RADIATION PROTECTION PROPERTIES OF ADDITIONAL SHIELDING CONTAINING HYDROGENE MATERIALS INSTALLED IN CREW CABIN OF RUSSIAN SEGMENT OF ISS

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TSURUGA, JAPAN

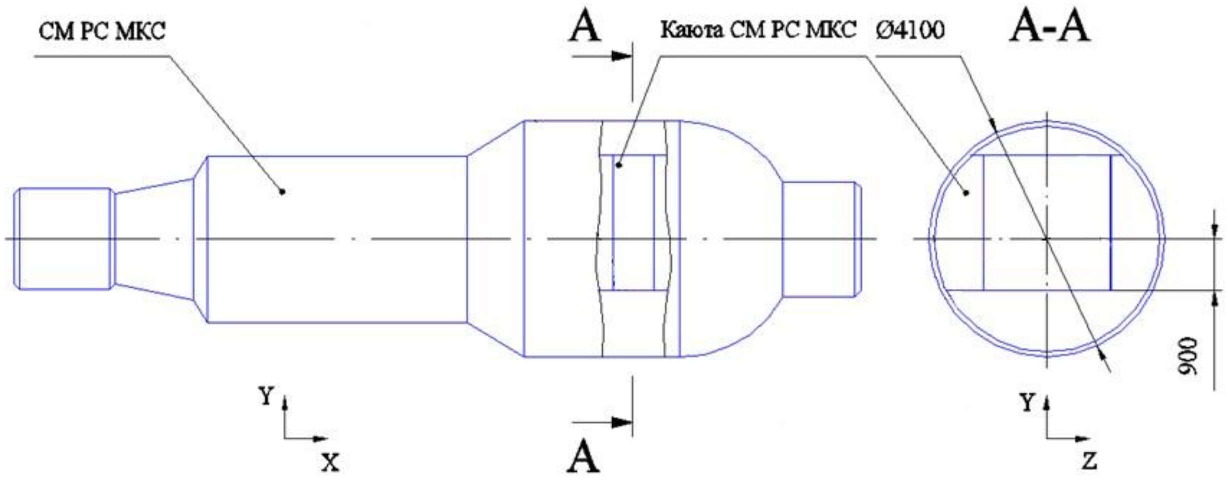
WRMISS 2018

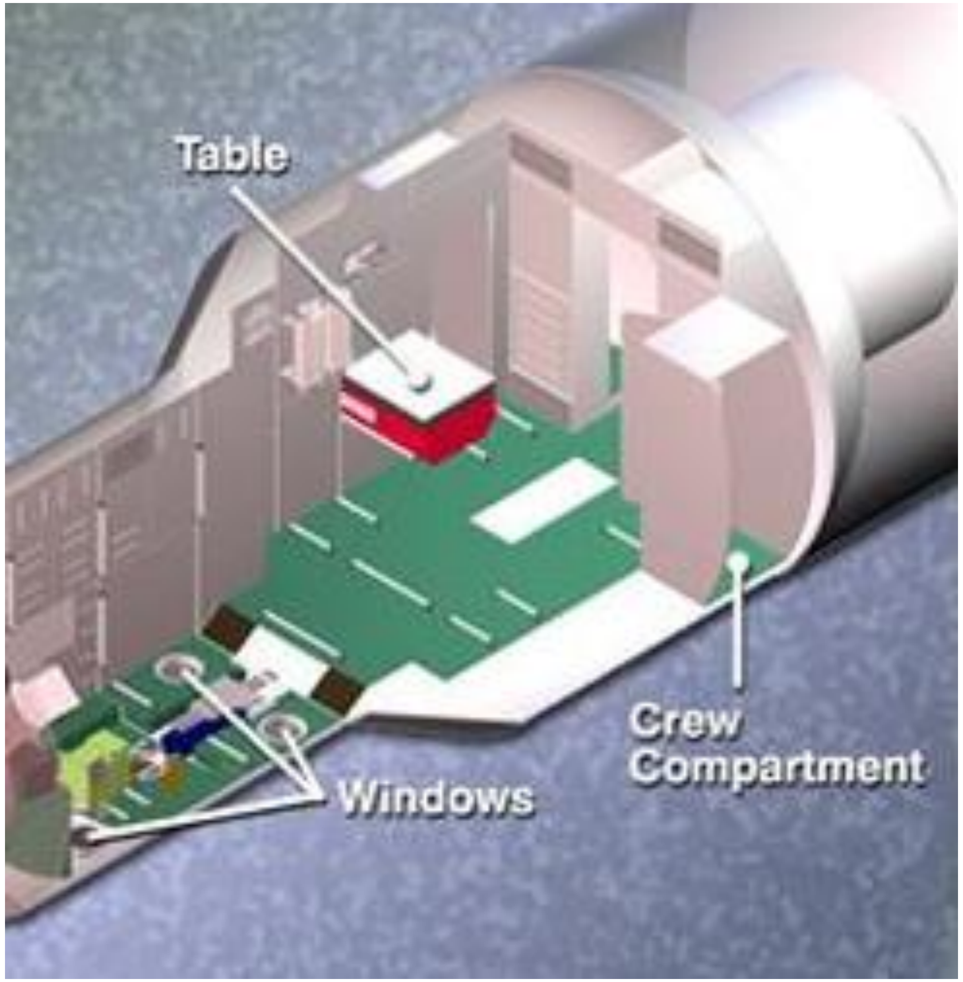
Participants of the current project

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

Introduction: Crew cabin shielding characteristic

Scheme of Service Module of Russian Segment of ISS





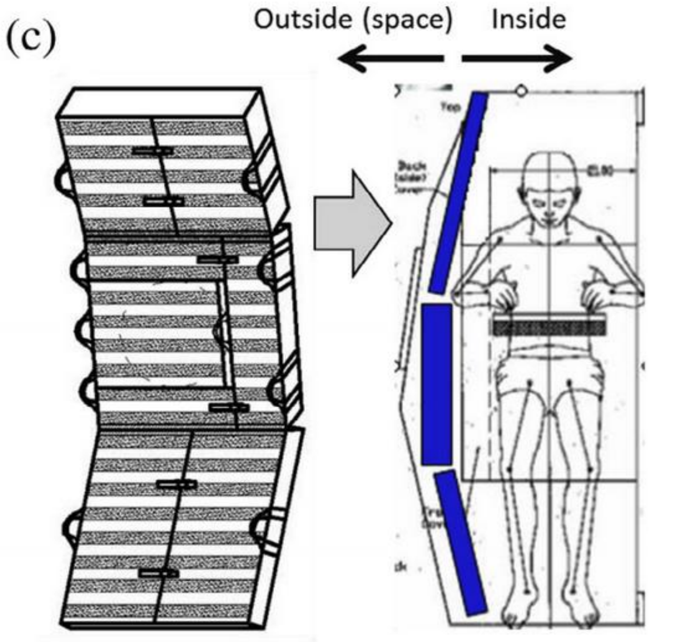
Protective curtain thickness is estimated to be **6.3** g/cm^2
Crew cabin outer wall thickness is estimated as ~ **1.5** g/cm^2
(2 Al layers with 2 mm thickness (0.4 cm * 2.7 g/cm^3 = 1.08 g/cm^2)
+ also an additional shielding of the anti-meteorite protection (outside) and the cabin interior cover (inside))


