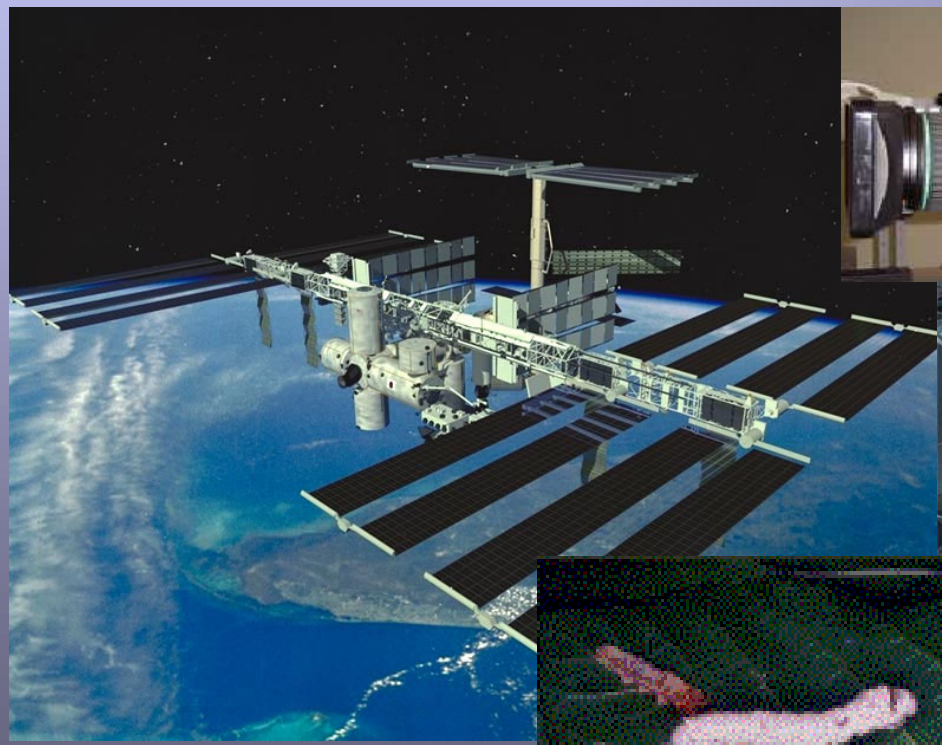
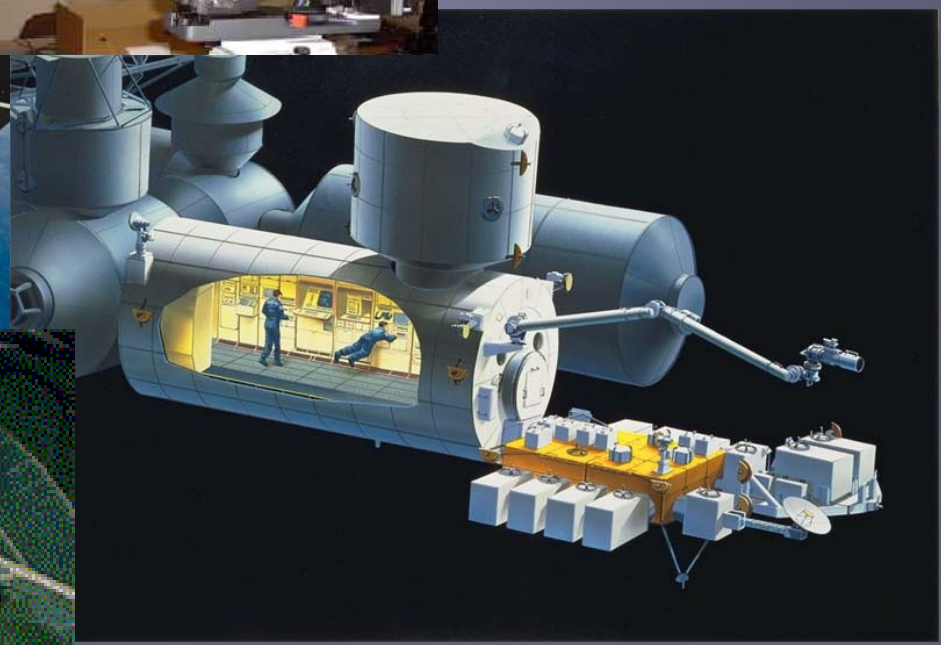

pades
Passive Dosimeter for Lifescience Experiments in Space

Development of a Passive Dosimeter for Life Science Experiments in Space (PADLES) in NASDA





Participants of NASDA group

- **Hiroko Tawara** — **KEK / NASDA**
- **Shigeki Kamigaichi, Mitsuyo Masukawa, Aiko Nagamatsu** — **NASDA**
- **Takayoshi Hayashi** — **WASEDA / NASDA**
  Hidenori Kumagai, Michiko Masaki — **AES**
- **Hiroshi Yasuda, Nakahiro Yasuda** — **NIRS**

Plan of Presentation

- Objective
- Methodology（TLD&CR-39）
- Ground performance test
- Applications
- Summary
- Future Work

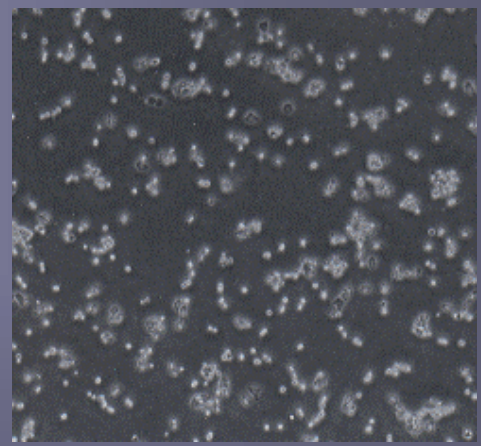
Objective

PADLES for biological samples to confirm biological damage in space

Investigating biological effects due to space radiation and microgravity requires precise measurements of space radiation.

Silkworm

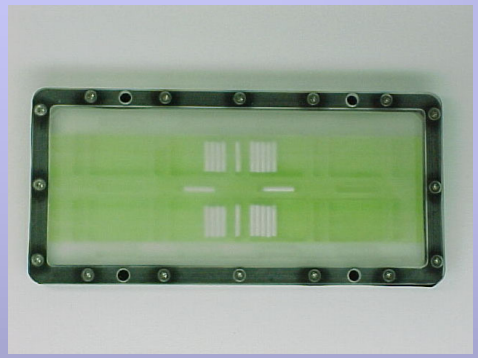
(a) **The absorbed dose**
(c) **LET distributions of heavy-charged particles in the LET region above 10 keV/ μ m**
(b) **The dose equivalent**
(d) **Tracking of heavy charged particles for biological samples**



