Space radiation dosimetery for the Matoroshka-R #1 Experiment onboard the KIBO using PADLES from May - Sep. 2012 (Increment 31/32)

spherical tissue equivalent phantom

Area PADLES #8

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4. S.P. Korolev Rocket and Space Corporation (RSC-Energia)

PADLES（Passive Dosimeter for Life science Experiments in Space）

TLD MSO-S: Thermo Luminescence Dosimeter

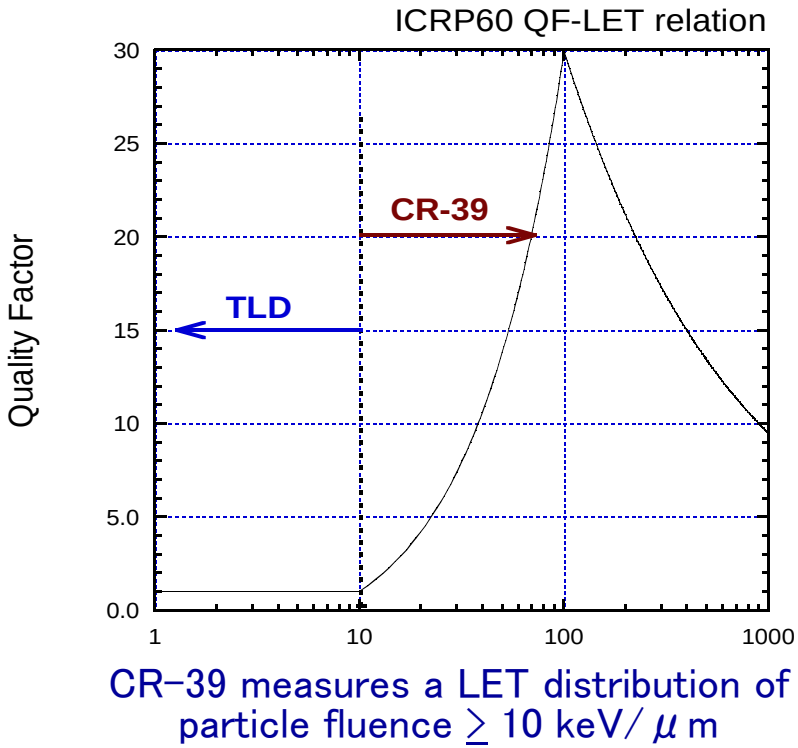
(MSO-S; Kasei Optonics industry)

Mg_2SiO_4 : Tb powder enclosed in a Pyrex glass test tube with Ar gas

CR-39 PNTD: Plastic nuclear track detectors

(HARZLAS TD-1; Fukuvi Chemical industry)

Allyl diglycol carbonate polymer doped with anti oxidant (0.1wt% NAUGARRD)



CR−39 measures a LET distribution of particle fluence ≥ 10 keV/μm

■ Total absorbed dose : D_{TOTAL} （Gy-water）

$$
\begin{aligned}
&D_{TOTAL} \\
&= D_{\le 10keV/\mu m-water} + D_{>10keV/\mu m-water} \\
&= (D_{TLD} - \kappa D_{CR-39}) + D_{CR-39} \\
&= D_{TLD} + (1-\kappa) D_{CR-39}
\end{aligned}
$$

■ Total dose equivalent : H_{TOTAL} (Sv)

$$
\begin{aligned}
&H_{TOTAL} \\
&= D_{\le 10keV/\mu m-water} + H_{>10keV/\mu m-water} \\
&= (D_{TLD} - \kappa D_{CR-39}) + H_{CR-39}
\end{aligned}
$$

κ : mean TL efficiency for LET above 10 keV/μm

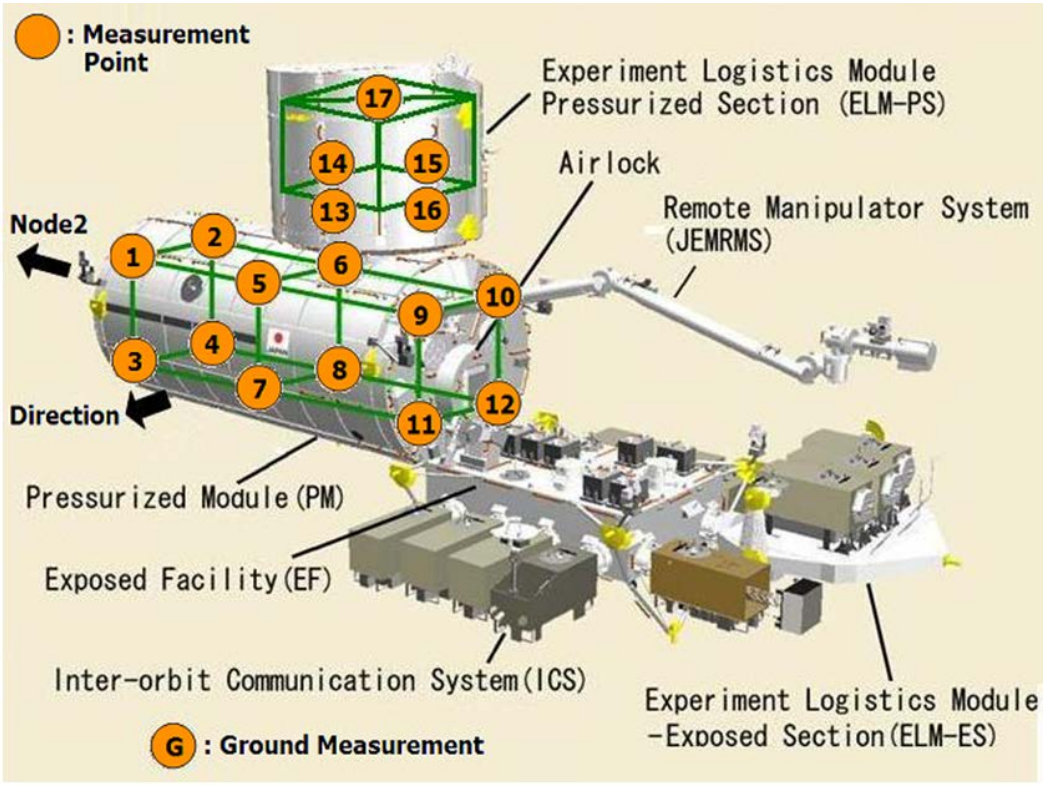
T. Doke et al. (1995); Estimation of dose equivalent in STS-47 by a combination of TLDs and CR-39. Radiat. Meas. 24, 75-82.

A. Nagamatsu et al.,(2006), (2009), (2011), (2013)

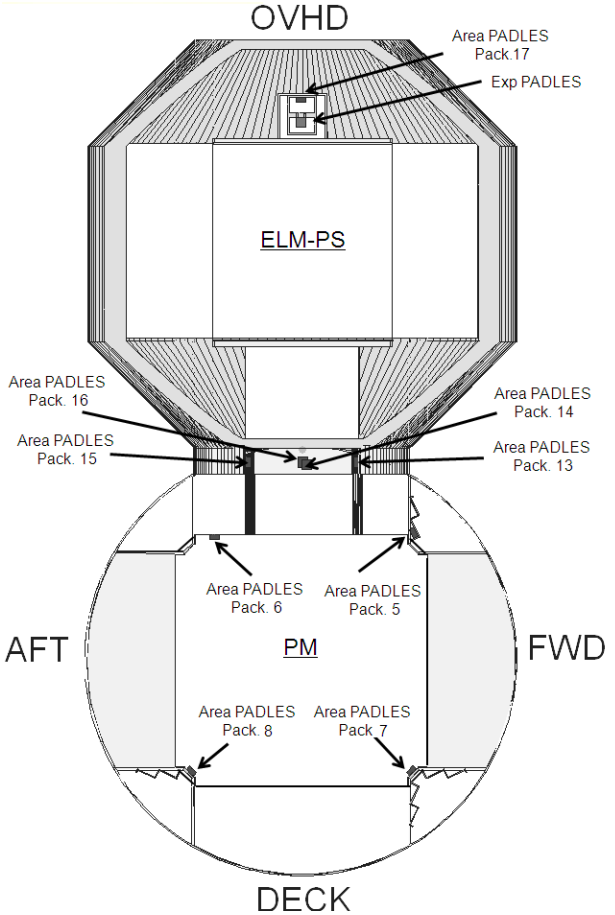
H. Tawara et al., (2008), (2011)

Area PADLES ~ Area Monitoring from 1J（Inc17), June 2008 ~

Area monitoring aims to measure radiation doses at 17 fixed locations inside the KIBO. The dosimeters are replaced every expedition (approximately 6 months) throughout the KIBO program.



