DLR WRMISS 2015

The Results of 5 Sessions of Experimental Study of Local Water Shielding Efficiency to Space Radiation with the Protective Curtain in ISS Crew Cabin

R.V. Tolochek1 *, V.A. Shurshakov1, E.N. Yarmanova1, I.S. Kartsev1, I.V. Nikolaev2, S. Kodaira3, Y. Uchihori3, H. Kitamura3, H. Kawashima, I. Ambrozova4

1State Scientific Center of Russian Federation Institute of Biomedical Problems, Russian Academy of Science, Moscow, Russia
2 Rocket Space Corporation "Energia", Moscow region, Russia
3 National Institute of Radiological Sciences, Chiba, Japan
4 Nuclear Physics Institute, Academy of Sciences of Czech Republic, Prague, Czech republic

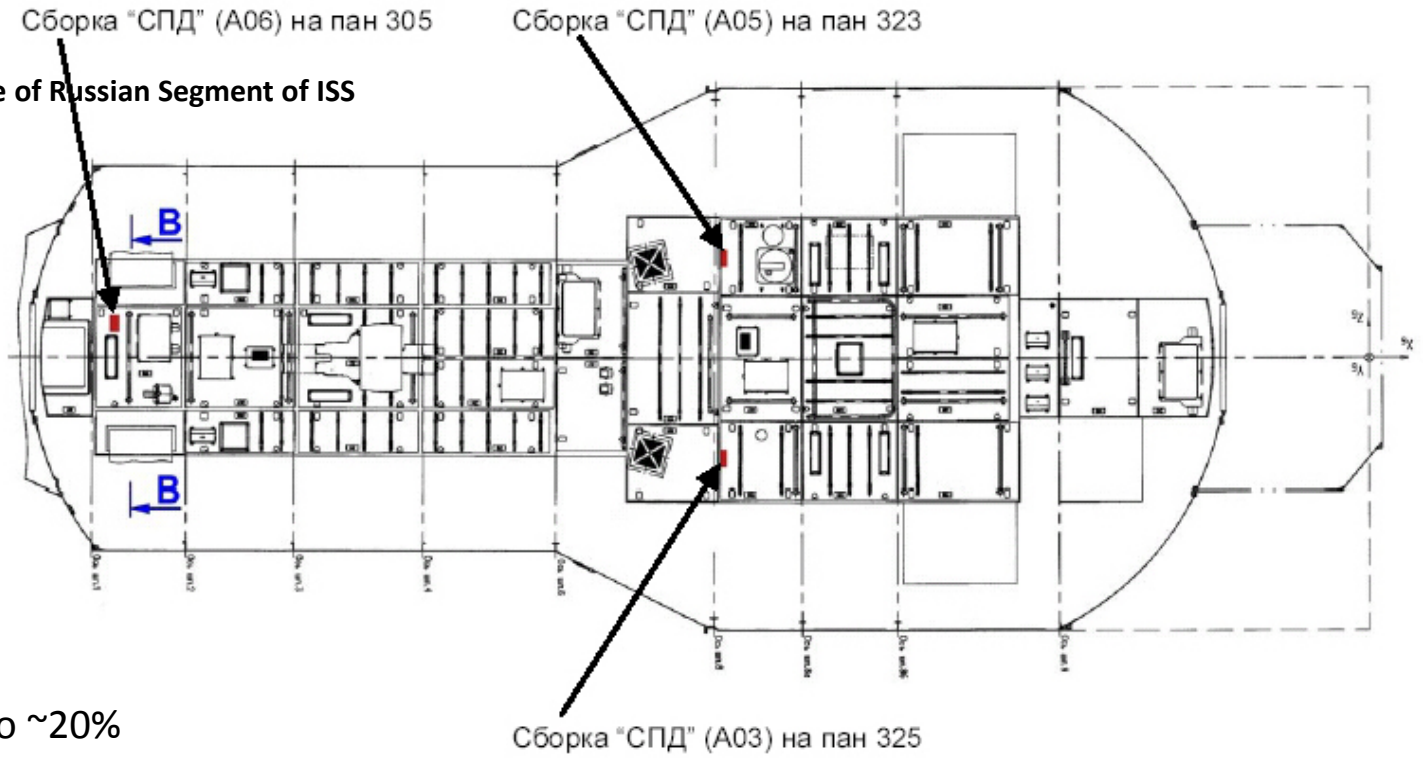
Participants of the current project

- IBMP, Russia (TLD)
- NPI, Czech republic (TLD, SSNTD)
- NIRS, Japan (TLD, SSNTD)
- MTA KFKI AEKI, Hungary (Pille-ISS)
- CCA, Canada (BUBBLE detectors)

In this report PNTD and TLD data is presented

Crew cabin shielding characteristic

Scheme of Service Module of Russian Segment of ISS



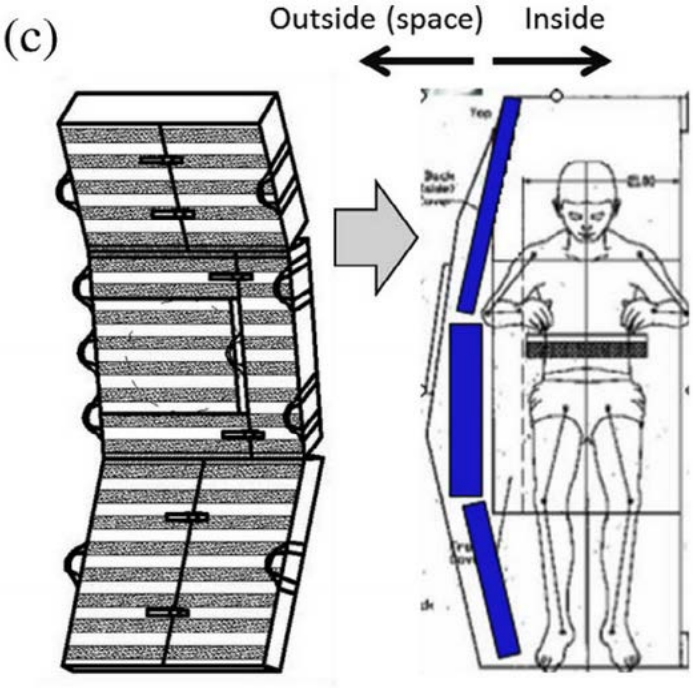
Dose difference is up to ~20%

Protective curtain thickness is estimated to be 6.3 g/cm2 (water)
Crew cabin outer wall thickness is estimated as ~ 1.5 g/cm2 (water)
(2 Al layers with 2 mm thickness (0.4 cm * 2.7 g/cm3 = 1.08 g/cm2)
+ also an additional shielding of the anti-meteorite protection (outside)
and the cabin interior cover (inside))

