

17th WRMISS Workshop @Austin, Texas,
4th -6th September 2012



Estimation of Organ Doses Using PADLES in the Phase 2B_KIBO Experiments of the MATROSHKA Project

Aiko Nagamatsu¹, Keiji Murakami¹,
Hiroko Tawara^{1,2}, Kiichi Kitajo³, Ken Shimada³,
Thomas Berger and Gunther Reitz

1. JAXA Space Environment Utilization Center
2. KEK Radiation Science Center
3. Advanced Engineering Services Co.,Ltd.
4. German Aerospace Center (DLR).

Organization chart related to Space Radiation Research in JAXA human space system and utilization directorate

① Material Science - Radiation Group (Utilization, OZ)

Keiji Murakami Ph.D. (Manager)



Passive (**PADLES**) and Active (**PS-TEPC**) Dosimetry for Area/ Bio/ Crew, Database construction, Code simulation and international joint study. (in cooperation with NIRS, JAEA and ISS partners.)

A. Nagamatsu Ph.D.



T. Fuse



PS-TEPC

S. Sasaki Ph.D. (KEK)
K. Terasawa (Keio Univ.)
and the research team

PADLES



H. Tawara Ph.D. (KEK) K. Kitajo (AES) K. Shimada (AES)



② Astronaut Medical Operations Group (Space medicine, SA)

Masafumi Yamamoto (Director)



Dose records and administration for JAXA astronaut Space weather.



M. Sato



T. Matsumura



T. Kaneko



A. Nagamatsu Ph.D.

③ Space Biomedical Research Office (OZ / SA)

Masafumi Yamamoto (Director)



Biological effects for space radiation particles



A. Nagamatsu Ph.D. T. Asaka Ph.D.



1. ISS Space radiation dosimetry

- **PADLES** (Passive type)

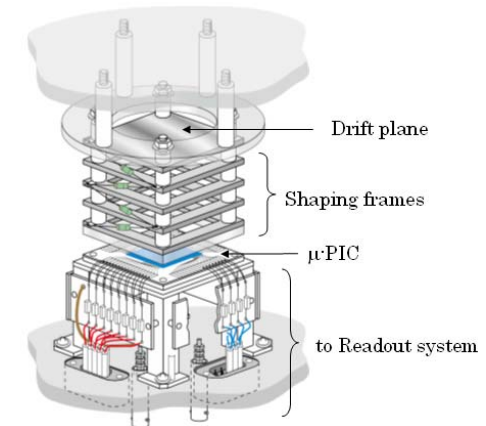
Jun.2008 ~ on board the KIBO



- **PS-TEPC** (Active type)

Target Vehicle

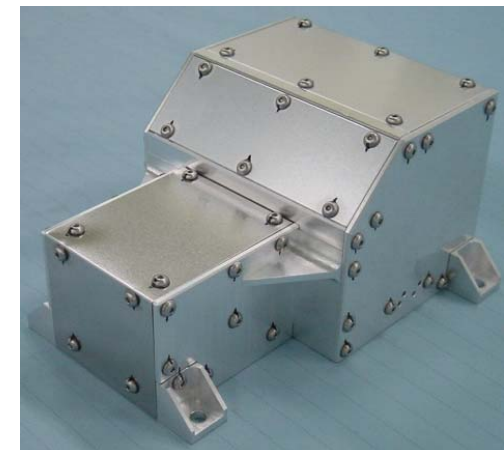
HTV5 (2014 June)



2. Lunar radiation dosimetry

- **RRMD-V** (Active type)

later on 2016



I . PADLES Methodology

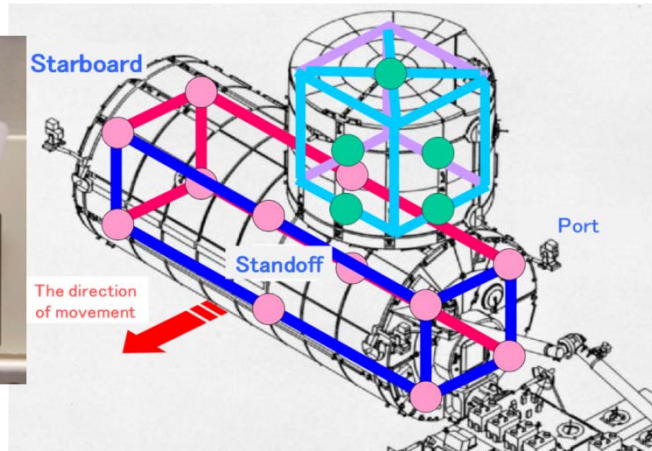


Space Radiation dosimetry using **PADLES**

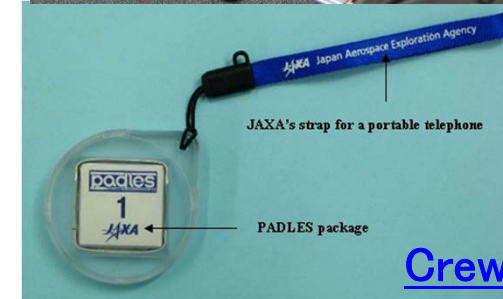
Radiation area monitoring on board the KIBO



Area PADLES



Crew personal dosimetry

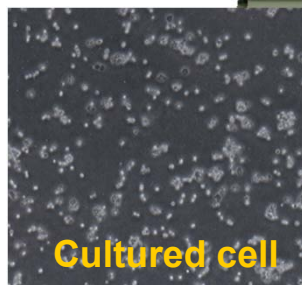


Crew PADLES

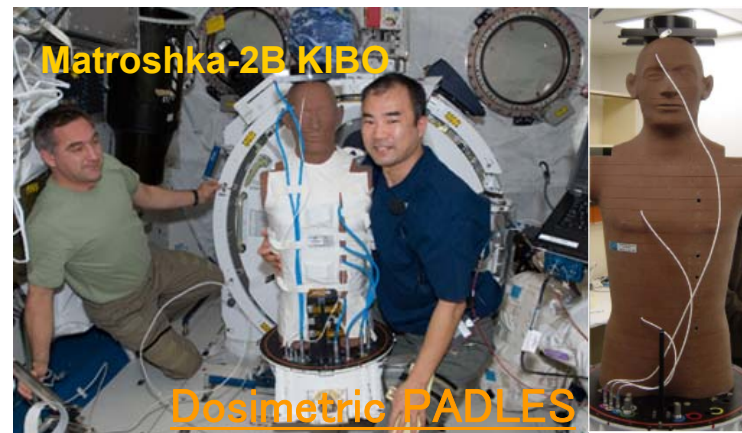
Radiation dosimetry of biological samples



Bio PADLES



International Cooperation



PADLES (Passive Dosimeter for Life science Experiments in Space)

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

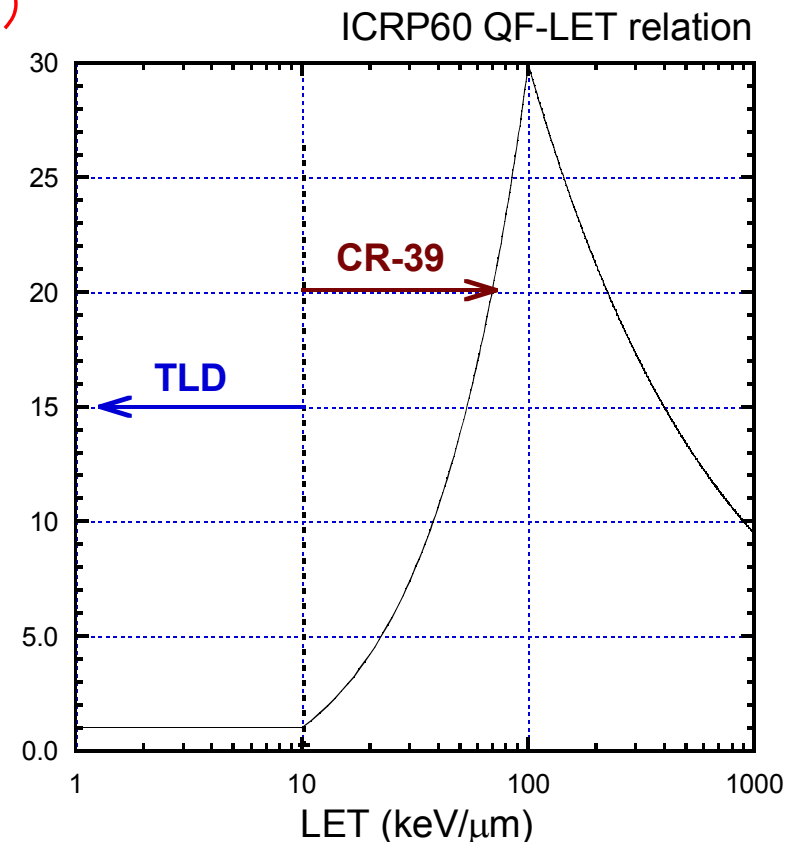
$$\begin{aligned}
 D_{TOTAL} &= D_{\leq 10 \text{ keV} / \mu\text{m-water}} + D_{> 10 \text{ keV} / \mu\text{m-water}} \\
 &= (D_{TLD} - \kappa D_{CR-39}) + D_{CR-39} \\
 &= D_{TLD} + (1 - \kappa) D_{CR-39}
 \end{aligned}$$