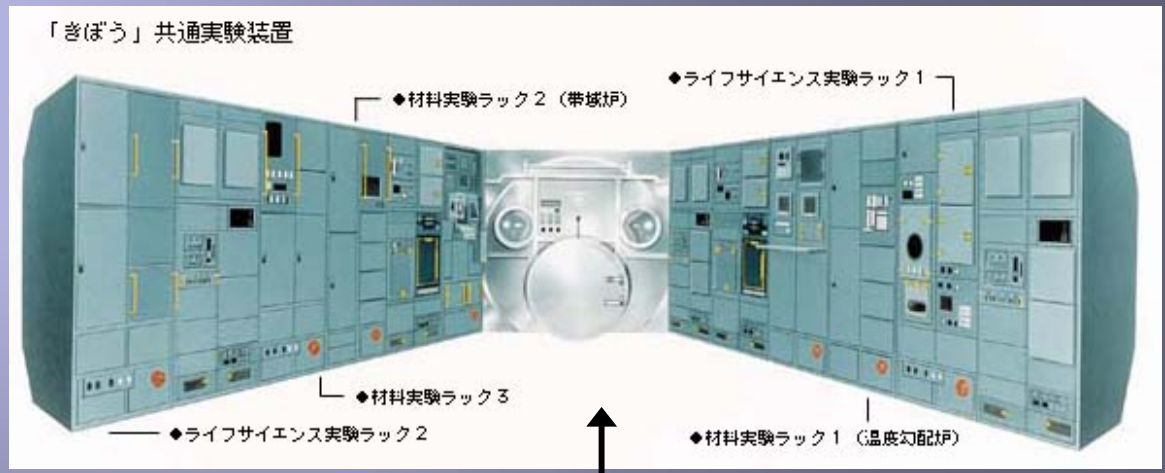
Culture cells

Loading to JEM : KIBO

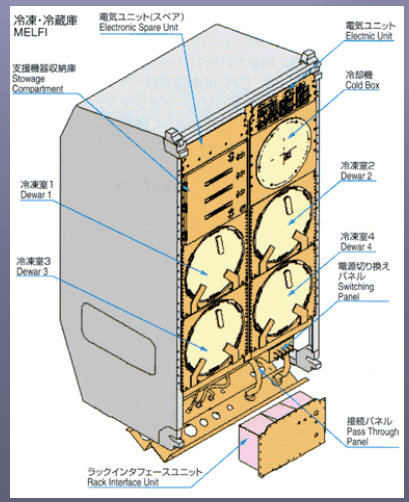
■ PADLES is located close to biological samples in JEM



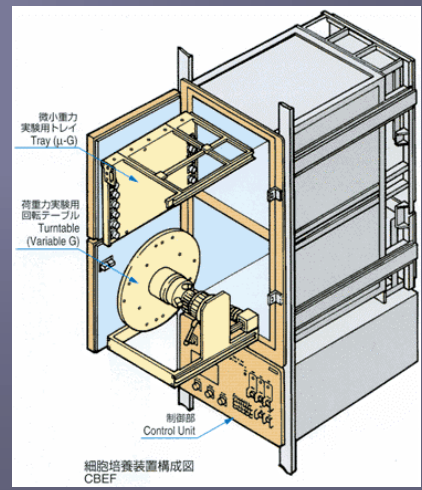
PADLES with biological samples



BEU



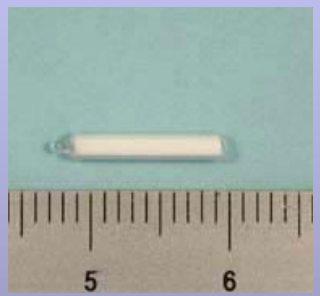
MELFI



CBEF

Constituent Elements

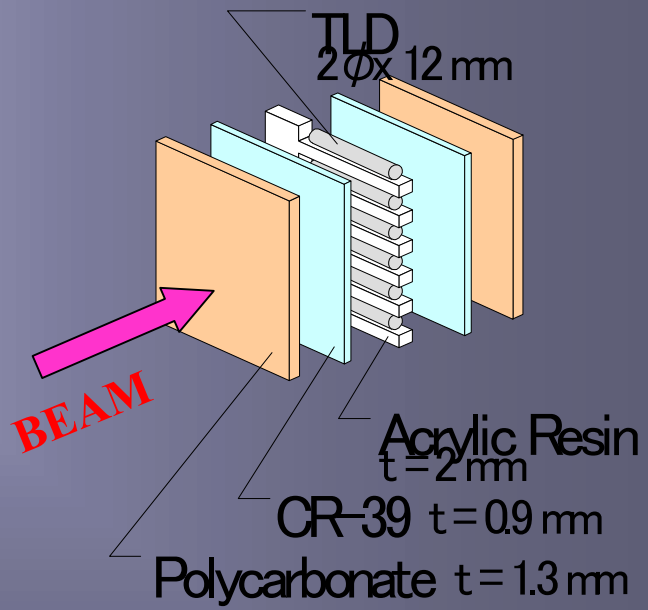
TLD-MSO-S (thermoluminescent dosimeters)



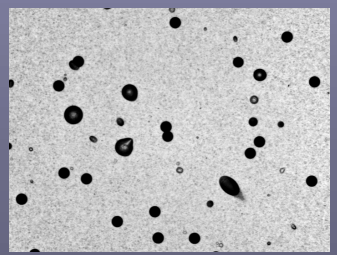
Mg_2SiO_4 : Tb powder enclosed

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)

Methodology I

(a) The absorbed dose : D_{TLD}

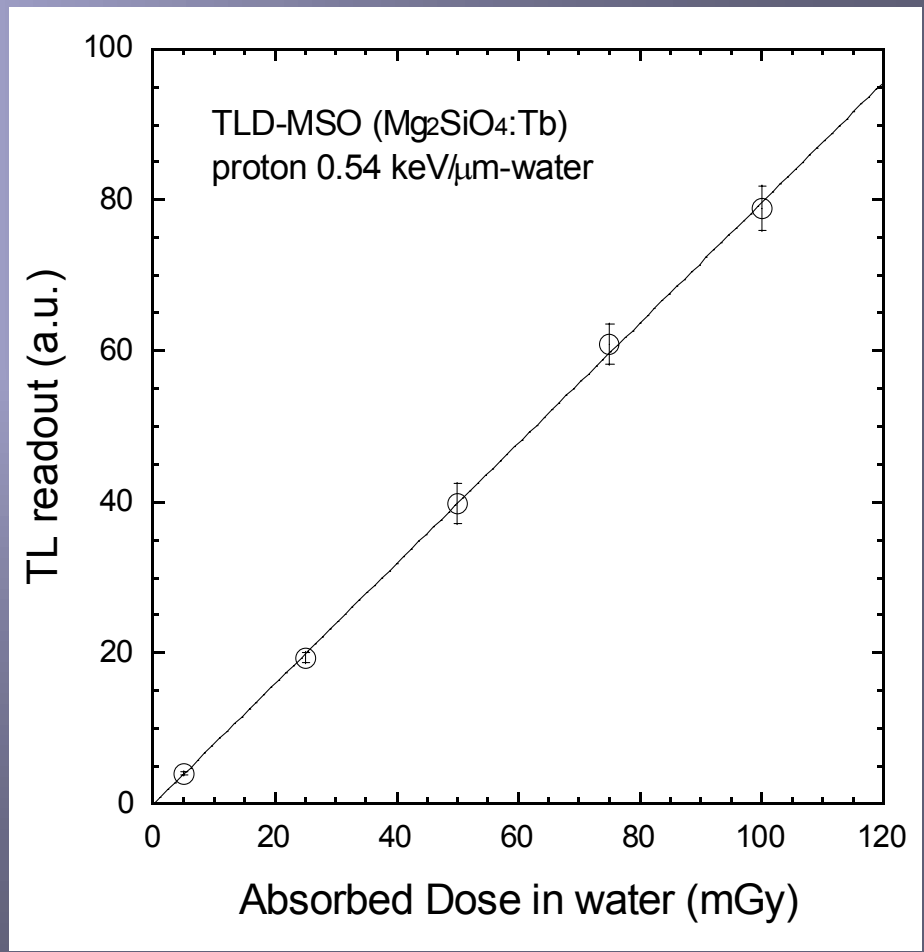
$$D_{\mathrm{TLD}} = f M K_{\mathrm{proton}}$$

