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DOBIES

Dosimetry for Biological Experiments In Space

- Partners:
  - SCK-CEN: F. Vanhavere, J-L. Genicot
  - NPI: F. Spurny, I. Jadrnickova
  - DIAS: D. O'Sullivan
  - JSC: D. Zhou
  - OSU: E. Yukihara

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Objective

Develop a standard dosimetric method to measure accurately Absorbed Doses & Equivalent Doses in biological samples with a combination of different passive detectors

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Detectors

- SCK•CEN: TL and OSL
- NPI: TL and TE
- DIAS/JSC: TE
- OSU: OSL

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TL measurements: SCK-CEN

Materials:

-LiF:Mg,Ti: MTS-100, MTS-600, MTS-700

-LiF:Mg,Cu,P: MCP-100, MCP-600, MCP-700

Calibration: Co-60 (dose in tissue)

Reader: Harshaw 5500

TTP: (MTS): T_{max}=340°C, 1°C/s

(MCP): T_{max}=255°C, 1°C/s

TLD's used by NPI

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Al_2O_3:C:

- **H*(10) ≥ 1 μSv**
- **rapid decrease of light conversion factor (relative response RR) with LET above ~ 1 keV/μm**

Czech alumophosphate (AlP) TL glass

- **H*(10) ≥ 10 μSv**
- **slower decrease of relative response RR with LET above ~ 1 keV/μm**

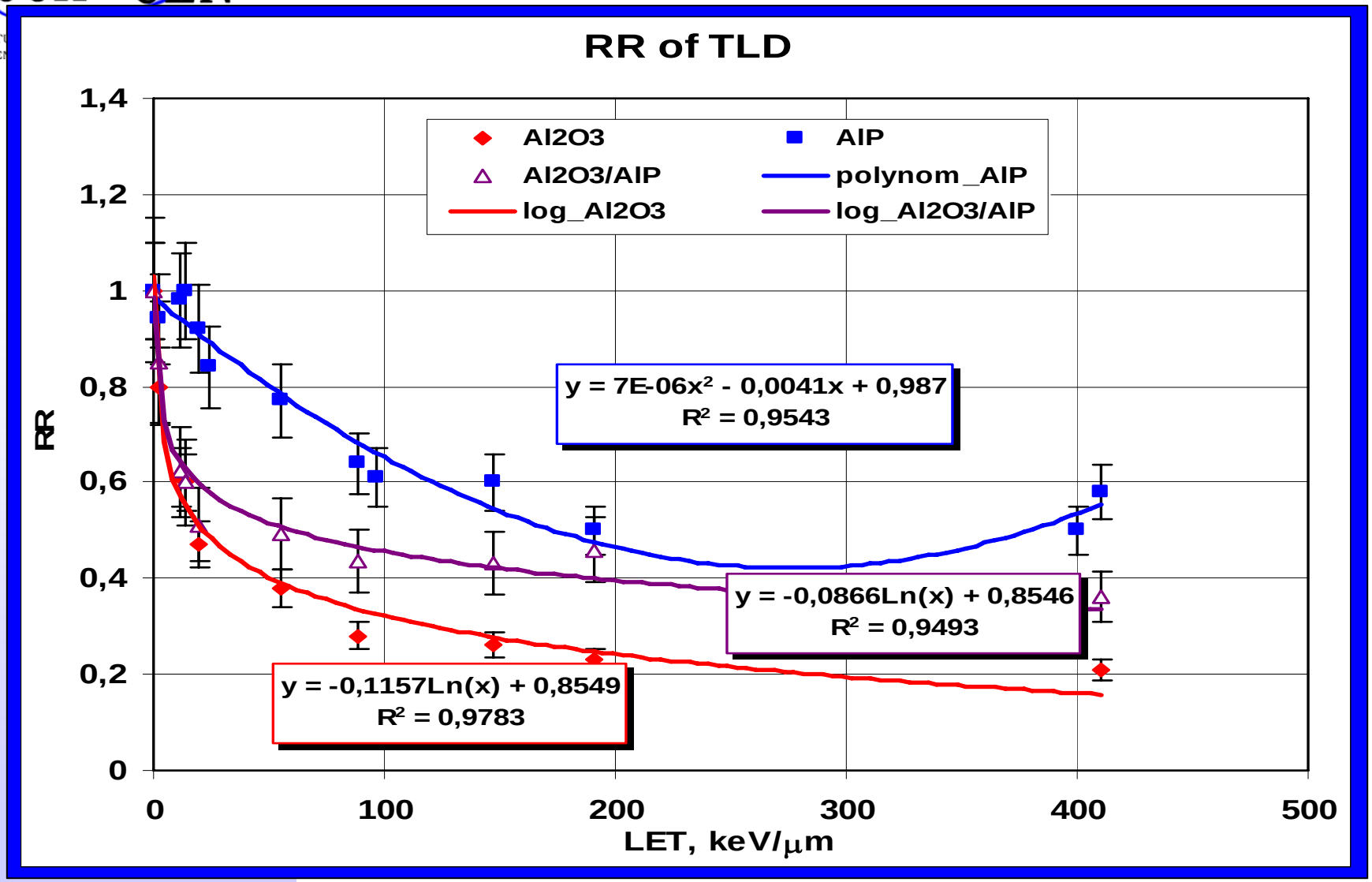
$CaSO_4$:Dy from INRNE BAS

- **H*(10) ≥ 1 μSv**
- **slower decrease of relative response RR with LET above ~ 10 keV/μm**