Area PADLES (No. 1-17)

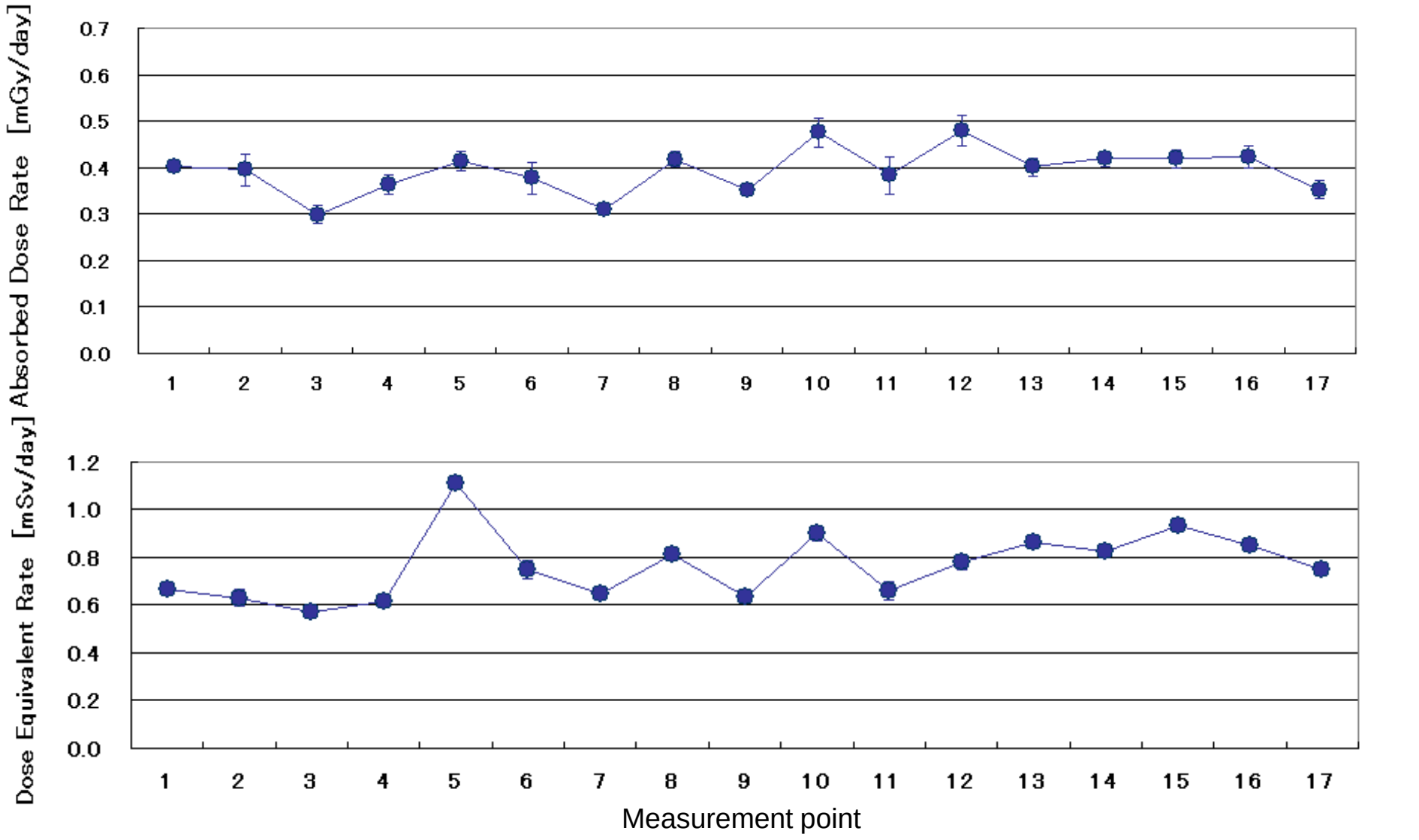


The results of Area PADLES are expected to:

- Form the basis for life science experiments (radiobiology)
- Contribute to risk assessments for astronauts
- Assist in updating existing space radiation models.

Results of Area PADLES #8 (14 May 2012 - 16 Sep. 2012 for 125 days)

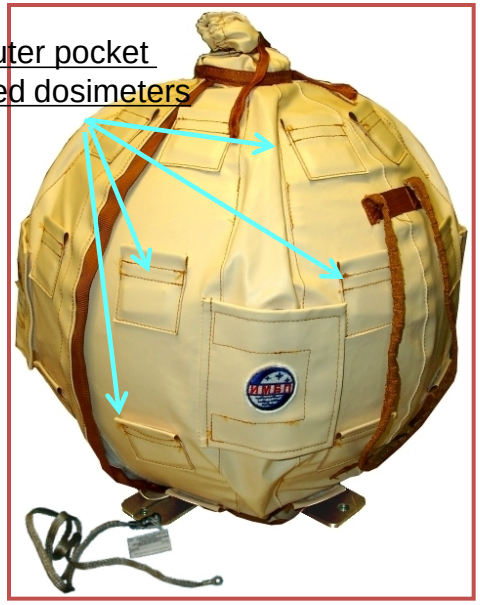
Averaged D_{total} 0.393 ± 0.005 mGy/day, H_{total} 0.765 ± 0.014 mSv/day

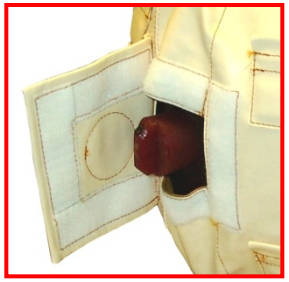


Matroshka-R Experiment #1 (14 May 2012 - 16 Sep. 2012 for 125 days)

■ Verification of dose distribution in a human body in space flight using very simplified model of spherical tissue equivalent phantom

- Long-term dose measurements inside the phantoms, in the various habitat modules
- Verification of the space radiation transport codes for calculating the dose distribution inside ISS and inside the phantom





Rod contained dosimeters

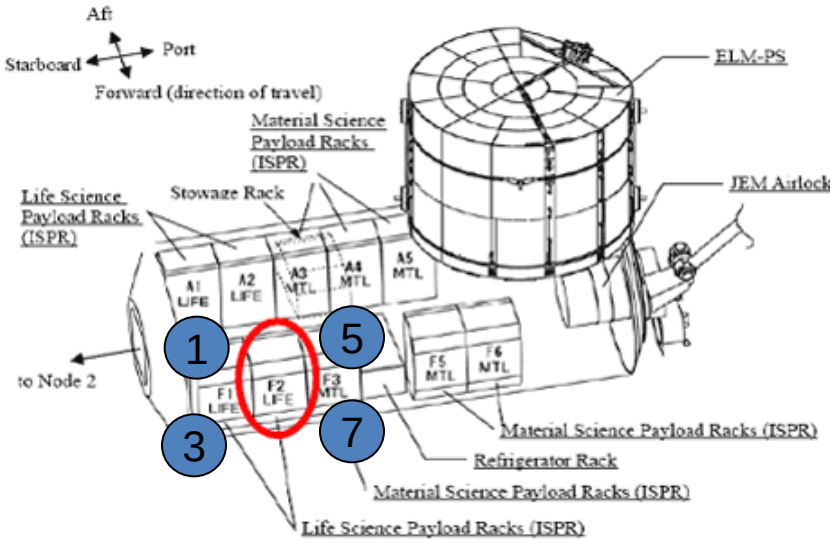
Size: 370 x 370 x 390 mm; mass: 32 kg

Shurshakov et al., 2008; Jadrnickova et al., 2010; Ambrozova et al., 2011 and Kolskova et al., 2012