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

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

κ : mean TL efficiency for high-LET particles

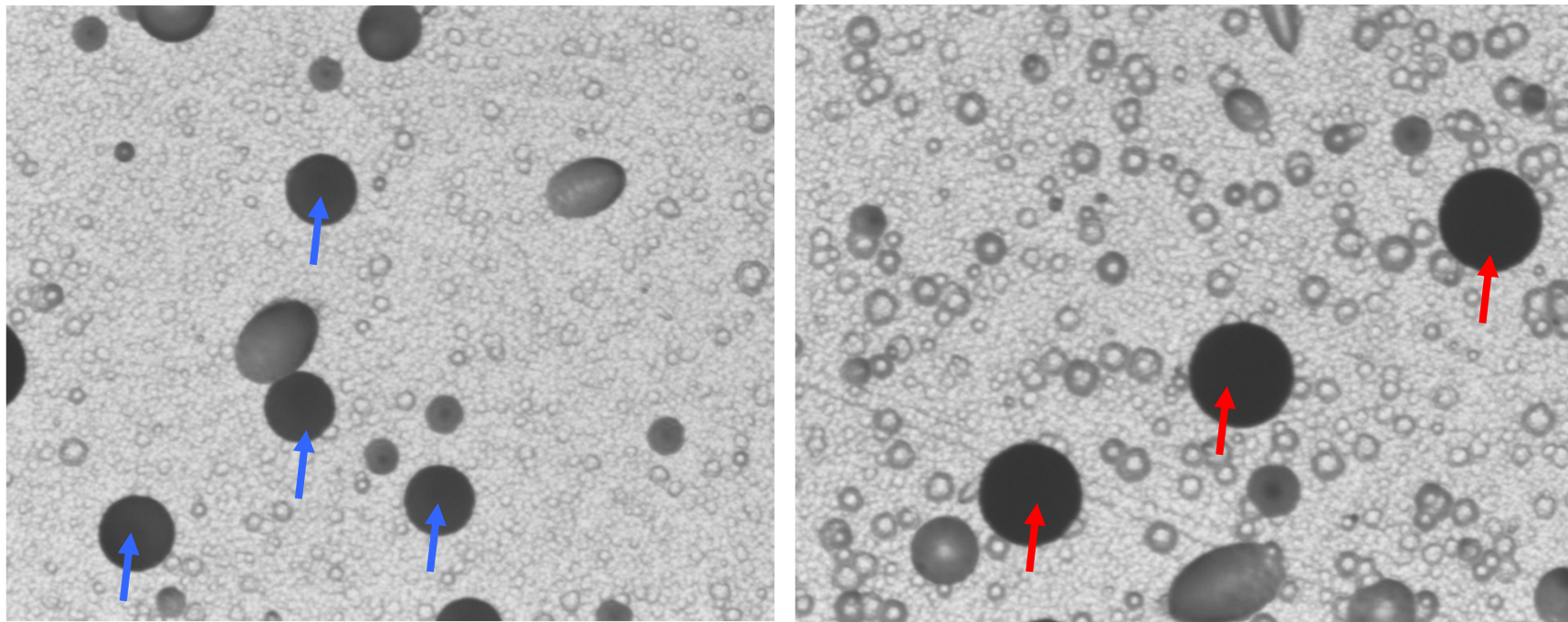
Quality Factor



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)
 H. Tawara et al., (2008)

CR-39 sensitivity check before LET measurements

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.

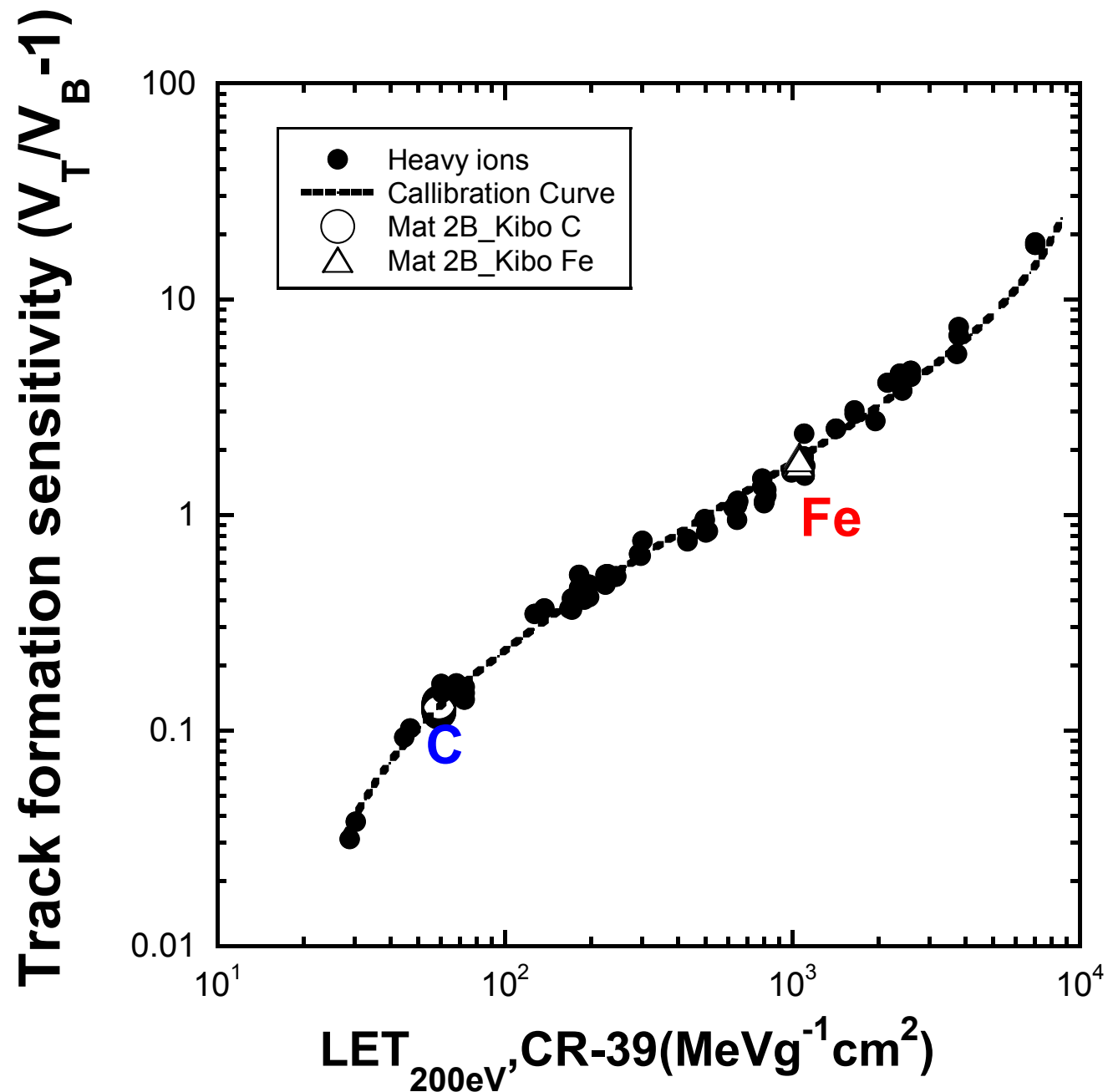


Reference sample after 23 μ m etching on board the Mat 2B_KIBO
Package No.5 Stomach

Kept in 310/322 days. It has a magnification of $\times 200$.

(blue arrow) C 290MeV/n, (red arrow) Fe 500MeV/n

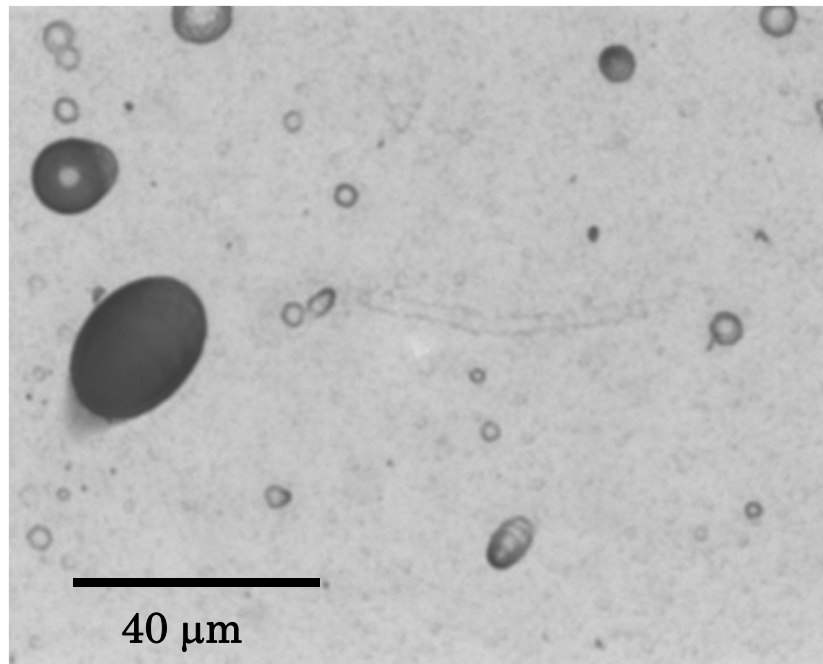
Results of Matroshka 2B_Kibo ~ CR-39 sensitivity check ~