(Gy-water)

f : correction factor (fading effects, temperature dependence)

M : TLD reader output,

K_{proton} : the conversion factor for water equivalent absorbed dose



Methodology Ⅱ

(b) The differential LET distribution : dN/dL (>10keV/mm)

$$\frac{dN}{dL} = \frac{\Delta N}{\Delta L}\frac{1}{TS\,\Omega}$$

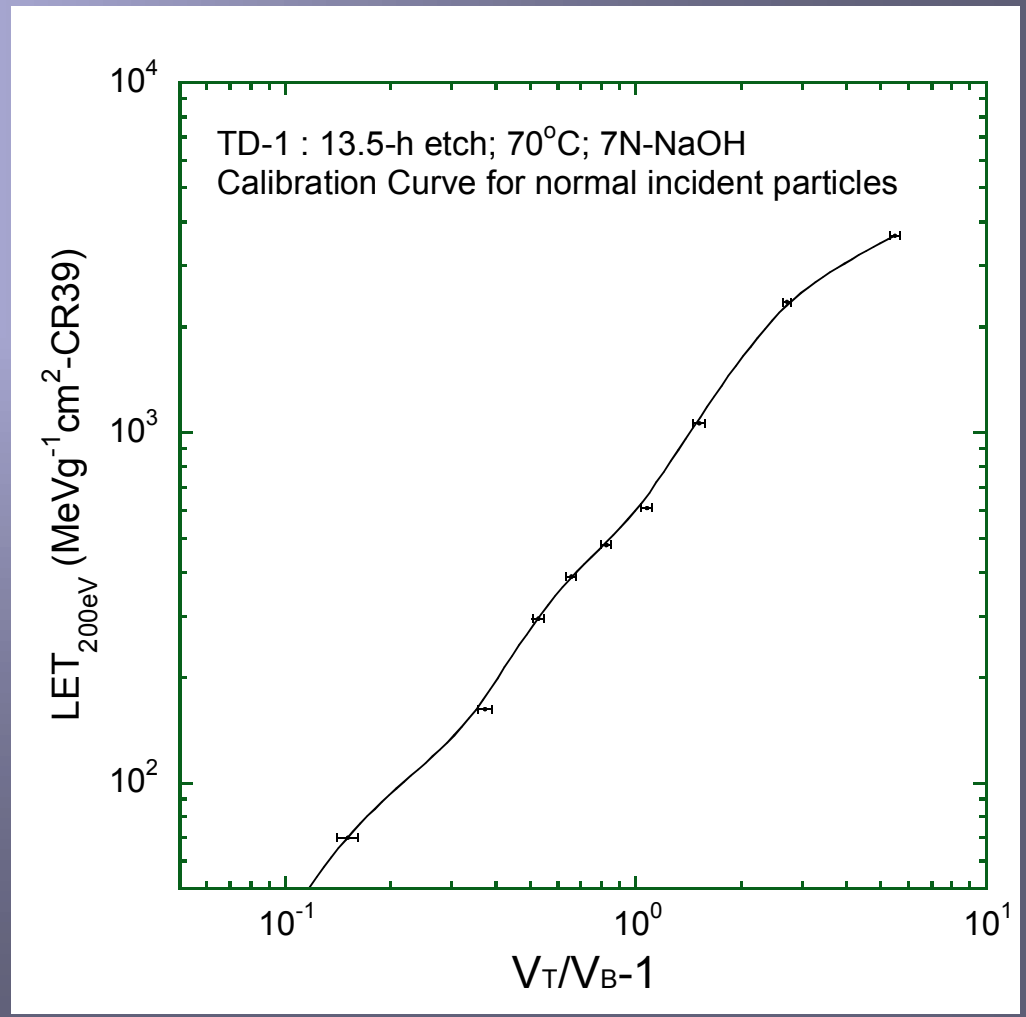
(particles $s^{-1}cm^{-2}sr^{-1}$ $(keV/\mu m)^{-1}$)

DL : range of LET bin (keV/μm),

T : observation time (sec) ,

S : scan area (cm^2),

Ω : solid angle=2π



Methodology Ⅲ

(continued)

The absorbed dose for > 10 keV/μm : D_{CR-39}

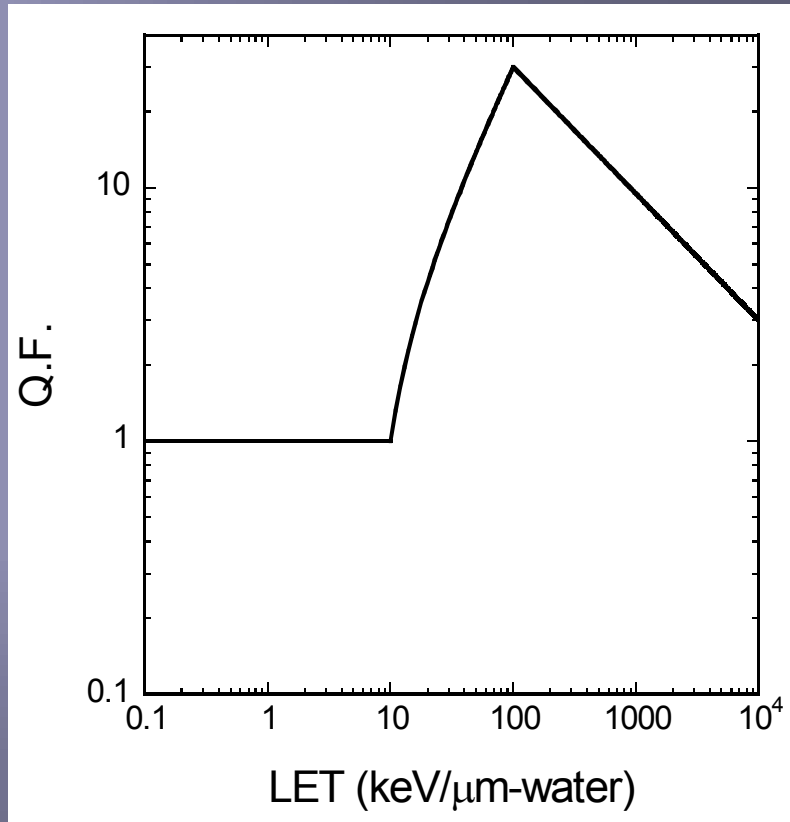
$$D_{CR-39} = 1.602 \times 10^{-6} 4\pi T \sum_{>10\text{keV}/\mu\text{m-water}} \left(dN/dL \, L_c \Delta L \right)$$

