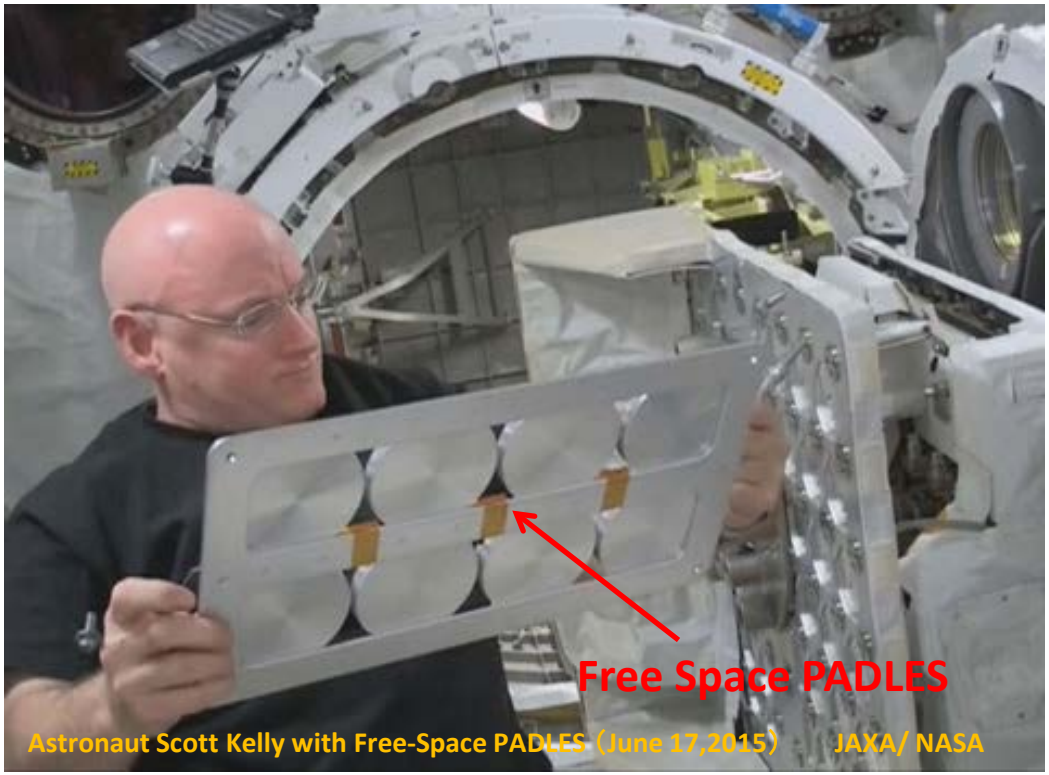
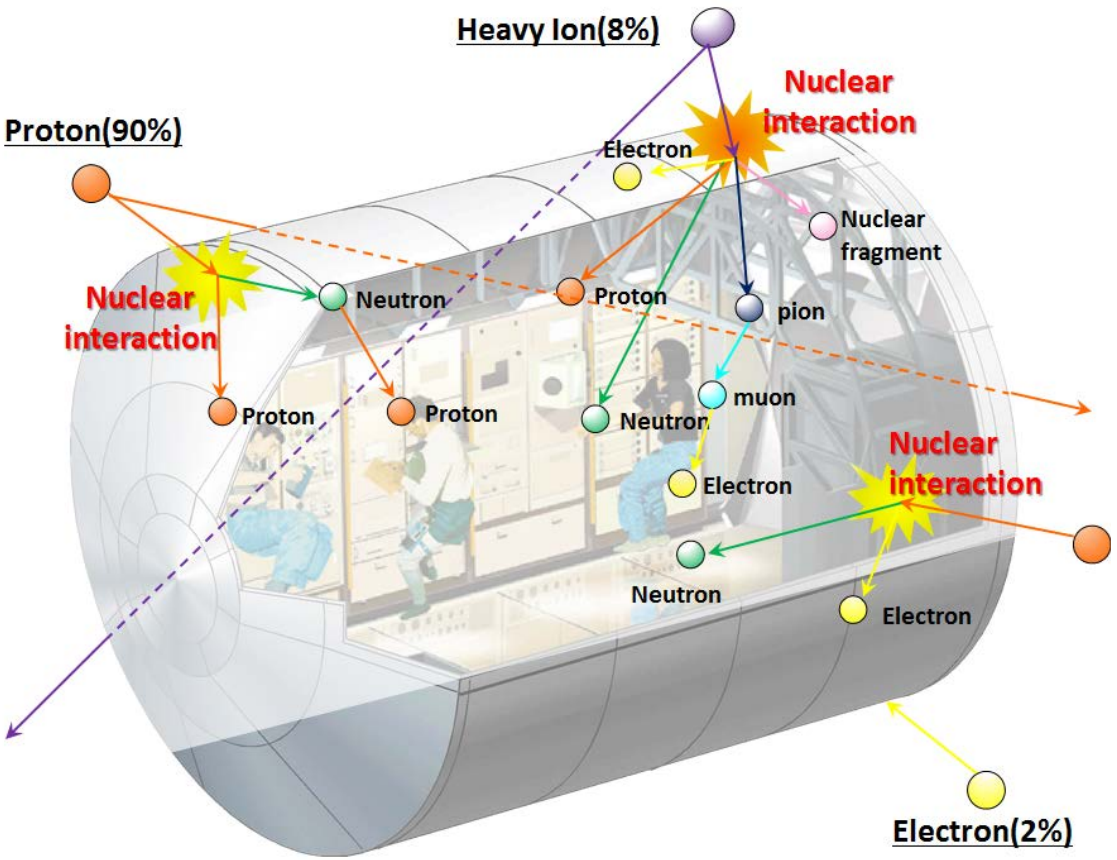
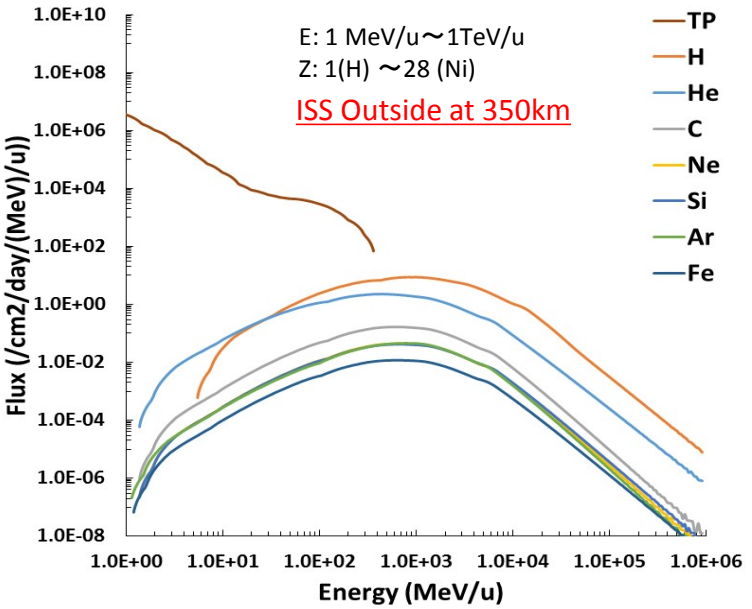
Shielding evaluation of the ISS 'KIBO' hull walls for space radiation between radiation dosimetry inside/outside and PHITS simulation



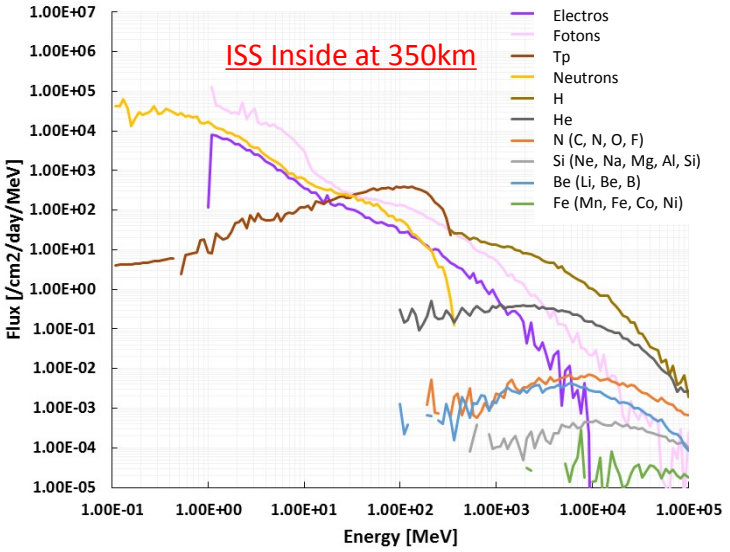
Aiko Nagamatsu (JAXA), Ken Shimada (AES), Keisuke Nishi (AES), Chiemi Matsumura (JAXA), Jun Shimada (JAXA), Daisuke Masuda (JAXA), Nakahiro Yasuda (RINE), Kazuo Takeda (RIST), Tatsuhiko Sato (JAEA)

