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# Characterising Passive Dosimeters for Dosimetry of Biological Experiments in Space

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# DOBIES: DOsimetry of BIological Experiments in Space

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- **Objective:** *establish standard dosimetric method to measure doses to ( $\mu$ )biological samples*
  - Combination of different techniques
  - Measurement and calculational procedure
  - For different samples, locations, packing materials
- **Through**
  - Study of LET dependencies
    - ♣ Standard high energy fields
  - Measurements during space flights
- **DOBIES: SCK-CEN, NPI, DIAS, OSU**

# Types of dosemeters

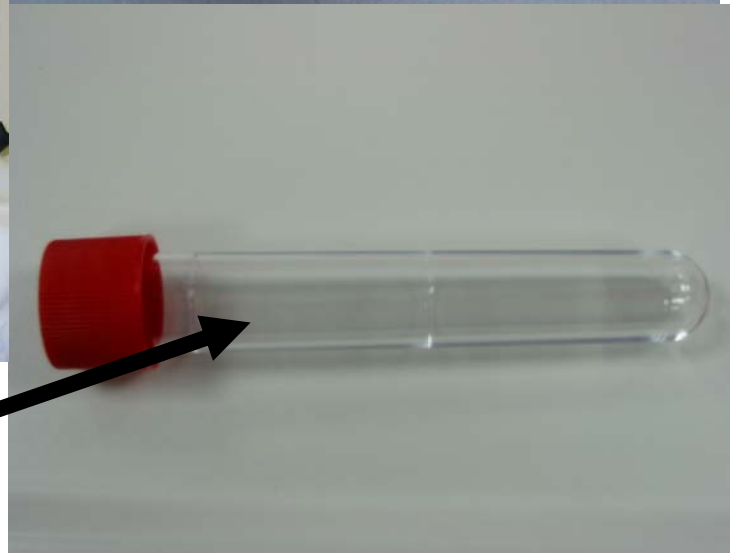
- **Track etch detectors:**
  - Page, Tastrak: NPI
  - CR-39: DIAS
- **Thermoluminescence detectors**
  - LiF:Mg,Ti SCK•CEN
  - LiF:Mg,Cu,P SCK•CEN , NPI
  - Al<sub>2</sub>O<sub>3</sub>:C, Al-P NPI
  - CaSO<sub>4</sub>:Dy NPI
- **Optically Stimulated luminescence detectors**
  - Al<sub>2</sub>O<sub>3</sub>:C (Luxel, TLD500) SCK-CEN
  - Al<sub>2</sub>O<sub>3</sub>:C (Luxel) OSU

## Some examples of space measurements with biological experiments

Three shuttle flights:

- **MESSAGE 2:** effects of the space flight conditions on bacterial gene expression
  - ♣ October 2003: 10 days (7S)
  
- **MOBILIZATION:** gene transfer between model bacteria:
  - ♣ april 2004: 11 days (8S)
  
- **BASE A:** bacterial adaptation to space flight environments :
  - ♣ September 2006: 11 days (13S)