LiF's from IFJ Krakow

- **MTS-6; MTS-7; MTT-7; MCP-N; MCP-7**
- **different decrease of relative response RR with LET above ~ 1 keV/μm**

Relative responses of TLDs as a function of LET – regressed ICCHIBAN 2-8 results



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OSL: Dosimeters of Al_2O_3:C

OSU
OKLAHOMA STATE

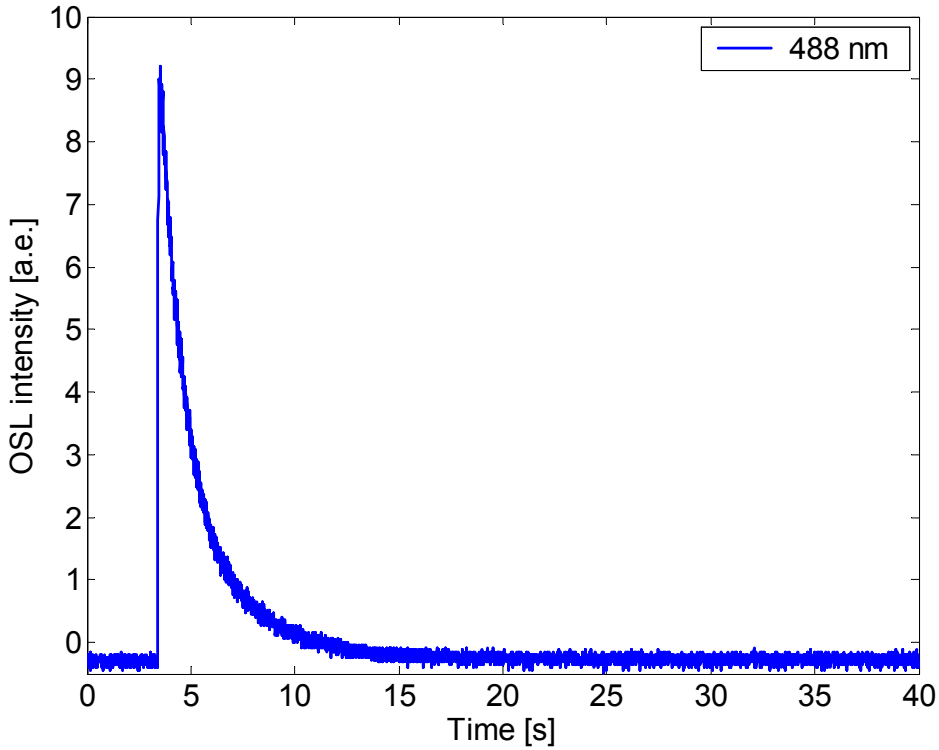
Chips
(single crystals)

Luxel
(powder in plastic film)

Optically stimulated luminescence at the SCK-CEN

- Optically stimulated luminescence : Al_2O_3:C detectors
  - TLD500 chips
  - Luxel strip
- Ar-ion laser: 488 nm, 120 mW
- 100 seconds of stimulation
- Continuous mode
- Discrimination through filter pack

Calibration with Co-60, dose in tissue



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Current OSL setup

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NPI: LET spectrometer based on a PADC track-etch detectors

- polyallyldiglycolcarbonate (PADC) – $C_{12}H_{18}O_7$
  - Page 0.5 mm (Page Moulgings Ltd, England),
  - Tastrak 0.5 and 1 mm (Track Analysis Systems Ltd, Bristol)
- etching in 5 N NaOH at 70^{o}C for 18 hours
- automatic optical image analyzer LUCIA G

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DIAS/JSC: LET spectrometer based on a PADC track-etch detectors

- manufactured by American Technical Plastics (ATP)
- approximately 600 ± 50 μm thick
- chemically etched in 6.25N NaOH at 60^{o}C
- evaluated manually

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Laboratory exposures: SCK-CEN results

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IRMM irradiations

- November 2006: Van de Graaff at JRC Geel

target	ion	Edeeltje	Eneutr	nominal current	nominal distance
		MeV	MeV	µA	cm
LiF	p	1,954	*0,150*	9	50
LiF	p	2,094	*0,327*	10	50
T	d	889	*15,998*	4	50
T	d	3,055	*19,497*	5	50
D	d	1,943	*4,995*	5	50

Note: the yield for the 0.15 and the 0.3 MeV neutrons have been measured using the 5" Bonner sphere.