(mGy-water)

The dose equivalent for > 10 keV/μm : H_{CR-39}

$$H_{CR-39} = 1.602 \times 10^{-6} 4\pi T \sum_{>10\text{keV}/\mu\text{m-water}} \left(Q(L_c) \, dN/dL \, L_c \Delta L \right)$$

(mSv-water)



Q-L relation :ICRP Pub.60 (1990).

Q : quality factor. *Q-L relation ICRP Pub.60(1990)

Methodology Ⅳ

(c) –1 The total absorbed dose : D_{TOTAL}

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

(mGy)

(c) –2 Total dose equivalent : H_{TOTAL}

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

(mSv)

κ : mean TL efficiency for high-LET particles from TLD

Methodology V

(continued)

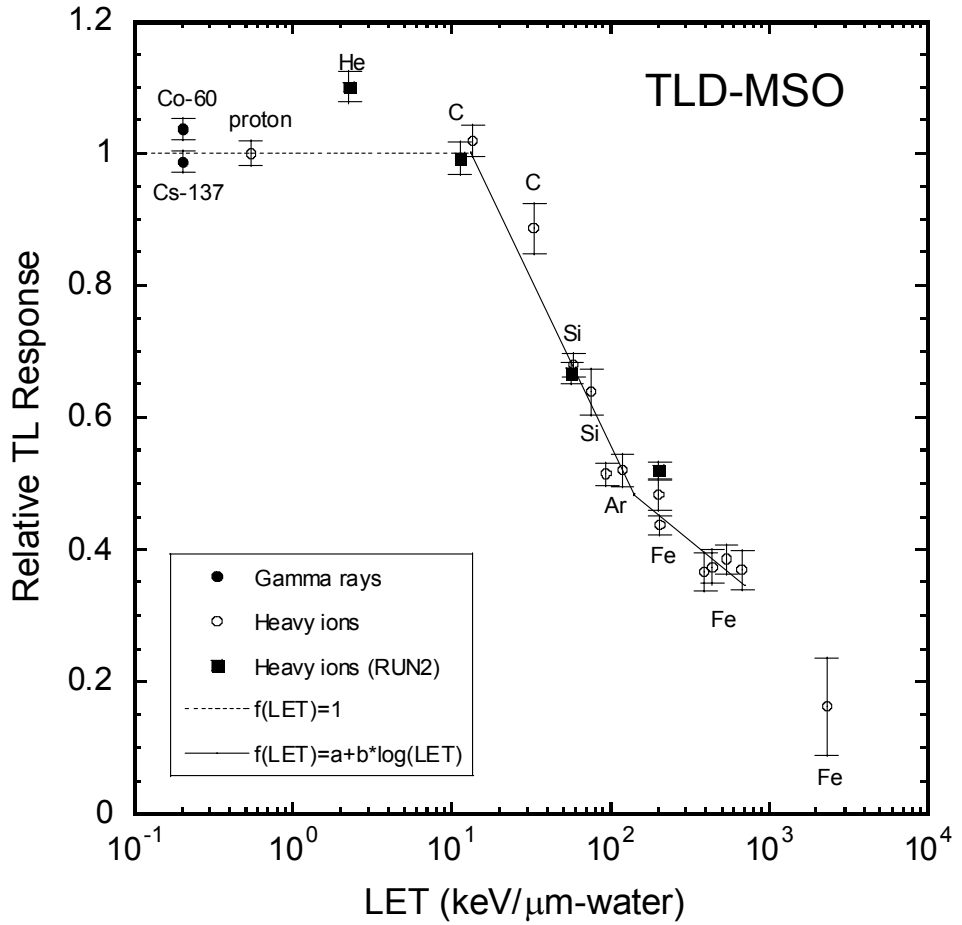
The mean TL efficiency for high-LET particles of TLD-MSO : κ

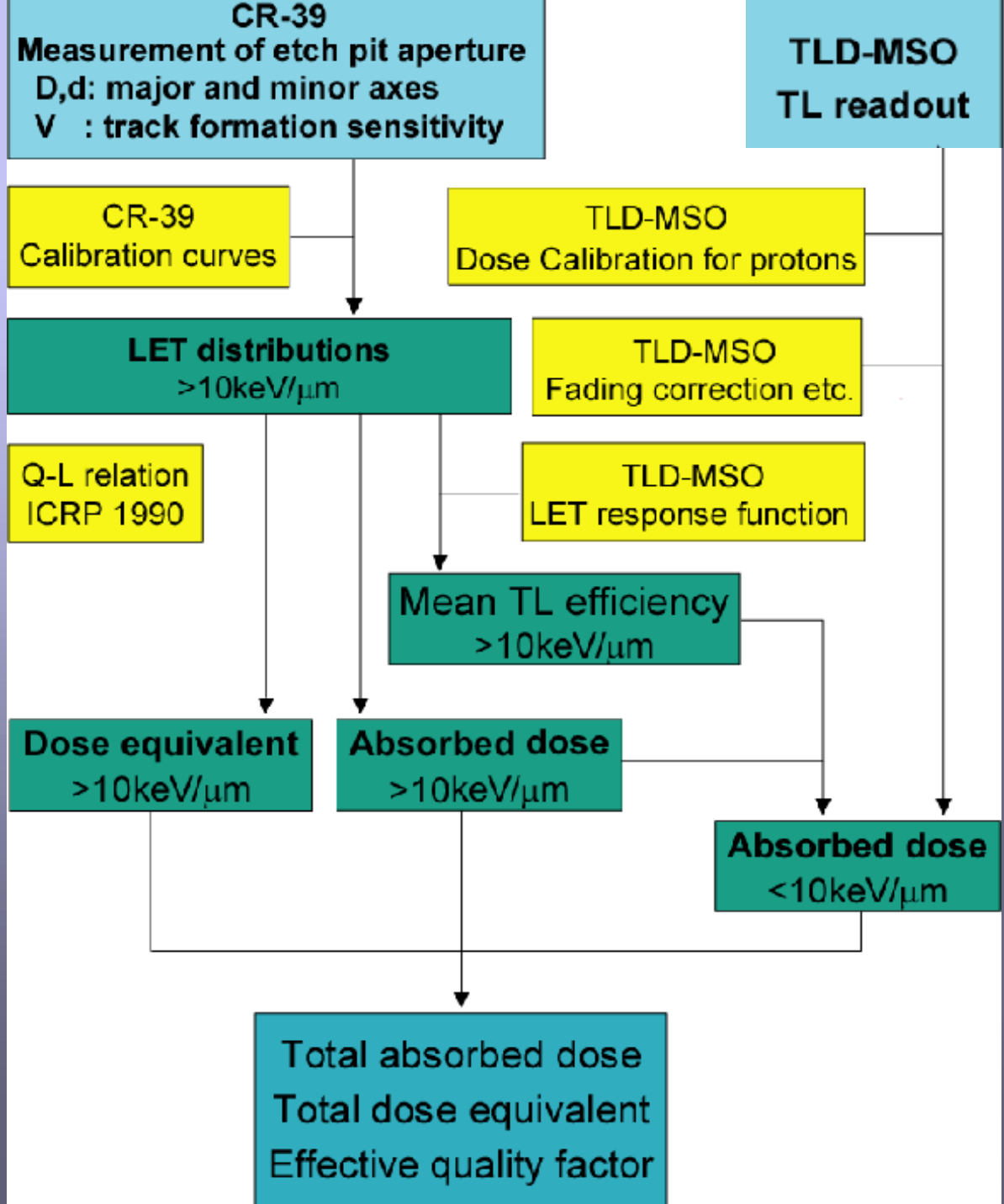
$$\kappa = \frac{\sum_{>10\mathrm{keV}/\mu\mathrm{m}} \left(f(LET)\, \Delta D(LET) \right)}{D_{\mathrm{CR-39}}}$$