Surface on CR-39 PNTD after chemical-etching using 7N NaOH

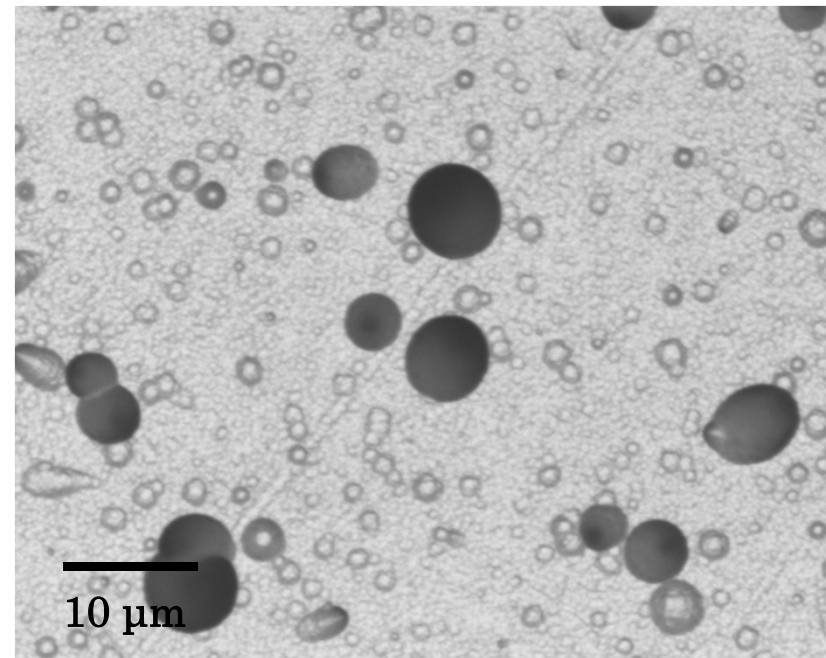
8 μ m etching (SRP) sample

$>50\text{keV}/\mu\text{m}$

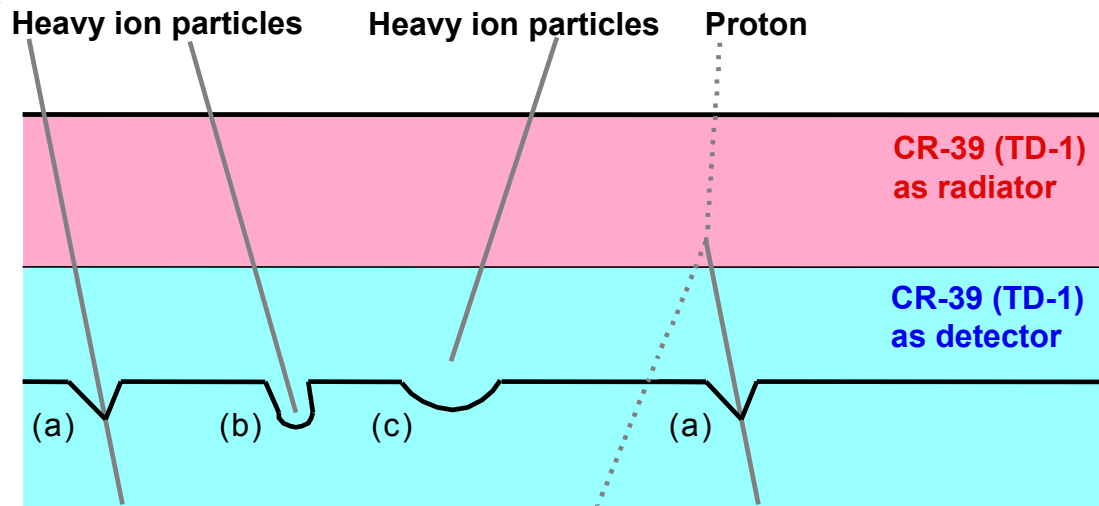


23 μ m etching (LRP) sample

$\leq 50\text{keV}/\mu\text{m}$

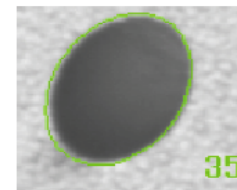
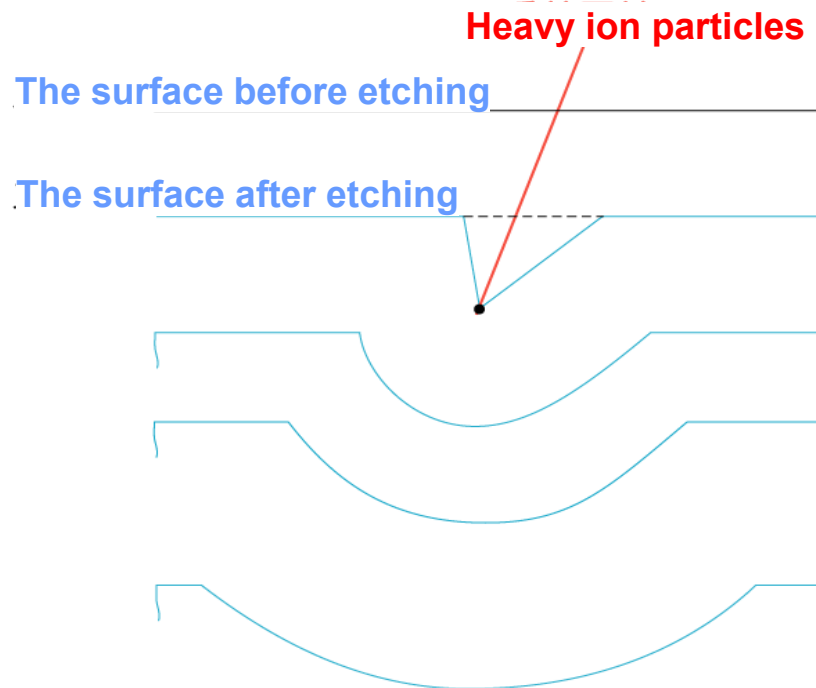


Definition of detection surface on CR-39 PNTD

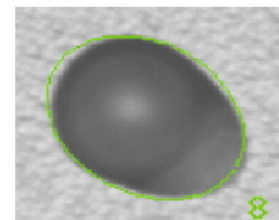


After chemical etching,
we detect the particles
passing through the surface.

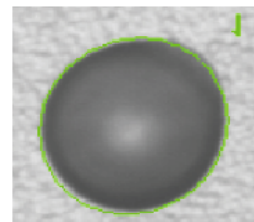
← The surface for fluence
measurements



○ (a) selected



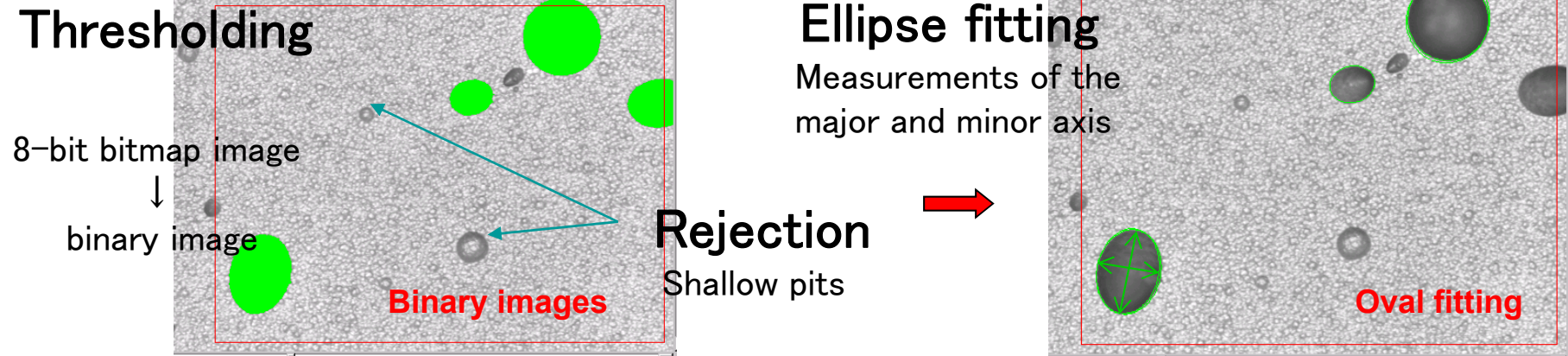
× (b) rejected



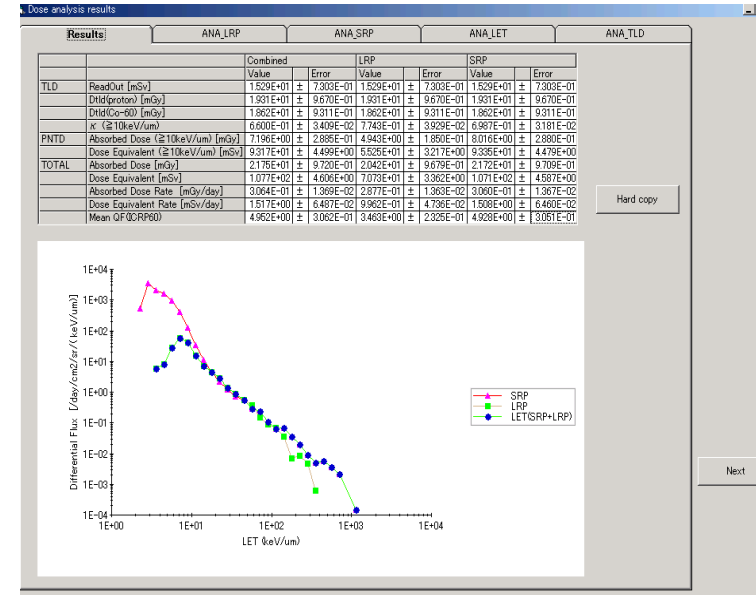
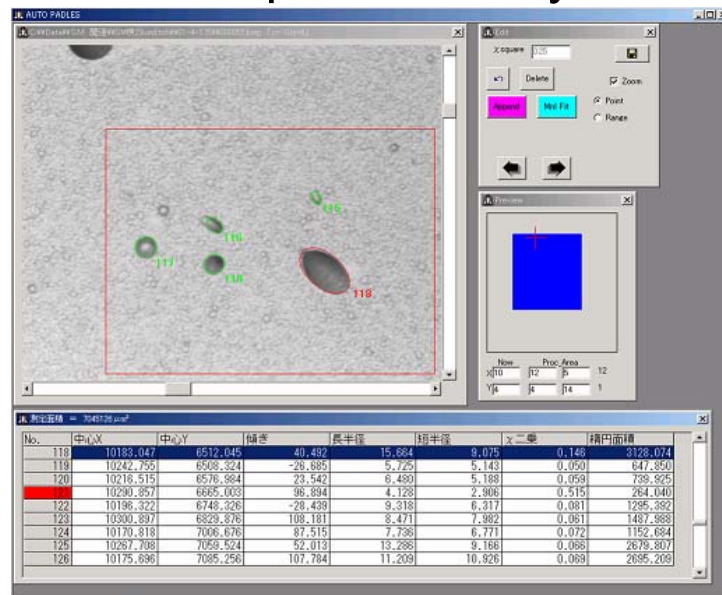
× (c) rejected

AUTO PADLES program

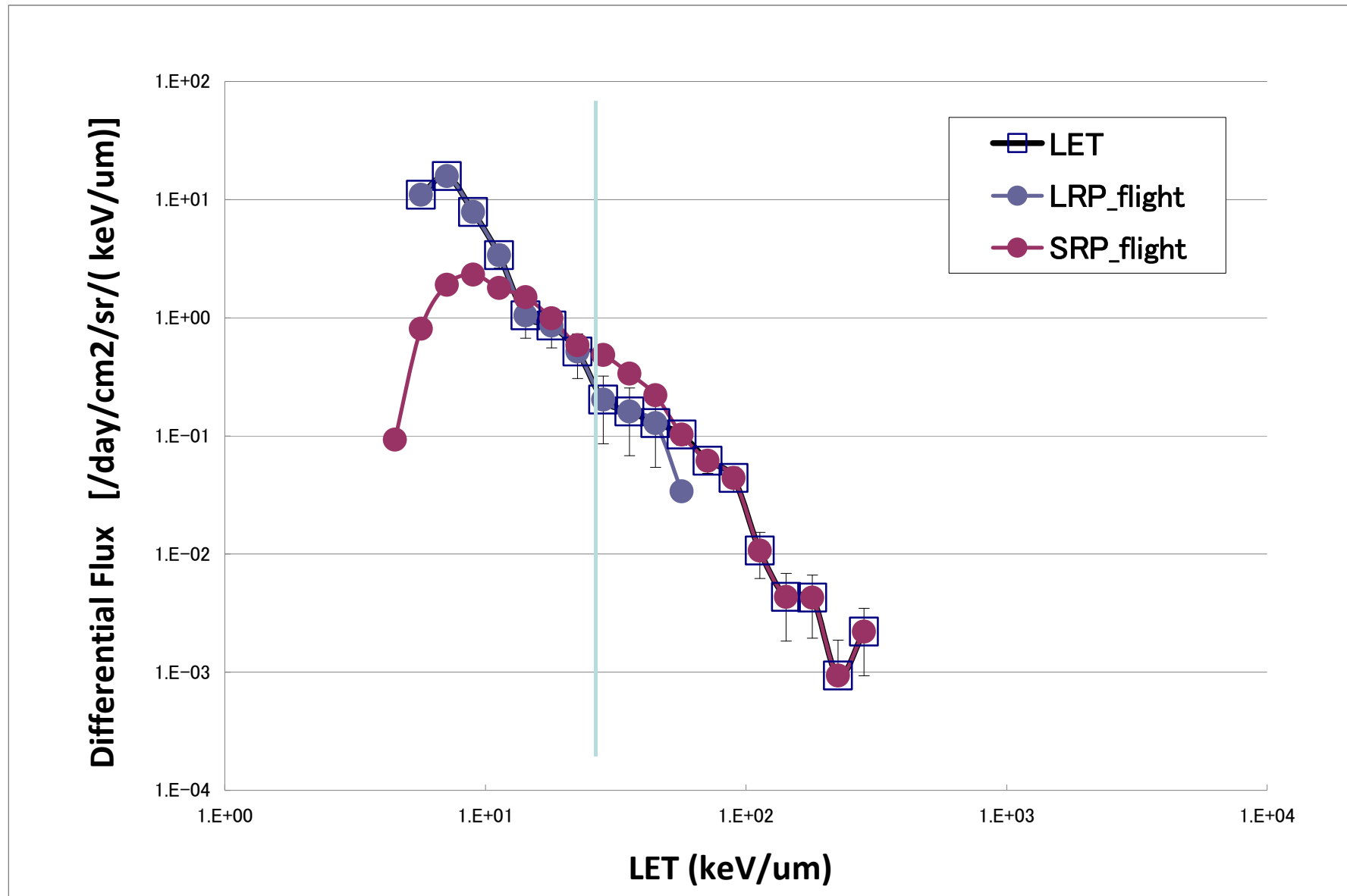
- Automatic measurement LET obtained from the measurement of the major and minor axis of heavy ions tracks. We have developed the soft ware 'AUTO PADLES' for measuring several thousand tracks. (Ellipse fitting program, N. Yasuda et.al. (2005))