CREW CABINS IN ZVEZDA MODULE
ISS FOOD WARMER
photo by NASA

Protective curtain design

Hygenic wipes and towels

	Mass, kg
Upper part	14,600
Middle part	25,600
Bottom part	24,000
All	64,200



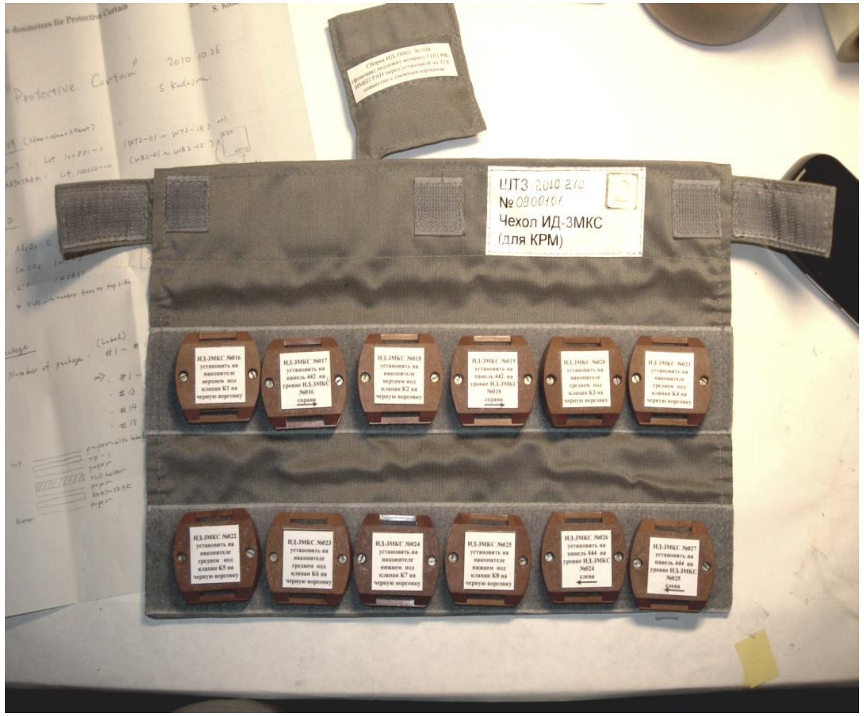
Estimated thickness: 6.3 - 6.5 g/cm2

Tissue bag containing 4 layers of hygienic wipes and towels

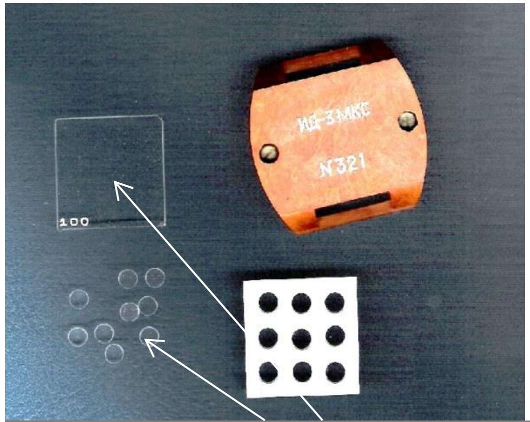
Photo of protective curtain made during pre-flight preparations (Baikonur, Kazakhstan, 2010)

Measuring instruments

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



Detector kit – flight model



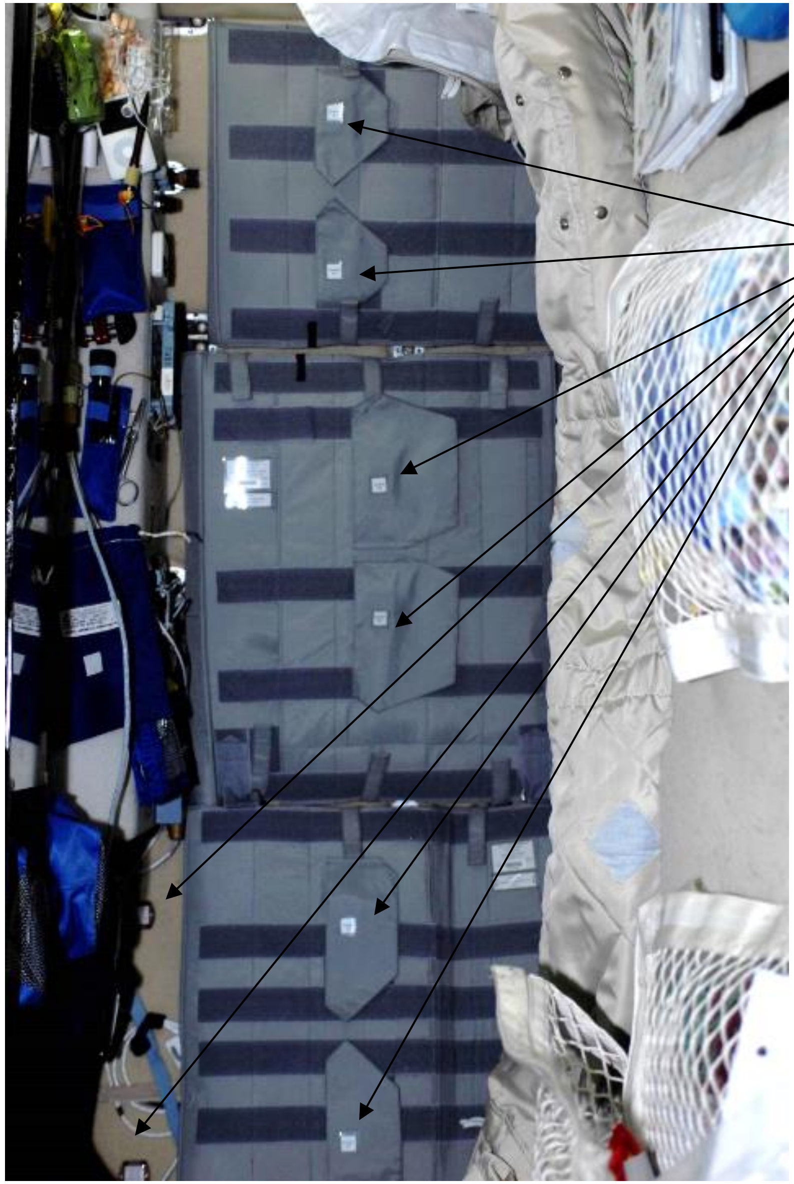
Detectors: TLD, SSNTD **Participants: NPI, QST/NIRS, IBMP**

