# INVESTIGATIONS OF THE RELATIVE EFFICIENCY OF THERMOLUMINESCENT DETECTORS TO PROTONS AT THE IFJ PAN KRAKÓW

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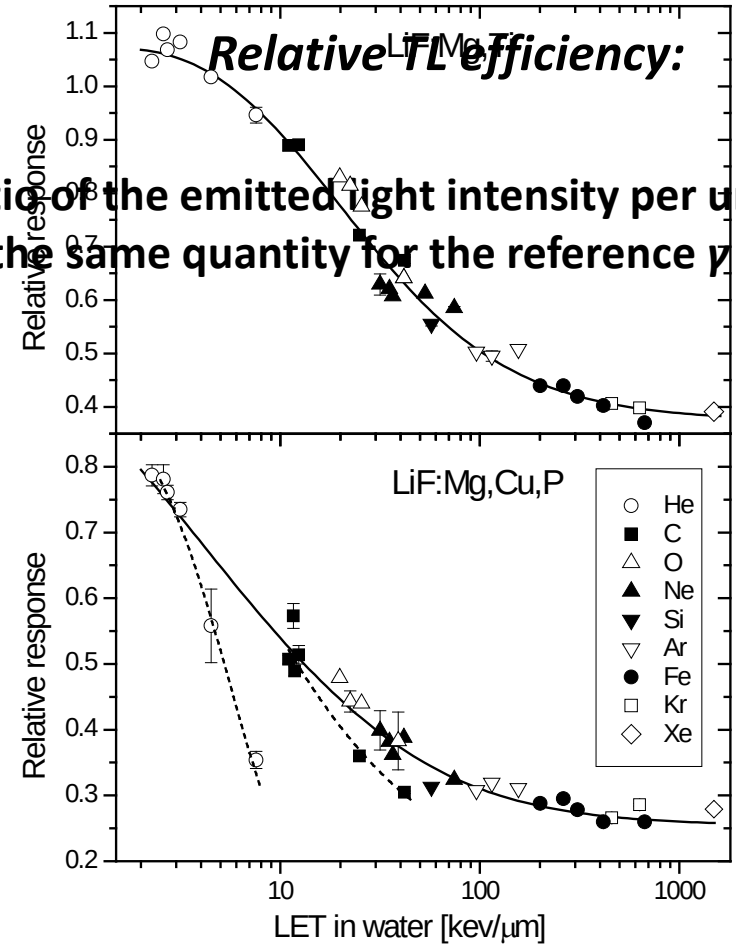


***Relative TL efficiency:***

$$\eta = \frac{\left(\frac{TL}{Dose}\right)_{protons}}{\left(\frac{TL}{Dose}\right)_{\gamma}}$$

**Ratio of the emitted light intensity per unit dose for a given radiation type *(protons)* to the same quantity for the reference *γ* - radiation ($^{137}Cs$ or $^{60}Co$)**

**Efficiency investigations at HIMAC**
(ICCHIBAN and other projects):

ions from He to Xe

…but not that much reliable data on protons

# LiF:Mg,Ti EFFICIENCY

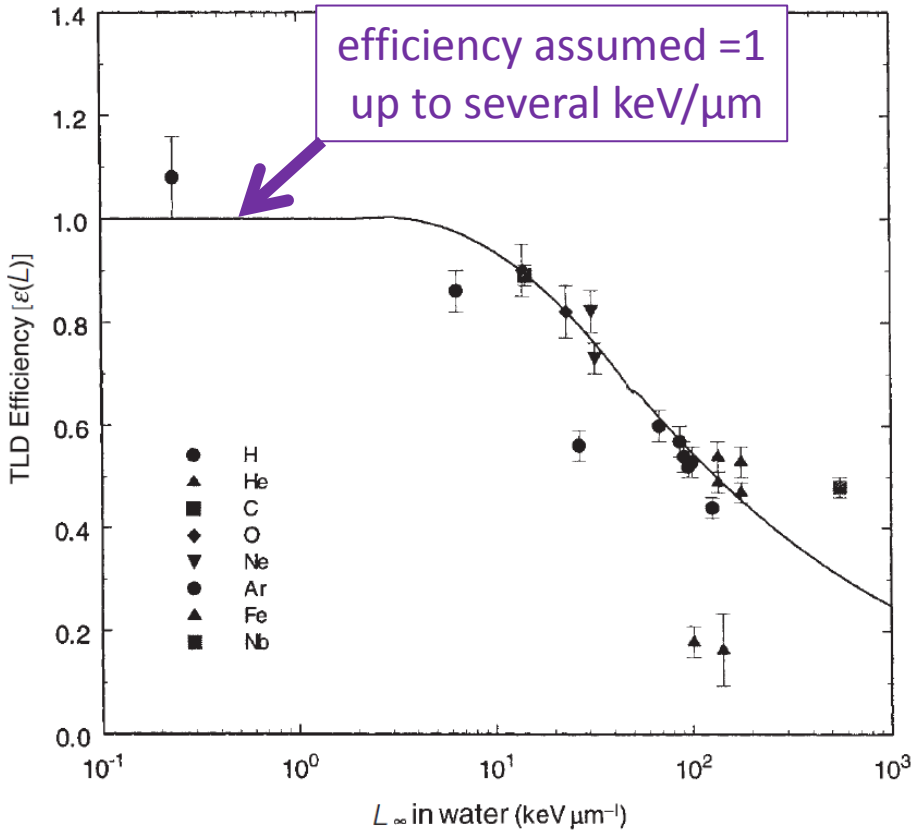


**Fig. C.4.** Response of Peak 5 from TLD-600® and TLD-700® to dose-averaged LET (Equation C.1). The response is normalized to $^{60}$Co gamma rays, and is therefore defined as the TL efficiency [$\varepsilon(L)$] with respect to $^{60}$Co (adapted from Benton *et al.*, 2000).

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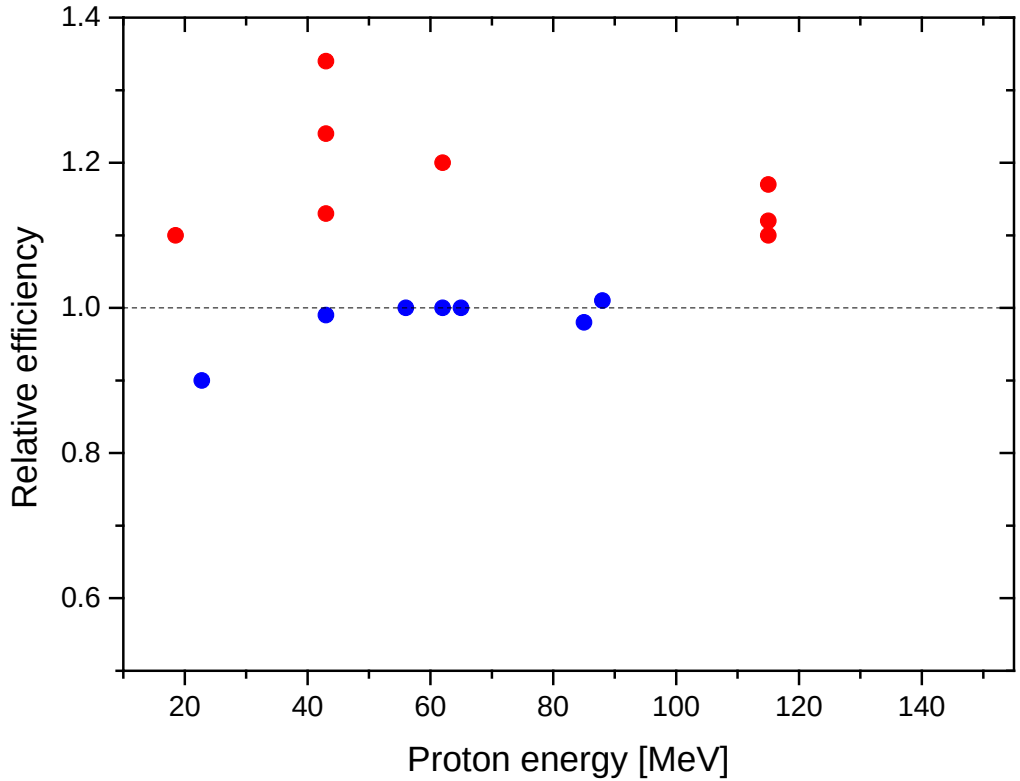
# EFFICIENCY DATA FOR LiF:Mg,Ti

