

Intercomparison of passive radiation monitors in Russian segment of ISS (Space Intercomparison/BRADOS) II

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Space Intercomparison/BRADOS

We conducted an intercomparison experiment for passive radiation dosimeters, Space Intercomparison/BRADOS, aboard the International Space Station (Russian Service Module).

Phase-1

- Intercomparison for passive dosimeters from five labs
- Exposure duration: 91.5 days

Phase-2

- Spatial distributions of dose (rate) at 5 locations
 - Intercomparison for passive dosimeters of NIRS and IBMP
 - Exposure duration: 268.5 days
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Locations of BRADOS boxes and Averaged shielding

No. of Box	Location	Exposure duration (days)	Average shielding (g/cm ²)
A46	Starboard side	91.5	35.6
A41	Starboard side	268.5	35.5
A42	Port side	268.5	31.0
A43	Floor, Starboard side	268.5	33.2
A44	Starboard side	268.5	34.0
A45	Ceiling near the R-16, port side	268.5	40.3

Participants and detectors

NIRS-CHIYODA

Plastic detector (TT-A(CR-39): Chiyoda Technol corporation)

Glass detector (FD-P33-7: Chiyoda Technol corporation)

NIRS-NAGASE

Plastic detector (TD-1(CR-39), BARYOTRAK(CR-39): Nagase landauer Inc.)

Optical stimulated detector (OSL $\text{Al}_2\text{O}_3:\text{C}$: Nagase landauer Inc.)

Thermoluminescence detector (LiF(TLD-100): Nagase landauer Inc.)

IBMP

Plastic detector (TD-1(CR-39): Nagase landauer Inc.)

Thermoluminescence detector (TLD-100)

ATI

Plastic detector (TD-1(CR-39): Nagase landauer Inc.)

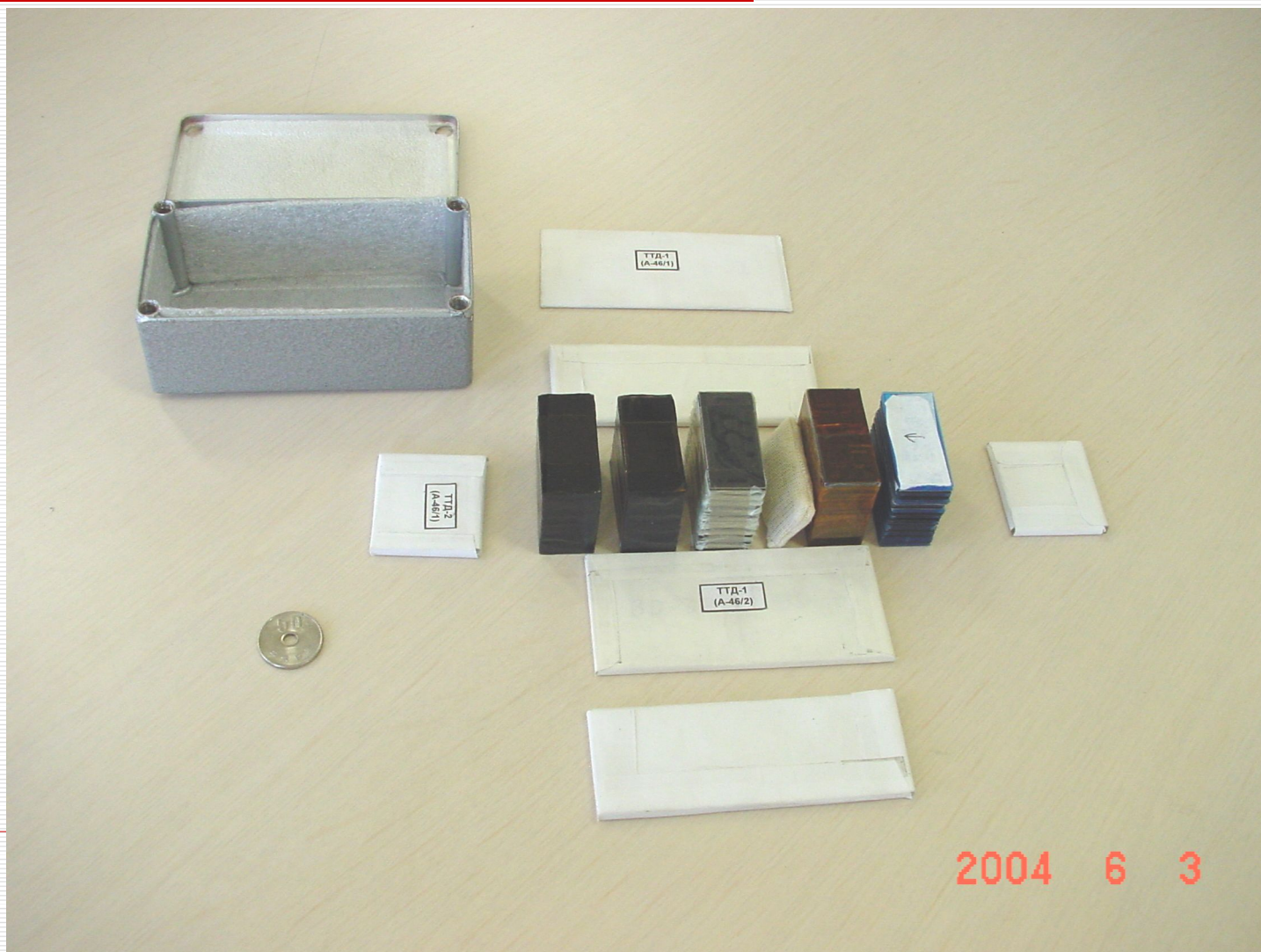
Thermoluminescence detector (LiF-300, 600, 700)

OSU/Eril research

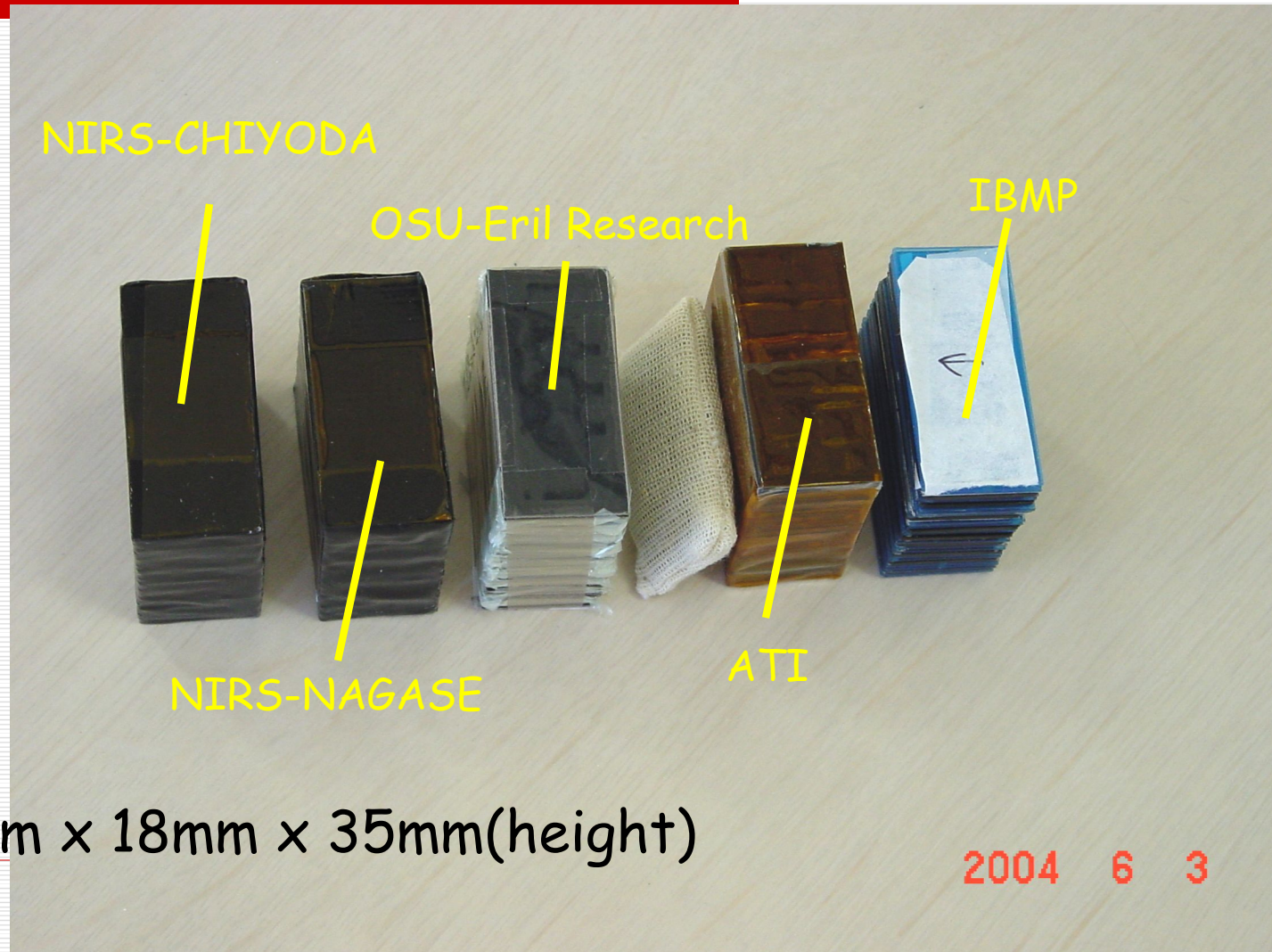
Plastic detector (USF-4(CR-39): American Technical Physics)