Where,

$$\Delta D(L_c) = 1.602 \times 10^{-6} \left({\Delta N(L_c)}/{\Delta L}\, L_c \Delta L \right)$$

(mGy-water).



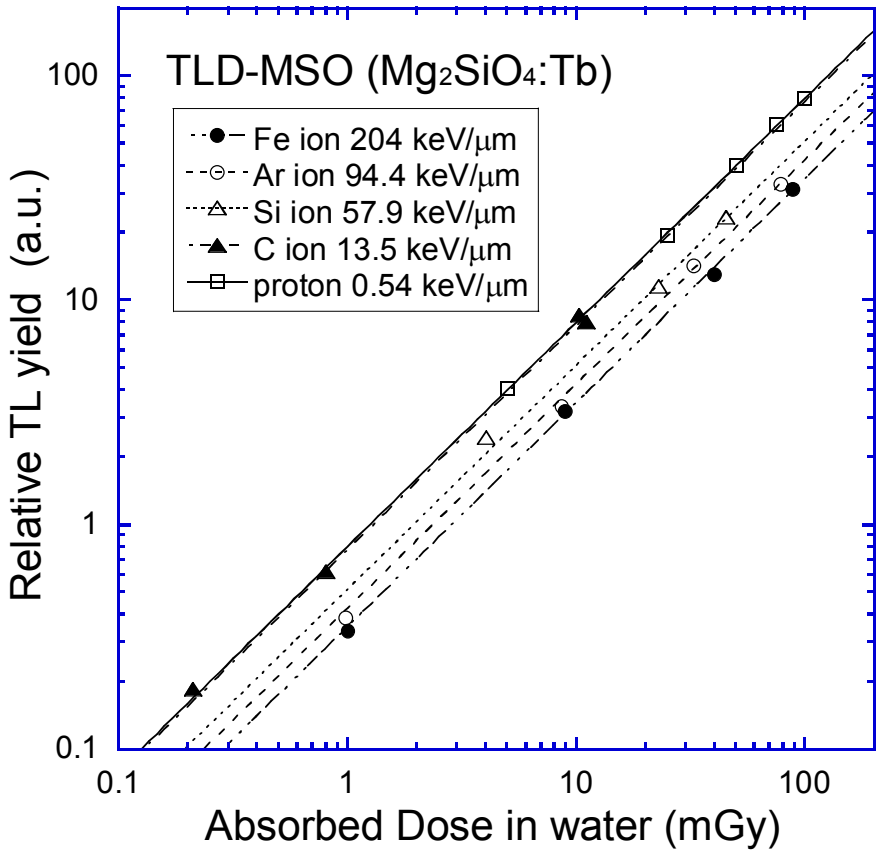

CR-39
Measurement of etch pit aperture
D,d: major and minor axes
V : track formation sensitivity
TLD-MSO
TL readout
CR-39
Calibration curves
TLD-MSO
Dose Calibration for protons
LET distributions
>10keV/μm
TLD-MSO
Fading correction etc.
Q-L relation
ICRP 1990
TLD-MSO
LET response function
Mean TL efficiency
>10keV/μm
Dose equivalent
>10keV/μm
Absorbed dose
>10keV/μm
Absorbed dose
<10keV/μm
Total absorbed dose
Total dose equivalent
Effective quality factor