<Background> Space Radiation interaction with material onboard the ISS





Simulated Energy Spectrum outside of the ISS



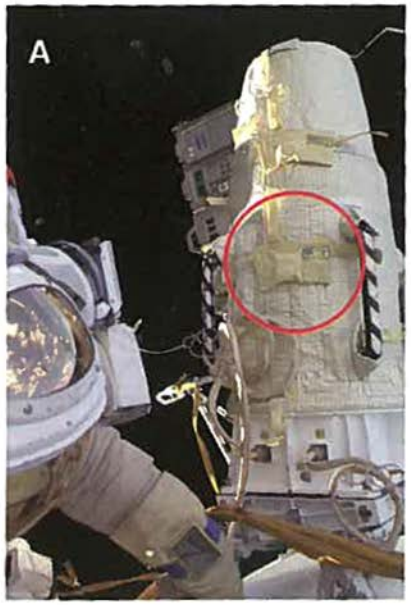
Simulated Energy Energy Spectrum inside of the ISS

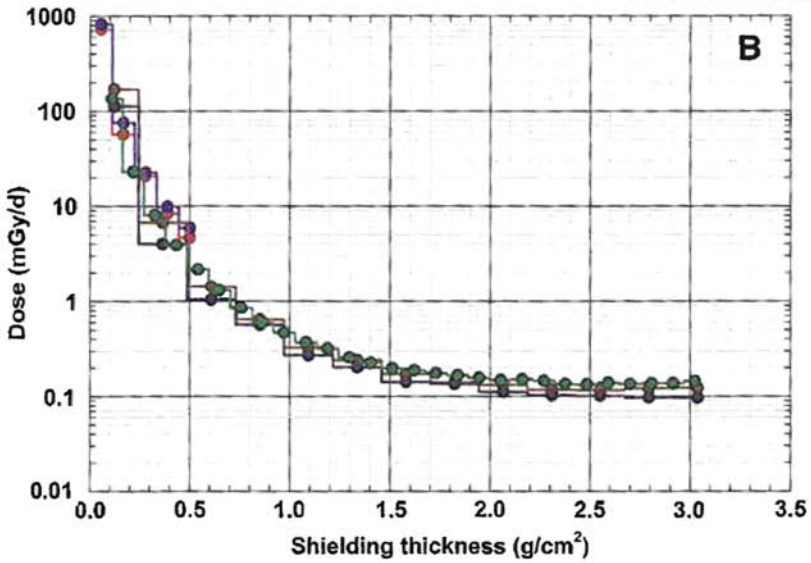
Three basic processes of energetic charged particle interactions onboard the ISS,

- Energy loss (dE/dx)
- Nuclear reactions
- Collisions with material nuclei

<Motivation> Direct measurement inside/outside ISS

- Shielding effect of each ISS module has not been looked at so far.
- There is limited data regarding outside doses.
  Past mesuarement data in most cases measured by only TLD.
  ⇒ We tried to measure outside doses with PADLES (TLD<10 keV/μm and CR-39 > 10 keV/μm)in all LET regions up to 1000 keV/μm in this time.
- Direct comparative study with inside / outside results are expected to be useful for
  - benchmark study of simulation code,
  - verifying current dose management process.





accounting for only upper shileding material on the surface of dosimeters.

FIG. 5. Decrease of the absorbed dose rate with shielding (B), as measured during the MATROSHKA mission (January 2004 to August 2005) (A) (data: ATI, DLR, IFJ). The circle indicates the position of the TLD stack attached to the MATROSHKA phantom.

T. Berger et, al., Cosmic Radiation Exposure of Biological Test System during the EXPOSE-E Mission, ASTROBIOLOGY Vol12, Numb 5(2012)

<Purpose of this work> Direct measurement inside/outside ISS

This is a series experiment jointly conducted with ExHAM or Small satellite deployment one or two times in a year.

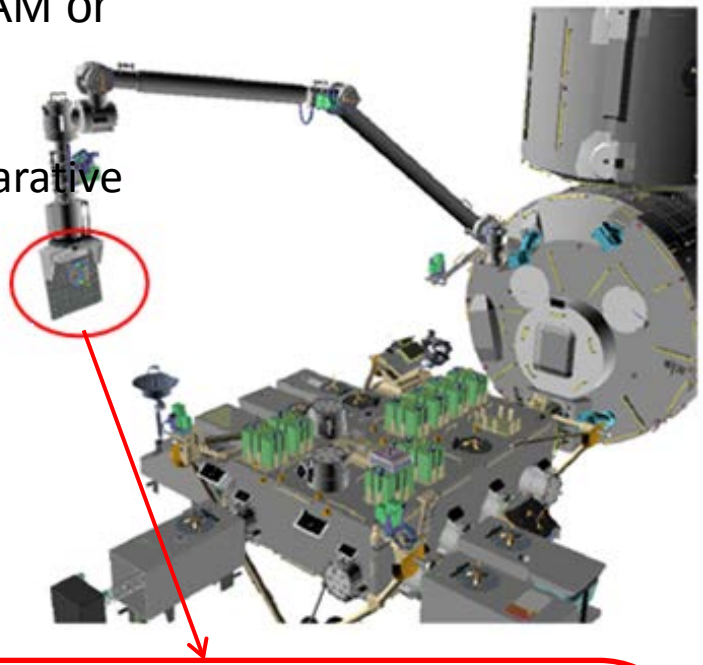
We try to conduct direct radiation measurement for comparative study with inside/outside results obtained from PADLES.

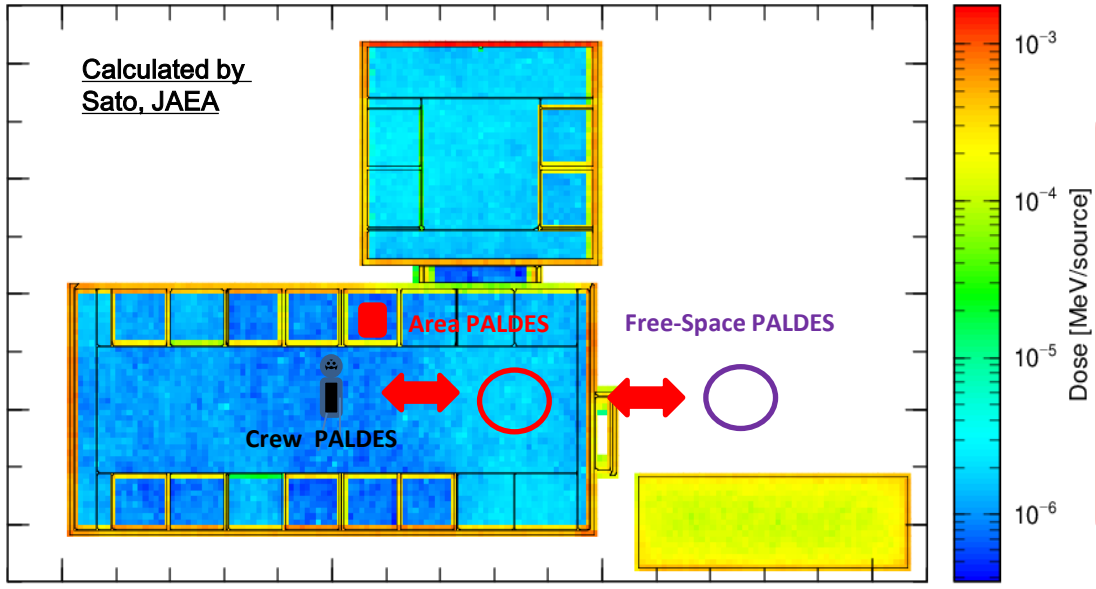
For Free Space PADLES experiment, a set of ①②③ is used.