Optical stimulated detector (OSL $\text{Al}_2\text{O}_3:\text{C}$: Landauer Inc.)

Detector assembly



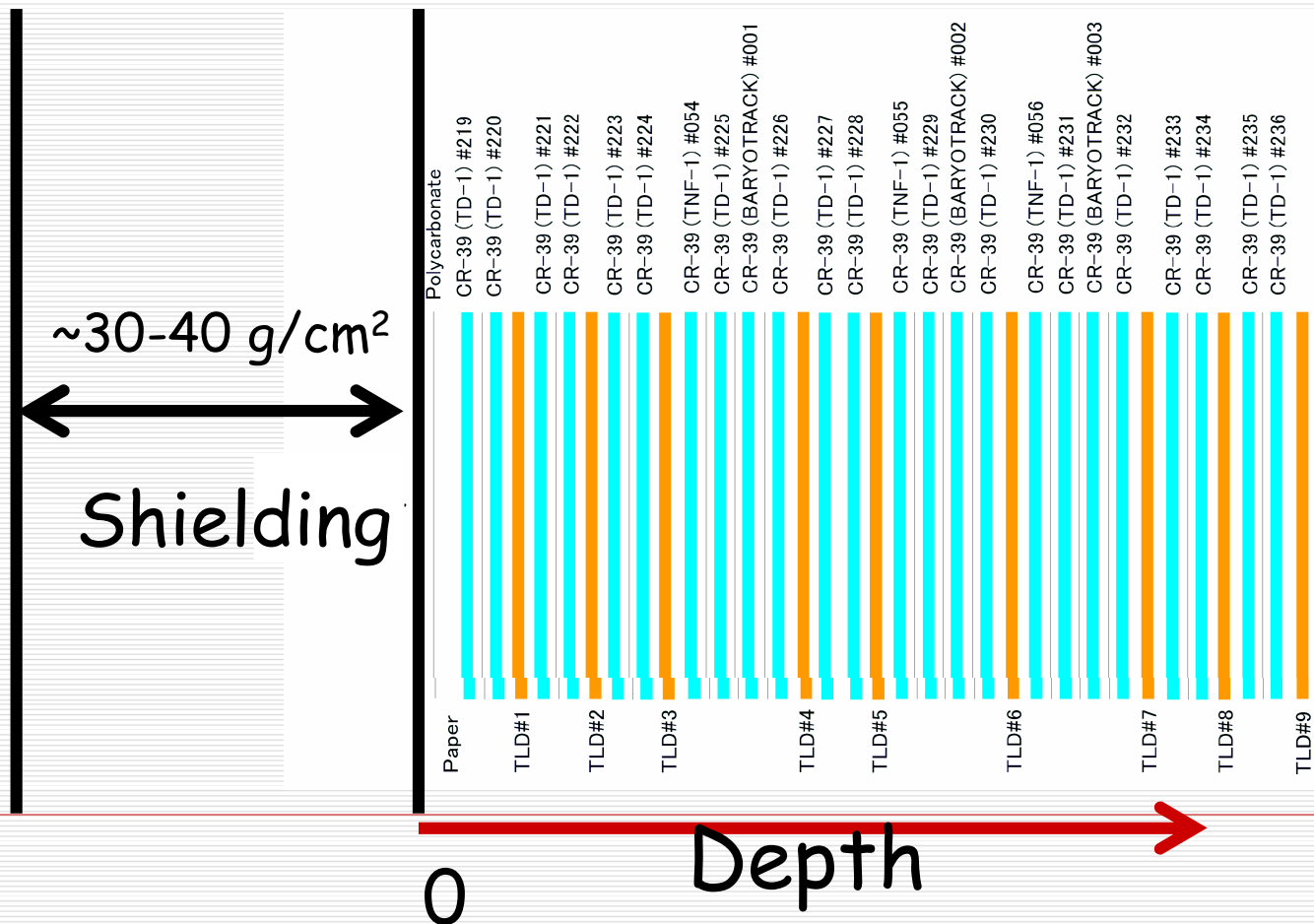
Detector packages



55mm x 18mm x 35mm(height)

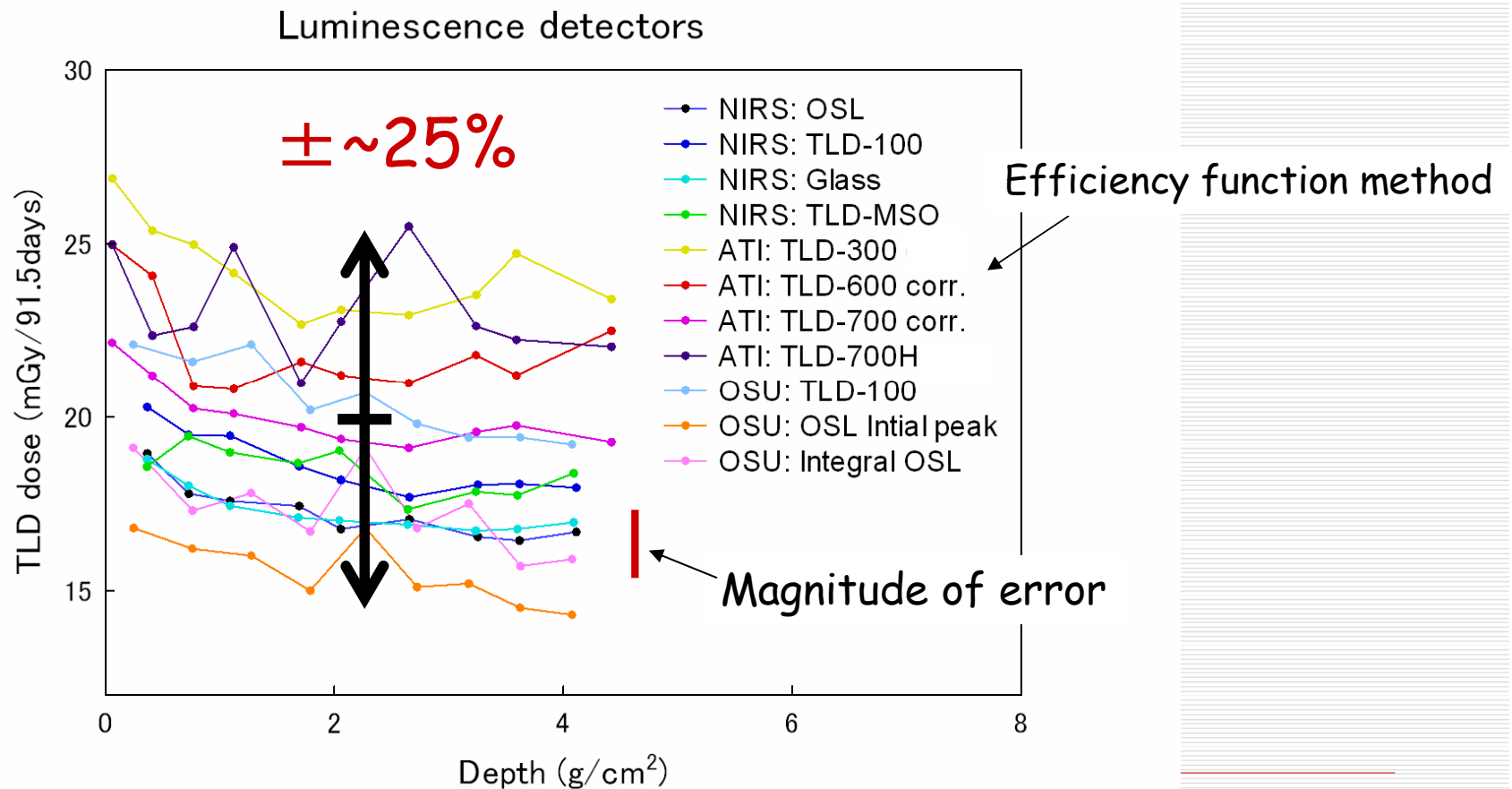
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Configurations of stack