Protective curtain design

Hygenic wipes and towels

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



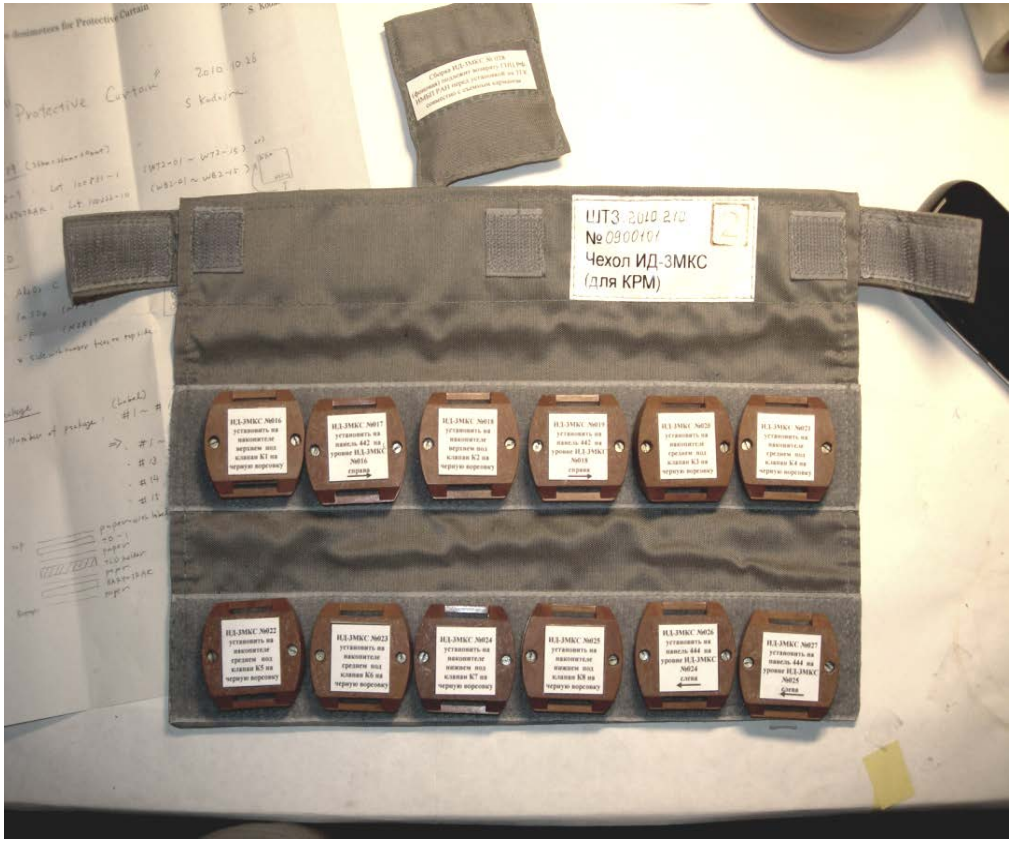
Estimated thickness: 6.3 - 6.5 g/cm2

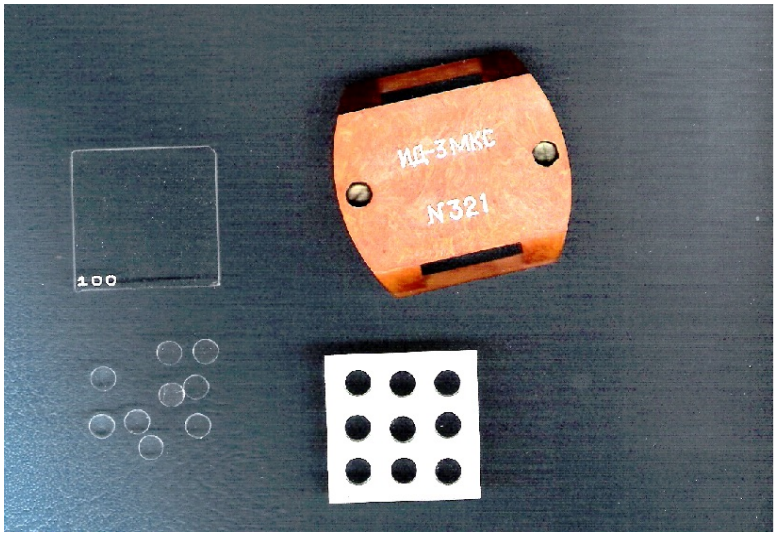
Tissue bag containing 4 layers of hygienic wipes and towels

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

Measuring instruments

To study radiation effect thermoluminescent detectors (TLD) and solid state nuclear track detector (SSNTD) have been used.



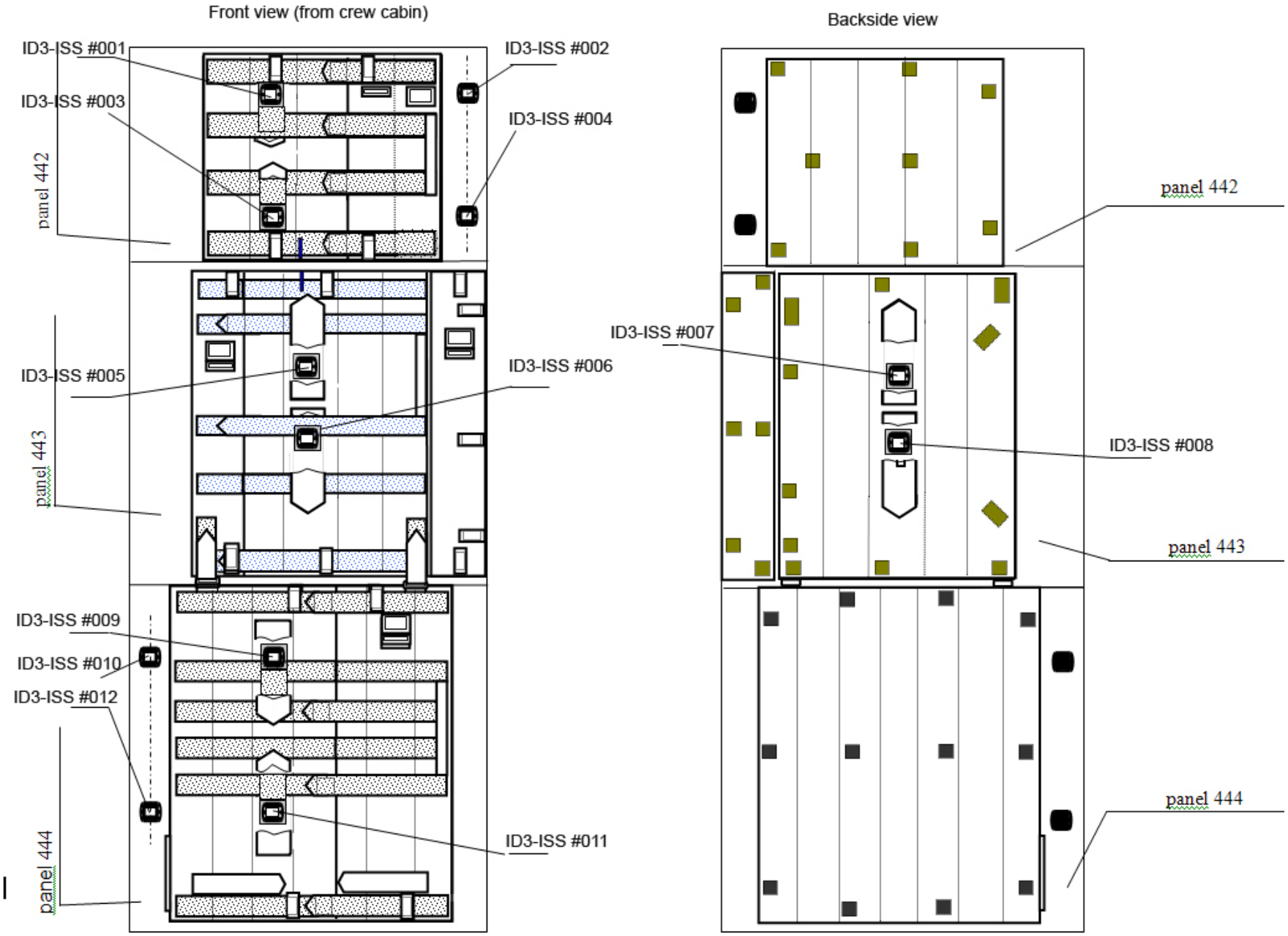


12 passive detectors packages + 1 background control

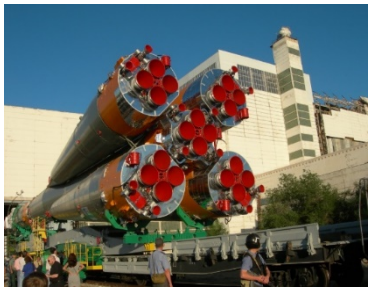
TLD and SSNTD

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

Detector packages arrangement



5 Sessions Flight Data

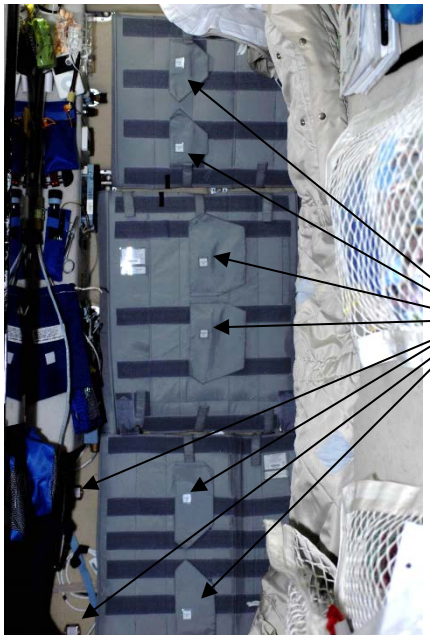


The passive detector packages were exposed in the Service Module starboard crew cabin during 5 sessions:

session#	Start	End	Duration, days	
1	16.06.2010	26.11.2010	163	SOYUZ TMA-19
2	15.12.2010	24.05.2011	160	SOYUZ TMA-20
3	21.06.2011	27.04.2012	311	Progress M - 11 M SOYUZ TMA - 22
4	15.05.2012	19.11.2012	188	SOYUZ TMA - 04 M SOYUZ TMA - 05 M
5	26.09.2013	11.03.2014	166	SOYUZ TMA - 10M

