Some problems to be solved for automatic analysis of a CR-39 nuclear track detector in space radiation

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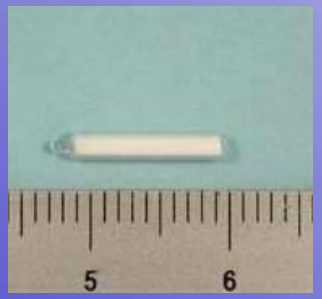
Plan of Presentation

1. **Introduction ~ PADLES system ~**
   - Dosimeters (CR-39 / TLD)
   - Dosimetric quantities : LET(keV/μm), D(Gy) , H(SV)
   - Exclusive hardware and software for PADLES
2. **Some problems to be solved for the analysis of CR-39 used for space radiation dosimetry**
   - Etching depth dependence of LET distributions above several keV/μm and its effect on dosimetric results
   - Thresholding of bitmap images to get etch-pit mouths as binary objects and its effect on calibration curves of CR-39
   - Bubble-like etch pits increasing with the exposure time in space and its effect on dosimetric results
3. **A future plan for PADLES experiments inside ISS JEM**

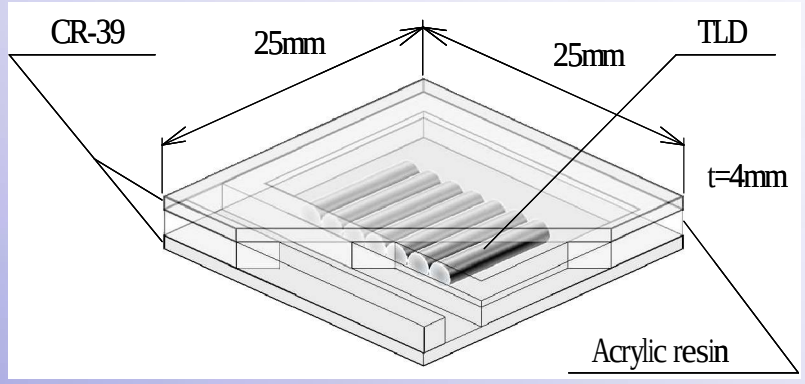
1. Introduction ~Dosimeters (CR-39 / TLD) ~

■ PADLES
(Passive Dosimeter for Life-science Experiments in Space)

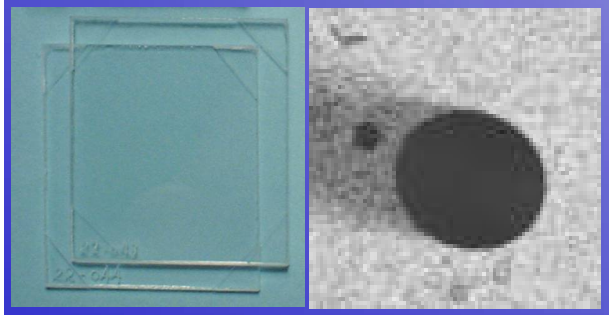
TLD-MSO-S (thermoluminescent dosimeters)



Mg_2SiO_4:Tb powder enclosed
a pyrex glass with Ar gas
(Kasei Optonics industry)



CR-39 (plastic nuclear track detectors)

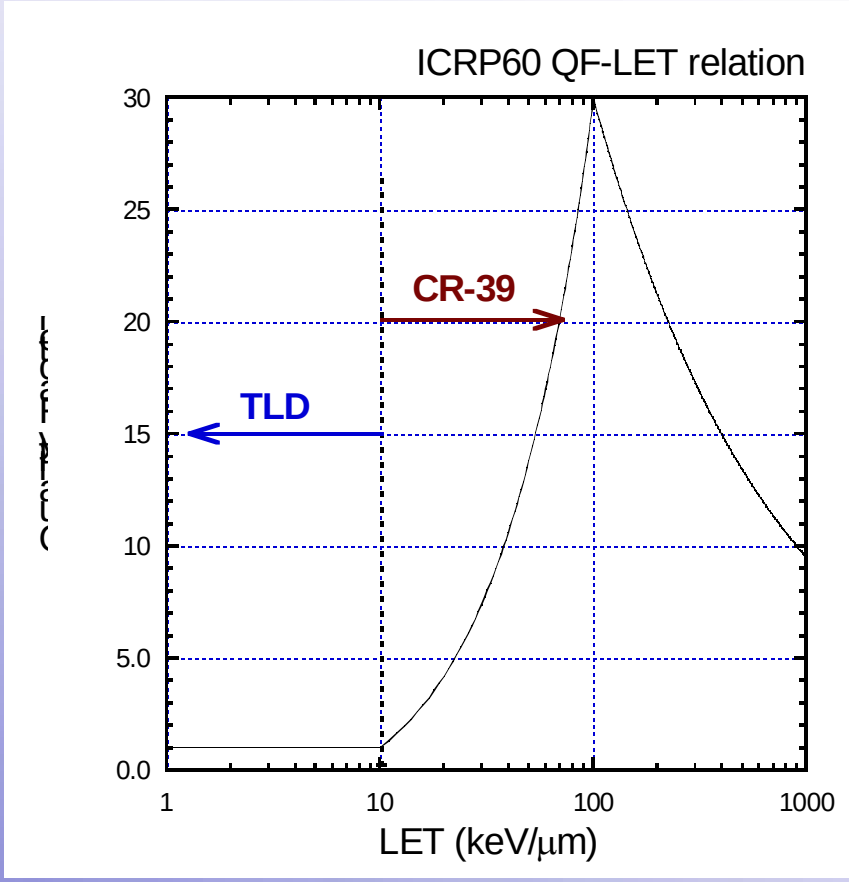


HARZLAS TD-1 are doped
with 0.1%wt NAUGARD 445
(Fukuvi Chemical industry)

1. Introduction ~ Dosimetric quantities ~

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

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



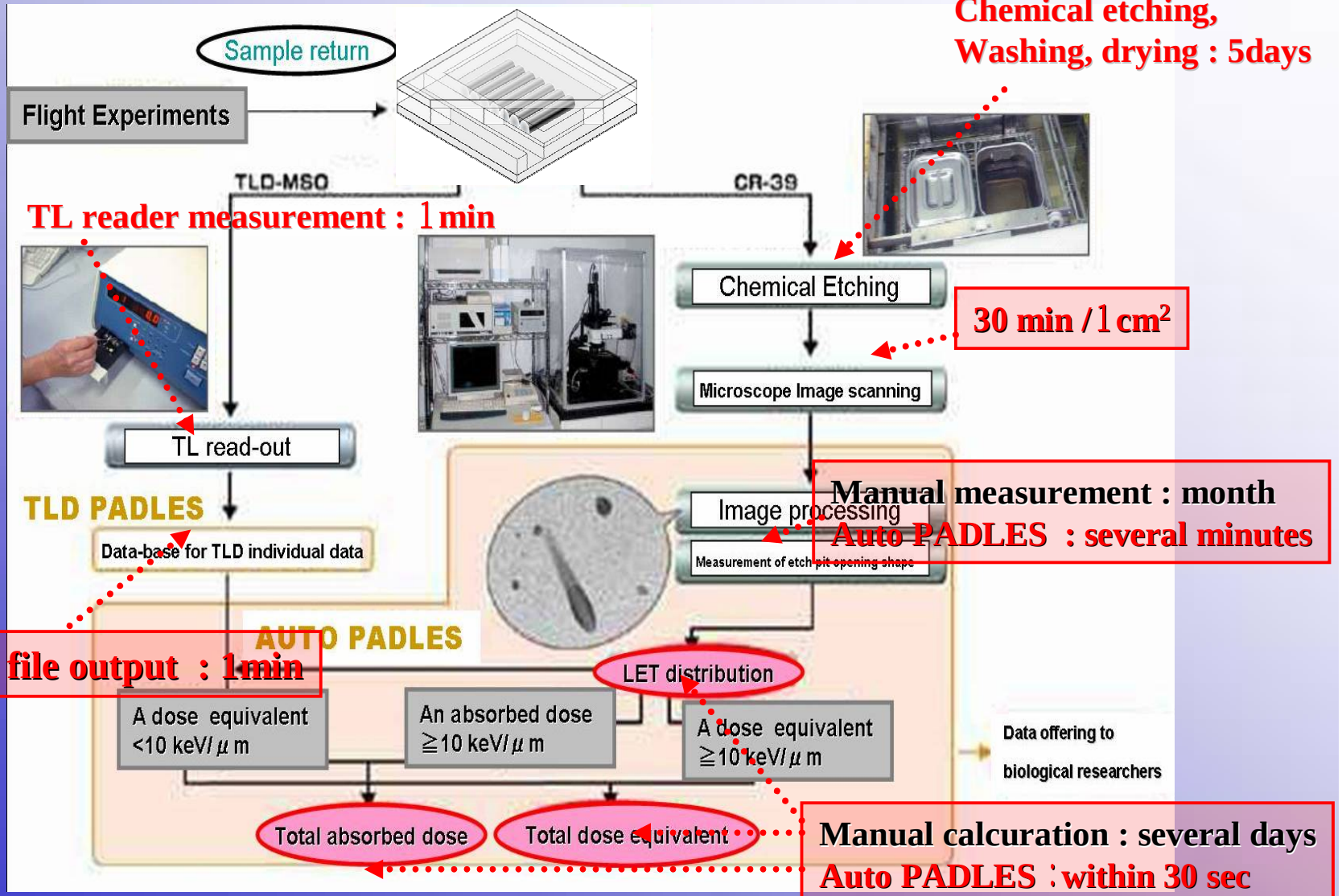
Total dose equivalent : H_{TOTAL} (Sv)