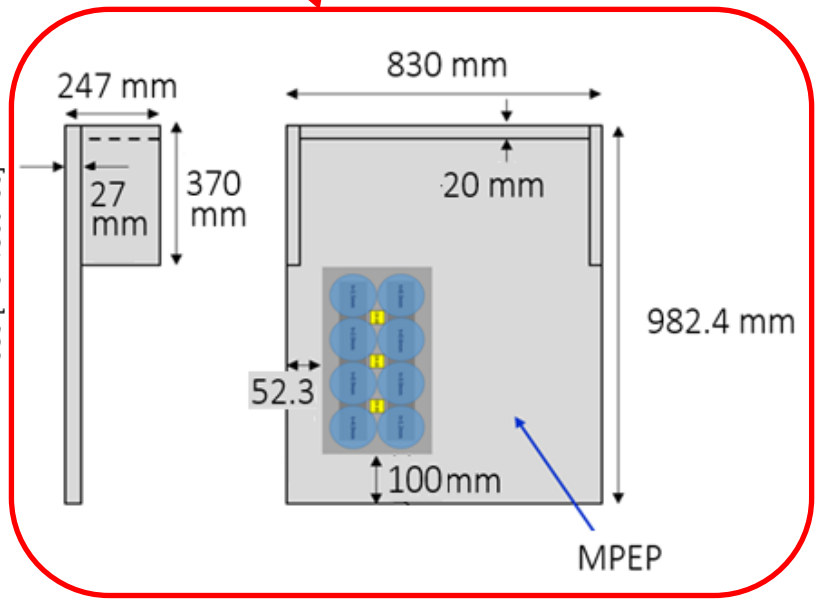
① Free-Space PADLES equipment with 8 Dome case

② Flight-control dosimeter kept inside ISS

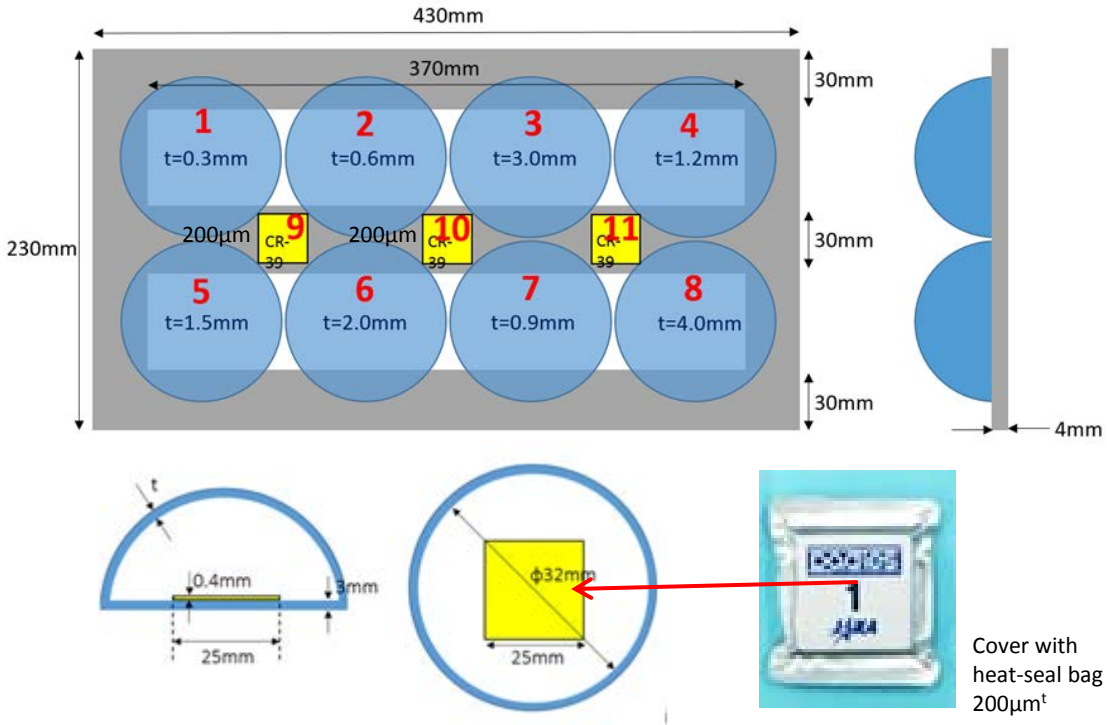
③ Ground control dosimeter kept on the ground







<Flight Experiment> A component of Free-Space PADLES equipment



Cover with heat-seal bag 200μm^{t}

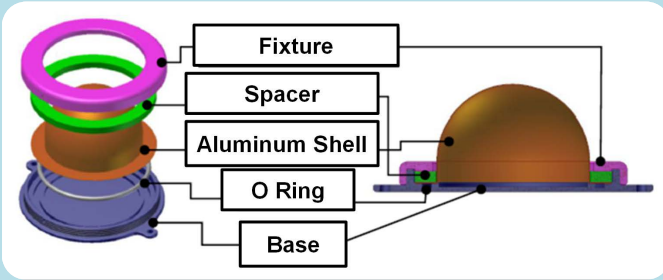
Free-Space PADLES equipment is made of AL.
Dome case : 0.3, 0.6, 0.9, 1.2, 1.5, 2.0, 3.0, 4.0 mm^{t}
The internal diameter of all cases were same.

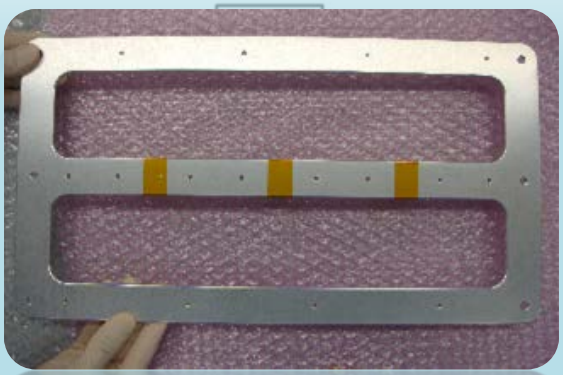
8 Free-Space PADLES
Dome case

Dosimeters and thermal loggers

*Each Free-Space Dome case includes two dosimeters and two thermal loggers.

Dome Case Parts

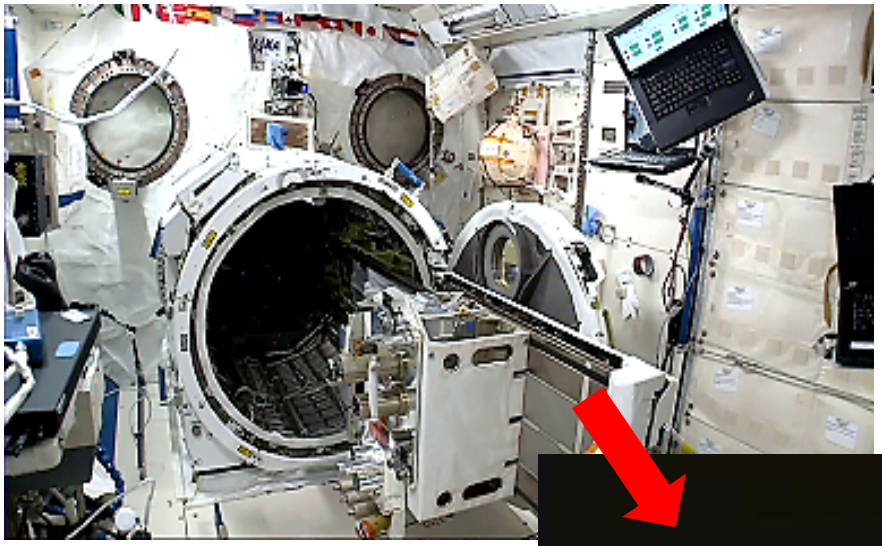




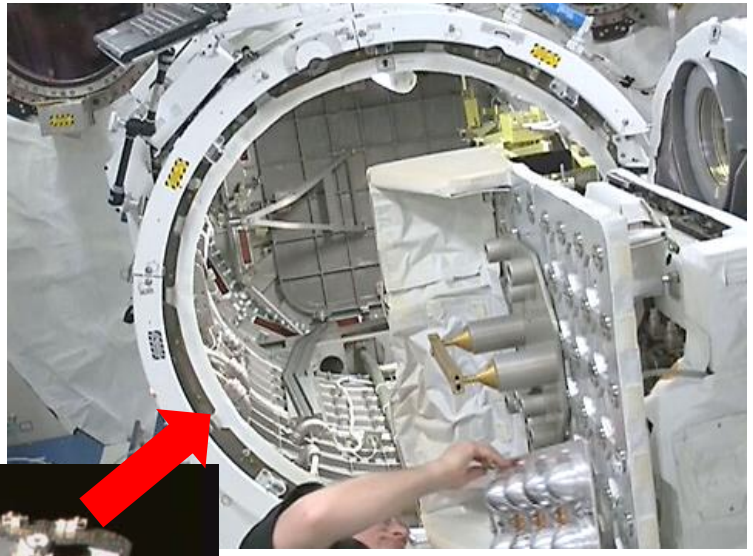
Free-Space Base plate

<Flight Experiment> Overview of Free-Space PADLES experiment

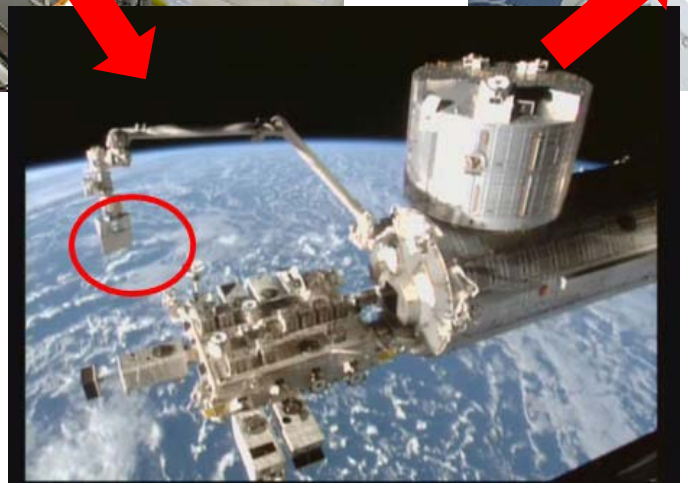
Event	Schedule	Orbiter
Launch	April 10, 2015	Spx-6
Flight Experiment	Total flight duration: May 14 to June 17, 2015 (240 days) Period in an exposed area: June 1 to 14 , 2015 (14 days)	ISS 'KIBO'
Return	December 11, 2015	43S



