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Deconvolution study of the glow curves of LiF:Mg,Ti and LiF:Mg,Cu,P

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RADIATION PROTECTION DOSIMETRY AND CALIBRATION EXPERT GROUP

Motivation

- **Luminescent detectors** have been used in **space experiments** since decades

- SCK•CEN
  - TLDs and OSLDs
  - Space life experiments
  - DOSIS and DOSIS-3D

The aim of this study is to investigate the possibility of **improving our measurements** by a **carefully analysis** of the glow curve structure and using **deconvolution** software

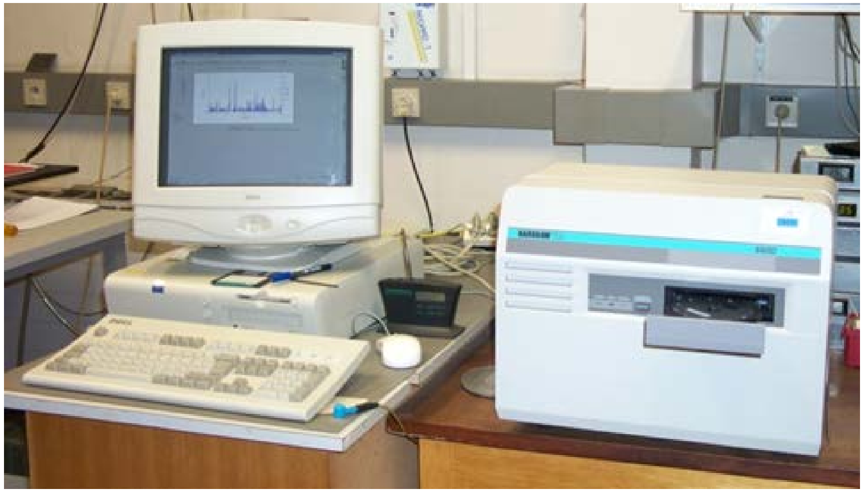
SCK•CEN TLD space protocols

- Detectors
  - LiF:Mg,Ti – MTS-N, MTS-6, MTS-7
  - LiF:Mg,Cu,P – MCP-N, MCP-6, MCP-7

- Annealing
  - LiF:Mg,Ti – 400°C for 1 h + 100°C for 2 h
  - LiF:Mg,Cu,P – 240°C for 12′

- No pre-reading heat

- Harshaw 5500
  - LiF:Mg,Ti – up to 340°C at 1°C/s
  - LiF:Mg,Cu,P – up to 255°C at 1°C/s



SCK•CEN TLD space protocols

- Individual factors
  - ^{60}Co photons
  - Secondary standard laboratory LNK of SCK•CEN
- Calibration
  - Separate group, same batch
  - ^{60}Co photons
  - Similar dose
  - Simultaneous with the experiment
- Background
  - 2 separate groups, same batch
    - 1 for BG of the experiment
    - 1 for BG of the calibration

Experimental methodology

- TLDs exposed to different radiation qualities
  - MTS-6, MTS-7, MCP-6, MCP-7
  - Heavy Ion Medial Accelerator in Chiba (HIMAC)
  - The Svedberg Laboratory (TSL) Uppsala

