



Atominstitute of the Austrian Universities

Vienna University of Technology  
A - 1020 Vienna, Stadionallee 2, Austria



# The BRADOS Intercomparison (“Space ICCHIBAN”) Experiment Onboard ISS *First Results*

Michael Hajek, Manfred Fugger and Norbert Vana

9<sup>th</sup> Workshop on Radiation Monitoring for the International Space Station  
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# Experimental History

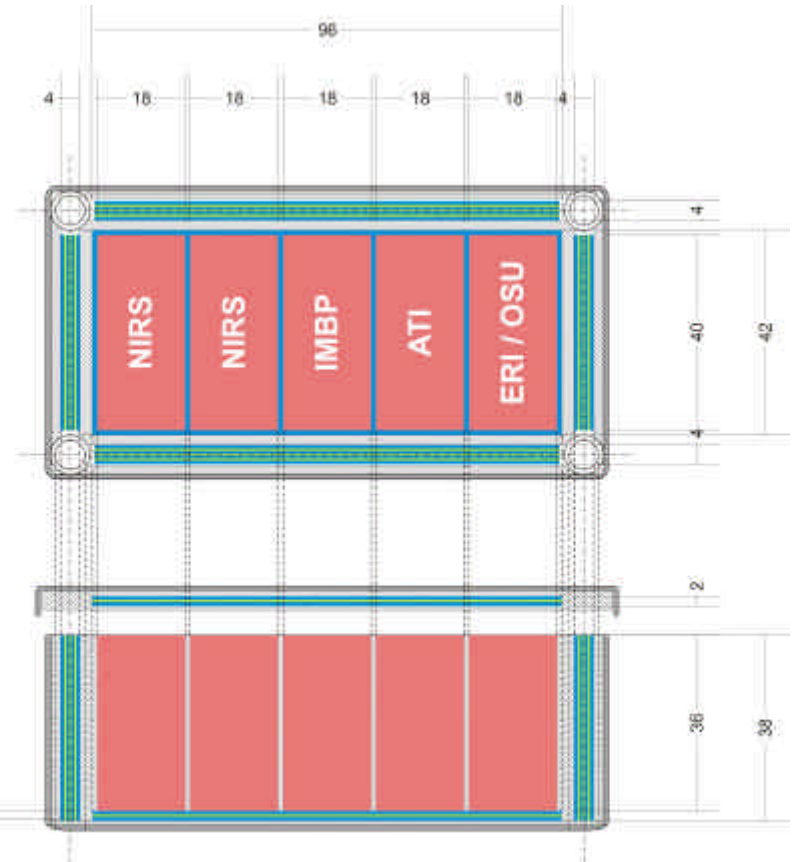
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- Russian invitation to NIRS to conduct space-based intercomparison experiment onboard the Russian Segment of ISS
  
- Participants included
  - National Institute of Radiological Sciences (TLD, PNTD)
  - Institute for Biomedical Problems (TLD)
  - Atomic Institute of the Austrian Universities (TLD, PNTD)
  - Eril Research Inc. (TLD, PNTD)
  - Oklahoma State University (OSLD)



# Experimental Configuration

- ATI detector stack comprised of 10 TLD and 28 PNTD layers
- Total thickness: 35.4 mm





# Flight Parameters

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- Launch: January 29, 2004 (Progress M1-12)
- Docking to ISS: February 1, 2004
- Landing: April 30, 2004
  
- Exposure duration: 91.5 days
- Exposure location: Panel ? 443 (commander sleeping quarter)
  
- Average apogee: 384.4 km
- Average perigee: 361.8 km
- Solar activity: quiet



# Detector Stack Configuration

<i>Detector</i>	<i>Material</i>	<i>Dimensions (mm<sup>3</sup>)</i>	<i>Density (g/cm<sup>3</sup>)</i>
TLD-300	CaF <sub>2</sub> :Tm	3.2 × 3.2 × 0.9	3.18
TLD-600	<sup>6</sup> LiF:Mg,Ti	6.4 × 6.4 × 0.9	2.64
TLD-700	<sup>7</sup> LiF:Mg,Ti	6.4 × 6.4 × 0.9	2.64
TLD-700H	<sup>7</sup> LiF:Mg,Cu,P	3.2 × 3.2 × 0.4	2.64
CR-39	Harzlas TD-1	40 × 18 × 0.9	1.30