Free-Space PADLES was carried outboard via JEM Airlock（June 1, 2015）, JAXA/ NASA



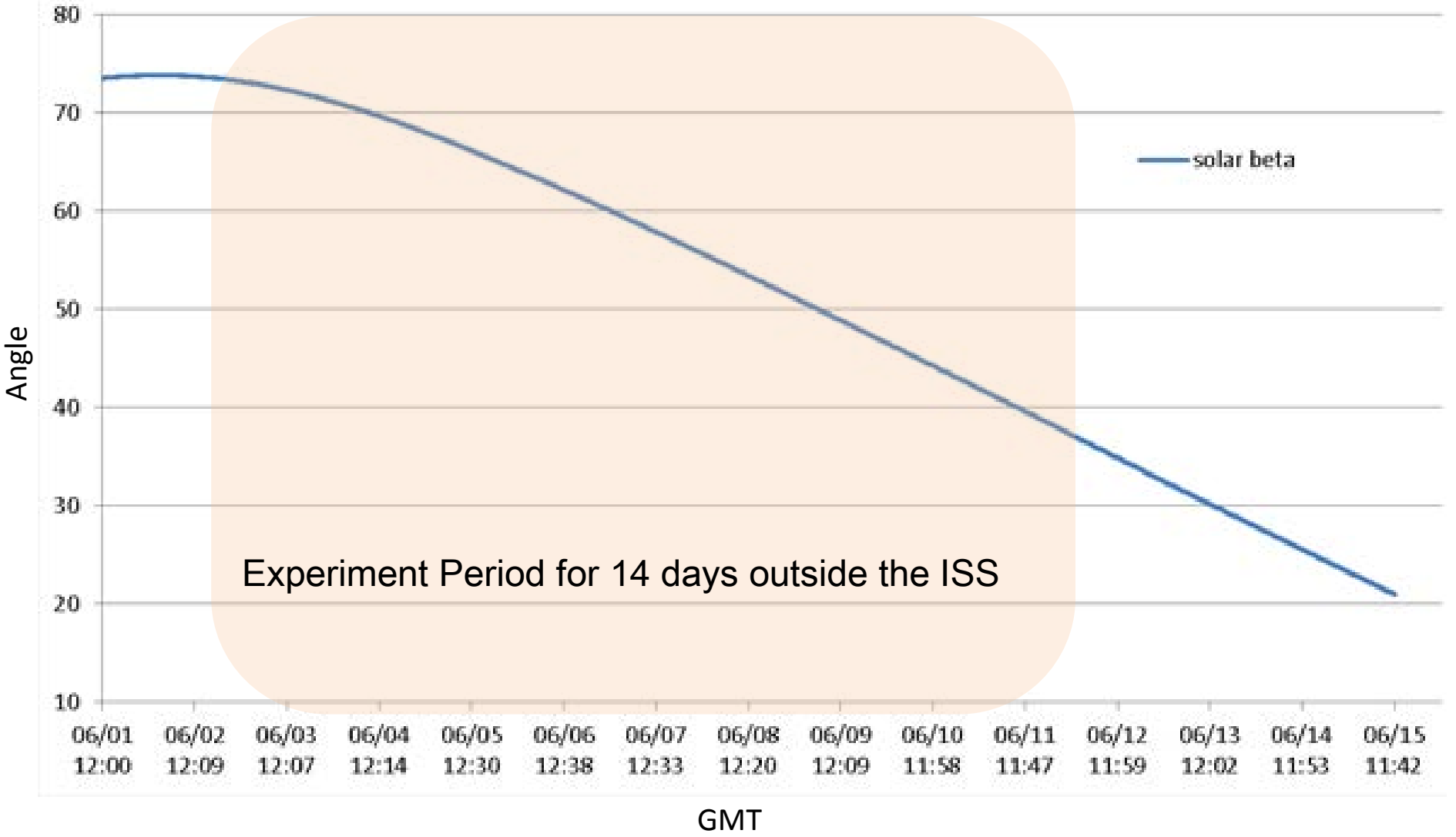
Astronaut Scott Kelly with Free-Space PADLES after removing from the airlock（June 17,2015）, JAXA/ NASA



Free-Space PADLES was exposed outboard for two weeks. JAXA/ NASA

<Flight Experiment> Solar Beta Angle for 14 days

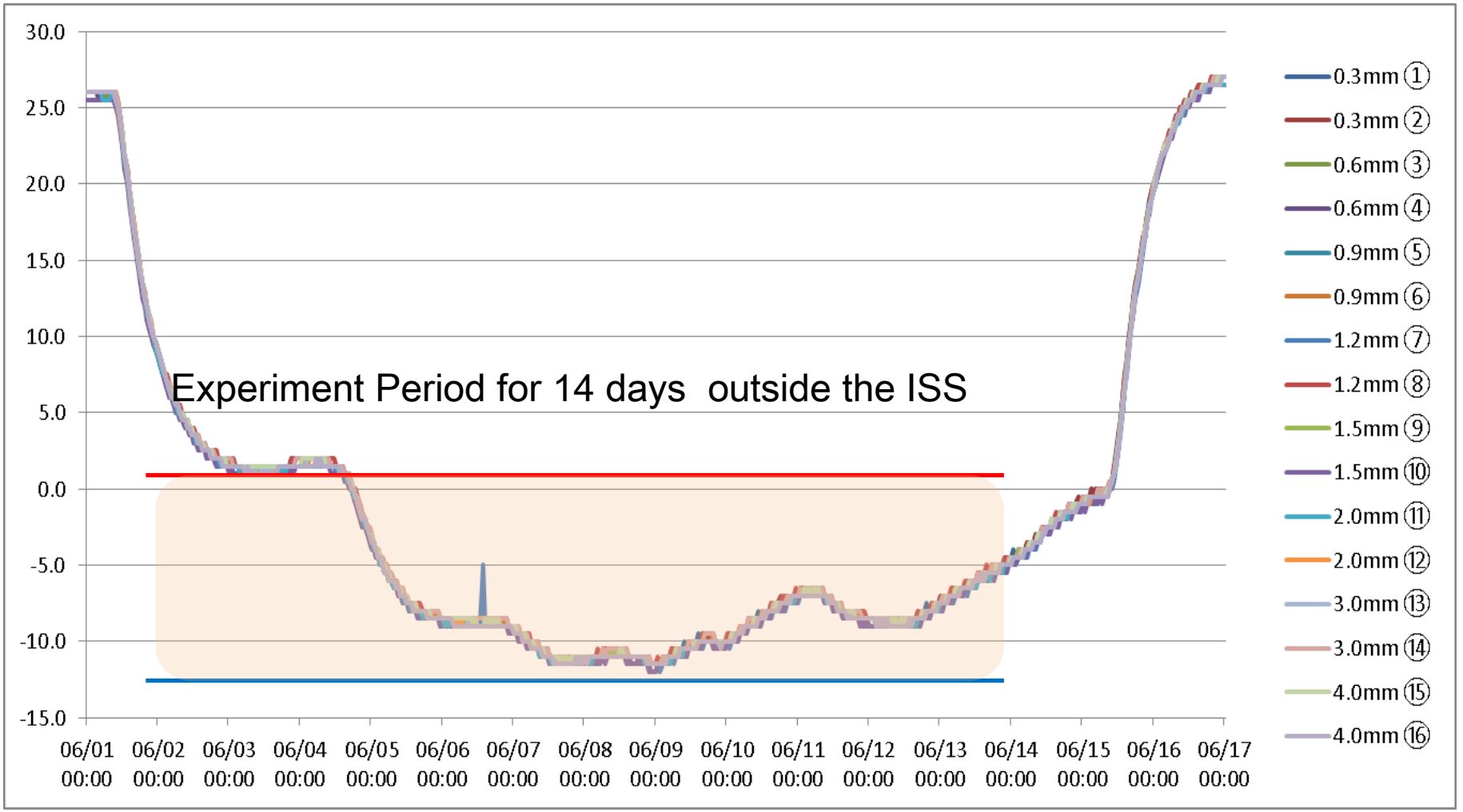
Averaged Altitude of ISS : 408.2 km between May 14 to June 17, 2015 (240 days)
407.7 km between June 1 to 14 , 2015 (16 days)
Solar Beta Angle: 74° to 21° from the beginning



<Flight Experiment> Experiment environment

Thermal analysis －15.1 to＋4.6 ℃
Measurement by thermal loggers－12.0 to ＋2.1 ℃

DS1922L-F5#
(CRES305/Maxim integrated Co.)