	0.15 MeV	0.3 MeV	5.0 MeV	16.0 MeV	19.5 MeV
Yield/charge/sr at target (sr-1 uC-1):	2,98E+06	1,63E+06	5,37E+06	1,48E+07	1,85E+06
Yield/charge/cm2 1000 mm from target (cm-2 uC-1):	2,98E+02	1,63E+02	5,37E+02	1,48E+03	1,85E+02
Relative uncertainty (%) (estimated for 0.15 and 0.3 MeV):	8,0	8,0	3,3	2,8	3,1

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IRMM irradiations

En	**Hn**	**Ktissue**								
[MeV]	[mSv]	[mGy]	MTS 100	MTS 600	MTS 700	MCP 100	MCP 600	MCP 700	Luxel	TLD 500
0,150	7,62	0,5	**2,28**	**2,85**	**2,06**	**1,26**	**1,52**	**1,66**	**1,56**	**1,67**
			0,12	0,52	0,31	0,10	0,04	0,07	0,09	0,12
0,327	7,18	0,36	**0,87**	**0,75**	**0,77**	**0,44**	**0,53**	**0,49**	**0,53**	**0,56**
			0,28	0,56	0,19	0,01	0,05	0,01	0,02	0,03
4,995	17,06	1,27	**0,32**	**1,15**	**0,46**	**0,12**	**0,15**	**0,15**	**0,24**	**0,09**
			0,17	0,41	0,22	0,00	0,01	0,00	0,02	0,04
15,998	13,53	1,69	**0,29**	**0,92**	**0,61**	**0,09**	**0,13**	**0,11**	**0,20**	**0,09**
			0,13	0,45	0,14	0,00	0,01	0,01	0,02	0,03
19,497	4,15	0,53	**13,94**	**13,90**	**11,93**	**3,26**	**4,00**	**3,08**	**13,76**	**2,64**
			1,24	0,56	1,61	0,30	0,58	0,39	0,33	0,45

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IRMM irradiations

- Reference gamma doses? TEPC measurements
- Uncertainties MTS too large:
  - Need to repeat measurements with higher doses
- Small amount of thermal neutrons
  - Large room
- Calculation of LET

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ICCHIBAN series

- **NSRL ICCHIBAN**
- not participated in all irradiations

			[mGy]	TLD500	MCP-7	MTS-7
p	1 GeV/n	no Al	50	**43,3**	**66,5**	**45,8**
				0,3	1,4	1,1
p	1 GeV/n	20 cm Al	50	**32,8**	**49,0**	**34,2**
				0,8	0,7	0,5
O	1 GeV/n	no Al	50	**22,6**	**30,4**	**40,5**
				1,2	1,0	0,2
O	1 GeV/n	20 cm Al	50	**16,3**	**23,4**	**27,4**
				0,4	0,2	0,1

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HIMAC-ICCHIBAN-8

			TLD500	MCP700	MTS700
He	**150 MeV/n**	**50**	**40**	**44,2**	**46,3**
				0,4	0,5
He	**150 MeV/n**	**50**	**52**	**61,5**	**72,2**
				4,3	1,5
O	**400 MeV/n**	**50**	**23**	**24,7**	**34,4**
				0,9	0,2
O	**400 MeV/n**	**50**	**23**	**24,7**	**33,2**
				1,1	0,8
Ar	**500 MeV/n**	**50**	**15**	**17,9**	**22,7**
				0,3	0,0
Ar	**500 MeV/n**	**50**	**16**	**17,1**	**22,3**
				0,9	0,9
Fe	**200 MeV/n**	**50**	**12**	**13,9**	**17,2**
				0,7	0,3
Fe	**200 MeV/n**	**50**	**14**	**17,1**	**21,2**
				0,4	0,7