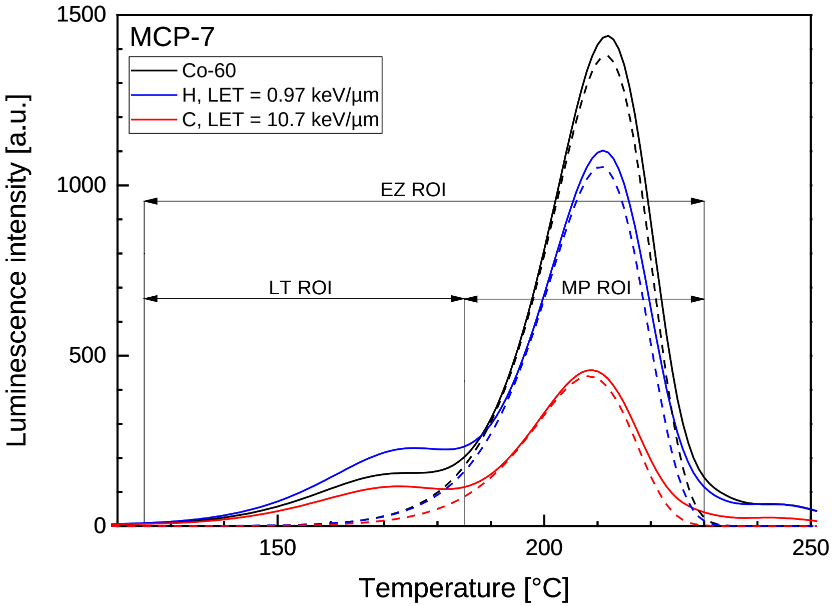
- Space protocols

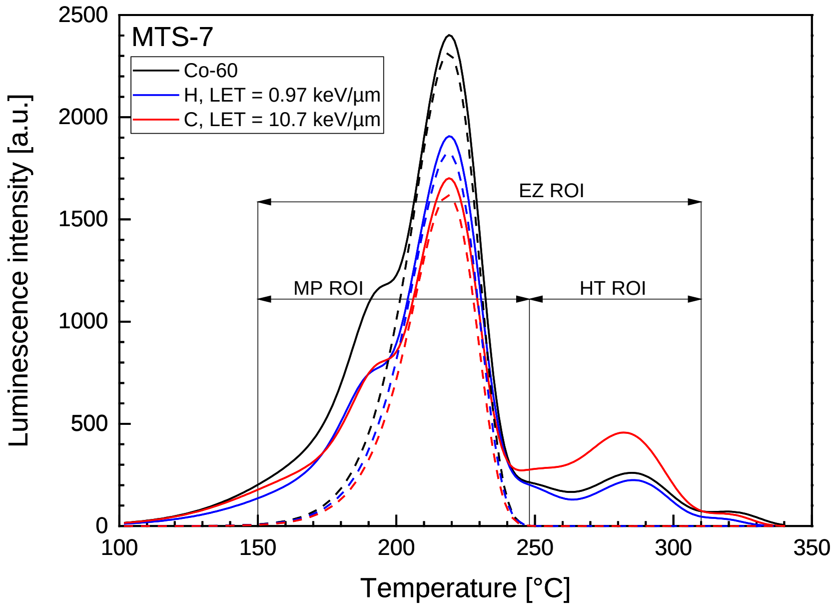
- Relative luminescent efficiency

$$\eta_{rel} = \frac{S/_D}{S_\gamma/_{D_\gamma}}$$

Ion	Primary energy [MeV/u]	LET [keV/µm]	Range in H_2O [mm]
H^+	70	1.0	40.2
H^+	40	1.5	14.6
$^4He^{2+}$	150	2.2	156.0
$^{12}C^{6+}$	400	10.7	278.7
$^{12}C^{6+}$	30	65.0	3.2
$^{12}C^{6+}$	15	125.0	0.8
$^{12}C^{6+}$	10	175.0	0.4

Glow curve structure & signal quantification



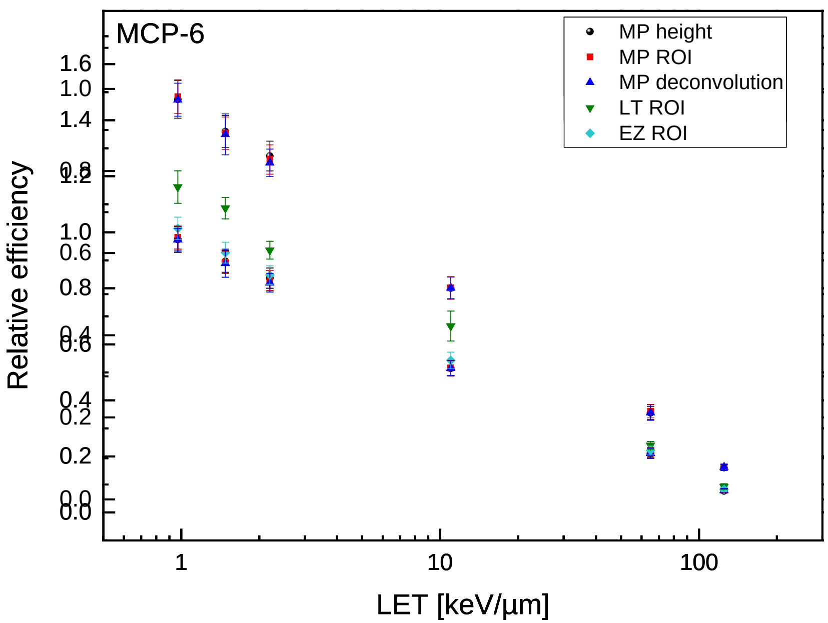


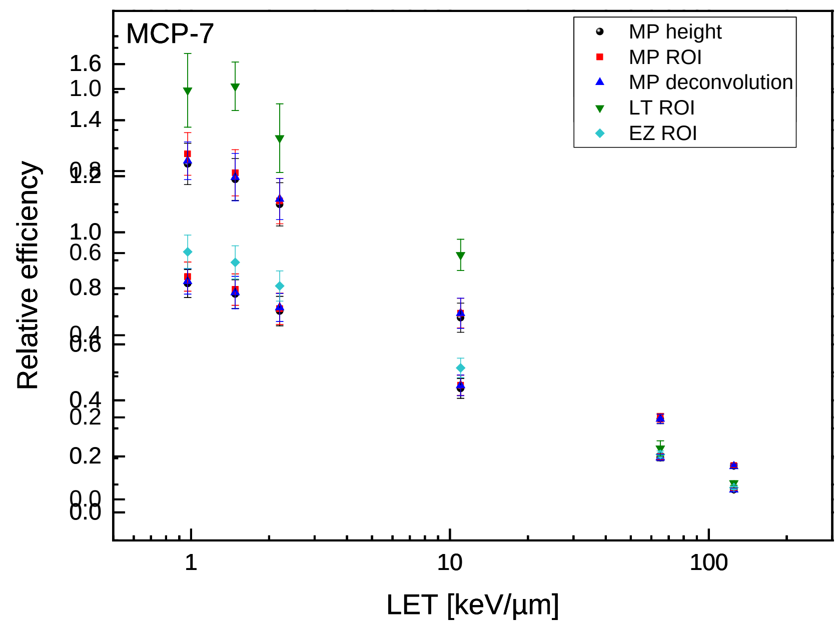
- Main peak (MP)
  - Height
  - ROI → 185-230°C
  - Deconvolution
- Low temperature (LT)
  - ROI → 125-185°C
- Extended zone (EZ)
  - ROI → 125-230°C

- Main peak (MP)
  - Height
  - ROI → 150-248°C
  - Deconvolution
- High temperature (HT)
  - ROI → 248-310°C
- Extended zone (EZ)
  - ROI → 150-310°C