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)

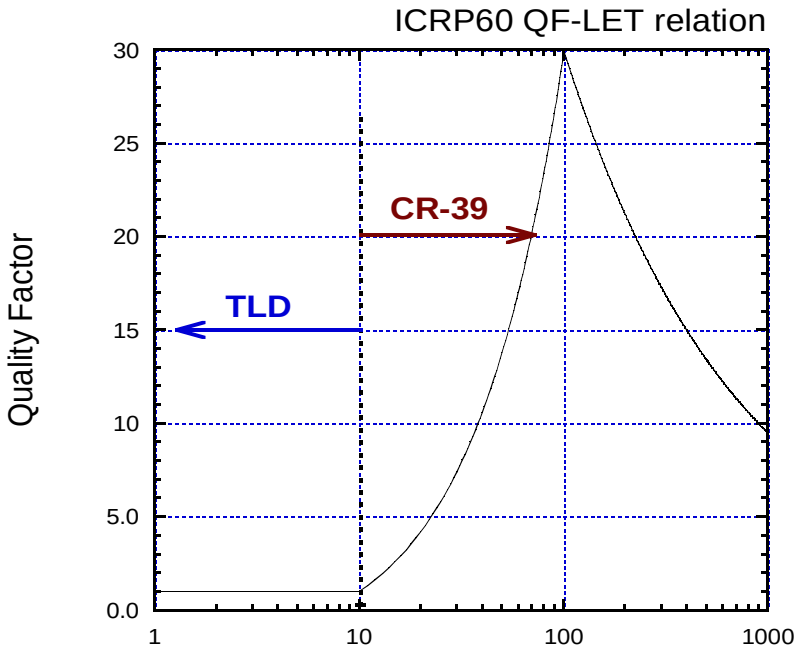
■ Total absorbed dose : D_{TOTAL} (Gy-water)

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

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

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

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

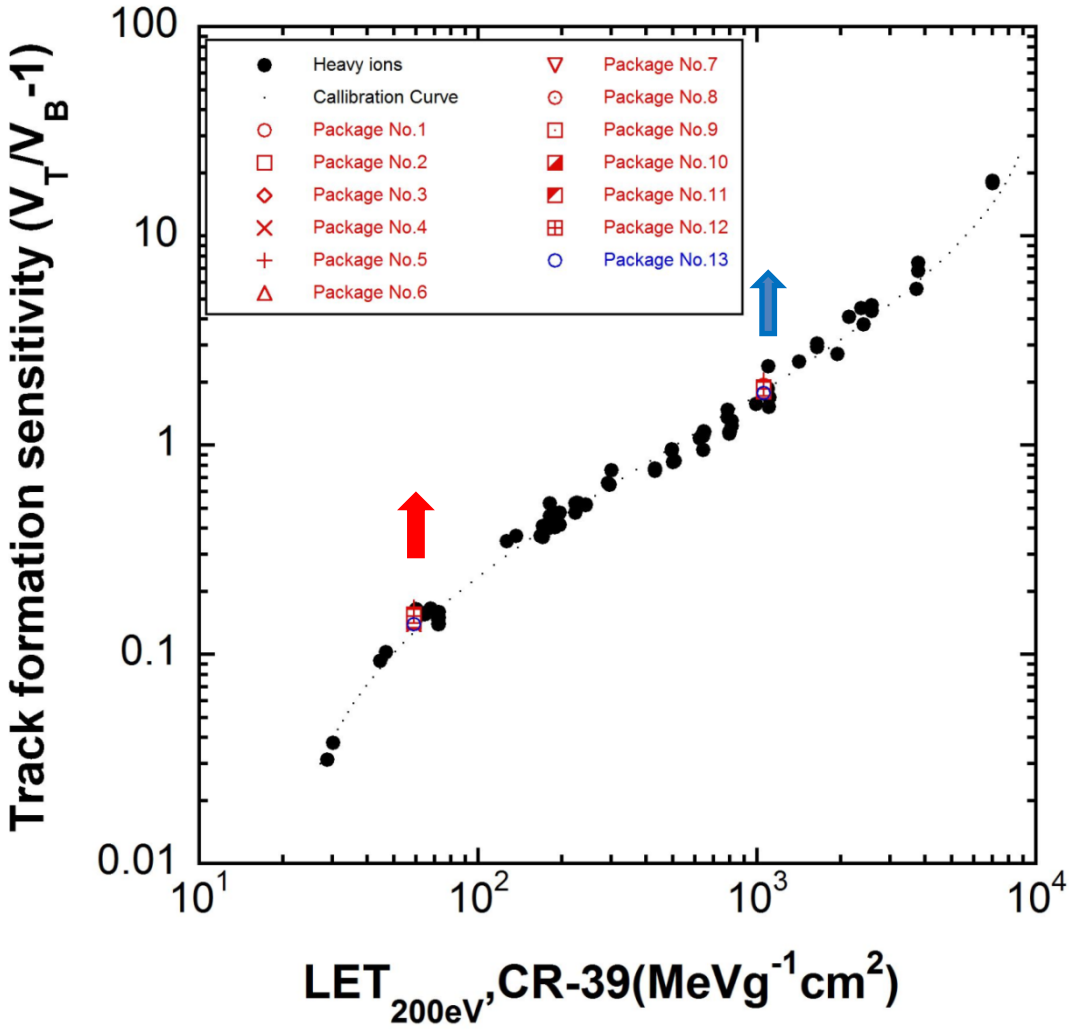


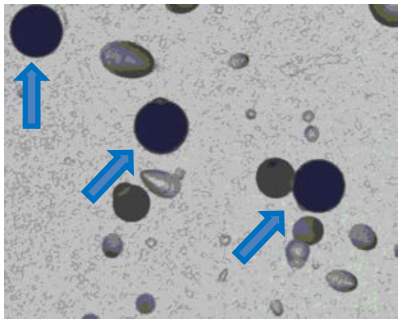
CR-39 measures a LET distribution of particle fluency ≥ 10 keV/μm

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), (2015)
H. Tawara et al., (2008), (2011)

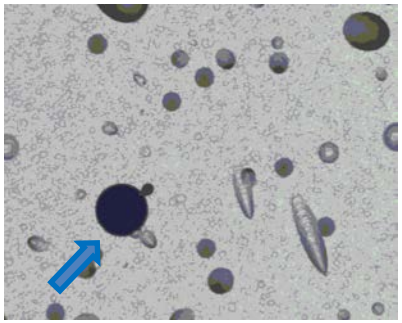
Sensitivity check with pre-irradiated CR-39 PNTD with known LET of C and Fe

One of the CR-39 plates is a sample previously exposed to C and Fe ions with the HIMAC heavy ion accelerator. This plate is used as a reference to check sensitivity stability of the CR-39 during a space flight experiment.