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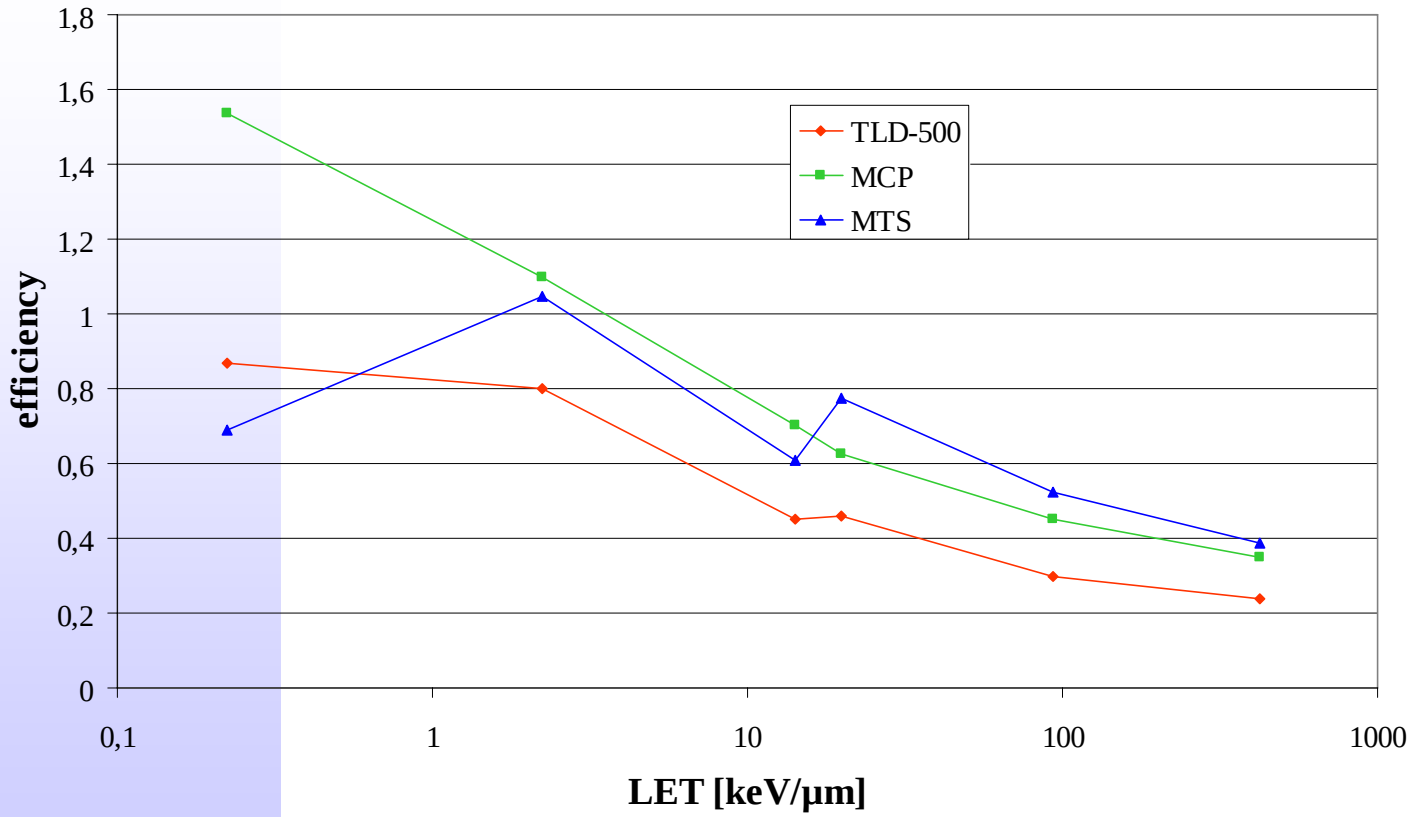
ICCHIBAN series

- **Efficiency curve**



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ICCHIBAN series

- **Comparison with OSU**

			SCK		OSU	
			TLD500	TLD-700	OSL single crystal	TLD-100
p	1 GeV/n	no Al	**0,87**	**0,69**	**1,00**	**0,92**
			0,01	0,02	0,05	0,04
O	1 GeV/n	no Al	**0,45**	**0,61**	**0,50**	**0,79**
			0,02	0,00	0,04	0,03
HIMAC-8						
He	150 MeV/n		**0,80**	**1,05**	**0,83**	**1,01**
			0,00	0,01	0,02	0,04
O	400 MeV/n		**0,46**	**0,78**	**0,46**	**0,76**
			0,00	0,00	0,01	0,04
Ar	500 MeV/n		**0,30**	**0,51**	**0,31**	**0,45**
			0,00	0,00	0,01	0,01
Fe	200 MeV/n		**0,24**	**0,39**	**0,26**	**0,41**
			0,00	0,01	0,02	0,01

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Future

- **Other Ground experiments:**
  - Neutron sources
  - Mono-energetic neutrons: IRMM: october 2007
  - high energy fields
    - ♣ iThemba
    - ♣ Dubna
    - ♣ Other ICCHIBAN runs?
- Set-up of efficiency curve: compare with literature
- Glow curve deconvolution (TLD) – decay curve deconvolution (OSL)

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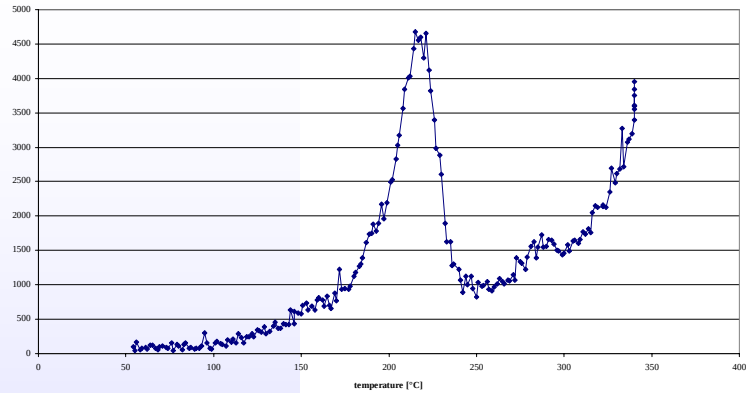
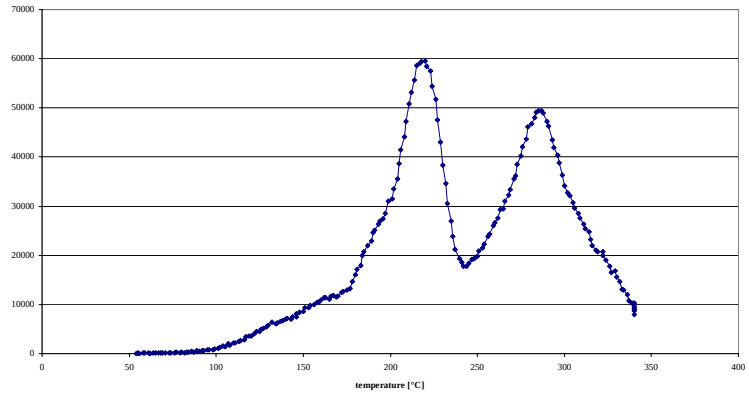
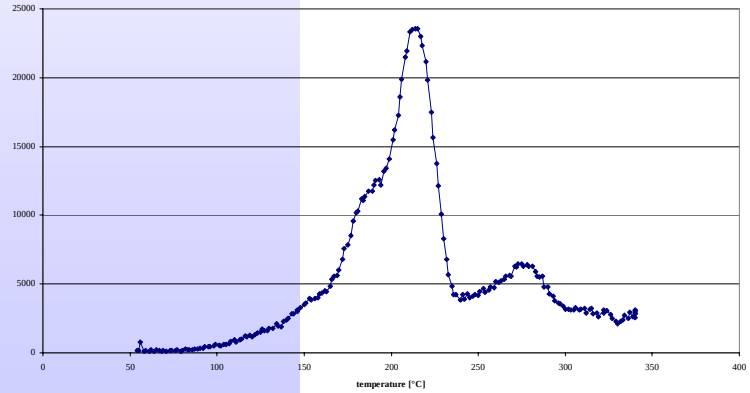
Dose information from glow curve