Luminescence detectors

Results from luminescence detectors



INTERCOMPARISON OF COSMIC RAYS WITH HEAVY ION BEAMS AT NIRS

Table 3. TLD and OSLD results from the Blind #1 exposure and differences between measurement and nominal dose values.

Laboratory	Detector	Dose (mGy)	Percentage difference
Nominal ATI		103.00	
	TLD-600 ($^6\text{LiF:Mg,Ti}$)	108.23 ± 0.36	4.8
	TLD-700 ($^7\text{LiF:Mg,Ti}$)	111.48 ± 0.59	7.6
DLR	TLD-600 ($^6\text{LiF:Mg,Ti}$)	120.73 ± 5.3	14.7
	TLD-600H ($^6\text{LiF:Cu,P}$)	75.01 ± 5.3	27.2
	TLD-600 corrected ^b	103.19 ± 4.5	0.0
	TLD-700 ($^7\text{LiF:Mg,Ti}$)	119.27 ± 4.9	13.6

Blind Exposure	150 MeV/n ^4He	400 MeV/n ^{12}C	490 MeV/n ^{28}Si	500 MeV/n ^{56}Fe
#1 Space	100 mGy	1 mGy	1 mGy	1 mGy

KFKI OSU	TLD-300 ($\text{CaF}_2\text{:Tm}$)	107.65	4.3
	TLD-600 ($^6\text{LiF:Mg,Ti}$)	101.71	1.3
	$\text{CaSO}_4\text{:Dy}$	91.34 ± 4.16	11.3
	TLD ($\text{Al}_2\text{O}_3\text{:C}$)	88.5 ± 2.1	14.1
	Luxel OSL ($\text{Al}_2\text{O}_3\text{:C}$)	103.2 ± 0.6	0.2
	Luxel OSL I_0 ($\text{Al}_2\text{O}_3\text{:C}$)	136.3 ± 0.9	24.4
	Luxel POSL ($\text{Al}_2\text{O}_3\text{:C}$)	90.37 ± 0.9	12.3

^aHigh Temperature Ratio (HTR) method

^bEfficiency function method.

^cSlow cool annealing

ICCHIBAN-2

Short summary for luminescence detectors

- ❑ TLD dose were estimated to be 15 - 25 mGy/91.5days.
- ❑ TLD dose was gradually decreased ($\sim 10\%$ or more) with depth ($\sim 4 \text{ g/cm}^2$) from the wall.

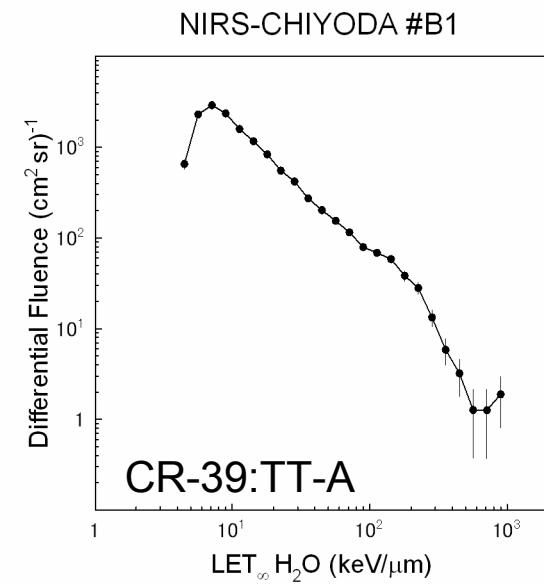
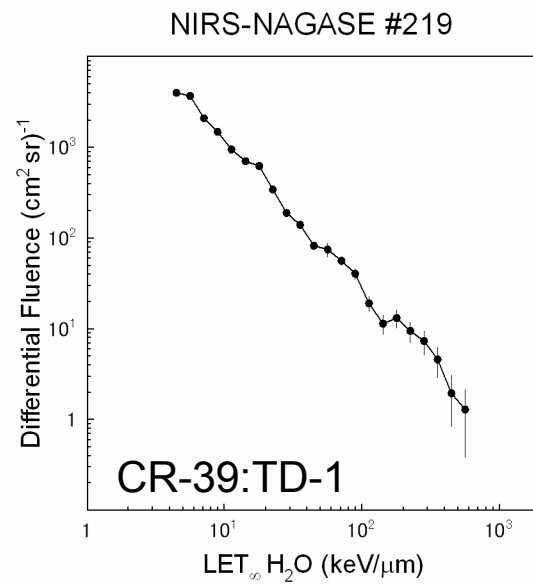
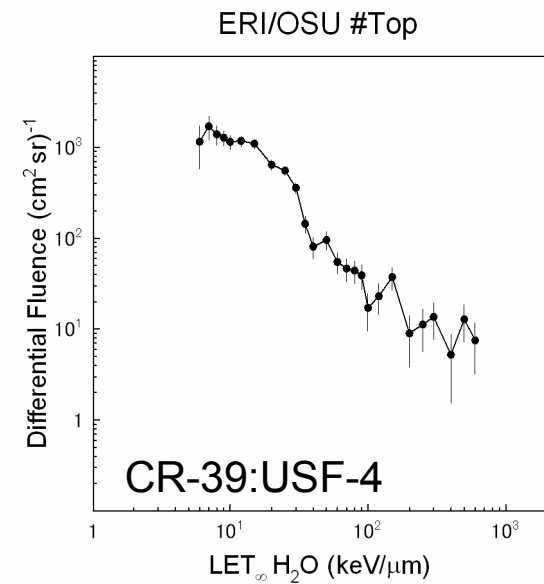
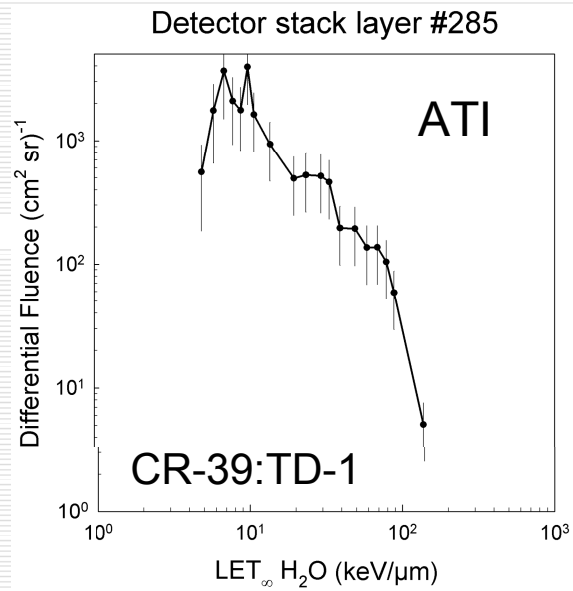
- ❑ We found big difference ($\pm \sim 25\%$).
- ❑ It can not explain using the results from the ICCHIBAN-2 (Blind#1) ($\pm 10\% @ \text{Max}$).