High values

1.34, 1.24, 1.17 (43 MeV) Schmidt et al. 1990
1.17, 1.12, 1.10 (115 MeV) Schmidt et al. 1990
1.20 (62 MeV) Schöner et al. 1999
1.10 (18.5 MeV) Mukherjee et al. 1981

Low values

0.90 (22.8 MeV) Bartoletta et al, 1999
1.00 (62 MeV) Fattibene et al, 1996
1.01 (88 MeV) Vatnitsky et al, 1995
~1.00 (40-85 MeV) Loncol et al., 1996



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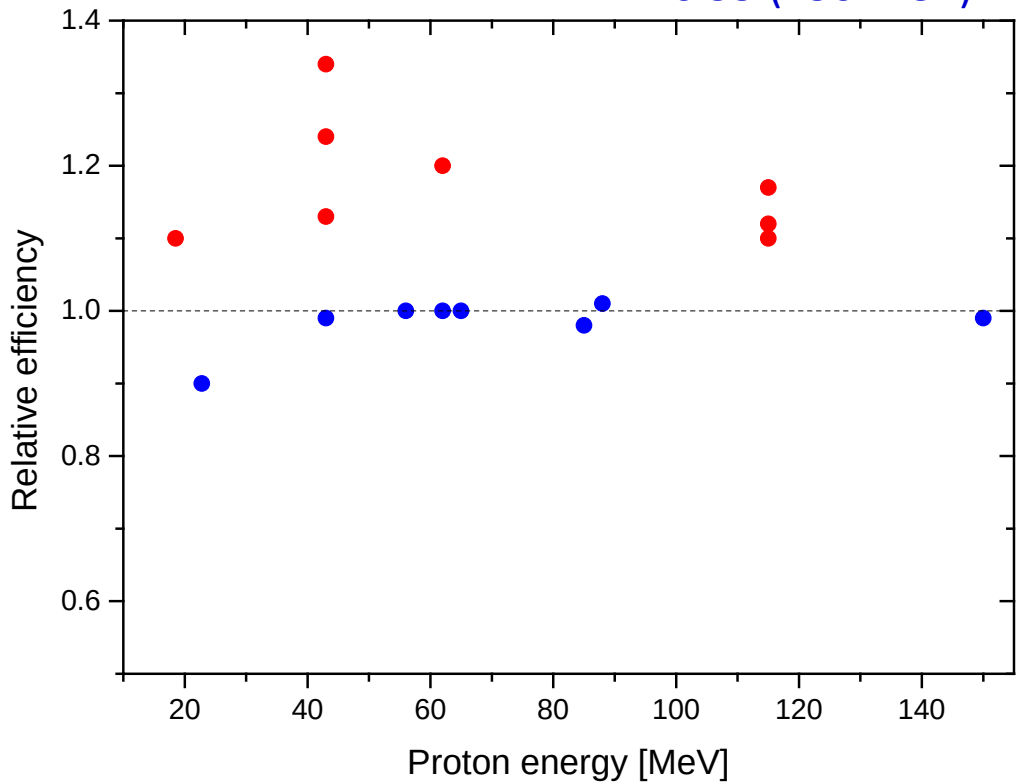
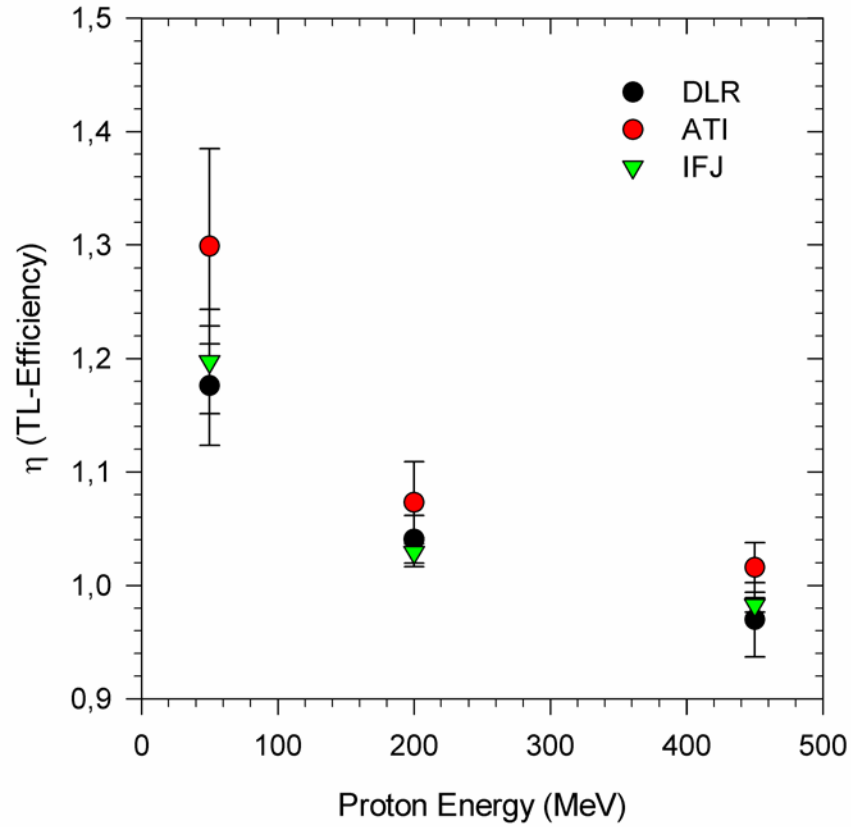
0.99 (150 MeV) Bilski 2006 [Dubna]



T. Berger, 14th WRMISS, Dublin, 2009

Brookhaven National Lab, NSRL




monoenergetic protons

50 MeV : 1.16-1.30

200 MeV: 1.03-1.07

450 MeV: 0.97-1.02

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1.18-1.30 (50 MeV) Berger 2009 [NSRL]