LiF:Mg,Cu,P

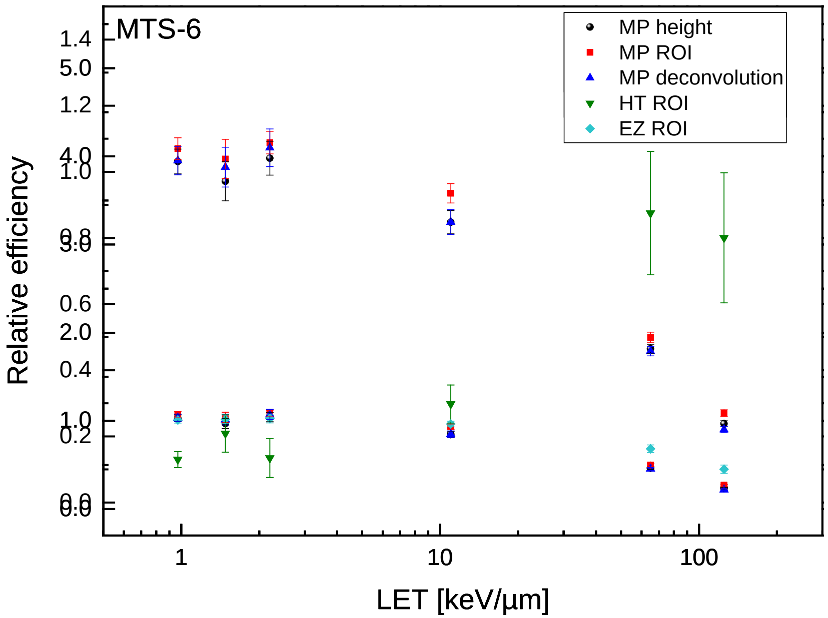
- No relevant differences were found between the methods involving the MP only
  - Typical deviation between average values ~ 2%
- LT peaks seem to be relatively enhanced by low LET HCPs
  - Efficiencies around 20% (MCP-6) and 70% (MCP-7) higher than their MP ones

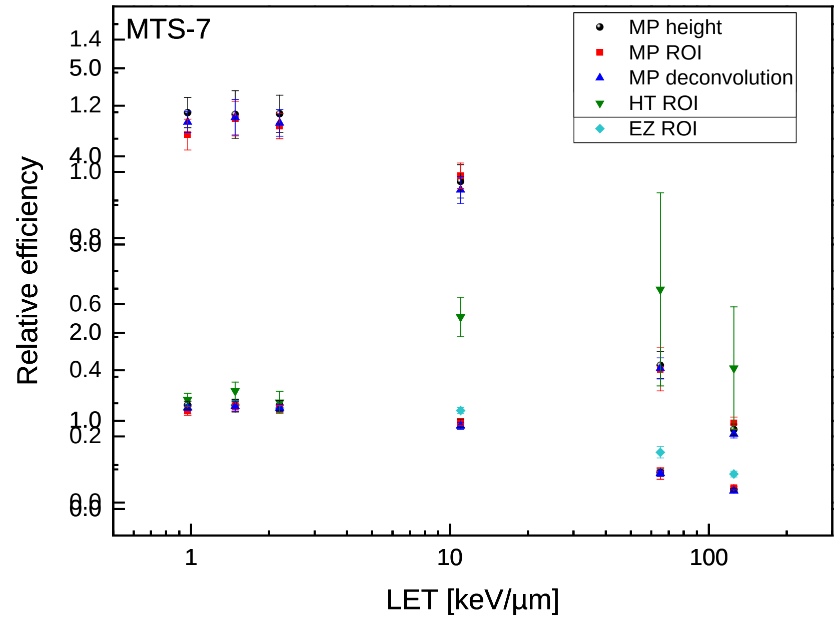




LiF:Mg,Ti

- No relevant differences were found between the methods involving the MP only
  - Typical deviation between average values ~ 5%
- HT signal is enhanced by high LET HCPs
  - Differences were found between the different isotopic composition