# Disassembling





# Thermoluminescent Efficiency

- Relative TL efficiency  $\eta_{k,?} = \frac{R_k / D_k}{R_? / D_?}$

$R_k, R_? \dots$  TL responses per unit mass

$D_k, D_? \dots$  absorbed doses

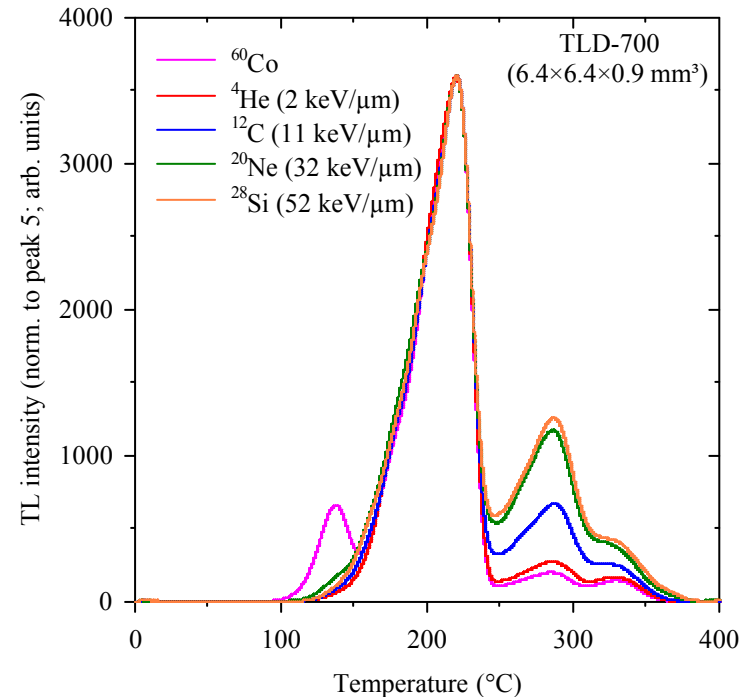
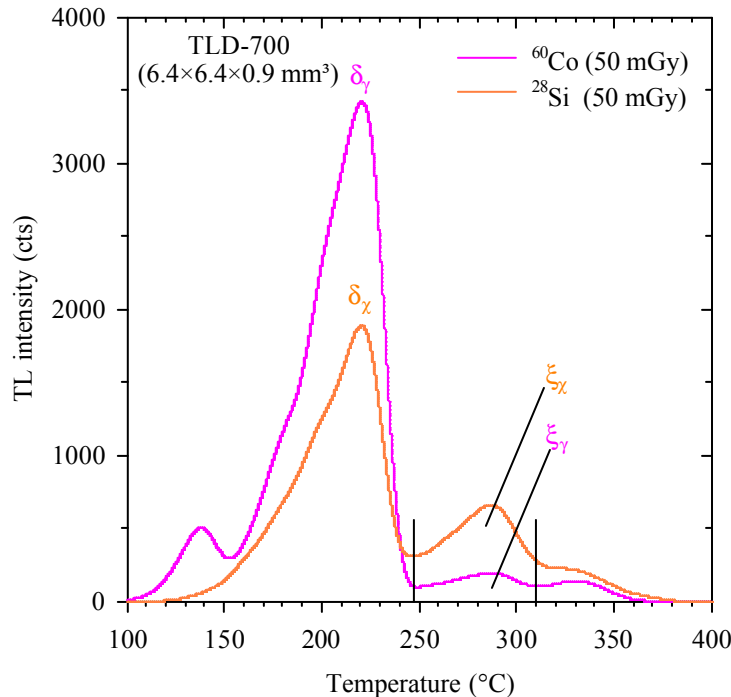
Reference radiation (?):  $^{60}\text{Co}$

- TL efficiency depends on LET and particle species
- Complicates precise dose determination in heavy ion fields, e.g. onboard a spacecraft



# High-temperature Ratio (HTR)

- High-temperature ratio in LiF:Mg,Ti TL glow curves  $HTR \equiv \frac{d_{\gamma}}{d_{\alpha}} \cdot \frac{?_{\alpha}}{?_{\gamma}}$
- High-temperature emission  $248 \div 310 \text{ }^{\circ}\text{C}$