BASE A

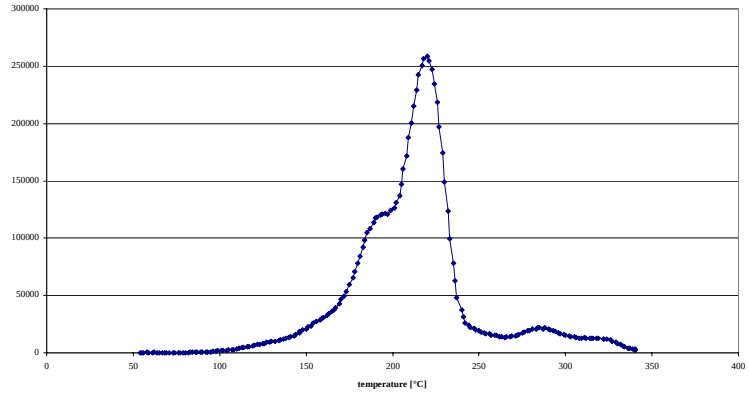


Thermal neutrons





Fast neutrons (19 MeV)



Co-60

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Space exposures: SCK-CEN results

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Past space measurements:

Two ESA projects:

- **MESSAGE 2:** effects of the space flight conditions on bacterial gene expression
  - ♣October 2003: 10 days
- **MOBILIZATION:** gene transfer between model bacteria :
  - ♣april 2004: 11 days

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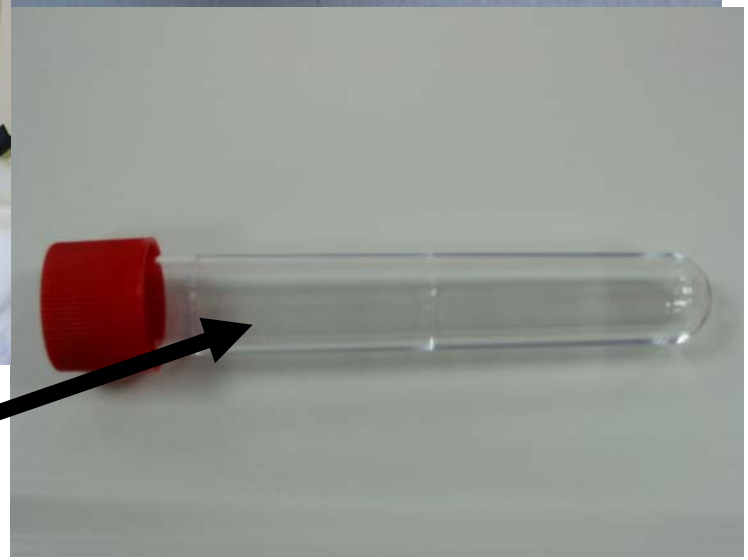
Transport bags



dosemeters inside

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Conclusions first experiments

- Dose rate measured: 162 µGy/day (OSL, TL), high-LET(>10 keV/µm) particles: ~ 5 µGy d^{-1}
  - ➢ **Total dose rate: ~ 180 µGy/day**

- **Different results for different types of detectors**:
  ≠ efficiencies to HCP with LET < detection threshold of TED's

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BASE-A flight

- **Undocking of 13S**: 18 September 2006 at 23:53 CET

  Landing of 13S: 29 September 2006 at 03:13 CET

- **Inclination**: Practically constant at approximately 51.6 degrees.