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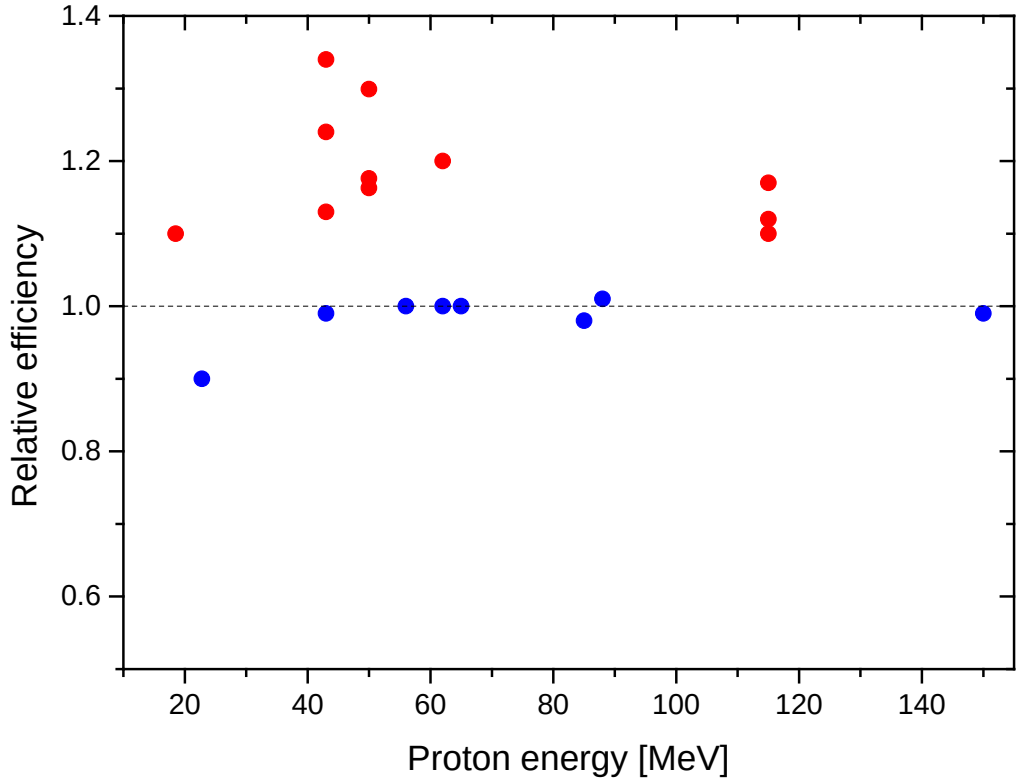
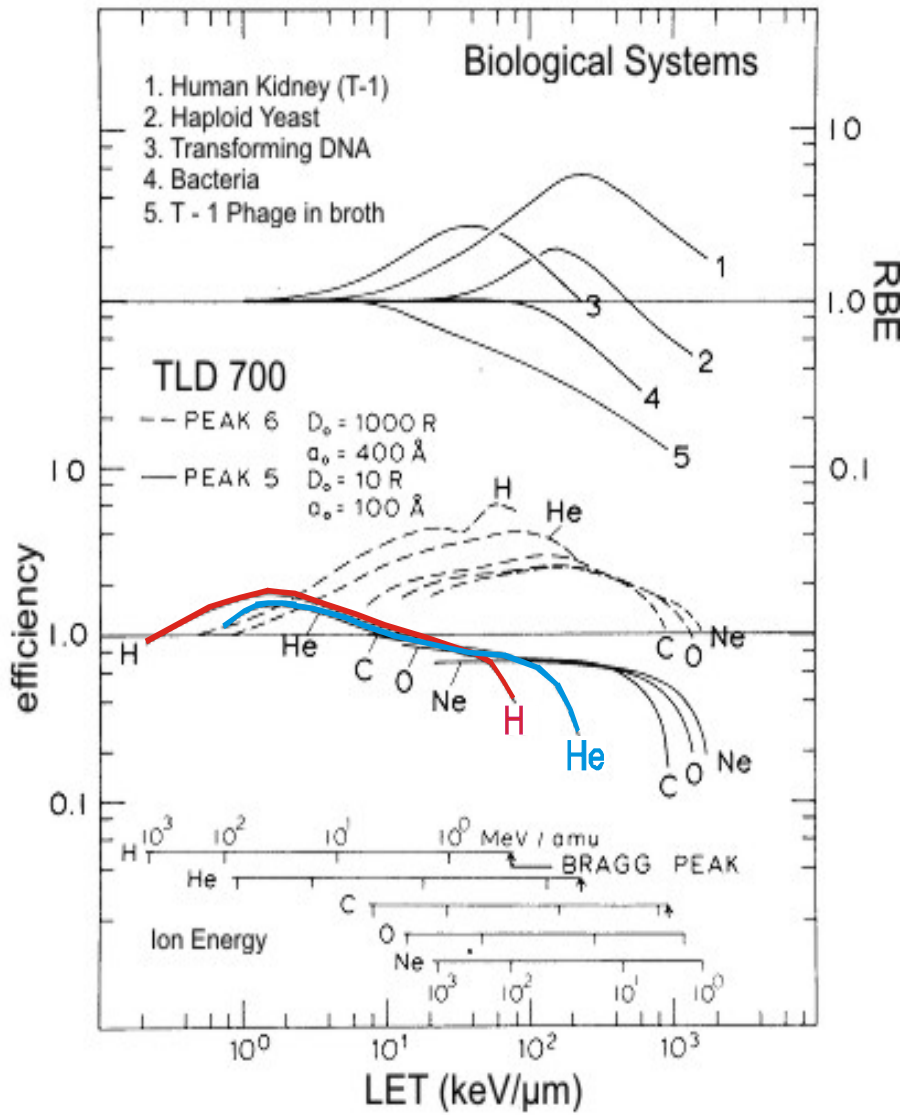


# MODEL EXPLANATION OF THE INCREASED EFFICIENCY

Track structure calculations:

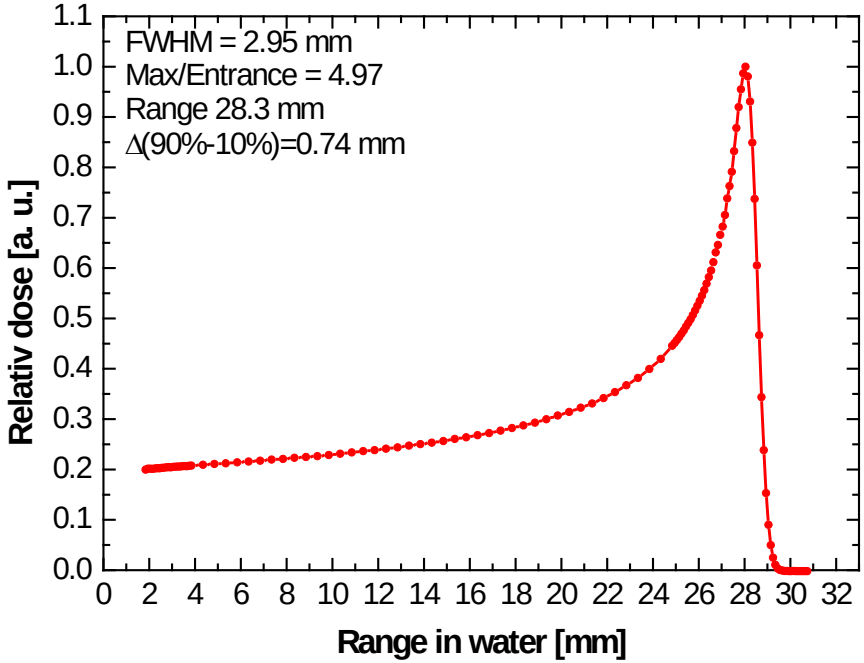
Waligorski and Katz, 1980

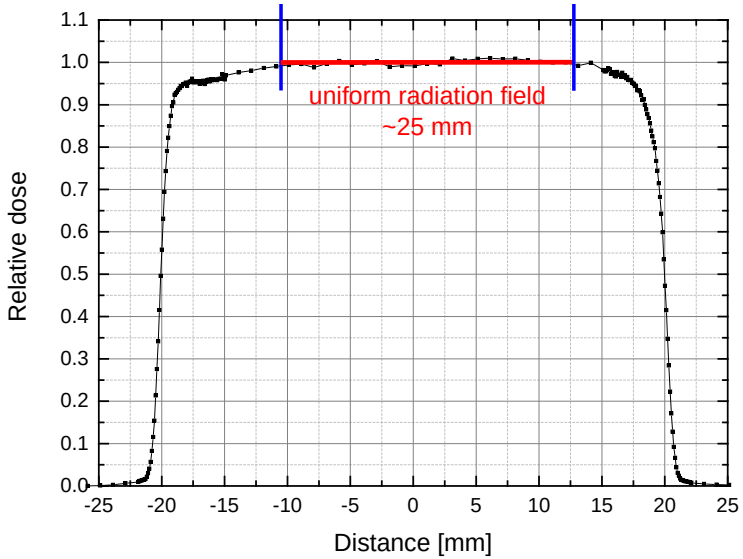


# AIC-144 cyclotron

**applied for radiotherapy of eye tumors since 2011**

- isochronous, developed at IFJ
- 60 MeV protons
- max range in water 28.3 mm



## Project from the National Science Centre, 2011-2014

*Efficiency of luminescent detectors to protons in measurements of the cosmic radiation doses on the Earth orbit and in accelerator beam dosimetry*