PHOTOS MADE ONBOARD ISS

Pille – ISS dosimeters

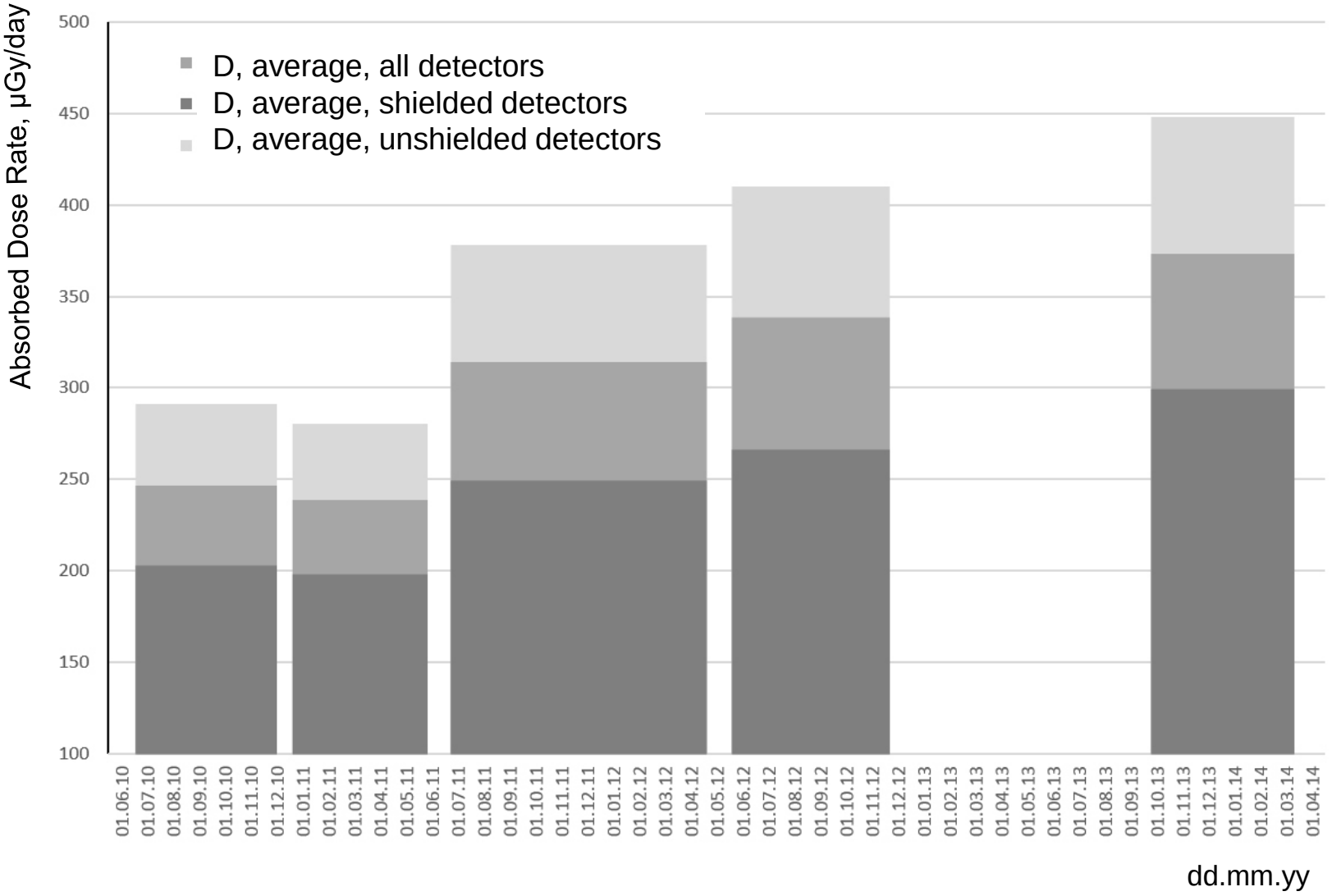


Passive detectors packages

BUBBLE dosimeters

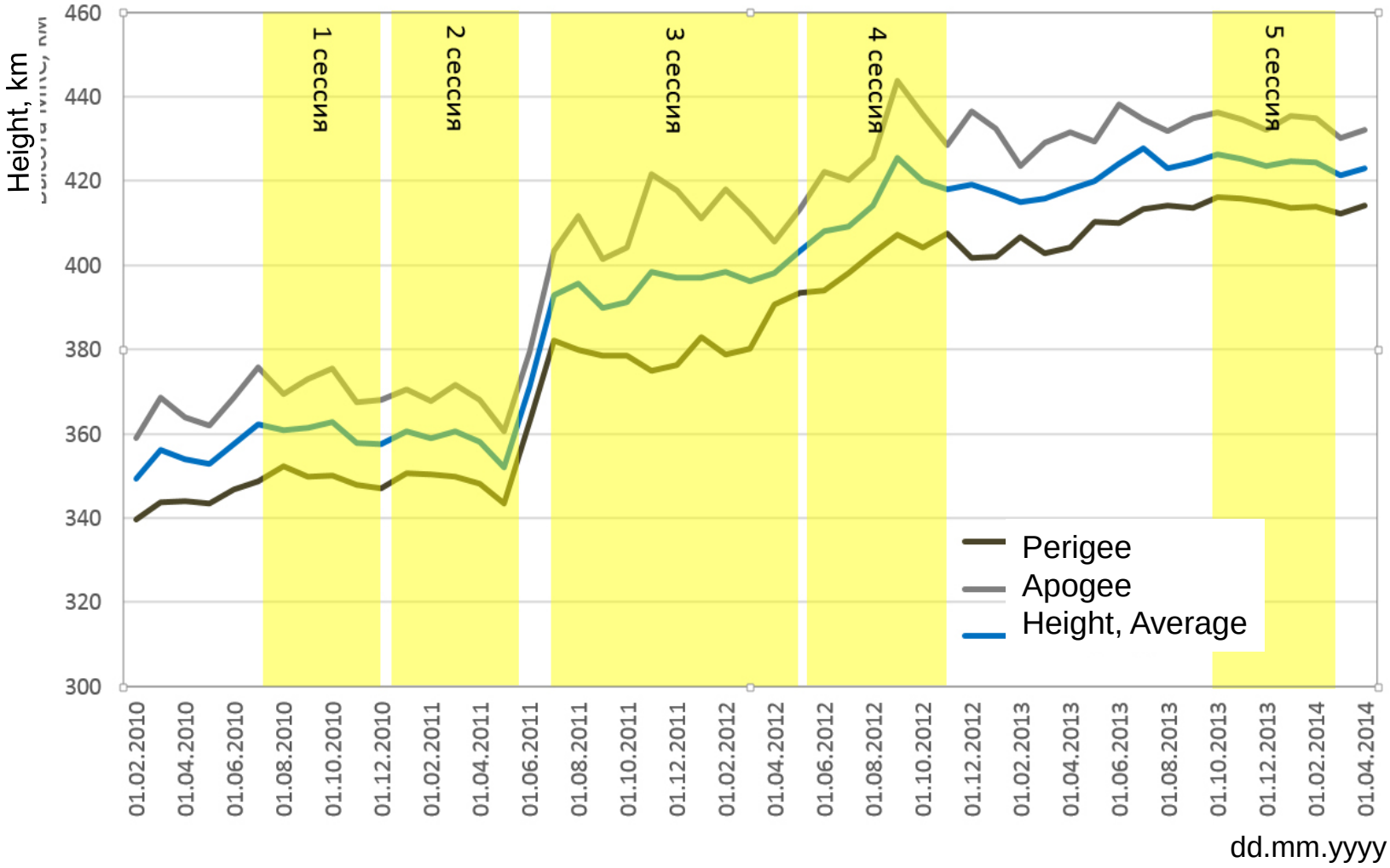
Overall view of protective curtain in starboard crew cabin, SM ISS

Resilts: Absorbed dose measurements (TLD, IBMP)