12 passive detectors packages

\+

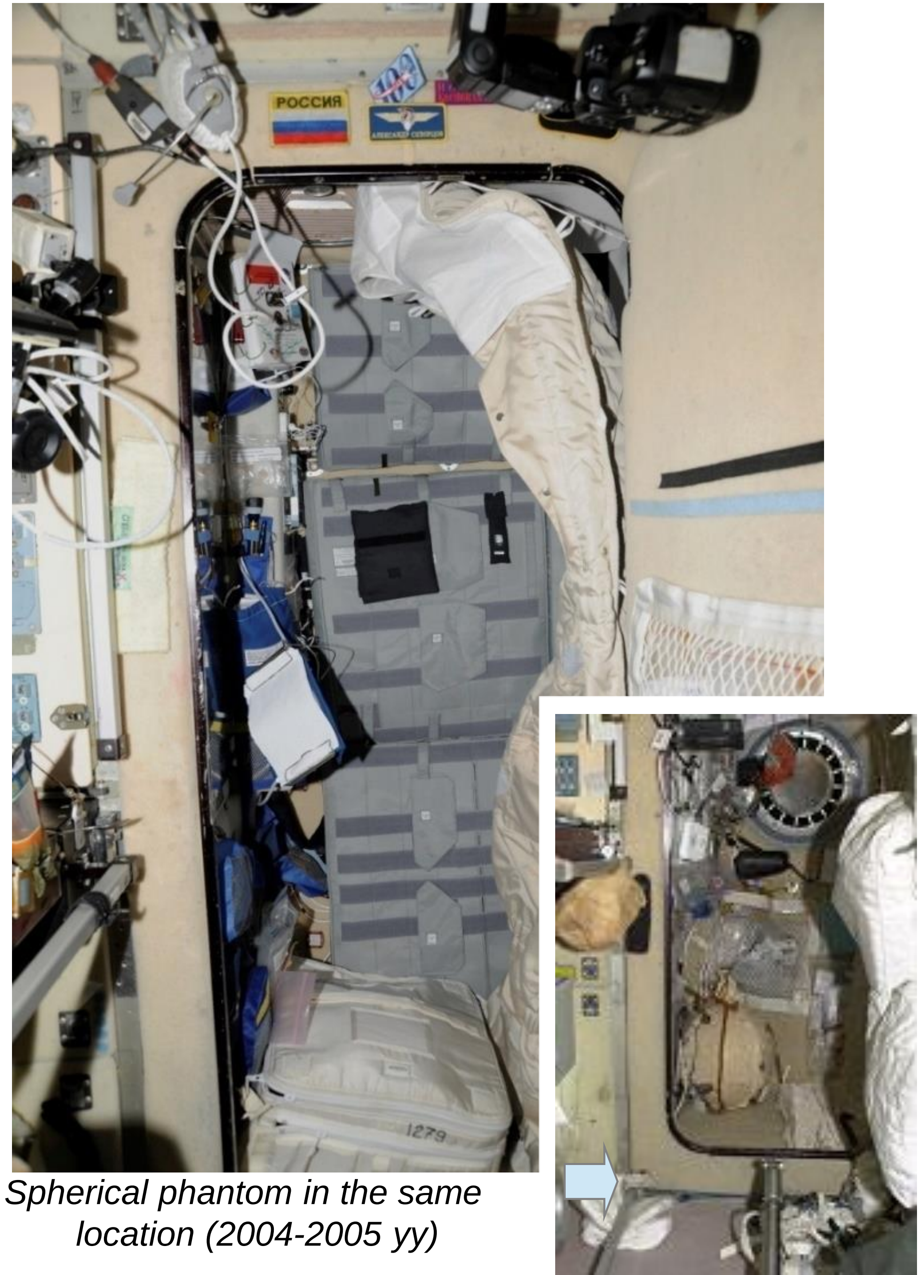
1 background control

PHOTOS MADE ONBOARD ISS



Passive detectors packages

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



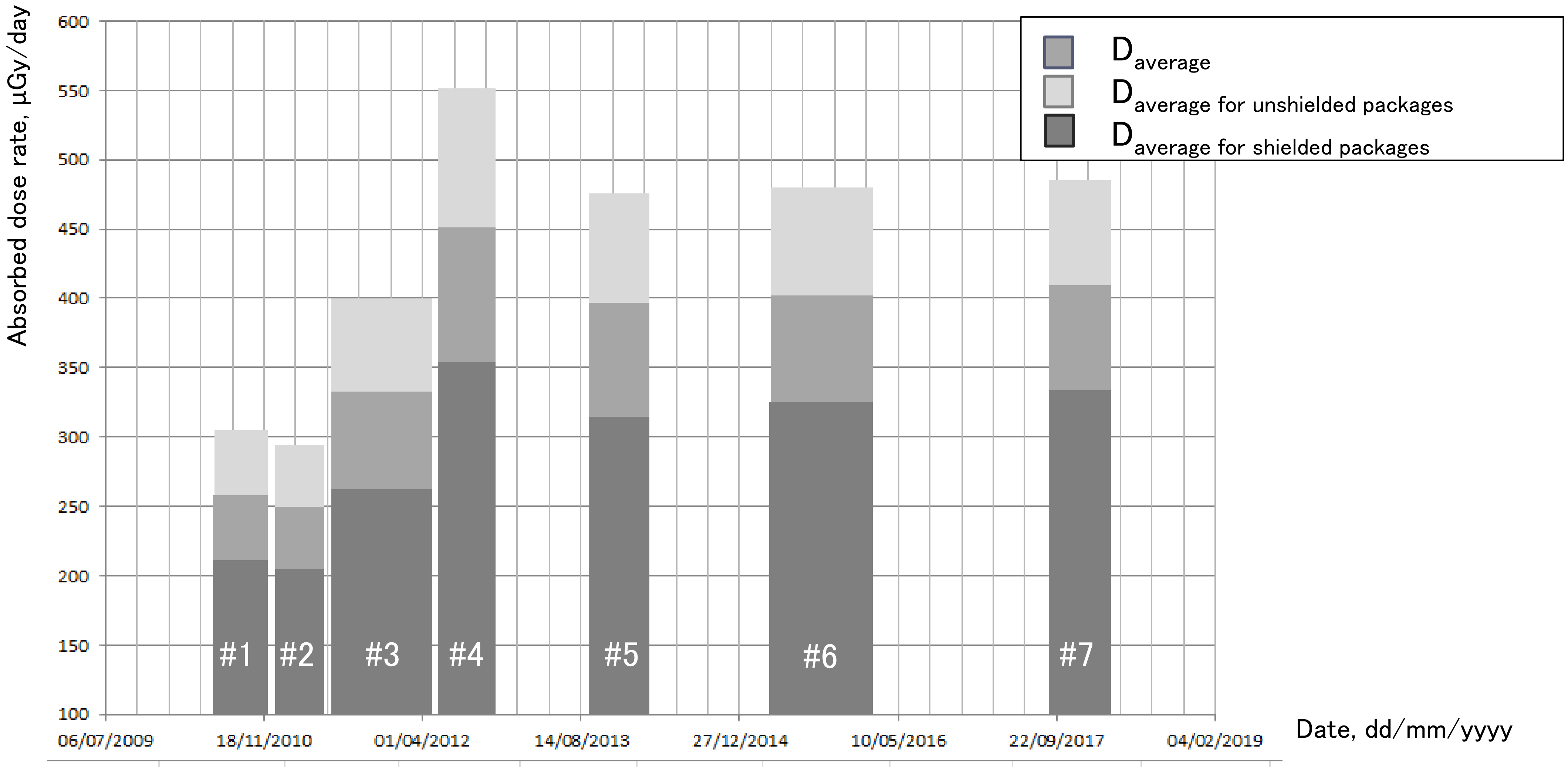
Spherical phantom in the same location (2004-2005 yy)

Flight Data

PNTD and TLD detector packages were exposed during 7 sessions:

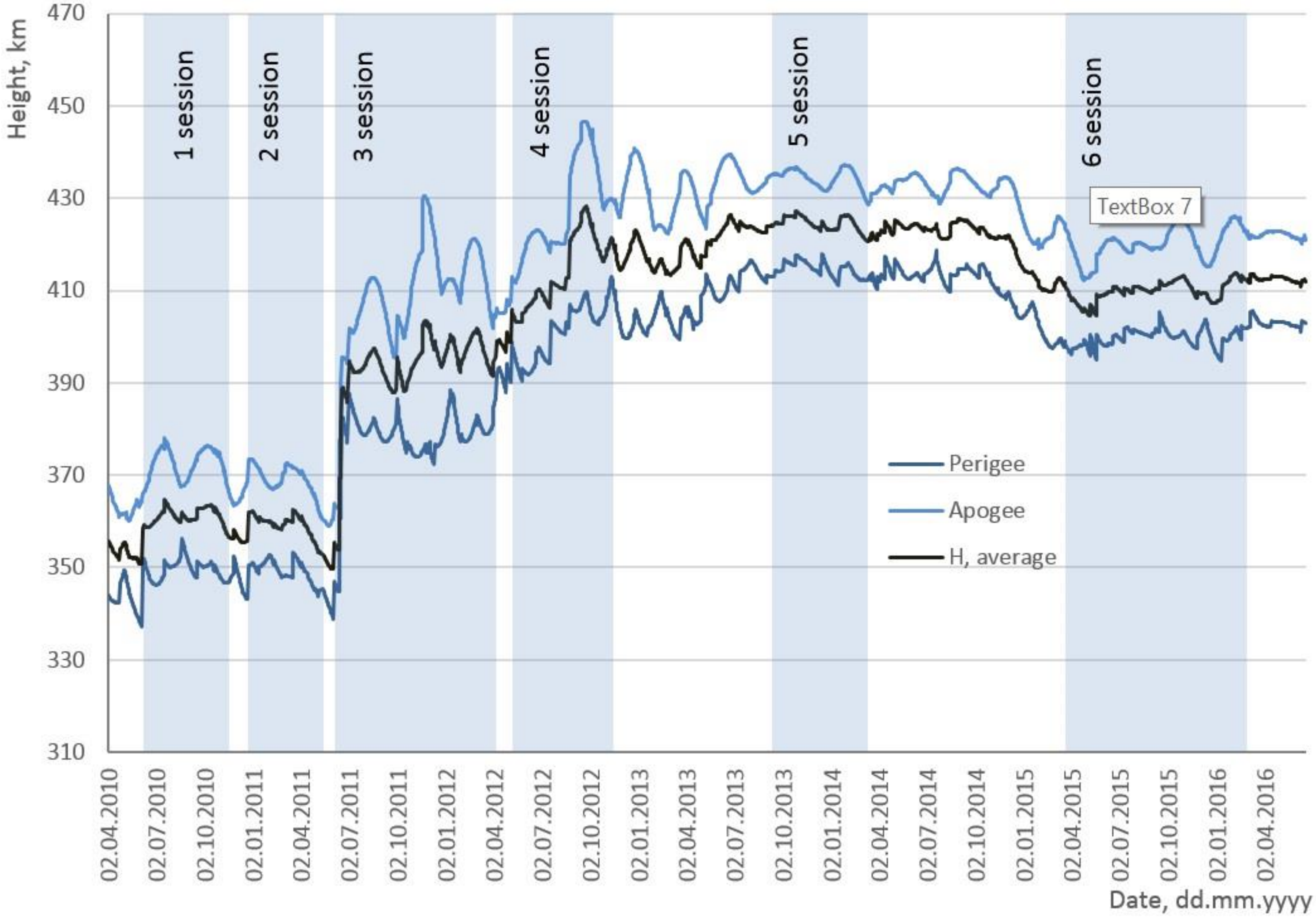
session#	Start	End	Duration, days		ISS mission#
1	16.06.2010	26.11.2010	163	SOYUZ TMA-19	24/25
2	15.12.2010	24.05.2011	160	SOYUZ TMA-20	25/26
3	21.06.2011	27.04.2012	311	Progress M-11M/ SOYUZ TMA-22	27/30
4	15.05.2012	19.11.2012	188	SOYUZ TMA-04 M/ SOYUZ TMA-05 M	31/32
5	26.09.2013	11.03.2014	166	SOYUZ TMA-10M	37/38
6	27.03.2015	18.02.2016	328	SOYUZ TMA-16M/ SOYUZ TMA-18M	43/46
7	13.09.2017	28.02.2018	168	SOYUZ MS-06	53/54