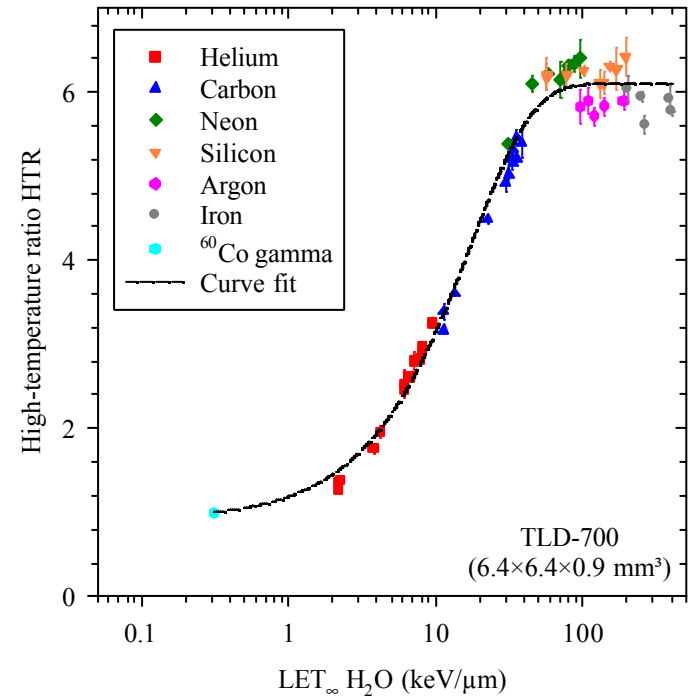
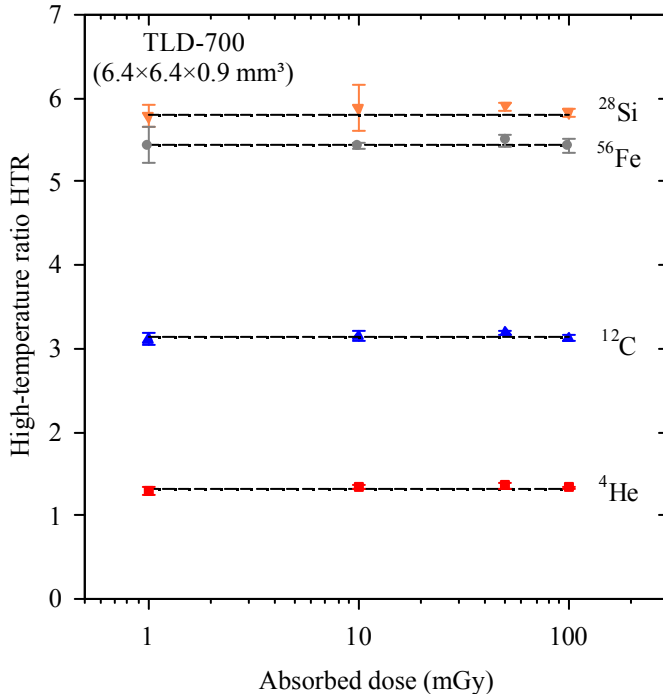






# High-temperature Ratio (HTR) contd.

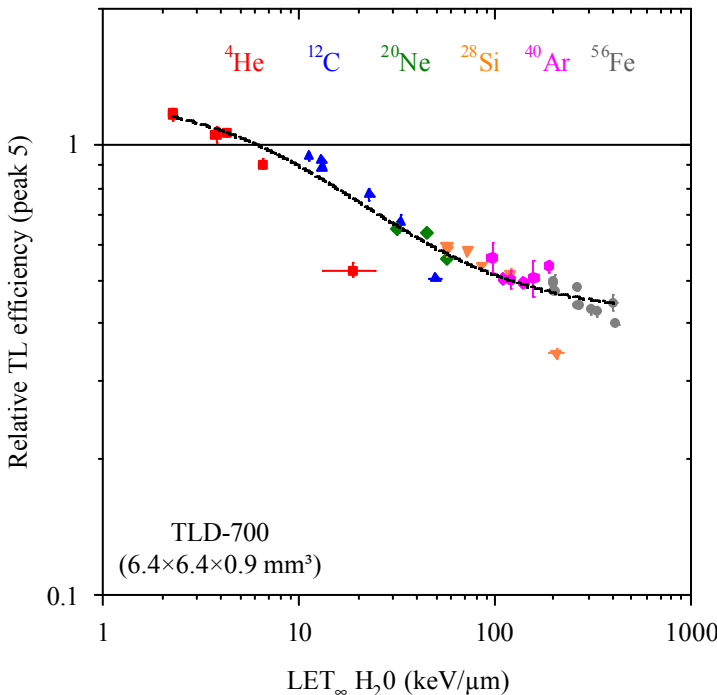
- HTR linear with dose
- HTR vs.  $LET_8 H_2O$  functional relationship