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

κ : **mean TL efficiency for high-LET particles from TLD**
(TLD-MSO $\leqq 1$)

1. Introduction ~ Exclusive hardware and software for PADLES ~

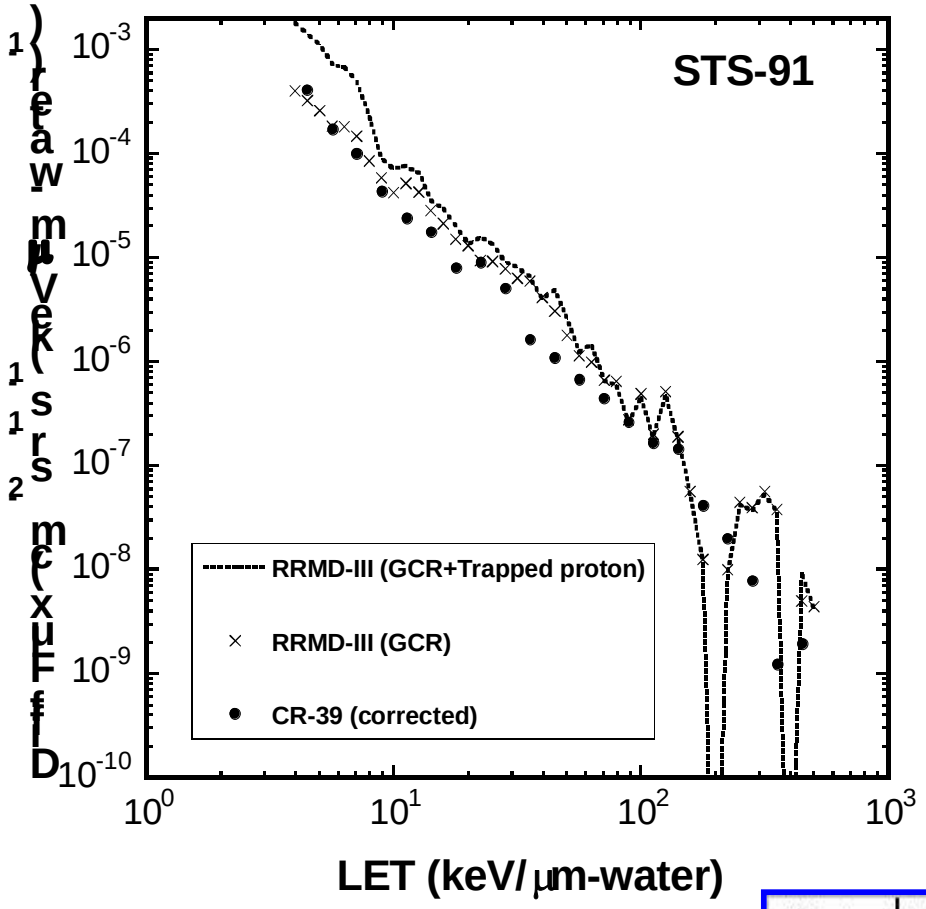
We will realize a data offering time less than 2 weeks per experiment.



2. The present problems on CR-39 analysis

- Etching depth dependence of LET distributions above several keV/μm and its effect on dosimetric results
- Thresholding of bitmap images to get etch-pit mouths as binary objects and its effect on calibration curves of CR-39
- Bubble-like etch pits increasing with the exposure time in space and its effect on dosimetric results

Comparison of RRMD-III and CR-39 (STS-84 and STS-91)



◎ Motivation

・The particle fluxes obtained from RRMD-III were two or three times higher than those obtained from the CR-39 plates.

◎ Bulk Etch = 33~40 μm
◎ Selected only conical etch pits for LET measurements

→Were short-range particles lost in CR-39 measurements in this study?

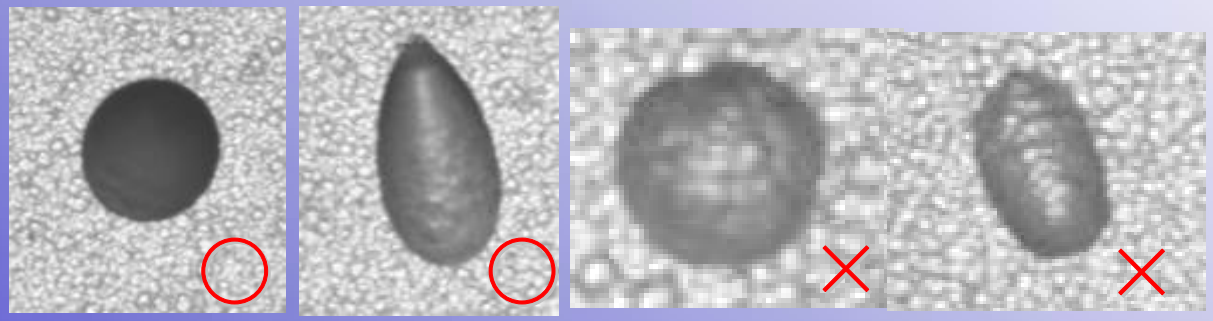
(H. Tawara et.al. 2002)

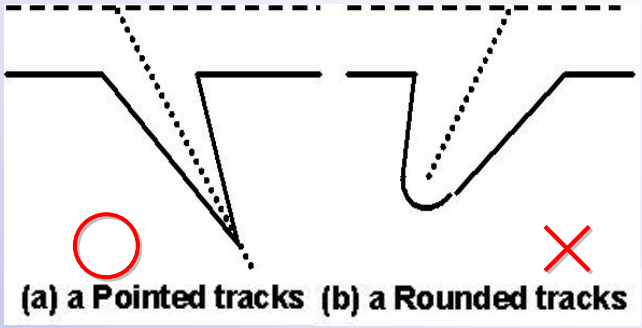
Mission	Absorbed dose rate (4-200 keV/μm) (μGy/day)			Dose equivalent ratea (4-200 keV/μm) (μSv/day)		
	CR-39		RRMD-III	CR-39		RRMD-III
STS-84	31.1 ± 4.6		89.9	141 ± 30		427
STS-91	22.6 ± 3.0		71.9	174 ± 26		405

Etch Pit analysis for LET measurements

1. Manual measurement (before STS-95 in JAXA)

Operators selected only the sharp - pointed conical etch pits by observing the bottom of the etch pits with adjusting a focus. As the results, short-range particles (roughly R < Bulk etch) were rejected in LET measurements.

