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Characterising Passive Dosemeters for Dosimetry of Biological Experiments in Space

F. Vanhavere (SCK•CEN, Belgium)

WRMISS Krakow, September 2008

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DOBIES: DOsimetry of BIological Experiments in Space

- **Objective**: *establish standard dosimetric method to measure doses to (μ)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**

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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_2O_3:C, Al-P — NPI
  - $CaSO_4$:Dy — NPI
- **Optically Stimulated luminescence detectors**
  - Al_2O_3:C (Luxel, TLD500) — SCK-CEN
  - Al_2O_3:C (Luxel) — OSU

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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)

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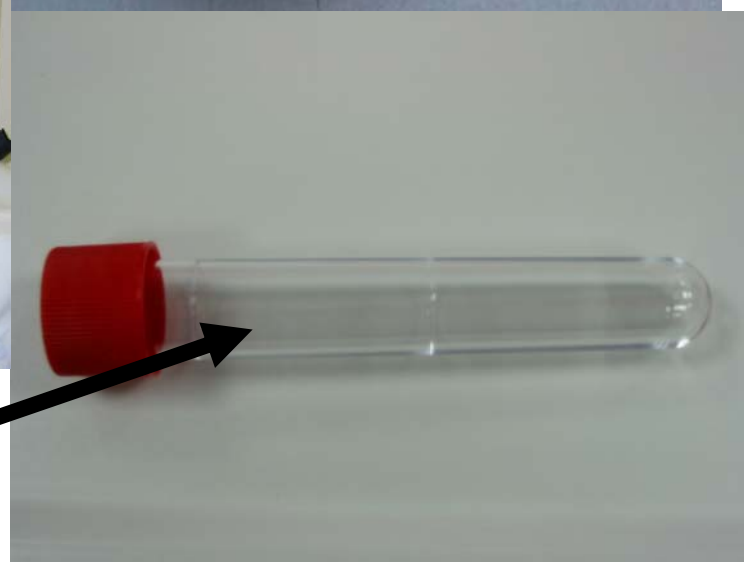
MESSAGE, MOBILIZATION



dosemeters inside

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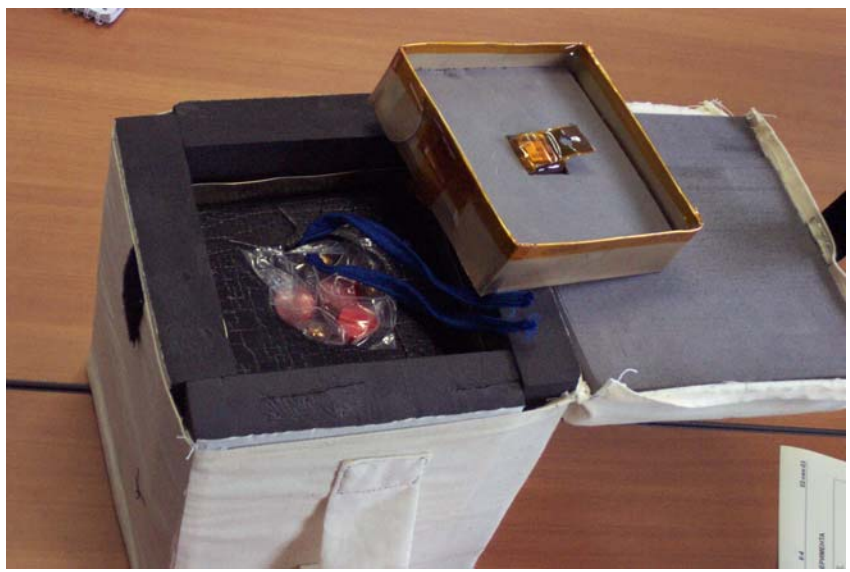

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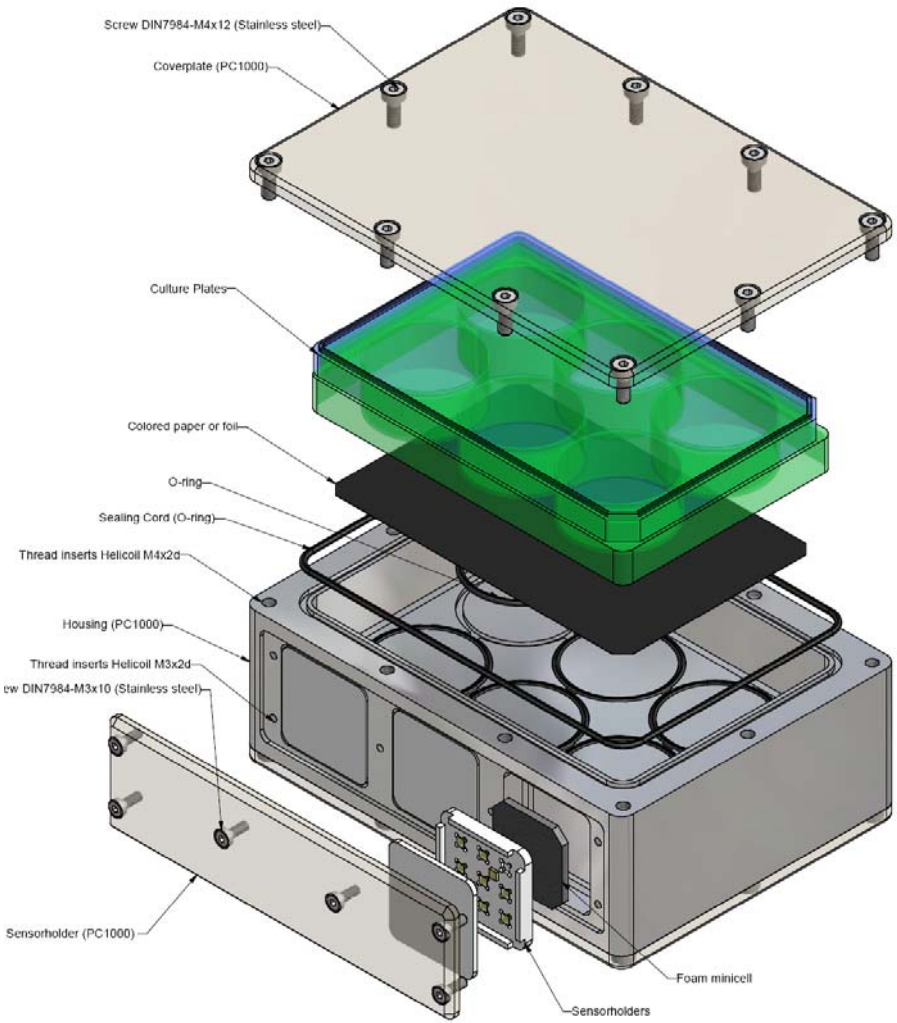
BASE-A flight