- an automatic calculation of LET distributions, absorbed doses, dose equivalents, by a combination of the TLD and CR-39 data.



LET Distribution combined with $<$ and $> 50 \text{ keV}/\mu\text{m}$



Mat 2B_Kibo Stomach

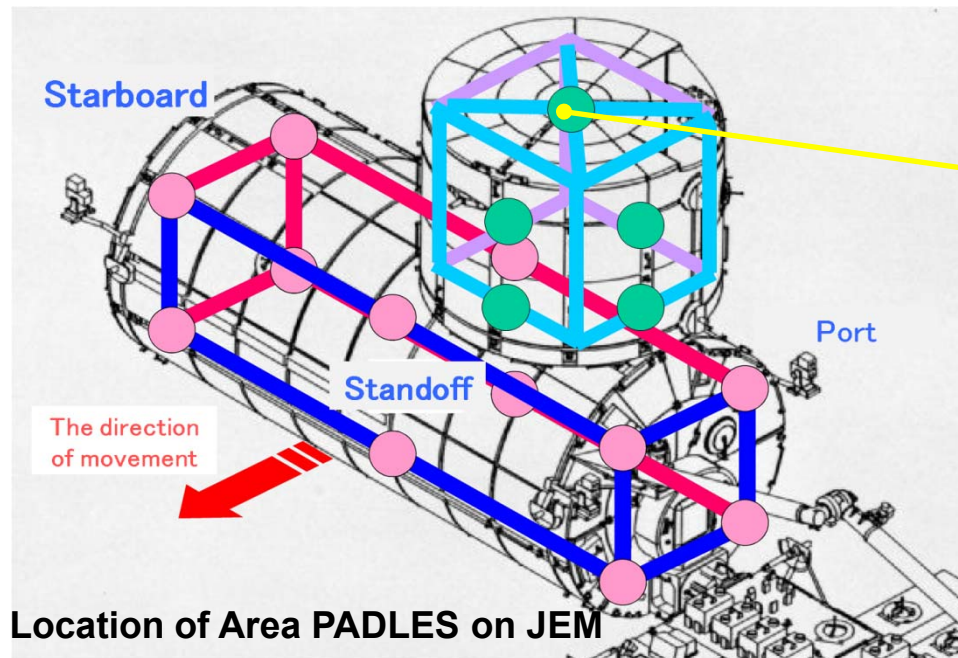
II . Area Monitoring Results of Area PADLES #5



ISS026E031765

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

- Area monitoring aims to perform a survey of the radiation environment at **17 fixed locations** inside the KIBO by **Area PADLES**.
- The dosimeters are replaced **every increment** throughout the KIBO program.



Area Dosimeter consists of casing holder (46 x 46 x 9mm) containing dosimeter package, tether with clip and velcro.

The results of Area PADLES are expected to:

- Perform the basis for **life science experiments (radiation biology)**
- Contribute to **risk assessments on space flights**
- Update existing **space radiation models**.

Area PADLES #1

Launch: STS-124/1J	Jun. 1 2008	Total duration: 301 days Installation: 278 days
Return: STS-119/15A	Mar. 29 2009	

Area PADLES #2

Launch: STS-119/15A	Mar. 16 2008	Total duration: 180 days Installation: 164 days
Return: STS-128/17A	Sep. 12 2009	

Area PADLES #3

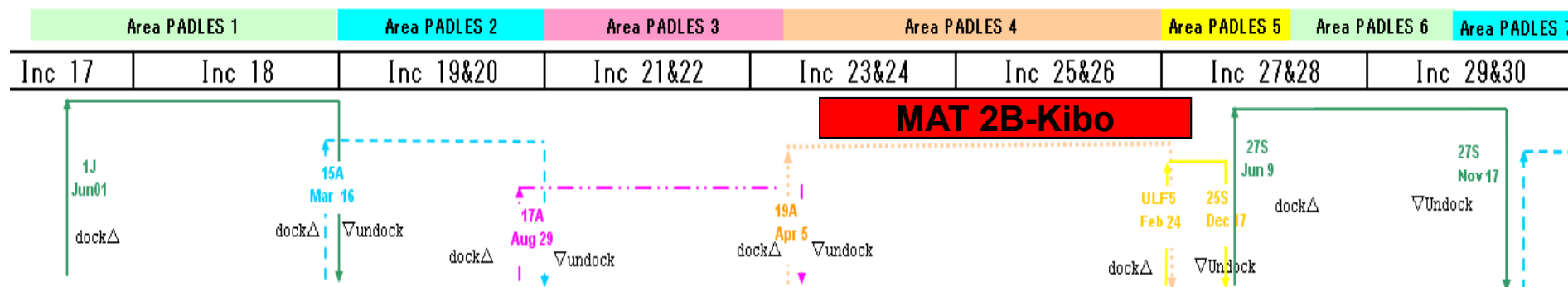
Launch: STS-128/17A	Aug. 29 2009	Total duration: 232 days Installation: 214 days
Return: STS-131/19A	Apr. 18 2010	

Area PADLES #4

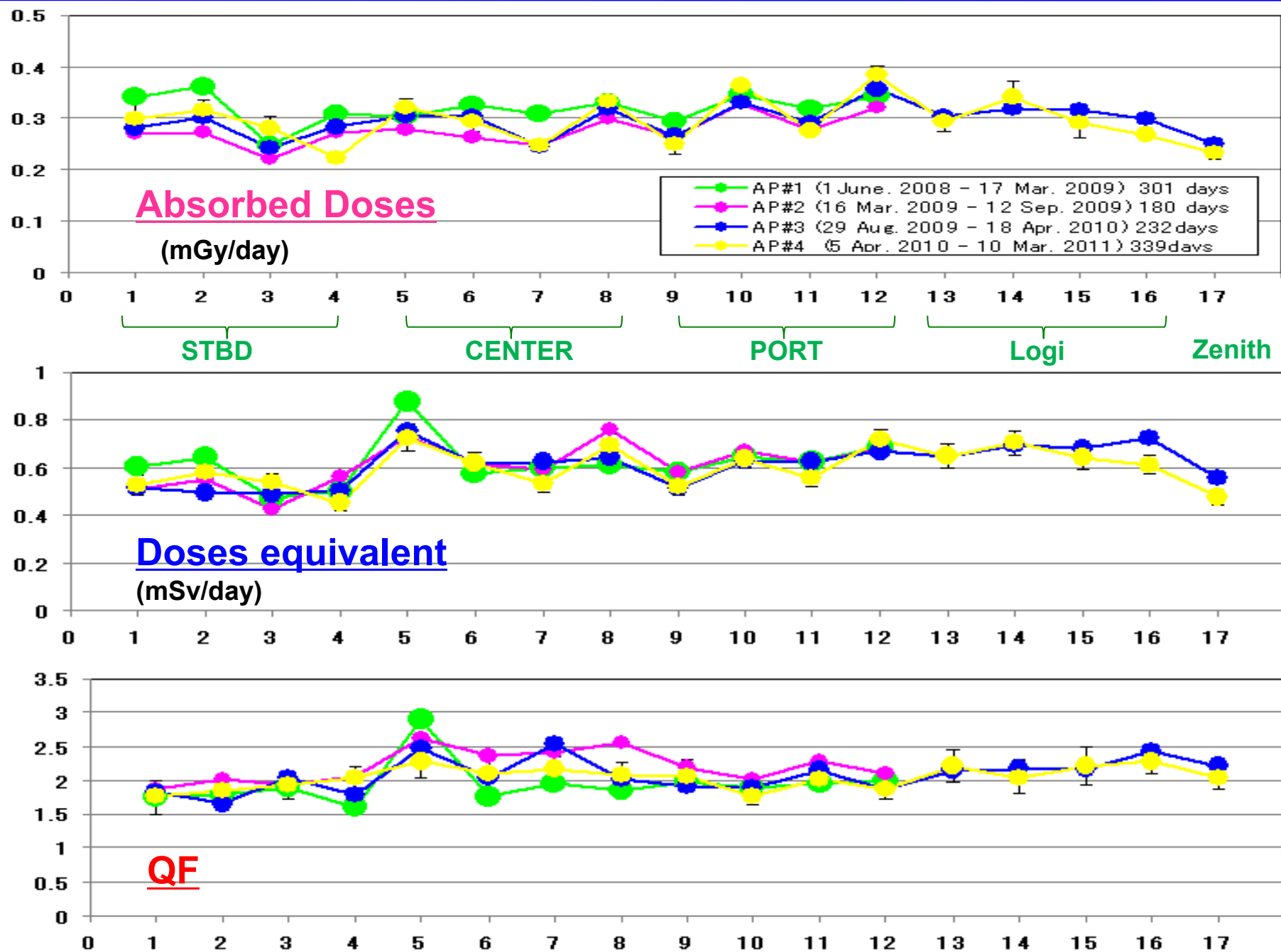
Launch: STS-131/19A	Apr. 05 2010	Total duration: 339 days Installation: 319 days
Return: STS-133/ULF5	Mar. 09 2011	