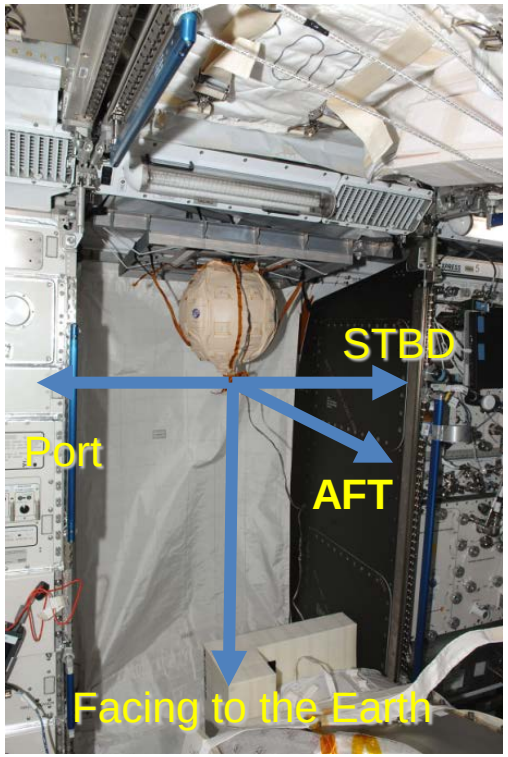
Experimental conditions of Matorshka-R experiment #1 (Inc 31/32)

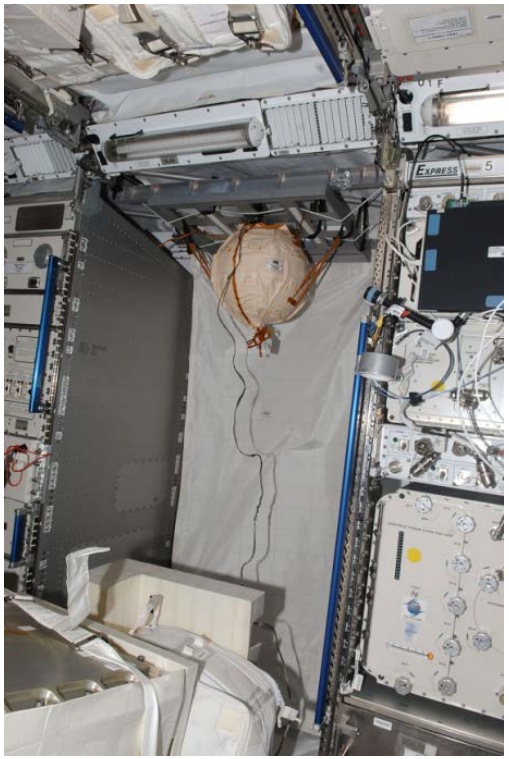
Event	Data	Vehicle	Location/Days
Launch	15 May. 2012	30S Soyuz TMA-04M	KIBO: JPM1F2 Rack2 Total: 125 Phantom:114 Between 23 and 24th over solar minimum.
Installation	21 May 2012	GMT142	
De-installation	12 Sep 2012	GMT256	
Return	15 Sep 2012	30S Soyuz TMA-04M	

*Base of the Spherical phantom was attached to the zenith of Rack 2 with the knot facing to the Earth.