# TL Efficiency Correction

- Experiments at the Heavy Ion Medical Accelerator (HIMAC), Japan
- Use HTR to determine average LET ( $\bar{L}$ )



$$? = \frac{1 + a \cdot \bar{L}}{b + c \cdot \bar{L}}$$

$$a = 0.0144 \pm 0.0043$$

$$b = 0.8021 \pm 0.0402$$

$$c = 0.0456 \pm 0.0092$$

## Poster presentations at SSD14 Conference:

Berger et al. *The efficiency of various TL dosimeter types to heavy ions.*

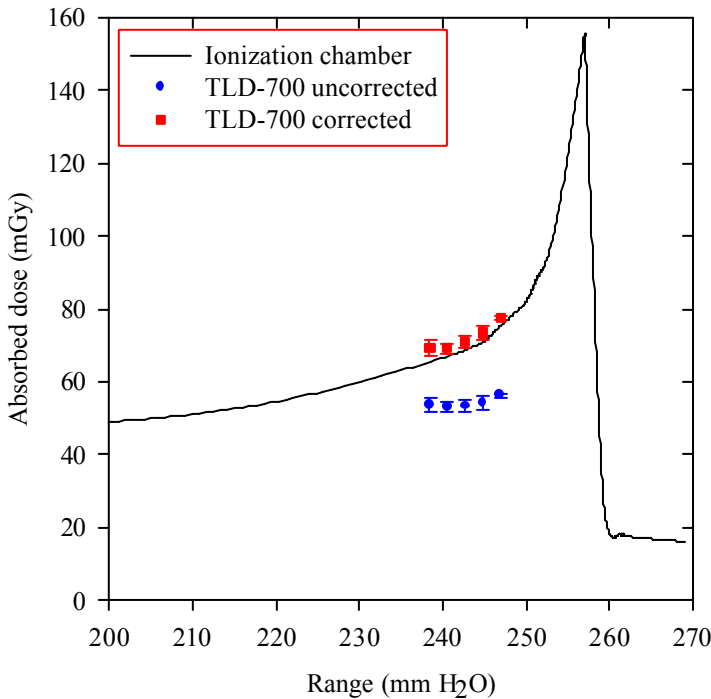
Berger et al. *Efficiency-corrected dose verification with TL dosimeters in heavy ion beams.*



