickness: 6.3 - 6.5 g/cm2

Tissue bag containing 4 layers of hygienic wipes and towels

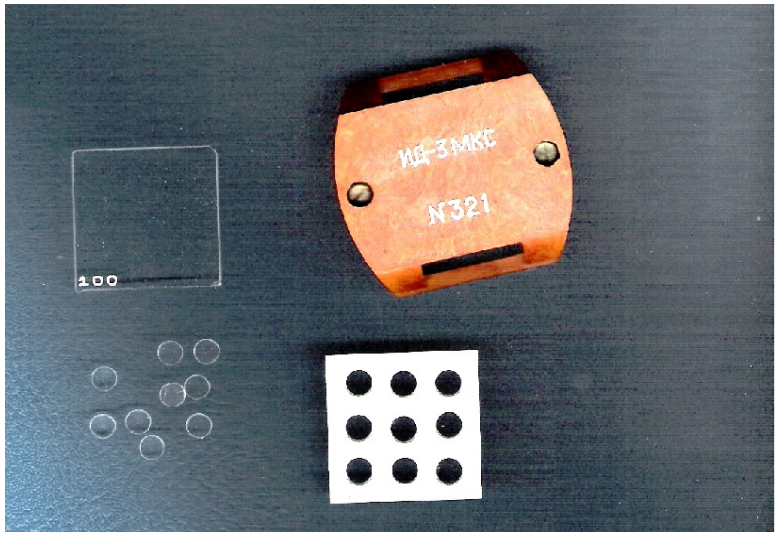
Photo of protective curtain made during pre-flight preparations (Baikonur, Kazakhstan, 2010)

Measuring instruments

Passive detector packages containing thermoluminescent detectors (TLD) and solid state nuclear track detector (SSNTD) have been used as a main measuring instrument.



Detector kit – flight model



12 passive detectors packages + 1 background control

TLD and SSNTD

Detector type	Material and name	Sizes	
TLD	LiF:Mg,Ti (tablet) (TLD 700)	3 mm ∅ / 0.9 mm	NIRS, 1-4 sessions (OSLD for 5th session)
	LiF:Mg,Ti (monocrystal) (DTG-4/ДТГ-4)	4.5 mm ∅ / 1 mm	IBMP
	$CaSO_4$:Dy	5 mm ∅ / 1 mm	NPI
	$Al2O_3$:C	5 mm ∅ / 1 mm	
SSNTD	CR-39 HARZLAS TD-1	27 x 27 x 1 mm	NPI, NIRS

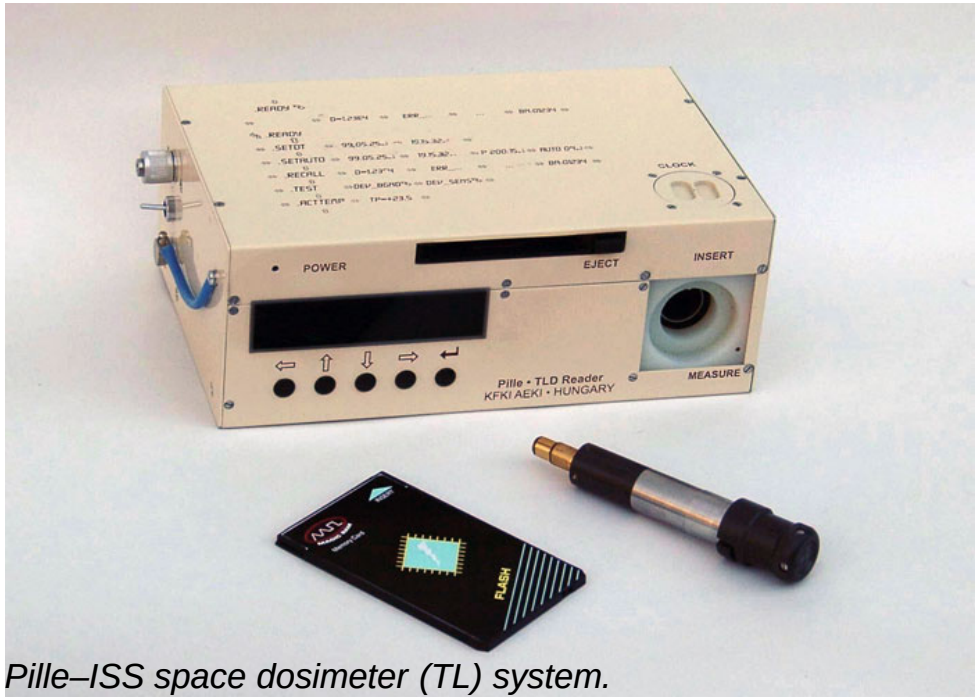
Measuring instruments

Pille-ISS detector was used for additional studies in period September 2010 – December 2011.

Main specifications of the Pille TLD system.

Dosimeter	
Type	Bulb
Material:	$CaSO_4$:Dy
TLD efficiency ($LET_{\infty,H2O}$ < 10 keV/μm):	1 ± 10% (relative to ^{137}Cs)
Dimensions:	Ø20 mm * 60 mm
Mass:	70 g (with carrying case)
Reader	
Measuring range (s < 10%):	3 mGy, 10 Gy ($CaSO_4$:Dy)
Read-out precision:	3 digits + exponent
Accuracy (above 10 mGy):	d < 5%
Storage of information:	PCMCIA memory card
Computer connection:	RS-232
Dimensions:	70 × 190 × 120 mm^3
Mass:	1.4 kg
Power consumption:	0.1/1/7 W (standby/ready/readout)

/Onboard cross-calibration of the Pille-ISS Detector System and measurement of radiation shielding effect of the water filled protective curtain in the ISS crew cabin, *P.Szanto et., Radiation Measurements 82 (2015) 59-63*

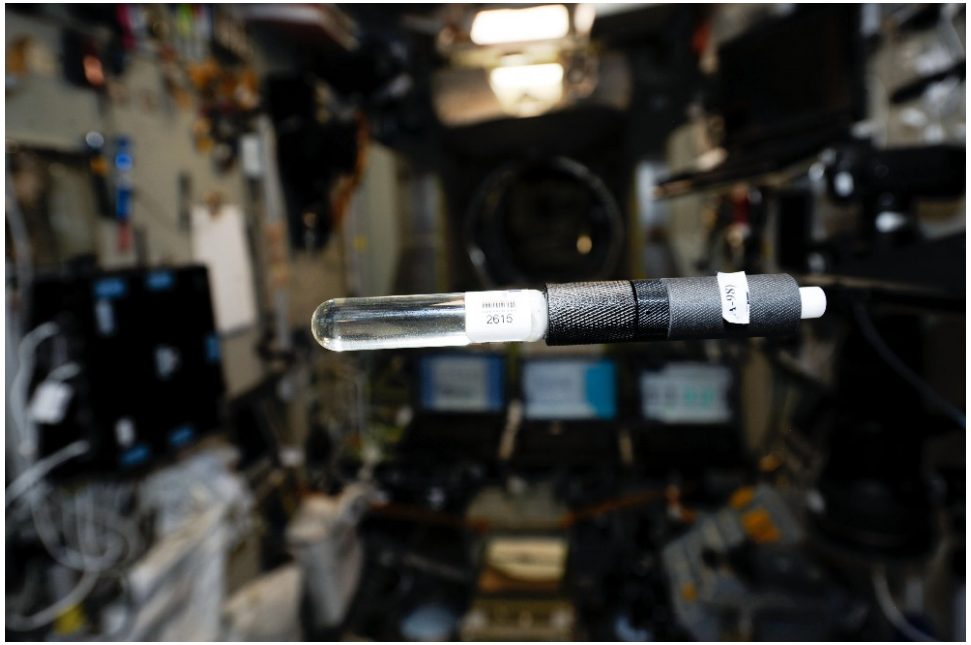


Pille–ISS space dosimeter (TL) system.