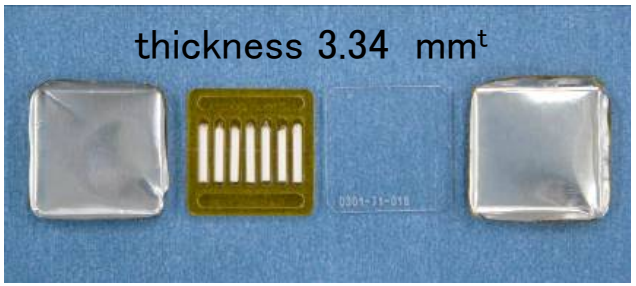


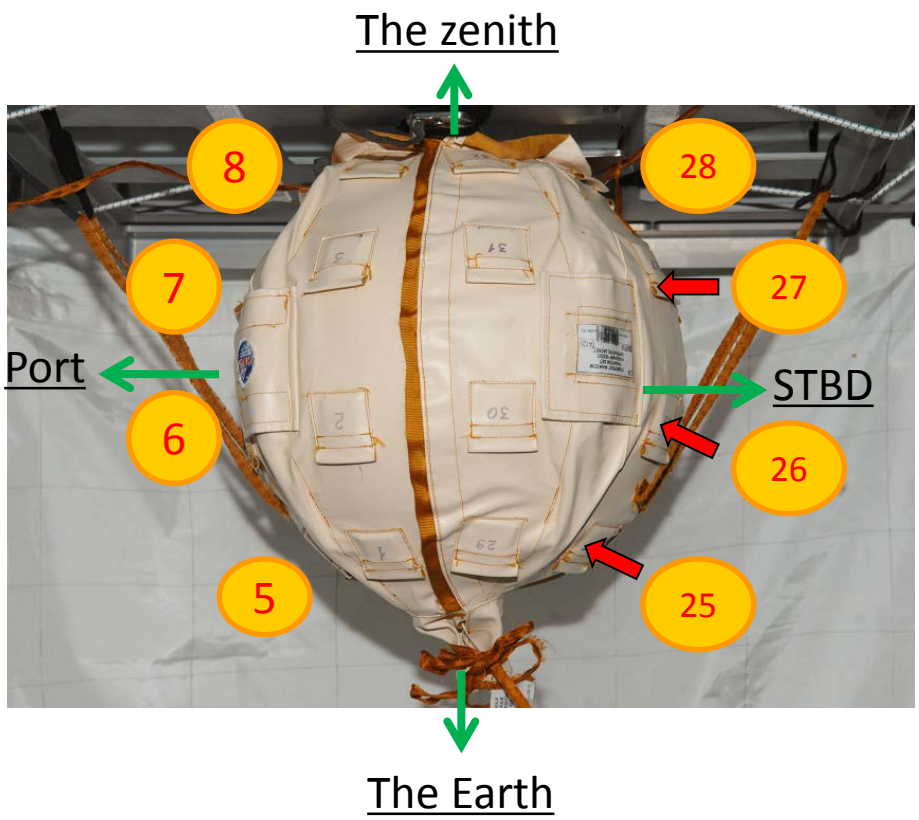
Area PADLES near the phantom



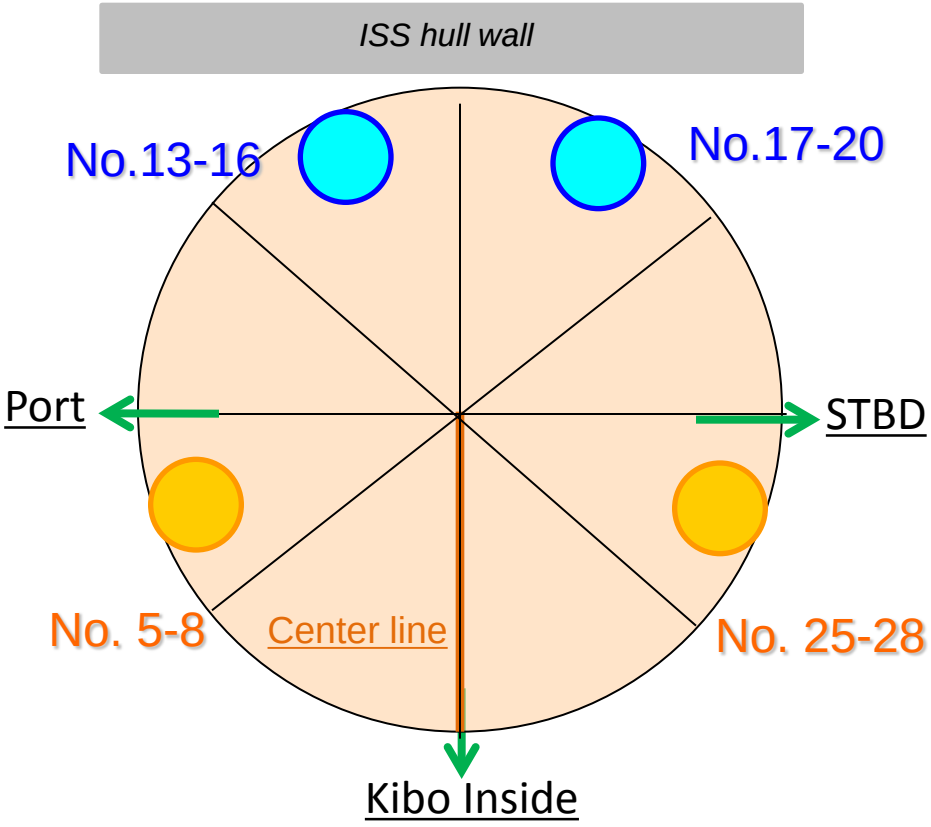


16 packages in outer pockets on spherical phantom poncho





Picture taken from the interior of the Kibo



Cross sectional view from the Zenith

Doses obtained from 16 packages in outer pockets

PADLES No.	TLD dose rate [mGy/day]	CR-39 dose rate (≧10keV/um)	Total dose rate [mGy/day]	CR-39 dose equivalent rate (≧10keV/um) [mSv/day]	Total dose equivalent rate [mSv/day]	Average Quality Factor
1	0.272 ± 0.017	0.024 ± 0.002	0.296 ± 0.017	0.249 ± 0.025	0.521 ± 0.030	1.76 ± 0.14
2	0.288 ± 0.027	0.023 ± 0.002	0.311 ± 0.027	0.323 ± 0.022	0.610 ± 0.035	1.96 ± 0.21
3	0.309 ± 0.026	0.019 ± 0.002	0.328 ± 0.026	0.191 ± 0.020	0.500 ± 0.033	1.52 ± 0.15
4	0.333 ± 0.022	0.025 ± 0.002	0.359 ± 0.022	0.255 ± 0.026	0.588 ± 0.034	1.64 ± 0.14
5	0.294 ± 0.022	0.035 ± 0.003	0.329 ± 0.022	0.380 ± 0.039	0.674 ± 0.044	2.05 ± 0.19
6	0.327 ± 0.012	0.045 ± 0.004	0.371 ± 0.011	0.359 ± 0.040	0.686 ± 0.041	1.85 ± 0.12
7	0.344 ± 0.029	0.021 ± 0.002	0.365 ± 0.029	0.192 ± 0.022	0.536 ± 0.036	1.47 ± 0.15
8	0.325 ± 0.016	0.022 ± 0.002	0.346 ± 0.016	0.205 ± 0.022	0.530 ± 0.027	1.53 ± 0.10
Averege	**0.311 ± 0.021**	**0.027 ± 0.002**	**0.338 ± 0.021**	**0.269 ± 0.027**	**0.581 ± 0.035**	**1.72 ± 0.15**
9	0.314 ± 0.027	0.036 ± 0.003	0.349 ± 0.027	0.272 ± 0.031	0.586 ± 0.041	1.68 ± 0.17
10	0.338 ± 0.017	0.040 ± 0.004	0.379 ± 0.017	0.305 ± 0.036	0.644 ± 0.040	1.70 ± 0.13
11	0.346 ± 0.015	0.064 ± 0.006	0.410 ± 0.013	0.482 ± 0.053	0.828 ± 0.054	2.02 ± 0.15
12	0.353 ± 0.019	0.035 ± 0.003	0.387 ± 0.019	0.293 ± 0.033	0.645 ± 0.038	1.67 ± 0.13
13	0.332 ± 0.037	0.042 ± 0.004	0.375 ± 0.036	0.389 ± 0.039	0.721 ± 0.053	1.92 ± 0.23
14	0.380 ± 0.023	0.047 ± 0.005	0.427 ± 0.022	0.479 ± 0.052	0.859 ± 0.057	2.01 ± 0.17
15	0.356 ± 0.010	0.041 ± 0.004	0.396 ± 0.009	0.320 ± 0.036	0.676 ± 0.037	1.71 ± 0.10
16	0.354 ± 0.018	0.029 ± 0.003	0.382 ± 0.018	0.279 ± 0.029	0.633 ± 0.034	1.66 ± 0.12
Averege	**0.347 ± 0.021**	**0.042 ± 0.004**	**0.388 ± 0.020**	**0.353 ± 0.039**	**0.699 ± 0.044**	**1.80 ± 0.15**

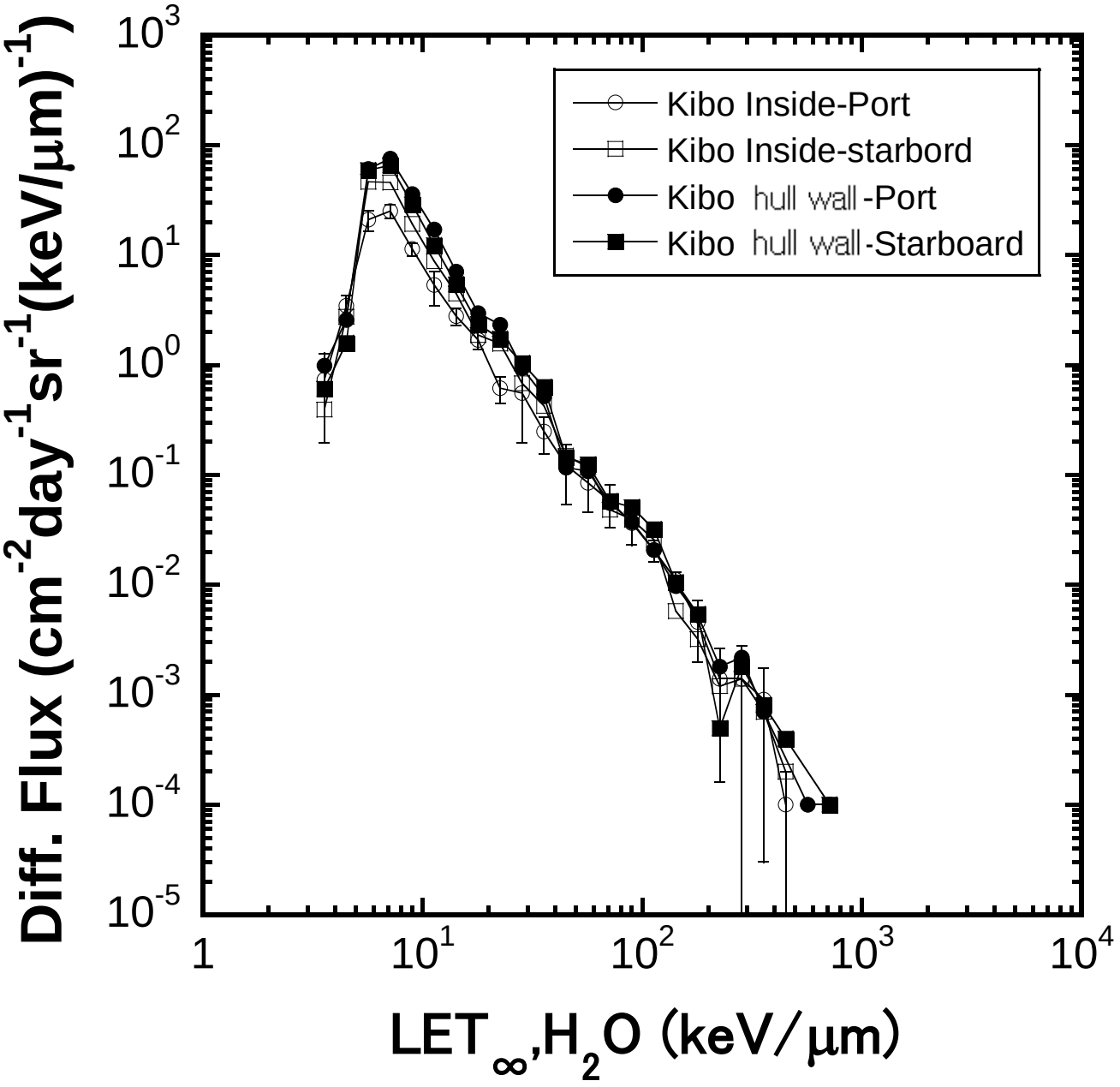
Facing to Kibo Inside : D_{total} 0.338± 0.005 mGy/day, H_{total} 0.581±0.035 mSv/day