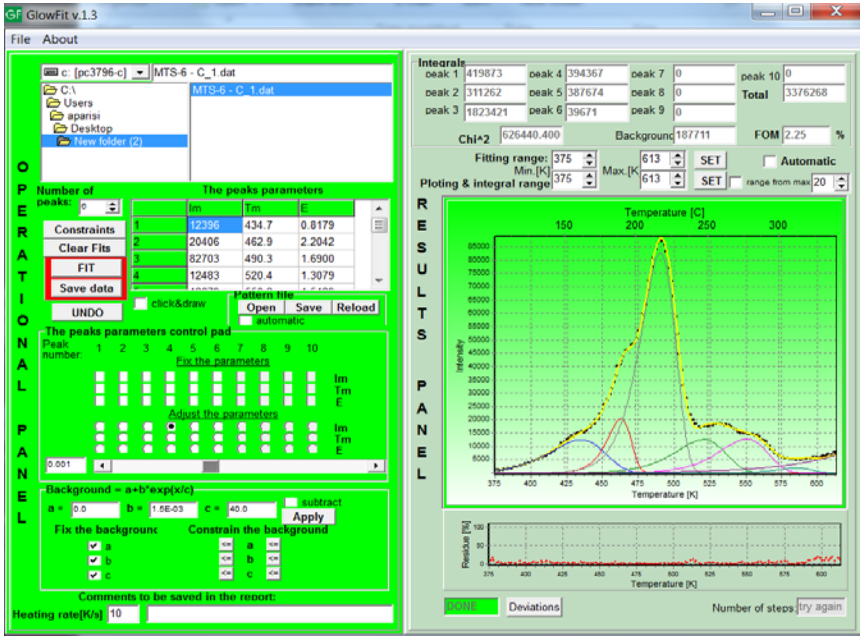




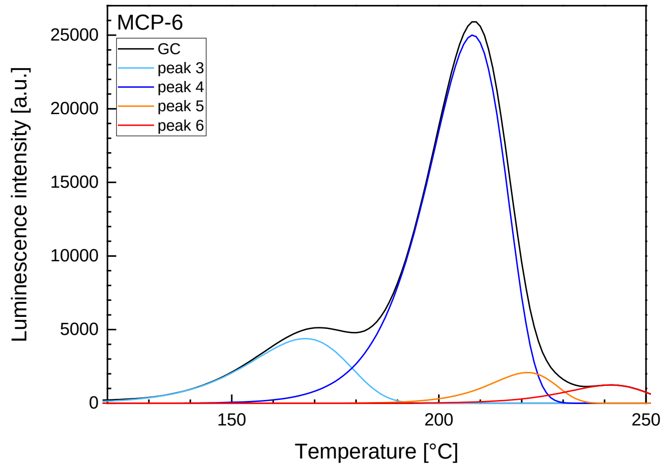
Deconvolution

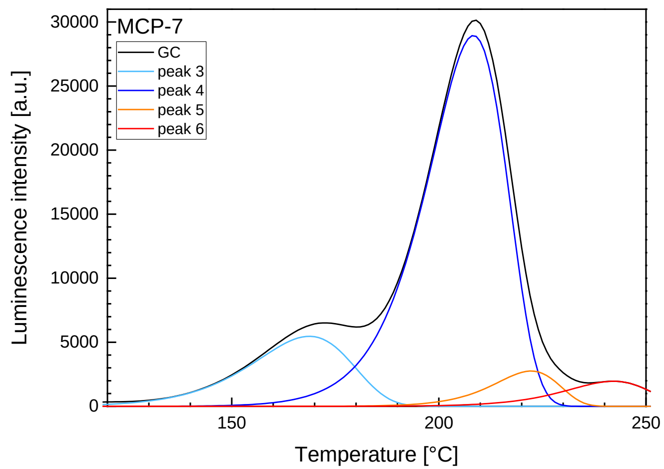
- GlowFit[1] v.1.3
  - IFJ, Krakow
- Fixed deconvolution parameters
  - LiF:Mg,Ti – 5 (+1) peaks
  - LiF:Mg,Cu,P – 4 peaks
  - Peaks 1 & 2 already faded
  - Classical numbering preserved
- FOM ~ 2%

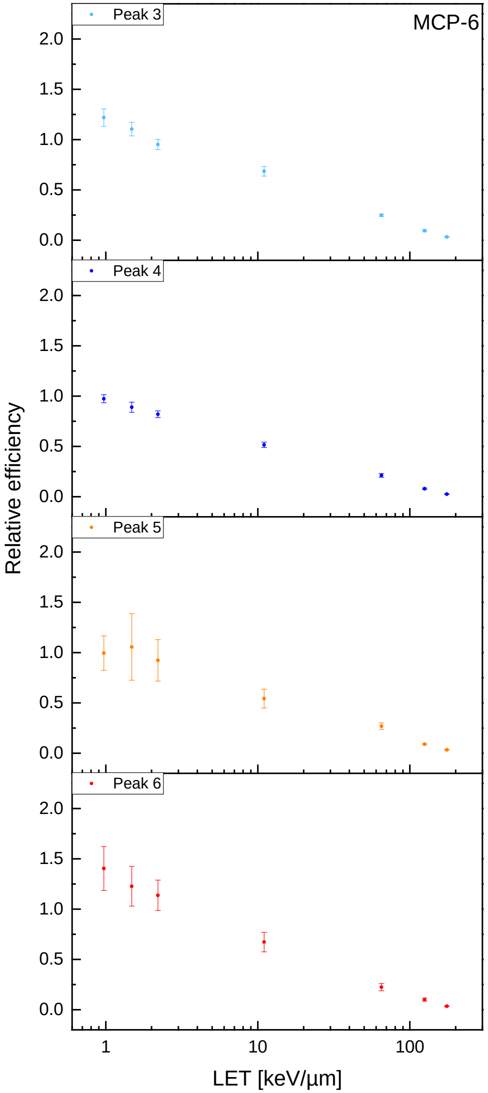
$$\mathrm{FOM} = \sum_{i_{start}}^{i_{stop}} \frac{|y_i - y_{i,fit}|}{A}$$