Measuring instruments

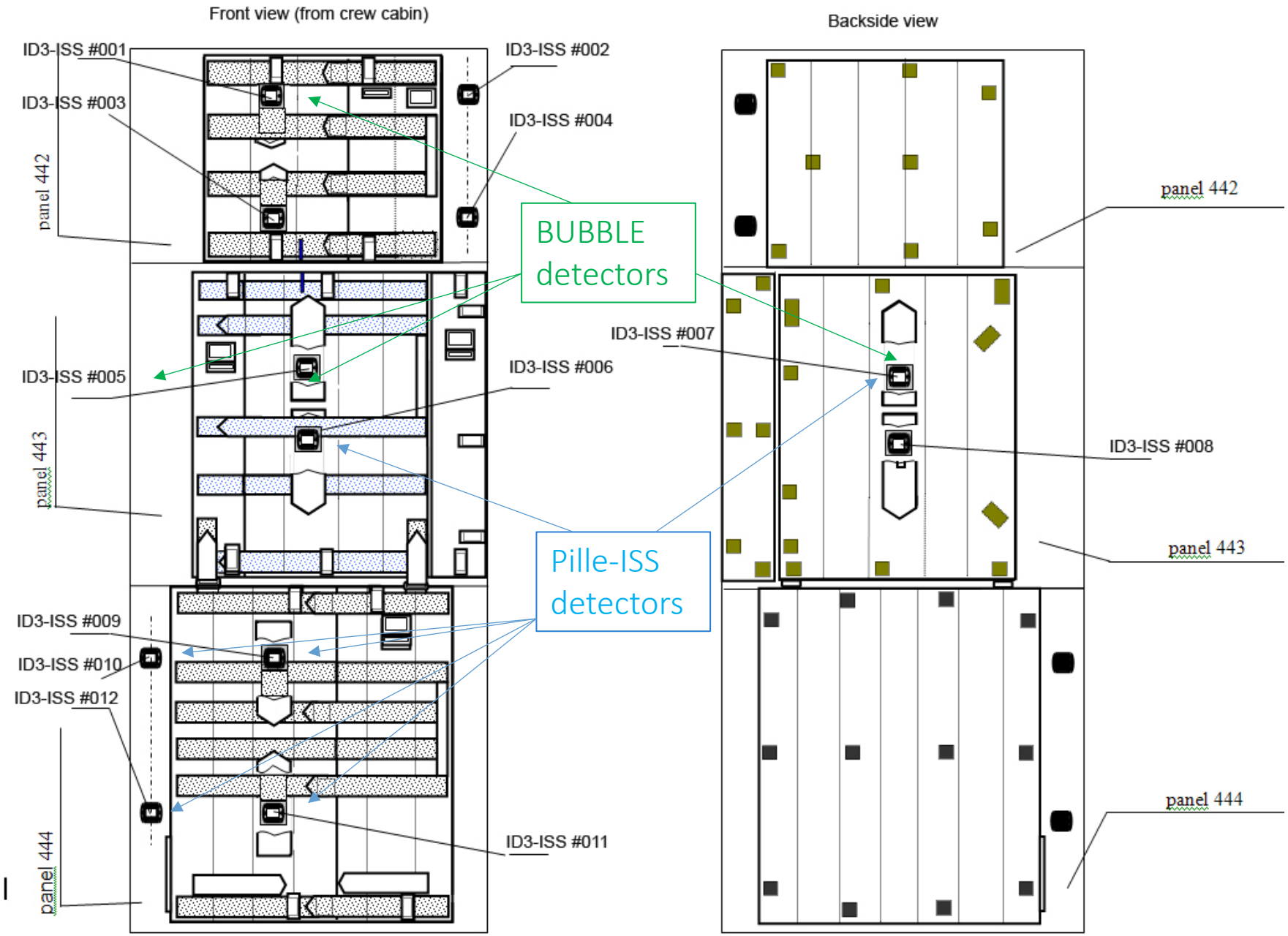
Bubble detectors were used for estimation neutron dose reduction.

Reader

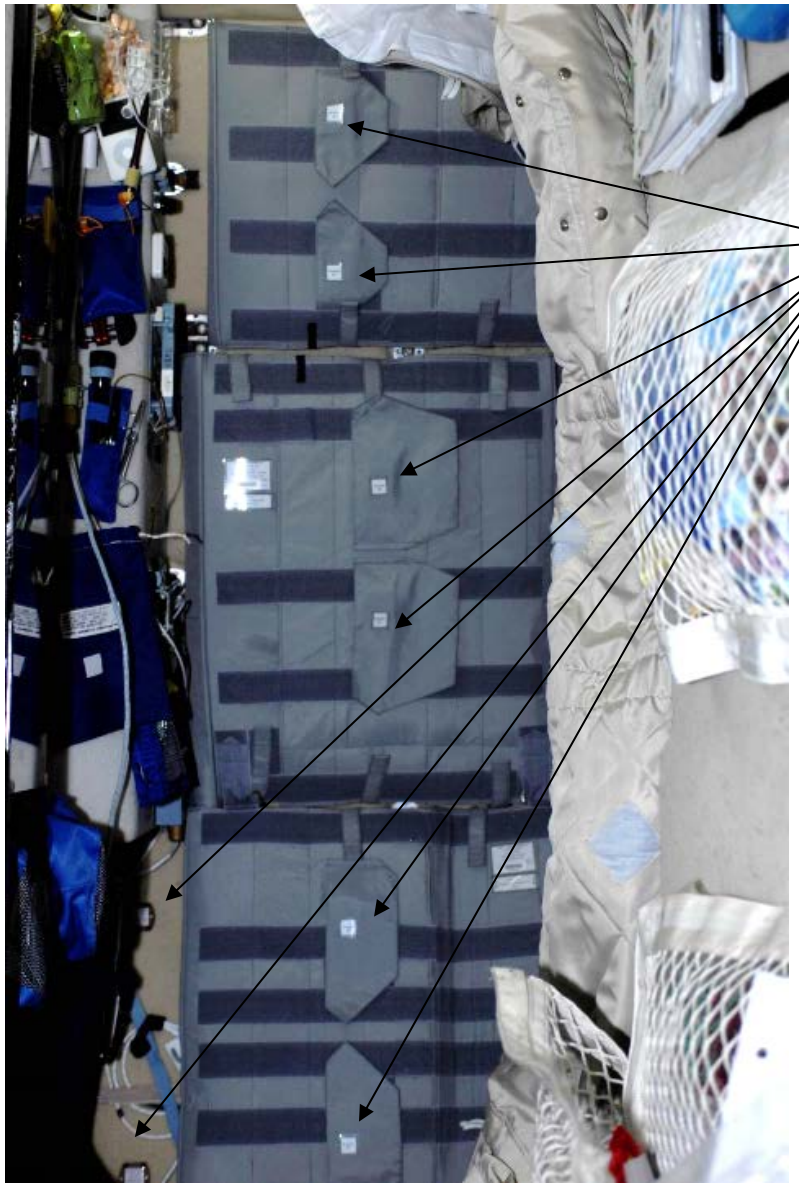


Bubble-detector

Detectors exposure locations



PHOTOS MADE ONBOARD ISS



Passive detectors packages

Overall view of protective curtain in starboard crew cabin, SM ISS

Spherical phantom in the same location (2004-2005 yy)

PHOTOS MADE ONBOARD ISS

Pille – ISS dosimeters (placed in the same locations as passive detectors packages)