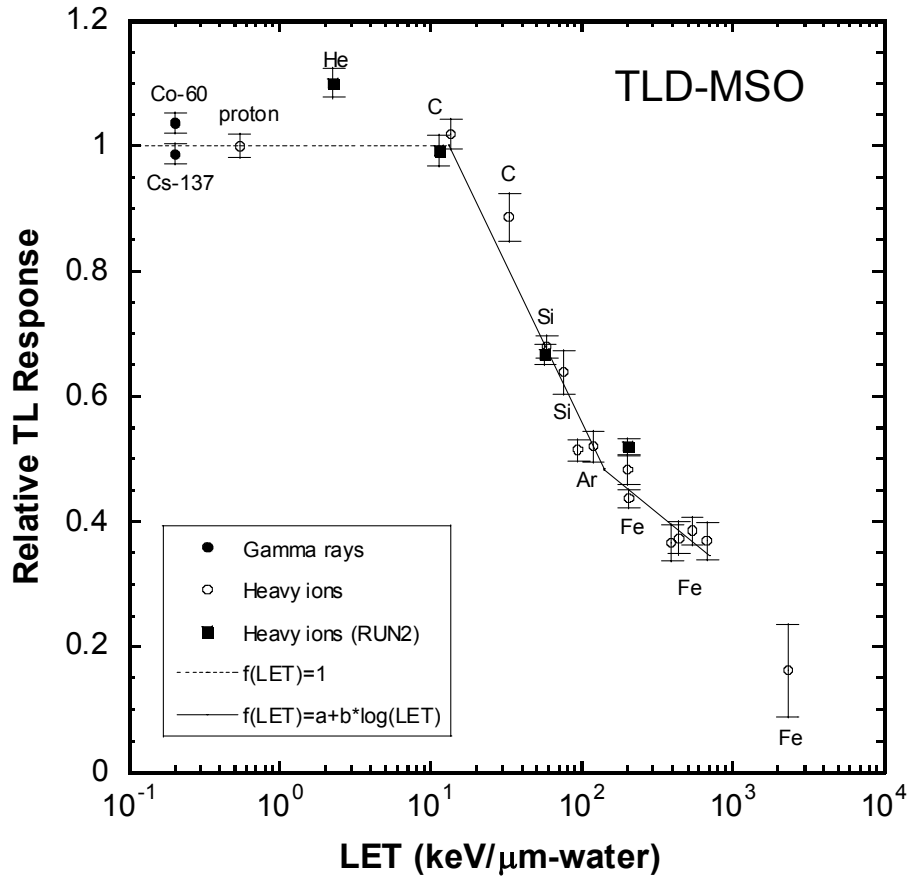
PADLES development schedule

Ground	SPACE
1997 : Introduction of dosimetric techniques from WASEDA univ.	
1999 :	STS-95 flight experiments (Genetic change induced in human cells in space shuttle experiment)
～ 2000 : Preparation of TLD reader and CR-39 auto scanning system	Analysis of STS-95 dosimeter packages
2001～ 2002 : Performance tests of TLD and CR-39 with heavy ion beams from HIMAC in NIRS	ISS Russian SM flight experiment (Radiation damage test of HDTV CCD device)
2002～2005 : Inprovement of the automatic CR-39 analysis system	
2006 ～ : Preparation and test of FM of PADLES	Loading to ISS KIBO with biological samples