- Precise calibration for $< 10 \text{ keV/um}$
- Fading?
- Incident angle?

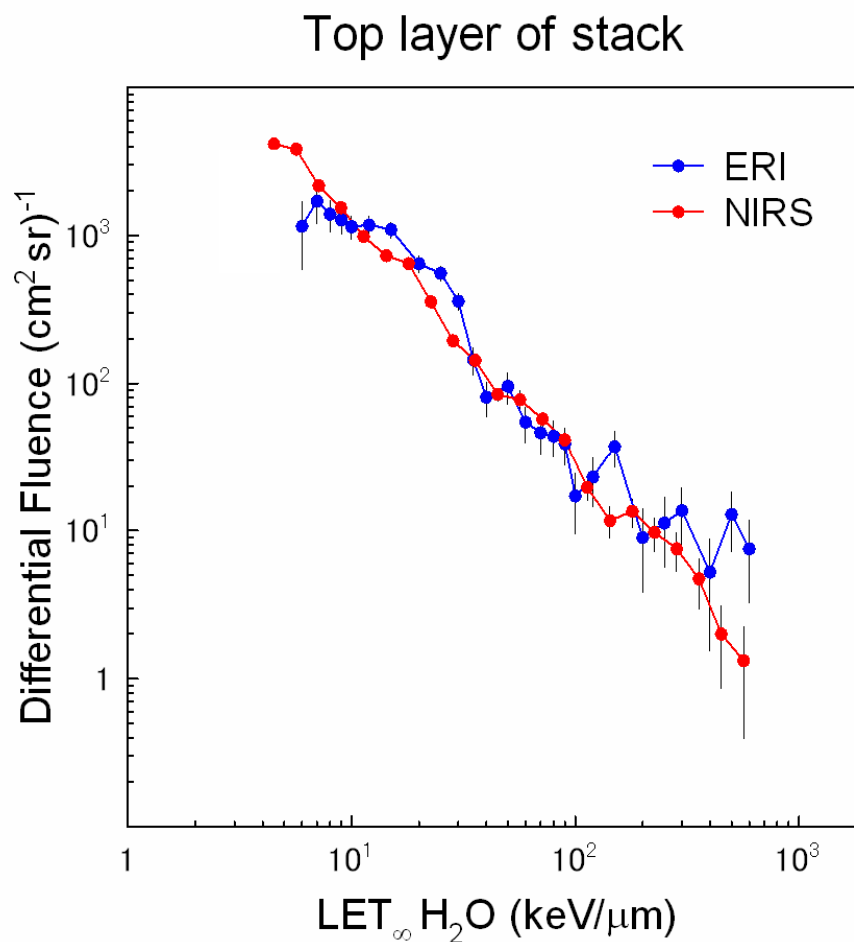
Give me comments !

CR-39 detectors

LET spectrum for top layer



Comparison of ERI and NIRS spectrum



Combining method
Short etch
+
Long etch

▪ Methodology

CR-39(Dose rate, Dose Equivalent rate, Quality Factor)

Top layer of stack	NIRS -NAGASE	NIRS -CHIYODA	OSU/ERI	ATI
Material	CR-39 /TD-1	CR-39 /TT-A	CR-39 /USF4	CR-39 /TD-1
Dose rate ≥ 10 keV/ μm ($\mu\text{Gy/day}$)	20 ± 1	36 ± 1	32 ± 2	41 ± 15
Dose Equivalent rate ≥ 10 keV/ μm ($\mu\text{Sv/day}$)	222 ± 9	410 ± 13	304 ± 24	480 ± 176
Quality Factor ≥ 10 keV/ μm ($\mu\text{Sv/day}$)	11.1 ± 0.7	11.4 ± 0.5	9.5 ± 1.0	11.7 ± 6.1

- Methodology (treatment for short range particle)
 - Material/Etching (ex. Incident angle dependence)
 - Calculation (Response curve $\rightarrow$ Dose)
 - Skill
-

ICCHIBAN-2

Table 4. CR-39 PNTD results from the Blind #1 exposure.

Laboratory	PNTD dose (mGy)	Percentage difference	PNTD dose equivalent (mSv)	Percentage difference
Nominal	3.00		37.72	
			40.09 ± 3.33	5.9
			37.30 ± 3.82	1.1
IMBP	2.26	24.7	—	—
INP	2.63 ± 0.07	12.3	33.78	10.4
JAXA	3.3 ± 0.2	9.1	41.5 ± 0.23	23.0
NPI				
Page	3.06	2.0	43.6	13.5
Tastrak 0.5	1.76	41.1	—	—
Tastrak 1.0	1.99	33.5	—	—

~30%

- Normal incident angle
- High energy ions

Blind Exposure	150 MeV/n ⁴ He	400 MeV/n ¹² C	490 MeV/n ²⁸ Si	500 MeV/n ⁵⁶ Fe
#1 Space	100 mGy	1 mGy	1 mGy	1 mGy

Dip angle dependence of sensitivity

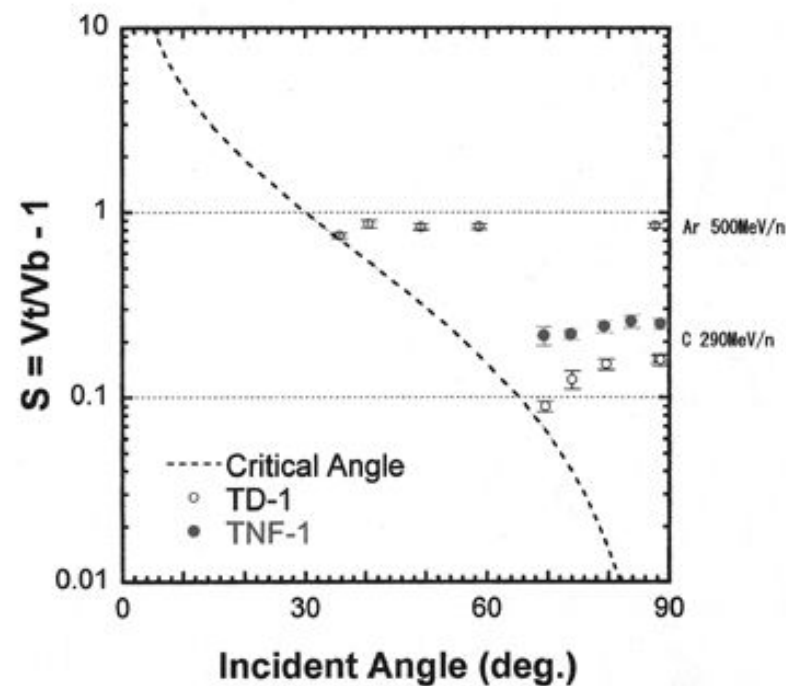
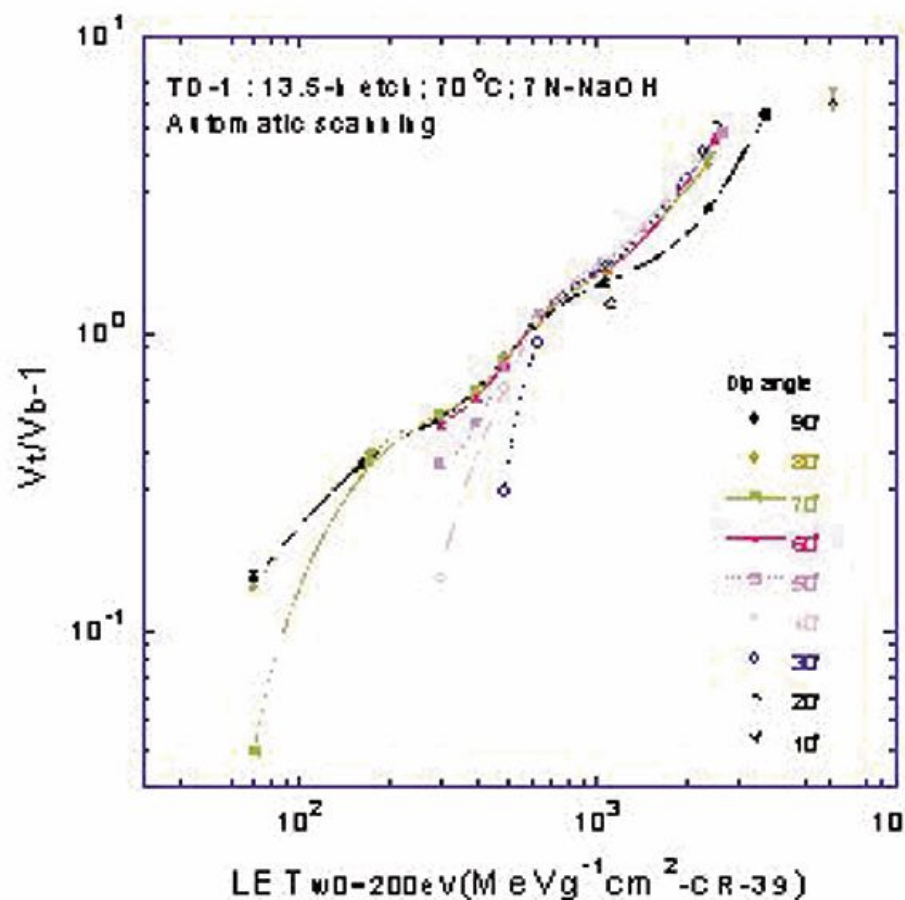