BUBBLE dosimeters

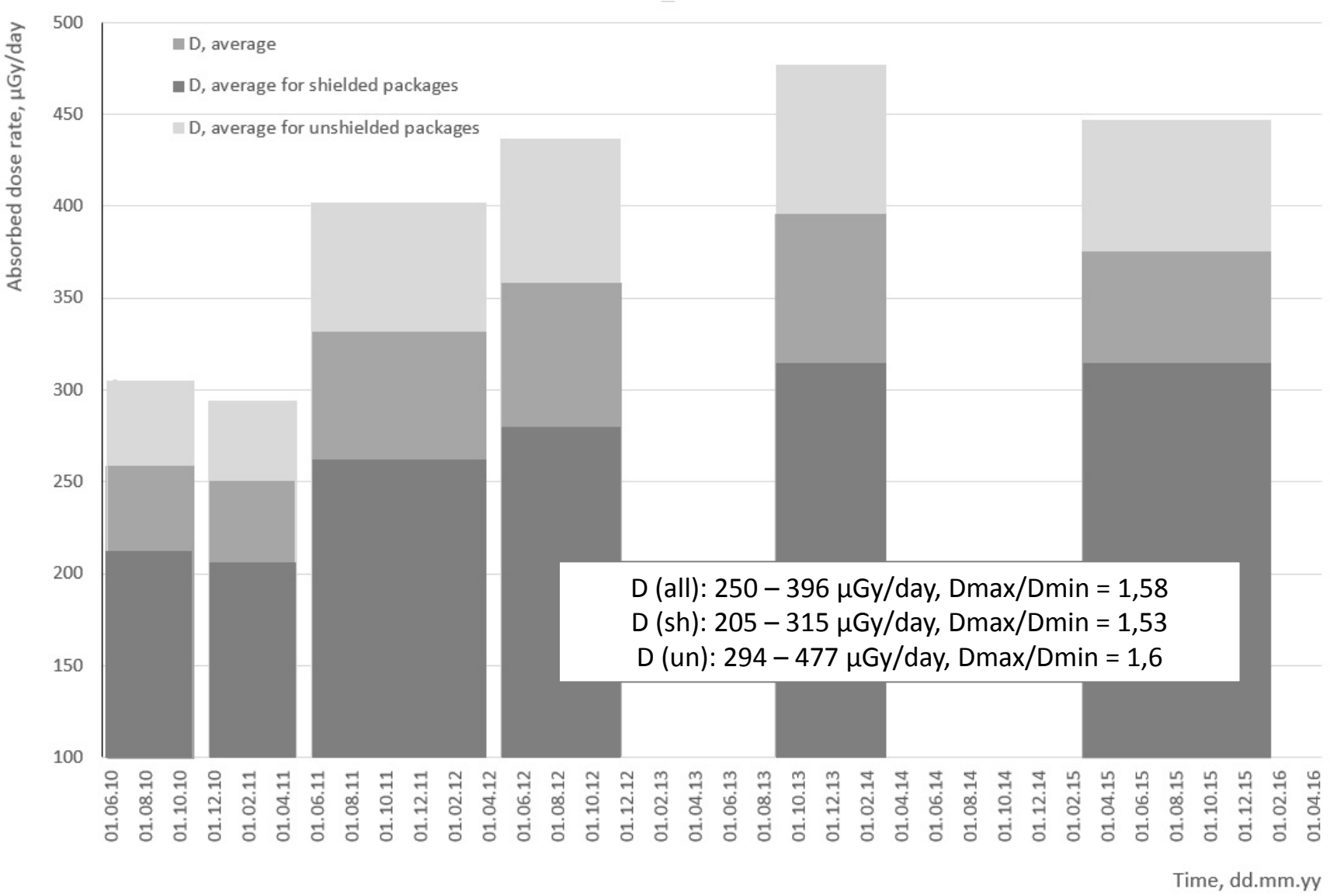
Flight Data

PNTD and TLD detector packages were exposed during 6 sessions:

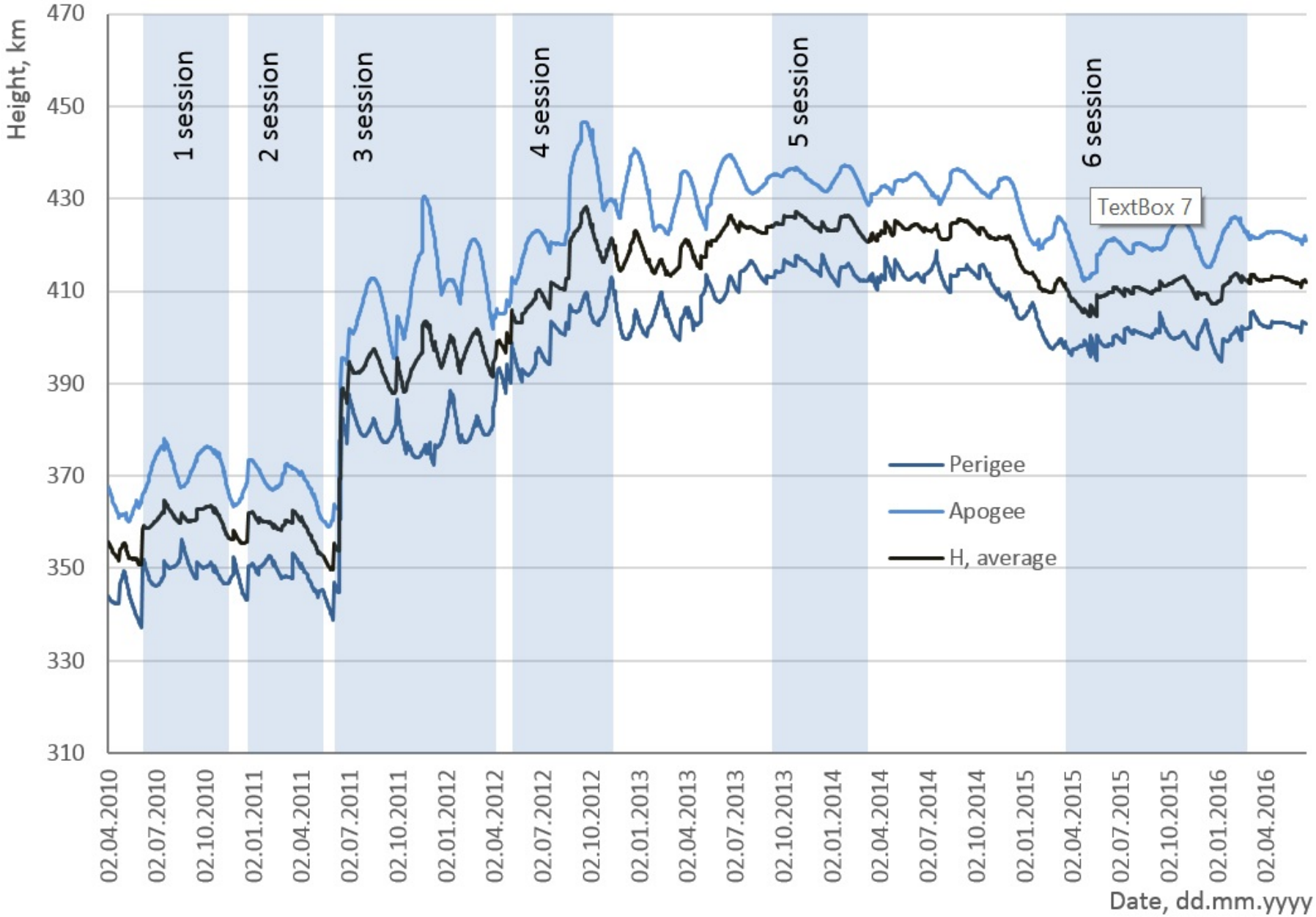
session#	Start	End	Duration, days		ISS mission#
1	16.06.2010	26.11.2010	163	SOYUZ TMA-19	24/25
2	15.12.2010	24.05.2011	160	SOYUZ TMA-20	25/26
3	21.06.2011	27.04.2012	311	Progress M-11M/ SOYUZ TMA-22	27/30
4	15.05.2012	19.11.2012	188	SOYUZ TMA-04 M/ SOYUZ TMA-05 M	31/32
5	26.09.2013	11.03.2014	166	SOYUZ TMA-10M	37/38
6	27.03.2015	18.02.2016	328	SOYUZ TMA-16M/ SOYUZ TMA-18M	43/46

BUBBLE detectors were exposed for about 30 sessions during 2009 – 2012 yy, #22-33 ISS missions.
Pille- ISS dosimeters measurements (16 sessions) were performed from Sep. 2010 to Dec. 2011 (#25-28 ISS missions)