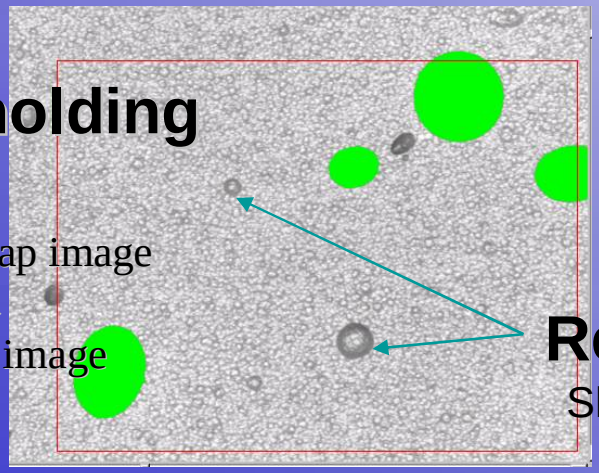




2. Automatic measurement (the present method in JAXA)

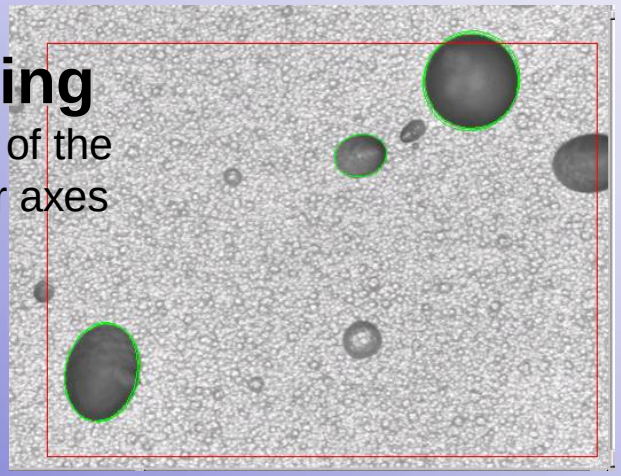
Thresholding

8-bit bitmap image
↓
binary image



Rejection
Shallow pits

Ellipse fitting
Measurements of the major and minor axes

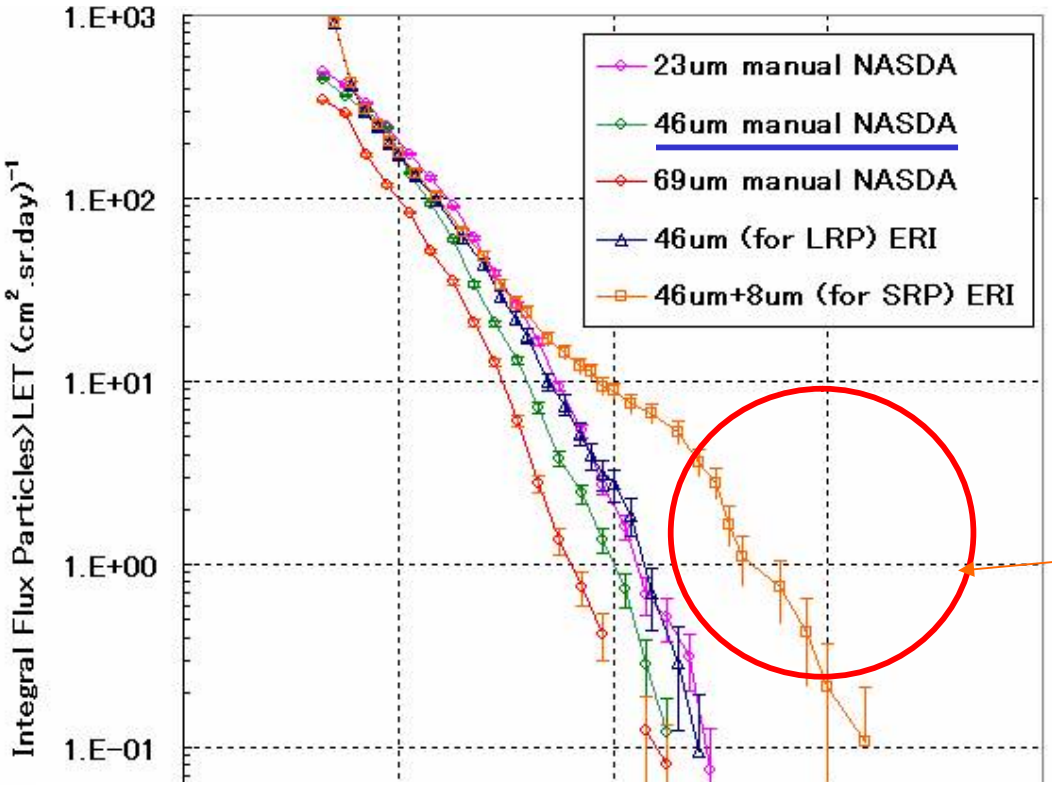


The ellipse fitting program developed by NIRS, SEIKO precision inc.

Etching depth dependence of LET distributions

STS-95 : 29/10/1998 – 7/11/1998 (8.9 days, Orbital Inclination: 28.45°, Orbital Altitude: **574 km**)