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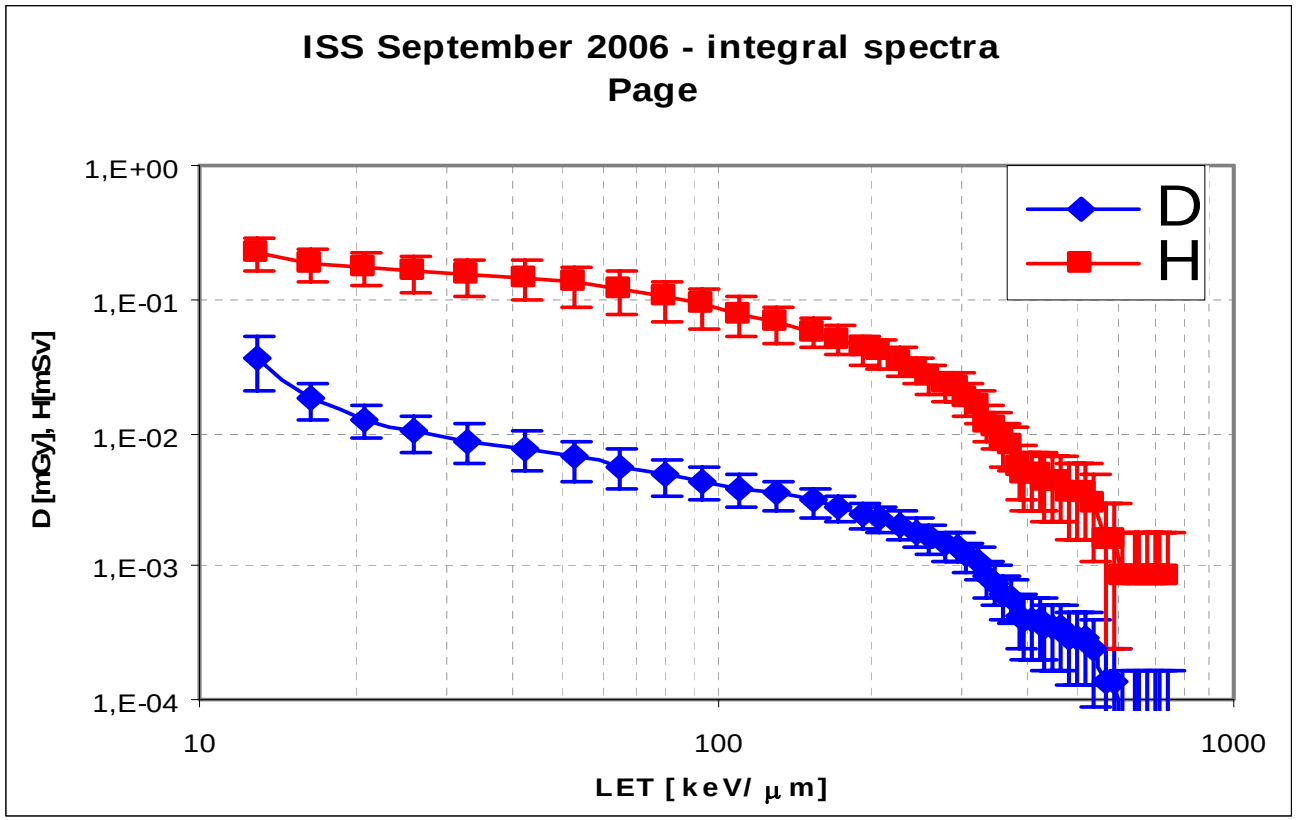
BASE-A: Track-etch detectors: high LET part