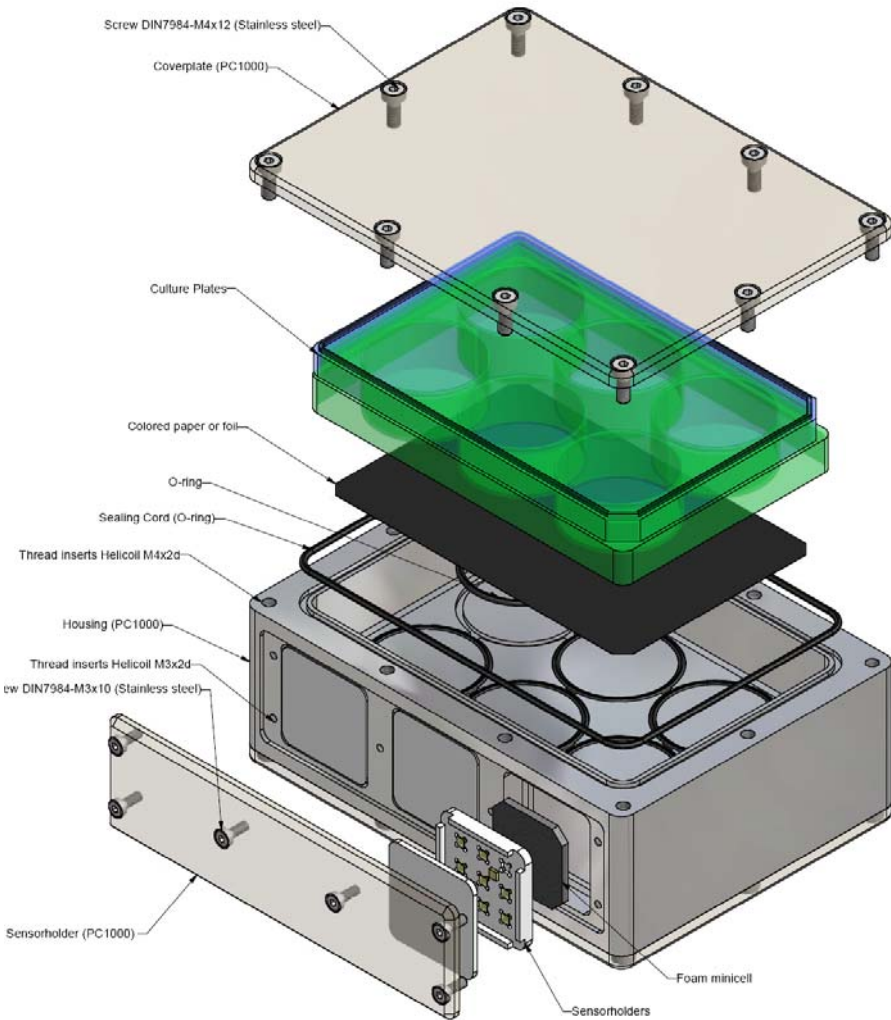
# MESSAGE, MOBILIZATION



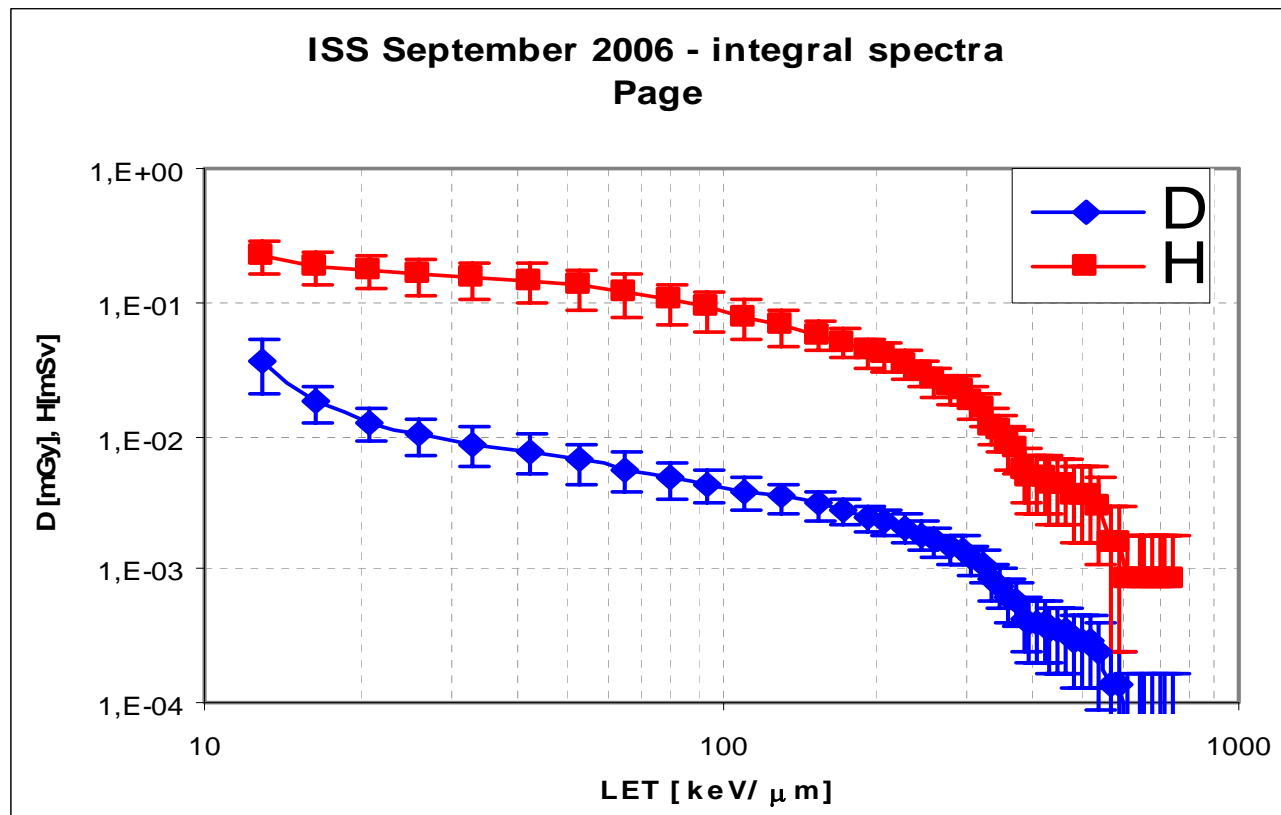
dosemeters inside



# BASE-A flight



# BASE-A: Track-etch detectors: high LET part

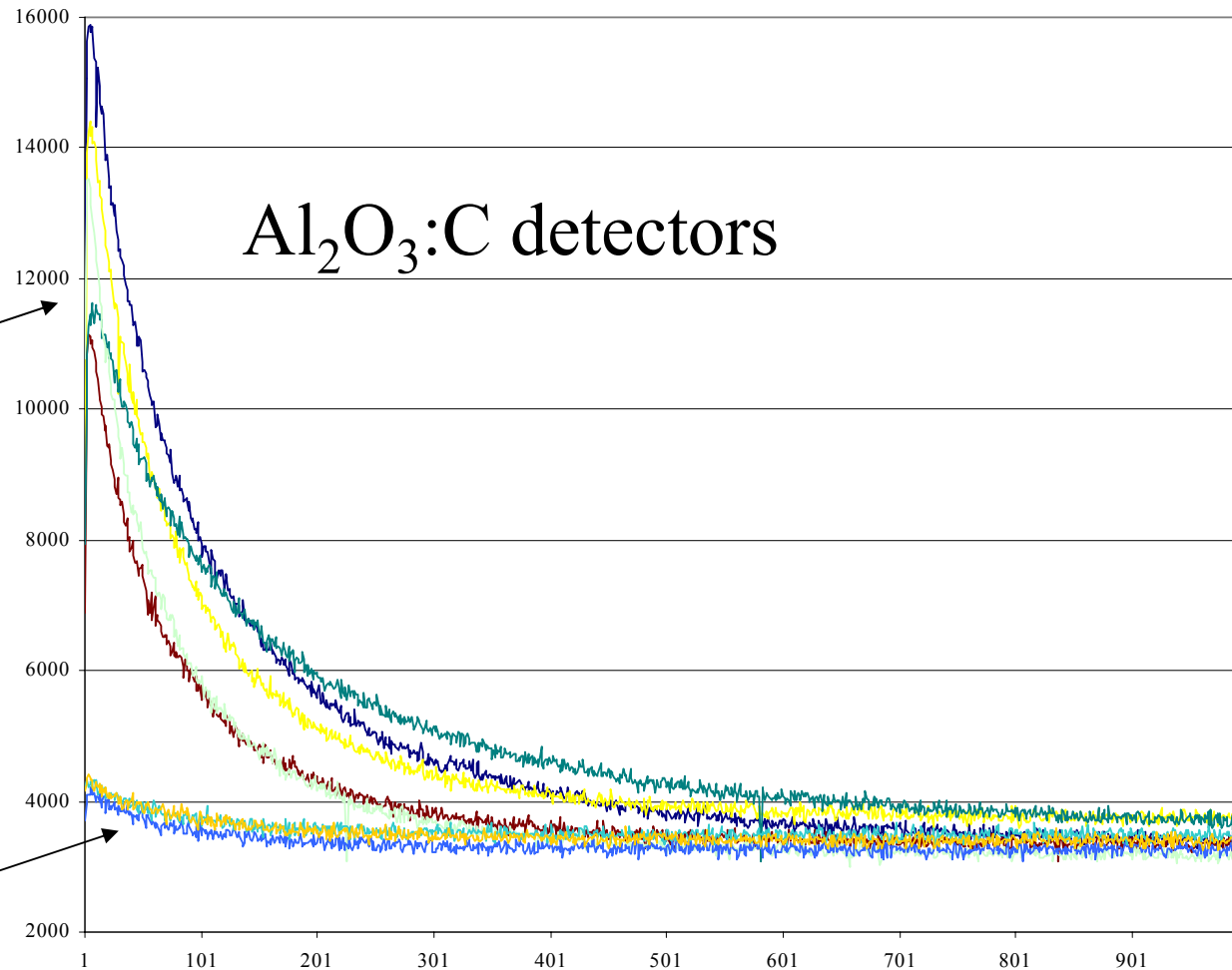


TED	$D$ (μGy/day)	$H$ (μSv/day)	$Q$
Page	33±5	203±18	6.2±1.1
Tastrak	17±3	183±14	10.7±2.1

# TL/OSL results: low LET part

Measurements

Control



## Comparison results: low LET part

Institution	Material	Techn.	ISS-7S Test Tubes [ $\mu\text{Gy d}^{-1}$ ]	ISS-7S Containers [ $\mu\text{Gy d}^{-1}$ ]	ISS-8S Test Tubes [ $\mu\text{Gy d}^{-1}$ ]	ISS-13S containers [ $\mu\text{Gy/day}$ ]
SCK-CEN	$\text{Al}_2\text{O}_3:\text{C}$	CW-OSL	$148 \pm 5$	$162 \pm 3$	$157 \pm 7$	-
OSU	$\text{Al}_2\text{O}_3:\text{C}$	CW-OSL	$170 \pm 2$	$165 \pm 2$	$163 \pm 5$	-