図2 CR-39飛跡生成感度の角度依存性データ

Short summary for CR-39 results

- ❑ High LET component ($\text{LET} \geq 10 \text{ keV}/\mu\text{m}$) of dose rate was measured to be 20 - 41 $\mu\text{Gy}/\text{day}$.
- ❑ For dose equivalent was measured to be 222 - 480 $\mu\text{Sv}/\text{day}$.
- ❑ We should check more carefully the procedures to extract the dose and dose equivalent.
 - Methodology
 - Material/Etching
 - Calculation
 - Skill

We should prepare the standard (guide).

Comparison of results for top layer (TLD + CR-39)

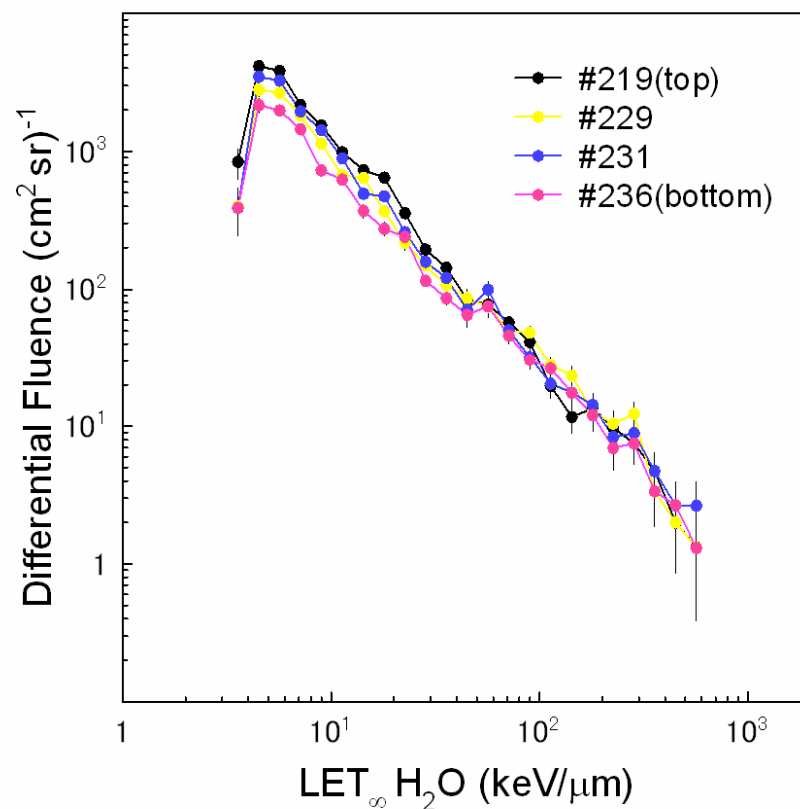
Top layer of stack	NIRS -NAGASE	NIRS -NAGASE	NIRS -CHIYODA	NIRS -CHIYODA	OSU/ERI	ATI	ATI
Method (combination)	CR- 39/OSL	CR-39 /TLD-100	CR-39 /Glass	CR-39 /TLD- MSO	CR- 39/OSL	CR-39 /TLD-700	HTR (TLD-700)
TLD Dose Rate ($\mu\text{Gy/day}$)	207 ± 10	222 ± 4	205 ± 2	192 ± 6	242 ± 20	293 ± 6	293 ± 6
Dose rate $\geq 10 \text{ keV}/\mu\text{m}$ ($\mu\text{Gy/day}$)	20 ± 1 (9%)	20 ± 1 (9%)	36 ± 1 (17%)	36 ± 1 (18%)	32 ± 2 (13%)	41 ± 15 (13%)	—
Total Dose Rate ($\mu\text{Gy/day}$)	213 ± 10	228 ± 4	218 ± 2	203 ± 6	255 ± 20	305 ± 89	242 ± 6
Dose Equivalent rate $\geq 10 \text{ keV}/\mu\text{m}$ ($\mu\text{Sv/day}$)	222 ± 9 (53%)	222 ± 9 (52%)	410 ± 13 (53%)	410 ± 13 (50%)	304 ± 24 (58%)	480 ± 176 (64%)	—
Total Dose Equivalent Rate ($\mu\text{Sv/day}$)	415 ± 14	430 ± 10	592 ± 13	577 ± 14	528 ± 51	744 ± 182	491 ± 10
Averaged Quality Factor	1.95 ± 0.1	1.89 ± 0.10	2.72 ± 0.1	2.84 ± 0.1	2.07 ± 0.2	2.44 ± 0.6	2.03 ± 0.03

Summary

- ❑ Contribution of high LET component to total dose : 9 - 18%
 - ❑ To Dose equivalent : 50 - 64%
 - ❑ We found big differences for both (TLD and CR-39 detectors). Space intercomparison gives quite a lot of knowledge.
 - ❑ It should be reflected to grand base ICCHIBAN and should be discuss about the strategy to make "standard".
 - ❑ We hope to do the space intercomparison again.
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LET spectra at different depth in stack

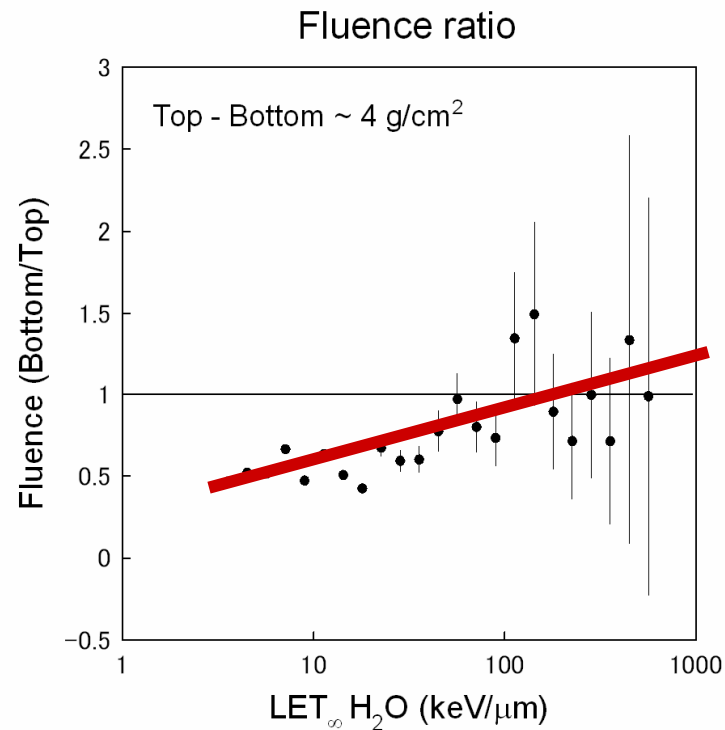
LET spectra in NIRS-NAGASE stack



Bottom

Ratio of fluence for LET spectra (Bottom / Top layer)