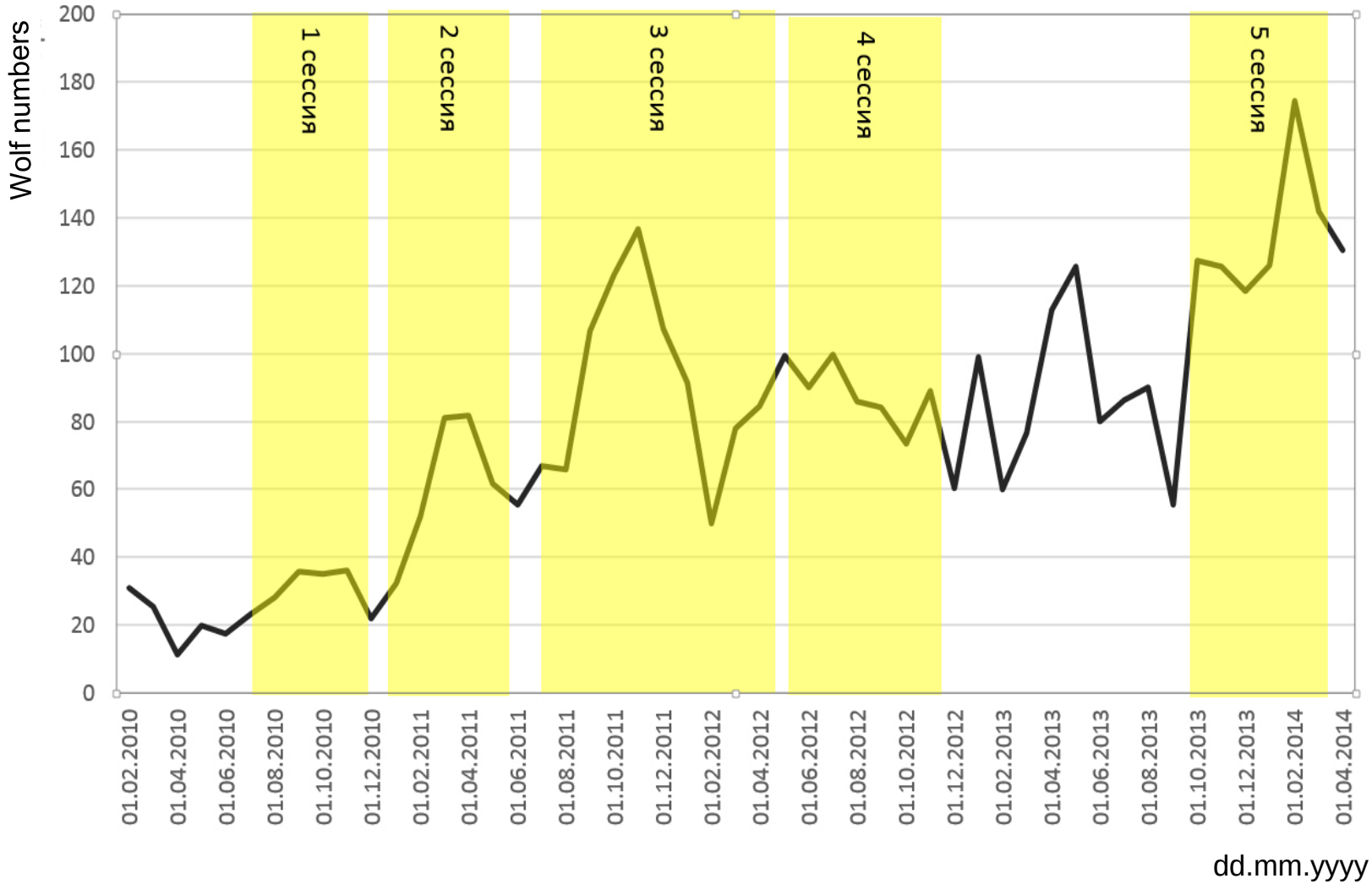


ISS flight data

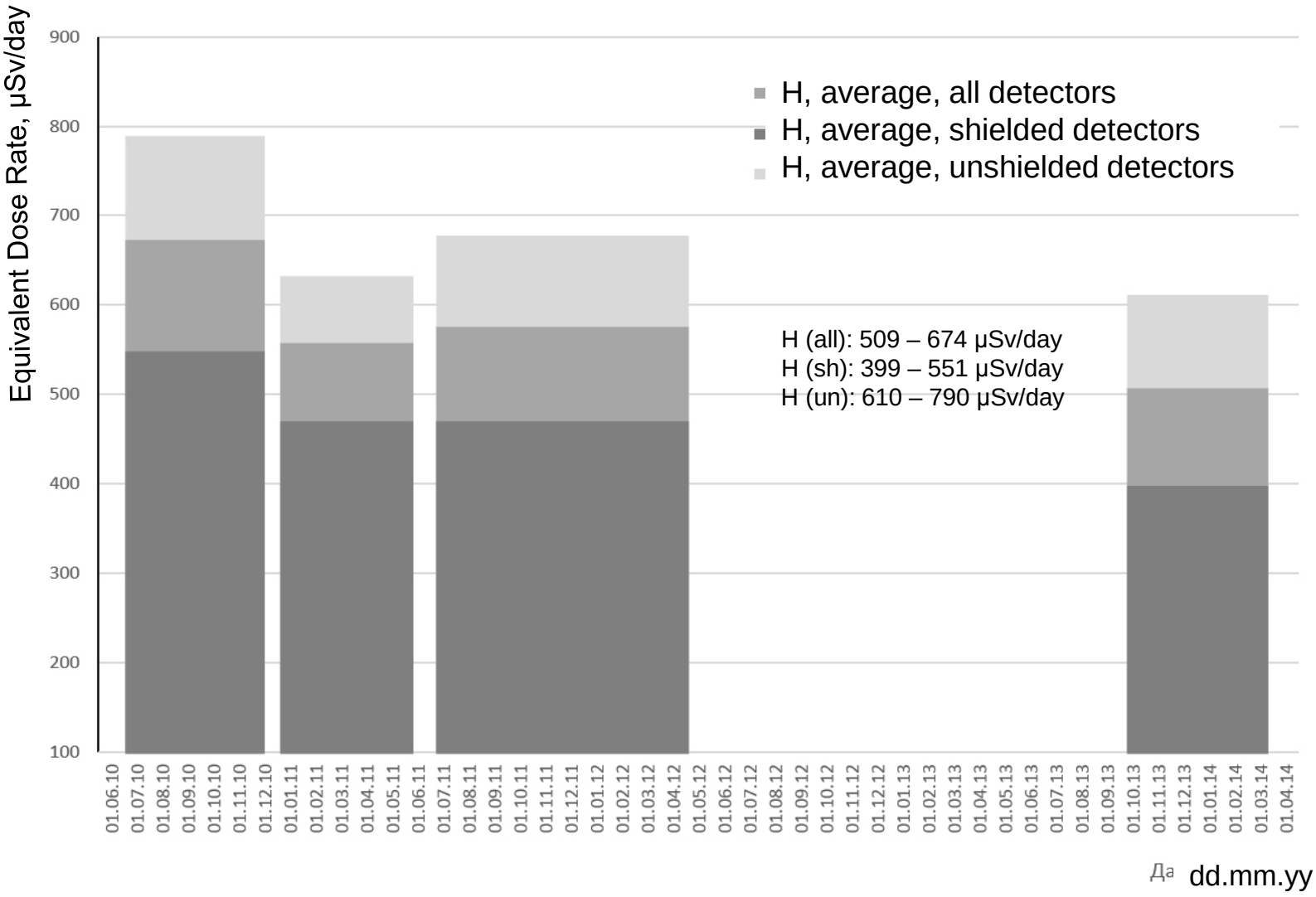
D (all): 250 – 396 μGy/day
D (shielded): 205 – 315 μGy/day
D (unshielded): 294 – 477 μGy/day
(IBMP data)



Solar activity

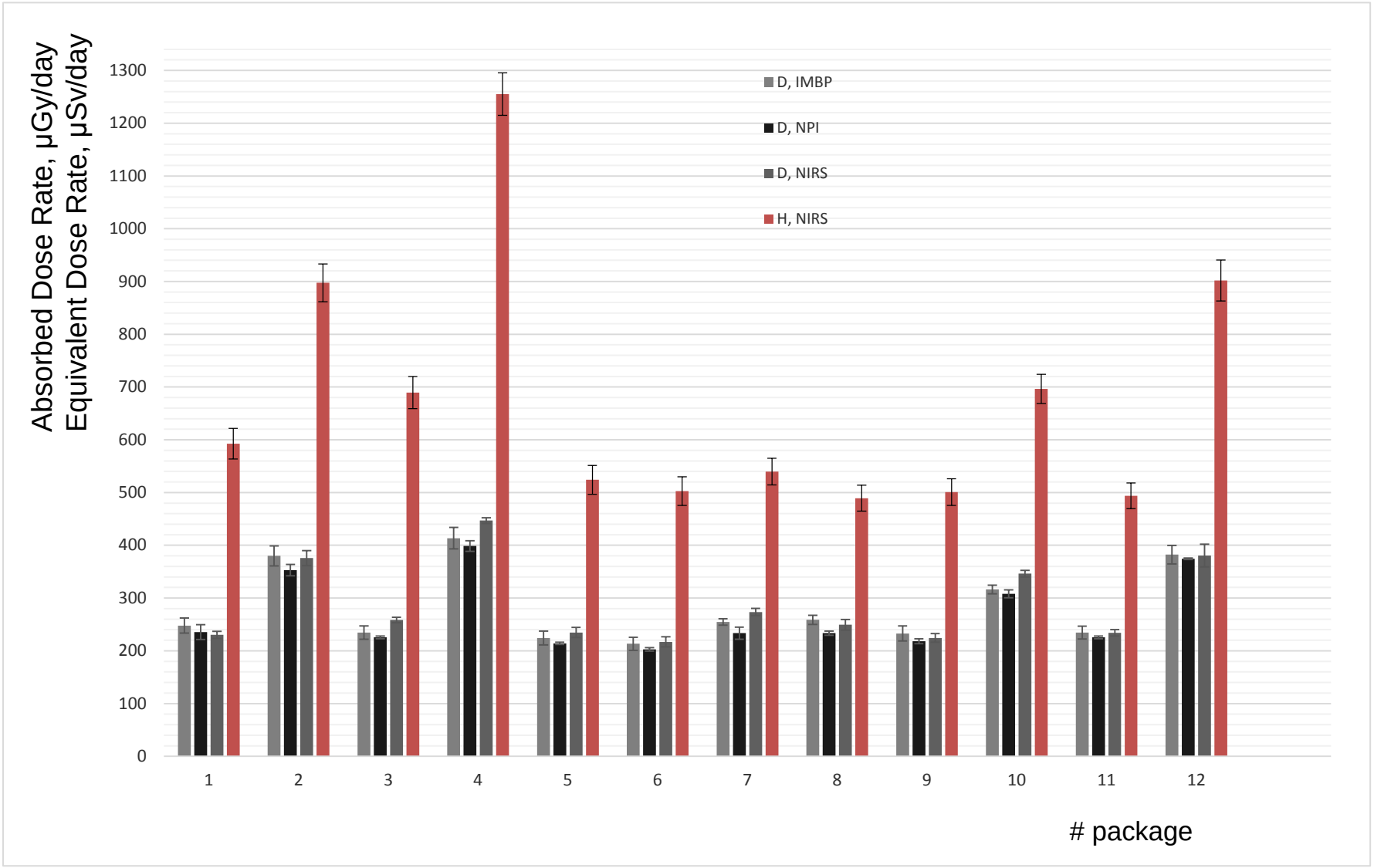


Resilts: Equivalent dose measurements (TLD+ SSNTD, NIRS)