*Research project with Heavy Ions at NIRS-HIMAC

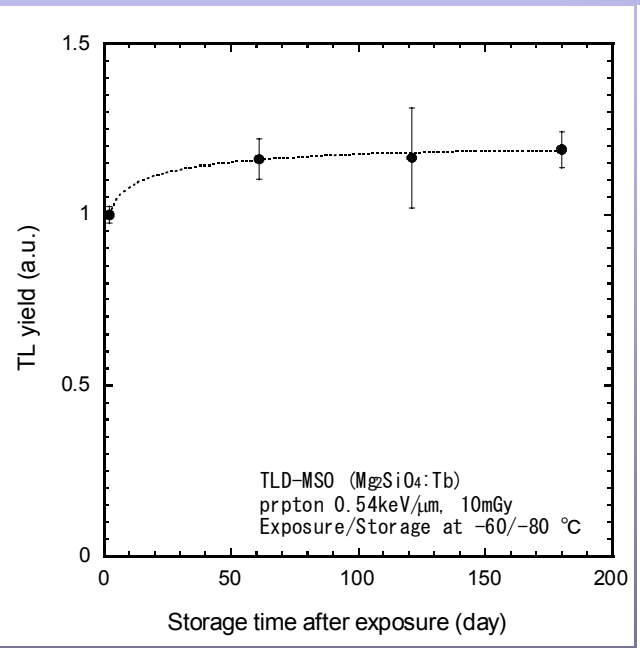
TLD-MSO: Dose and LET response function

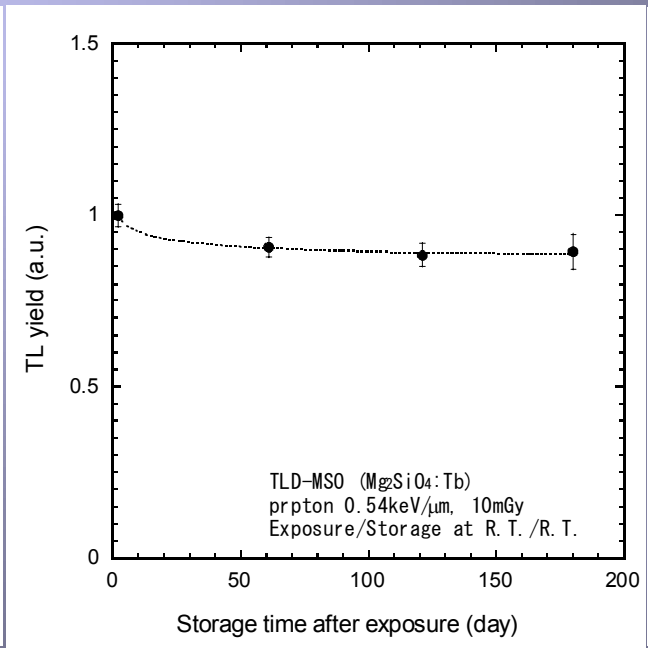


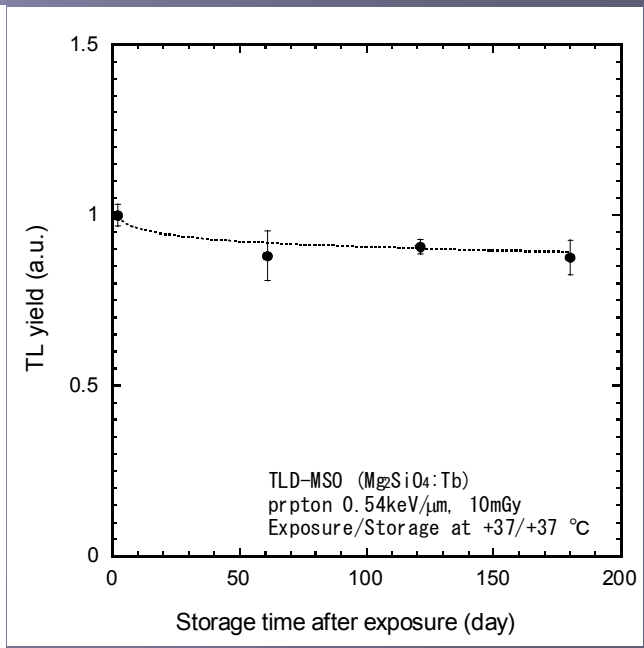


TLD-MSO : Fading effects

160 MeV/n proton exposure
storage time : up to 3 months

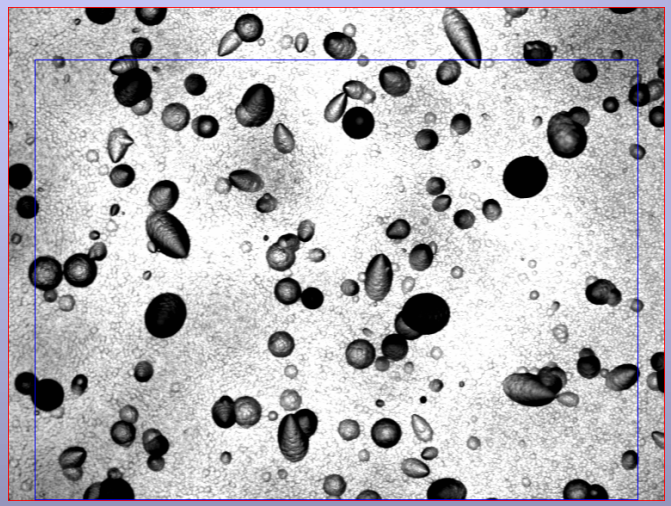




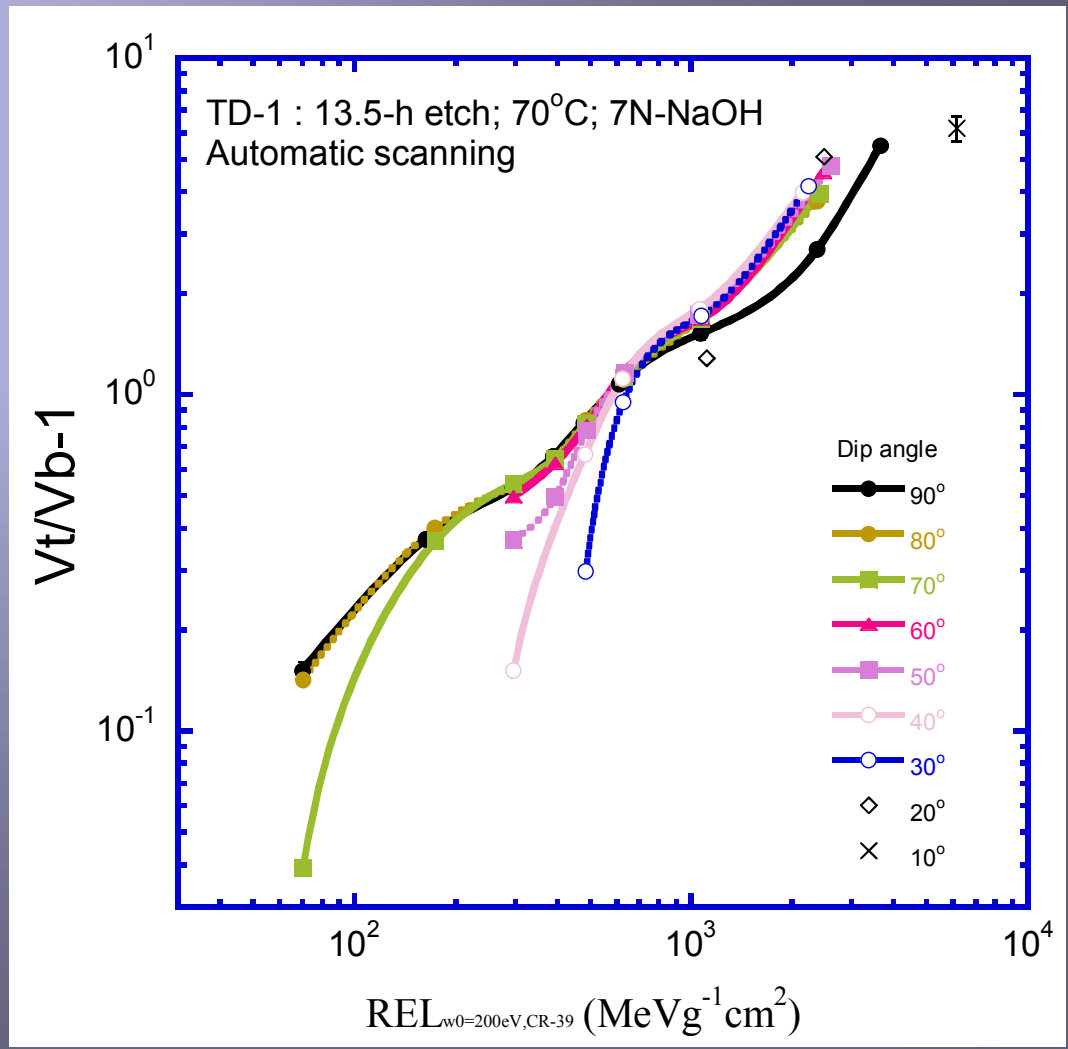


Exposure/storage at –80°C **Exposure/storage at R.T.** **Exposure/storage at 37°C**

CR-39: Calibration curves at various incident angles



Sample aboard ISS Russia SM
2001/8/21-12/10 **(71 days)**
TD-1 6N-NaOH 65h-etching, x100



Aplications

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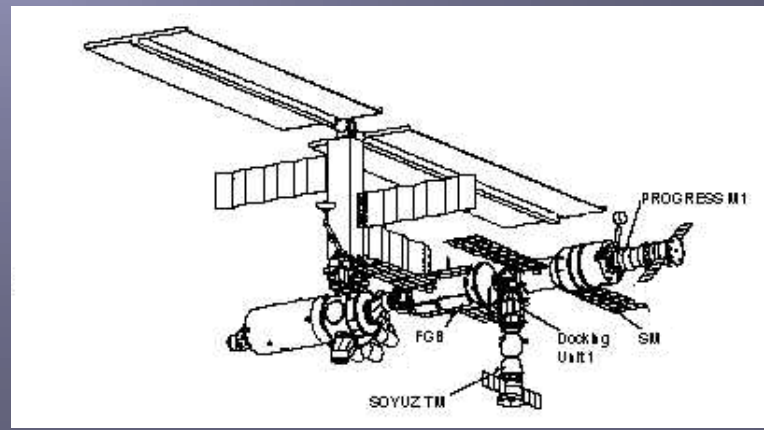
Space radiation damage test of the High-Definition TeleVison (HDTV) camera aboard ISS Russian module ZEVEZDA

To investigate white effects in HDTV CCD elements due to HZE particles, test stacks of CCDs sandwiched between CR-39 sheets are used in the ISS Russian SM.

HDTV



PADLES for HDTV CCD
L170 × W68 × T19mm

PADLES for ZVEZDA russia

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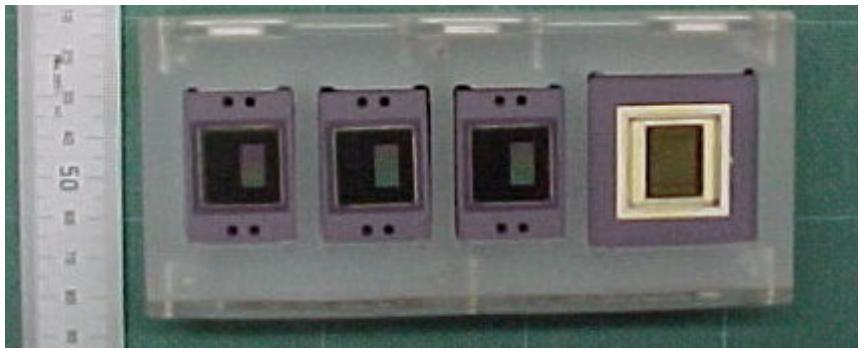
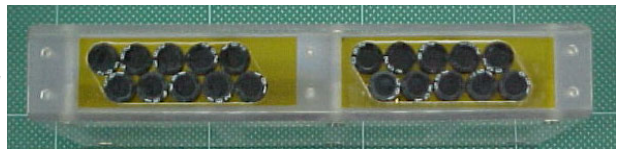