Joint research between ERIL resarch. and JAXA using STS-95 sample

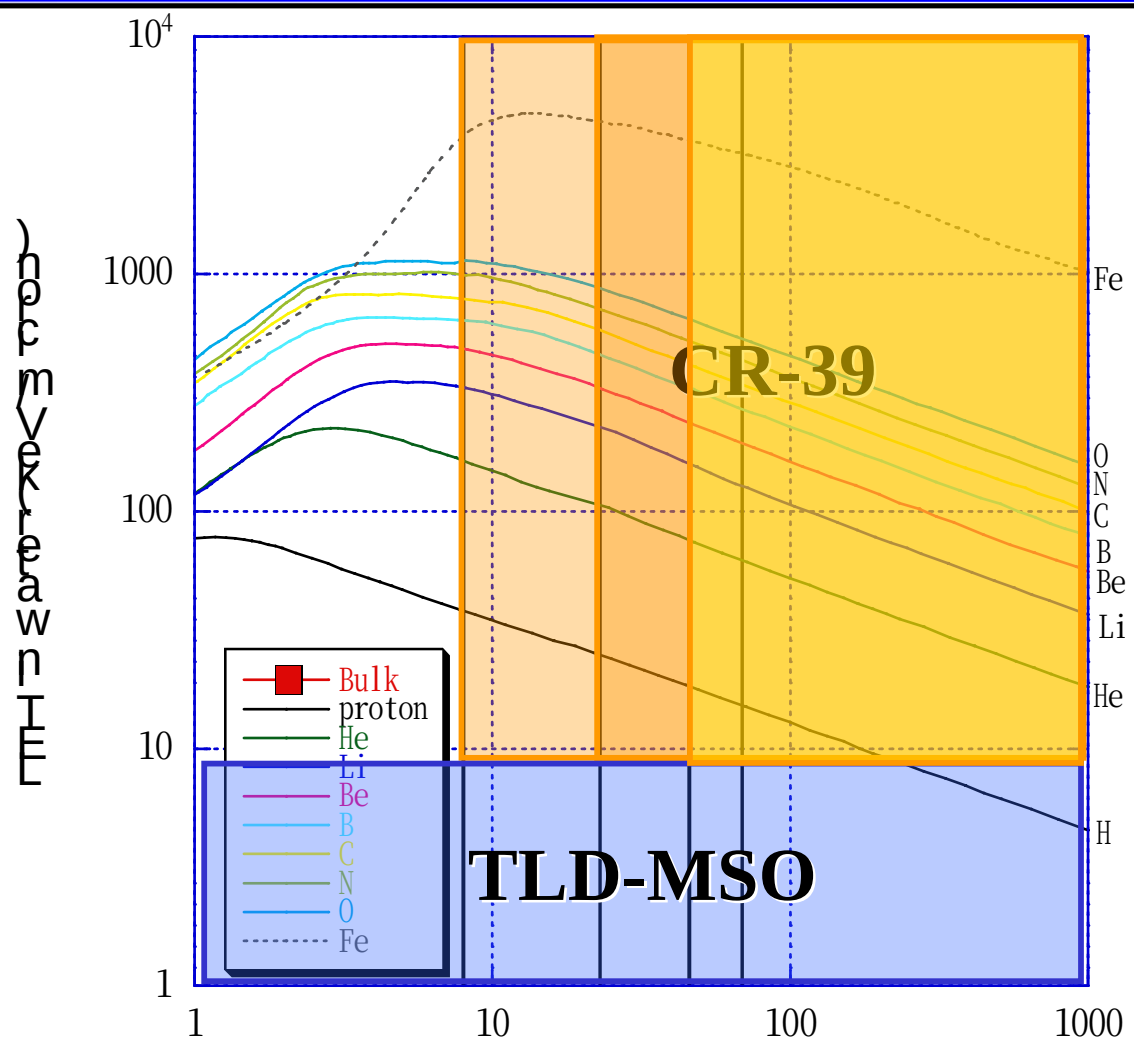


The high altitude caused a high intensity of protons,and consequently, increased target-fragments (short-range and high LET particles) in measurements of LET distributions.

1. Detected particle fluxes increased with decreasing bulk etch amounts.
2. ERI results (B=46μm, semi-automatic) well agreed with JAXA results (B=23μm, manual).
3. B=8 μm measurements was effective for detecting short-range and high-LET target fragments (≥ about 100 keV/μm).

→ **Now JAXA adopts the double detector method (a combination of the 8um and 23um bulk etch) to PADLES.**

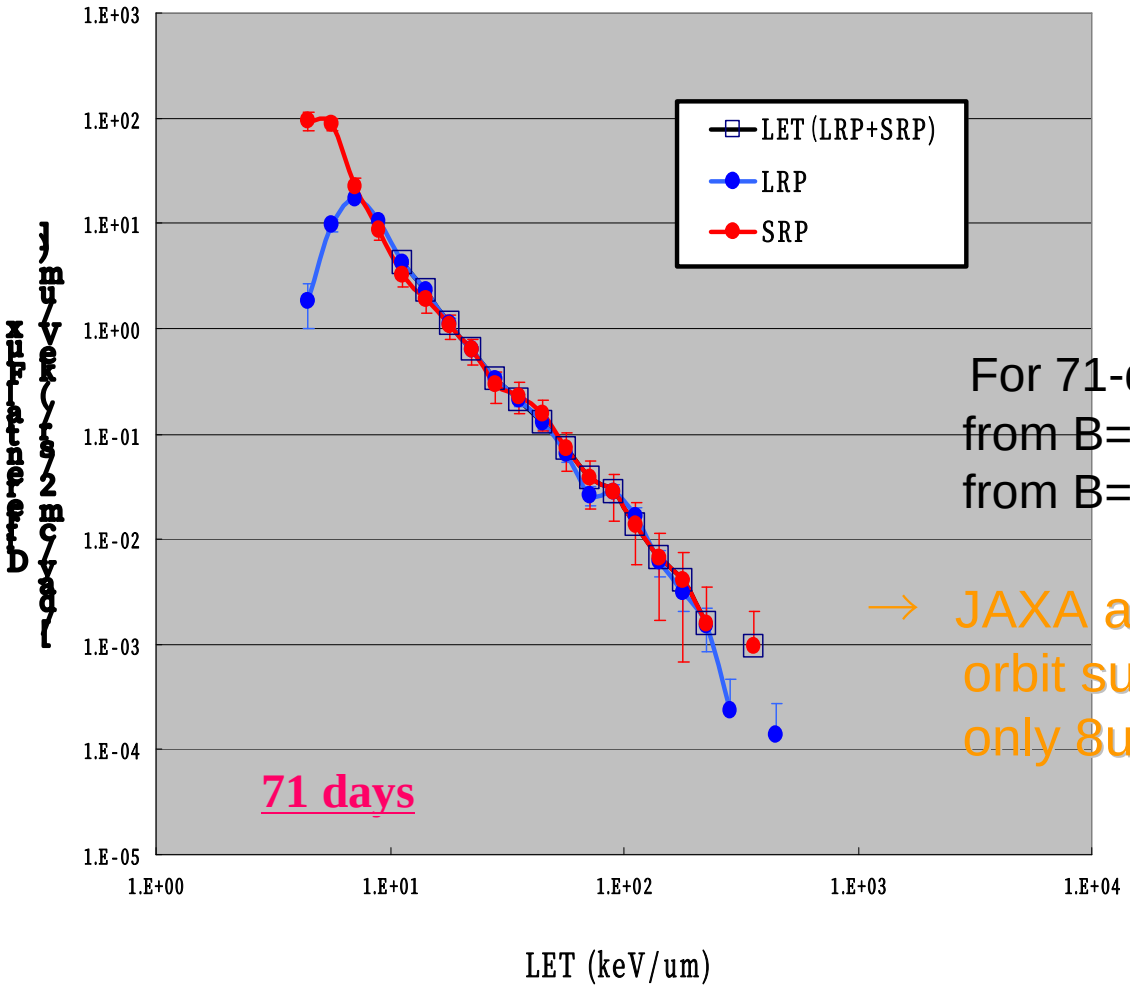
Measurable range of space radiation by PADLES



Range in CR-39 (μm) vs. LET-water (keV/μm) by SRIM 2003

Comparison of results from B=8μm and B=23 μm inside ISS

ISS Russian segment :launched at 31/8/2001 (71days) , 51.6°, ～400 km



For 71-day flight, the LET distribution from B=8 μm agreed well with those from B=23 μm.

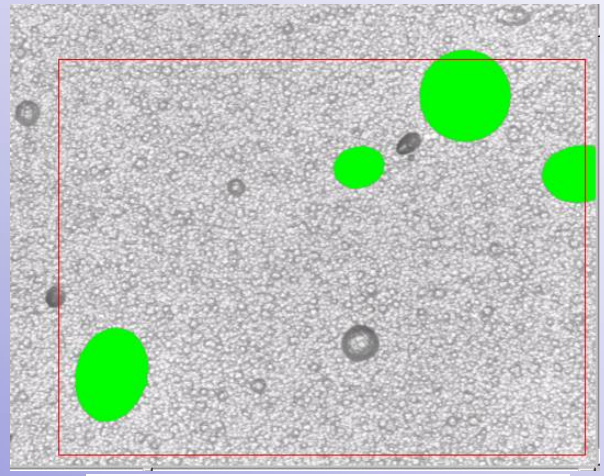
→ JAXA assumes samples Low earth orbit such as ISS flight are adopted only 8um etching method in future.

Thresholding of bitmap images

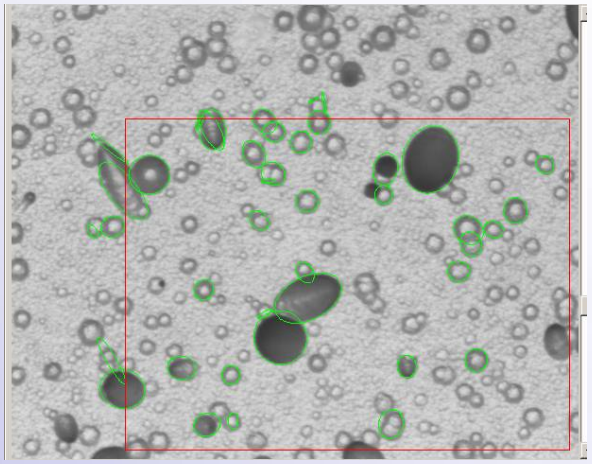
◎ Motivation : Optimum threshold levels depends on:

1. **Loading periods**
   →High track density causes overlapping of etch pits.
2. **Shallow pits**
   →Many bubble-like etch pits appeared in ISS-SM sample (446 days) sample.
3. **Track dip angle**
   →Tail of etch pits affects the ellipse fitting.
4. **Etching depth**
   →Surface becomes rough by heavy etching.