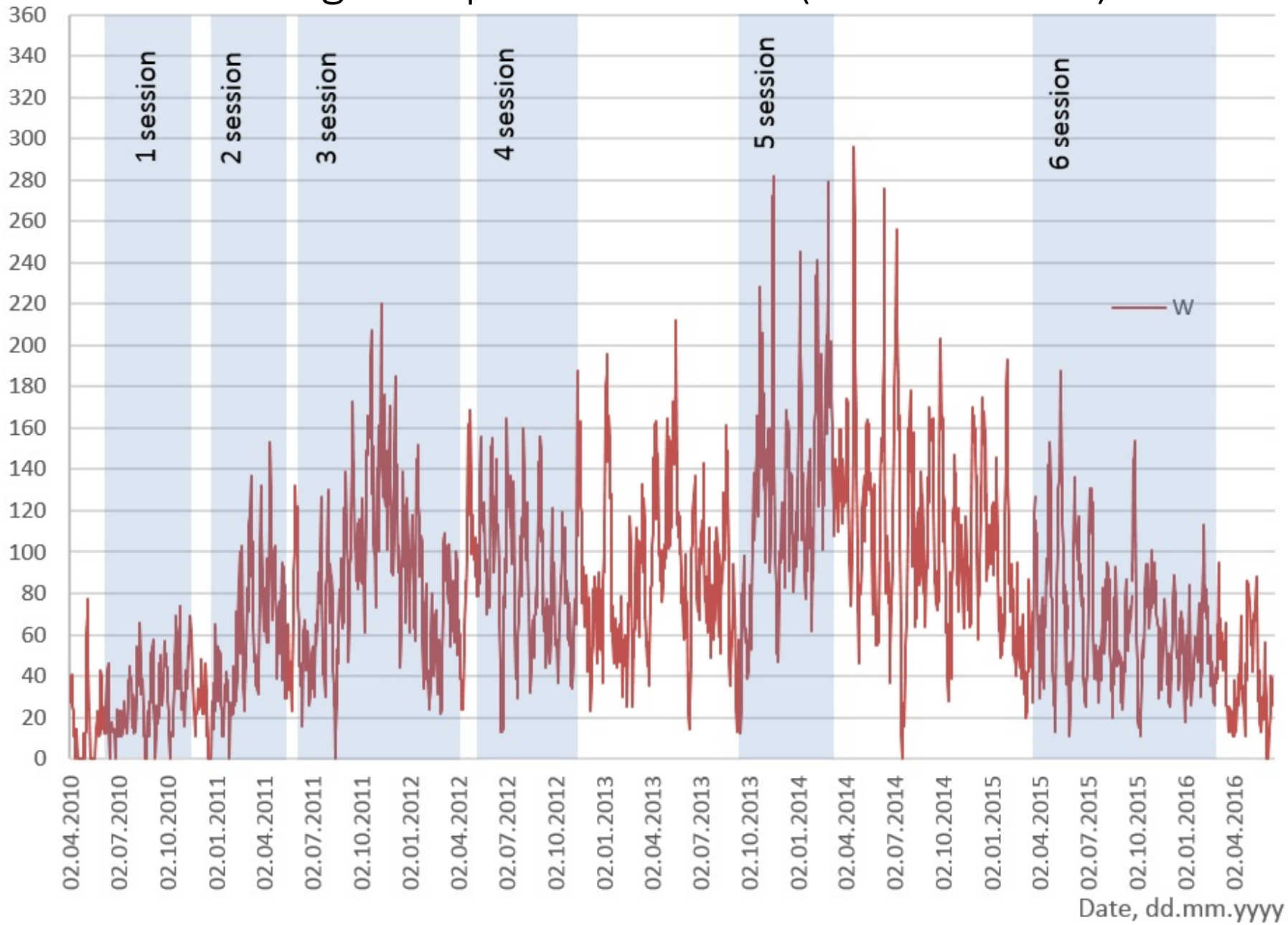
Resilts: Absorbed dose time dynamic (TLD, IBMP)



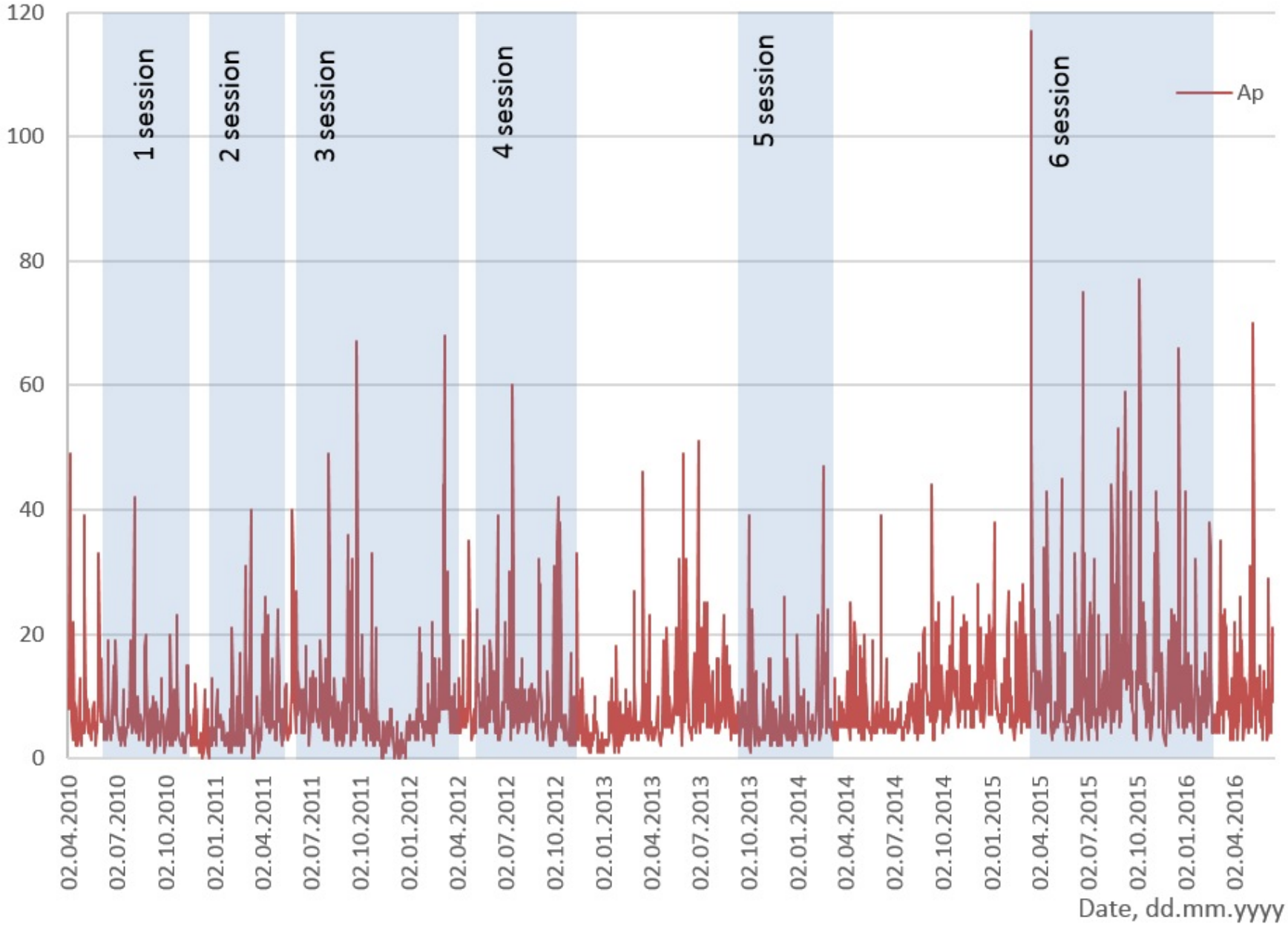
ISS parameters: flight altitude



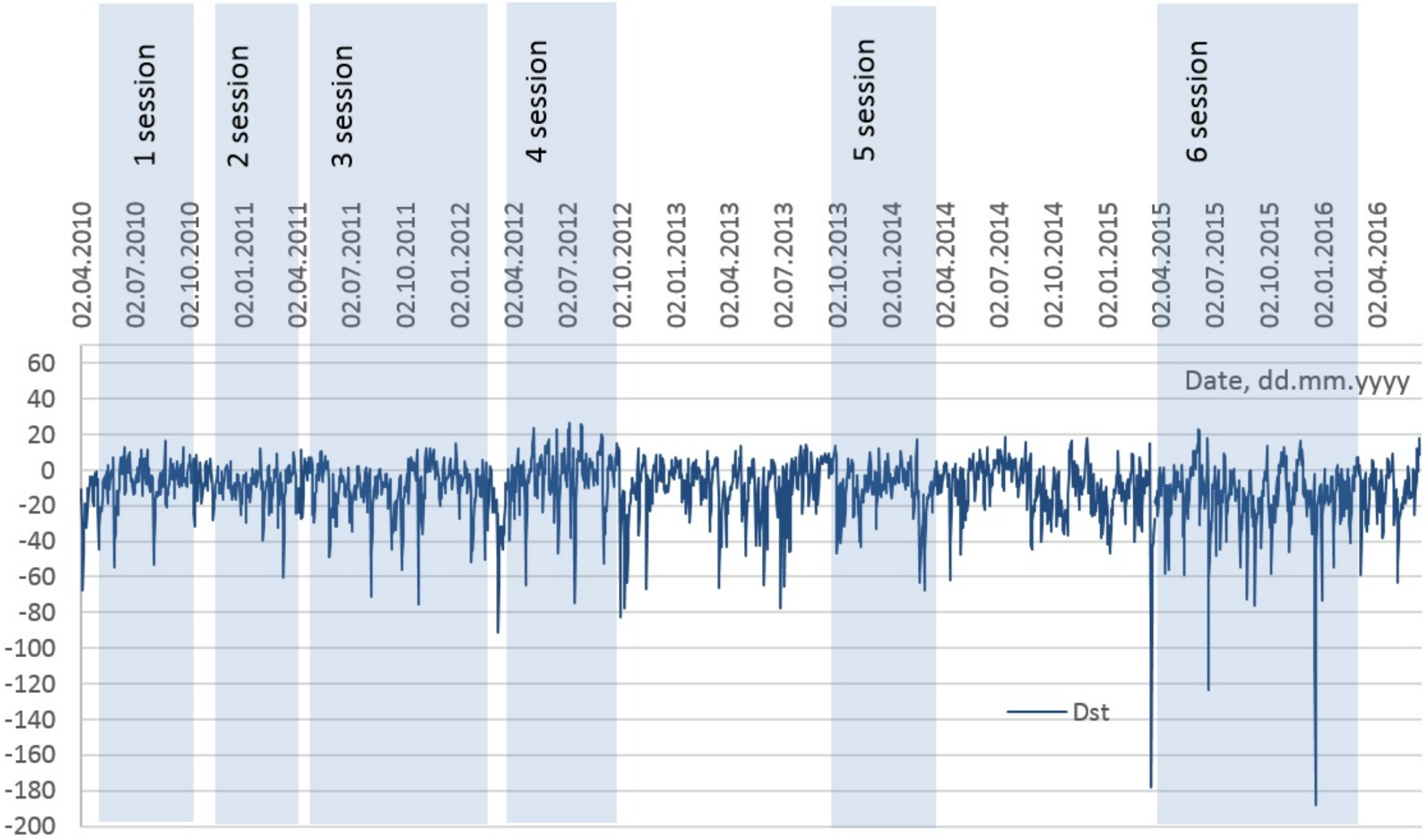
Geomagnetic parameters: W (Wolf number)