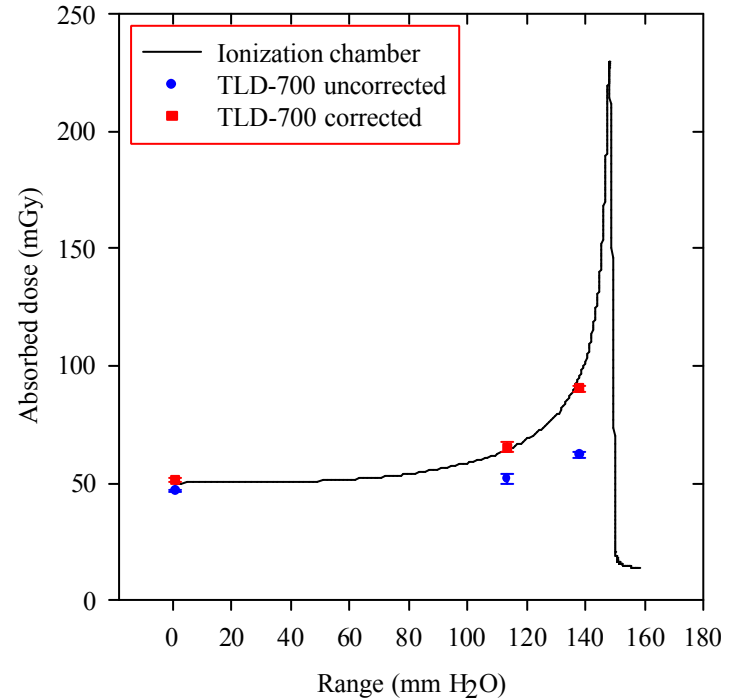
# TL Efficiency Correction: Carbon Ions

- Irradiations performed at HIMAC, Japan

$^{12}\text{C}$  400 MeV/n



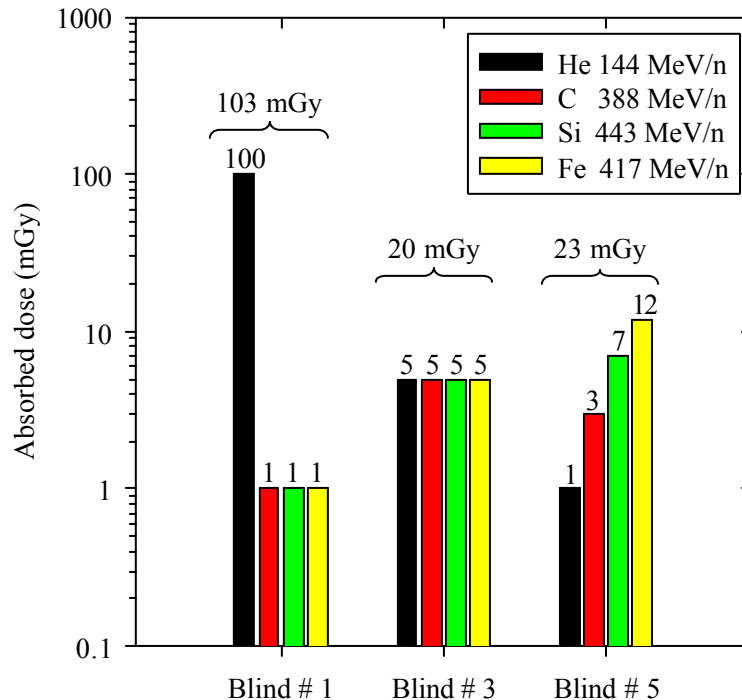
$^{12}\text{C}$  290 MeV/n





# TL Efficiency Correction: Mixed Fields

- ICCHIBAN-2 inter-calibration programme (May 2002)
- Composition of Blind exposures at first unknown to investigators



	<i>TLD-700 uncorrected</i>	<i>TLD-700 corrected</i>
Blind # 1	111.48 mGy	98.09 mGy
Blind # 3	14.60 mGy	16.93 mGy
Blind # 5	12.70 mGy	19.81 mGy