Preliminary





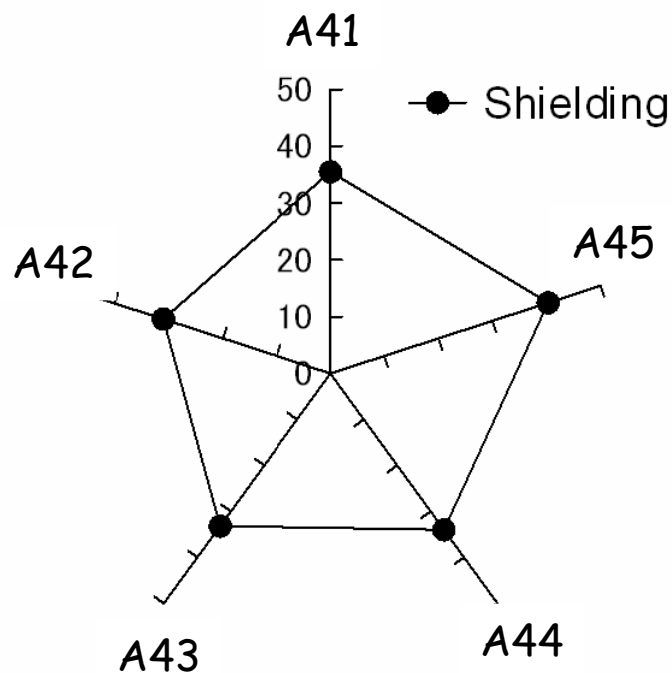
Averaged shielding for the locations of BRADOS boxes

No. of Box	Location	Exposure duration (days)	Averaged shielding (g/cm ²)	Standard deviation (g/cm ²)
A46	Starboard side	91.5	35.6	31
A41	Starboard side	268.5	35.5	31
A42	Port side	268.5	31.0	30
A43	Floor, Starboard side	268.5	33.2	38
A44	Starboard side	268.5	34.0	37
A45	Ceiling near the R-16, port side	268.5	40.3	42

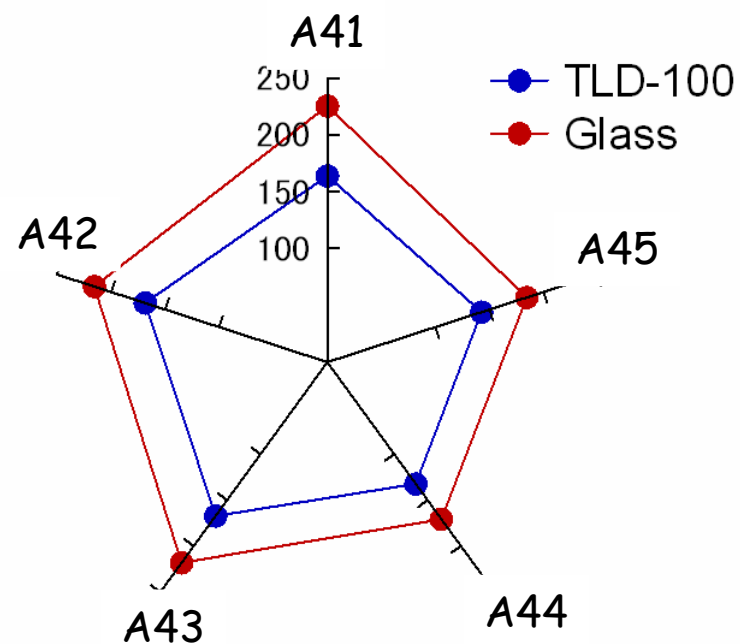
TLD dose rate from 5 locations (BARDOS phase-2)

Preliminary

Average I shielding (g/cm^2)



TLD Dose rate ($\mu\text{Gy}/\text{day}$)



Flight information (Experiment#1)

Launch (Progress M1-11(13P)):

2004/01/29 20:58(JPT) 2004/01/29 11:58(UTC)

Docking:

2004/01/31 22:13(JPT) 2004/01/31 13:12 (UTC)

Return (Soyuz TMA-3(7S)):

2004/04/30 21:12 (JPT) 2004/04/30 0:12 (UTC)

On board duration

in ISS Russian Segment (#443 panel): 91.5 days

Mean altitude -- 367.9 km

Apogee -- 373.0 km

Perigee -- 362.9 km

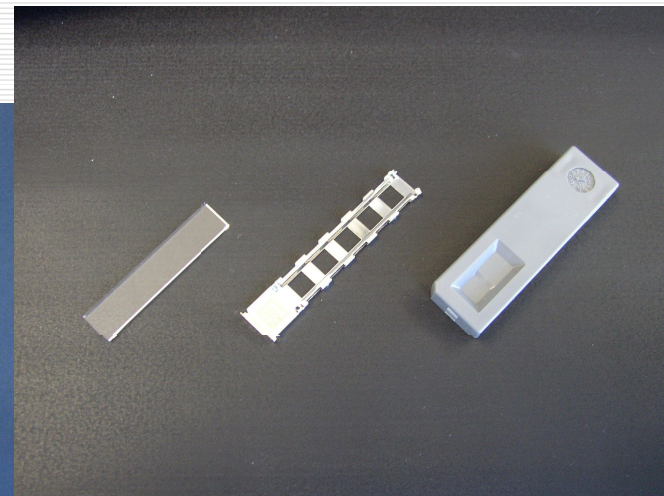
Period -- 91.9 min.