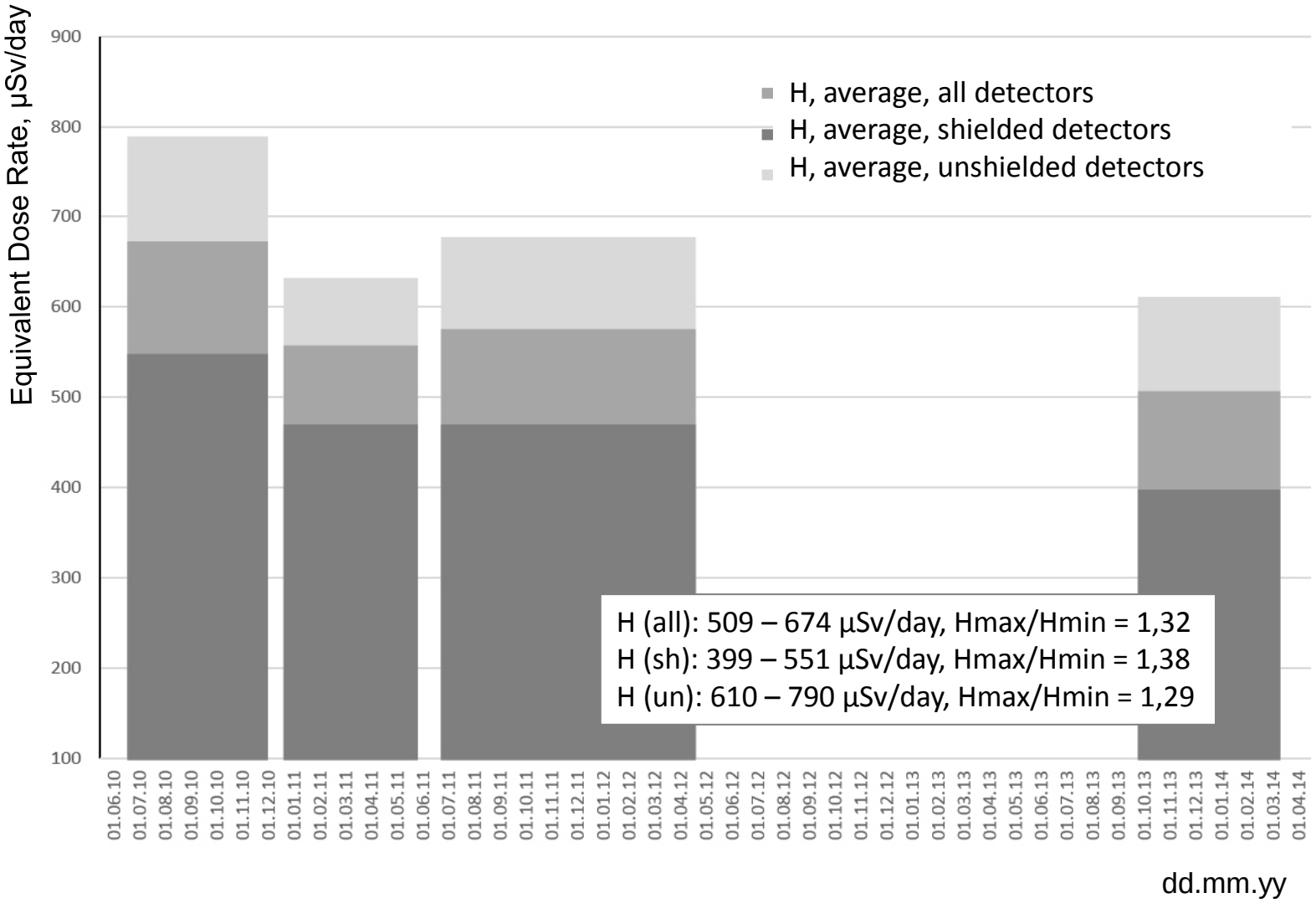
Geomagnetic parameters: Ap index



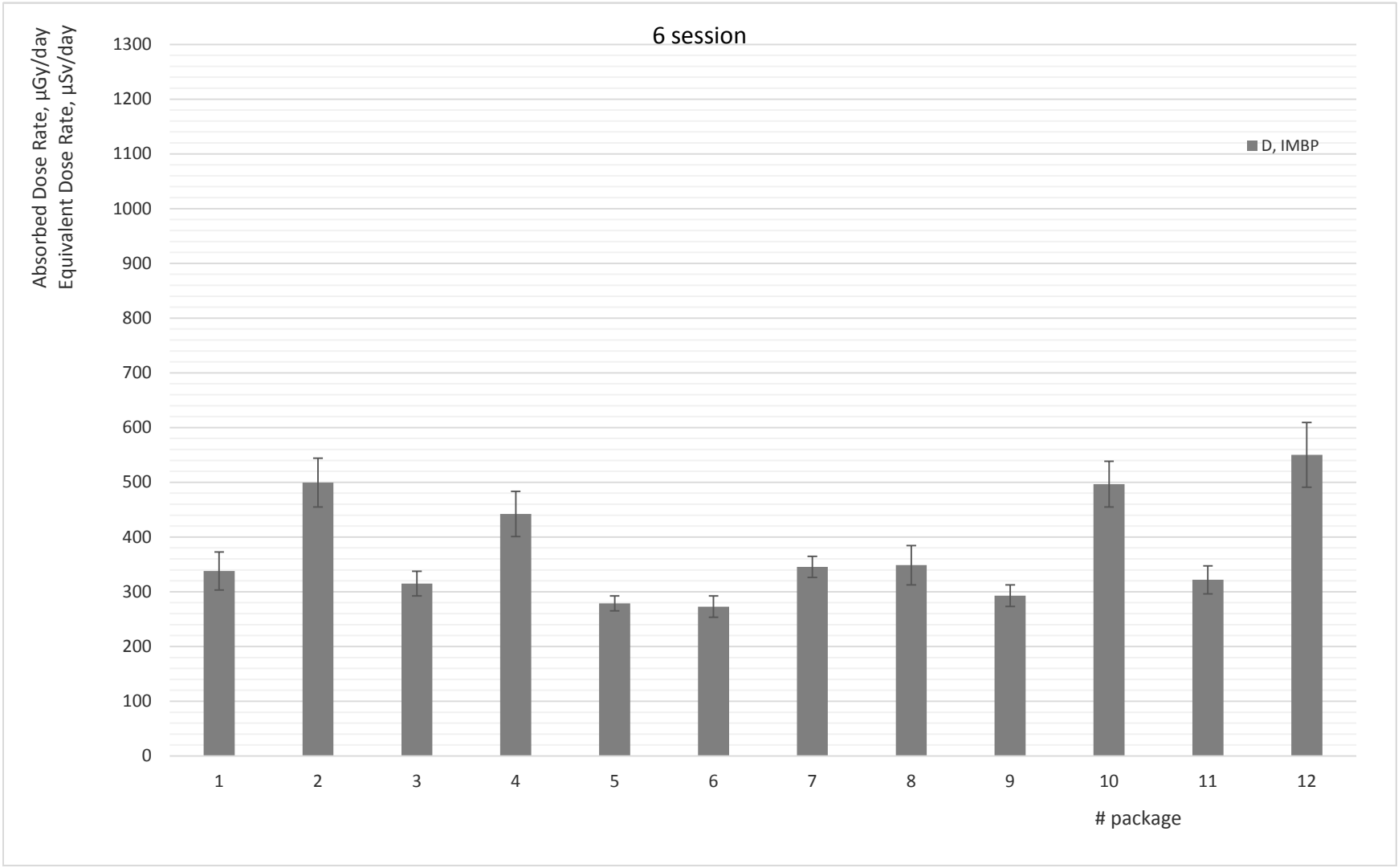
Geomagnetic parameters: Dst index



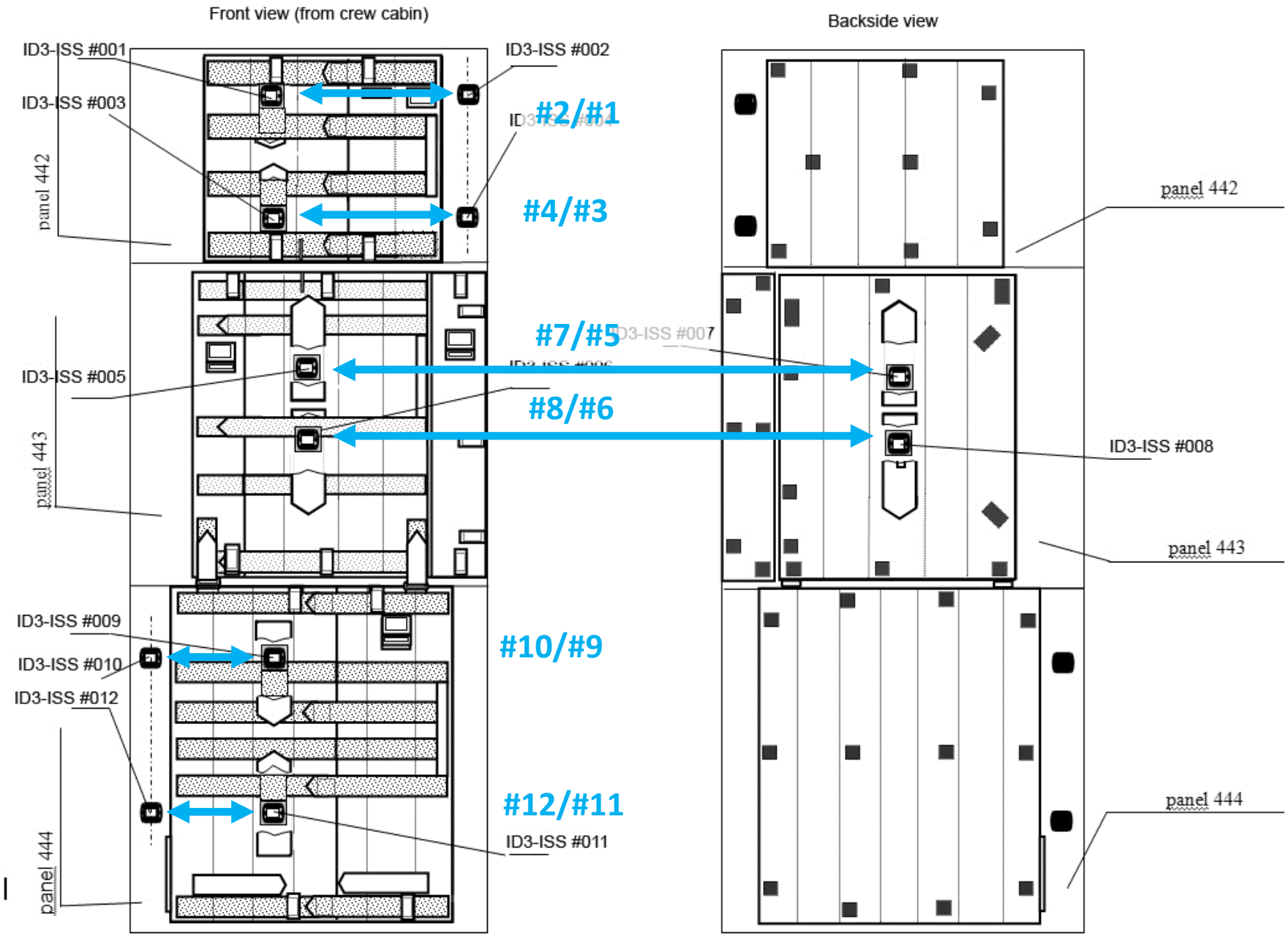
Resilts: Equivalent dose measurements (TLD+ SSNTD, NIRS)