Results: Absorbed dose rate time dynamic (TLD, IBMP)

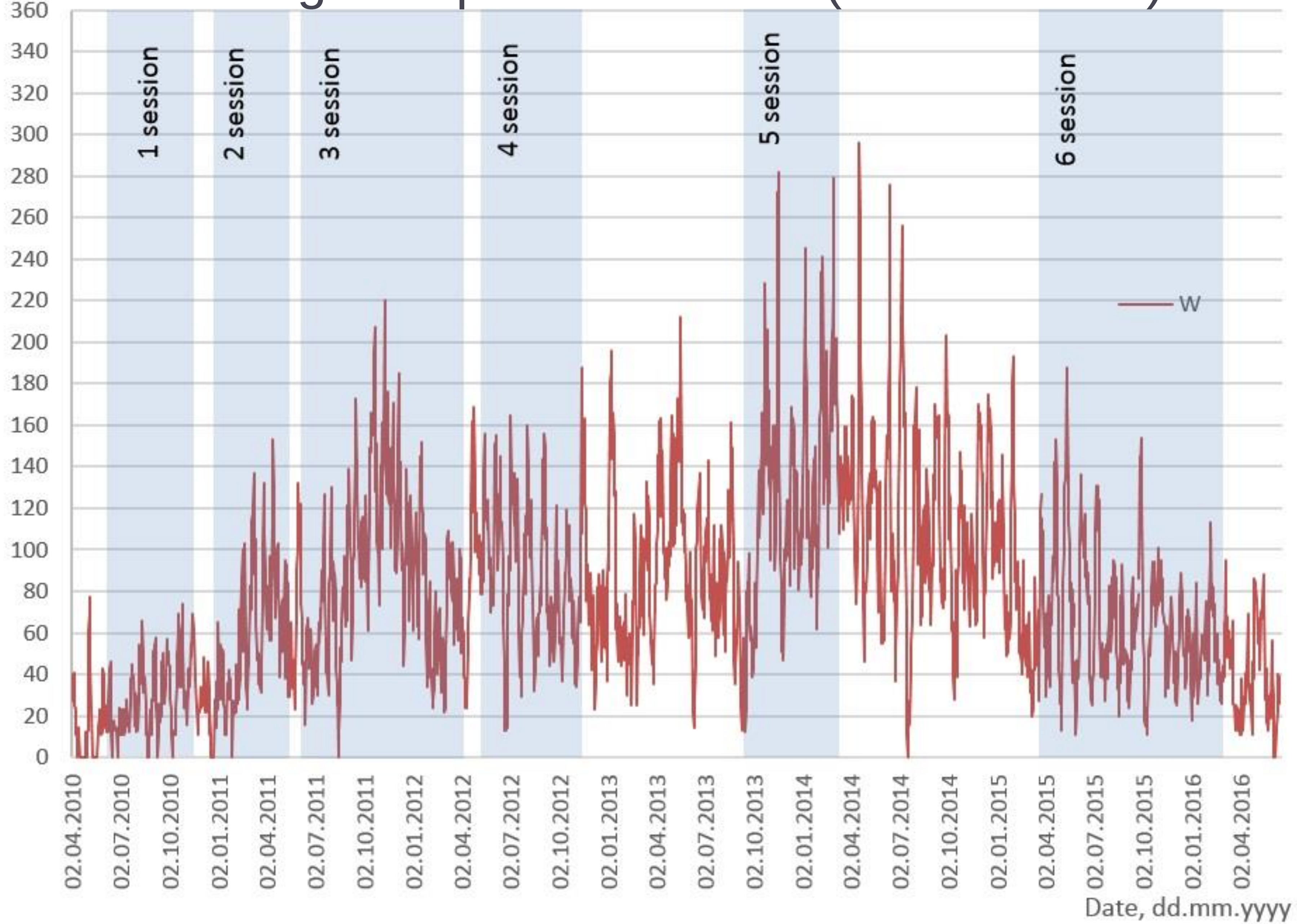


D (all): 250 – 396 µGy/day, Dmax/Dmin = 1,58
D (sh): 205 – 315 µGy/day, Dmax/Dmin = 1,53
D (un): 294 – 477 µGy/day, Dmax/Dmin = 1,6