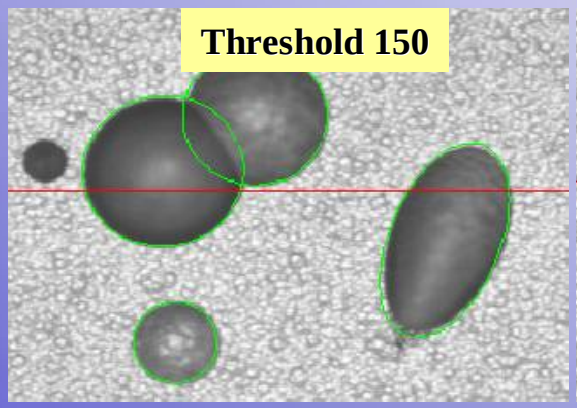
and so on.

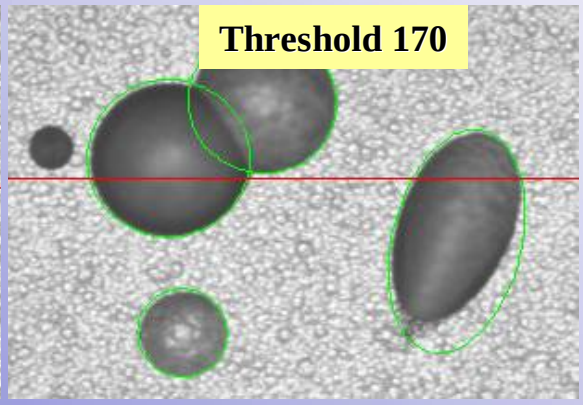


STS-95 8.9 days (46um)



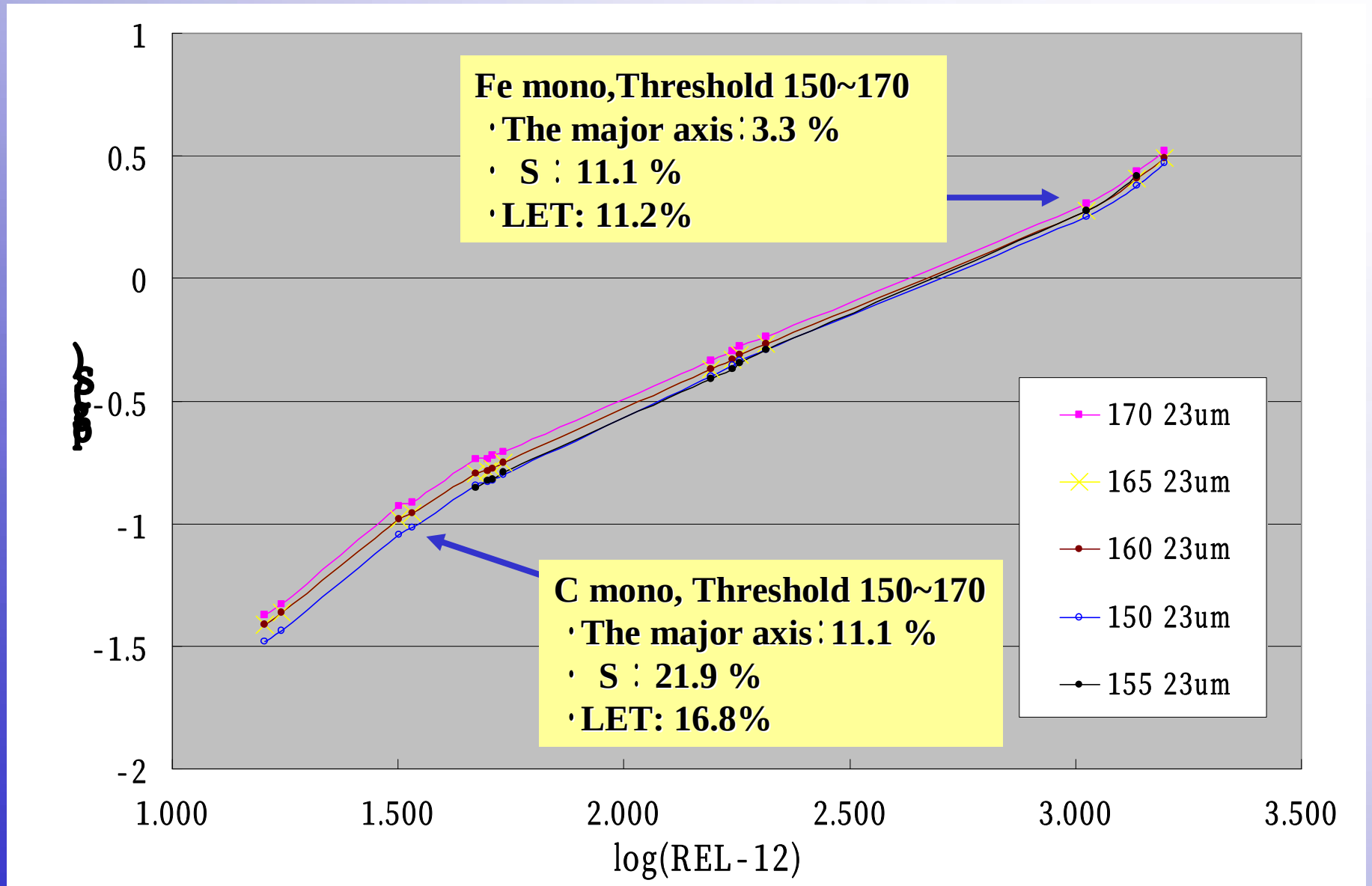
ISS SM 446 days (23um)