SCK-CEN	$^7\text{LiF}:\text{Mg,Ti}$	TL	$152 \pm 8$	$194 \pm 17$	-	$208 \pm 23$
SCK-CEN	$^7\text{LiF}:\text{Mg,Cu,P}$	TL	$143 \pm 1$	$154 \pm 4$	-	$199 \pm 21$
NPI	$^7\text{LiF}:\text{Mg,Cu,P}$	TL	-	$154 \pm 12$	$118 \pm 7$	
NPI	$\text{Al}_2\text{O}_3:\text{C}$	TL	-	$178 \pm 14$	$180 \pm 18$	

## Other space flights:

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- **ICCHIBAN space intercomparison 2**
- **DOBIES detectors were included**
- **From 12-05-2007 to 22-10-2007 in ISS**
- **See other presentation**
- **SCK:**
  - **MTS: 132  $\mu$ Gy/d**
  - **MCP: 149  $\mu$ Gy/d**
- **MCP higher ??**
  - **Fading effects?**

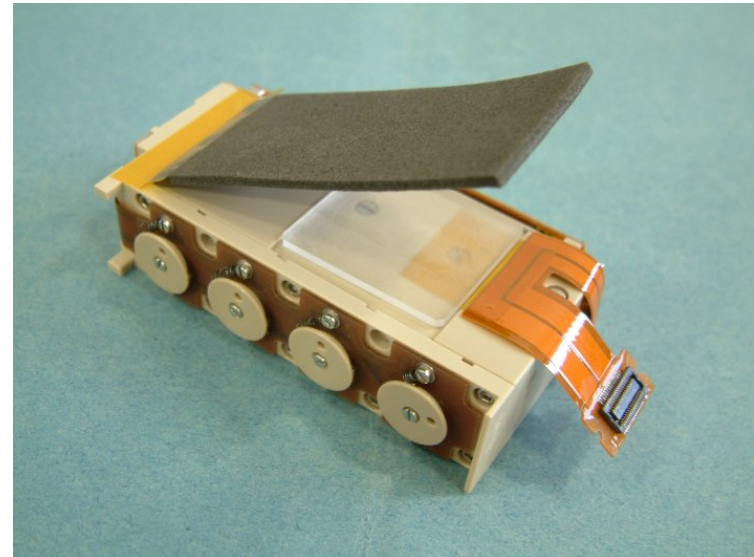
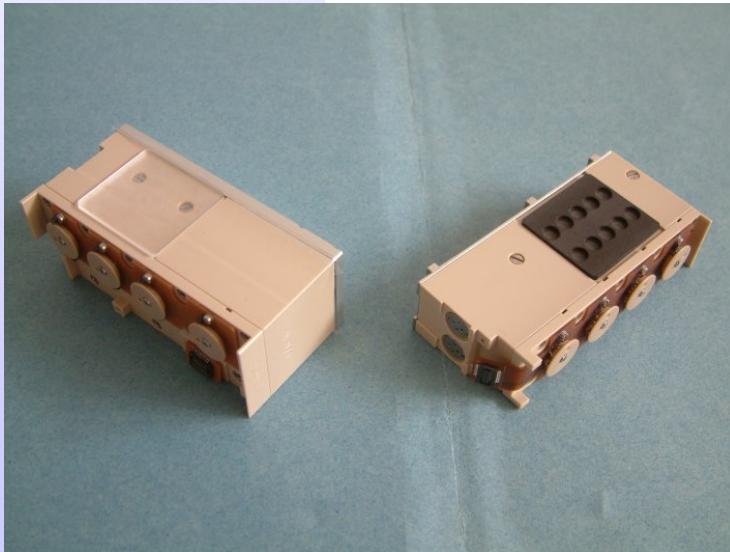
# Now in ISS: EXPOSE-E on EUTEF