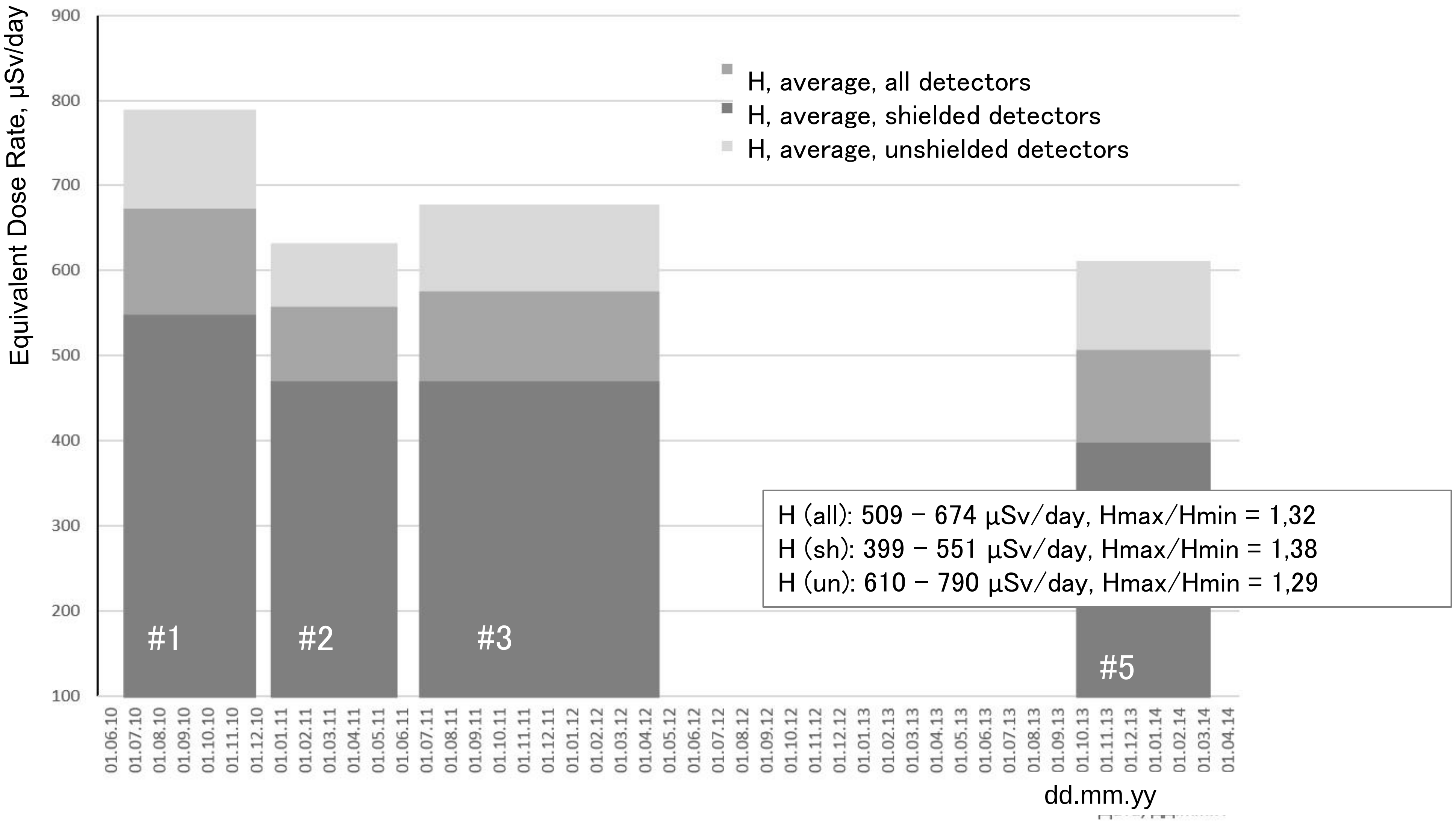
ISS parameters: flight altitude



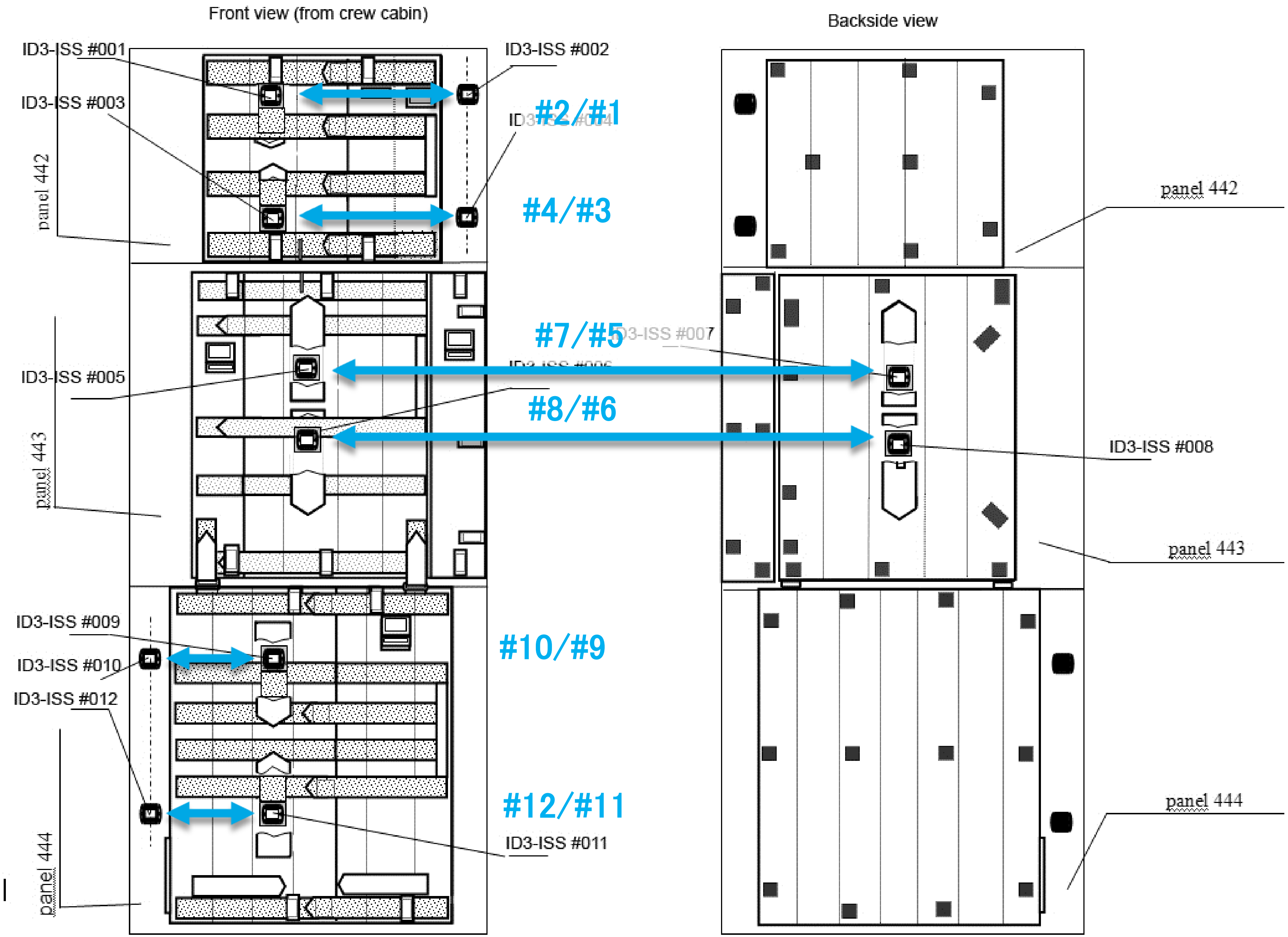
Geomagnetic parameters: W (Wolf number)



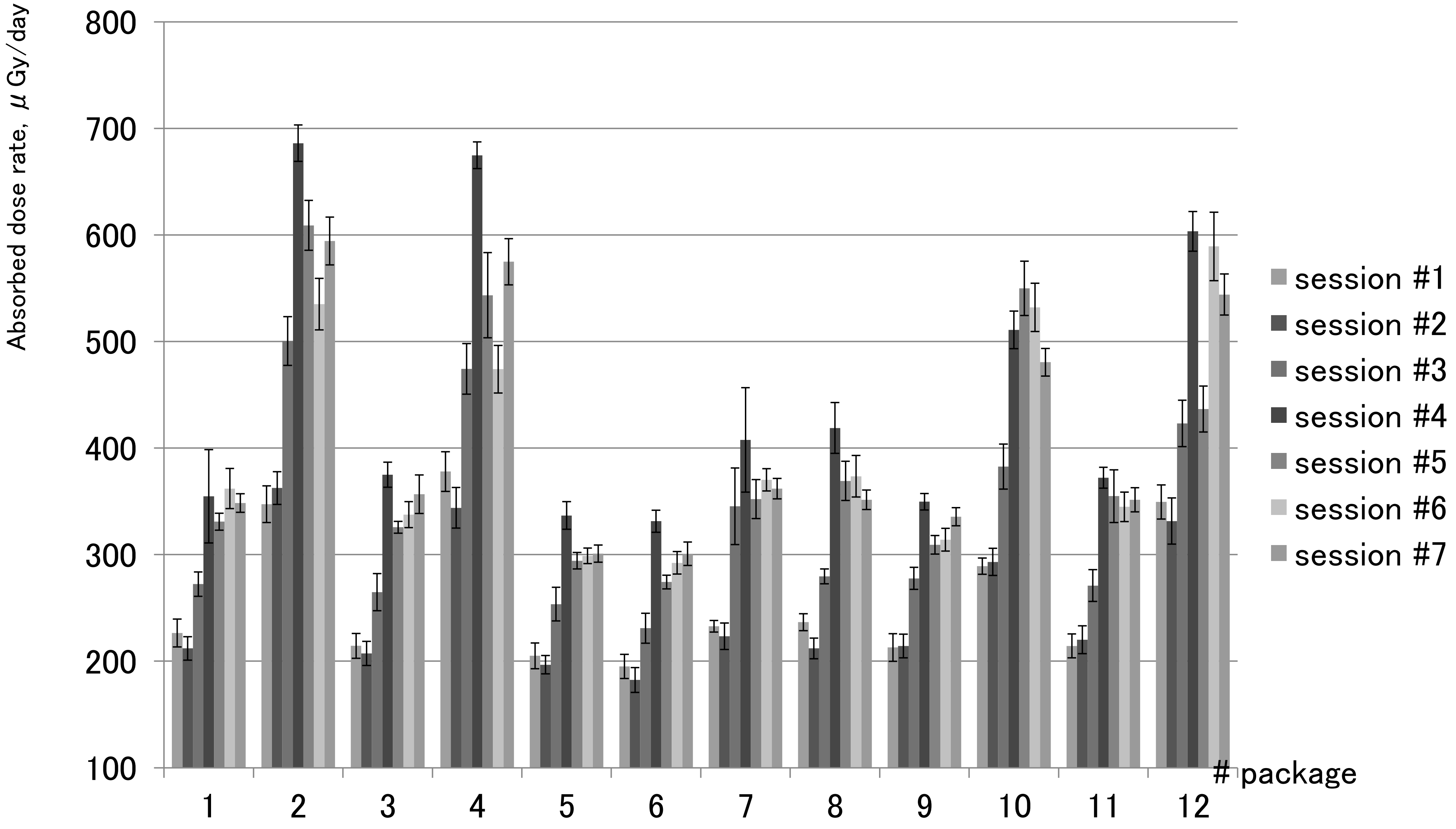
Results: Equivalent dose measurements (TLD+ SSNTD, NIRS)