Facing to Hull Wall: D_{total} 0.388 ±0.020 mGy/day, H_{total} 0.699±0.044 mSv/day

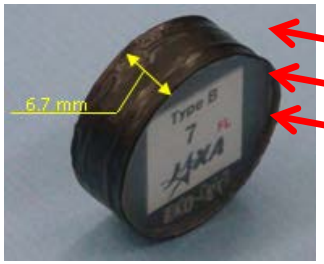
An average dose from PADLESs facing to the Kibo hull wall was higher than that from PADLESs facing to the interior of the Kibo:

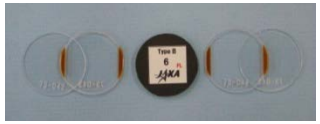
D_{total} +12.8 % H_{total} + 17.1%

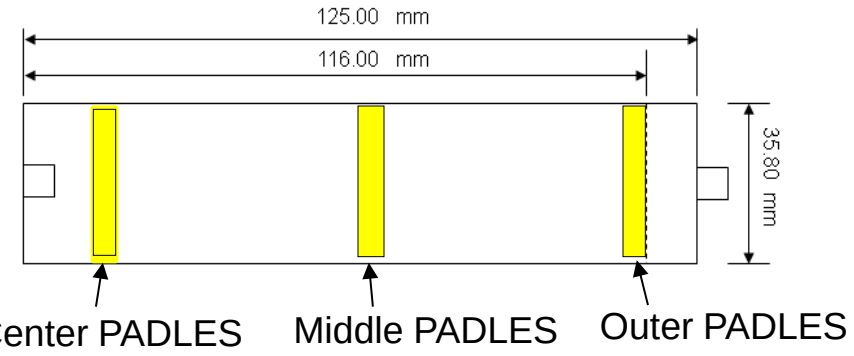
LET distributions (outer pockets)