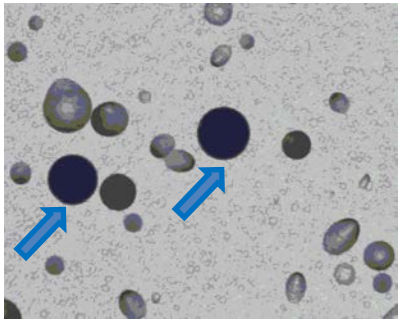




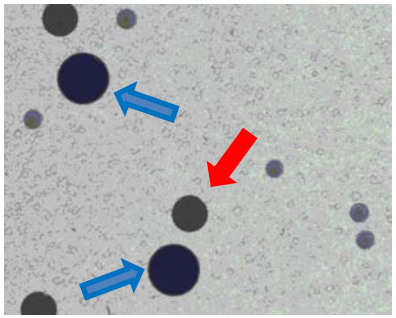
Outside
Dome Case
0.3 mm



Outside
Dome Case
4.0 mm

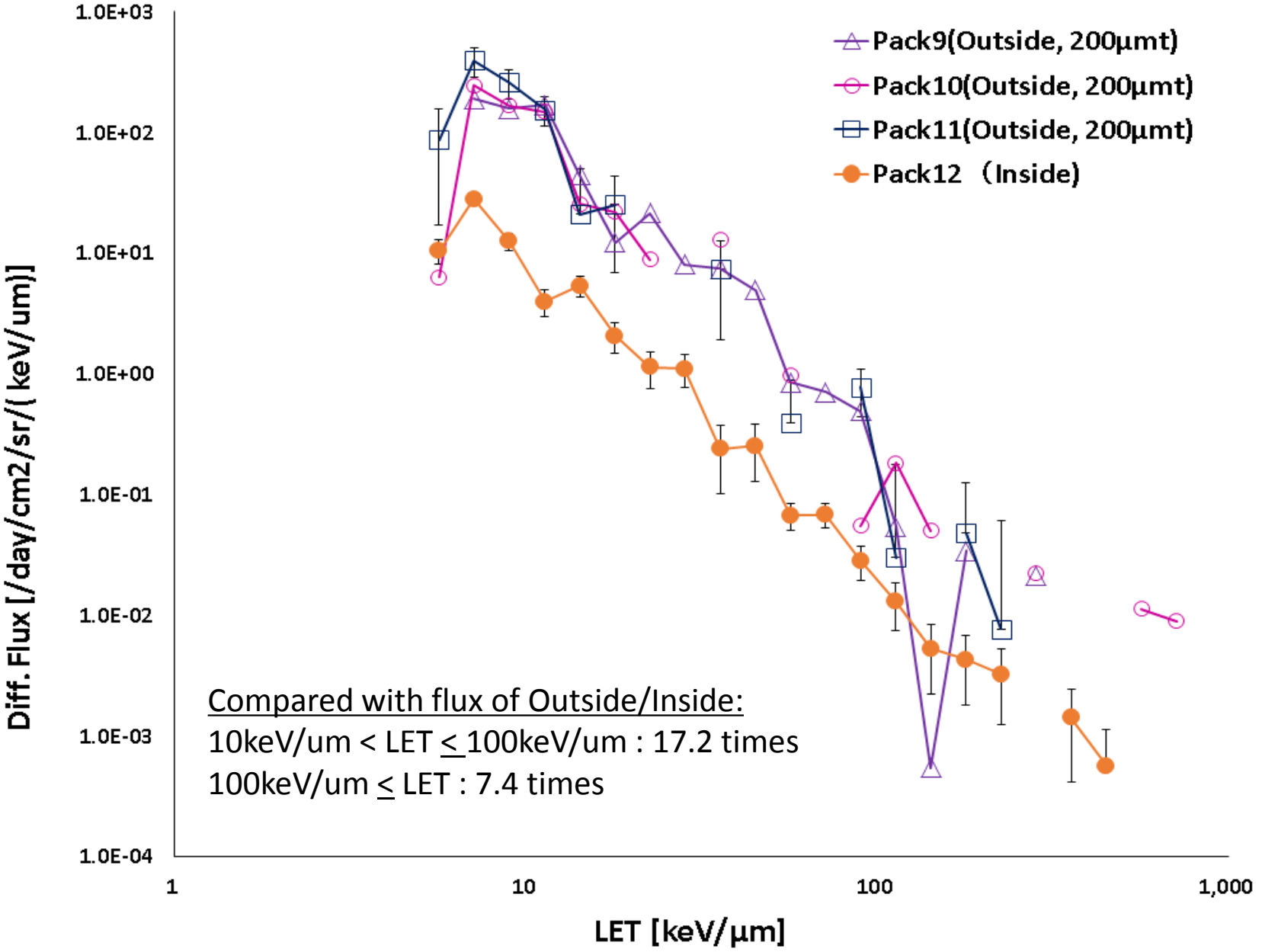


Inside



Ground Contorol

<Results> LET distributions – Preliminary (still under analysis up to N=10^4)



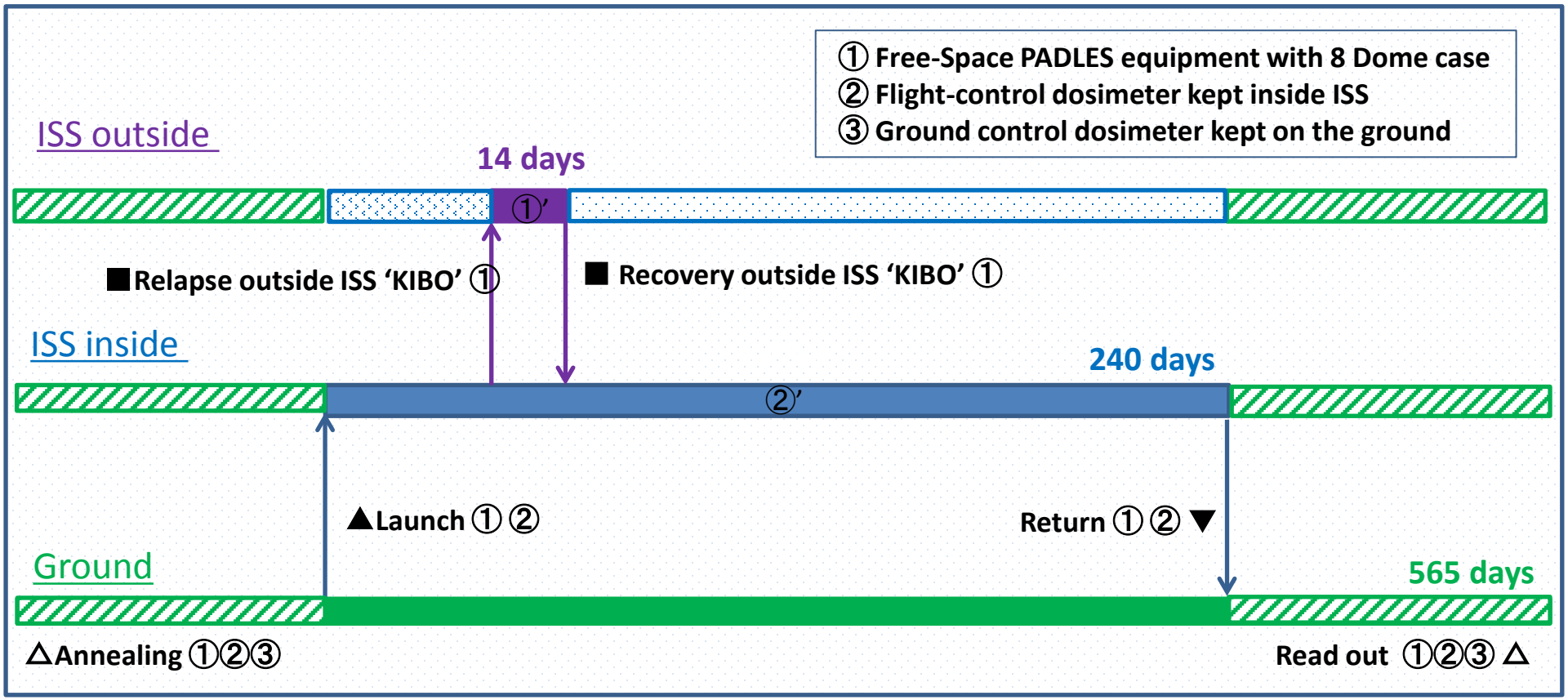
<Flight Experiment> Dose calculation using flight / ground control

◎ ISS Inside doses during 240 days

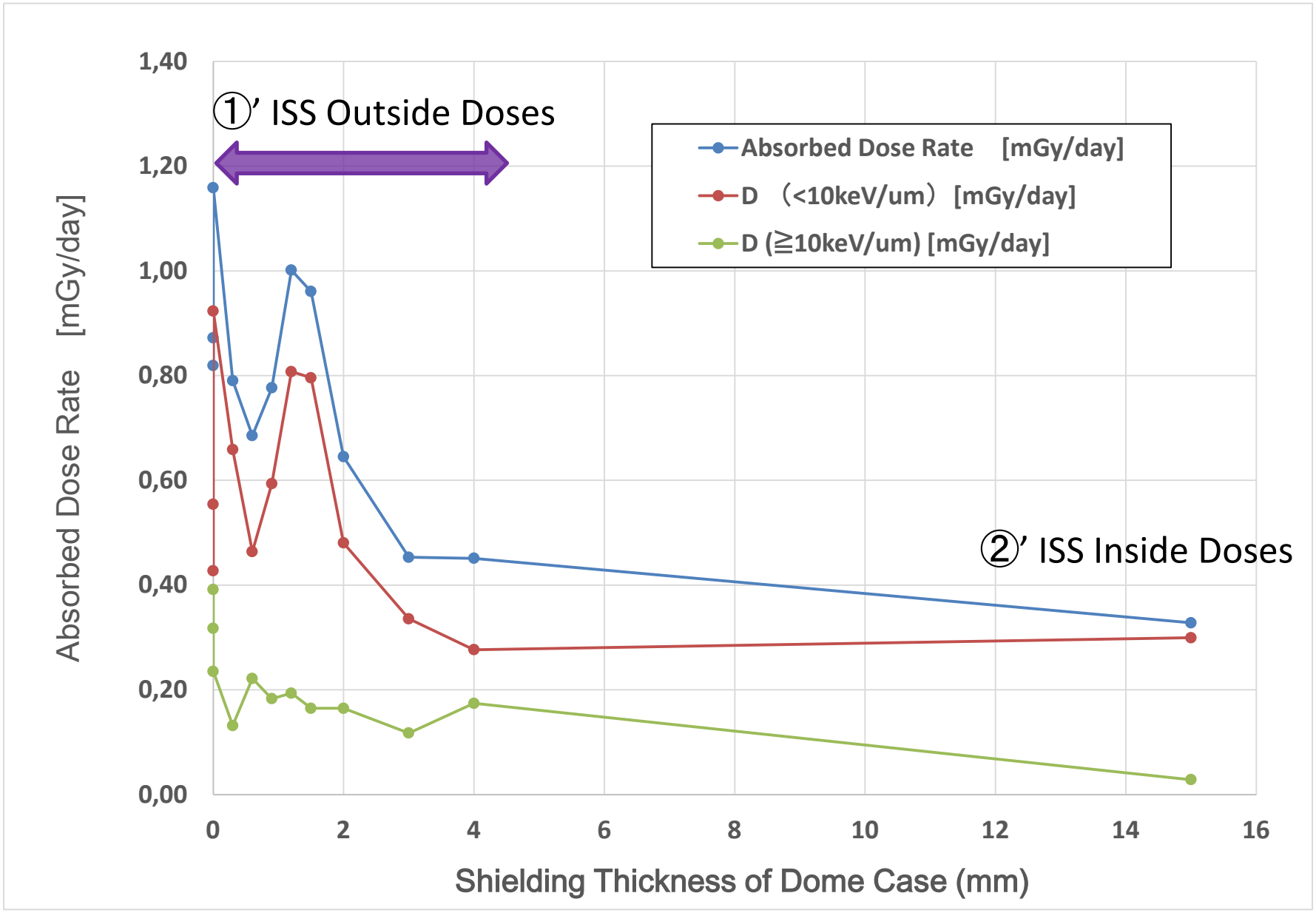
②' = ② − ③ ((565-240)/565))