- **Launched in January 2008**
- **Attached to Columbus:**
  - outside ISS
- **Space exposure**



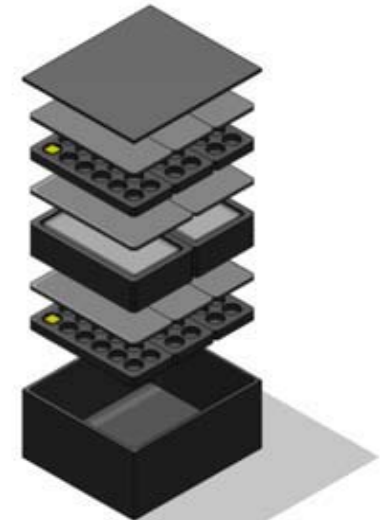
# In preparation

- **Space intercomparison 3**
  - Detectors have been sent to Japan
- **BASE B/C**
  - ISS shuttle flight october 2008
  - Holders ready
  - TLD/OSL/TED: DOBIES partners



# In preparation

- **ESA Combined Radiation Dosimetry Package (CRDP)**
  - Dose mapping of Columbus module
  - In collaboration with DOSIS (DLR)
  - Passive detectors in 10 locations
  - Launch february 2009



# Other flights planned

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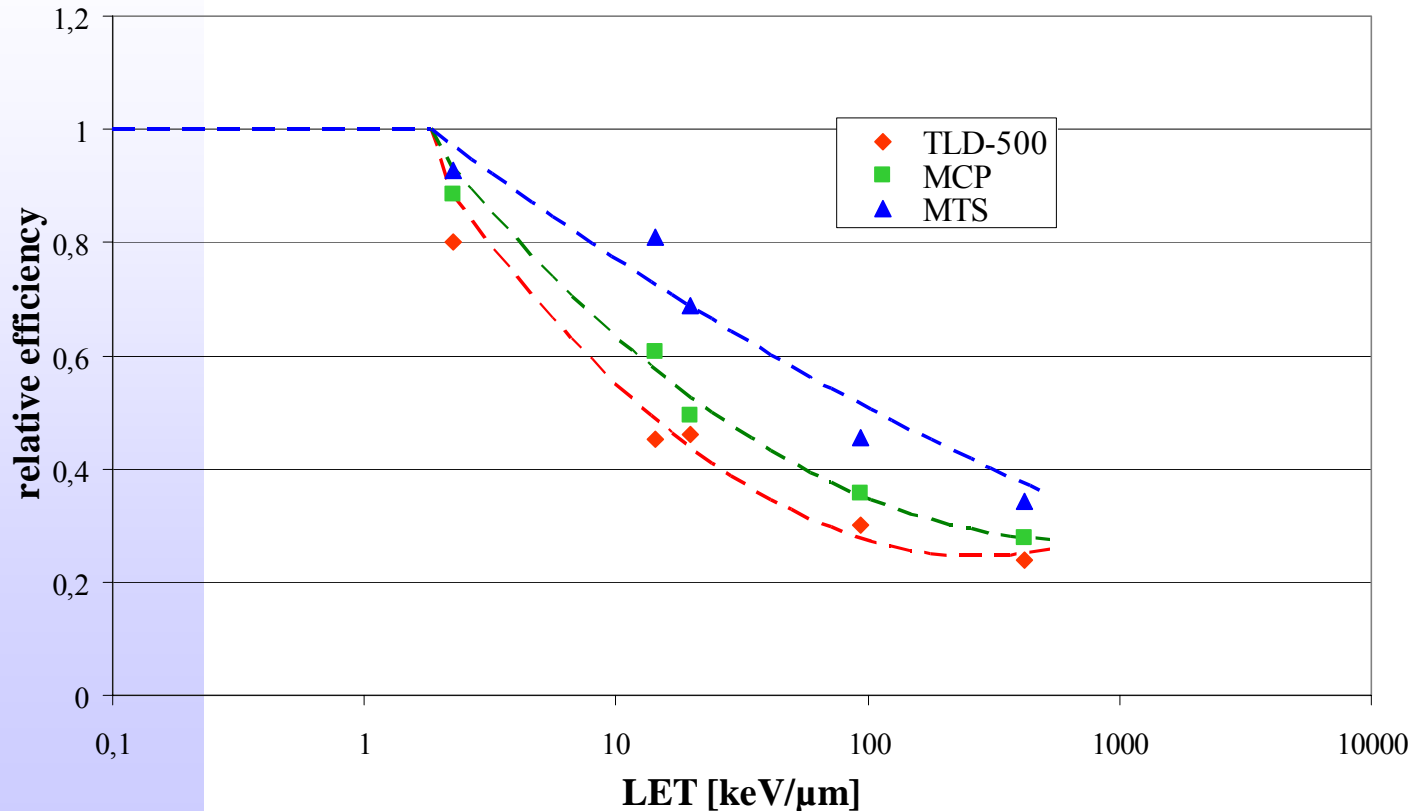
- **YING**
- **CSA**
- **Kubik experiment ??**

# Characterisation of detectors

- Different types of detectors give different results for low LET part of dose
  - Because of different efficiencies for high LET radiation
- Characterisation TLD and OSL
  - Dependent on technique and on material
- Correct TL/OSL results
  - High LET spectrum from TED
- OR: use different efficiencies to obtain information on high LET contribution
- Irradiation in standard high energy accelerators on earth