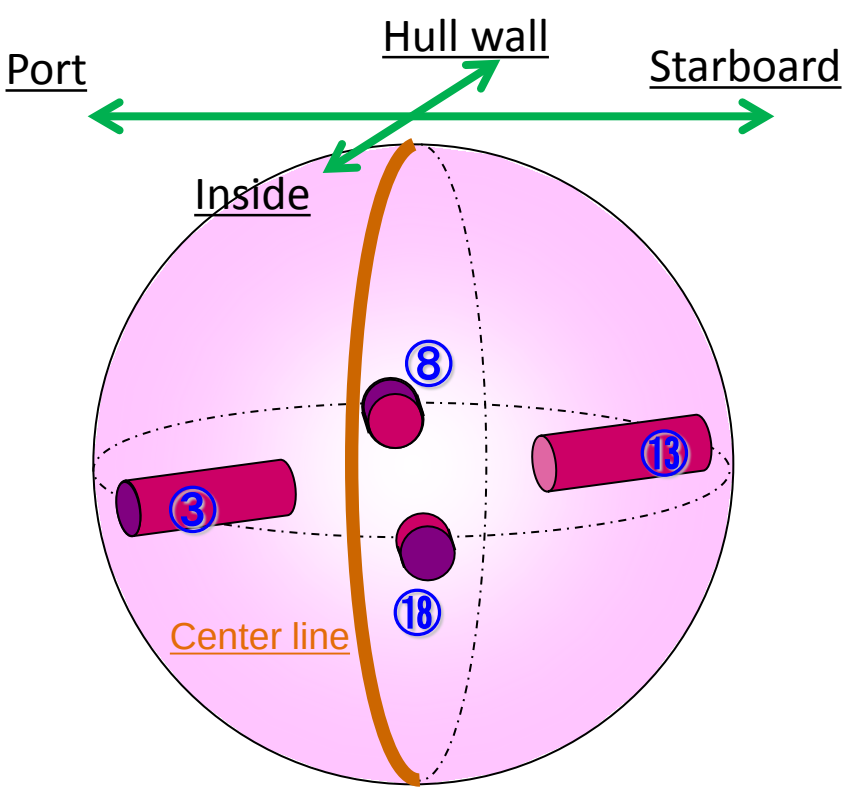
12 Packages in rods inside phantom

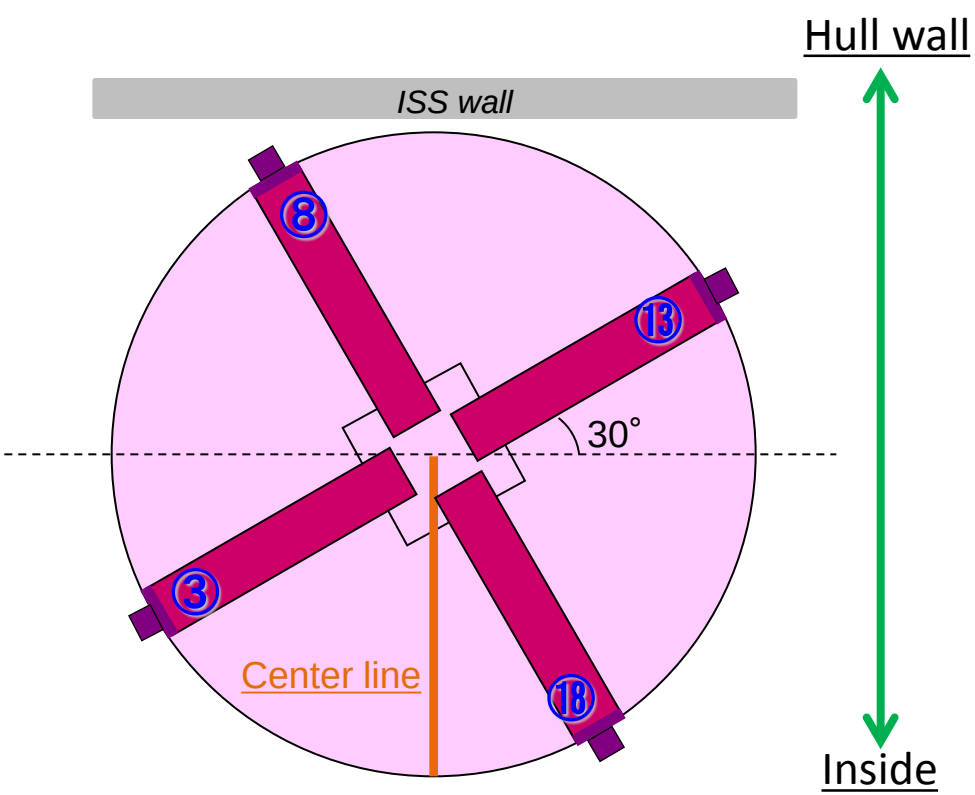




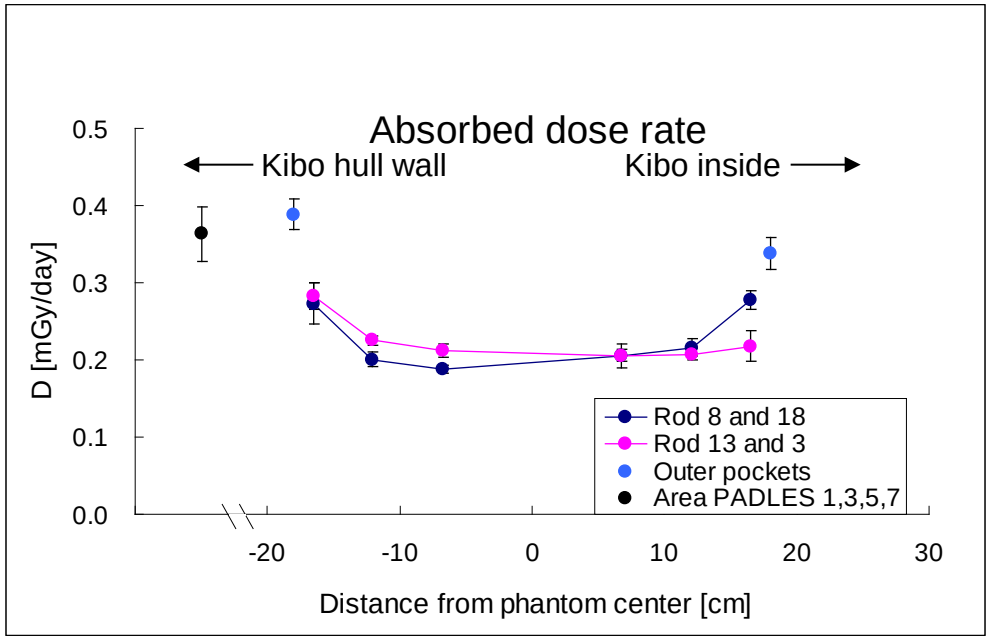


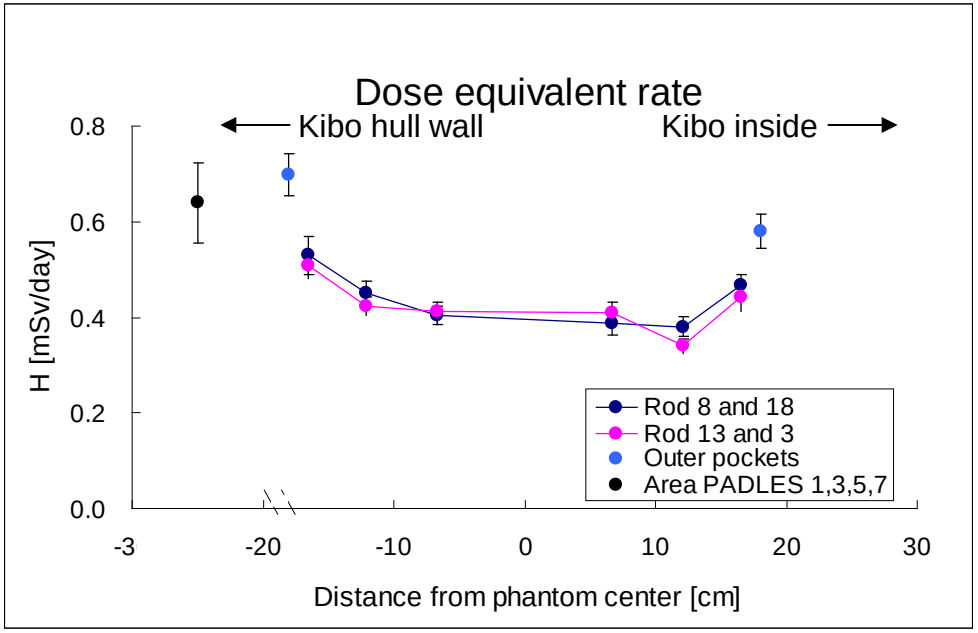
3 PADLES dosimeters are included per each rod