Dose Spatial Distribution

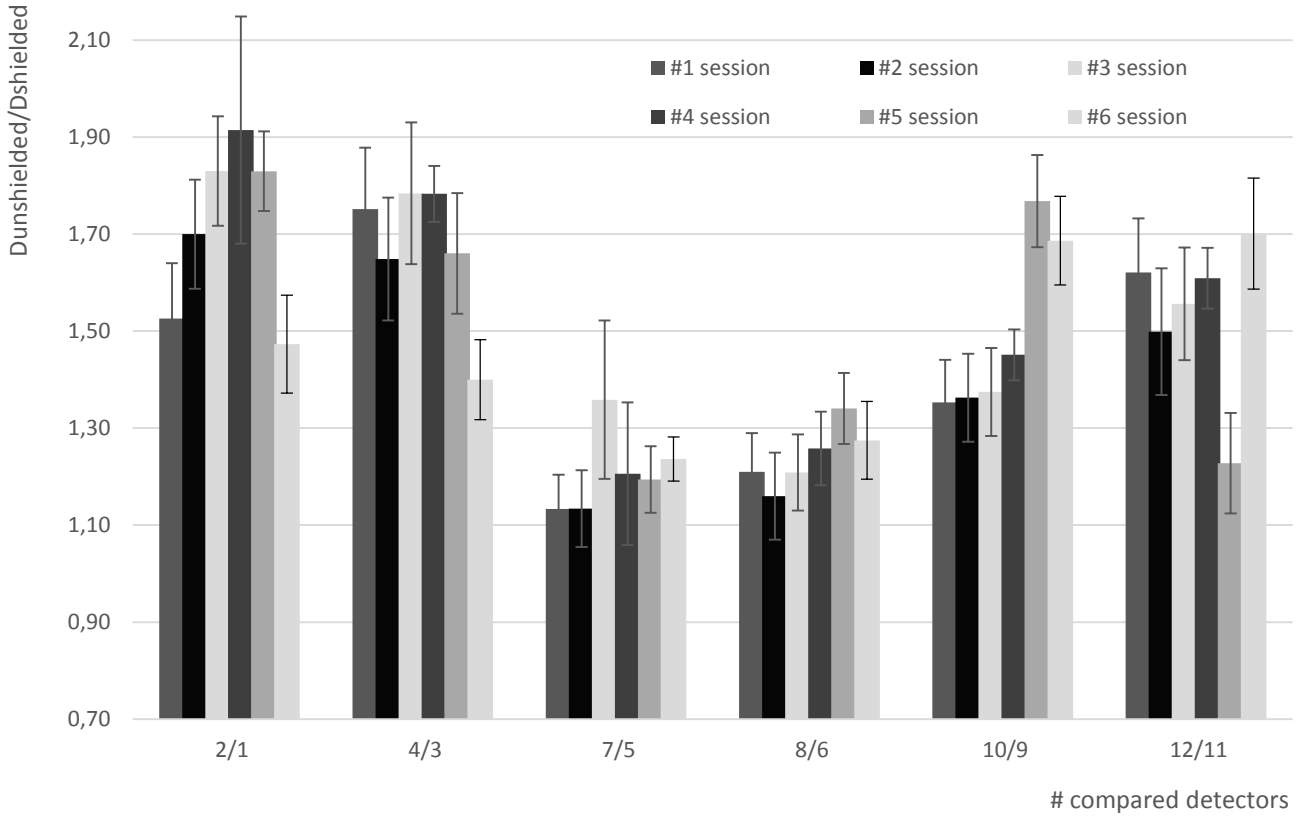


Passive detector packages comparison

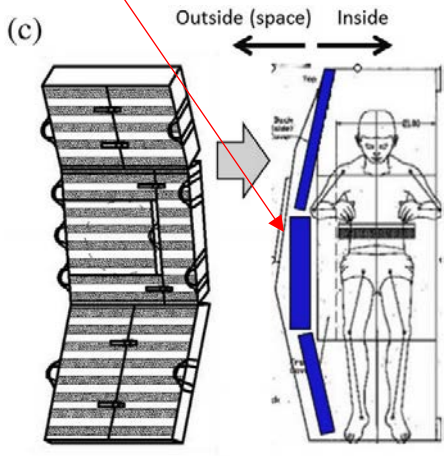


Results: Ratio of unshielded and shielded detectors (D)