Inclination (to Equator) -- 51.63 deg

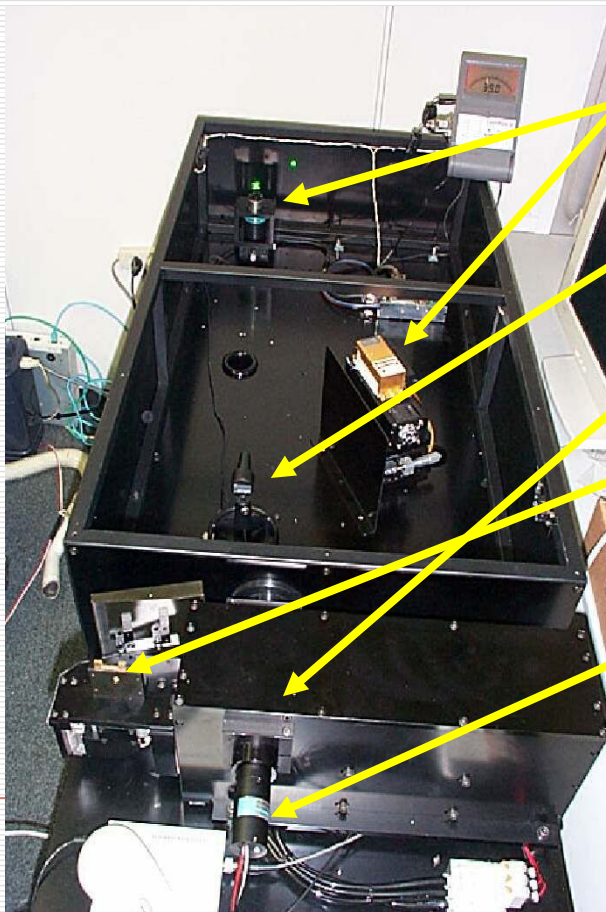
TLD(LiF) reader



Glass detector reader



OSL reader



Compass315M laser unit

Optical scanner

Laser Power meter

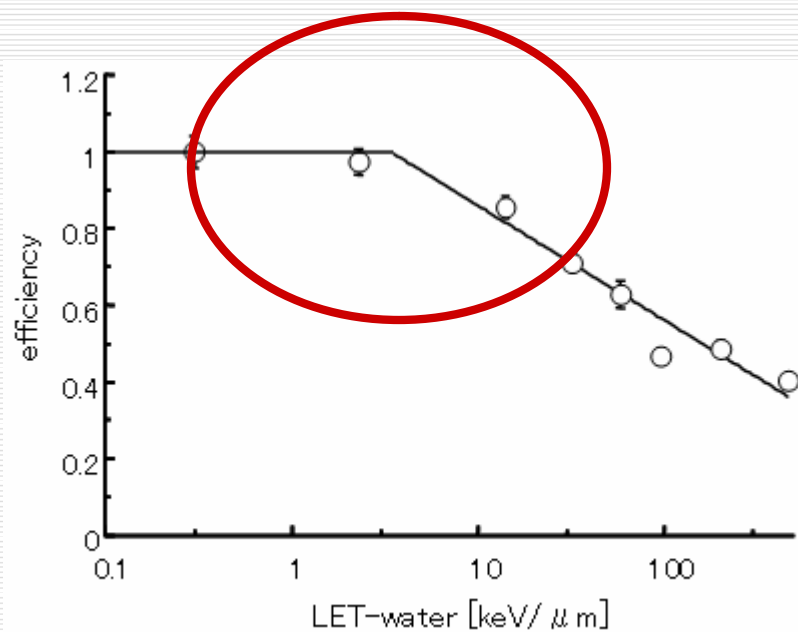
Optical filter unit

Detector transportation system

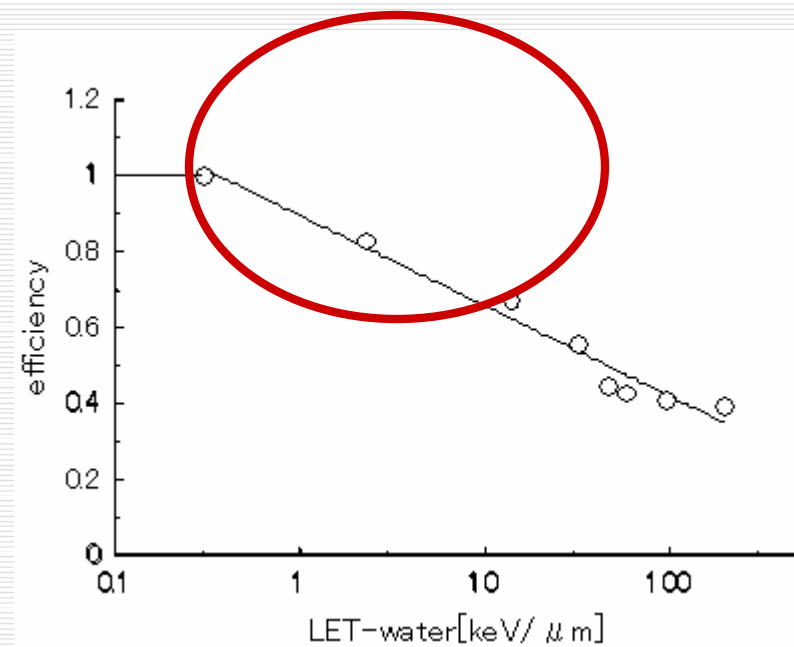
PMT



PL efficiency for high LET particles



OSL



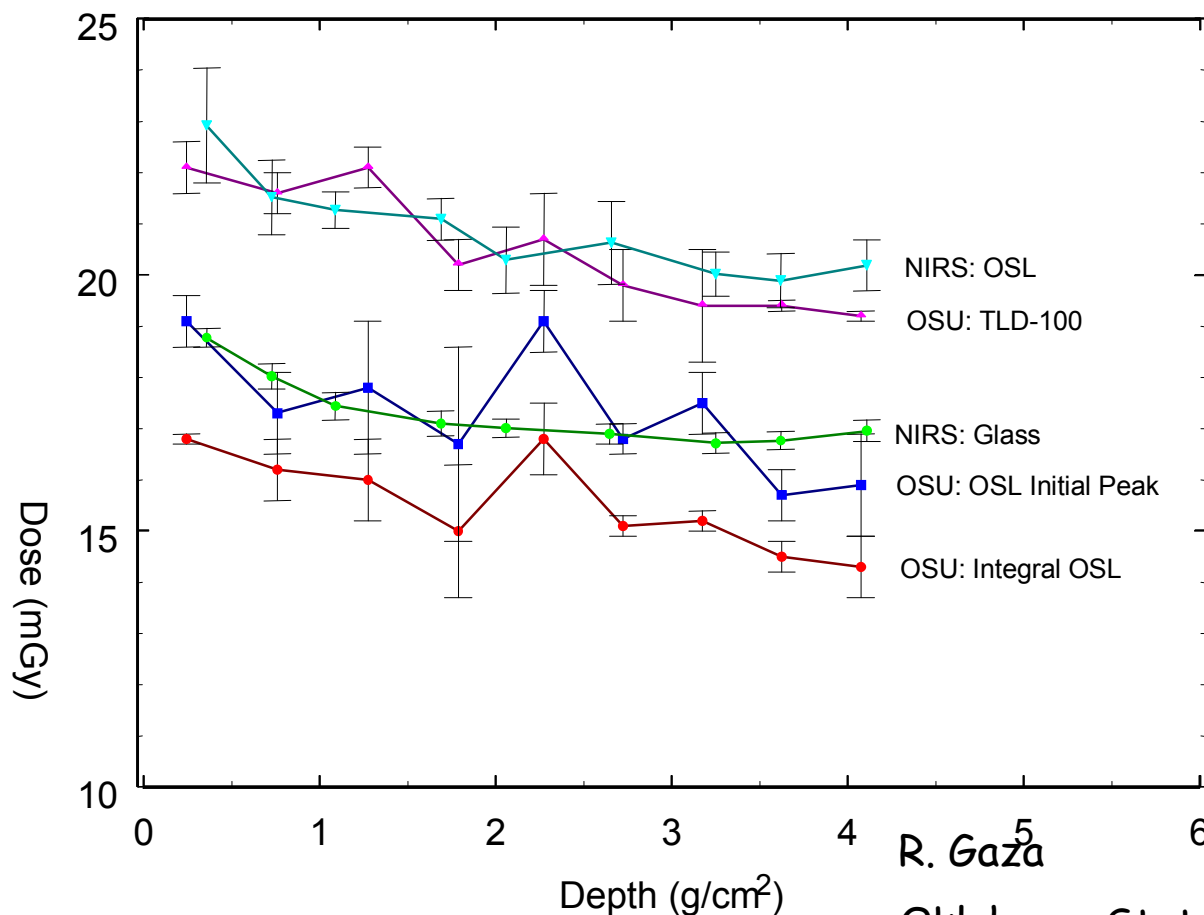
Glass

BRADOS Preliminary Results

NIRS and OSU Depth Dose Curves

91.5 days

Absorbed dose rate
> 200 $\mu\text{Gy}/\text{day}$

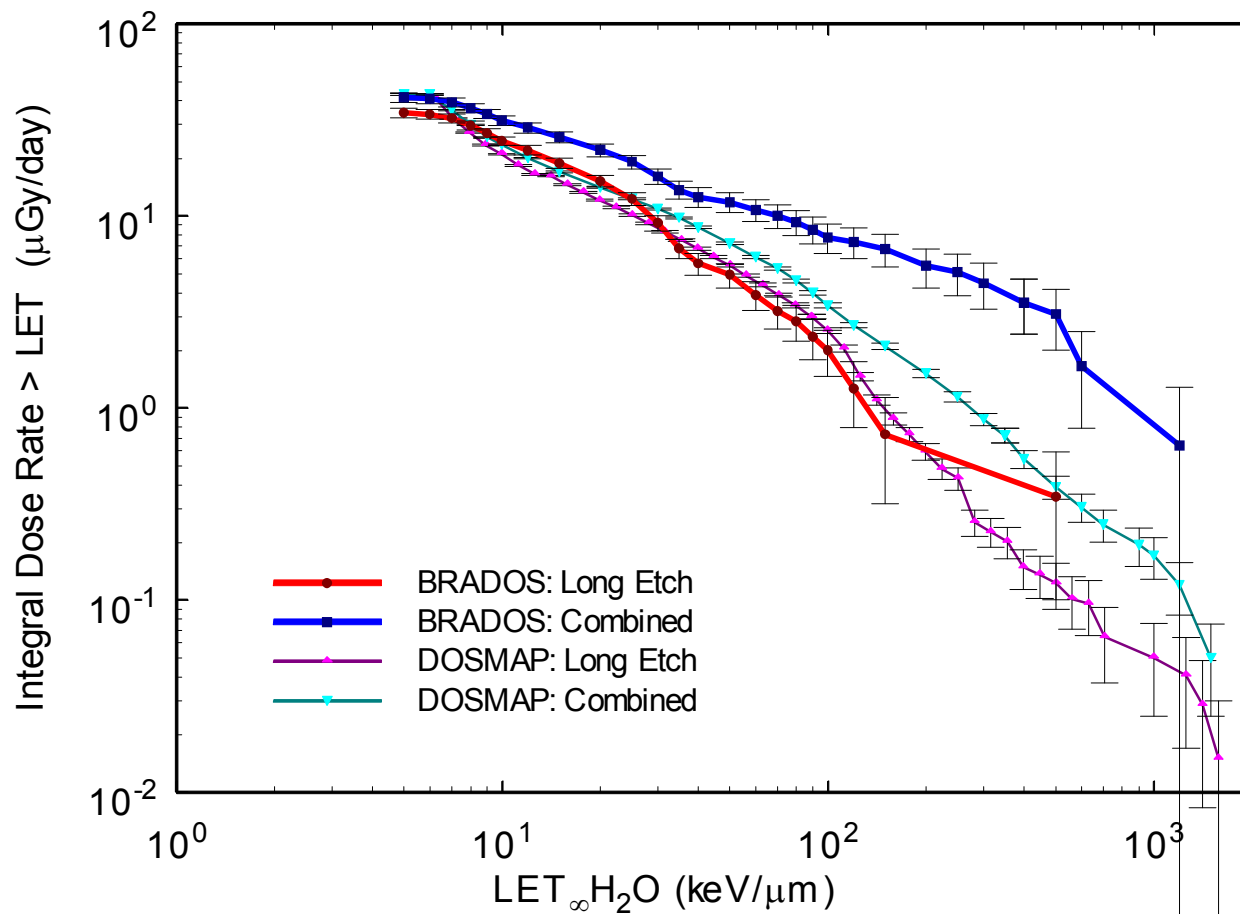


R. Gaza

Oklahoma States University, Oklahoma, USA

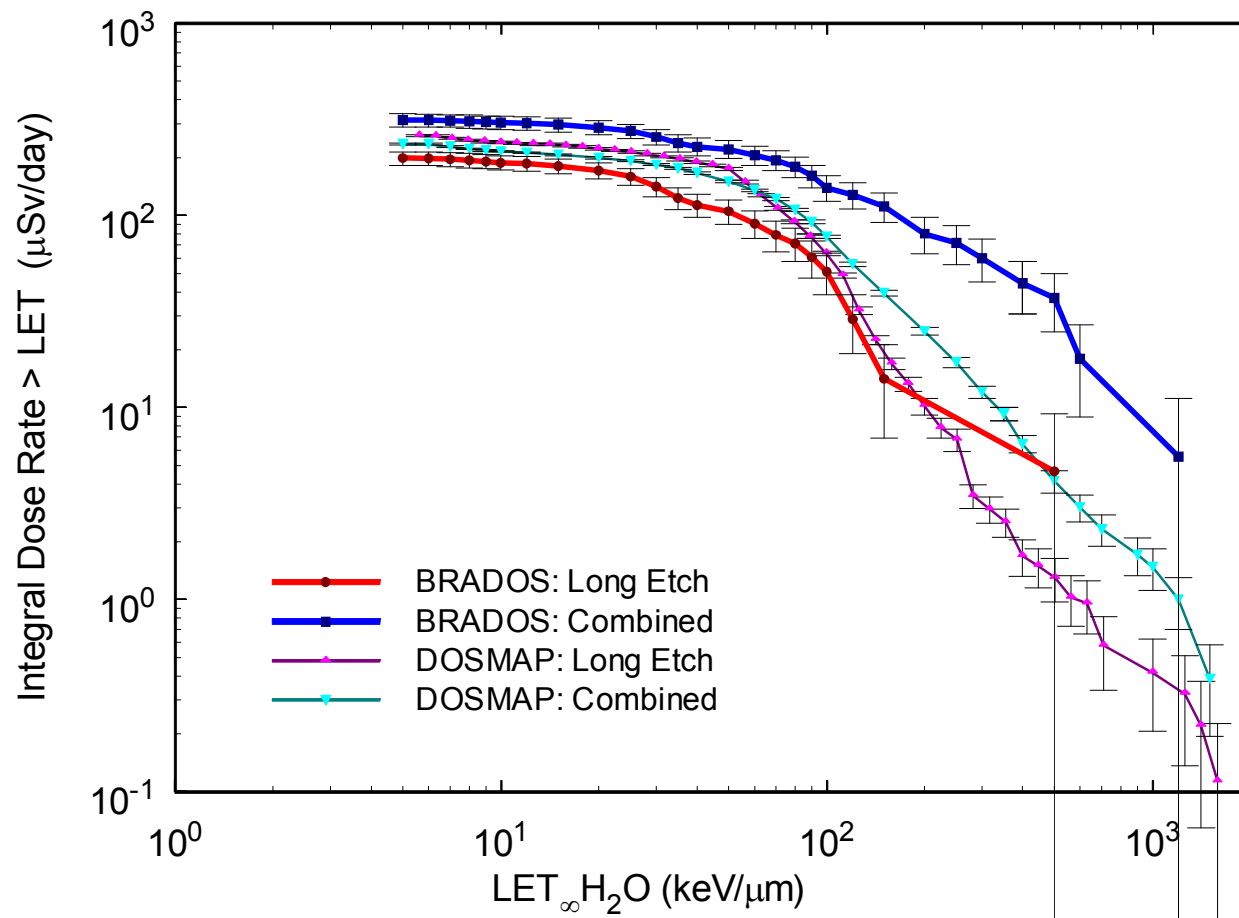
BRADOS: ERI Preliminary Results

Integral LET Dose Rate Spectra



BRADOS: ERI Preliminary Results

Integral LET Dose Equivalent Rate Spectra



Dose & Dose Equivalent Rate Comparisons on ISS and Mir

Mission	Dates	Dose Rate ($\mu\text{Gy/d}$)	High LET Dose Rate ($\mu\text{Gy/d}$)	High LET Contrib. to Dose	Dose Eq. Rate ($\mu\text{Sv/d}$)	High LET Dose Eq. Rate ($\mu\text{Sv/d}$)	High LET Contrib. to Dose Eq.	Mean Quality Factor
Mir-9	18 May–11 Oct 1991	365 ± 46	46.0 ± 1.2	12.6%	653 ± 42	334 ± 13	51%	1.79 ± 0.25