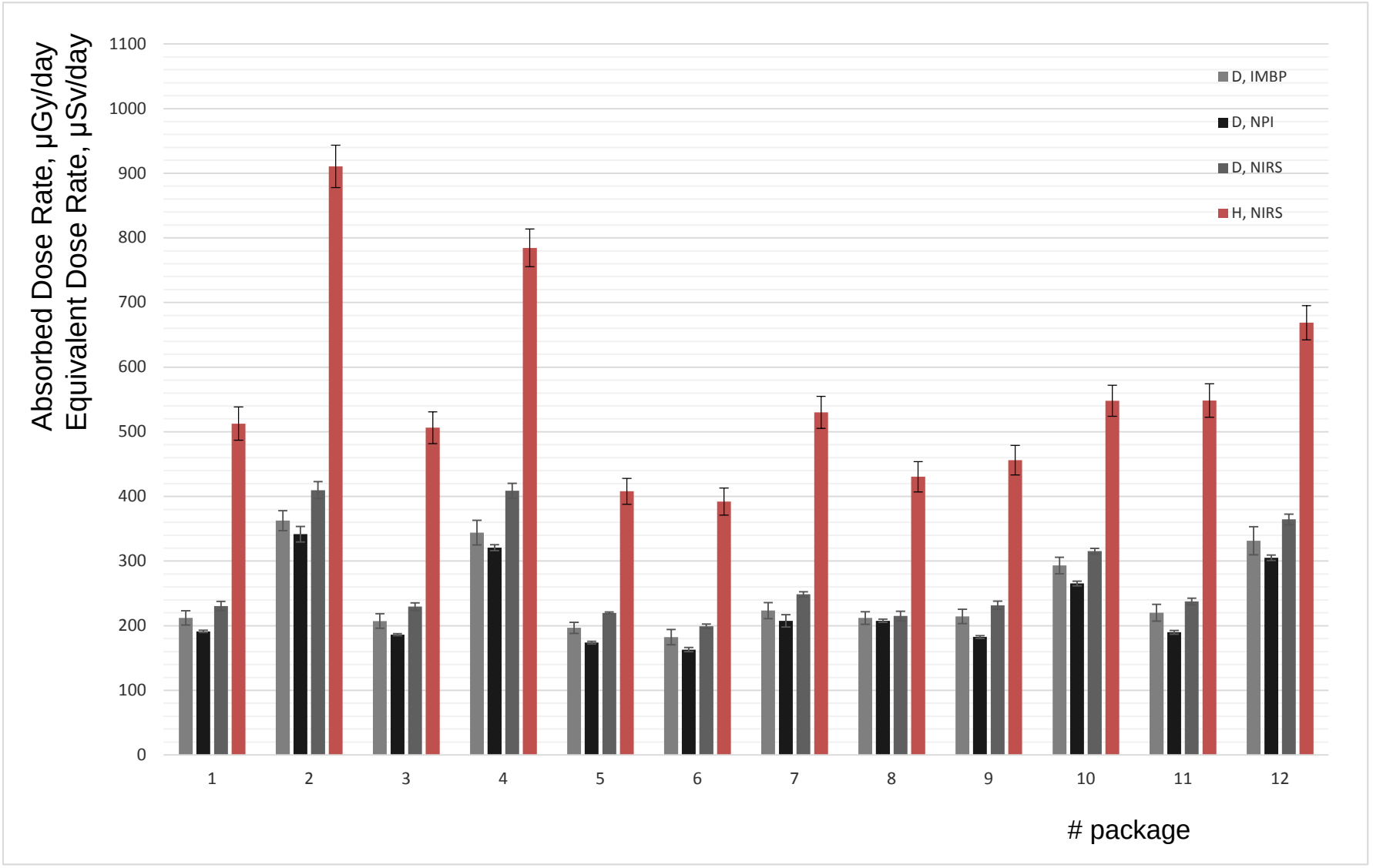
Dose Distribution

(1 session, IMBP, NPI, NIRS)



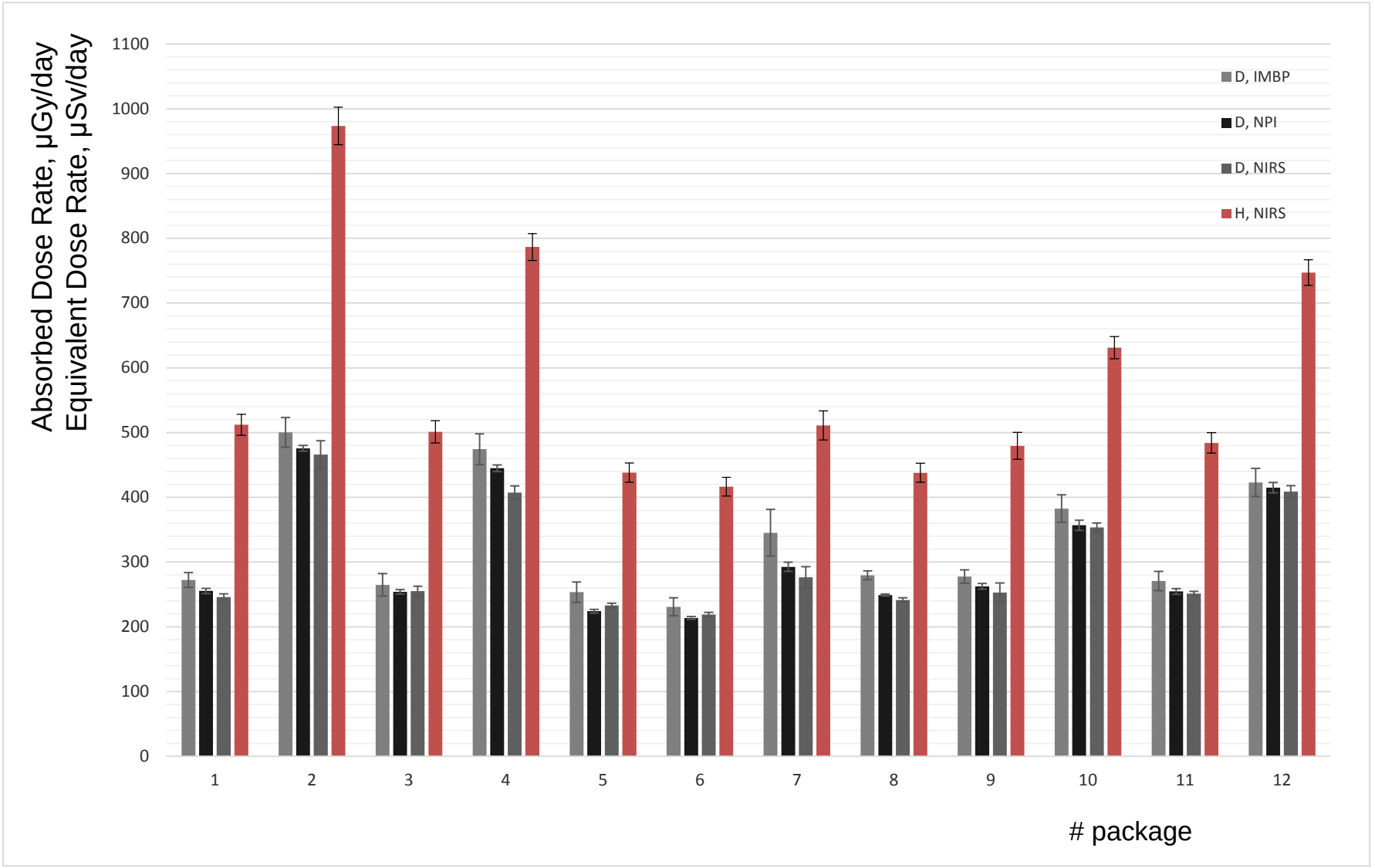
Dose Distribution

(2 session, IMBP, NPI, NIRS)