## Detectors under study:

- LiF:Mg,Ti (MTS-N, MTS-7)
- LiF:Mg,Cu,P (MCP-N)

manufactured at IFJ Kraków

- standard ø4.5x0.9 mm
- specially developed miniature ø3.2x0.3 mm

also OSL detectors: $Al_2O_3$:C, BeO

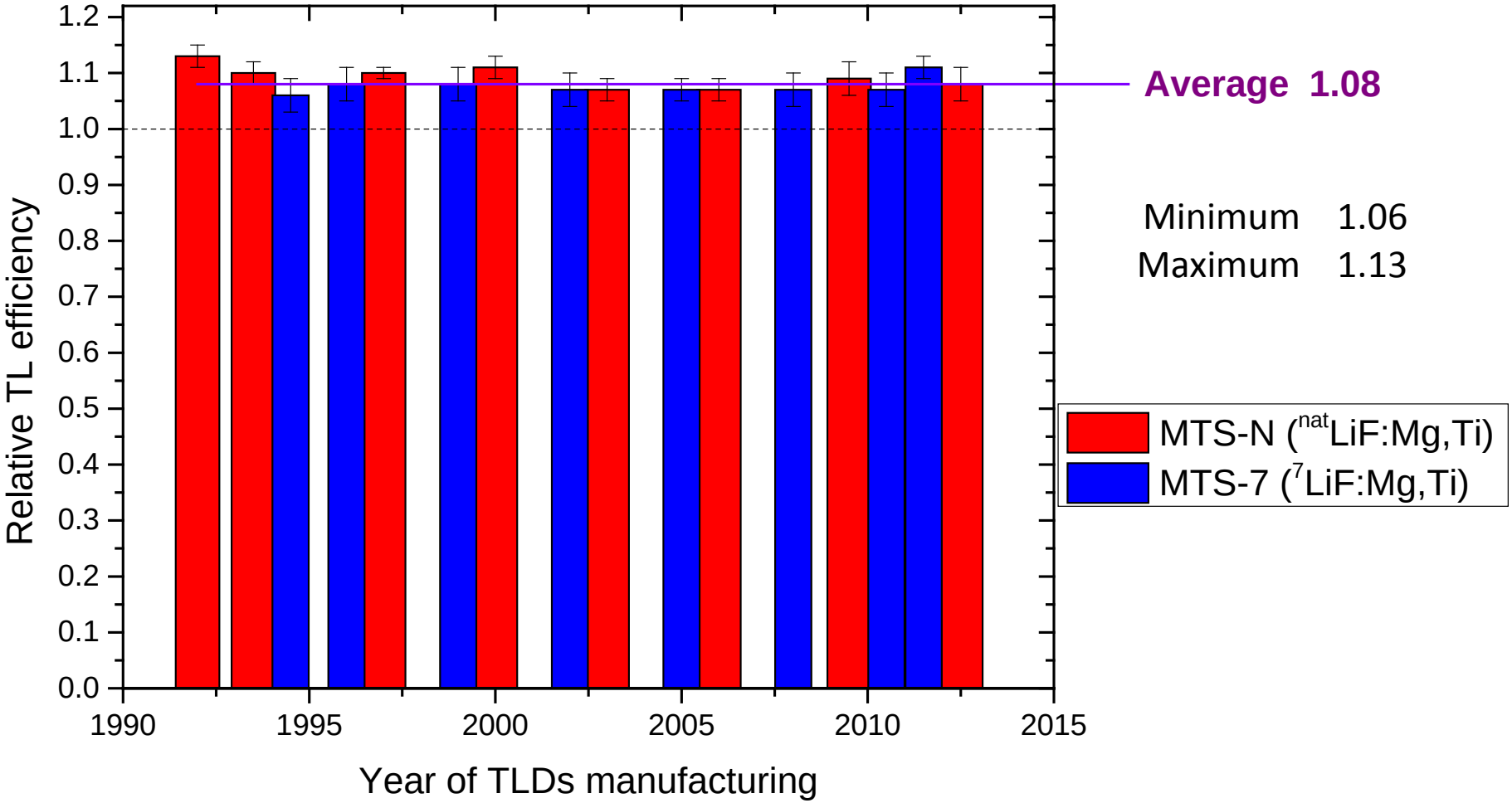
**Scale of experiments:**

50 experimental days with the proton beam
200 hours of proton irradiations
c.a. 10 000 TLD readouts