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

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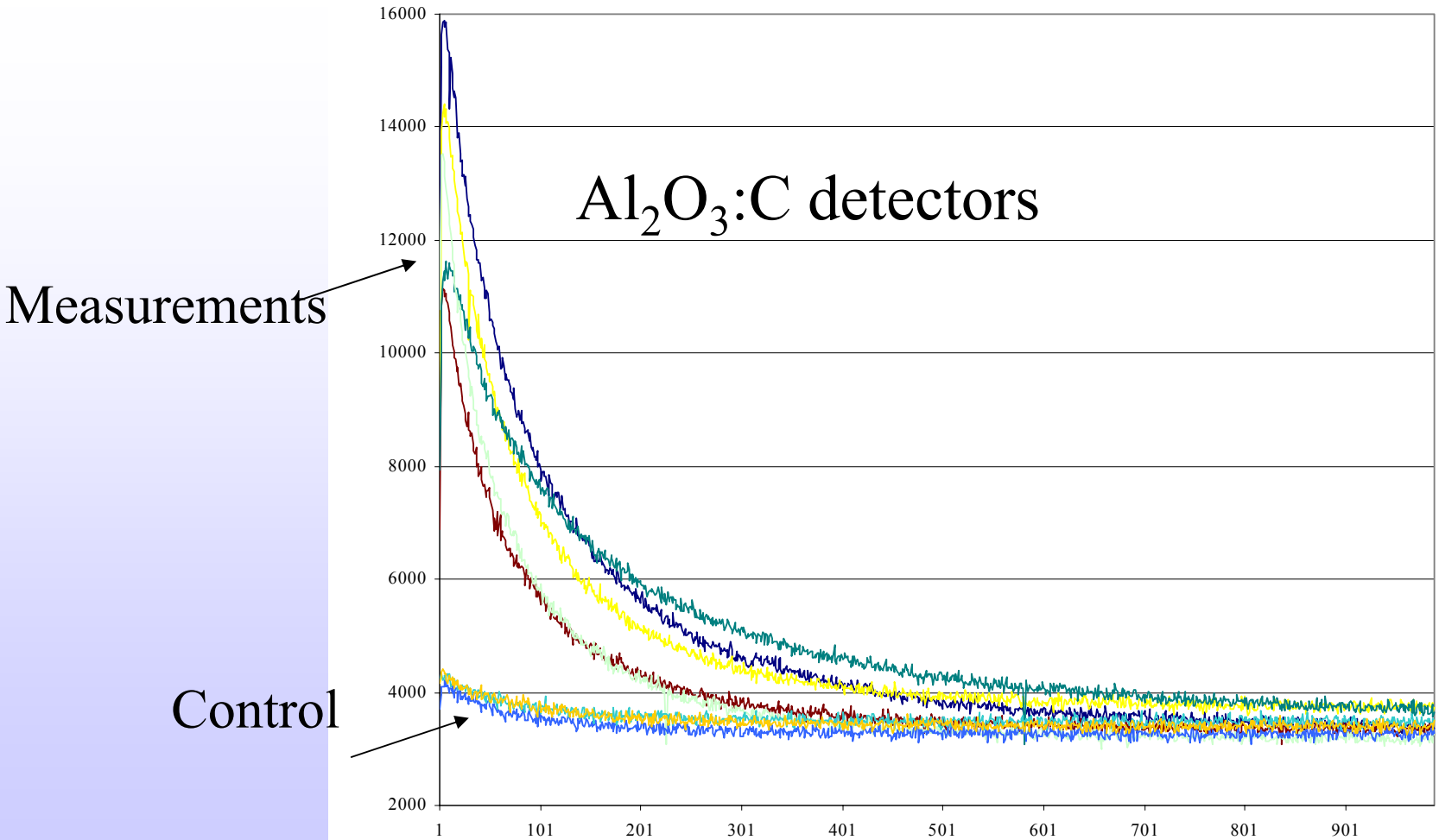
TL/OSL results: low LET part



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Comparison results: low LET part

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	**^{7}LiF:Mg,Cu,P**	**TL**	**143 ± 1**	**154 ± 4**	**-**	**199 ± 21**
NPI	**^{7}LiF:Mg,Cu,P**	**TL**	**-**	**154±12**	**118±7**	
NPI	**Al_2O_3:C**	**TL**	**-**	**178±14**	**180±18**	

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Other space flights:

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

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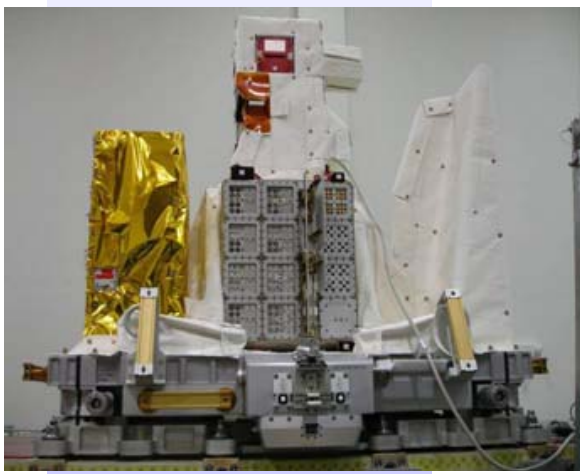
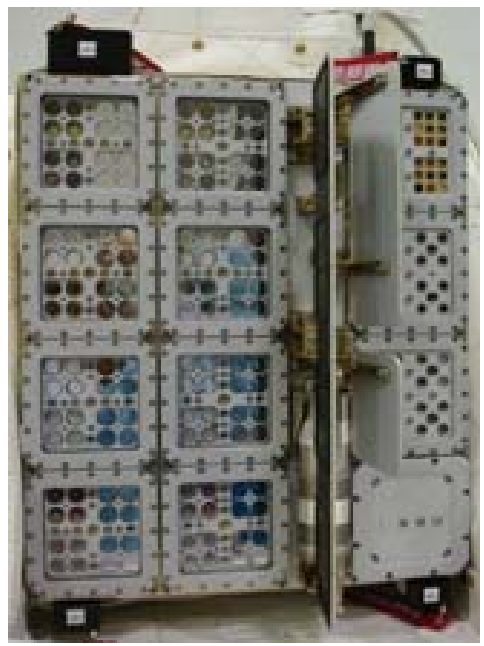
Now in ISS: EXPOSE-E on EUTEF