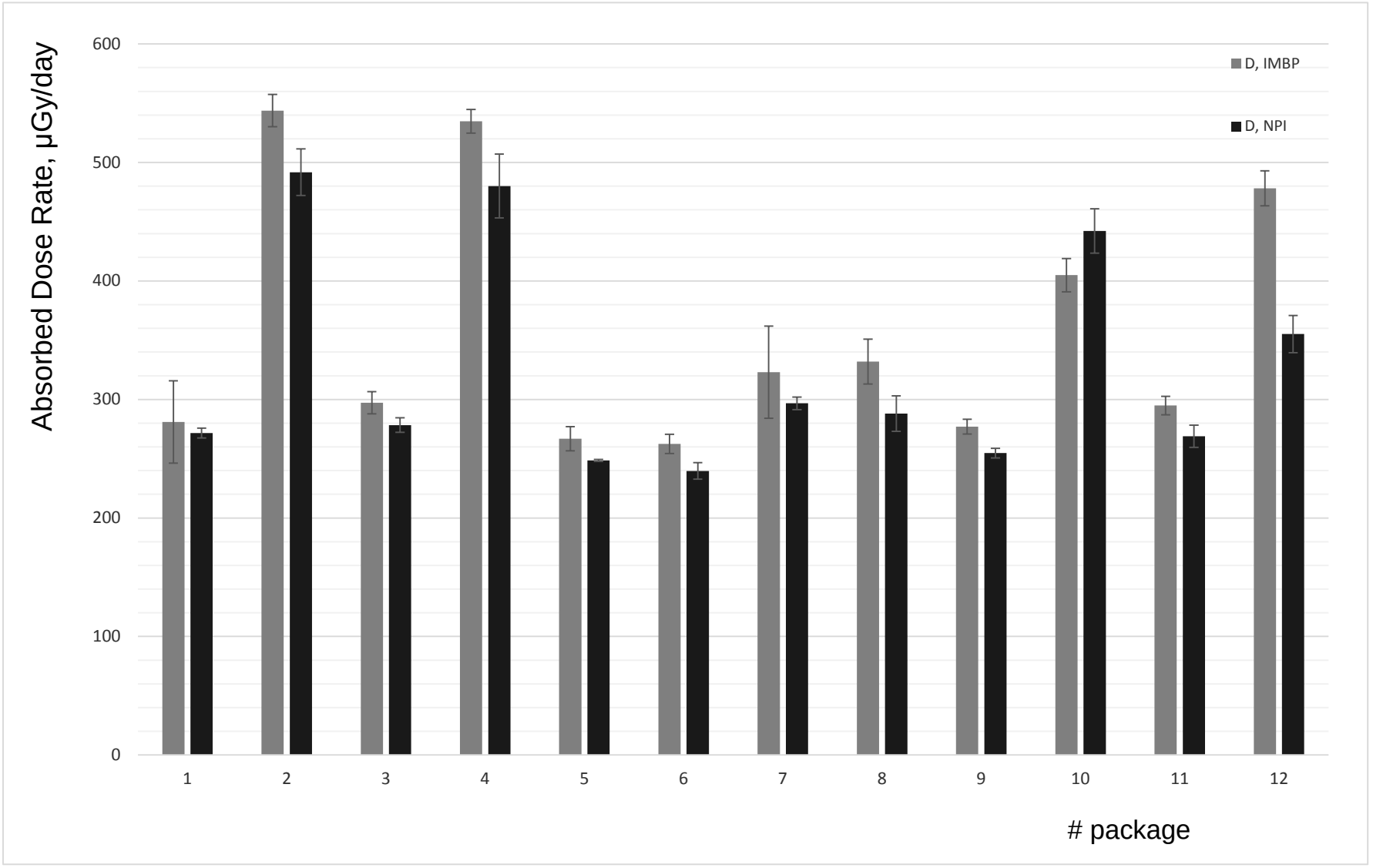
Dose Distribution

(3 session, IMBP, NPI, NIRS)



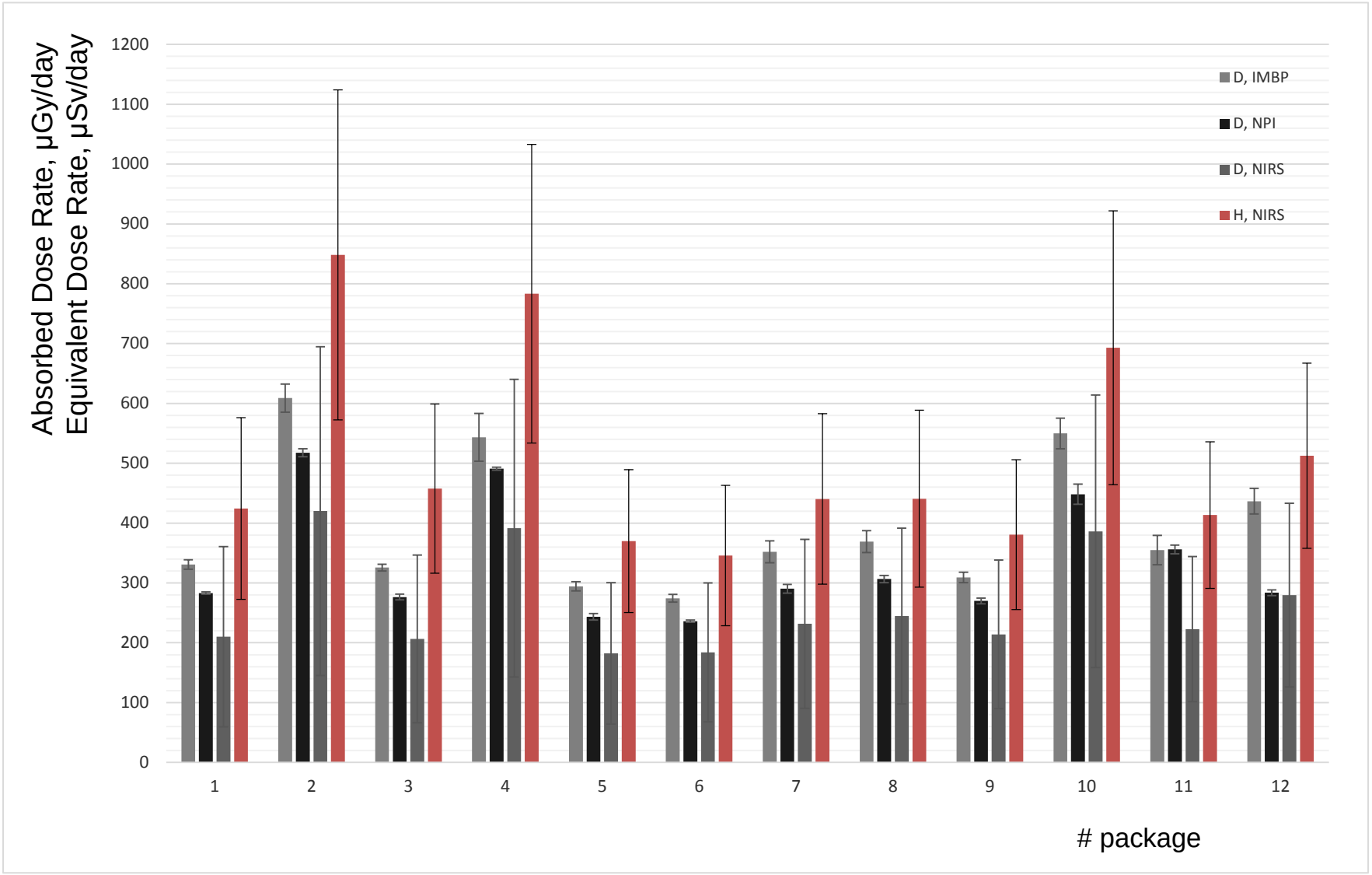
Dose Distribution

(4 session, IMBP, NPI, NIRS)