Passive detector packages comparison

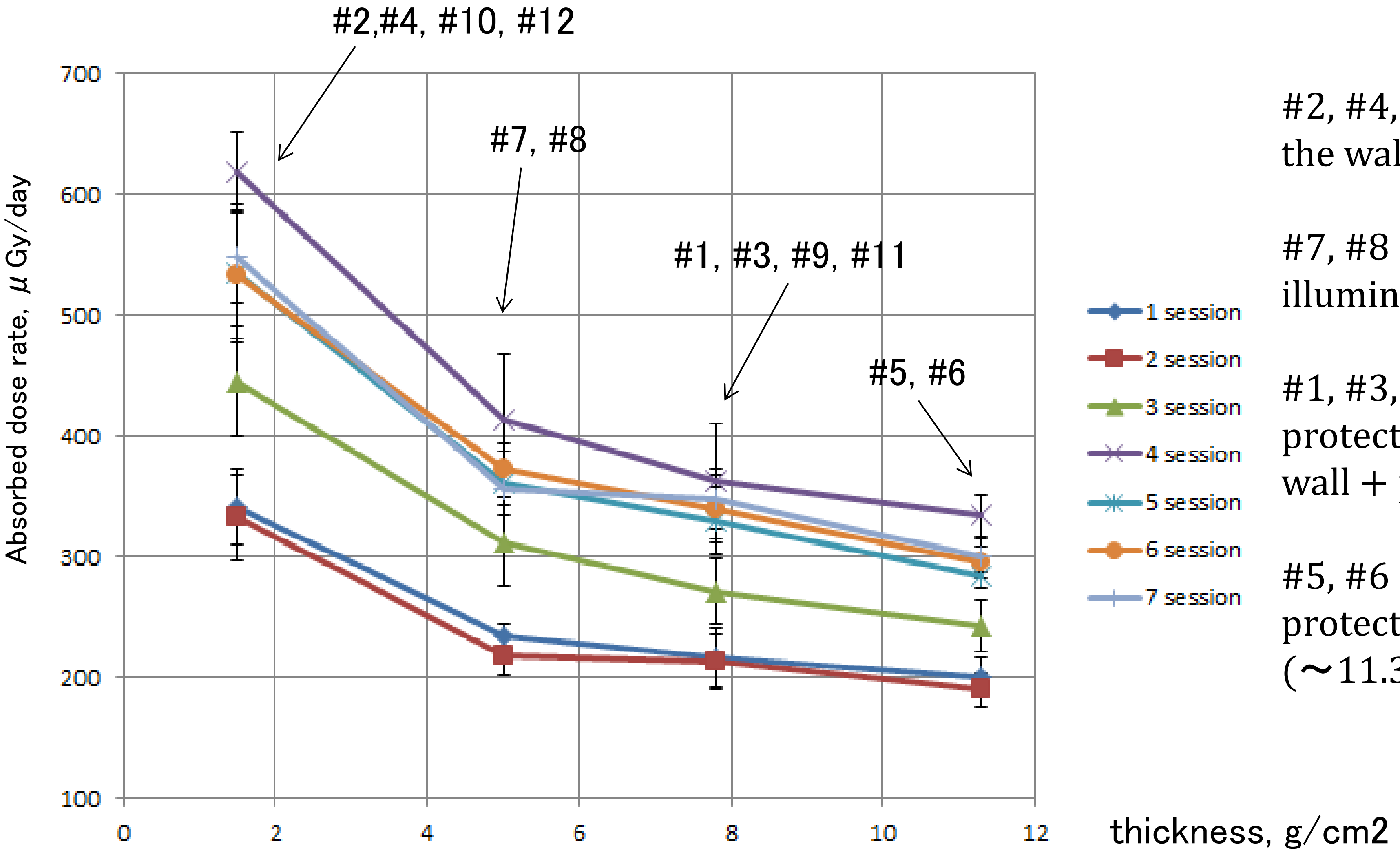


Dose Spatial Distribution (IBMP)



Difference in resilts by NPI, QST NIRS, IBMP groups: 5% (1 session), 8% (2 session), 9% (3 session)

Dose vs thickness of shielding material



#2, #4, #10, #12 – packages installed on the wall (∼1.5 g/g/cm^2)

#7, #8 – packages installed on the illuminator (glass∼5 g/g/cm^2)

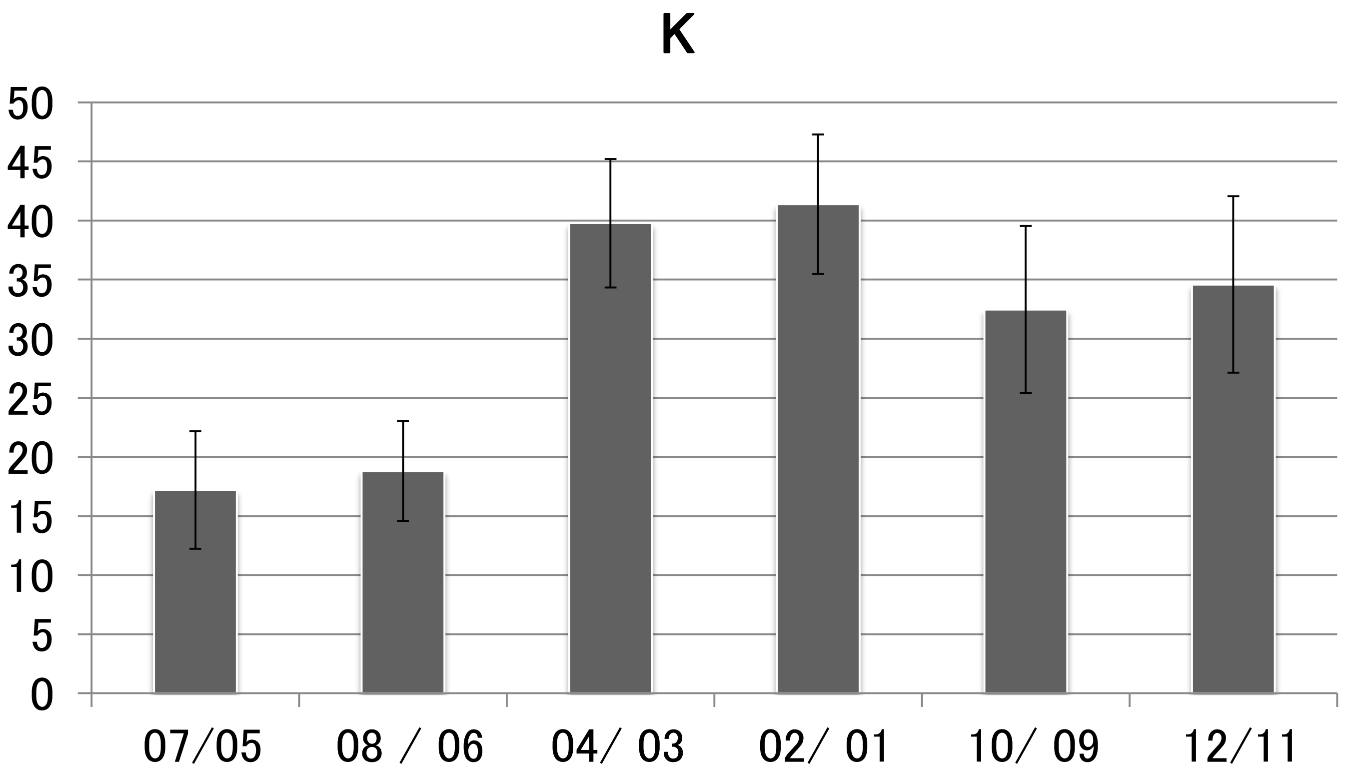
#1, #3, #9, #11 – packages installed on protective curtain (∼7.8 g/g/cm^2, wall + protective curtain)