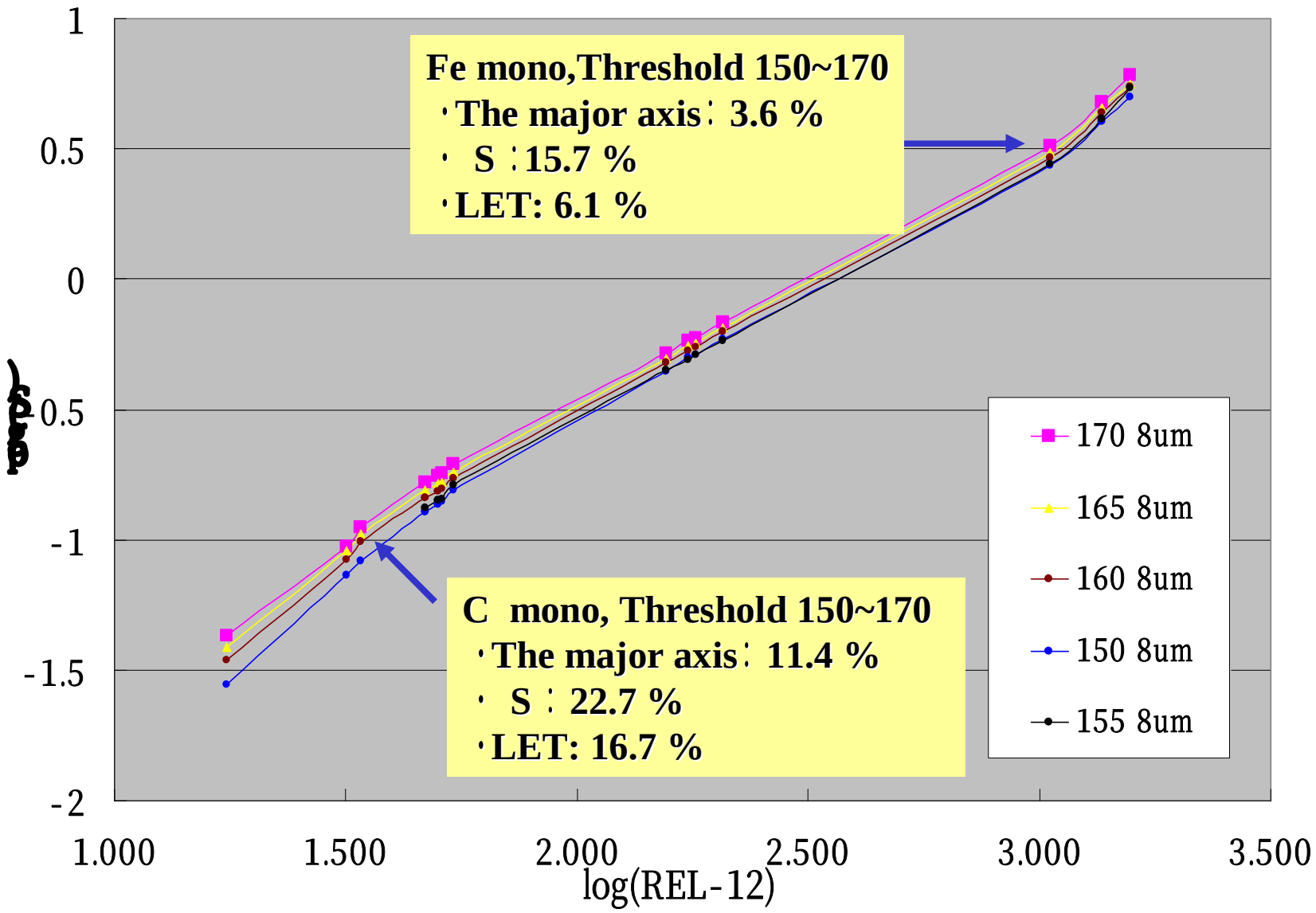


Therefore, We investigated different calibration curves for threshold levels.

B=23 μm calibration curves



B=8 μm calibration curves



Bubble-like etch pits in a long-term flight

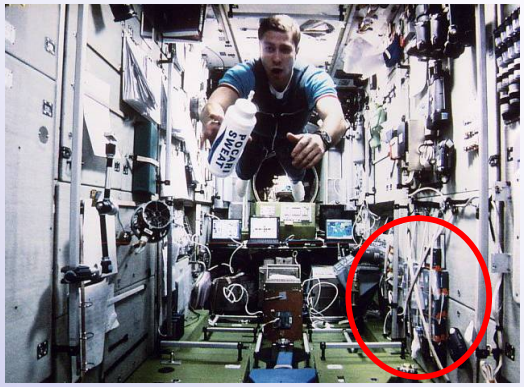
◎ Motivation

So far, we have participated two long-term flight experiments.

ISS Russian segment flight experiment

31/8/2001 – 10/11/2002 (71-446 days)

Space radiation damage test of
HDTV CCD device for HTDV images

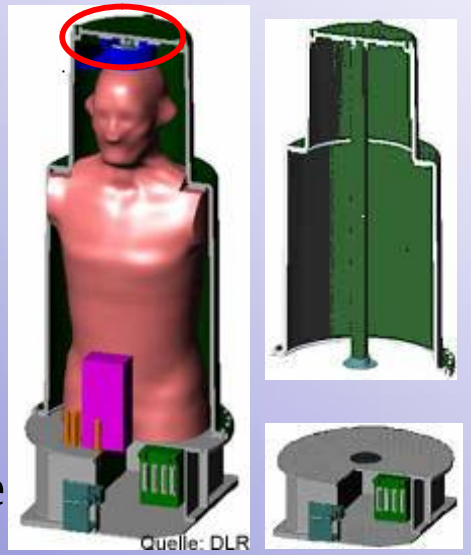


The MATROSHKA project

Now loading !

29/01/2004 – ??/09/2005 (1.8 year)
26/02/2004 – 18/08/2005 (539 days)

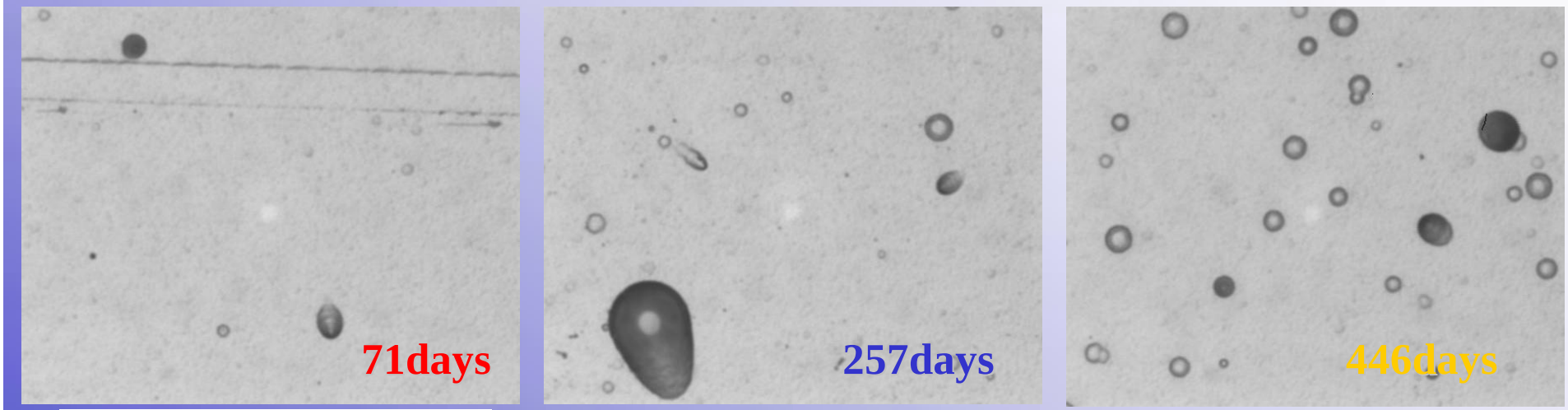
Simulation as exact as possible an astro
-naut while he leaves the protective area
of the spaceship to carry out work in space



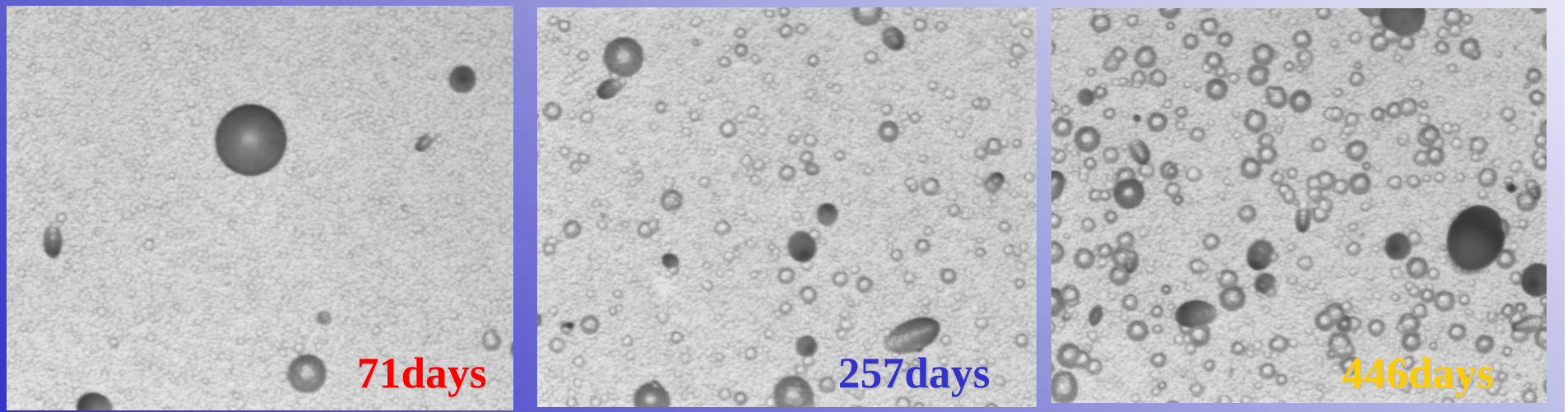
Bubble-like etch pits increasing with exposure time in ISS-SM