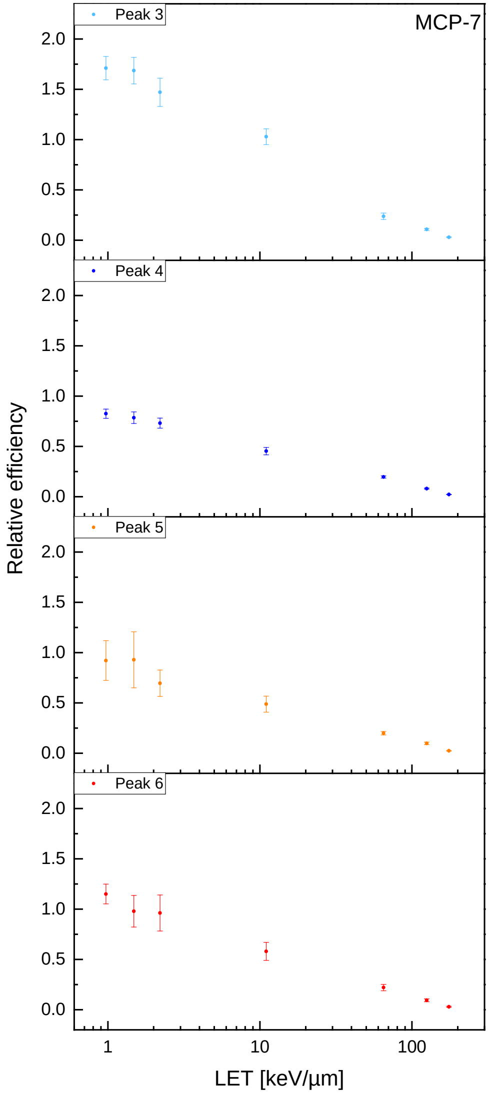


LiF:Mg,Cu,P peaks vs LET





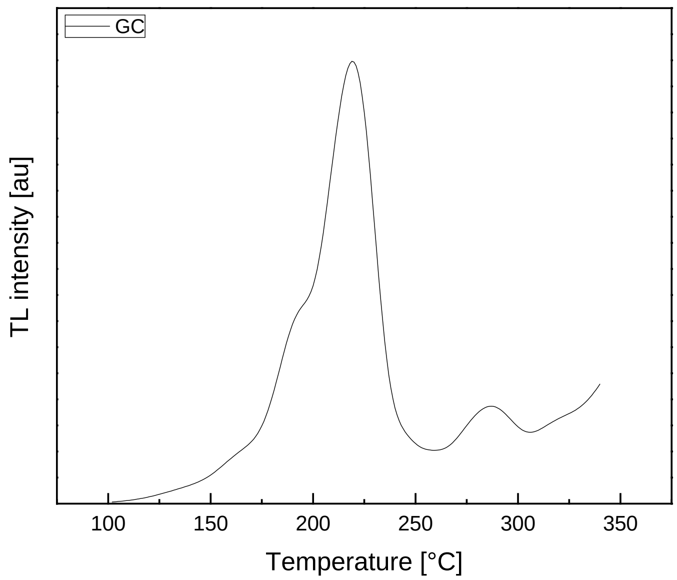




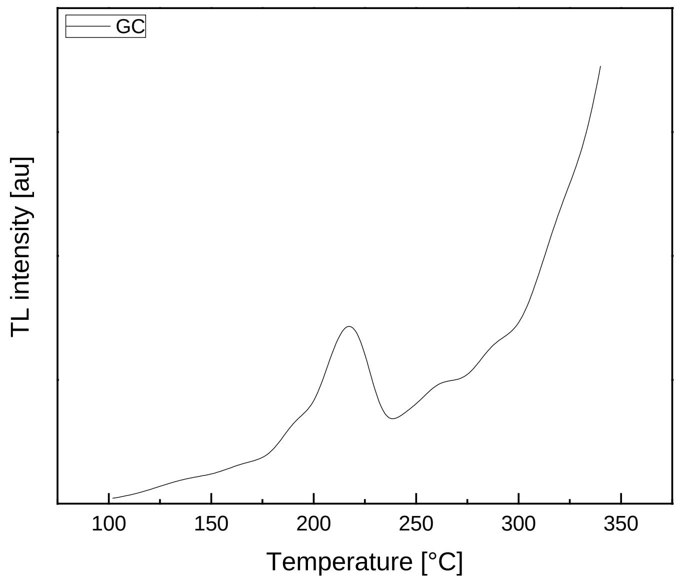
LiF:Mg,Ti inherent signal subtraction

- LiF:Mg,Ti – higher temperature and lower sensitivity than LiF:Mg,Cu,P
  - Electronic noise, planchet infra-red radiation, tribo- and chemiluminescence, black body radiation…
- Uniformity in the subtraction of this signal is crucial[1]

H, 0.5 keV/μm



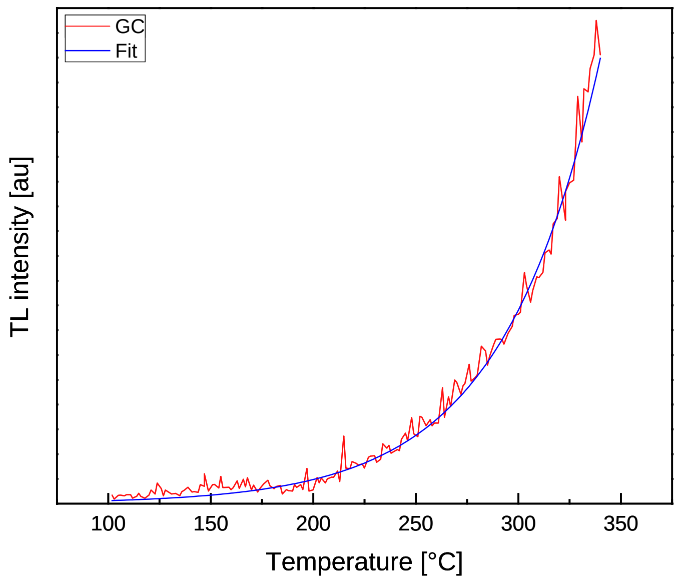
C, 175 keV/μm



[1]Bos et al., 1994

LiF:Mg,Ti inherent signal subtraction

- Each detector was **read a second time**
- It was possible to **fit all GCs** with the same 1-free-parameter function



$$I = x\, exp\left(\frac{T}{40}\right)$$

- We used then this function to **subtract the inherent signal** of each glow curve