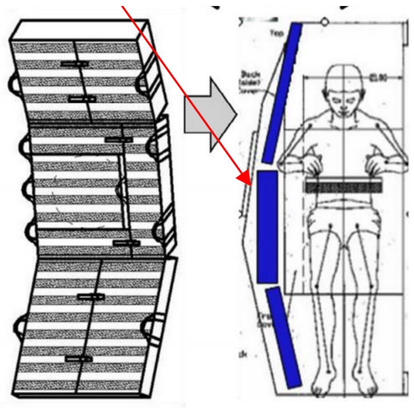
#5, #6 – packages installed on the protective curtain at middle section (∼11.3 g/cm^2, glass + protective curtain)

Results: Efficiency (D, IBMP)

# pack.	Ratio Dnshielded/ Dshielded, average for all time	K, %
2/1	1,72 ± 0,17	41± 6
4/3	1,67 ± 0,13	40± 5
7/5	1,21 ± 0,08	17± 5
8/6	1,23 ± 0,07	19± 4
10/9	1,50 ± 0,17	32± 7
12/11	1,54 ± 0,13	35± 7

$K = (1 - D_{shielded}/D_{unshielded})*100\%$





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

Results: Quality Factor

Spatial Distribution
(averaged 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

Q for different sessions may vary up to 30%

Time dynamic
(averaged for all packages means)

# session	⟨Q⟩
1	2,5
2	2,1
3	2,0
5	1,9

Q spatial distribution for a session may vary up to 60%

Preliminary Calculations for High Density Polyethylene

Calculations are done via shielding function calculation. Method is described in following articles:

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

Calculation of radiation loads on the anthropomorphic phantom onboard the space station in the case of additional shielding. D.A. Kartashov, Vyacheslav Shurshakov. Aviakosmicheskaia i ekologicheskaia meditsina, Mar 2014.

Decreasing radiation level may be as decreasing dE/dx:

$(dE/dx)_{HDP} > (dE/dx)_{water} > (dE/dx)_{Al}$

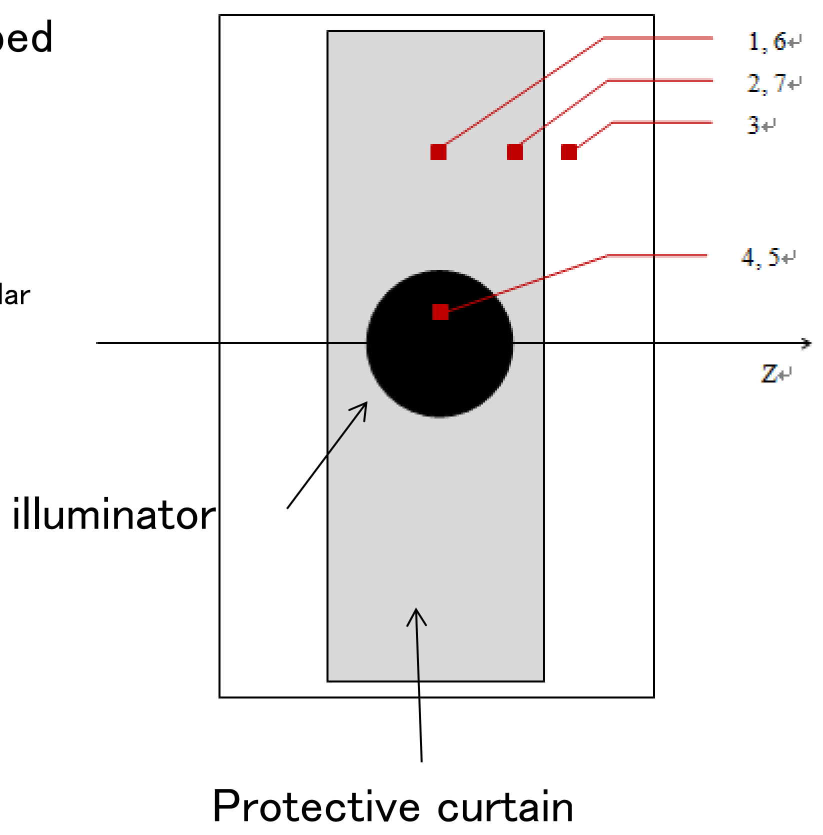
The sizes of protective curtain are the same as for experiment and previous calculations.Thicknes of protective curtain is 9 g/cm^2

***K* = 48 – 60 %** for packages on the wall and on the protective curtain surface (*K* = 17 – 50 % for experimental data)

***K* = 22 – 38** % for packages on the illuminator and the protective surface (*K* = 5 – 23 % for experimental data)

$K = (1 - D_{shielded}/D_{unshielded})*100\%$

Points of calculation



Conclusions

- The special facility for additional shielding of the crew cabin and detector arragement have been used from 2010 onboard ISS for more 8 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). Quality factor may vary significant depending on shielding conditions and flight factors like altitude, solar activity, etc.

- Protective curtain mostly effective against protons, increase of altitude increases its efficiency. Increasing sun activity reduces GCR flux, thus decreasing quality factor.

- New calculation for new design using polyethylene bricks instead water-containing hygenic materials are in process.