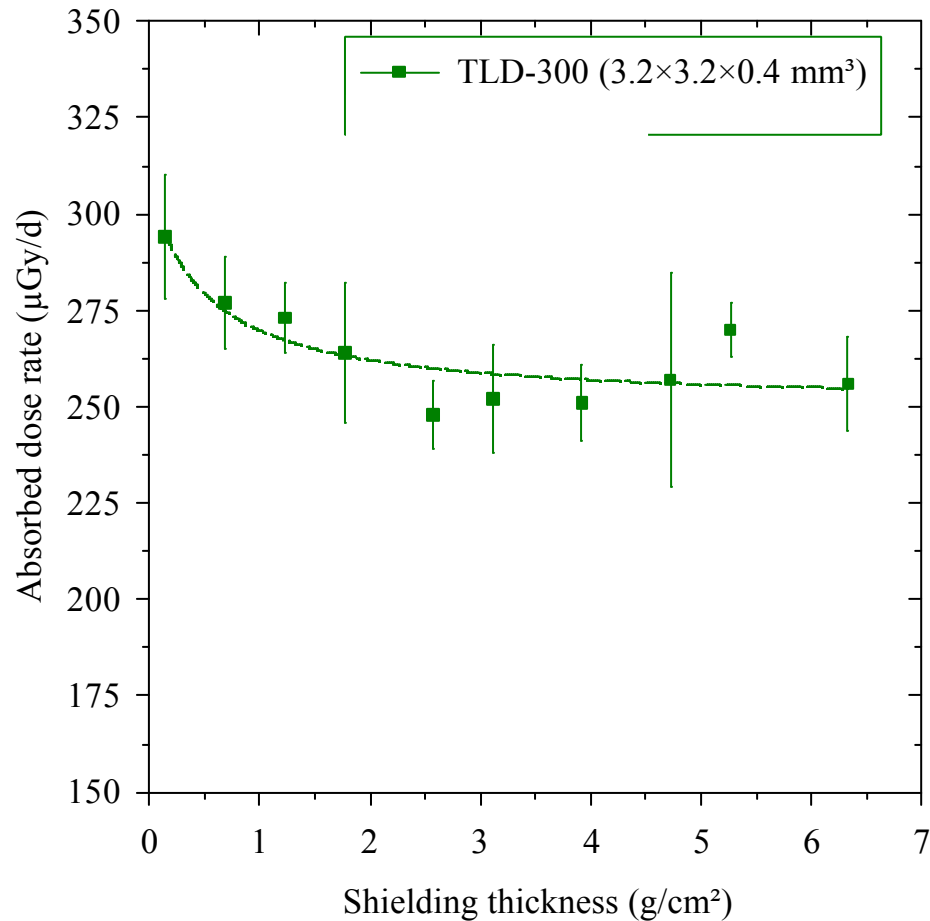


# TLD-300 Results

<i>Layer ?</i>	<i>Shielding (g/cm<sup>2</sup>)</i>	<i>Absorbed dose rate (μGy/d)</i>	
		<i>uncorrected</i>	<i>corrected</i>
1	0.14	294 ± 16	–
2	0.68	277 ± 12	–
3	1.23	273 ± 9	–
4	1.77	264 ± 18	–
5	2.57	248 ± 9	–
6	3.12	252 ± 14	–
7	3.92	251 ± 10	–
8	4.72	257 ± 28	–
9	5.27	270 ± 7	–
10	6.33	256 ± 12	–