Area PADLES #5

Launch: STS-133/ULF5	Feb. 24 2011	Total duration: 89 days Installation: 81 days
Return: TMA-20/25S	May 24 2011	



Absorbed Doses, Dose Equivalents and QF



Absorbed Doses, Dose equivalents and QF

Area PADLES #1 (12 places)

- ① Average absorbed dose : 0.32 ± 0.03 mGy/day
- ② Average dose equivalent : 0.62 ± 0.10 mSv/day
- ③ Average QF: 1.94 ± 0.32

Area PADLES #2 (12 places)

- ① Average absorbed dose : 0.28 ± 0.03 mGy/day
- ② Average dose equivalent : 0.61 ± 0.09 mSv/day
- ③ Average QF: 2.20 ± 0.25

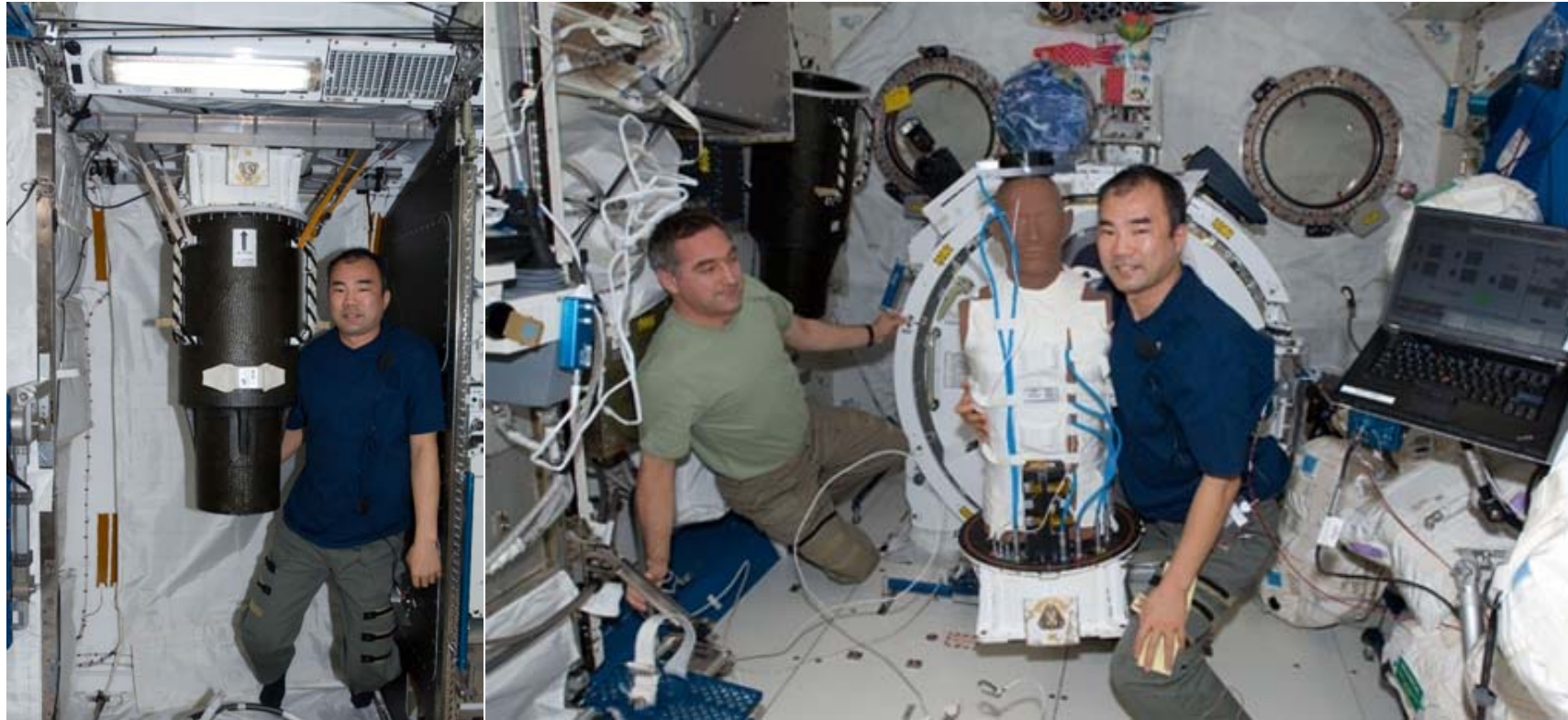
Area PADLES #3 (17 places)

- ① Average absorbed dose : 0.30 ± 0.03 mGy/day
- ② Average dose equivalent : 0.59 ± 0.08 mSv/day
- ③ Average QF: 2.02 ± 0.26

Area PADLES #4 (17 places)

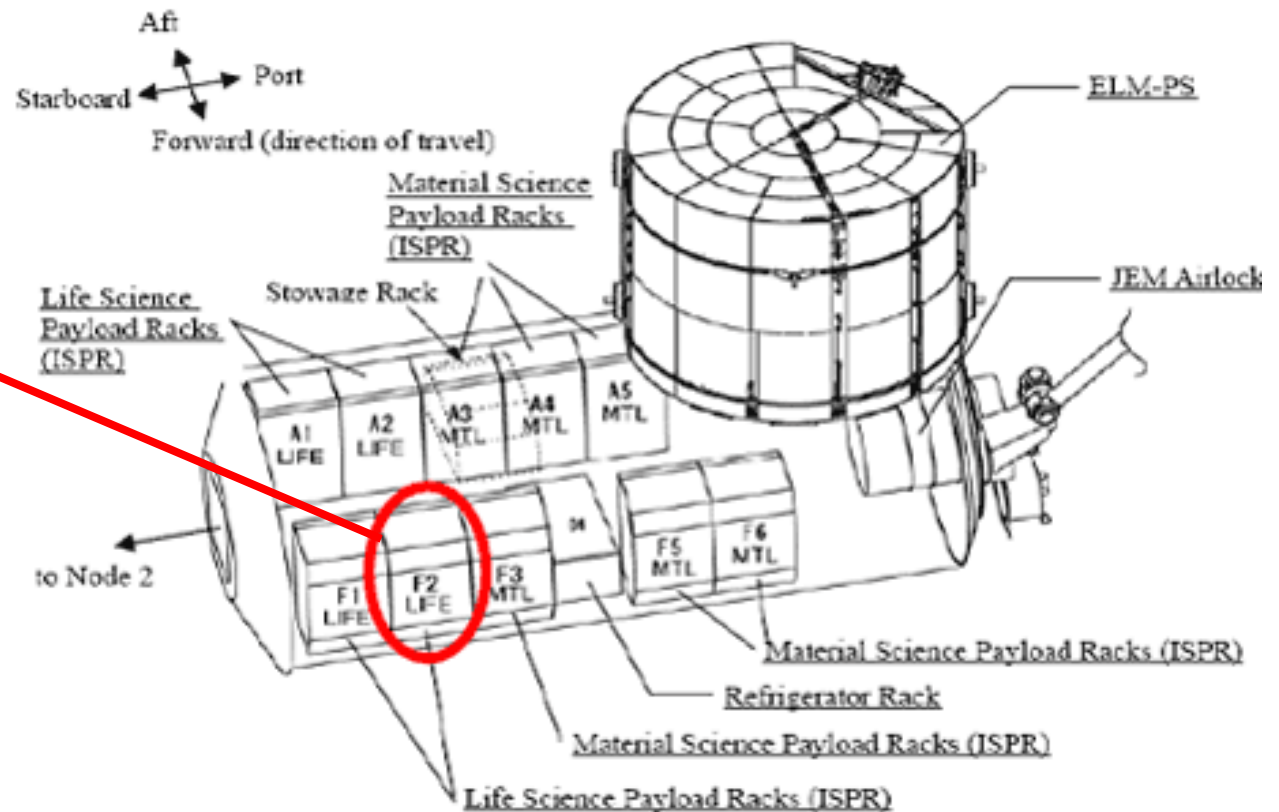
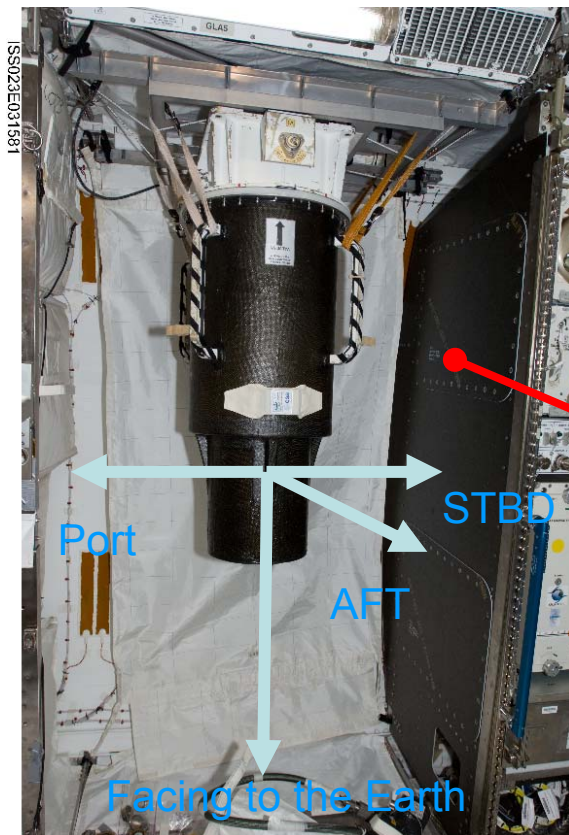
- ① Average absorbed dose : 0.29 ± 0.04 mGy/day
- ② Average dose equivalent : 0.60 ± 0.08 mSv/day
- ③ Average QF: 2.04 ± 0.17

III. Matroshka 2B_KIBO

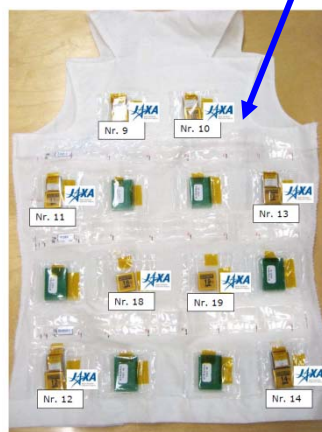
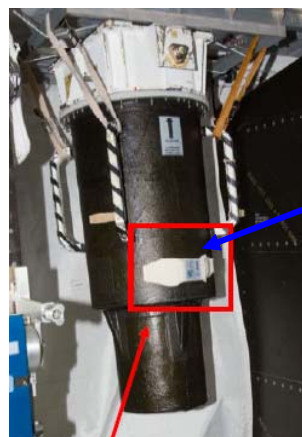