◎ ISS Outside doses

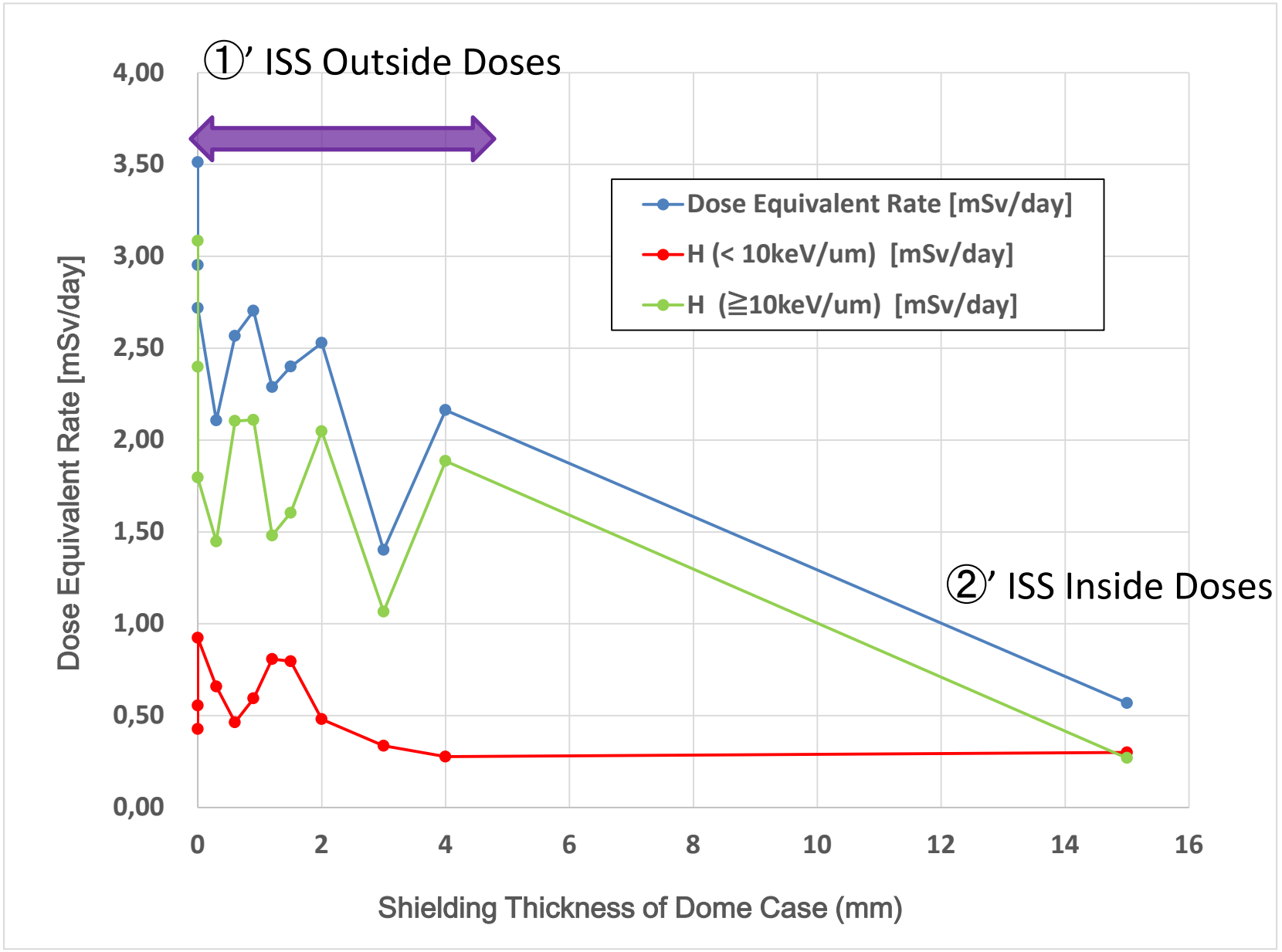
①' = ① −②' ((240-14)/240)



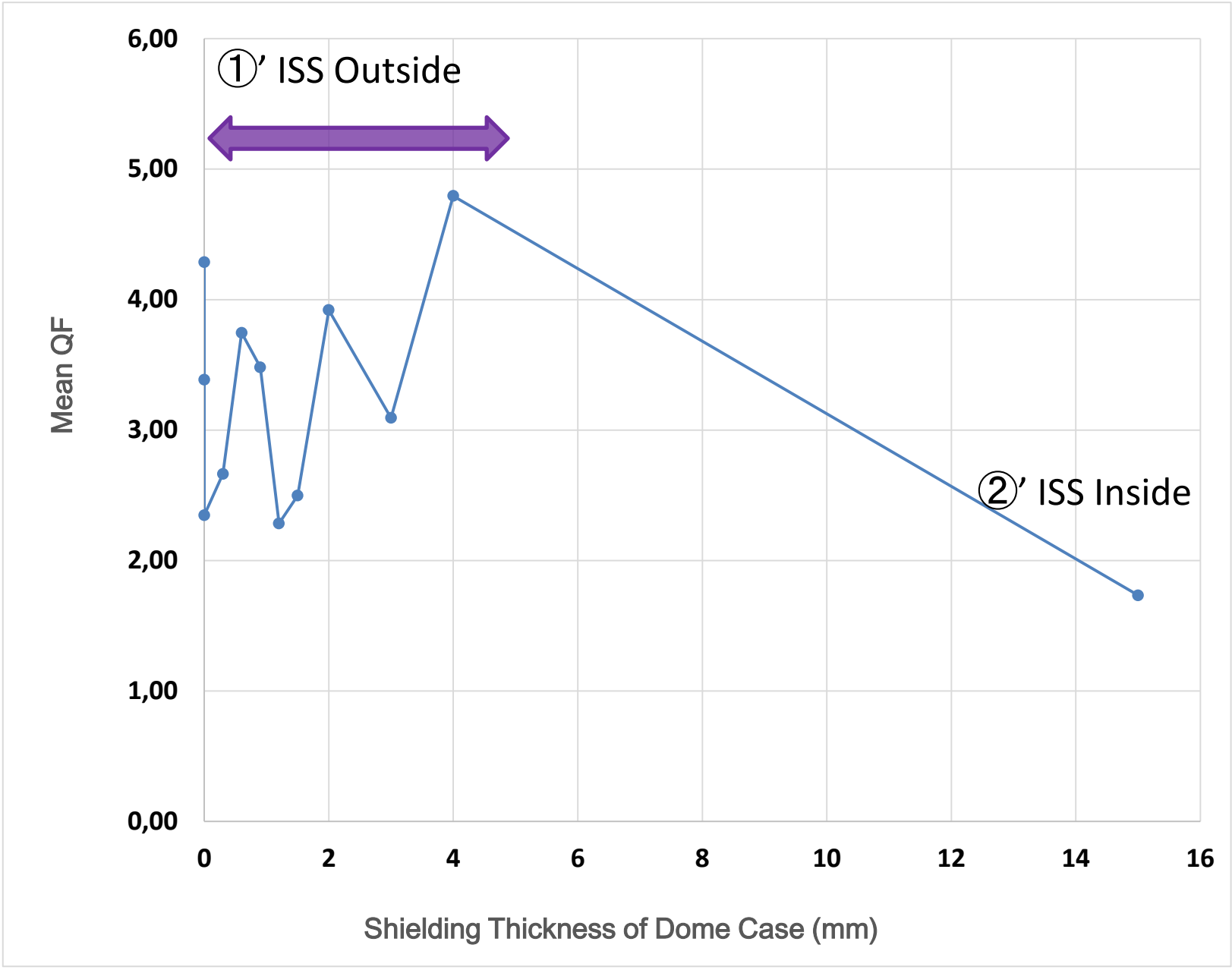
<Results> Variation of Absorbed Doses depending on ths AL thickness



<Results> Variation of Dose Equivalnets depending on ths AL thickness



<Results> Variation of Mean QF (ICRP60) depending on ths AL thickness



Summary of Free-Space PADLES experiment

Free-Space PADLES experiment to measure doses outside ISS 'KIBO' was conducted for
-240 days (May 14 to June 17, 2015) as total flight duration,
-14 days (June 1 to 14 , 2015) in an exposed area,
during the solar maximum of the 24th solar cycle.