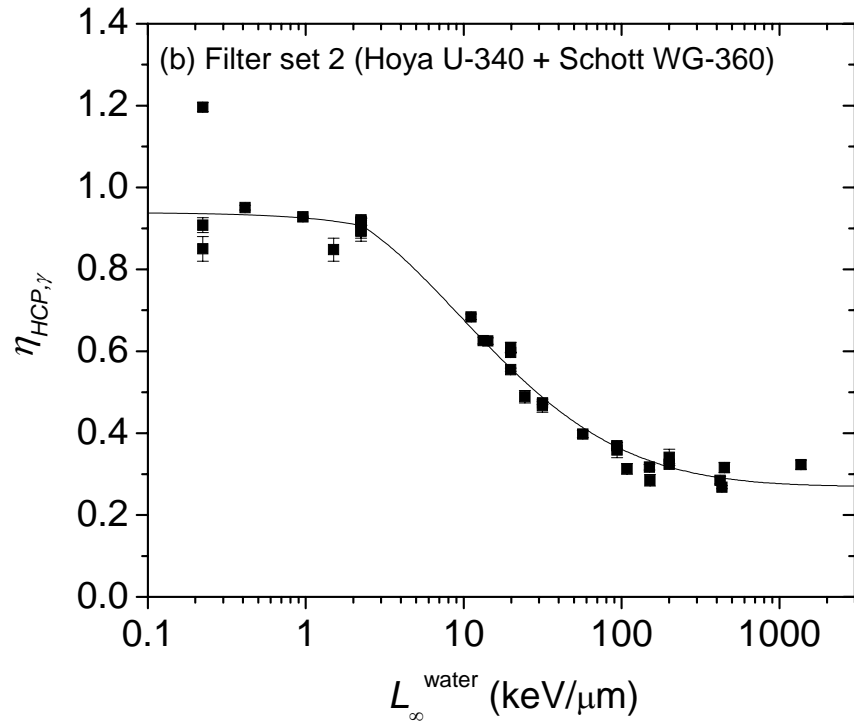
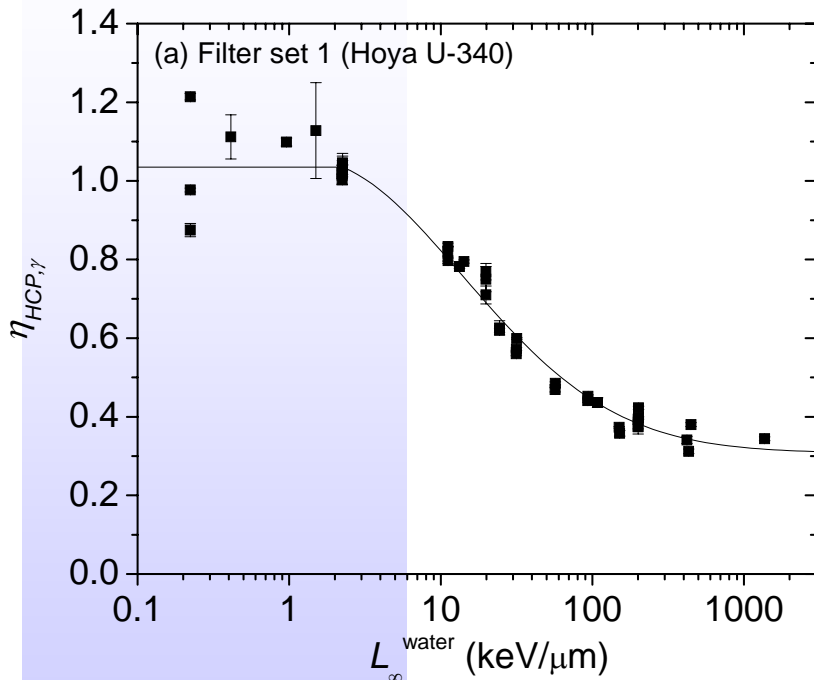
## Previous work: ICCHIBAN series

- Irradiations at HIMAC and NSRL: p, O, He, Ar, Fe ions
- Efficiency curve



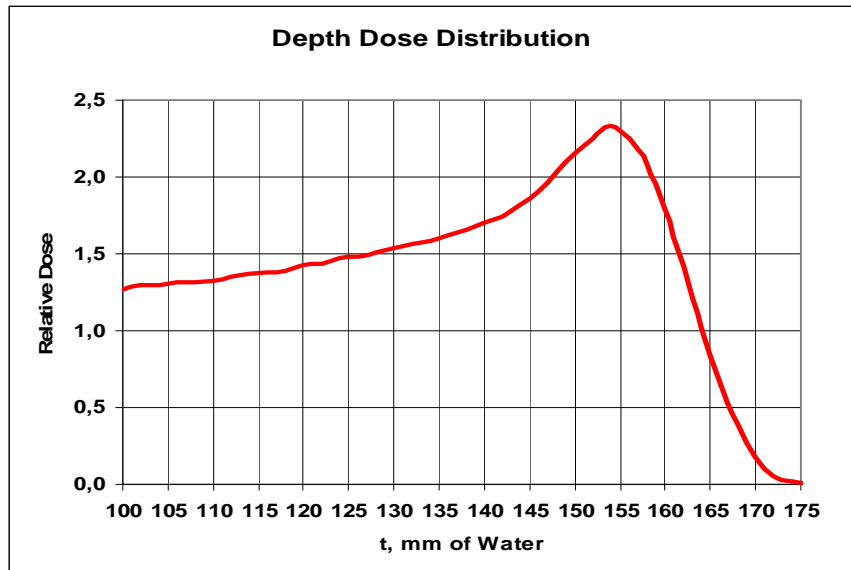
# ICCHIBAN series: well established efficiency curve of Luxel

- By Sawakuchi, Yukihiro, et al.