ISS Russian segment : 31/8/2001 – 10/11/2002, 51.6°, ～400 km

8 μ m etching (SRP)　×500



23 μ m etching (LRP)　×200

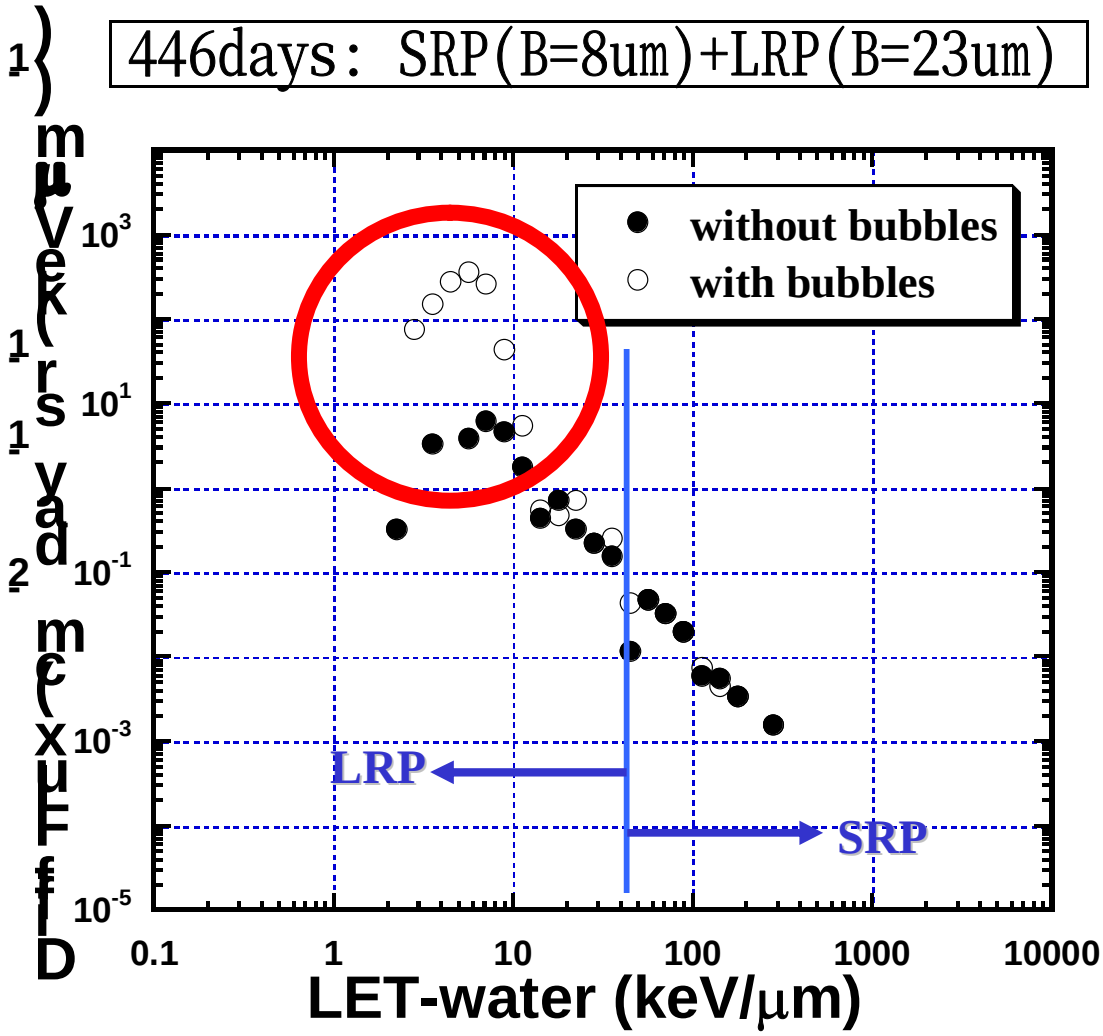


Bubble-like etch pits increasing with exposure time in ISS-SM

1. The density of bubble-like etch pits increased with increasing a loading time from 71 days to 446 days in ISS SM.

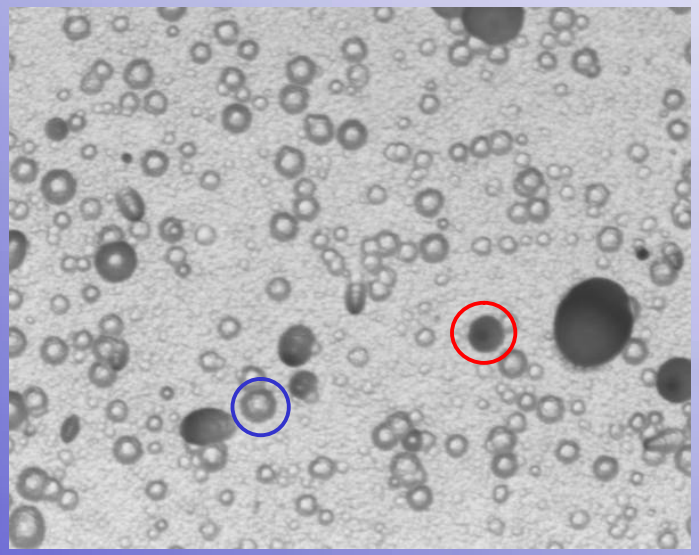
2. The bubble-like etch pits contributed to a lower LET region, mostly less than 10 keV/μm.