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





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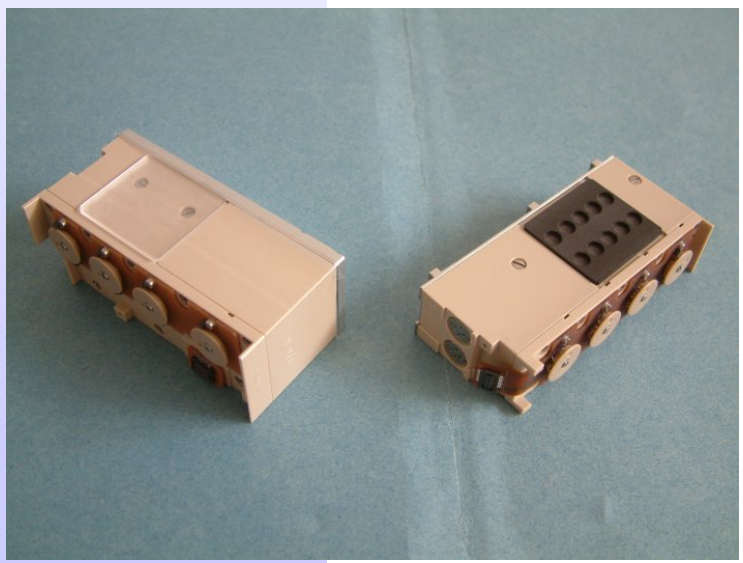
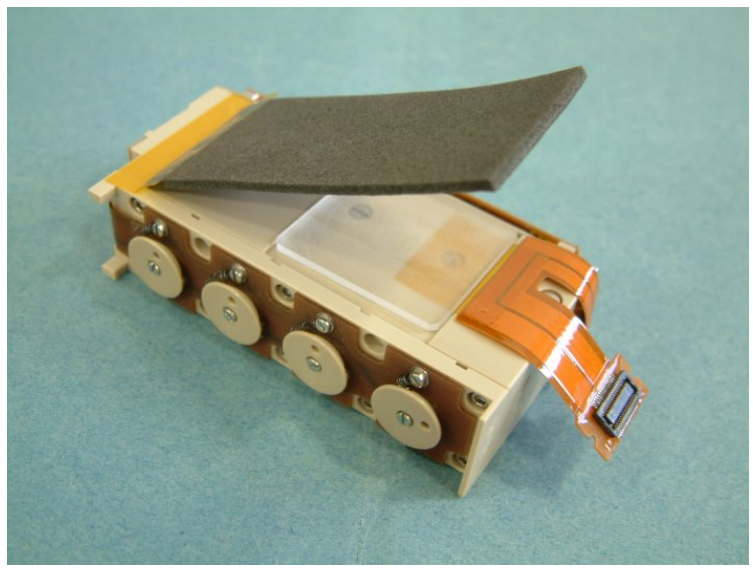
In preparation

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





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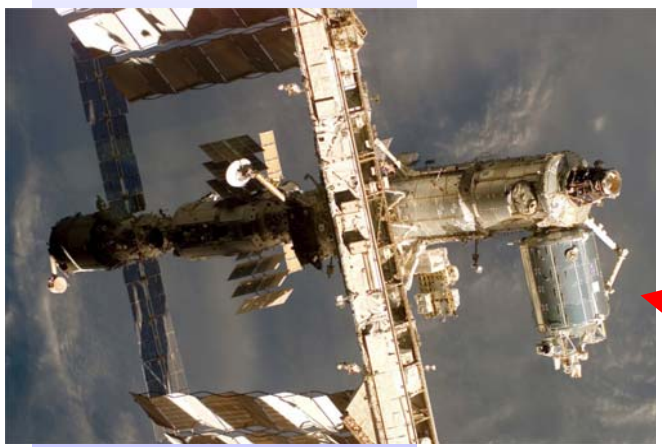
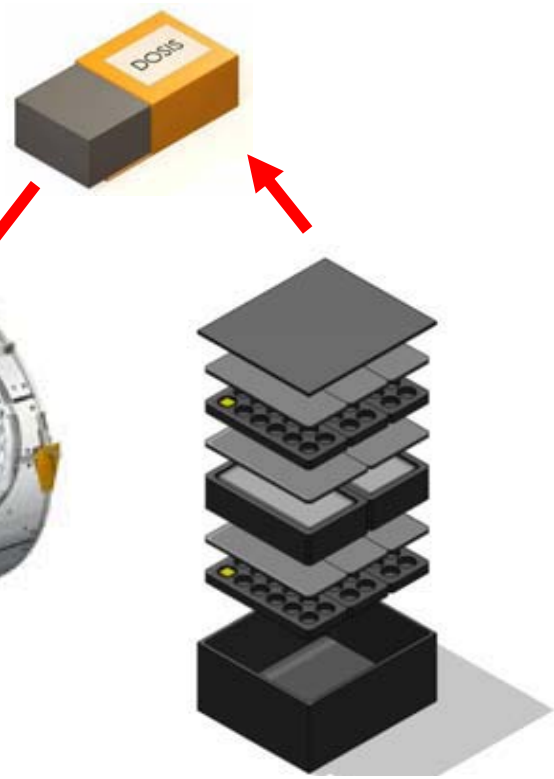
In preparation

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





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Other flights planned

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

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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