- The flux of outside LET distributions are increased by 17.2 times than inside ones over several keV/um to 1000 keV/um,
  - 10keV/um < LET ≤ 100keV/um : 17.2 times
  - 100keV/um ≤ LET : 7.4 times

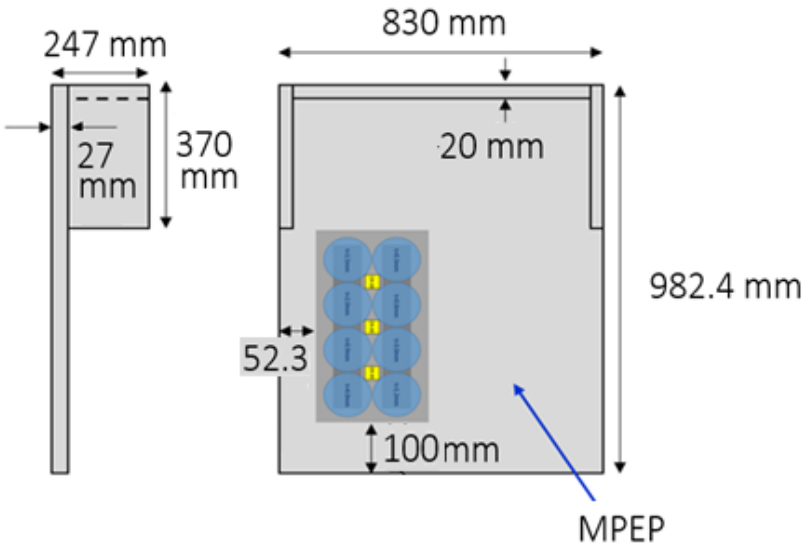
- Outside total doses obtained from PADLES (TLD/CR-39) varied in dome case with the range of thickness from 0.3 to 4 mm^t,
  : Absorbed doses 0.45 to 1.16 mGy/day,
  : Doses equivalents 1.40 to 3.51 mSv/day.

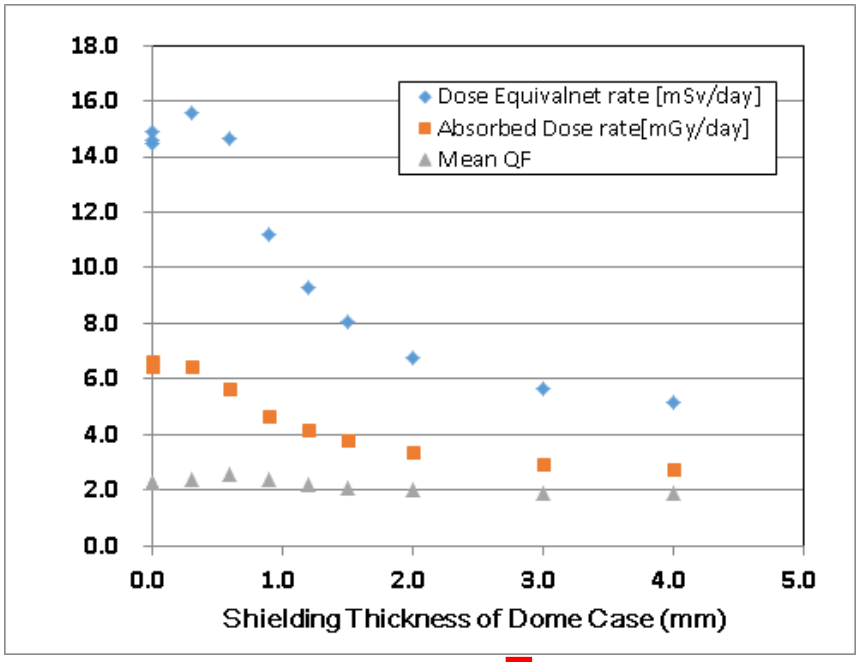
Inside doses kept in JPM1O2_A1 OVHD (equivalent to 15 cm^t in AL) during the experiment
: Absorbed doses 0.33 mGy/day,
: Doses equivalents 0.57 mSv/day.

Outside mean QF are higher (2.35 to 4.79) than inside (1.73).

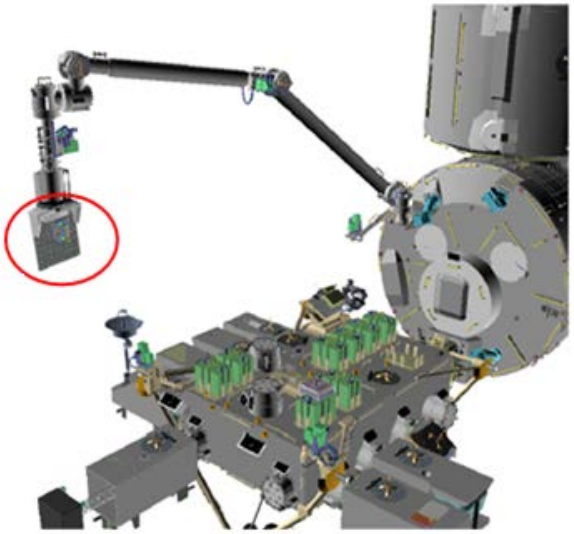
Future Plan : Comparative Study between Meas. and SIM. with PHITS

Step 1 : Free Space PADLES on the MPEP





Step 2 : Free Space PADLES on the MPEP close to ISS KIBO



☐ Estimation of dose reduction rate accounting for ISS 'KIBO' model,

— Contribution of 'KIBO' module to doses reduction in an exposed area

— Comparative study between Meas. and SIM.

JAXA detectors used for dose management system / research

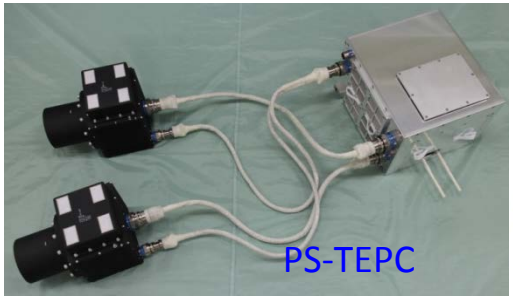
	Active	Passive
Personal doses	D-Space	Crew PADLES
Area doses (inside)	PS-TPEC	Area PADLES
(Outside)	RRMD-5	Free-Space PADLES

1 . ISS Space radiation dosimetry
- PADLES (Passive type)
From 2001 ~ aboard the ISS

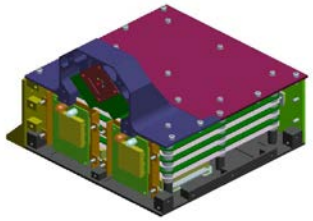
- PS-TEPC (Active type)
From end of 2016 ~ aboard the ISS KIBO

2. BLEO radiation dosimetry
- RRMD-V/DOES (Active type)
From 2018, using lunar satellites

- Personal alarm monitor
(Active type)
From 2017 ~ aboard ISS KIBO



RRMD-V



JAXA D-space part of the “au x HAKUTO MOON CHALLENGE”

The HAKUTO rover is perticipating to the Google Lunar XPRIZE challenges privately funded space exploration teams to land a privately funded rover on the Moon by the end of 2017, drive it for more than 500 meters and send high-definition videos and imageries back to Earth.

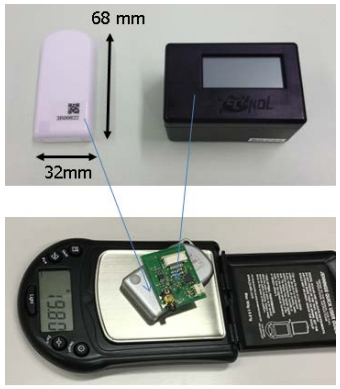


Fig.1 Radiation monitor and
Optical communication board

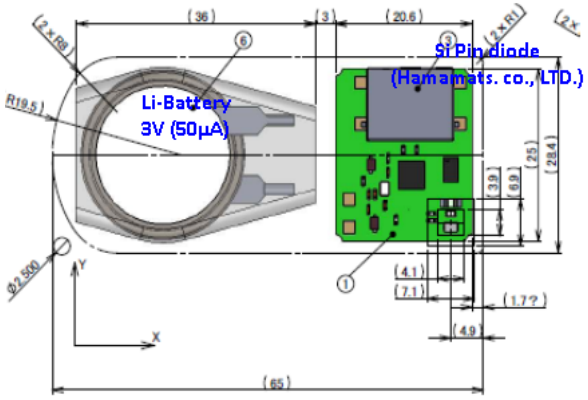


Fig. 2. Schematioc view of radiation monitor

HAKUTO https://team-hakuto.jp/