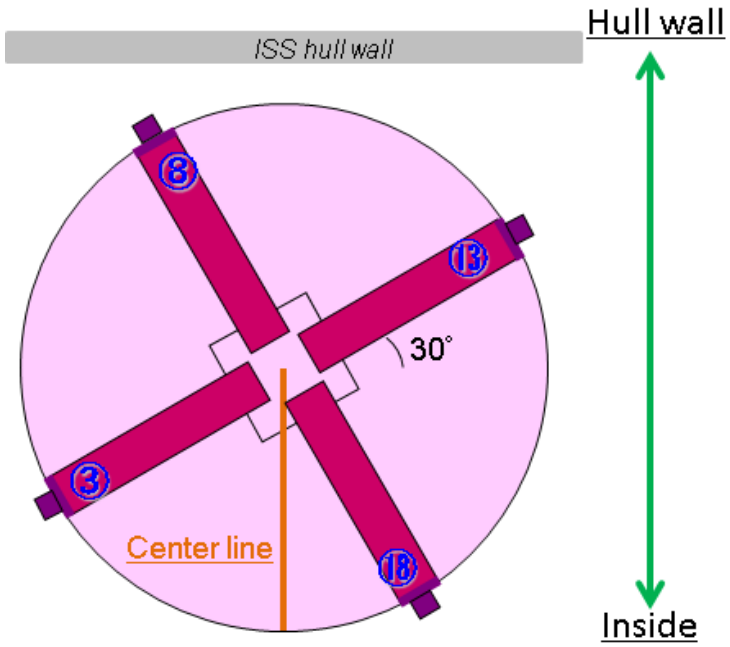




D_{total}, H_{total} from Rods inside phantom







D_{Total} : 0.19 – 0.28 mGy/day

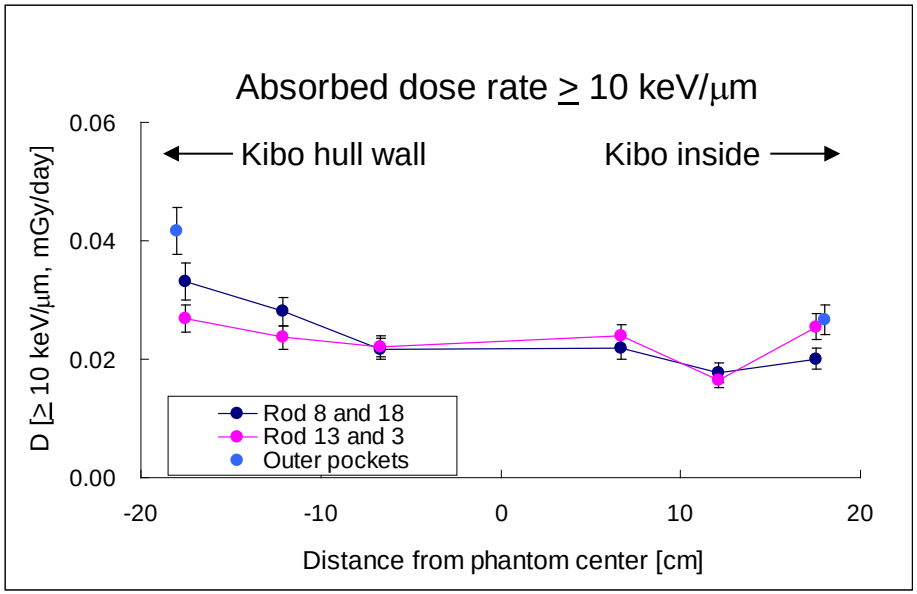
H_{Total} : 0.34 – 0.53 mSv/day

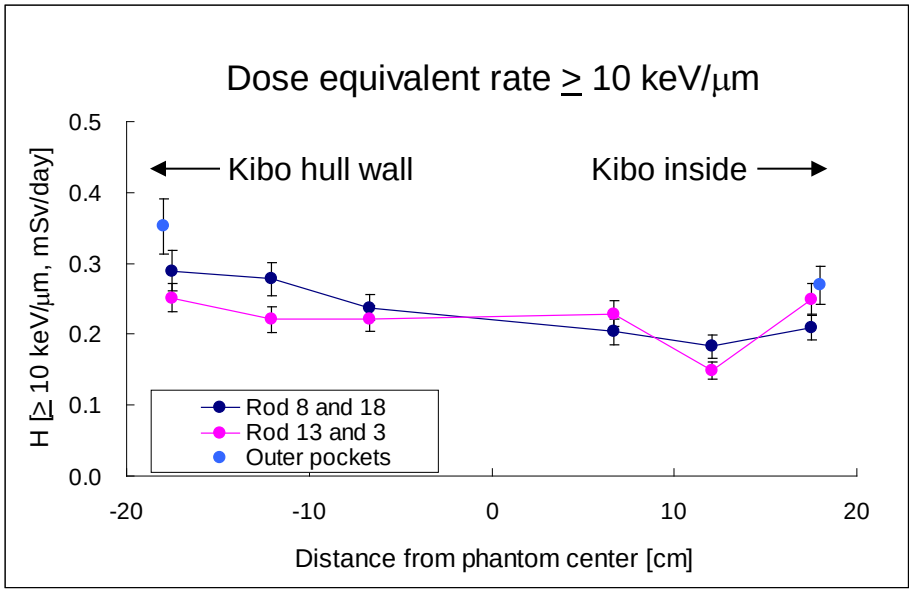
Qf : 1.6 – 2.2

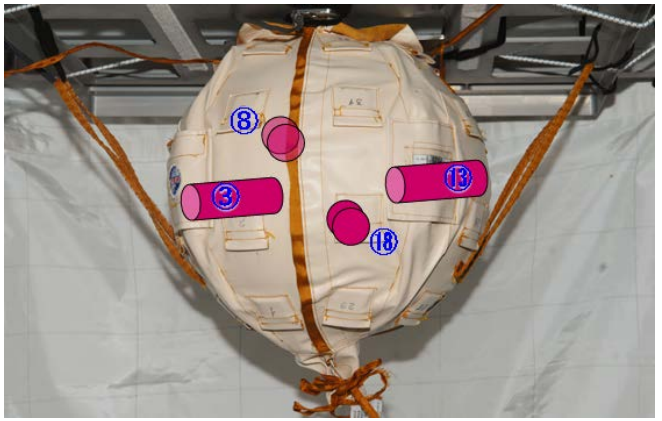
Effective shield thickness of the whole Kibo module: 54 g/cm^2

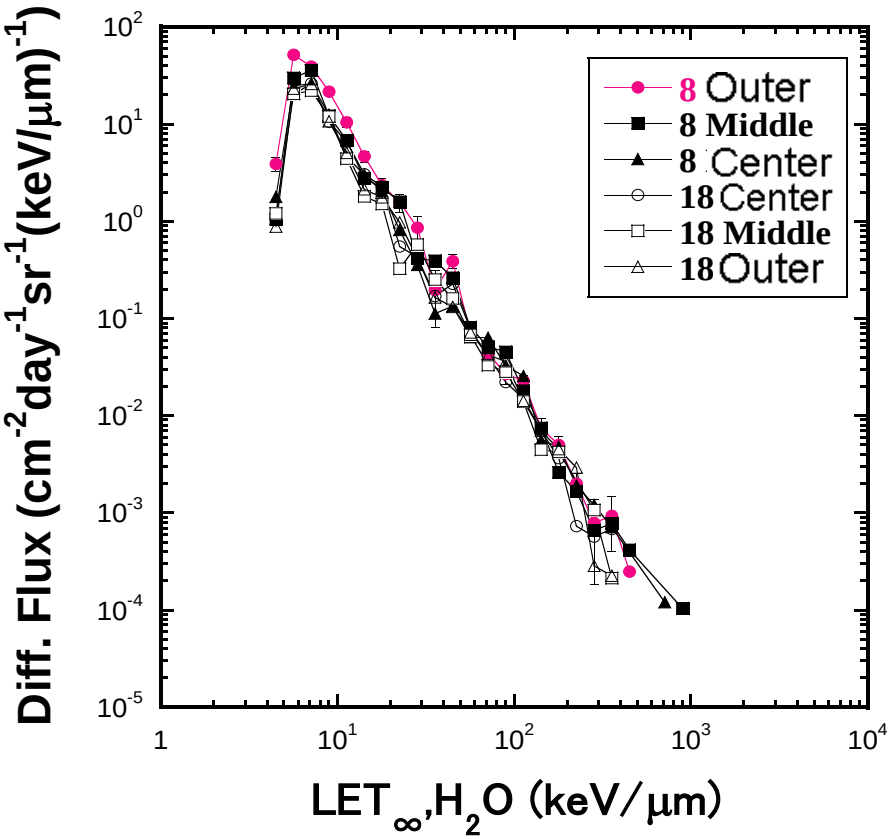
Shield thickness of hull wall near MATROSHKA-R: ~20 g/cm2

$D_{total \geq 10keV/\mu m}$, $H_{total \geq 10keV/\mu m}$ from Rods inside phantom









Summary 1

- During Increment 30/31 14 May 2012 - 16 Sep. 2011 for 125 days, space radiation dosimetry with PADLES were conducted.
  - Area PADLES #8 (17 monitoring points)
  - MATROSHKA-R spherical phantom: 16 outer pockets (16 PADLESs)
  - MATROSHKA-R spherical phantom: 4 inner rods (12 PADLESs)
- Averaged doses may be consistent from the point of view of shielding conditions.
  - 17 Area PADLESs: D_{total} 0.393 ± 0.005 mGy/day; H_{total} 0.765 ± 0.014 mSv/day
  - 4 Area PADLESs (No. 1, 3, 5 and 7) close to the MATROSHKA-R:
    D_{total} 0.356 ± 0.060 mGy/day; H_{total} 0.749 ± 0.244 mSv/day
  - 8 PADLESs in outer pockets facing Kibo hull wall:
    D_{total} 0.388 ± 0.020 mGy/day; H_{total} 0.699± 0.044 mSv/day
  - 8 PADLESs in outer pockets facing Kibo inside:
    D_{total} 0.338 ± 0.005 mGy/day; H_{total} 0.581± 0.035 mSv/day
  - 12 PADLESs in rods inside the spherical phantom:
    D_{total} 0.19 – 0.28 mGy/day; H_{total} 0.34 – 0.53 mSv/day

- The dose distributions inside Kibo and the phantom is not uniform.
- The doses close to Kibo hull walls are higher than inside the Kibo.
- The doses inside MATROSHKA-R phantom (35 cm diameter, tissue equivalent prepolymer Diafor-TDI) evidently decreases.

Summary 2

■ Shielding Condition

Effective shield thickness of the whole Kibo module surrounding the MATROSHKA-R:

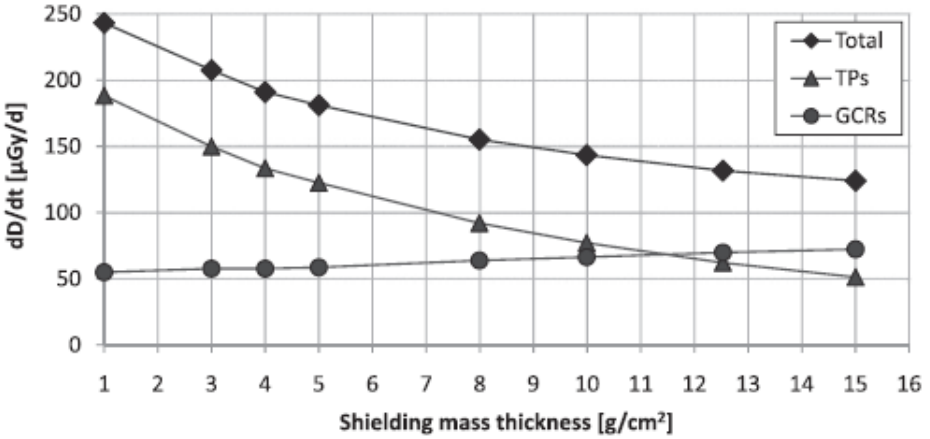
54 g/cm^2

Shield thickness of Kibo hull wall near the MATROSHKA-R (Rack 2):

~20 g/cm^2

●Kolıskova et.al. (2012) reported follows:

- Trapped protons (TPs) dose decreases with increasing shielding thickness.
- GCR dose slightly increases with increasing shielding thickness.