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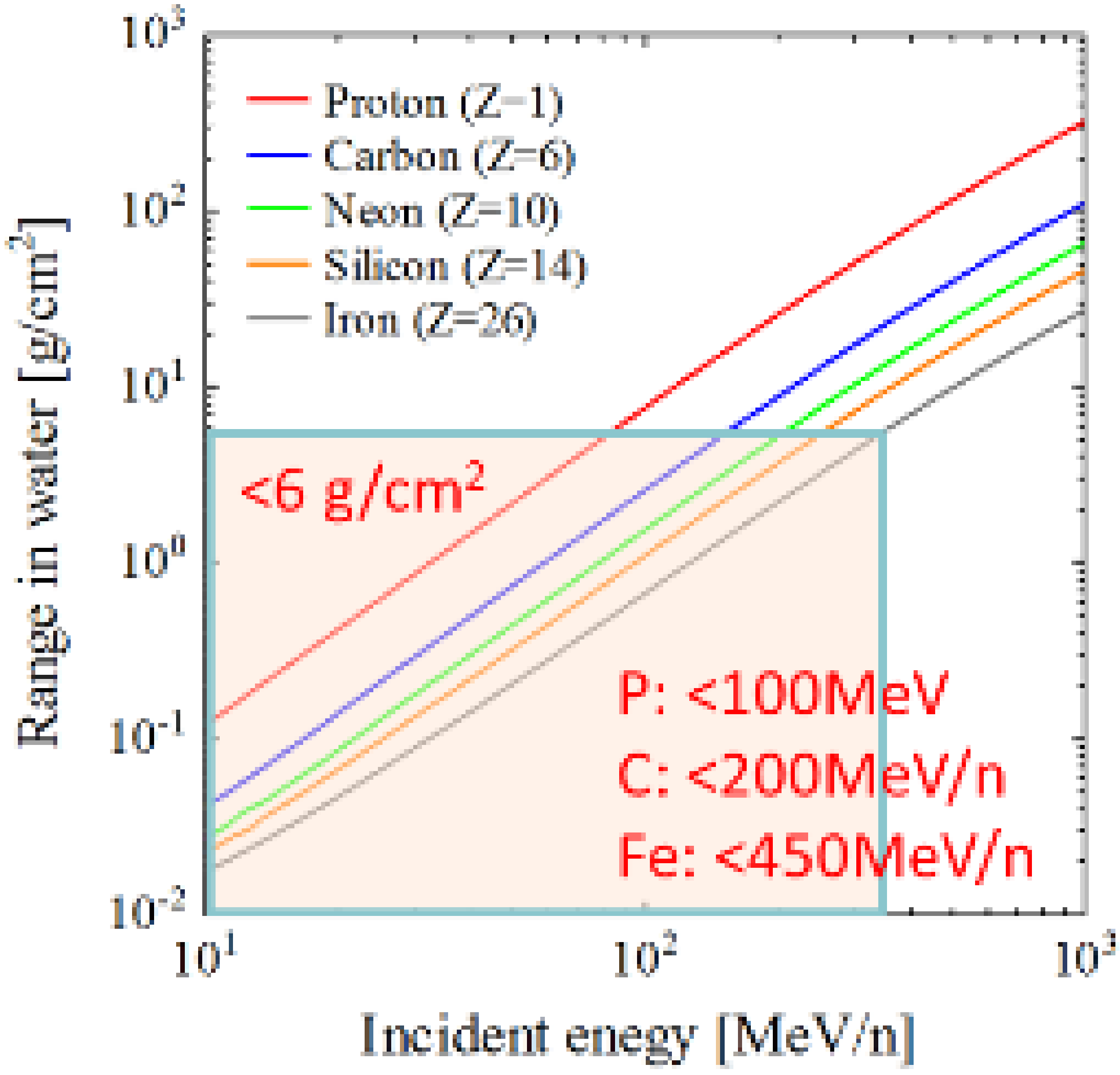
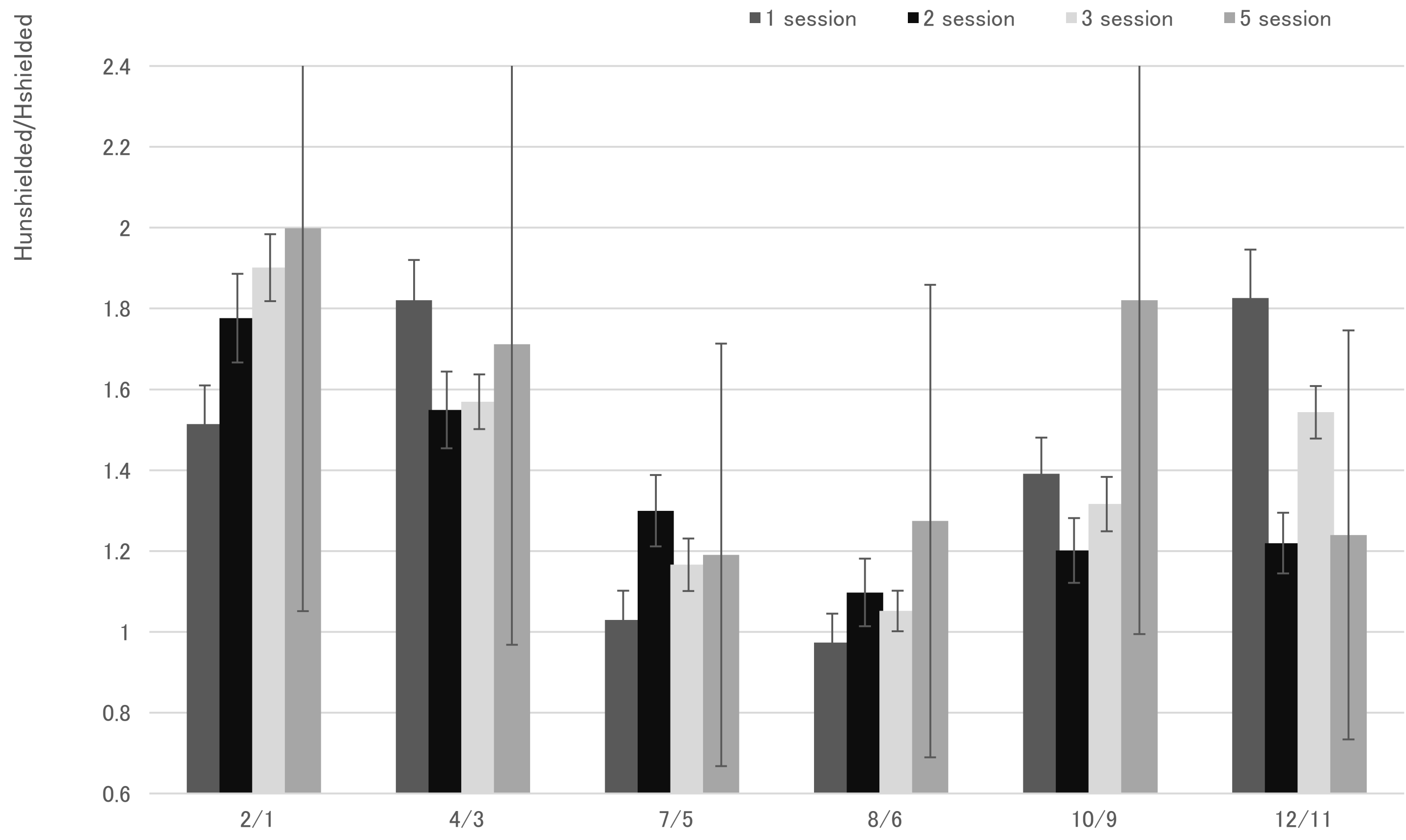
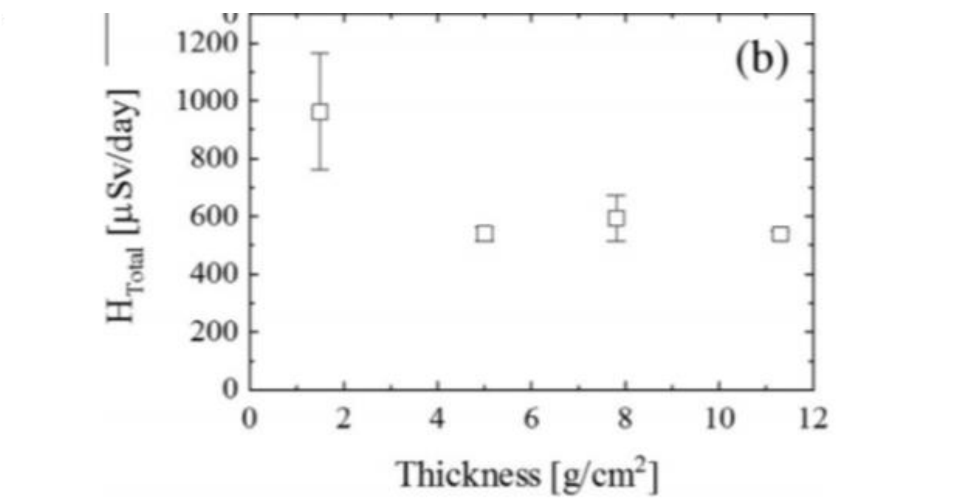
THANK YOU!



Proton (Z=1)
Carbon (Z=6)
Neon (Z=10)
Silicon (Z=14)
Iron (Z=26)
<6 g/cm²
P: <100MeV
C: <200MeV/n
Fe: <450MeV/n
Range in water [g/cm²]
Incident enegy [MeV/n]
10³
10²
10¹
10⁰
10⁻¹
10⁻²

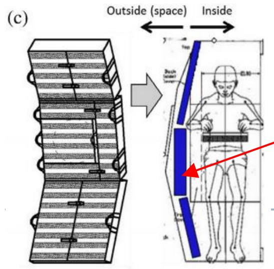
Resilts: Ratio of unshielded and shielded detectors





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

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



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

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


Thank you for your attention!

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