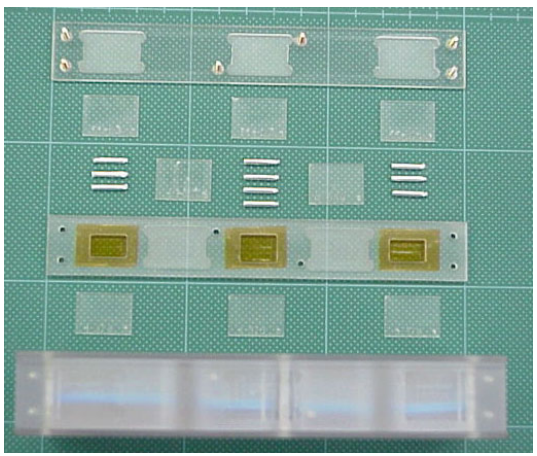
(UP)

(SIDE LEFT)

TLB-UD807



CCD C-MOS

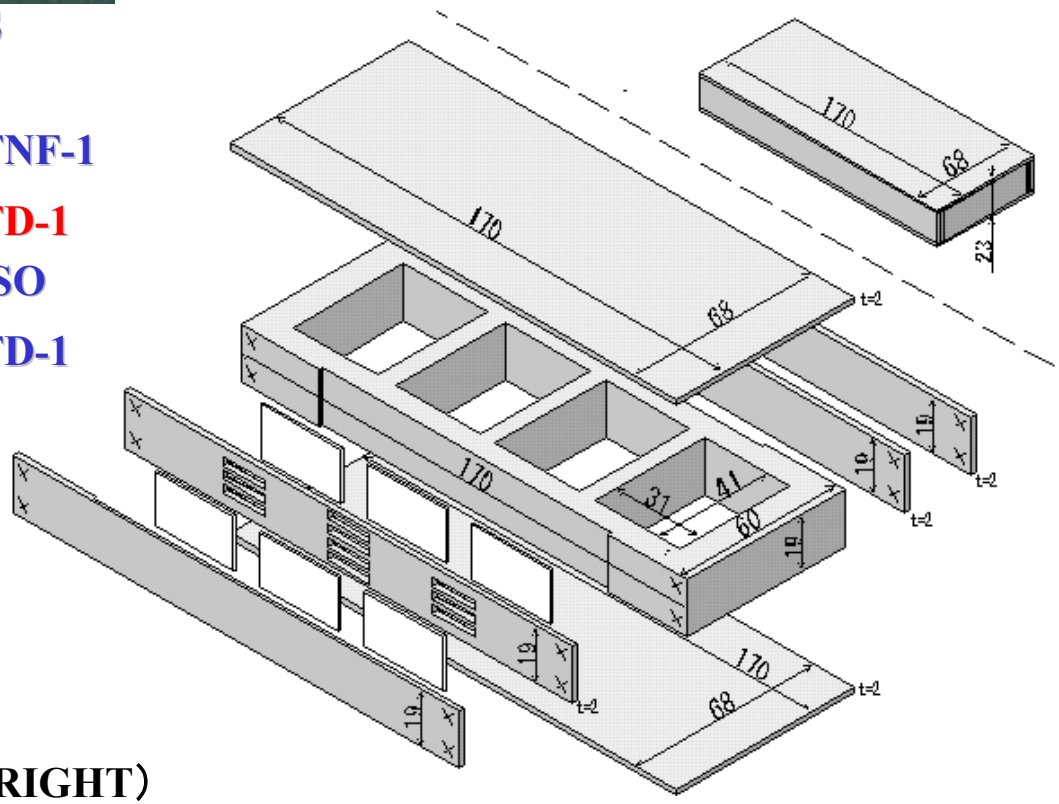


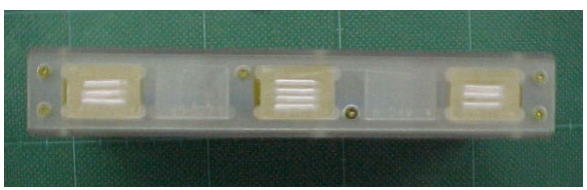
CR-39 TNF-1

CR-39 TD-1

TLD-MSO

CR-39 TD-1





(SIDE RIGHT)

ISS ZVEZDA Russia

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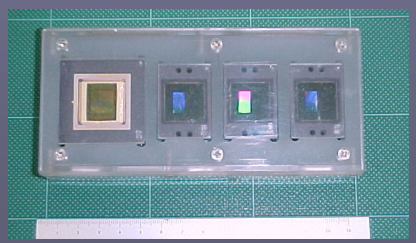
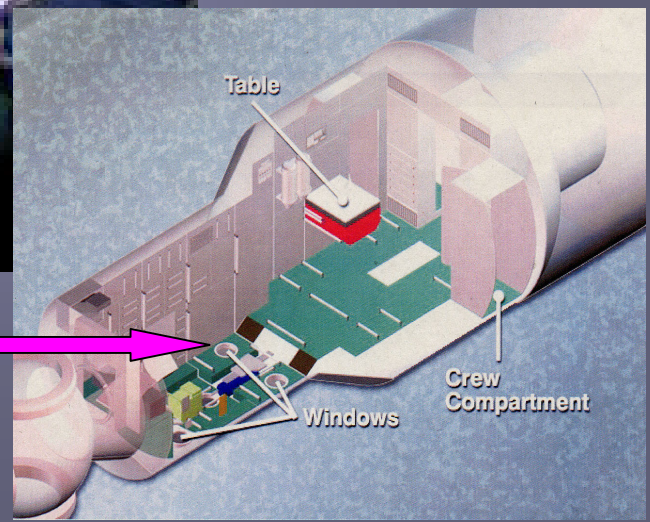
Altitude：400km

An angle of inclination

：51.6度





Preriminaly results from TLD

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Launch Schedule			
TLD annealing	2001/6/7	Contol: Ground storage days	186
Launch	2001/8/21	Flight sample: Ground storage days	115
Returan	2001/10/31	Flight sample: exposure days	71
TLD measurement of 10 TLD	2001/12/10		

■ **Absorbed doses rate on ISS ZVEZDA (21Aug.-31.Oct.in 2001)**

PADLES **0.215±0.015 mGy/day**

Russian I.C. **0.242 mGy/day**

NASDA

Summary

- **Objectives**

  Space radiation dosimtory for biological experiments

- **Methodology (TLD&CR-39)**

  We determine the absorbed dose and dose equivalent for space radiation in the entire LET region by a combination of the CR-39 and TLD-MSO date.

- **Ground performance tests**

  We obtained the calibration data using high-energy heavy-ion beams from HIMAC in NIRS.

- **Applications**

  PADLES can be applied for personal dosimetory and radiation damage research on electronic devices.

Future Work : Auto scanning and analysis system

PADLES with biological samples :

■ Manual measurement → several month to year required

（1 sheet of CR-39 ：252×189.42 μm/field、 2.5cm square samples
→ 約5400 fields/sample ）

↓

1 life science space experiments need up to 100 sheets of CR-39

↓

■ Auto and high-speed scanning system measurement
→ within two weeks after return

we aim to offer the datas to researchers quickly using the automatic CR-39 analysis system, which in cooperation partnership researchers NIRS


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