# Recent irradiations: Dubna

- Proton irradiations at Phasotron at JINR, Dubna, Russia
  - 145 MeV protons
    - ♣ In beam
    - ♣ In Bragg peak
  - 180 mGy
  - TL/OSL detectors
  - Track etch detectors



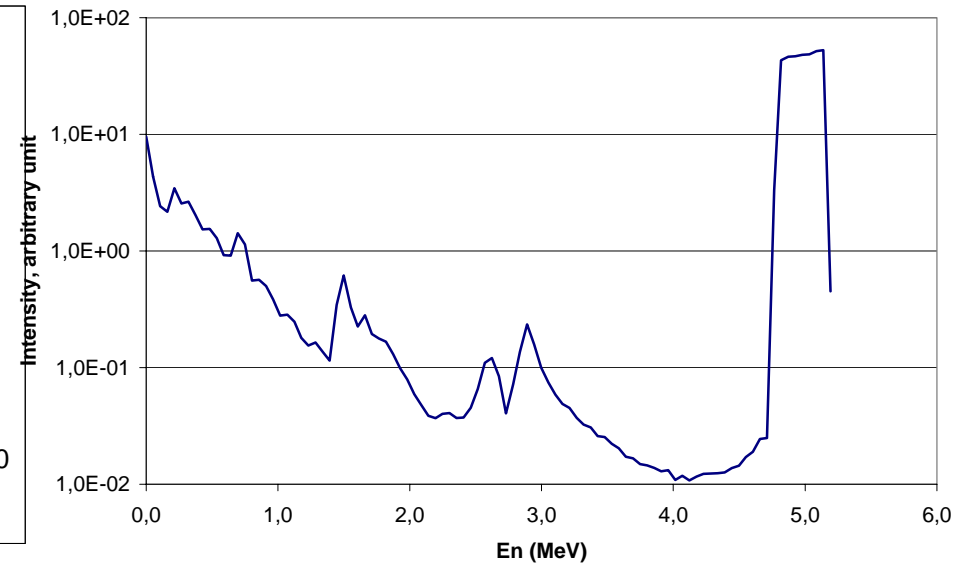
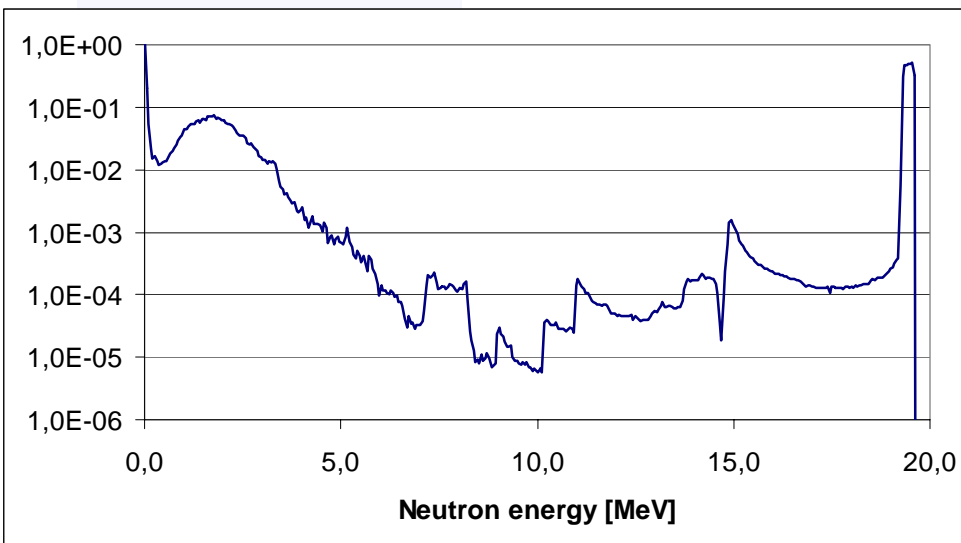
# Dubna irradiations: TL and OSL results

Luminescent detector	Participant	Dose in tissue, mGy	Dose in tissue, mGy
		145 MeV	Bragg peak region
MTS700	SCK	177 ± 8	193 ± 12
MCP700	SCK	216 ± 7	150 ± 9
MCP7	NPI	240 ± 12	153 ± 5
Luxel	SCK	150 ± 7	136 ± 6
TLD500	SCK	151 ± 10	107 ± 23
Luxel	OSU	185 ± 4	*)
TLD500K	NPI	160 ± 22	89 ± 8
Al-P glass	NPI	180 ± 13	199 ± 7
CaSO4:Dy	NPI	166 ± 25	172 ± 12

- Clearly see different responses of different types of detectors: 150-240 mGy
- No major discrepancies between groups
- Relative responses agree with efficiency curves

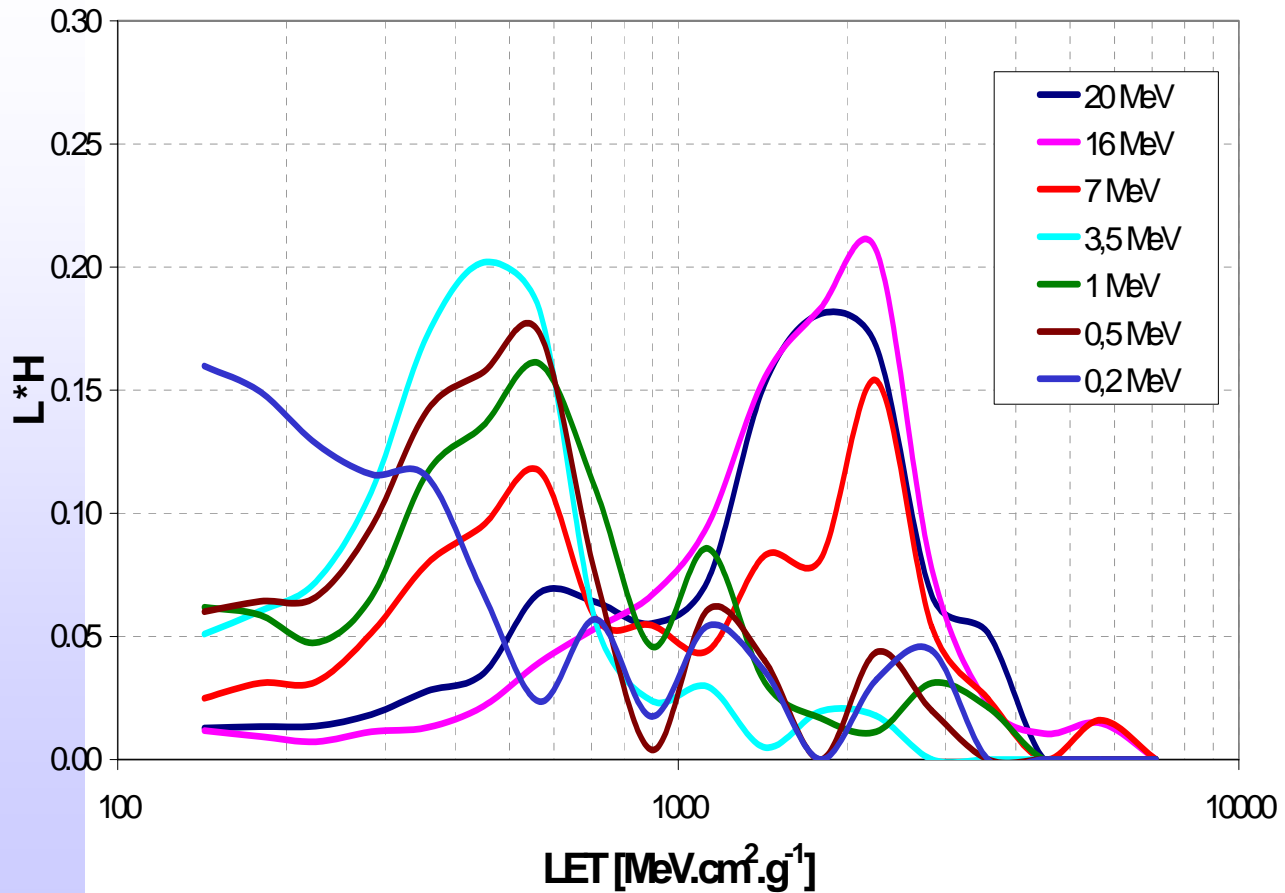
# Other recent characterisation tests: JRC-IRMM