Matroshka 2B_KIBO Flight conditions

Event	data	Vehicle	days
Launch	29 Apr. 2010	37P Progress	Total: 322 Phantom:311
Installation	4 May 2010		
De-installation	11 Mar 2011		
Return	17 Mar 2011	24S	

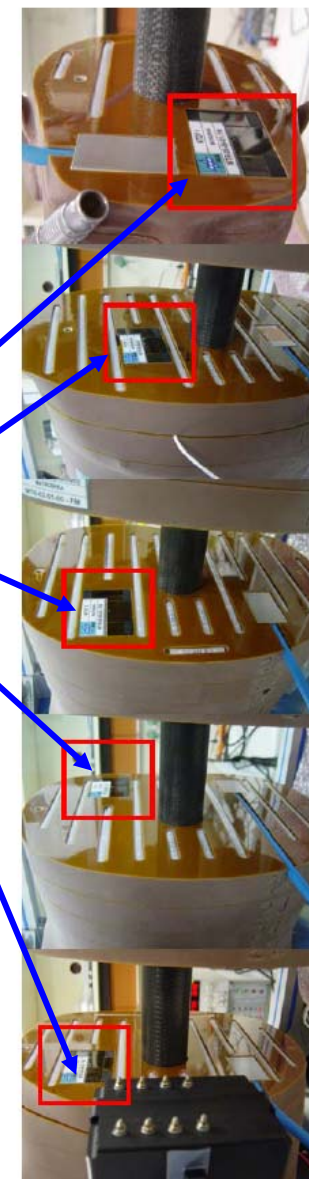


PADLES Positions



	Organs	Number
Outer container	Reference 1	1
	Reference 2	1
Poncho Front	Skin	3
	Back	8
NPTD	Eye	1
	Lung	1
	Stomach	1
	Kidney	1
	Intestine	1
	Top of the Head	1

JAXA PADLES # 20 - #25: Background Detector Packages at DLR, Cologne, German



Slice 3: Eye

Slice 15: Lungs

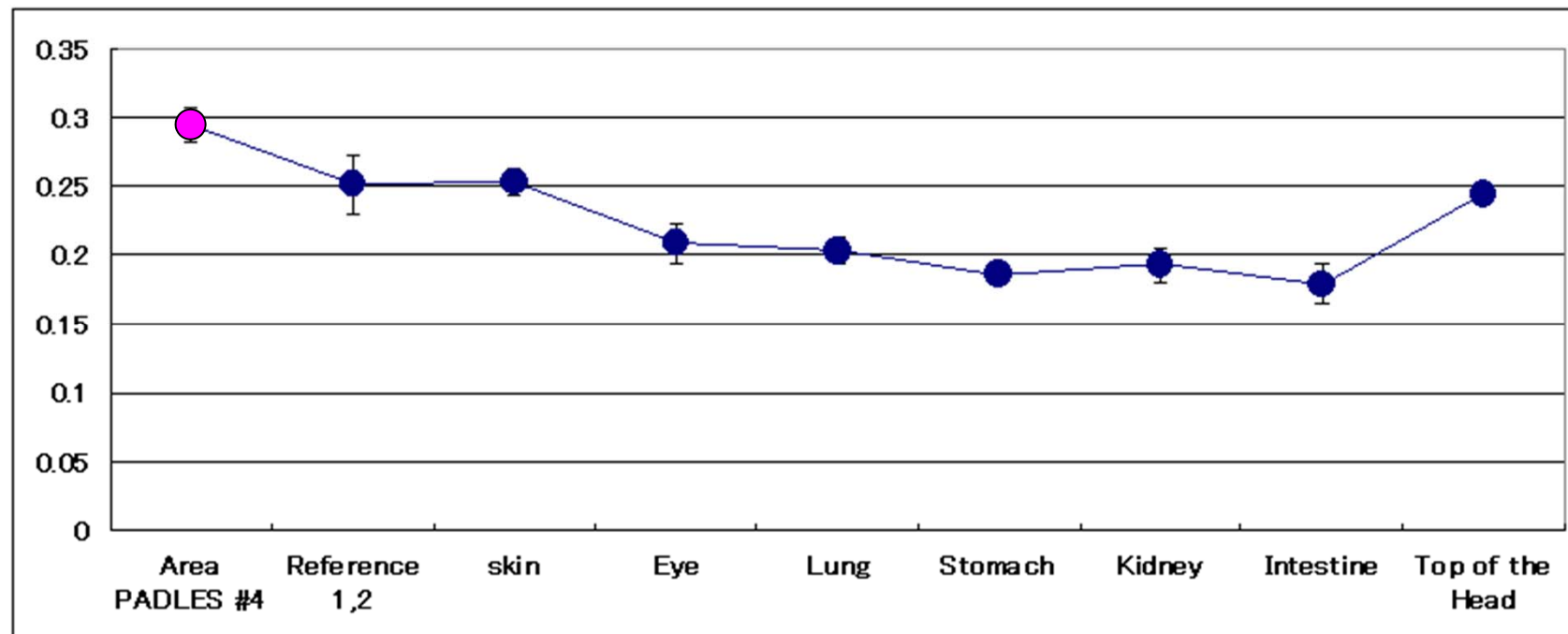
Slice 20: Stomach

Slice 22: Kidney

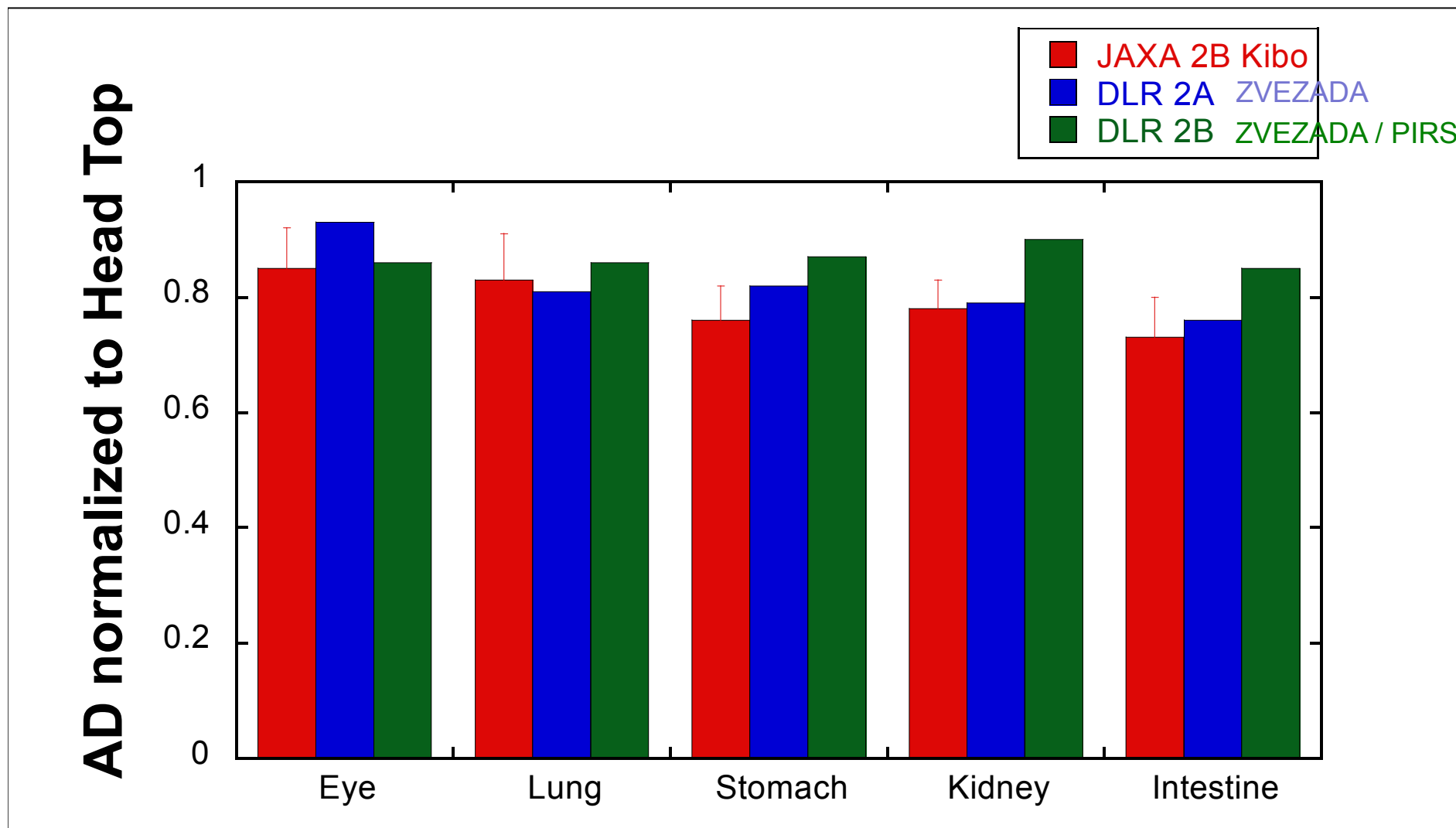
Slice 27: Intestine

Total absorbed doses combined with TLD and CR-39 data

Location/Organs	Absorbed Dose rate (mGy/day)		
Area PADLES #4	0.295	±	0.044
Reference 1,2	0.252	±	0.013
skin	0.253	±	0.021
Eye	0.209	±	0.010
Lung	0.203	±	0.015
Stomach	0.187	±	0.010
Kidney	0.193	±	0.007
Intestine	0.179	±	0.012
Top of the Head	0.245	±	0.014



Comparison between past Matroshka 2A/2B and 2B kibo

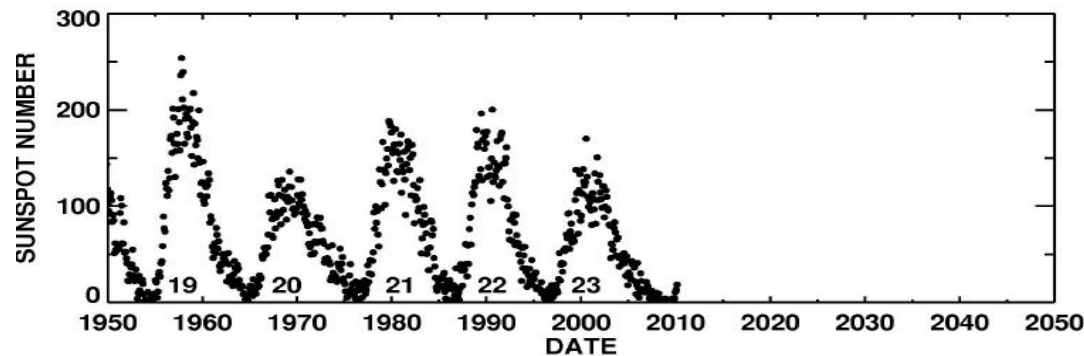


Reference : HAMLET: Results from the MTR-1/-2A and -2B Experiment
Part 1: Thermoluminescence Detectors, Thomas Berger (FP7 GA
218817) 、 16th WRMIS @ Prague

Summary

1. Area Monitoring

- Doses obtained Area PADLES #4 in Solar min (Apr 2010 to May 2011) changed between 0.22 ~ 0.38 mGy/day, 0.45 ~ 0.72 mSv/day.
- Area PADLES #8 (May 2012 – Sep. 2012) are installed onboard the Kibo.