  Altitude of ISS between docking of 13S and undocking of 13S: Decreases almost linearly from 342 km to 340.5 km (approximate values)

- hardware and experiment stackings from the Soyuz module to the Zvezda module in ISS, conduct of experiment (storage & pictures) done by German European astronaut Thomas Reiter (ISS Expedition 13 crew - ***Astrolab*-missie**)

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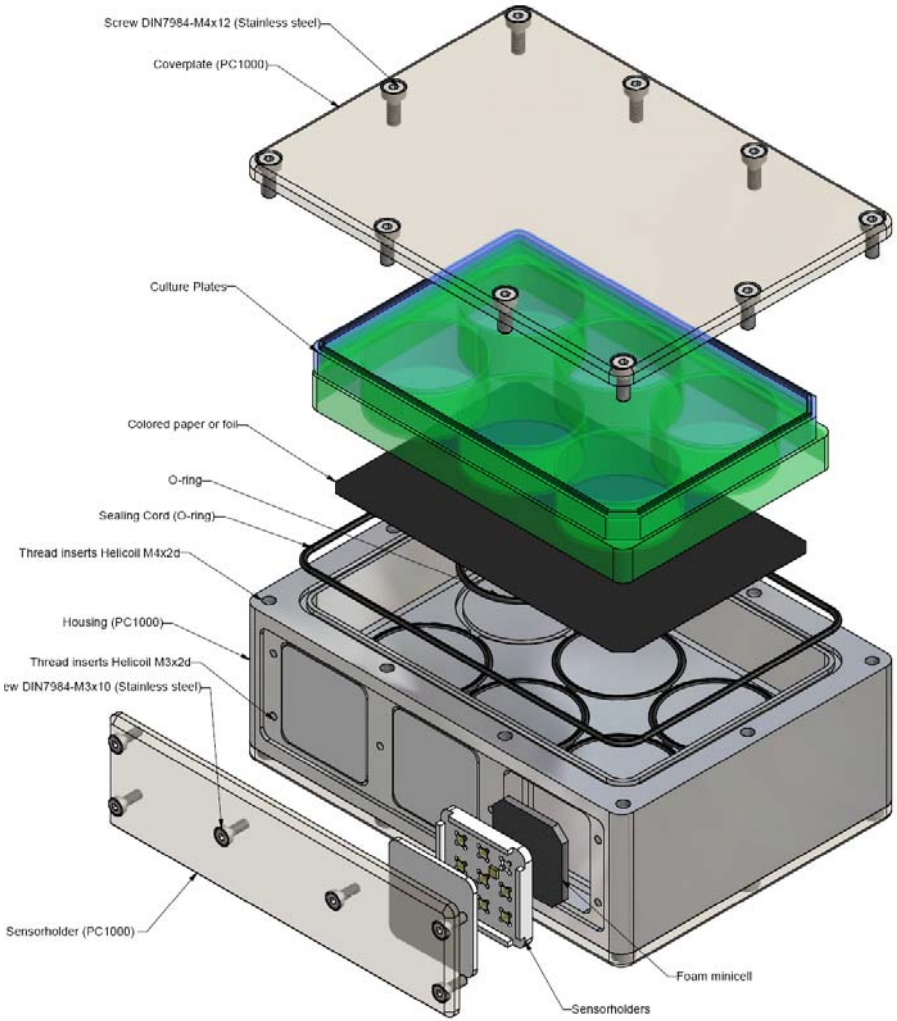
BASE flight



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BASE-A flight

- **Results:**
  - OSL results lost because of bleaching of detectors (holders were too transparant)
  - TL results: averaged over all results:

[µGy/day] D_{tissue}

MTS100	MTS600	MTS700	MCP100	MCP600	MCP700
198	**212**	**207**	**215**	**217**	**199**
13	21	19	15	9	21

  - Relative high spread: different containers

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BASE-A flight

- **Results per container:**
  - TL results (only statistical uncertainty):

	1MT	6MT	7MTS	1MC	6MC	7MC
1	**206**	**212**	**236**	**219**	**220**	**215**
	6	2		14	1	11
2	***193***	**209**	**203**	**219**	**213**	**204**
	1	5	11	13	5	20
3	***195***	**210**	**192**	**206**	**214**	**195**
	6	5		6	5	6
4	***195***	**217**	**213**	**210**	**260**	**191**
	4	9	9	2	67	30

  - 1MT: different positions
  - 6/7 MC/4: 2 high readings
  - Differences between containers, but not very high (5%)

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Comparison with previous flights

Institution	Material	Techn.	**ISS-7S** Test Tubes [µGy d^{-1}]	**ISS-7S** Containers [µGy d^{-1}]	**ISS-8S** Test Tubes [µGy d^{-1}]	**ISS-13S** containers [µGy/day]
SCK-CEN	**Al_2O_3:C**	**CW-OSL**	**148 ± 5**	**162 ± 3**	**157±7**	**-**
OSU	**Al_2O_3:C**	**CW-OSL**	**170 ± 2**	**165 ± 2**	**163±5**	**-**
SCK-CEN	**^{7}LiF:Mg,Ti**	**TL**	**152 ± 8**	**194 ± 17**	**-**	**208 ± 23**
SCK-CEN	**^{6}LiF:Mg,Ti**	**TL**	**-**	**-**	**-**	**212 ± 21**
SCK-CEN	**^{7}LiF:Mg,Cu,P**	**TL**	**143 ± 1**	**154 ± 4**	**-**	**199 ± 21**
SCK-CEN	**^{6}LiF:Mg,Cu,P**	**TL**	**-**	**-**	**-**	**217 ± 9**
NPI	**^{7}LiF:Mg,Cu,P**	**TL**	**-**	**154±12**	**118±7**	
NPI	**Al_2O_3:C**	**TL**	**-**	**178±14**	**180±18**	
NPI	**$CaSO_4$:Dy**	**TL**	**-**	**-**	**-**	**179**

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Absorbed dose to tissue (D_{tissue}) and corrected absorbed dose obtained using different TLDs with the standard deviation of all detectors. In the corrected absorbed dose, the contribution from particles with LET higher than 10 keV/µm was discounted.