LiF:Mg,Ti inherent signal subtraction

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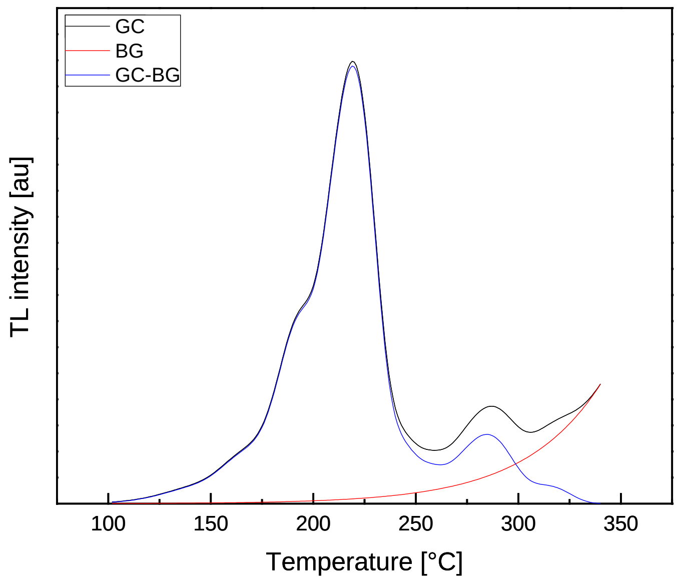
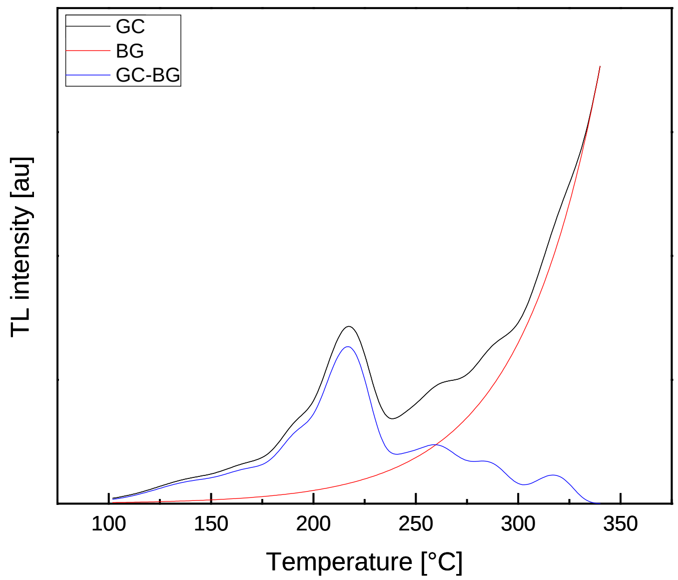