# TLD-300 Results contd.



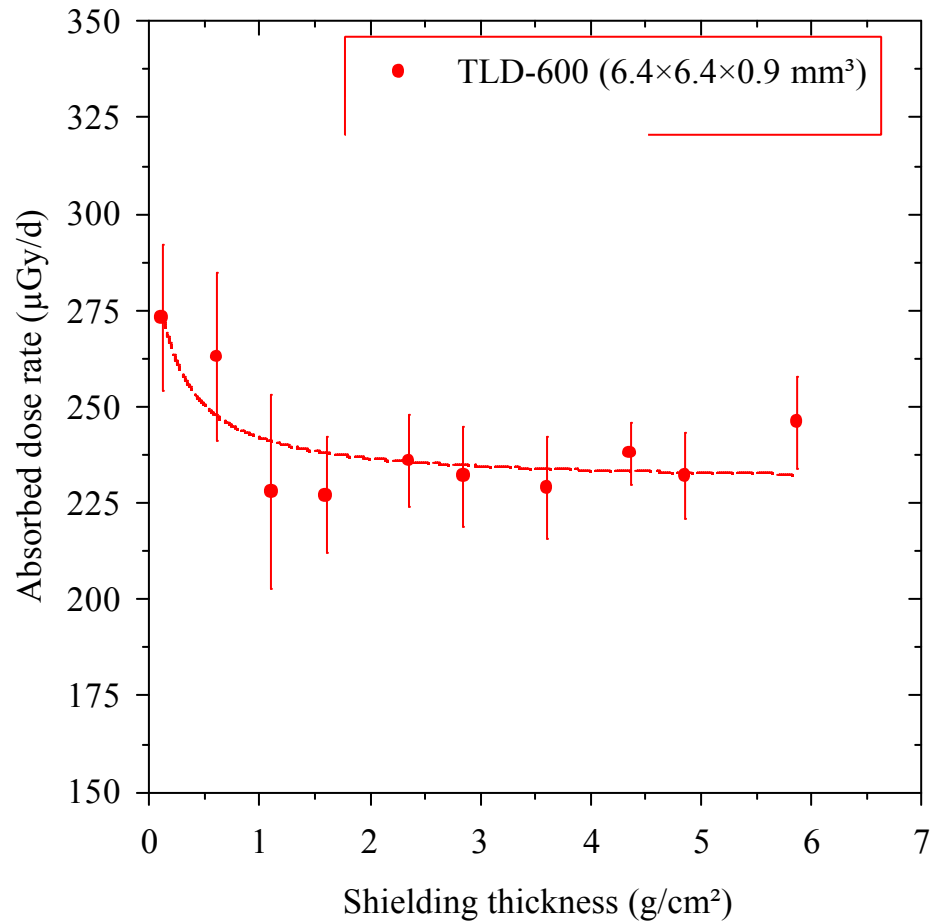


# TLD-600 Results

<i>Layer ?</i>	<i>Shielding (g/cm<sup>2</sup>)</i>	<i>Absorbed dose rate (μGy/d)</i>	
		<i>uncorrected</i>	<i>corrected</i>
1	0.12	310 ± 17	273 ± 19
2	0.61	300 ± 21	263 ± 22
3	1.11	260 ± 24	228 ± 25
4	1.60	259 ± 14	227 ± 15
5	2.36	268 ± 12	236 ± 12
6	2.85	265 ± 13	232 ± 13
7	3.60	260 ± 12	229 ± 13
8	4.36	271 ± 6	238 ± 6
9	4.85	263 ± 11	232 ± 11
10	5.87	277 ± 11	246 ± 12



# TLD-600 Results contd.





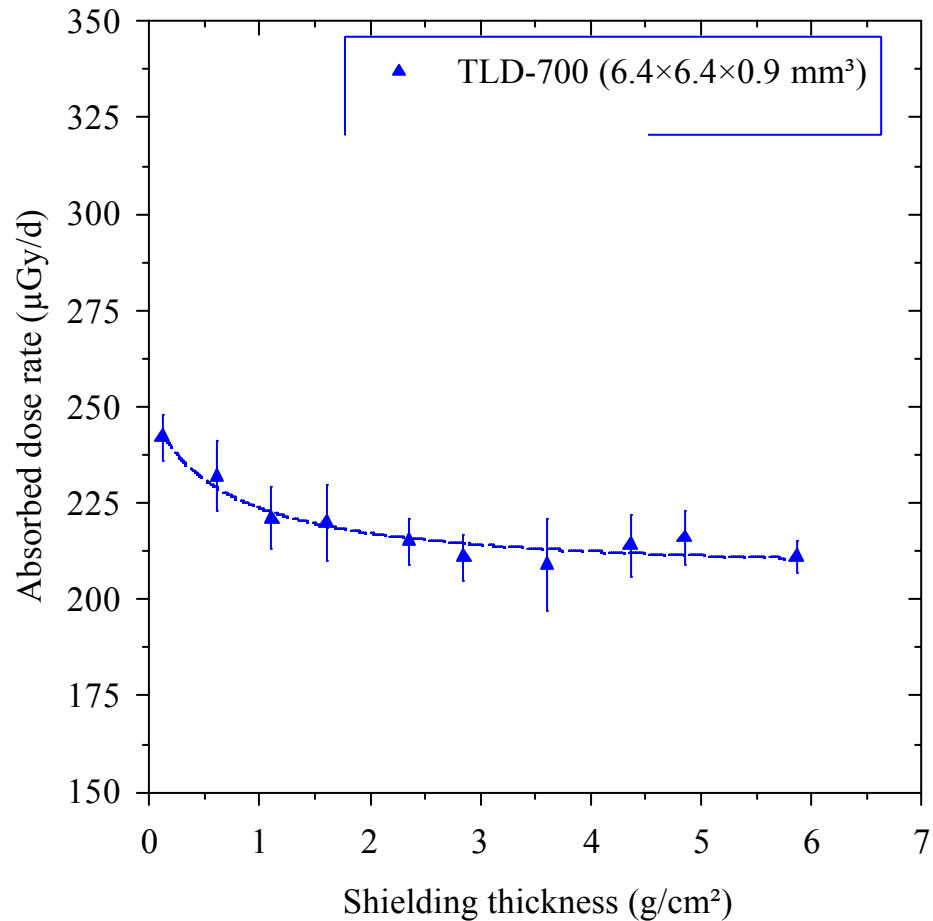


# TLD-700 Results

<i>Layer ?</i>	<i>Shielding (g/cm<sup>2</sup>)</i>	<i>Absorbed dose rate (μGy/d)</i>	
		<i>uncorrected</i>	<i>corrected</i>
1	0.12	289 ± 6	242 ± 6
2	0.61	278 ± 10	232 ± 9
3	1.11	265 ± 8	221 ± 8
4	1.60	262 ± 12	220 ± 10
5	2.36	258 ± 4	215 ± 6
6	2.85	254 ± 5	211 ± 6
7	3.60	251 ± 14	209 ± 12
8	4.36	259 ± 10	214 ± 8
9	4.85	259 ± 5	216 ± 7
10	5.87	250 ± 5	211 ± 4
<i>BRADOS-1 (2001), panel ? 443:</i>		<i>291 ± 5</i>	<i>249 ± 4</i>
<i>BRADOS-2 (2002), panel ? 443:</i>		<i>211 ± 9</i>	<i>180 ± 7</i>