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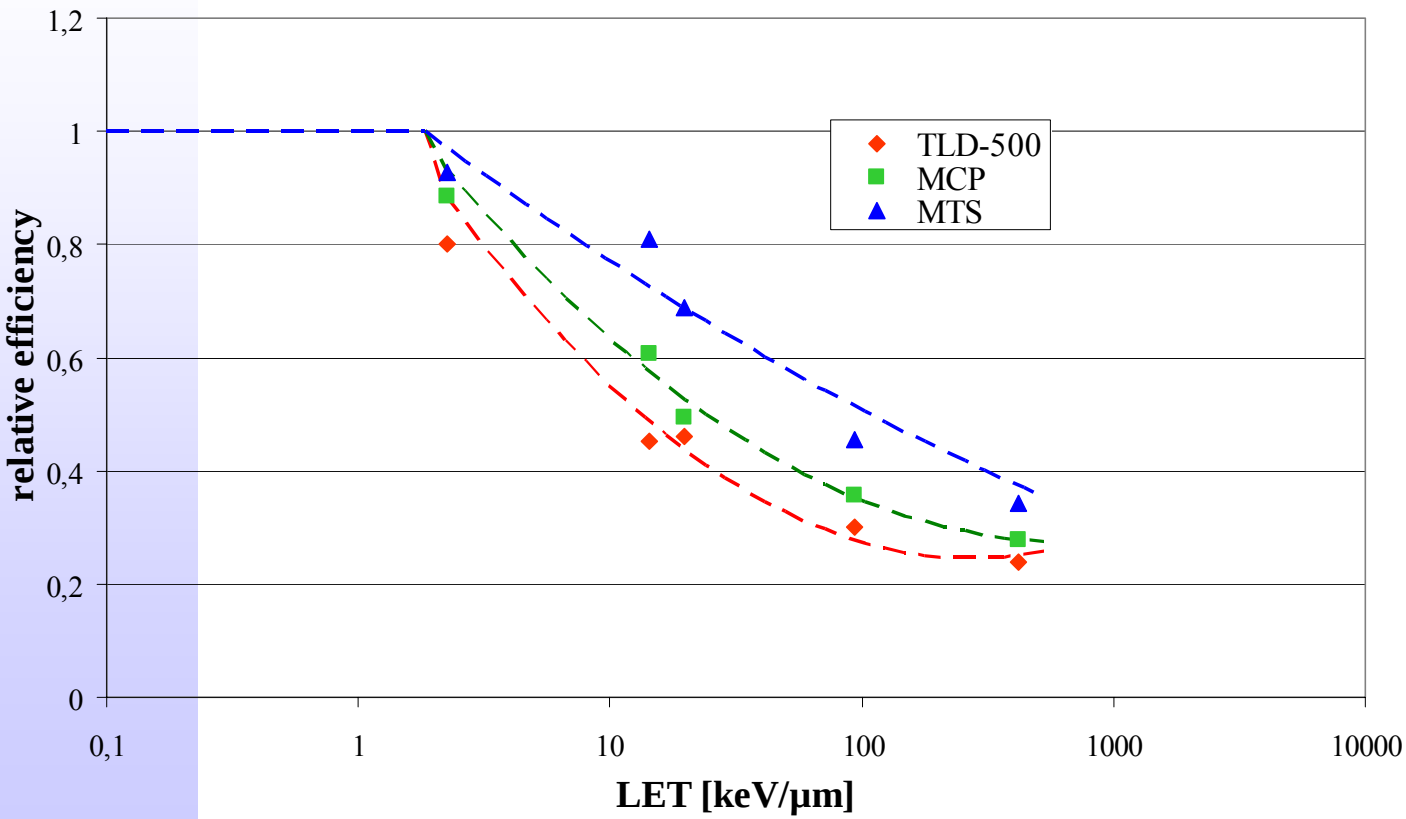
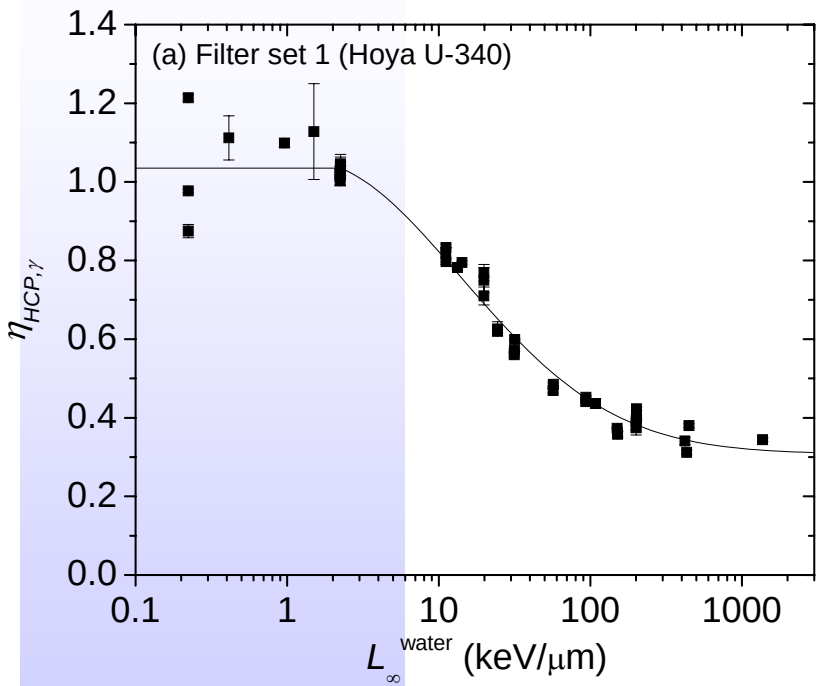
Previous work: ICCHIBAN series