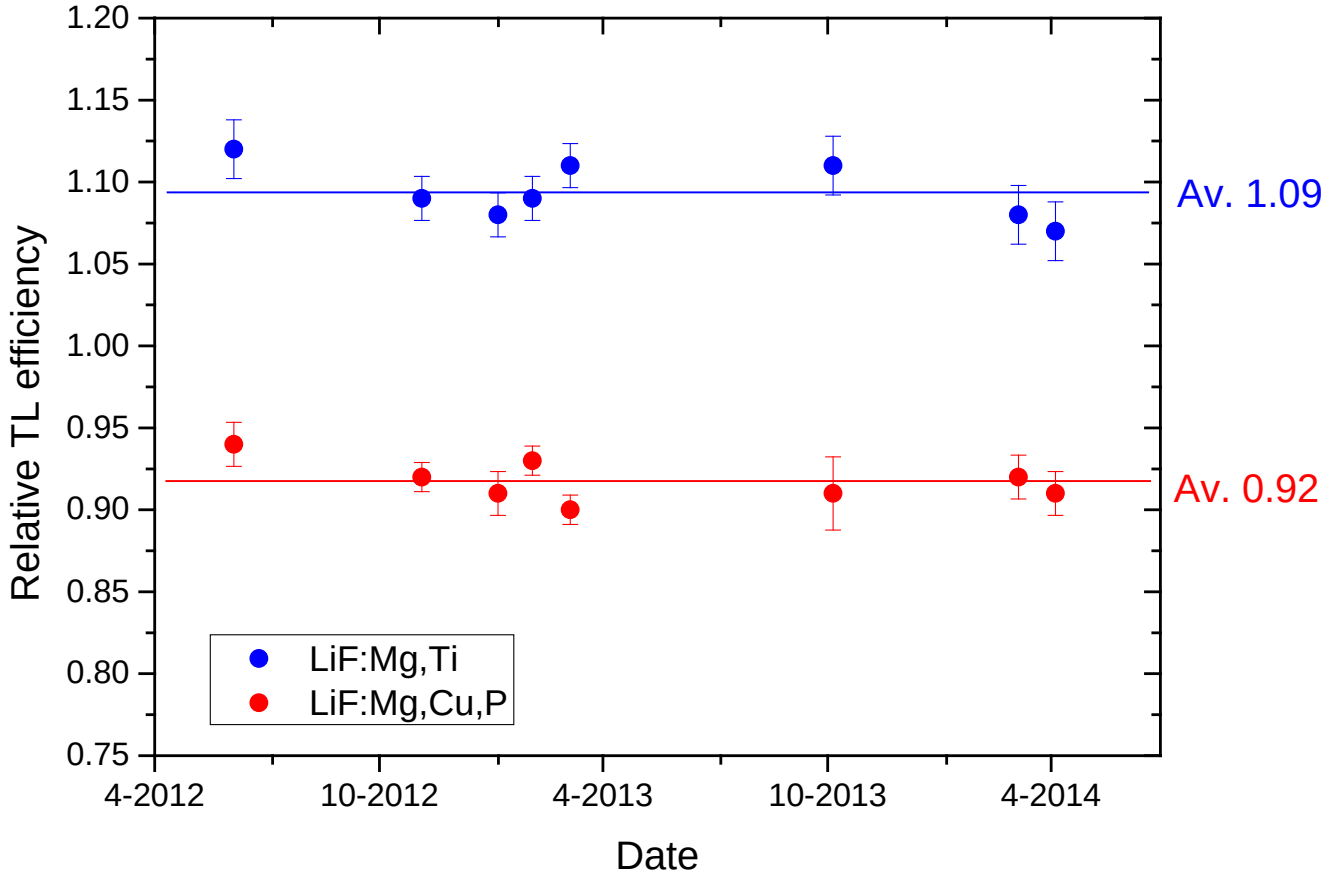
# COMPARISON BETWEEN DIFFERENT BATCHES

16 LiF:Mg,Ti batches produced over past 20 years

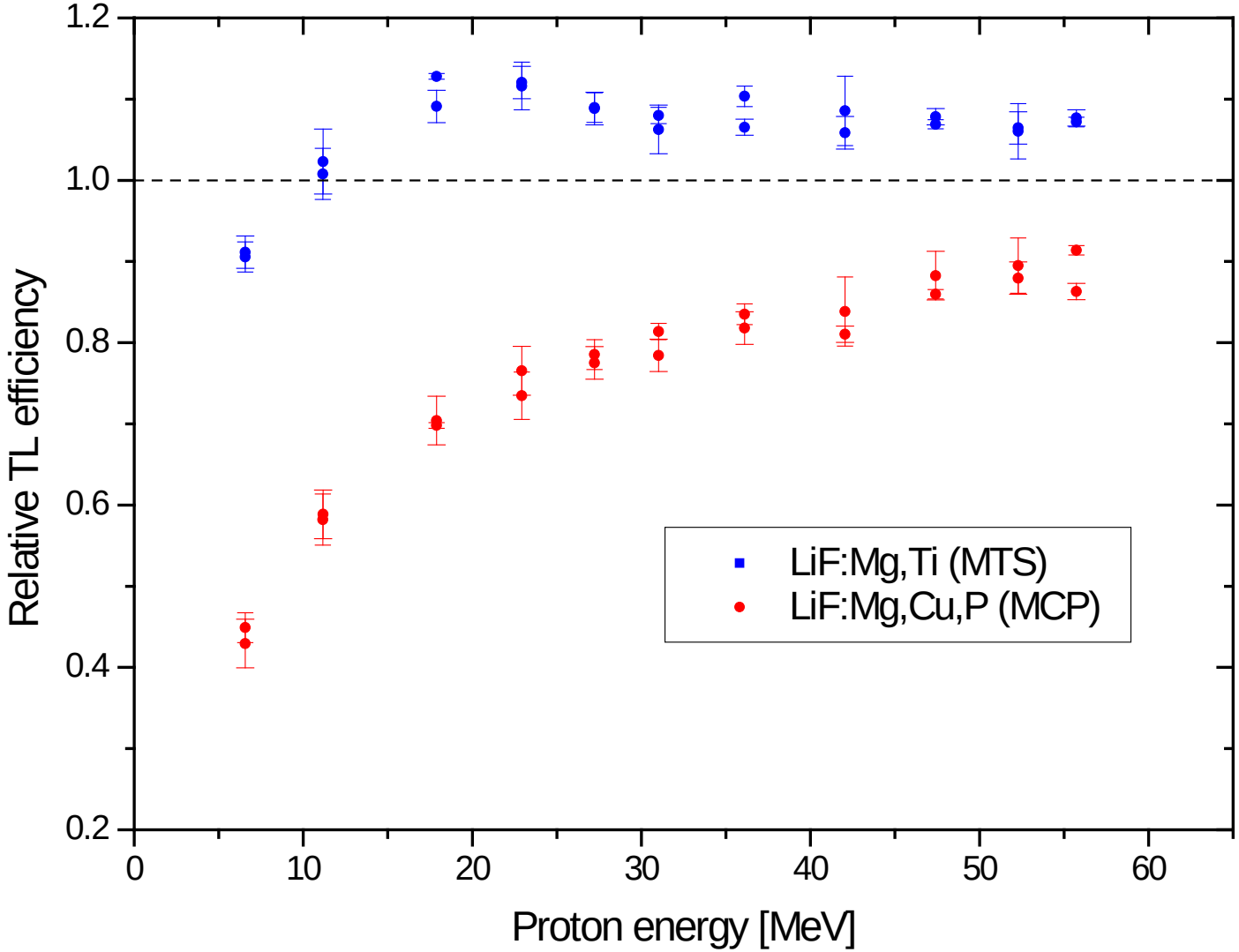
efficiency for 58 MeV unmodulated proton beam



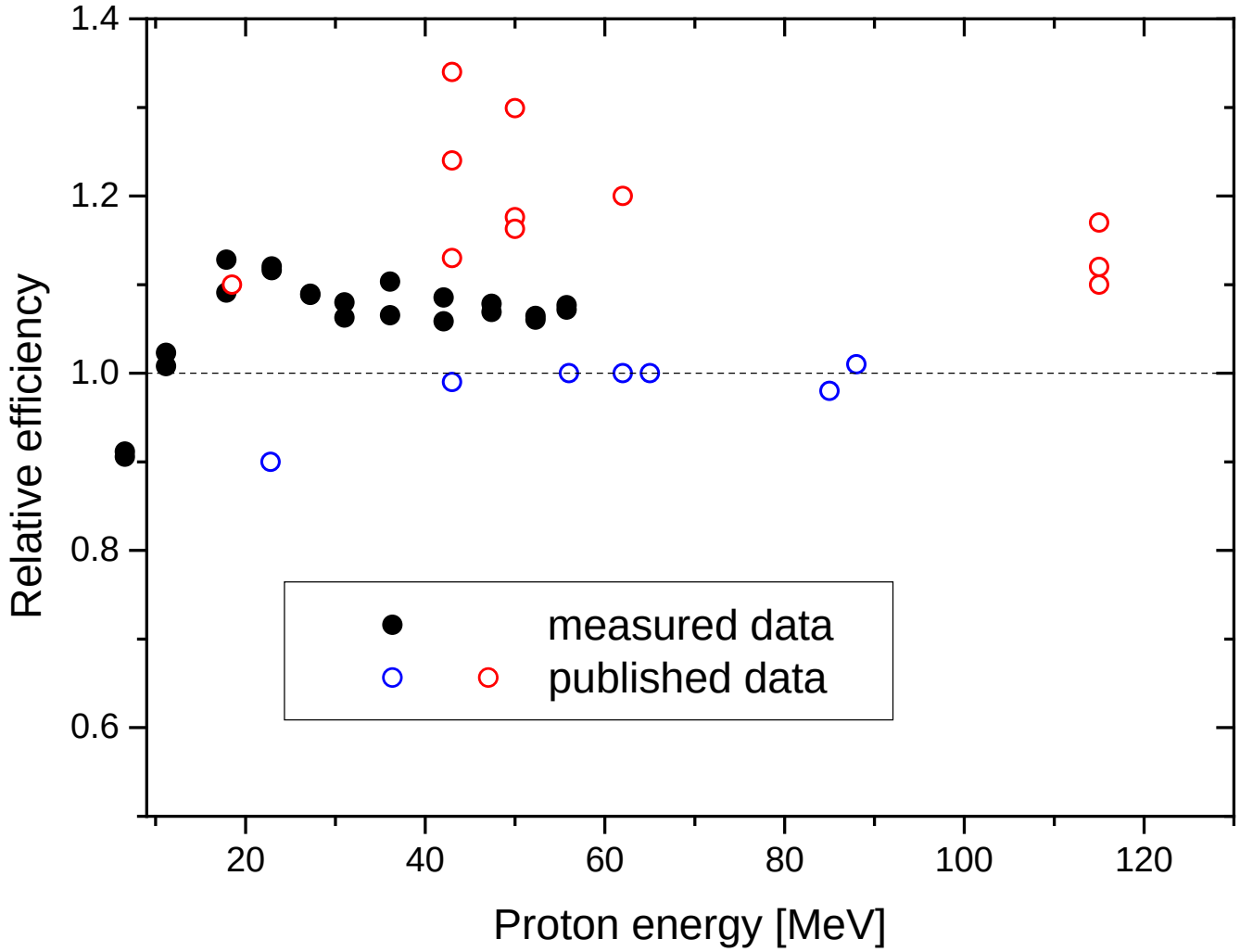
# REPRODUCIBILITY OF EFFICIENCY MEASUREMENTS
## proton energy ~58 MeV