# pack.	Ratio, average for all time	1/ Ratio %
2/1	1,71 ± 0,05	58
4/3	1,67 ± 0,03	60
7/5	1,21 ± 0,05	83
8/6	1,24 ± 0,01	81
10/9	1,50 ± 0,02	67
12/11	1,54 ± 0,02	65



illuminator



Ratio = unshielded detector/ shielded detector

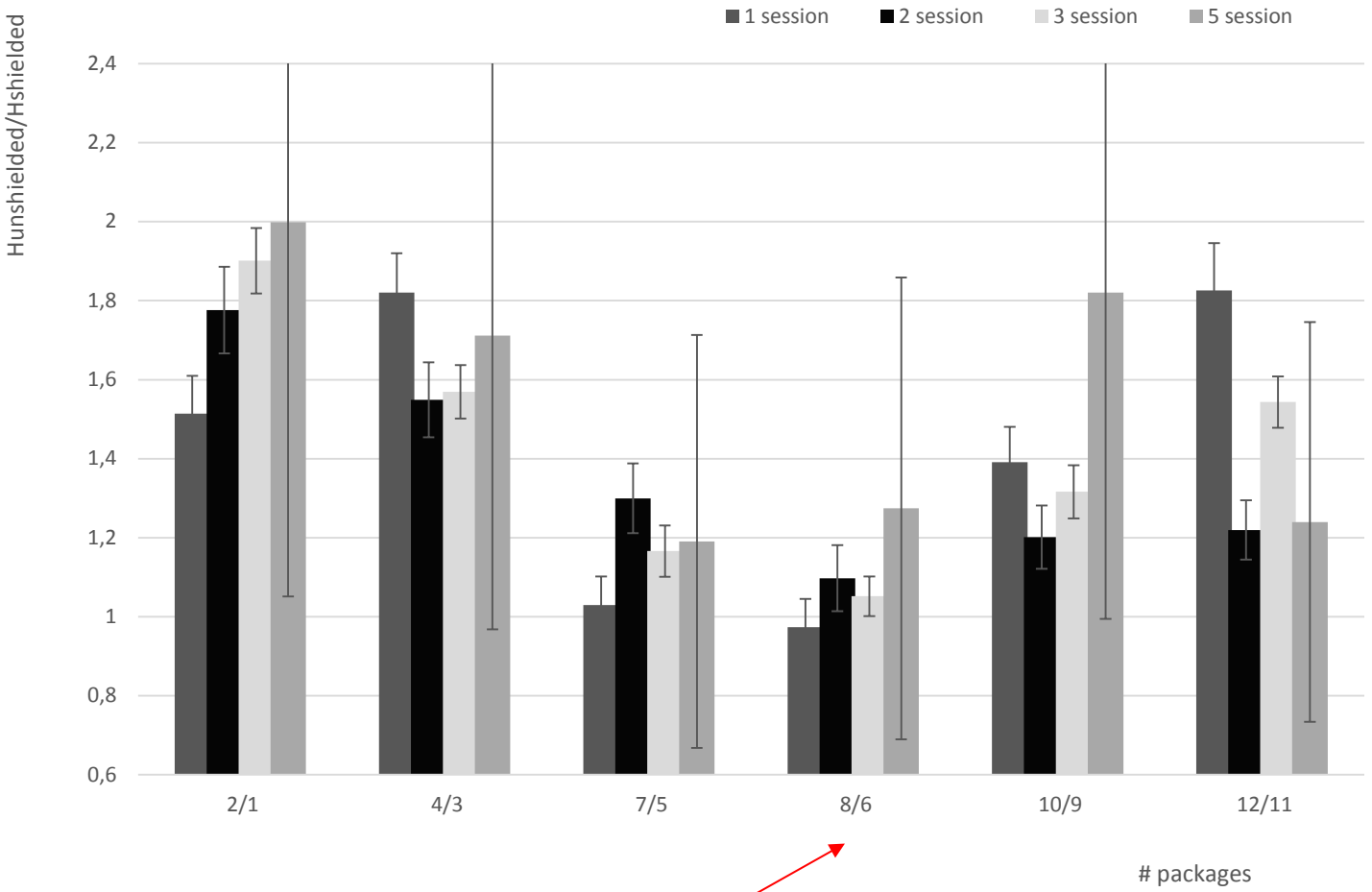
«illuminator» effect: thickness is about 5 g/cm^2

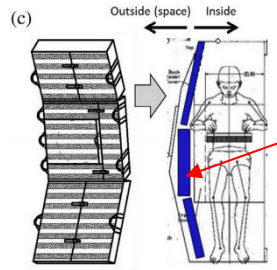
Results: Ratio of unshielded and shielded detectors (D): Pille-ISS data

	Average	# measurements	Average (TLD, IBMP)	Corresponding exposure sessions
2/1				
4/3				
7/5	1,29	13	1,23	2-4 sessions
8/6				
10/9	1,49	3	1,36	1-2 sessions
12/11	1,52	1	1,56	between 1 and 2 sessions

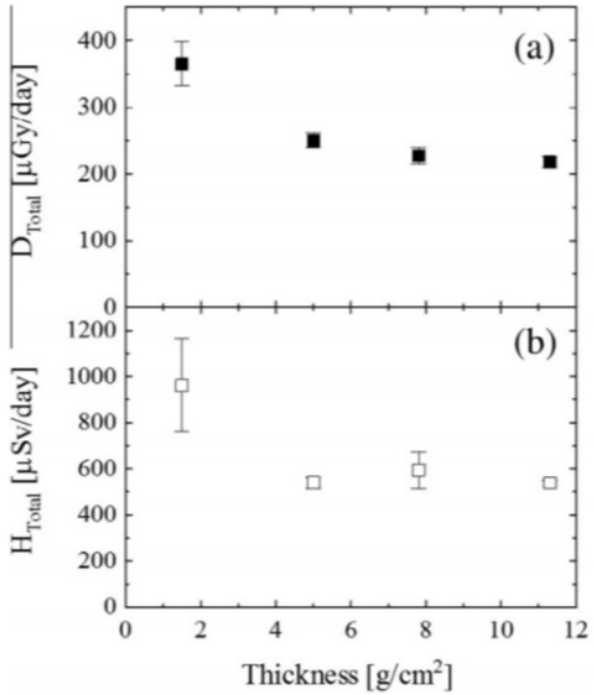
Data presented in next article:
Onboard cross-calibration of the Pille-ISS Detector System and measurement of radiation shielding effect of the water filled protective curtain in the ISS crew cabin, P.Szanto et., Radiation Measurements 82 (2015) 59-63

Resilts: Ratio of unshielded and shielded detectors





Ratio ~1
no difference between shielded and unshielded packages considering uncertainty range



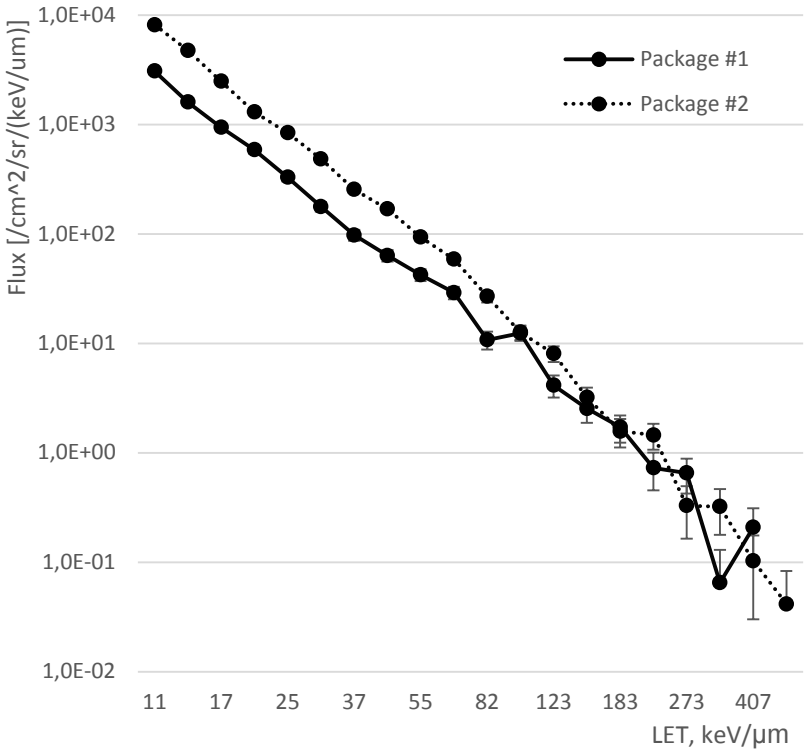
Variations of (a) total absorbed dose (D_{Total}) and (b) total dose ent (H_{Total}) rates as a function of the material thickness.