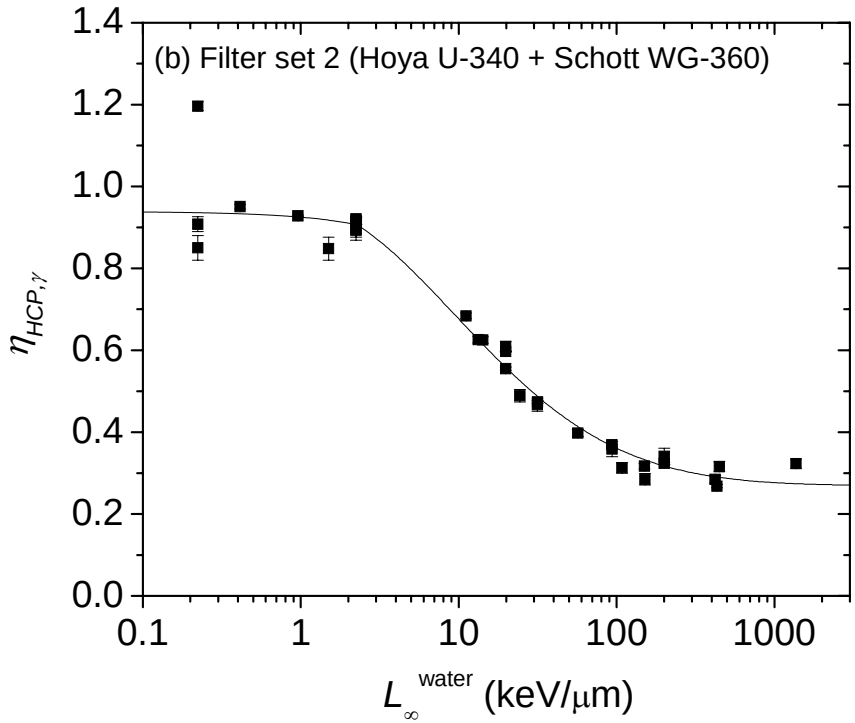
- **Irradiations at HIMAC and NSRL: p, O, He, Ar, Fe ions**
- **Efficiency curve**



ICCHIBAN series: well established efficiency curve of Luxel

- By Sawakuchi, Yukihara, et al.





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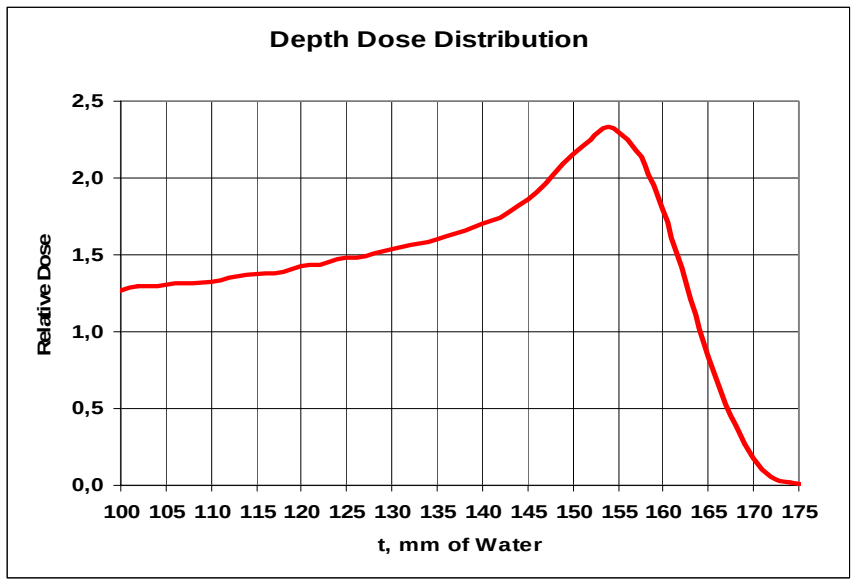
Recent irradiations: Dubna

- 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

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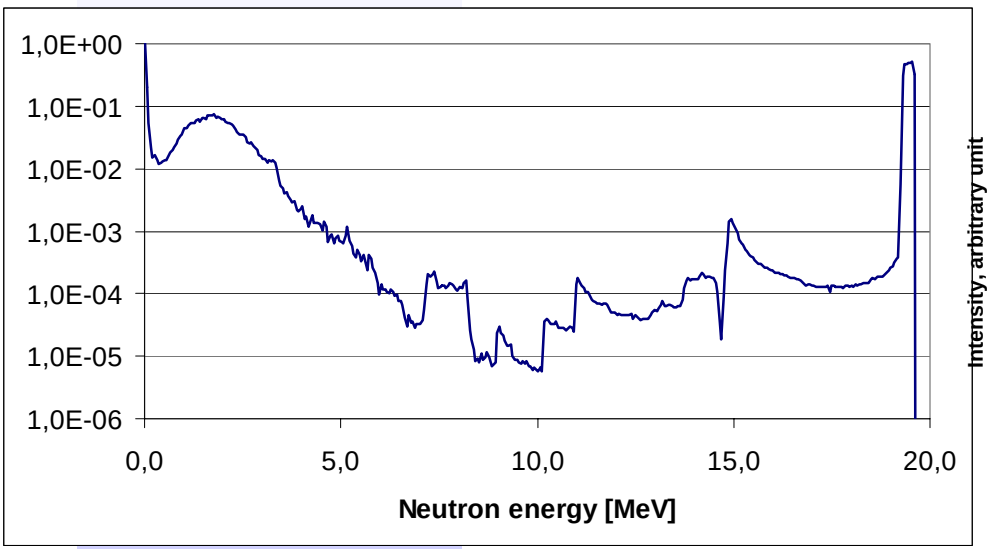
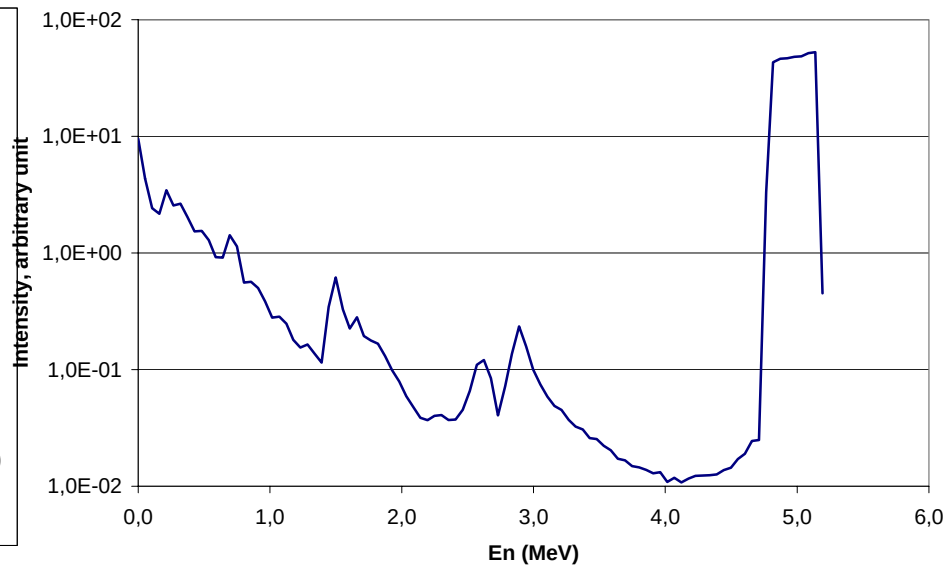
Other recent characterisation tests: JRC-IRMM