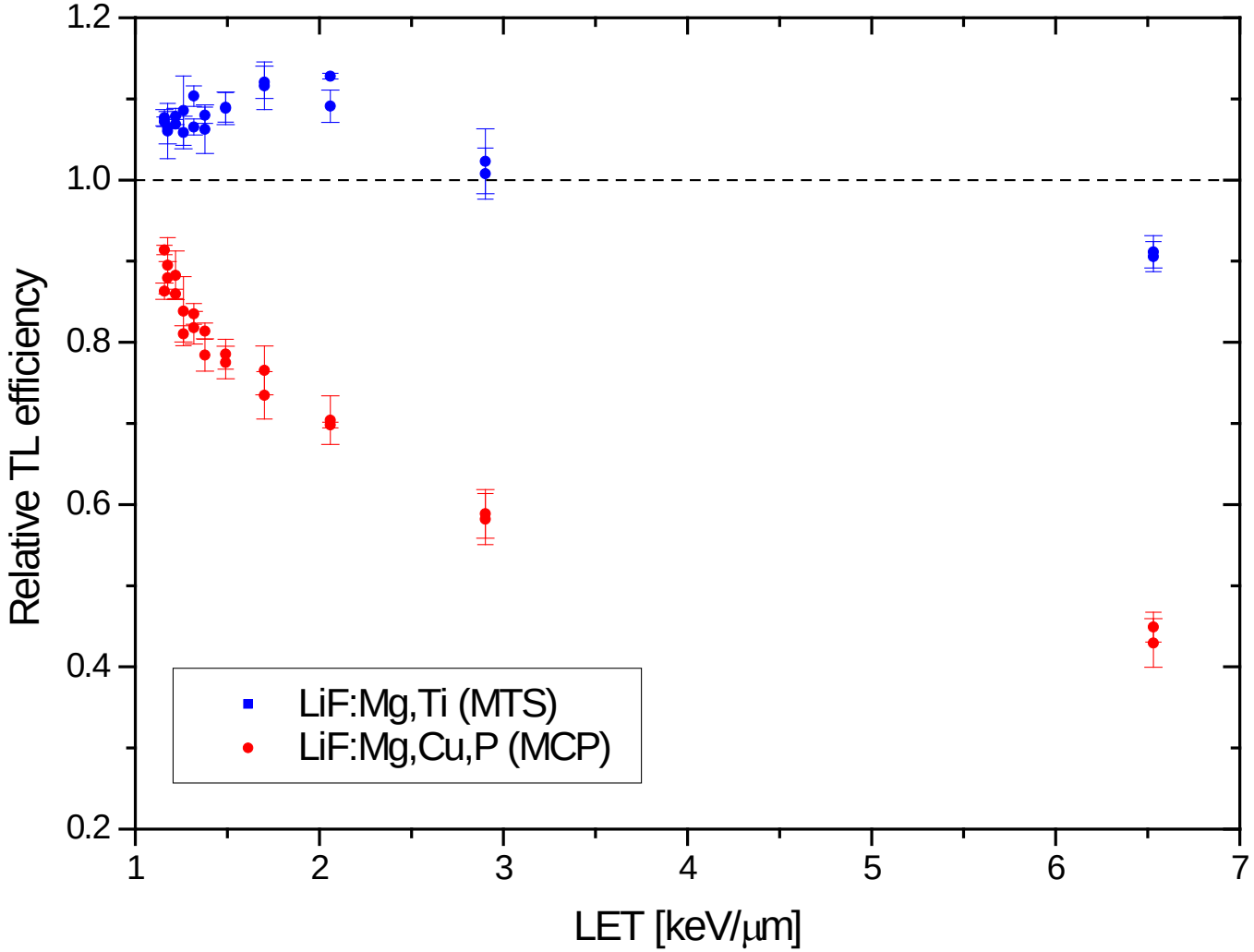
# ENERGY DEPENDENCE



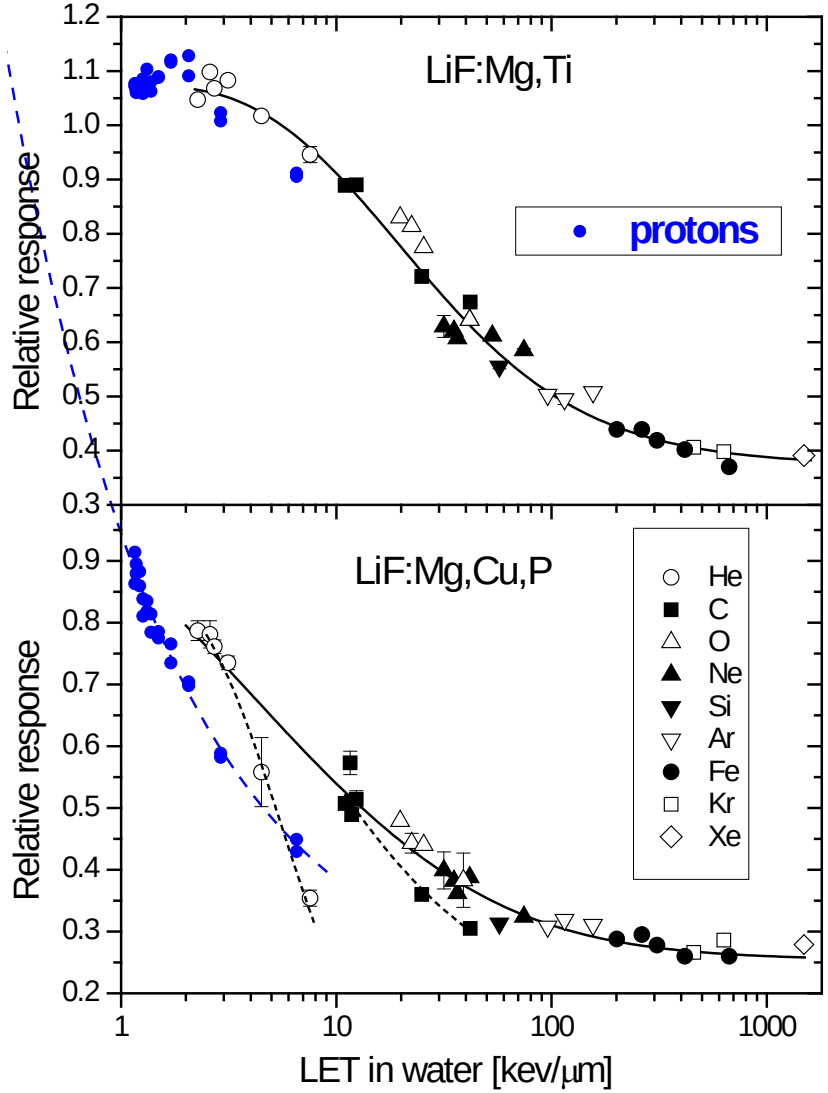
# COMPARISON WITH THE PUBLISHED DATA
# LiF:Mg,Ti