2. Matroshka 2B Kibo

- Area PADLES near Matroshka 2B_Kibo phantom are:
 - No.5: On Z-panel under the close out of ICS (O4) Rack
 - No.7 Close out panel on stand-off between MELFI (D4) / Work Station (F4) RackNo.5 shows $0.32 \text{ mGy} \pm 0.02$, No.7 are 0.25 ± 0.01
- The differences between Area PADLES and Skin doses are about 15%.
- The differences due to depth doses in the human body onboard the ISS are within 30% of those of absorbed dose.

IV. Operational support on Tsukuba Space Center







2010.03.10 19:24(JST) on the day before Japan Earthquake 3.11



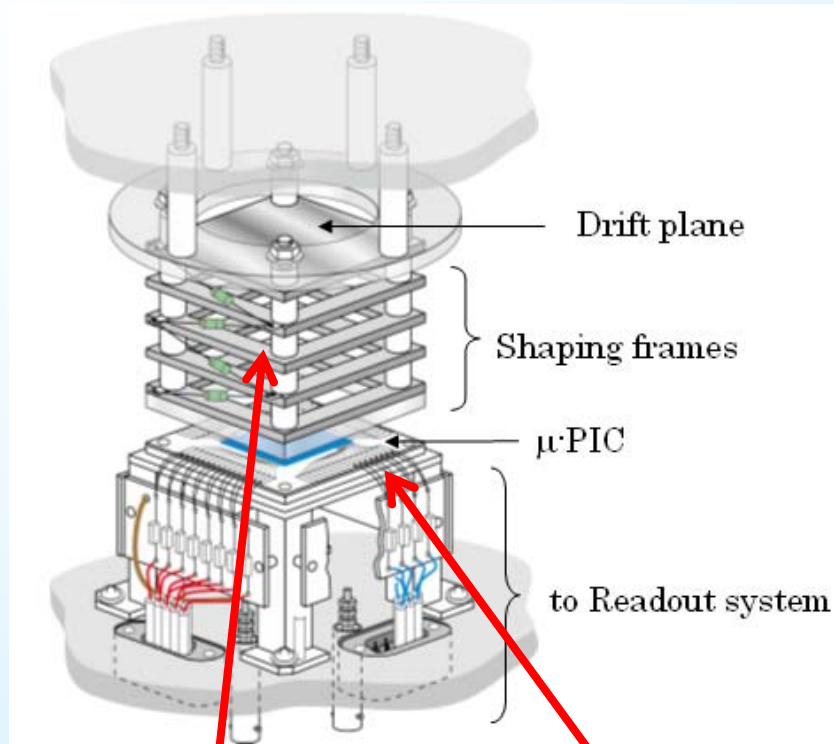
Thank you very much for your attention.

Acknowledgement:

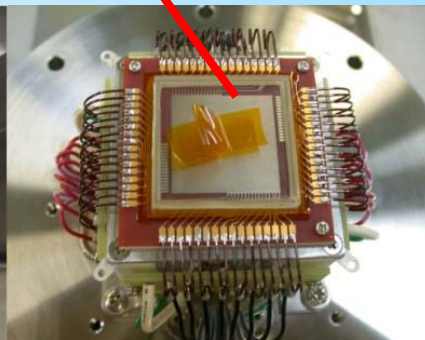
- PI team and all participants under FP7 project HAMLET.
- ESA/ROSCOSMOS and JAXA Payload Integration Agreement (PIA) For MATROSHKA' approved on 19 Aug. 2009 and revised on 2 Sep. 2010, as part of Kibo utilization framework.



Future work : PS-TEPC (Under developing) (Position-Sensitive Tissue Equivalent Proportional Camber)



Shaping Frame
(A-150)

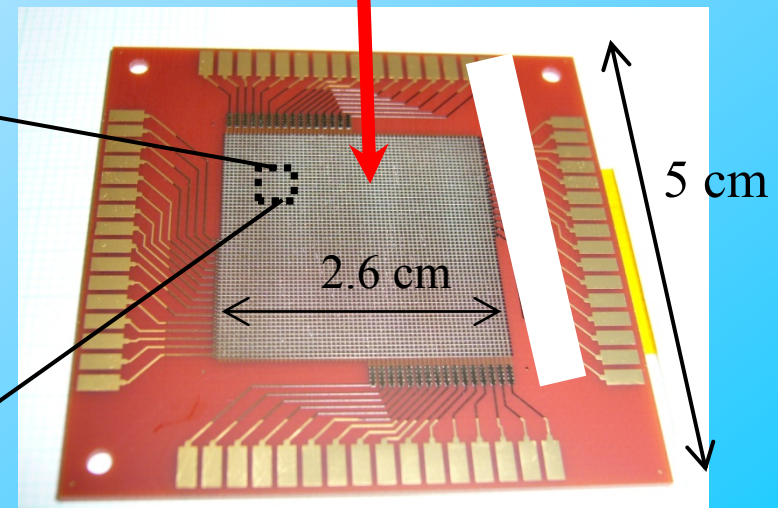
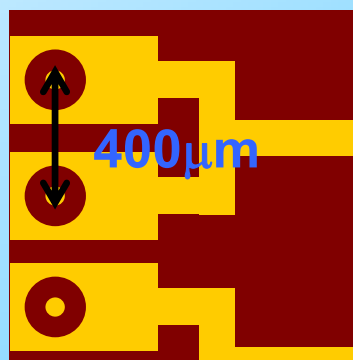
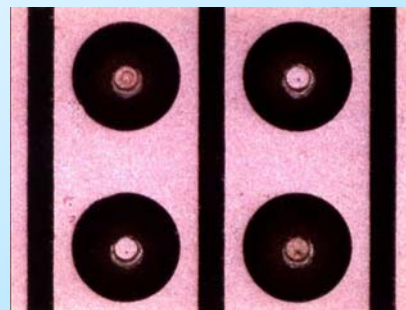
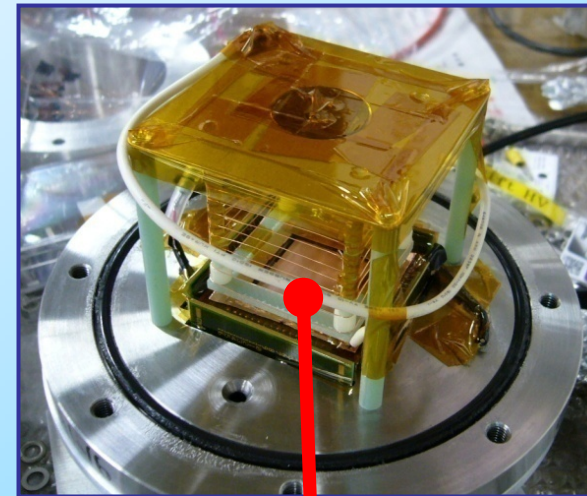
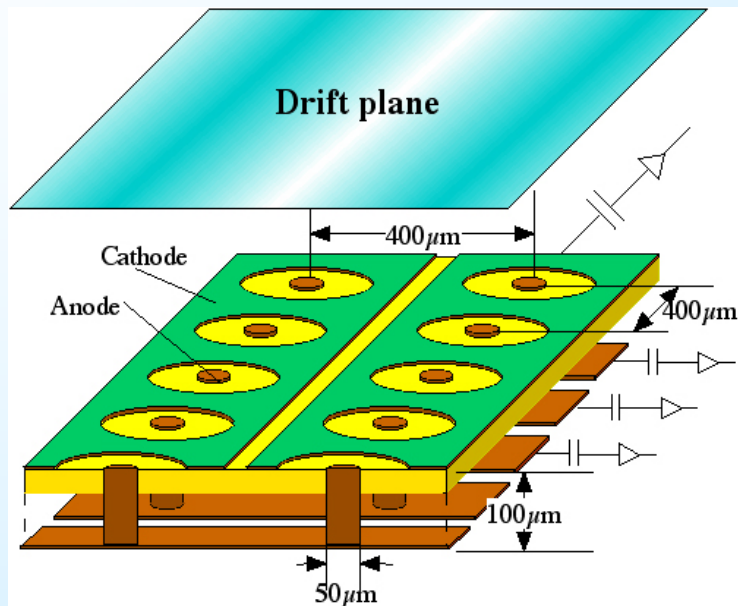