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





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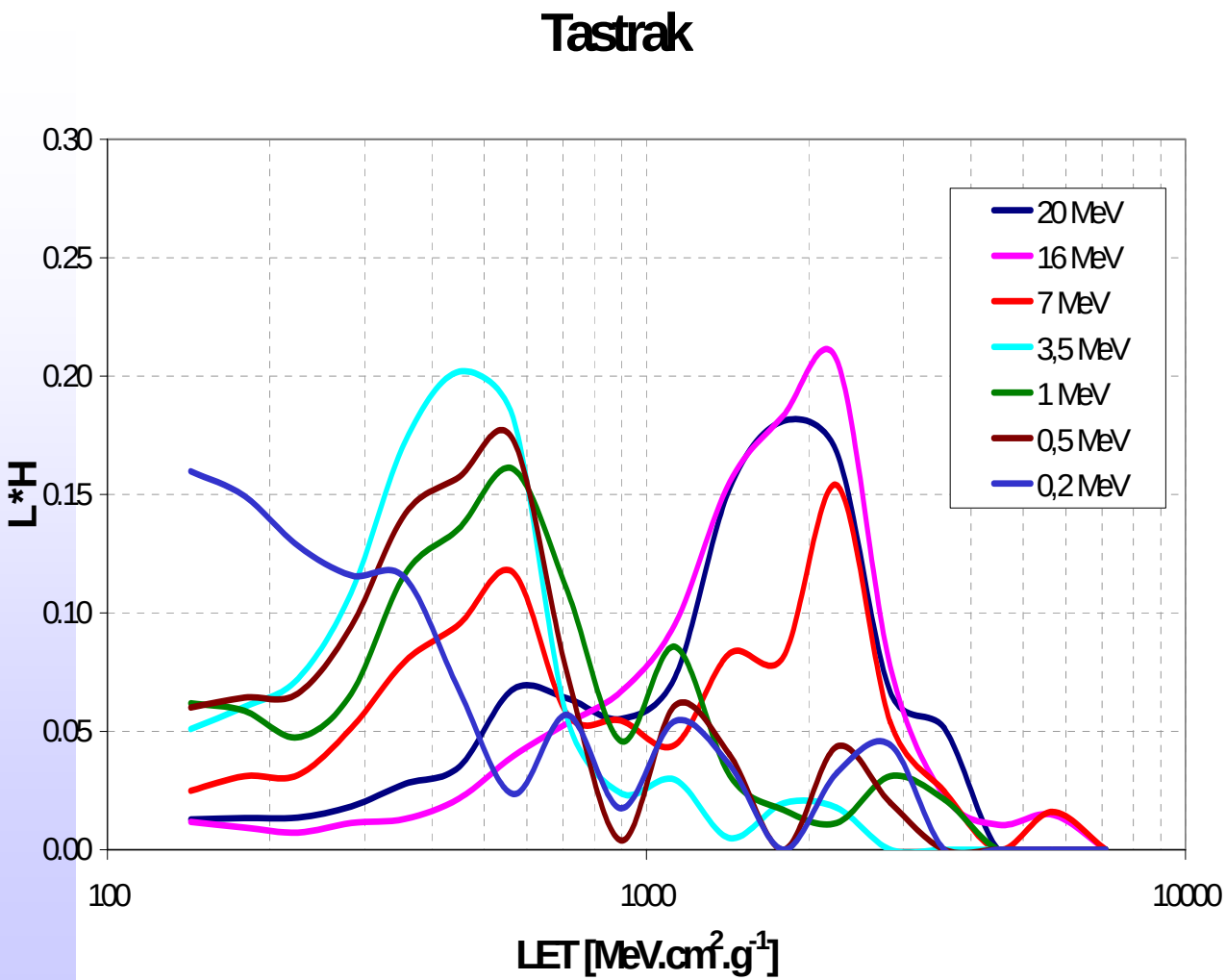
Some preliminary results from NPI