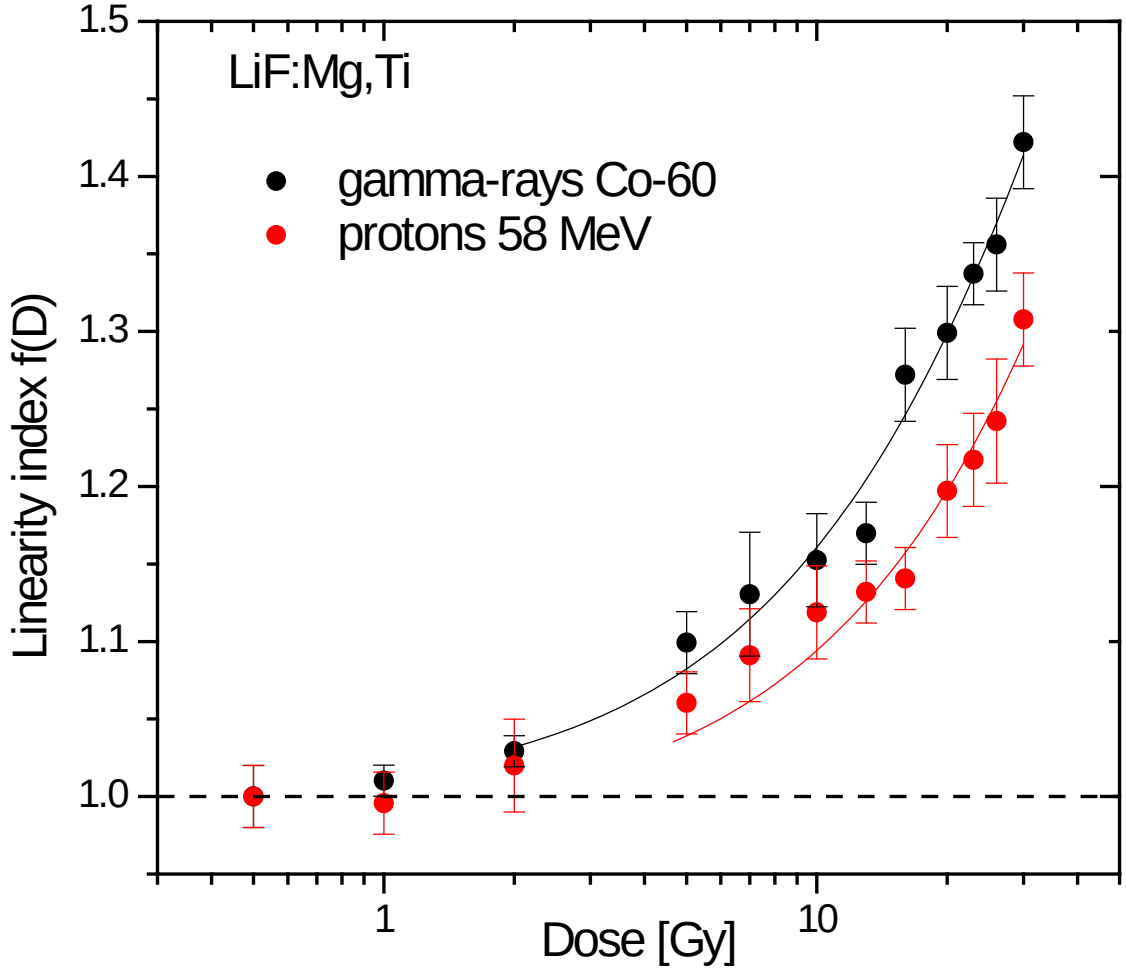
# LET DEPENDENCE



# COMPARISON WITH HIMAC DATA



# DOSE RESPONSE

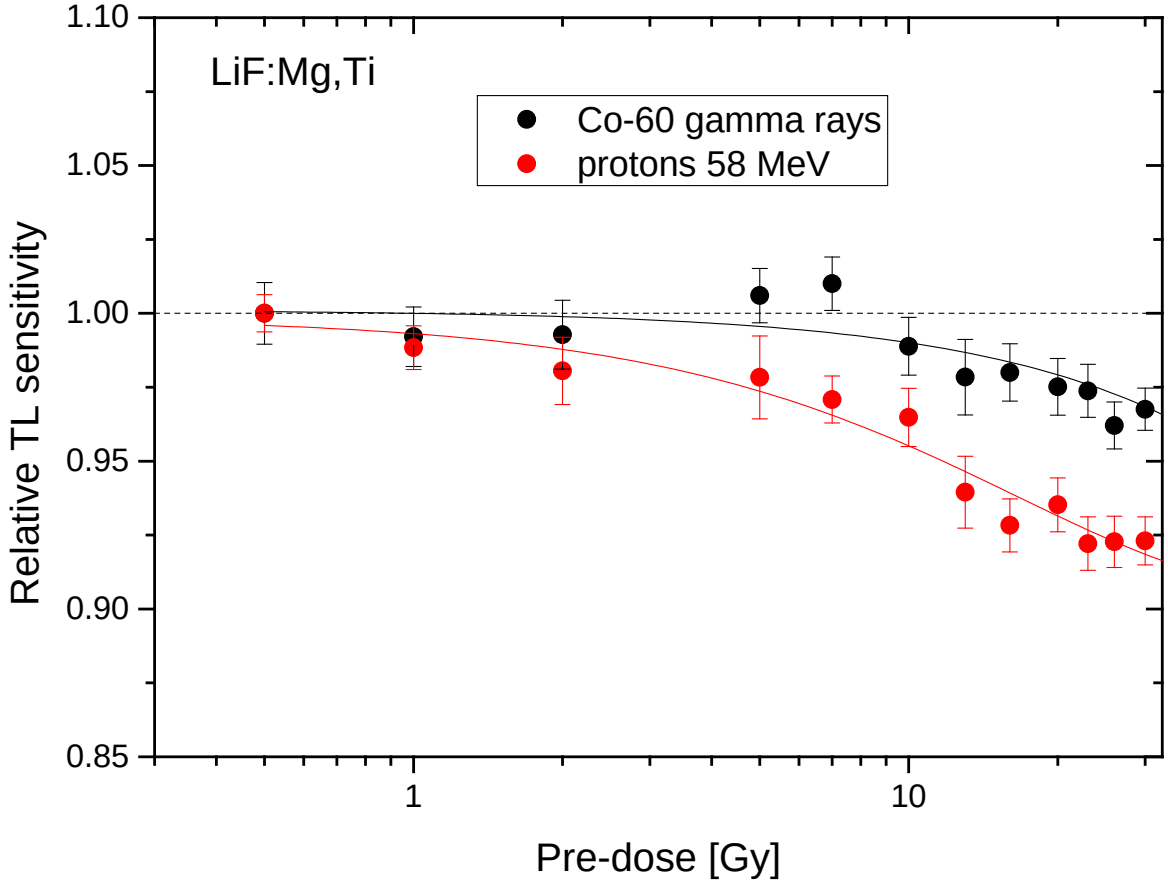



*Linearity index:*

$$f(D) = \frac{\frac{TL(D)}{D}}{\frac{TL(D_0)}{D_0}}$$

$D_0$ – "low" dose (0.5 Gy)