TLD	***D*** $_{tissue}$ **[µGy/day]**	**Corrected** ***D*** $_{tissue}$ **[µGy/day]**
$CaSO_4$:Dy	180±15	160±20
^{nat}LiF:Mg,Ti (MTS-100)	198±13	178±18
^{6}LiF:Mg,Ti (MTS-600)	212±21	192±26
^{7}LiF:Mg,Ti (MTS-700)	208±23	188±28
^{nat}LiF:Mg,Cu,P(MCP-N)	215±15	205±18
^{6}LiF:Mg,Cu,P (MCP-6)	227±39	217±42
^{7}LiF:Mg,Cu,P (MCP-7)	199±21	189±24

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- The absorbed doses obtained with TLDs at different laboratories were consistent, but the uncertainties are of 10% in general.
- Although different materials were shown to have different efficiencies to HZE particles during ground-based experiments, these differences could not be resolved in the space exposures due to the uncertainties involved.
- The contribution from high LET particles to the TLD results, calculated based on TED data, did not exceed 10%.

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TED results

DIAS/JSC →

NPI ↘

Detector location	*D* (µGy/day)	*H* (µSv/day)	Quality Factor
Stack 1	29.9 ± 1.9	353 ± 22	11.81
Stack 2	29.2 ± 2.8	342 ± 32	11.70
Stack 3	31.5 ± 3.2	366 ± 37	11.61
Stack 4	33.4 ± 2.1	392 ± 25	11.74
Average	31.0 ± 3.1	363 ± 31	11.72

PADC	Method	*D* (µGy/day)	*H* (µSv/day)	*Q*
Page	Uncorrected	33±5	203±18	6.2±1.1
	Corrected	36±6	290±46	8.1±1.8
Tastrak	Uncorrected	17±3	183±14	10.7±2.1
	Corrected	21±4	261±38	8.1±1.9

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BASE A: Conclusion

- The average values of the total dosimetric quantities are equal to ~220 µGy/day for *D*, and *H* varies from 480 to 580 µSv/day, depending on which TED result is used.

- The *D* and *H* values are ~20% to 40% higher than previously measured (Goossens et al., 2006). This difference can be related to variations in solar activity or exposure location at the ISS, or both..

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Still in space

- **BRADOS space intercomparison**

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Future flight opportunities

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EXPOSE-EUTEF

- Several research groups involved: exo biology
- **Outside of ISS,** attached to Colombus module
- Exposure for 1,5 years
- Launch date october 2007 (STS 1E)
- Passive dosimetry shared by DOBIES and DOSIS (DLR)
- Active detector: R3D
- Holders prepared by DLR

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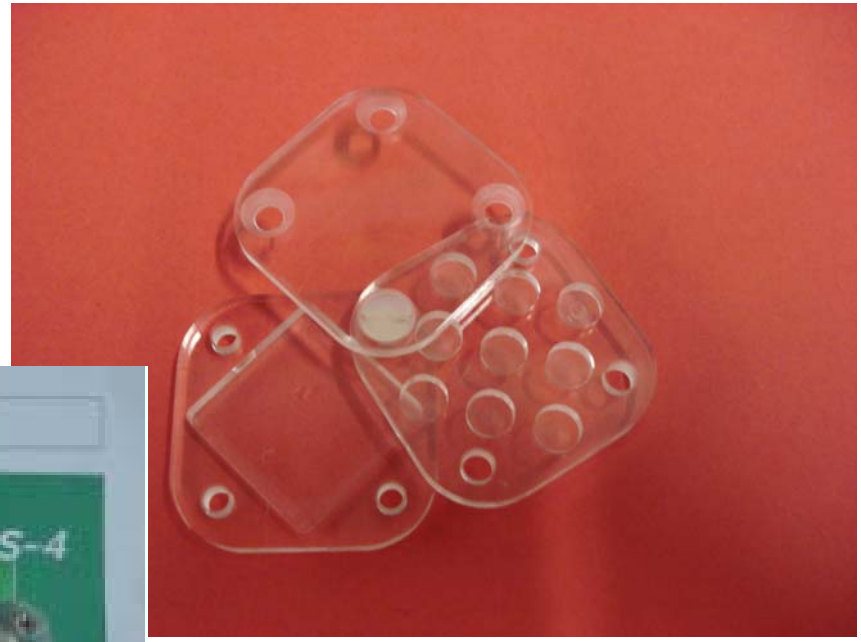
EXPOSE-EUTEF: holders