μ-PIC

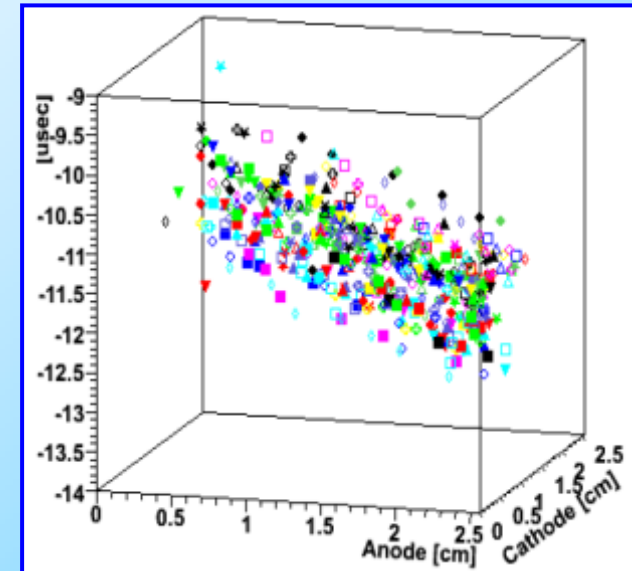
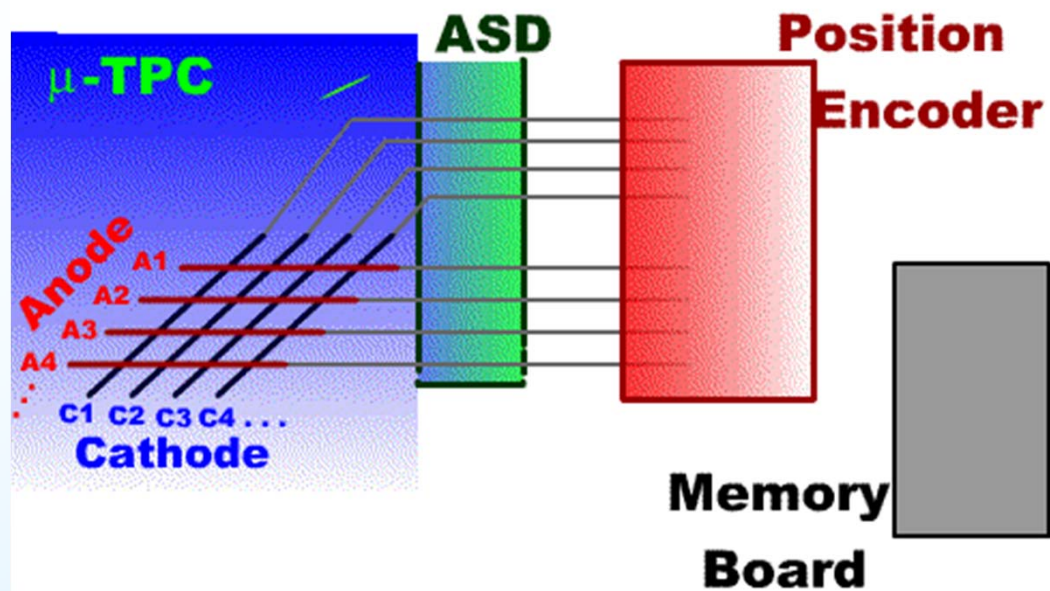
LET [keV/μm]	0.2 - 1000
Principle and detectors	• LET spectrometry by 3-D tracking determination • Gas TPC (Methan Tissue-Equivalent Gas) • μ-PIC and tissue equivalent drift plane • Strip spacing : 0.8 mm
Sensitivity	Protons, Heavy ions and neutrons
Size of the effective volume	2.6 x 2.6 x 50 mm
Present status	Ground performance test at HIMAC
Members	S. Sasaki, K. Terasawa, K. Miuchi, K. Takahashi, K. Saito, H. Matsumoto, T. Fuse, A. Nagamatsu, T. Tanimori, H. Tawara, Y. Uchihori, H. Kitamura, T. Doke, and JAXA ground support team.

Micro Pixel Chamber (μ -PIC) in PS-TEPC

- 400 μ m pitch electrodes
- 2.5cmX2.5cm size, 64 anodes & 64 cathodes



Methodology



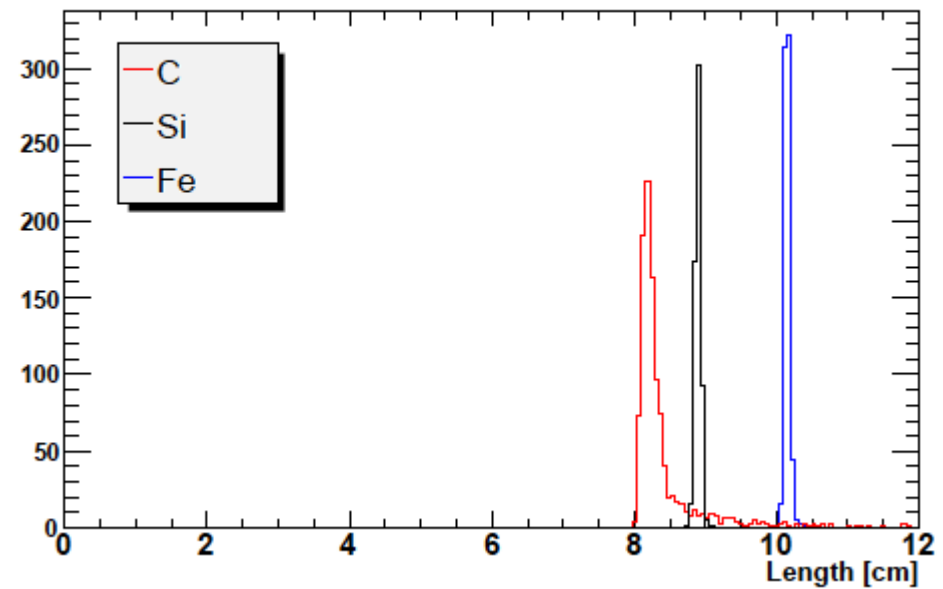
X, Y, Z information on μ-Pic

Each track is fitted as 3D linear function

Track length

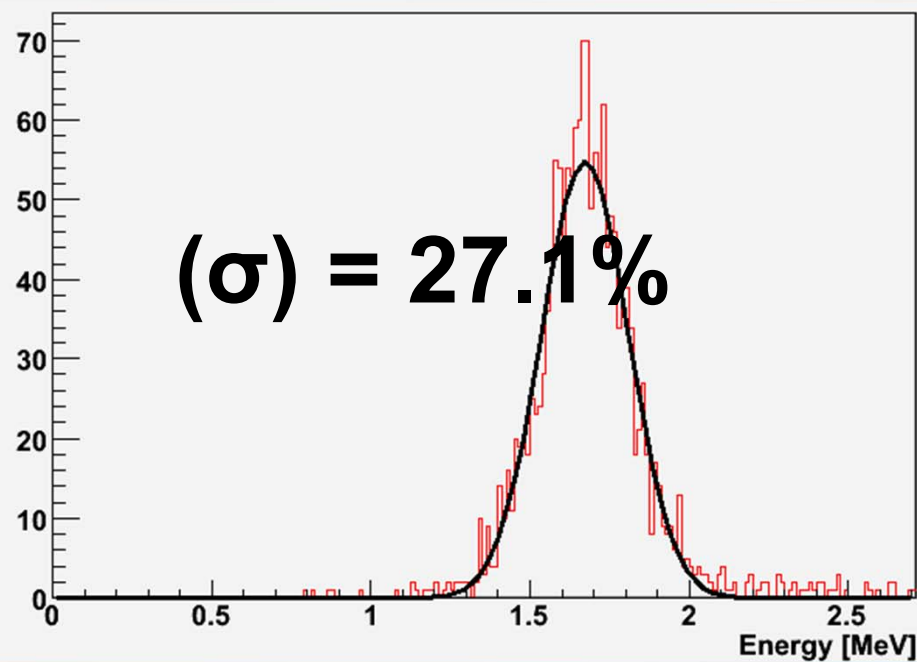
LET

Track length

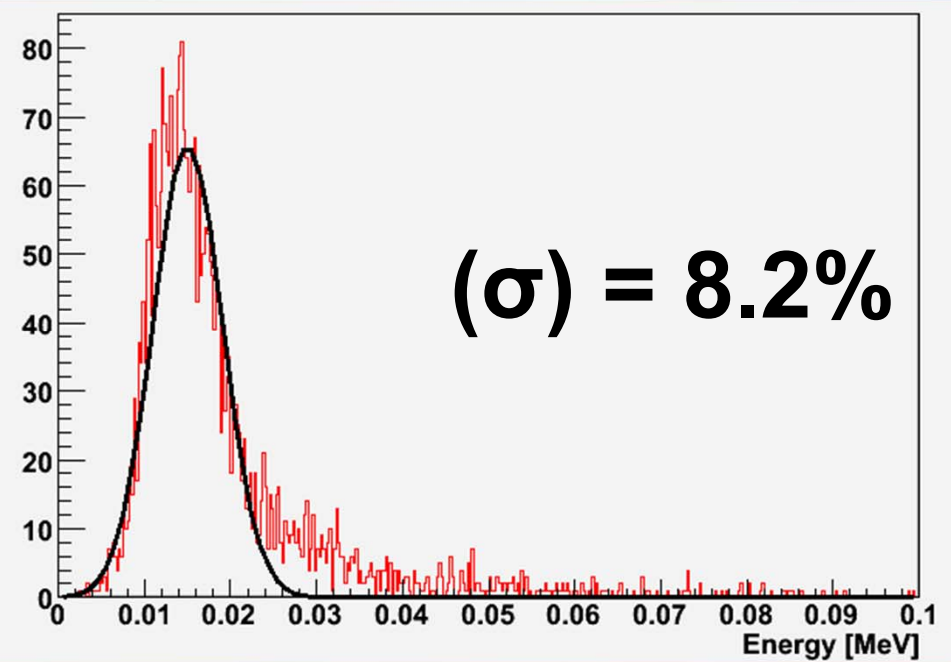


Preliminary Ground test (at Himac)

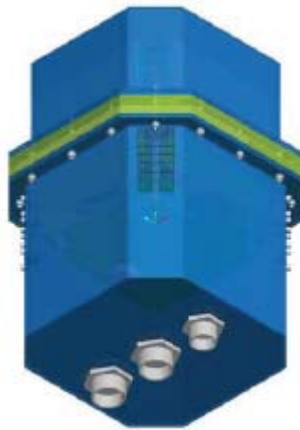
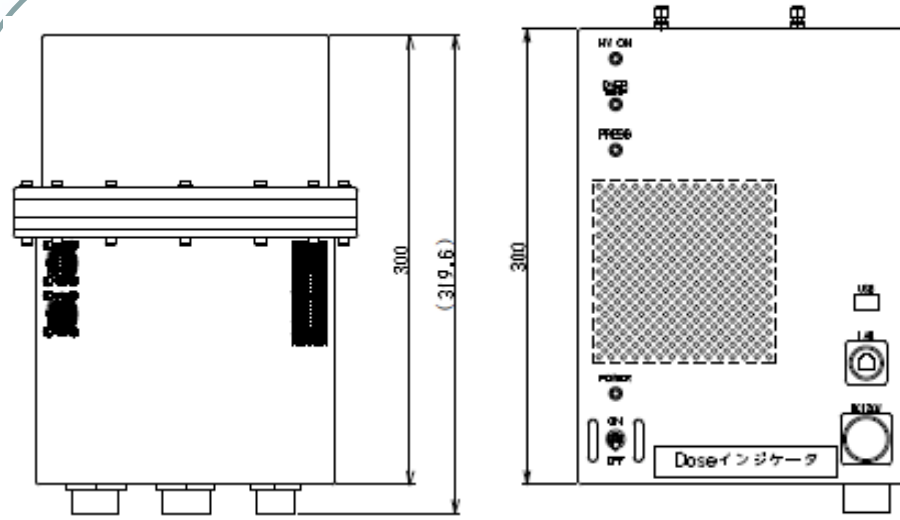
H 230MeV/n



Si 800MeV/n



Draft Design of flight model



Detector Unit



Control Unit

Flight model Characteristics

- Portable system in JEM (Po and Data connection is needed)
- Onboard calculation capability using onboard Laptop
- Wide LET range and charge particle, neutron sensitivity

Target Vehicle
HTV5 (2014 June)