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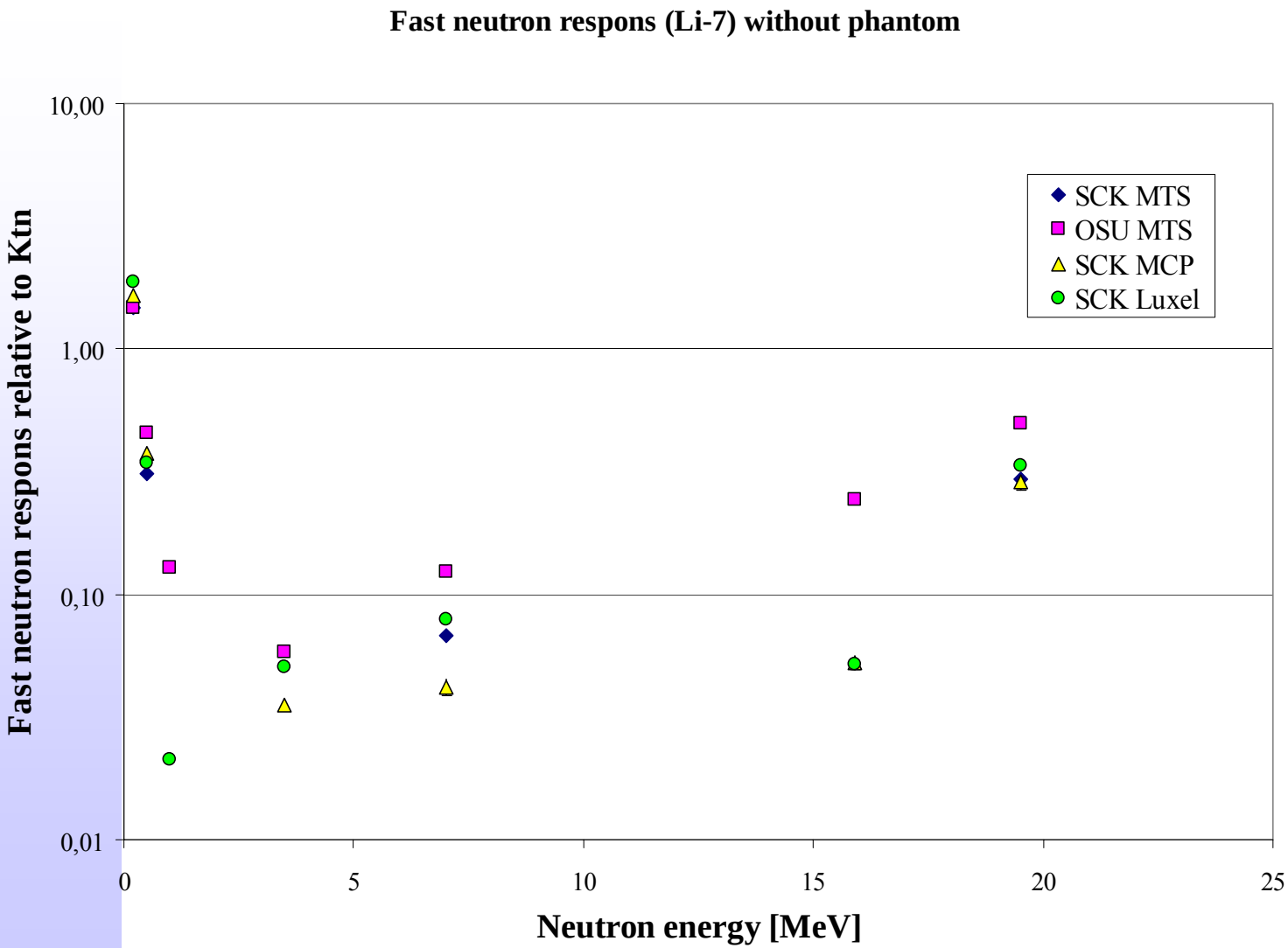
Some preliminary results from SCK-CEN and OSU



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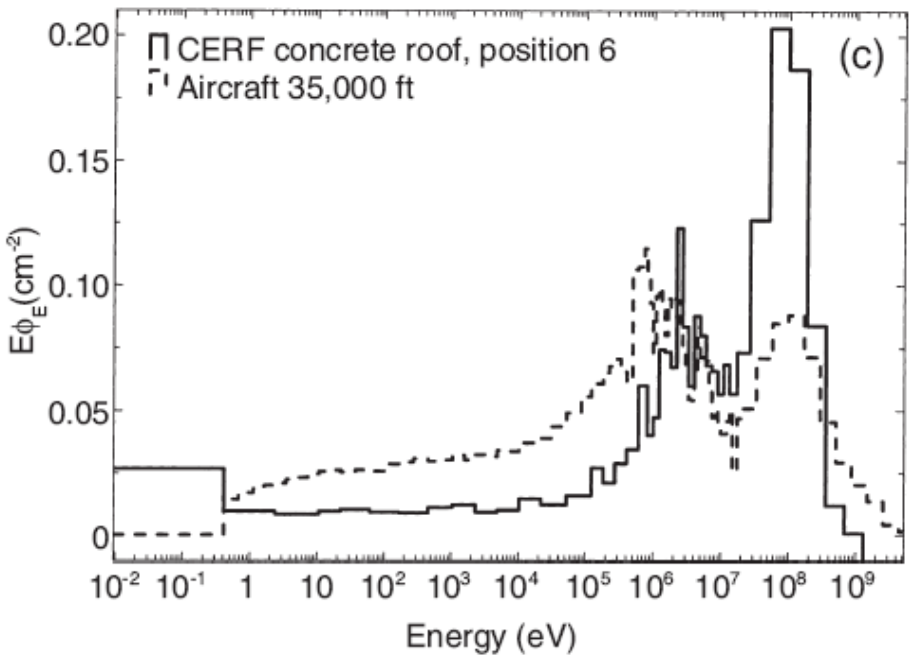
CERF field

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



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

	MTS100	MTS600	MTS700	MCP100	MCP600	MCP700	Luxel	TLD500	wbbadge
Response	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

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CERF field: conclusions

- 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

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Example of how to use efficiencies (1)

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

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Example of how to use efficiencies (2)

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

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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

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Intercomparison between NPI, OSU, SCK

		Dtissue [mGy]	*Unc. [mGy]*	*Dtissue [mGy]*	*Unc. [mGy]*
	Reference	**3.30**	**0.06**	**110.0**	**2.0**
NPI	AlP glass	-	-	102.2	4.7
NPI	Al_2O_3:C	-	-	94.5	7.4
NPI	$CaSO_4$	-	-	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_2O_3: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