Dependence of absorbed dose in the whole phantom on aluminum ISS wall mass thickness for constant altitude 345 km. (Kolıskova et.al. (2012), advanced in Space Research 49, 230-236)

● Predicted radiation environment of MATROSHKA-R:

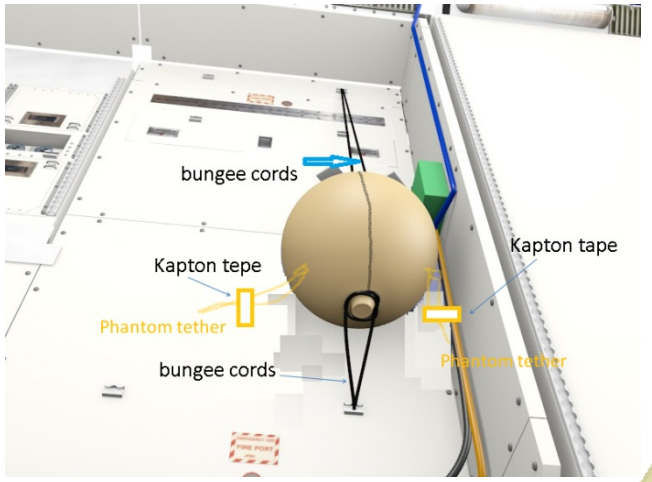
- Dose due to TPs decreases one fourth or less by Kibo hull wall and racks of ~20 g/cm^2 .
- Dose due to GCRs does not change with shielding of the Kibo very much.

Now Onboard: Are PADLES experiment #9 (Inc 35/36)

In Preparation: Are PADLES experiment #10 (Inc 37/38)

Area PADLES dosimeters were handed over by Expedition 33/34 long-duration stay cosmonaut Evgeny Tarelkin to Expedition 32/33 long-duration stay astronaut Akihiko Hoshide for installation on 25 October 2012.

In Preparation: Matorshka-R Experiment #2 will start from Inc 37 (Oct. 2013)



ESA/DLR/ROSCOSMOS/JAXA
Matroshka 2B_KIBO Flight conditions

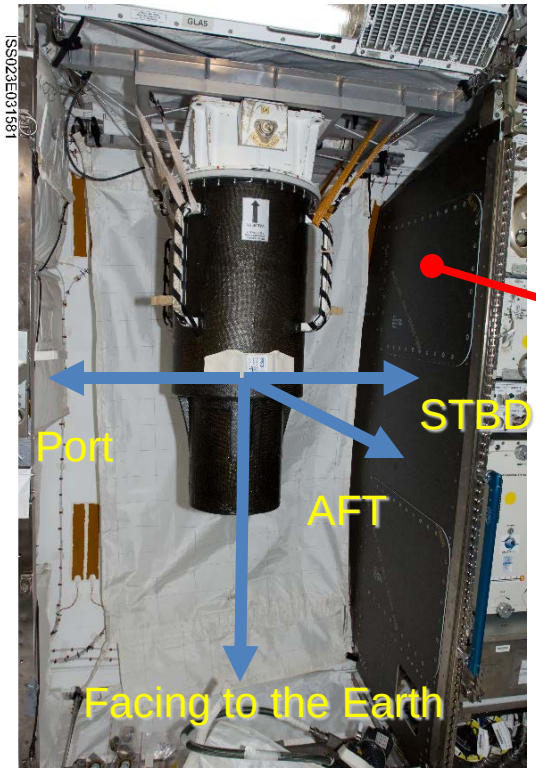
The configuration of Mat-R #1 and #2 experiment onboard the KIBO.

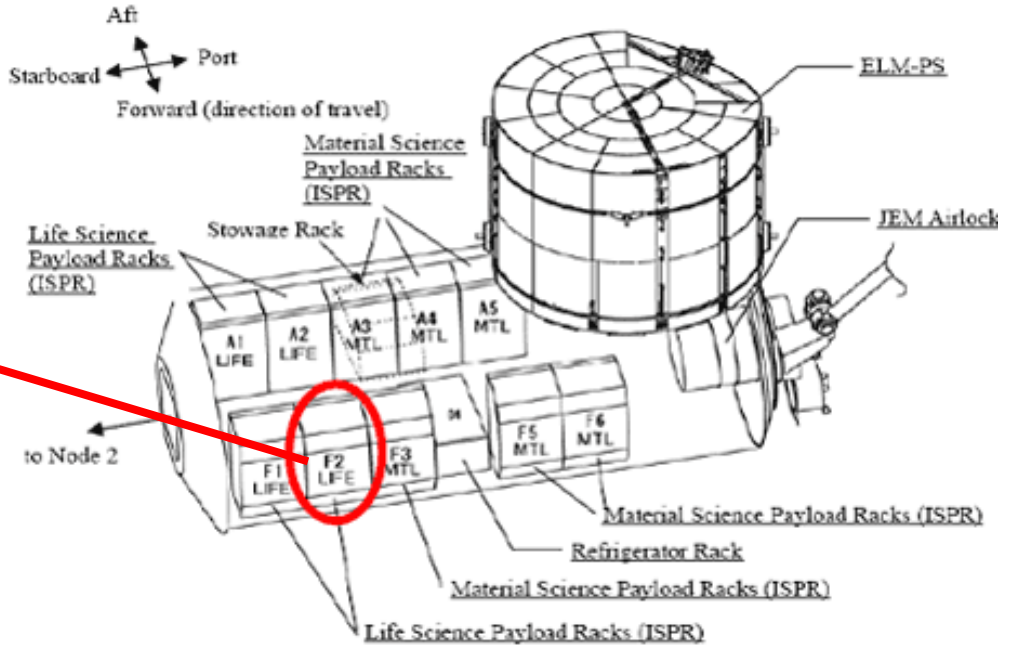
Back Up

Experimental conditions of Matroshka 2B_KIBO Flight experiment (Inc 23-26)

Event	Data	Vehicle	Location/Days
Launch	29 Apr. 2010	37P Progress	KIBO: JPM1F2 Rack2
Installation	4 May 2010		Total: 322
De-installation	11 Mar 2011		Phantom:311
Return	17 Mar 2011	24S	Between 23 and 24th over solar minimum

*Base of the human phantom was attached to the zenith of Rack2 with the head facing to the Earth.

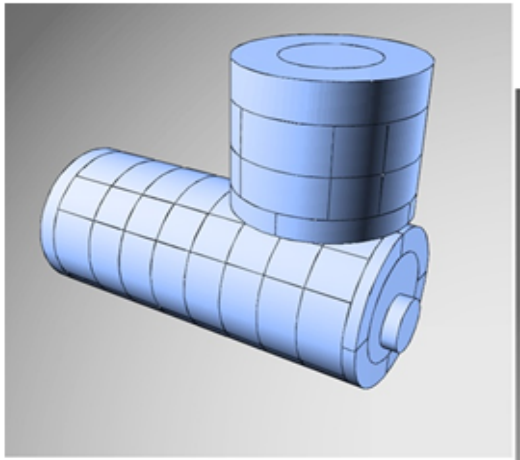


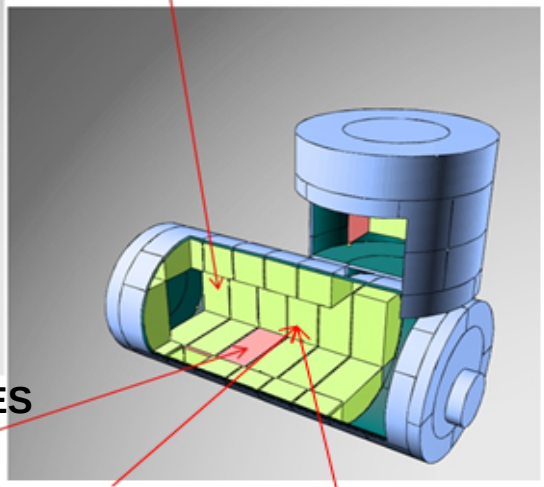


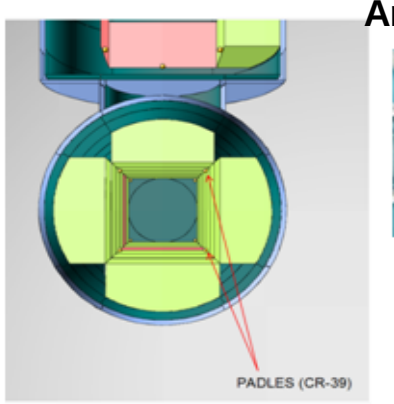
Particle transport simulation based on PHITS with exact geometry of Kibo(ISS)

This study are expected to:

- Contribute to risk assessments of astronauts on space flights
- Feasibility study for effective shielding materials and thickness







Area PADLES

MATROSHKA
ファントム

MATROSHKA –R
球体ファントム