# SENSITIVITY LOSS DUE TO PREVIOUS IRRADIATION (radiation damage)

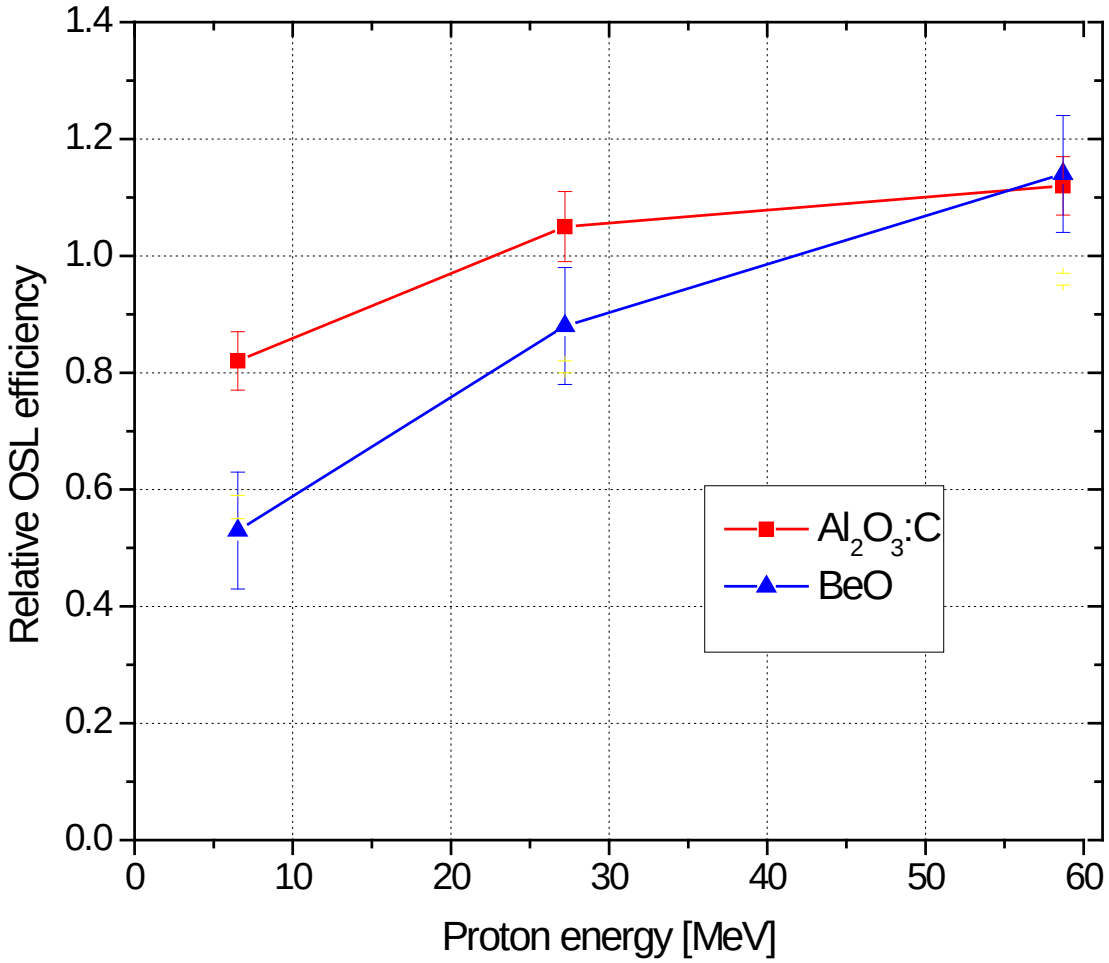
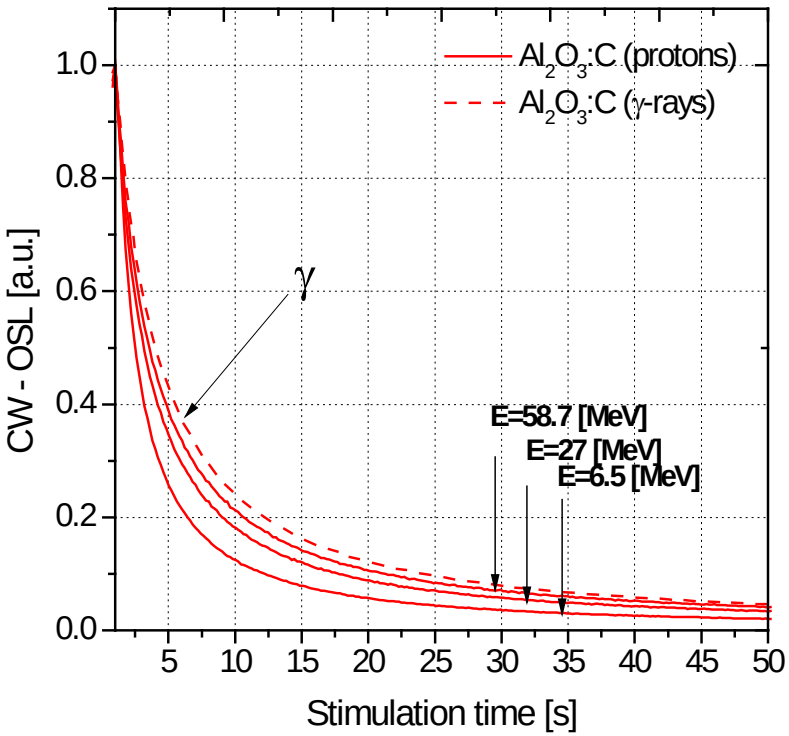
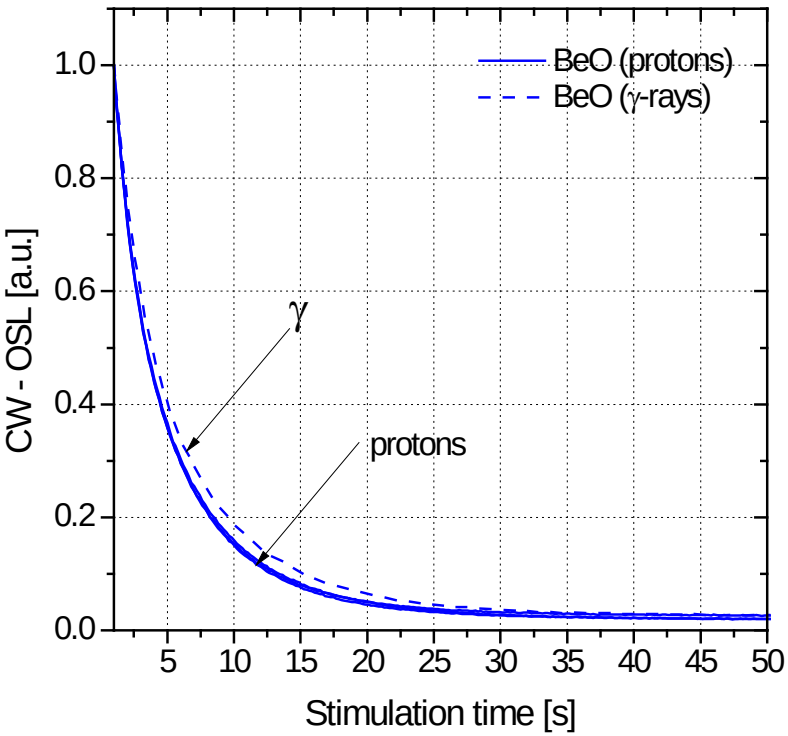


# SUMMARY

The large scale, systematic investigations of the relative TL efficiency of LiF detectors to protons (energy up to 60 MeV) realized at the IFJ Kraków, produced the following main results:

- Overresponse of LiF:Mg,Ti to protons is confirmed, as the relative efficiency was found to exceed significantly unity in all cases when $E_p$> ~15 MeV
- However, the very high values of LiF:Mg,Ti efficiency (reported in the past up to 1.34) were not confirmed. Typical values are 1.07-1.10 and no result above 1.17 was registererd
- Efficiency of LiF:Mg,Cu,P decreases steeply with increrasing LET (decreasing proton energy)
- Proton exposures with doses > 1 Gy cause a sensitivity loss (radiation damage) not observed for gamma-rays at this dose level

# OSL DETECTORS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