- JRC-IRMM: quasi mono-energetic neutrons
  - 200 keV to 19.5 MeV neutrons



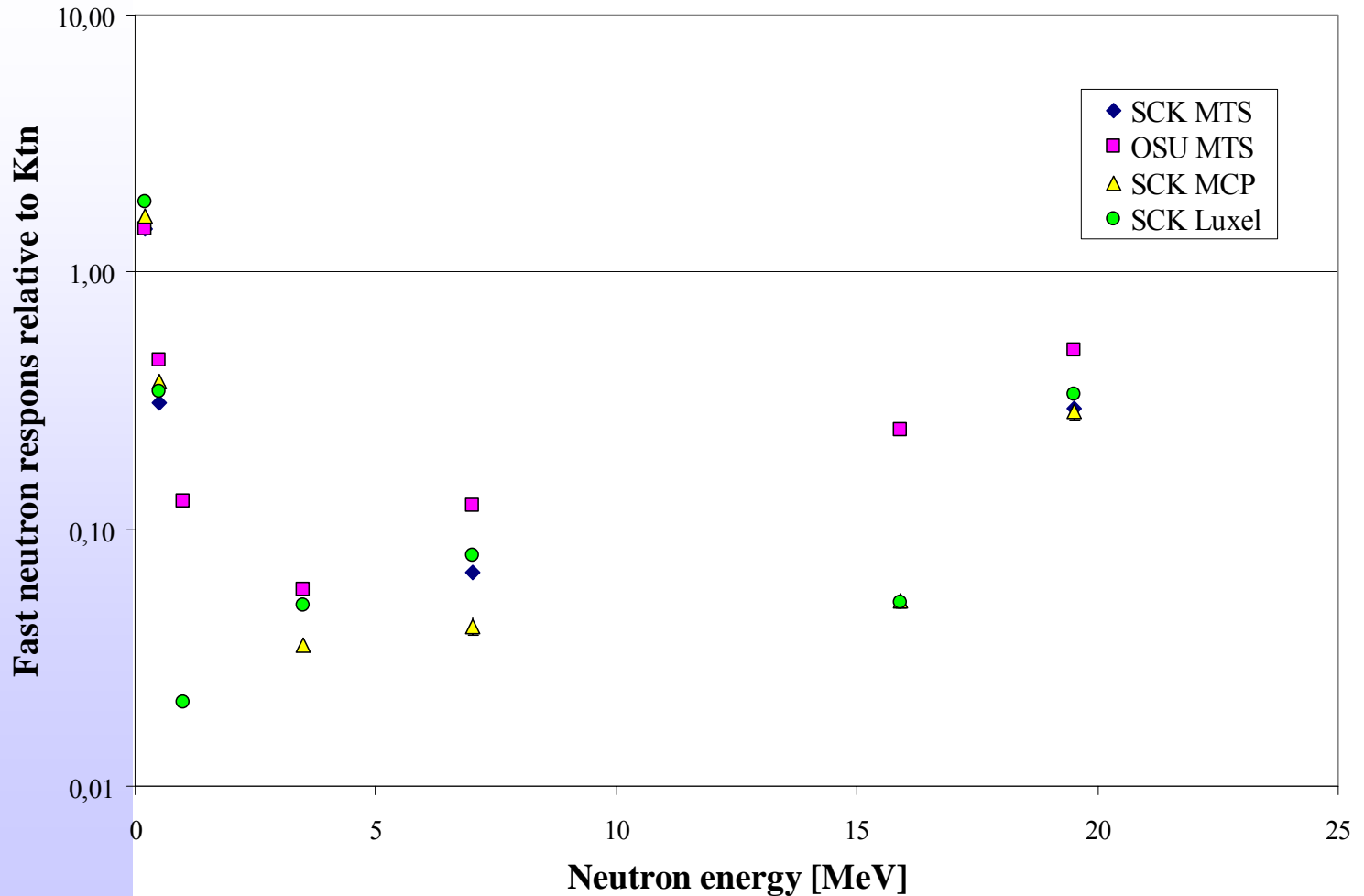
# Some preliminary results from NPI

## Tastrak



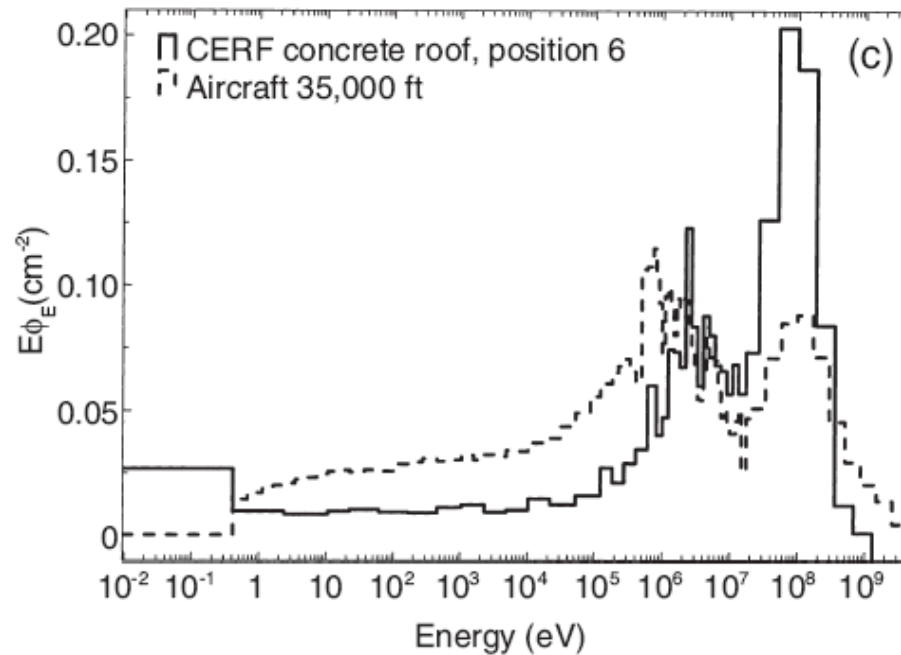
# Some preliminary results from SCK-CEN and OSU

Fast neutron respos (Li-7) without phantom



# CERF field

- **CERN: CERF field irradiation: november 2006**
- **Simulated 'realistic' calibration field**



# CERF field: relative response in $H^*(10)$

	<u>MTS100</u>	<u>MTS600</u>	<u>MTS700</u>	<u>MCP100</u>	<u>MCP600</u>	<u>MCP700</u>	<u>Luxel</u>	<u>TLD500</u>	<u>wbbadge</u>
<b>Response</b>	0,38	0,85	0,37	0,26	0,40	0,26	0,24	0,24	0,28
Unc.	0,04	0,06	0,11	0,01	0,01	0,03	0,01	0,01	0,01

# CERF field: conclusions

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- Luxel and TLD 500 gave same result
- OSL lower than TLD
- MCP lower than MTS
- Thermal neutrons present: around half of the dose on MCP
- TL/OSL measure 24 to 37% of total dose

# Example of how to use efficiencies (1)

- MESSAGE results:
  - Low LET (TL/OSL, SCK only): ranging from 143 to 152  $\mu\text{Gy/d}$
  - High LET (CR-39): 23  $\mu\text{Gy/d}$ , 250  $\mu\text{Sv/d}$
- Total absorbed dose?
  - 1st method: assume zero efficiency for high LET
    - Range from 166 to 175  $\mu\text{Gy/d}$  (393 to 402  $\mu\text{Sv/d}$ )
  - 2nd method: use CERF calibration on low LET results
    - Total result H from 410 to 620  $\mu\text{Sv/d}$
  - 3rd method: use TED spectrum and TL/OSL efficiency to correct results
    - High LET contribution between 6 and 11  $\mu\text{Gy/d}$  (only  $>5/9$  keV/ $\mu\text{m}$ )