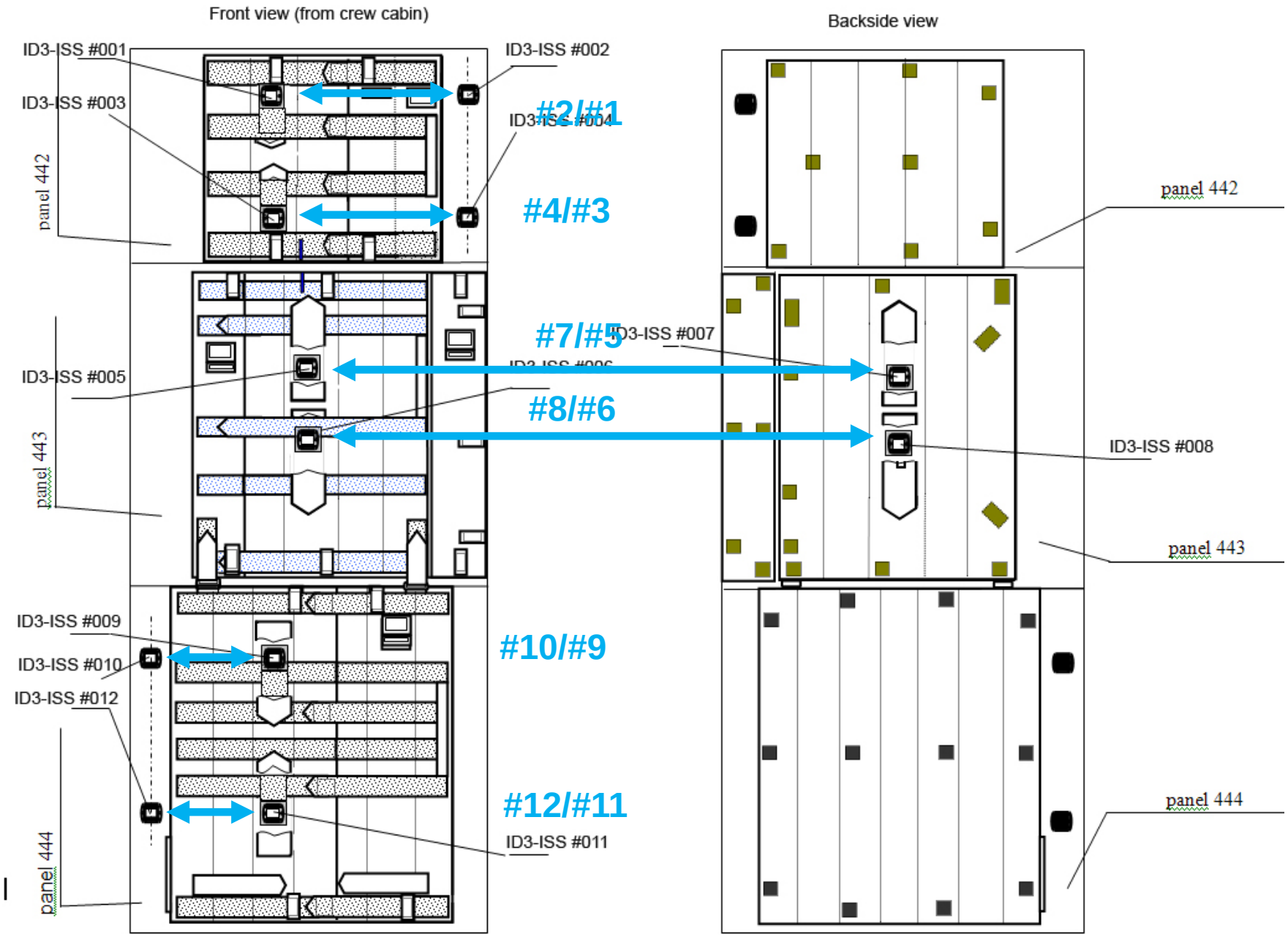


Dose Distribution

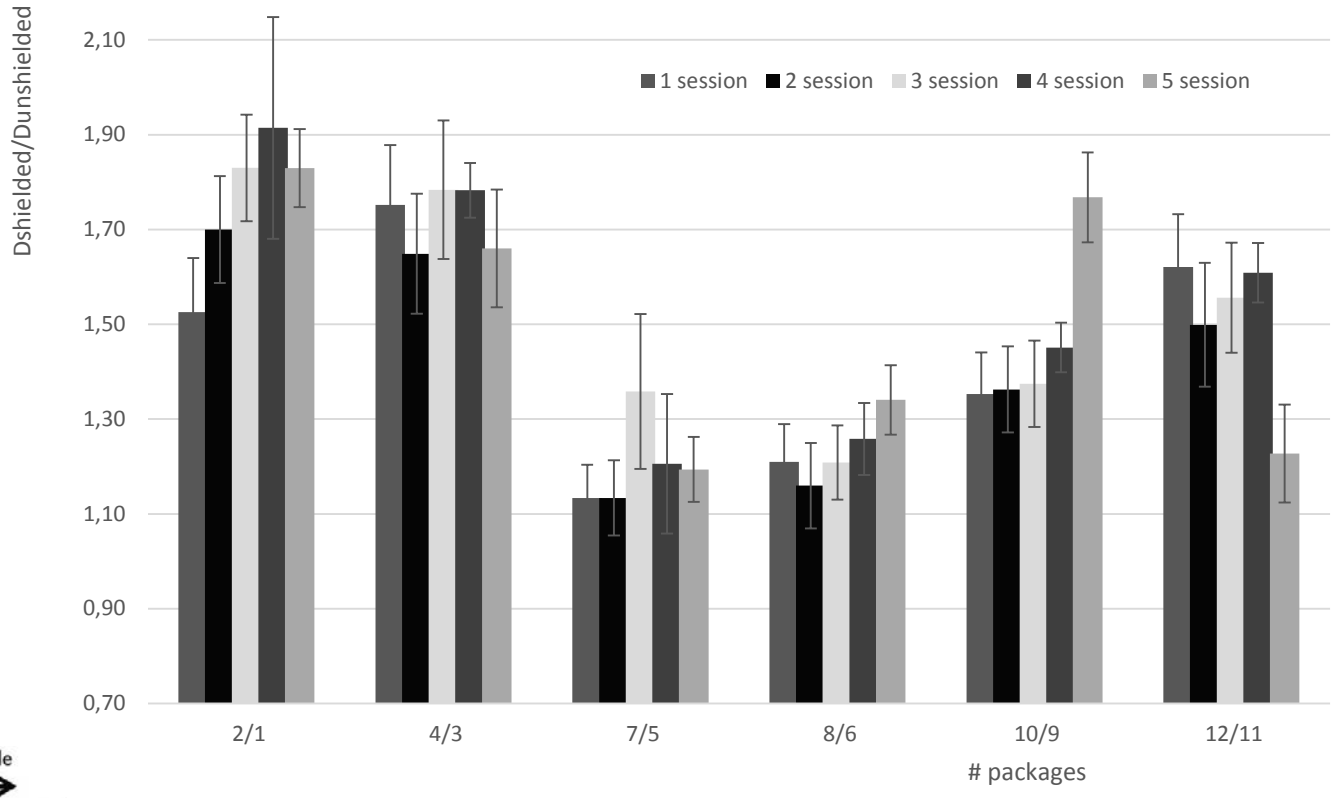
(5 session, IMBP, NPI, NIRS)