$x = 11 \cdot 10^{-3}$

C, 175 keV/µm

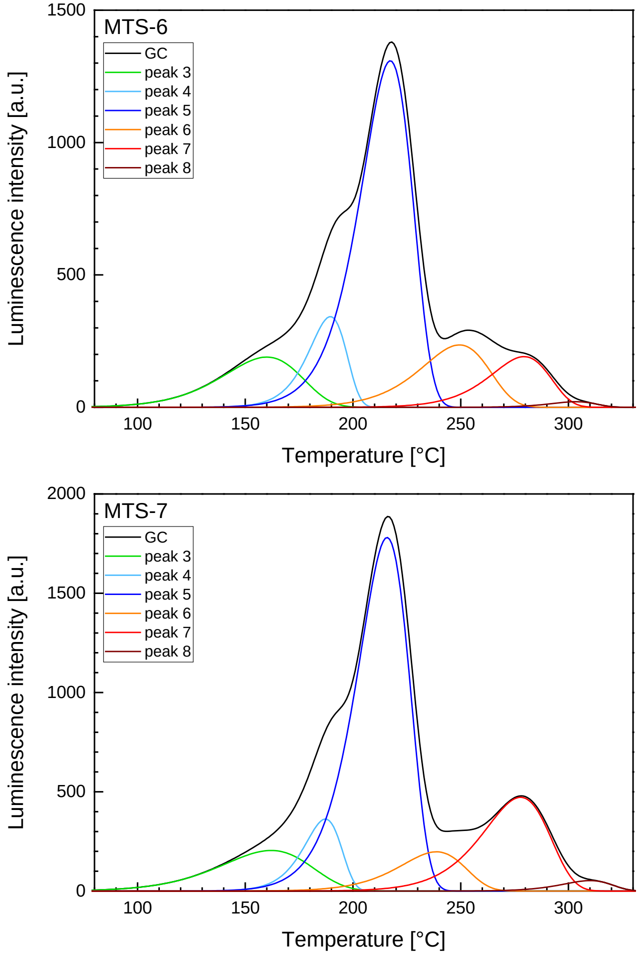


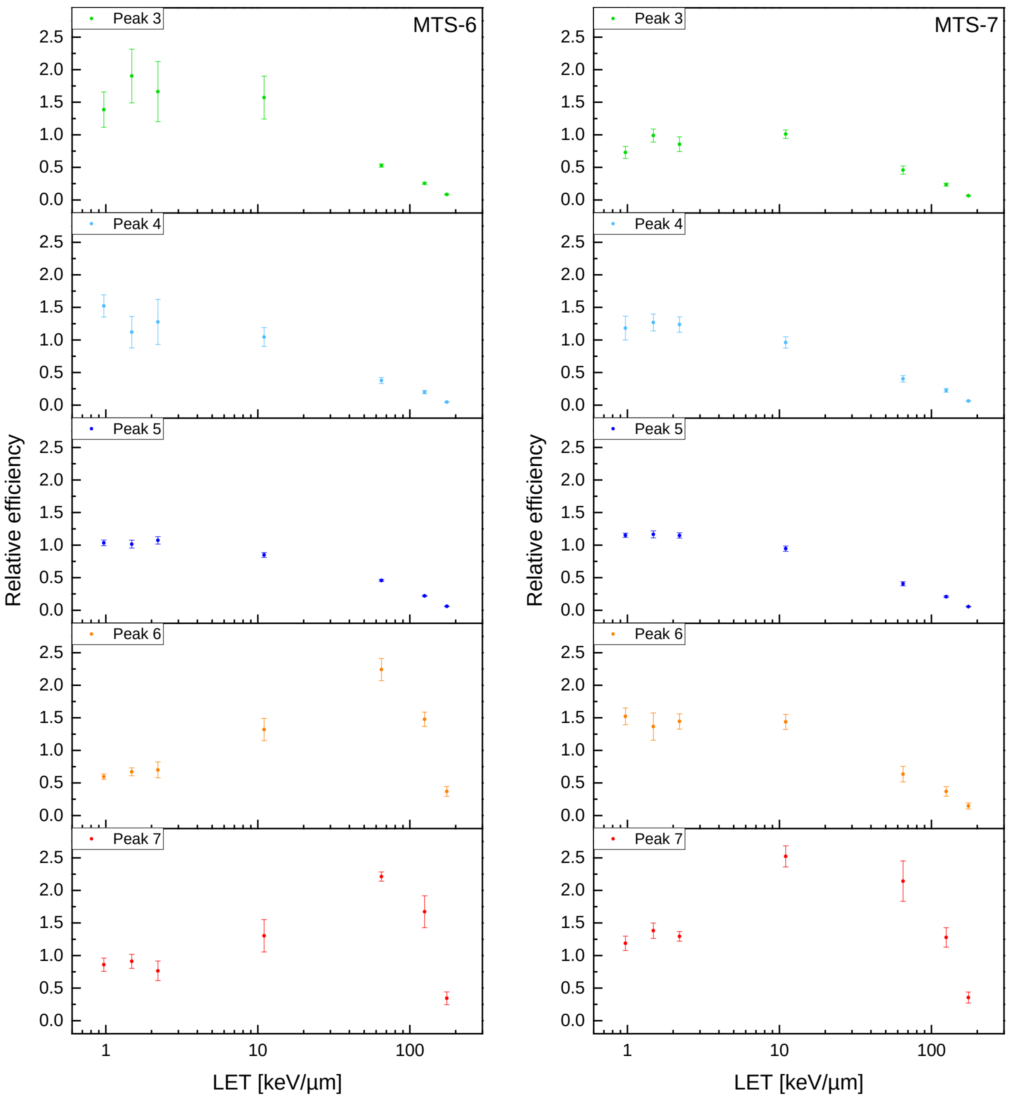
$x = 7.8 \cdot 10^{-3}$

$$I = x\, exp\left(\frac{T}{40}\right)$$

[1]Bos et al., 1994

LiF:Mg,Ti peaks vs LET





HTR method

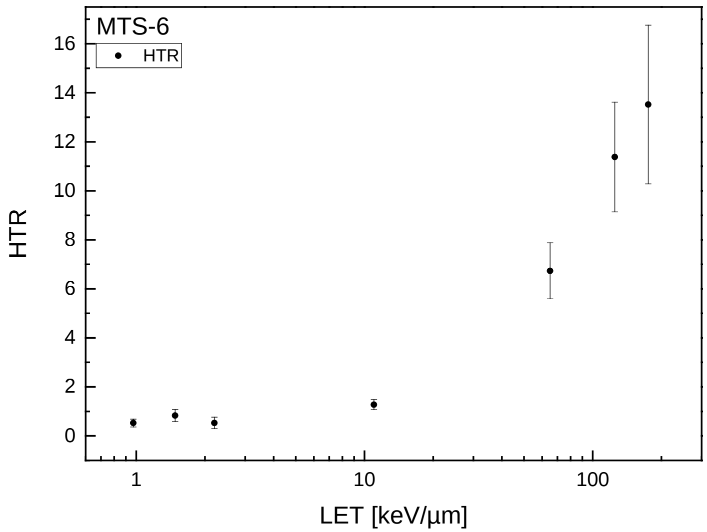
- High temperature ratio (HTR) method[1]
  - ATI, Vienna
  - Uses the different LET dependence of the MP and HT signals for average LET determination

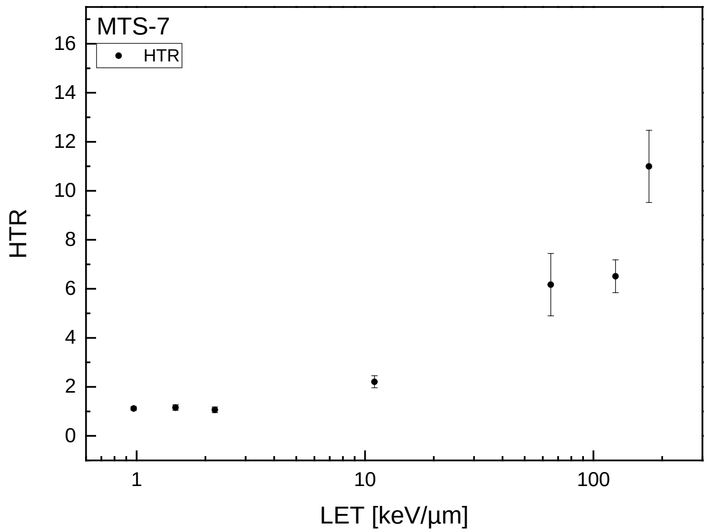
- Investigate the possibility to improve HTR method using deconvolution[2]

$$HTR = \frac{S_{HT\ zone}/S_{MP\ zone}}{\left(S_{HT\ zone}/S_{MP\ zone}\right)_{\gamma}}$$

$S_{HT\ zone} \rightarrow deconvoluted\ HT\ peak$

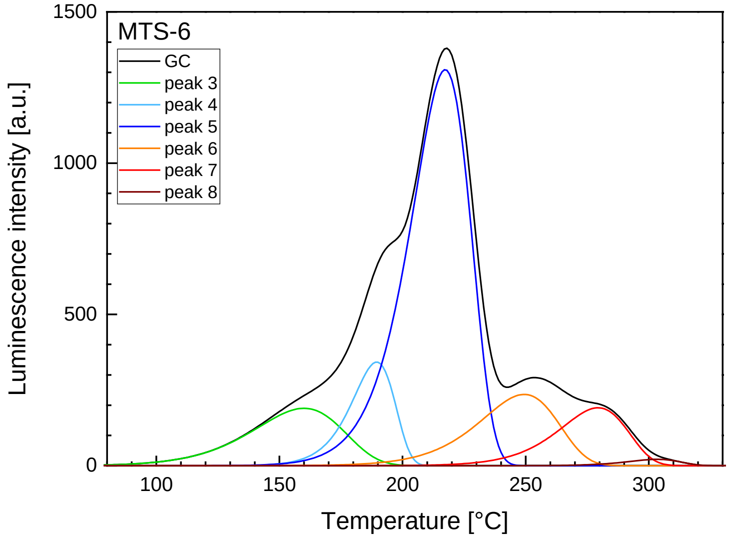
$S_{MP\ zone} \rightarrow deconvoluted\ main\ peak$