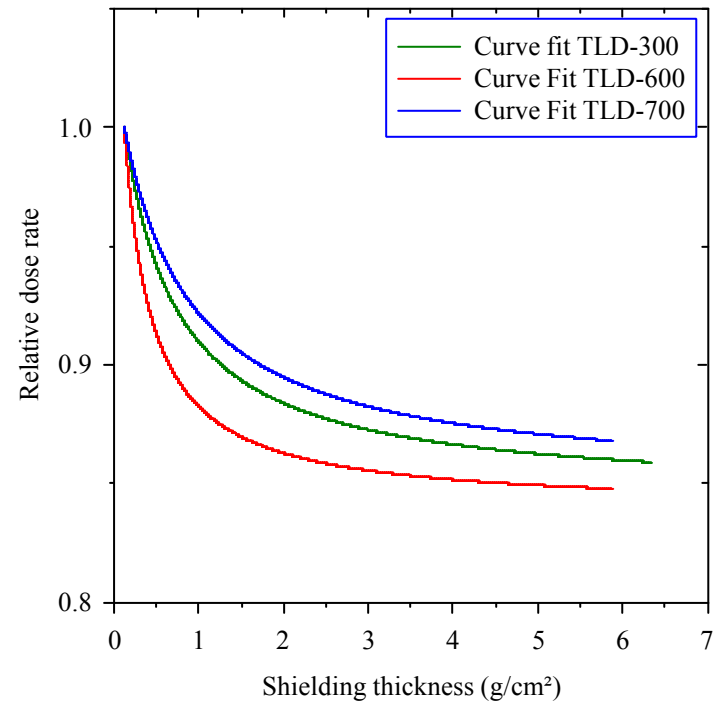
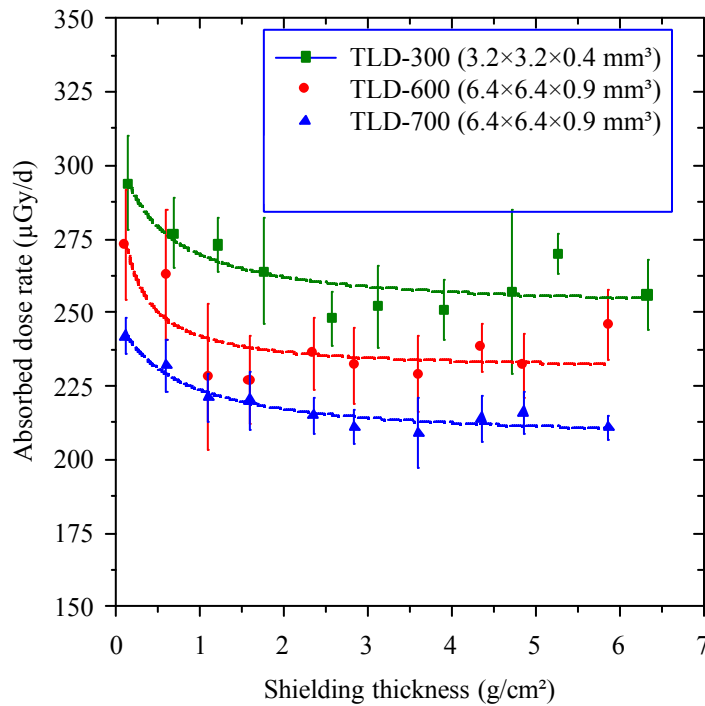


# TLD-700 Results contd.





# Summarized TL Results





# Open Work

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- Read-out and evaluation of PNTD
- Evaluation of TLD-700H
- Correction of TL-300 doses for TL efficiency
- Combination of TLD and PNTD
  - separation of low-LET and high-LET component



# Acknowledgements

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