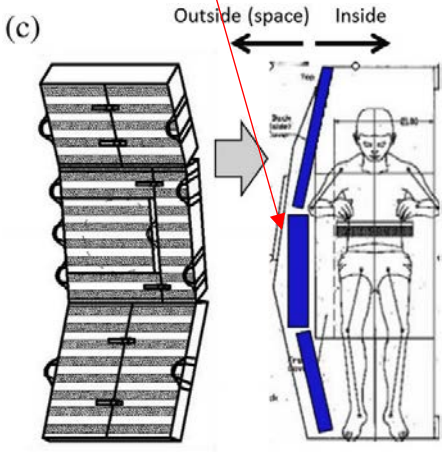
Detector packages comparison



Resilts: Ratio of unshielded and shielded detectors



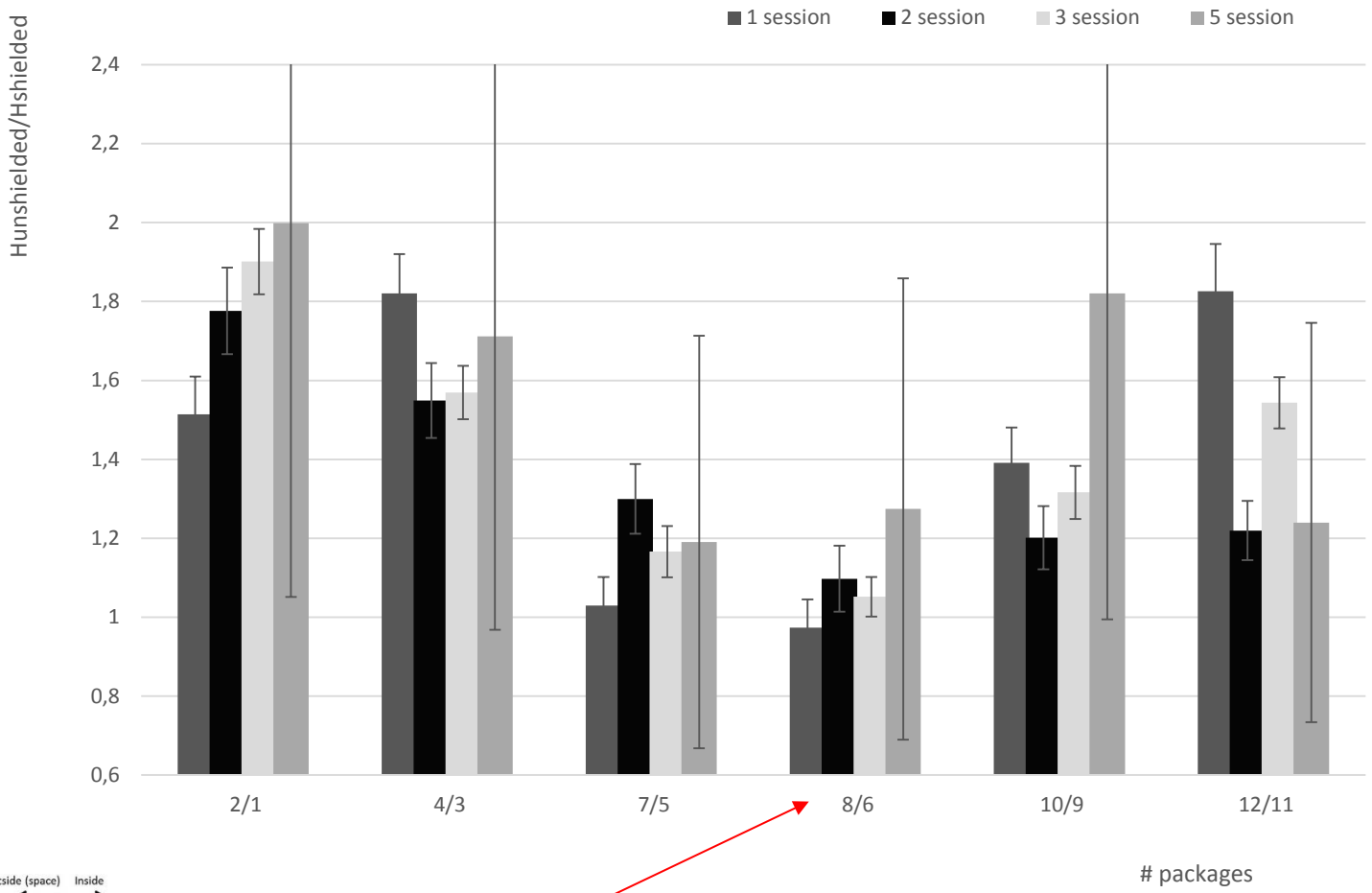
illuminator

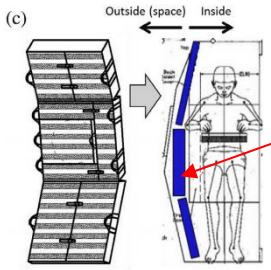


Ratio = unshielded detector/ shielded detector

«illuminator» effect

Resilts: Ratio of unshielded and shielded detectors



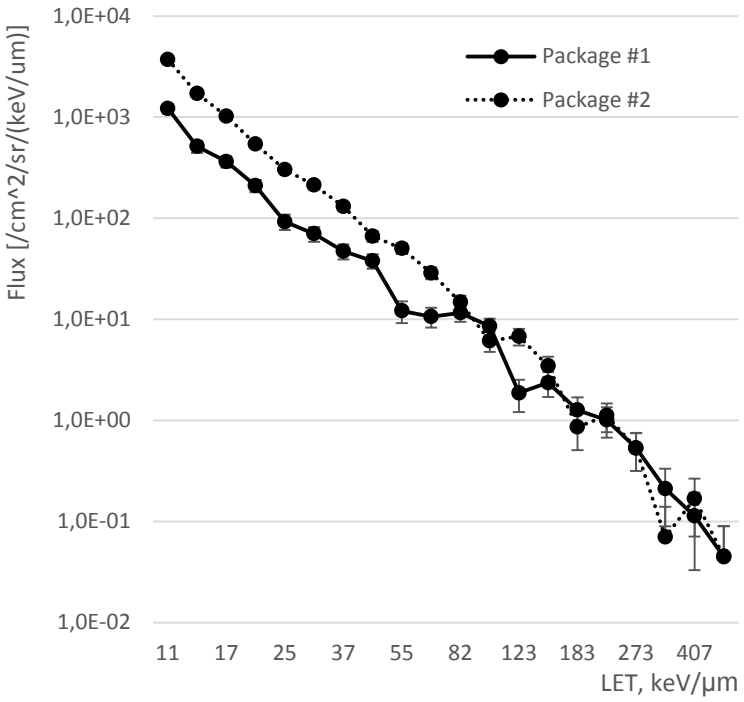


Ratio < 1 !

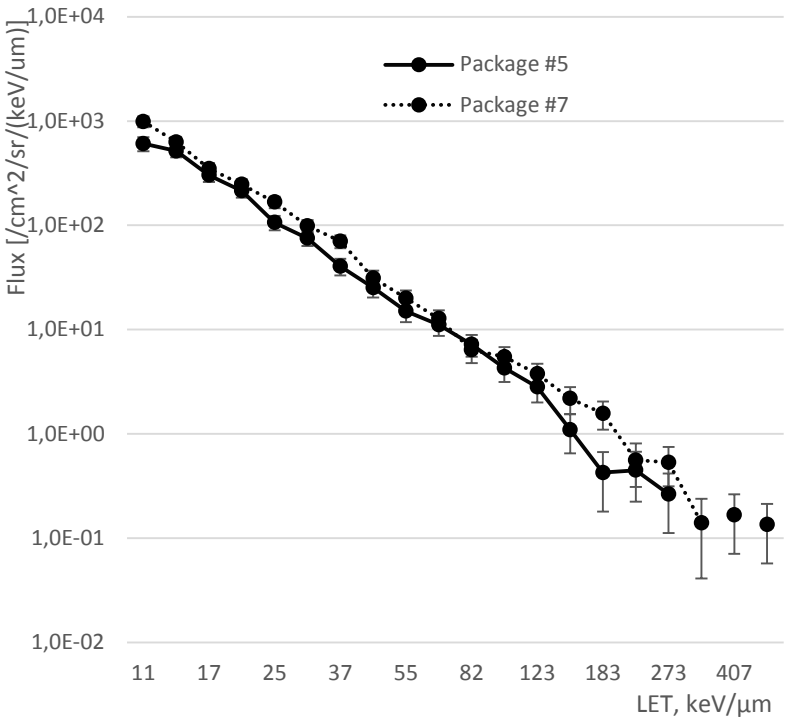
Ratio = unshielded detector/ shielded detector

LET spectra

Pack#2 and Pack#1, 2 session

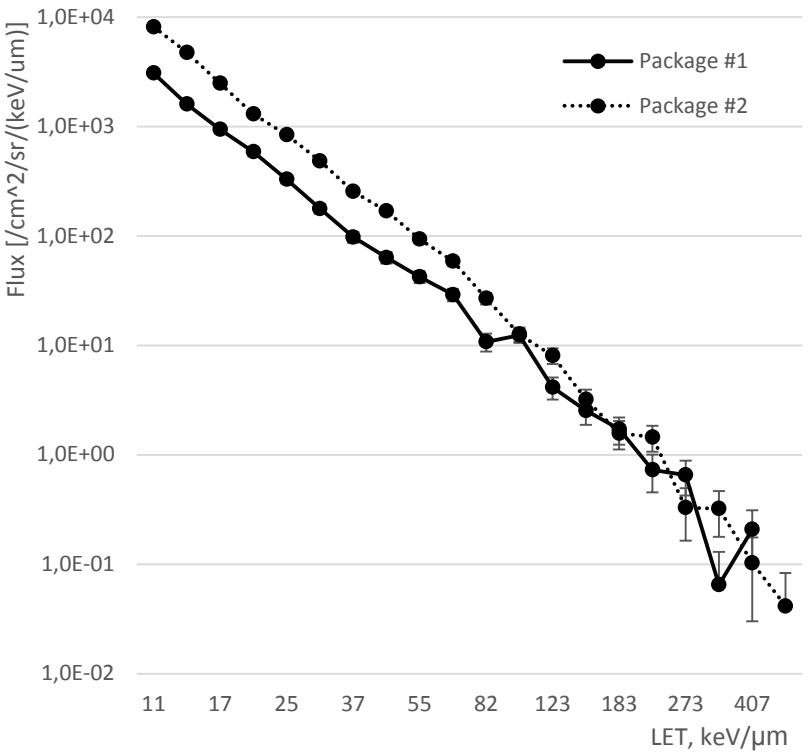


Pack#7 and Pack#5, 2 session

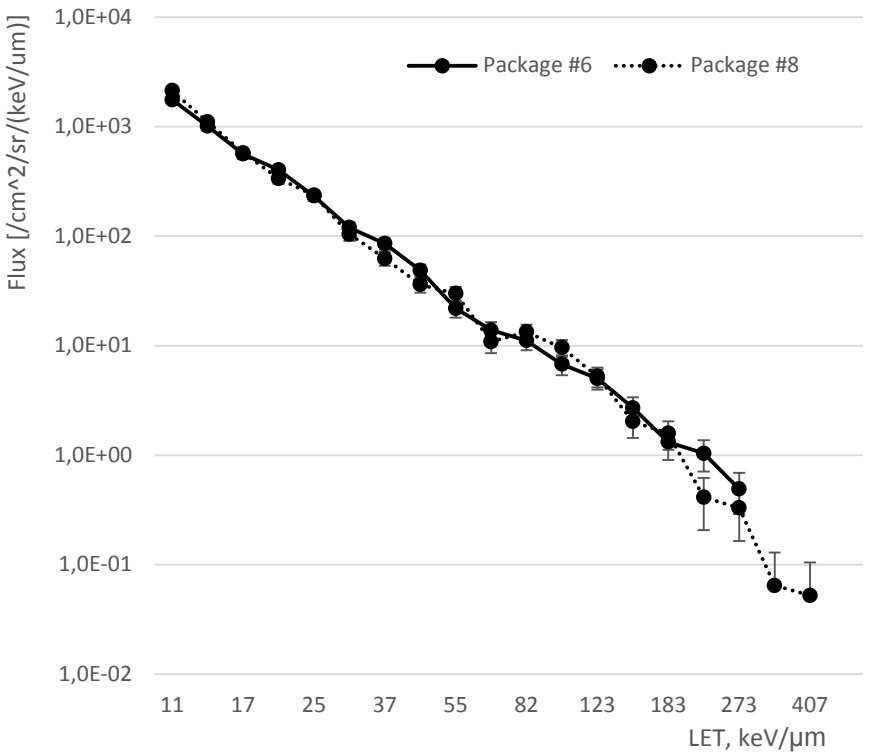


LET spectra

Pack#2 and Pack#1, 3 session



Pack#8 and Pack#6, 3 session



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

Conclusion

- The special facility for additional shielding of the crew cabin and detector arragement have been used from 2010 onboard ISS and 5 experimental sessions studying its protecting effect were done.

- 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
  (Sato T. et all. "Evaluation of dose rate reduction in a spacecraft compartment due to additional water shield". Cosmic Research, 2011;
  Ploc O. et all. "PHITS simulations of the Protective curtain experiment onboard the Service module of ISS: Comparison with absorbed doses measured with TLDs". Advances in Space Research, 2013.)

- In this report, IBMP TLD data and PNTD and TLD data from NPI and NIRS was presented. Some improvements for last session are needed, though.

- In Feburary, 2015, detector kit for one-year session is successfully launched to ISS.

Thank you for your attention!