    - Total result from 158 to 165  $\mu\text{Gy/d}$  (385 to 392  $\mu\text{Sv/d}$ )
    - Missing part of 2-5/9 keV/ $\mu\text{m}$

## Example of how to use efficiencies (2)

- MESSAGE results
  - 4th method: use different efficiencies to estimate high LET contribution
    - E.g. 2 detectors:
      - $D_{\text{tot,MTS}} = D_{\text{lowLET}} + \eta_{\text{avg,MTS}} * D_{\text{highLET}}$
      - $D_{\text{tot,MCP}} = D_{\text{lowLET}} + \eta_{\text{avg,MCP}} * D_{\text{highLET}}$
    - $D_{\text{lowLET}} = 155 \mu\text{Gy/d}$
    - $D_{\text{highLET}} = 60 \mu\text{Gy/d}$
    - No TED necessary
    - High LET from  $2 \text{ keV}/\mu\text{m}$
- To be elaborated with different detectors combinations and experiments
- Required accuracy?

# Conclusion

- Already now operational to determine doses in biological experiments
  - Different biological experiments running (Expose, Base B/C, YING,...)
- Characterisation of detectors is important
  - To better estimate radiation doses
  - To optimize and simplify methods

## Intercomparison between NPI, OSU, SCK

		<i>D<sub>tissue</sub></i> [mGy]	<i>Unc.</i> [mGy]	<i>D<sub>tissue</sub></i> [mGy]	<i>Unc.</i> [mGy]
	<b>Reference</b>	<b>3.30</b>	<b>0.06</b>	<b>110.0</b>	<b>2.0</b>
NPI	AIP glass	-	-	102.2	4.7
NPI	Al <sub>2</sub> O <sub>3</sub> :C	-	-	94.5	7.4
NPI	CaSO <sub>4</sub>	-	-	103.8	6.0
OSU	Luxel, OSL, U-340	3.36	0.10	107.1	0.4
OSU	Luxel, OSL, U-340 and WG-360	3.0	0.6	112.0	1.7
OSU	Al <sub>2</sub> O <sub>3</sub> :C chips	3.6	1.5	113.3	1.6
OSU	TLD-100	3.26	0.22	109.2	2.2
SCK	MTS-100	3.36	0.14	104.9	7.9
SCK	MCP-100	3.20	0.11	104.2	4.4