3. The bubble-like etch pits must be short-range particles (R<23μm.)

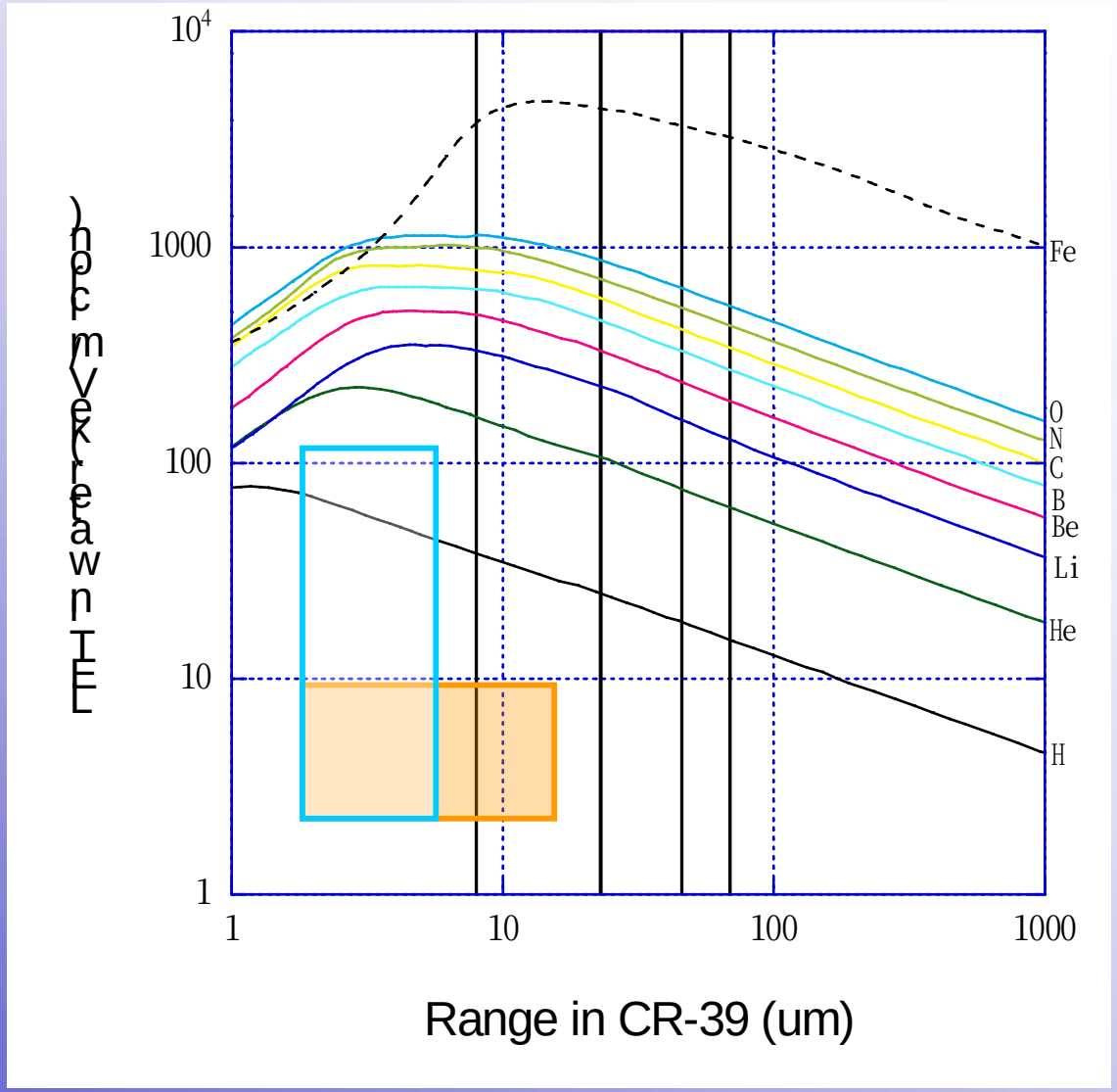


What are source radiation for such bubble-like etch pits, proton?

Bubble-like etch pits increasing with exposure time in ISS-SM

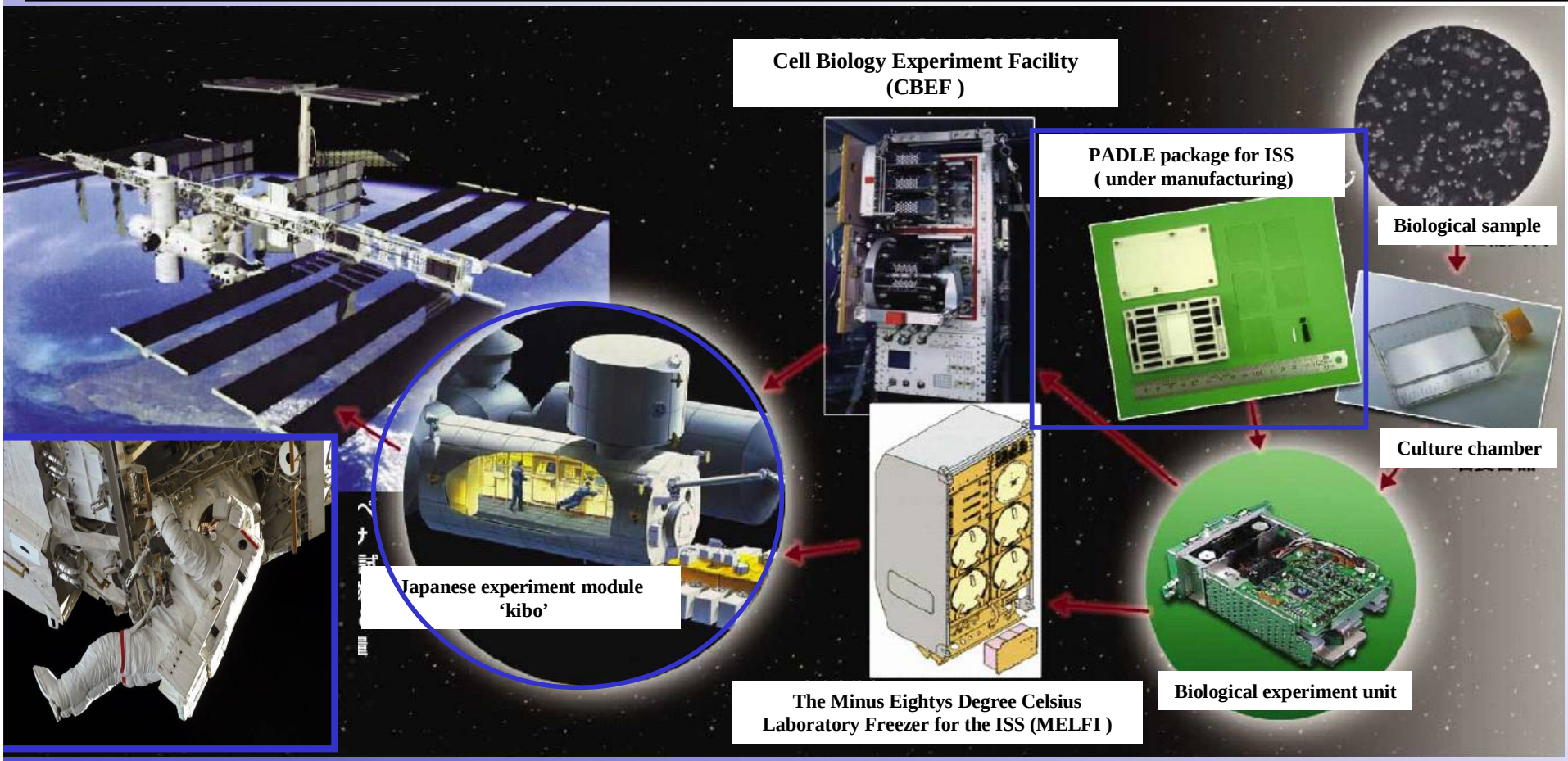


Both etch pits (blue and red) are recognized as the same LET particle, if the same calibration curve.
However, the LET of rounded etch pit (blue one) must be underestimated.
So, we could not conclude at the present study that the bubble-like etch pits are attributed to low-energy protons.



Range in CR-39 (μm) vs. LET-water (keV/μm) by SRIM 2003

A future plan for PADLES experiments inside ISS JEM



- ISS biological research experiments
- A personal dosimetry for Japanese astronauts inside ISS and during EVA
- Monitoring radiation environments inside JEM

Conclusions

1. Etching depth dependence of LET distributions

- Considering Short Range Particles (SRP) such as target fragmentations, we introduced the double detector method (combination of B=8μm and B=23μm) through the joint research with ERIL Research (Dr. E. Benton).
- In the low earth orbit around 400 km such as ISS, LET distributions would be measured by using only the 8um-etch sample.

2. Thresholding of bitmap images to get etch-pit mouths as binary objects and its effect on calibration curves of CR-39

- Optimum threshold levels depends on loading periods, depth of etch pits ,track dip angle, etching depth, and so on.
- We need calibration curves corresponding to different threshold levels to obtain the consistent dosimetric results.

3. Bubble-like etch pits increasing with the exposure time in space and its effect on dosimetric results

- The density of bubble-like etch pits increased with increasing a loading time from 71 days to 446 days in ISS SM.
- These etch pits contributed to a LET region less than 10 keV/μm.
- The bubble-like etch pits must be short-range particles (R<23μm.)
- The bubble-like etch pits are probably attributed to low-energy protons.

Acknowledgements

From JAXA, Special Thanks to ...

■ **Dr. E. Benton @ ERIL RESEARCH, INC.**

A joint resarch between ERIL RESERCH and JAXA

- ANALYSIS OF NASDA CR-39 PLASTIC NUCLEAR TRACK DETECTORS EXPOSED ON THE STS-95 SPACE SHUTTLE MISSION – (Jan. 2003)

■ **Dr. N. Yasuda et. al @ NIRS and SEIKO precision inc.**

A high-speed and semi-automatic analysis system for track detectors with an ellipse fitting algorithm inside AUTO PADLES

■ **Dr. Y.Uchibori and ICCHIBAN Working Group**

JAXA participates all passive runs of ICCHIBAN project from 2002.

Thanks you for your attention !!


pades
Passive Dosimeter for Lifescience Experiments in Space