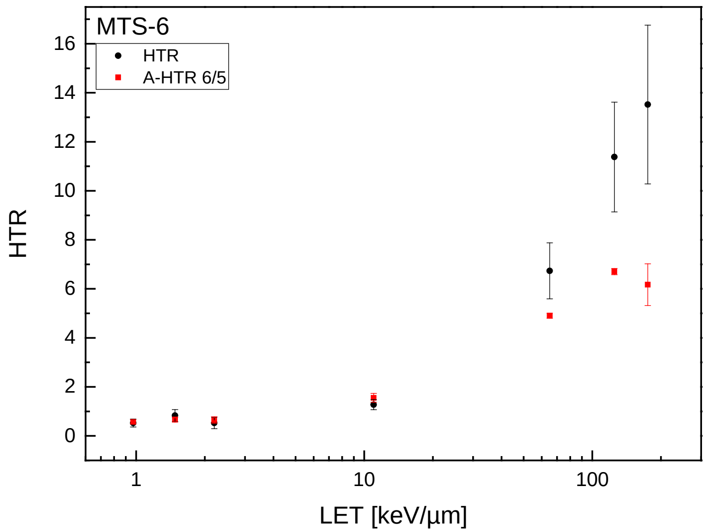


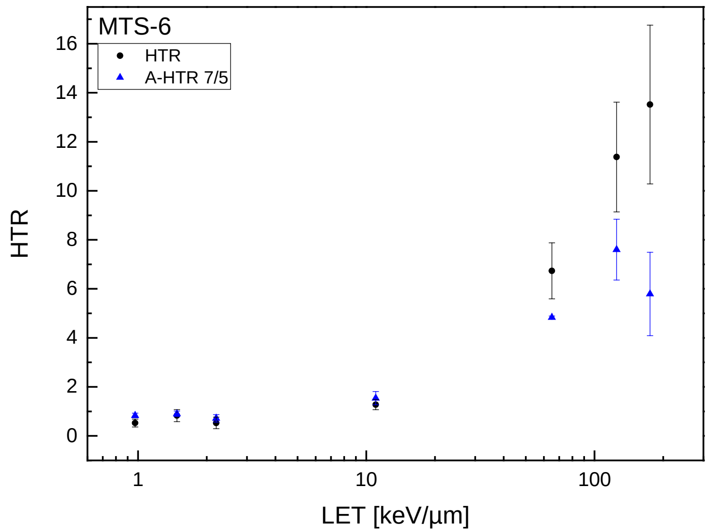
[1]Vana et al., 1996 [2]Puchalska and Bilski, 2008

A-HTR: MTS-6



- 2 parameters instead of 1
- 2-3 times lower dispersion

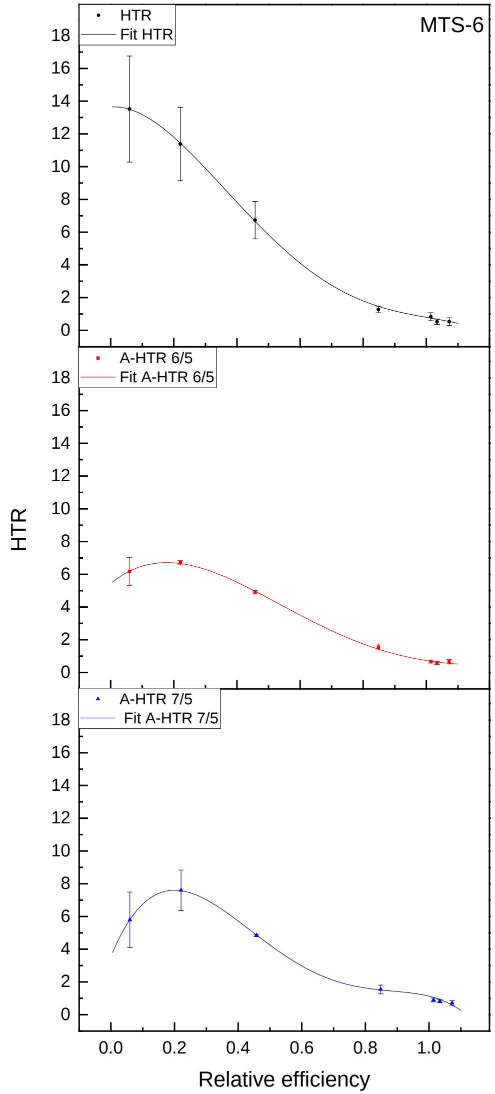




A-HTR: MTS-6 - application to DOSIS 3D

- Values fitted with a 4th order function
- HTR values were calculated for 3 DOSIS 3D boxes
  - Box 2 – highest dose
  - Box 7 – average dose
  - Box 9 – lowest dose
- Efficiency was calculated for each detectors
  - Differences found between the different methods
  - Limitations of HTR in mixed fields or in the available data?

Box	Calculated relative efficiency [%]		
	HTR	A-HTR 6/5	A-HTR 7/5
2	99.3 ± 1.2	93.7 ± 3.2	94.0 ± 1.0
7	98.3 ± 1.7	93.0 ± 2.0	95.7 ± 1.5
9	99.7 ± 0.6	95.3 ± 2.1	91.7 ± 1.2



Conclusions

- Optimized ROIs were implemented in SCK•CEN protocols
  - MCP LT and MTS HT zones were excluded from GC signal quantification
- A more in depth investigation has been started on MTS HT peaks
  - Batch dependence, linearity…
- The possibility of combining different detectors (TLDs and OSLDs) to assess correctly space radiation doses and LET is under investigation

Thank you for your attention

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References

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