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YING-B experiment

- Main researchers: Free University of Brussels
- Determine the effect of microgravity on expression and functionality of Flo proteins (yeast)
- 1 separate experimental container (90x58x24mm) with all sensors
  - Including radiation sensors: same holders as BASE-A (now in black)
    - ♣ OSL/TLD:
    - ♣ TED:
- BIO#4 mission: **spring/autumn 2008**

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Mobilisatsia-3 experiment

- Main researchers: SCK-CEN
- Same configuration as Mobilisatsia 2
- **october 2007**

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BASE-B experiment

- Main researchers: SCK-CEN
- Same configuration as BASE-A
- BIO#4 mission: **spring/autumn 2008**

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CFS-A experiment

- Main researchers: Rumania, EU-SURE program
- Same hardware as BASE/YING
- **spring 2008**
- **3 containers for 10/11 days, 1 container for 6 months**

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Other possibilities to be discussed with ESA

- KUBIK container: 6 months exposure inbetween biological experiments
  - Needs to be negociated
- EMCS container:
  - Long waiting list
- Small detector packages on different locations in the ISS
  - Foreseen together with DOSIS experiment (Columbus)

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End-goal of DOBIES

- Small and cheap passive dosemeter for biological experiments
  - ➢ Which type of detectors ?
  - ➢ How many detectors for sufficient accuracy?
  - ➢ Simple algorithm
  - ➢ Correct for high LET contribution
    - ♣no need for TED every time?

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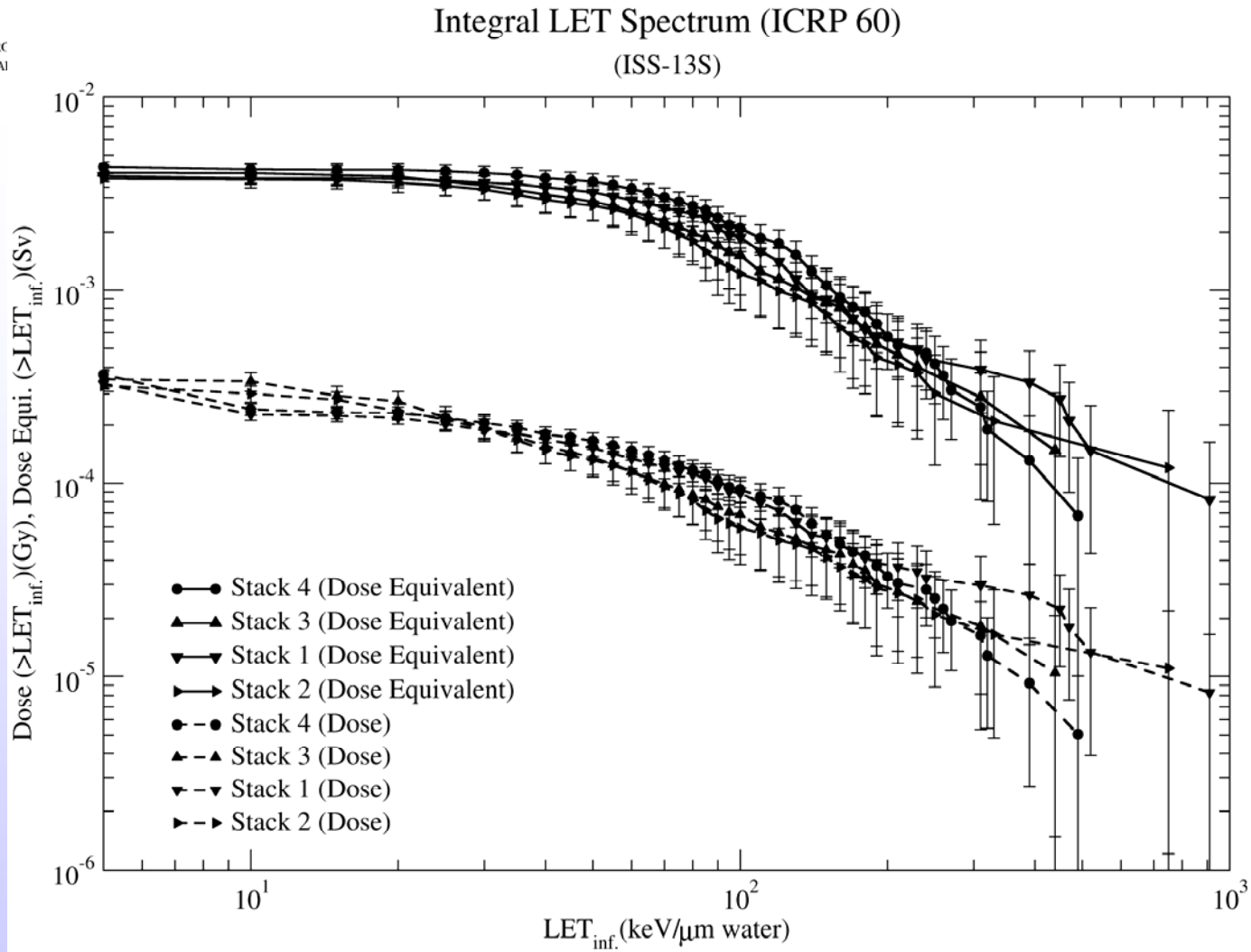

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