Mir-18	14 Mar–26 Jun 1995	273 ± 40	29.9 ± 3.1	10.9%	589 ± 101	346 ± 47	59%	2.16 ± 0.49
Mir-21	22 Mar–26 Sep 1996	336 ± 19	22.6 ± 1.1	6.7%	595 ± 25	282 ± 15	47%	1.77 ± 0.14
Mir-22	16 Sep 1996 – 22 Jan 1997	319 ± 17	28.3 ± 1.5	8.9%	649 ± 28	358 ± 22	55%	2.03 ± 0.17
Mir-23	12 Jan–22 May 1997	335 ± 16	29.5 ± 1.1	8.8%	706 ± 23	400 ± 16	57%	2.11 ± 0.13
ISS DOSMAP	3 May–9 Aug 2001	190 ± 6	23.5 ± 0.2	12.4%	383 ± 12	216 ± 2	56%	2.01 ± 0.07
ISS BRADOS	31 Jan–30 Apr 2004	255 ± 20	31.6 ± 1.8	12.3%	528 ± 51	304 ± 24	58%	2.07 ± 0.23

Conclusions

- ❑ We conducted an intercomparison experiment for passive Radiation dosimeters, Space Intercomparison/BRADOS, aboard the International Space Station.
 - ❑ The absorbed dose rates at the wall of the Flight Engineer's sleeping quarter were measured as a function of depth from the wall.
 - ❑ Preliminary results shows that the absorbed dose rates was about 250 $\mu\text{Gy/day}$, and gradually decreased ($\sim 10\%$ or more) with depth.
 - ❑ We plan a future experiment of larger scope to include passive dosimeters from all laboratories participating in the ICCHIBAN project.
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