S. Kodaira et al. / Advances in Space Research 53 (2014) 1–7

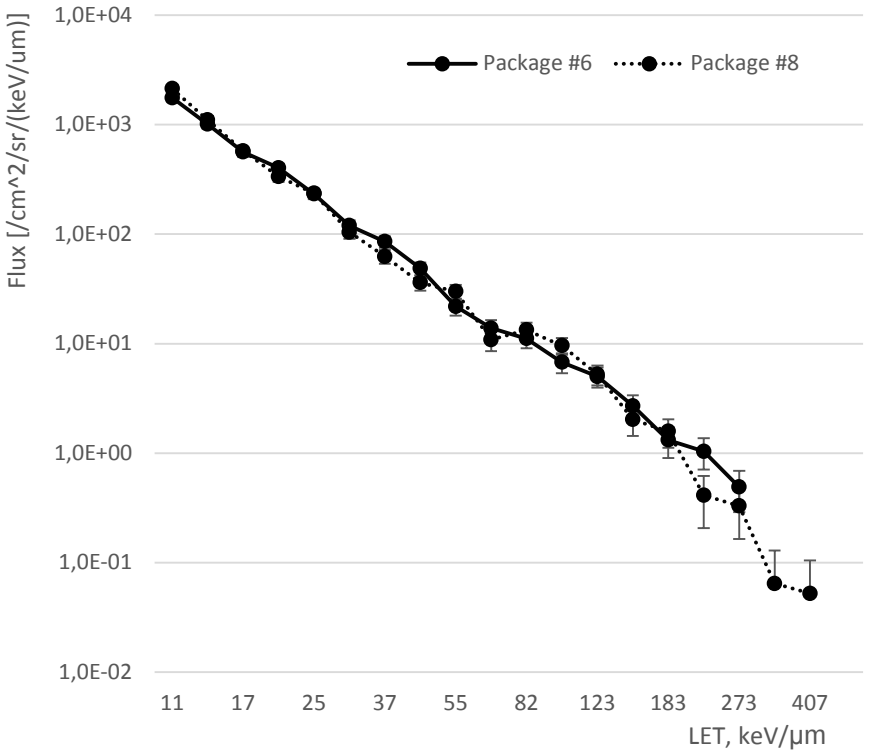
↑4 points with different shielding thickness: outer wall, glass, outer wall + protective curtain, glass +protective curtain

LET spectra

Pack#2 and Pack#1, 3 session
Hunshielded/Hshielded = 1,9



Pack#8 and Pack#6, 3 session
Hunshielded/Hshielded = 1,05



Resilts: Quality Factor

Spatial Distribution
(average for all sessions)

# package	<Q>
1	2,30
2	2,25
3	2,34
4	2,24
5	2,08
6	2,10
7	2,04
8	1,98
9	2,05
10	1,91
11	2,13
12	2,04

Time dynamic
(average for all packages means)

# session	**<Q>**
1	2,5
2	2,1
3	2,0
5	1,9

BUBBLE-dosimeter results

SPND A28 and A27 dose rate for 3 sessions (2010) in detector configuration shown on figure above.

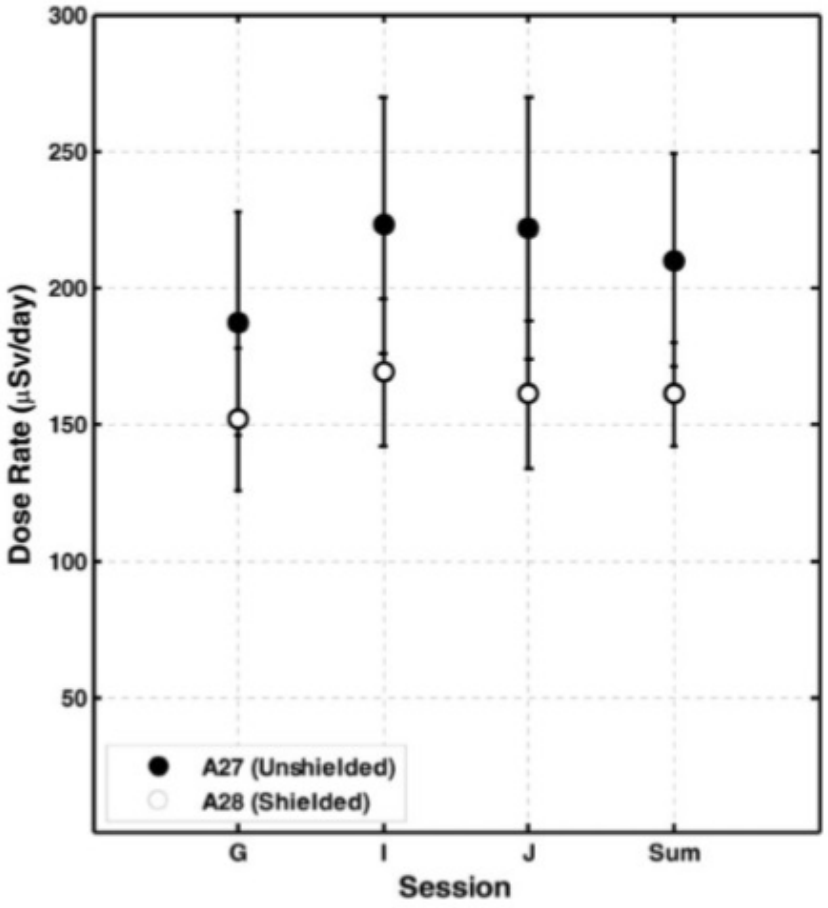
A28 = 161±19 µSv/day

A27 =210±39 µSv/day

$H_{unshielded}/H_{shielded} = 1,3 \pm 0,3$

or $H_{shielded}/H_{unshielded} = 77 \pm 17\ \%$

This result is very similar to the value (72 ± 17 %) measured during ISS-21 using a water shielding in JEM



Data taken from:
M.B. Smith et al. Bubble-detector measurement in the Russian segment of the International Space Station during 2009–12. Radiation Protection Dosimetry (2014), pp. 1–13

Conclusions

- The special facility for additional shielding of the crew cabin and detector arragement have been used from 2010 onboard ISS for more 6 years.
- The unshielded- shielded absorbed dose ratio can vary from 1.13 to 1.91 (or from 12% to 48%) and depend on shielding conditions.
- Quality factor was measured. The data shows that quality factor varies from 1,78 (pack # 9 located on protective curtain surface, 5 session) up to 3.5 (pack #4 located on the wall, 1 session).
- Protective curtain experiment was simulated by different calculating methods
- IBMP TLD data and PNTD and TLD data from NPI and NIRS was presented. Some improvements for last sessions are needed.
- New design is developed to use polyethylene bricks instead water-containing hygenic materials.

Publications.

Sato, T., Niita, K., Shurshakov, V.A., Yarmanova, E.N., Nikolaev, I.V., Iwase, H., Sihver, L., Mankusi, D., Endo, A., Matsuda, N., Iwamoto, Y., Nakashima, H., Sakamoto, Y., Yasuda, H., Takada, M., Nakamura, T., 2011. Evaluation of dose rate reduction in a spacecraft compartment due to additional water shield. Cosmic Res. 49, 319–324.

P. Szanto et al. Onboard cross-calibration of the Pille-ISS Detector System and measurement of radiation shielding effect of the water filled protective curtain in the ISS crew cabin. Radiation Measurements 82 (2015) 59-63

Ploc O., Sihver L., Kartashov D., Tolochek R., Shurshakov V..”PHITS simulations of the Protective curtain experiment onboard the Service module of ISS: Comparison with absorbed doses measured with TLDs”. Advances in Space Research 52, 2013. c. 1911–1918.

Д.А. Карташов, Р.В. Толочек, В.А. Шуршаков, Е.Н. Ярманова. Расчет радиационных нагрузок в отсеке космической станции при использовании дополнительной защиты. Авиакосмическая и экологическая медицина, 2013, т. 47, No 6, стр. 61-66.

M.B. Smith et al. BUBBLE-DETECTOR MEASUREMENTS IN THE RUSSIAN SEGMENT OF THE INTERNATIONAL SPACE STATION DURING 2009–12. Radiation Protection Dosimetry (2014), pp. 1–13


Thank you for your attention!