Master Degree in Physics
Università degli Studi di Padova

Physics Laboratory Course

Report

on

Microdosimetry

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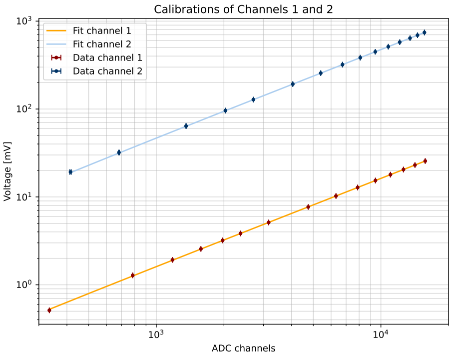
1. Introduction

In this report, we analyse a microdosimetric spectrum to extract key physical quantities characterizing energy deposition at the microscopic level. From a voltage spectrum, we derive the frequency and dose distributions, convert them to lineal energy, and estimate the frequency-mean (y_{F}) and dose-mean (y_{D}) lineal energies.

2. ADC Calibration

Using a function generator, we simulated voltage pulses to analyze the detector response and perform the calibration from ADC channels to millivolts.



Channel 1

Parameter	Value
m [mV/ADC]	$(1.62630 \pm 0.00001) \cdot 10^{-3}$
q [mV]	$(-1.75 \pm 0.01) \cdot 10^{-2}$

Channel 2

Parameter	Value
m [mV/ADC]	$(4.7555099 \pm 0.0000009) \cdot 10^{-2}$
q [mV]	$(-8.464 \pm 0.001) \cdot 10^{-1}$

Figure 1. Calibration for Channels 1 and 2. On the left: the plot with raw data and linear calibration fit. On the right: the fit parameters for Channel 1 and 2 respectively

3. Analysis procedure

The same analysis was performed both for the Mini-TEPC detector and the commercial FWT one.

First of all, given the two spectra of channel 1 and 2, they have been logharitmically rebinned imposing N=60 bins/decade. In the following step, the two spectra have been cut in order to have one unique spectrum without the initial noise.

Subsequently, calling h the pulse amplitude (in mV) we determined the frequency distribution given in Eq. 1

$$f(h) = \frac{n(h)}{N \cdot \Delta h} \quad \text{for which} \quad \int f(h)\, dh = 1 \tag{1}$$

where $n(h)$ are the counts, N is the total number of events and Δh are the widths of the bins.

Then the dose distribution was calculated using $\overline{h}_{\mathrm{F}} = \int_0^\infty h f(h)\, dh$ as follows in Eq. 2.

$$d(h) = \frac{h}{\overline{h}_F}\, f(h) \quad \text{for which} \quad \int d(h)\, dh = 1 \tag{2}$$

Finally a sigmoid function has been fitted onto the final part of the $h \cdot d(h)$ distribution, in order to find the abscissa h_{TC} at which the tangent line at the inflection point intersects the x-axis, which yields the conversion between pulse aplitude and the lineal energy given by the coefficient $a = \frac{15.5}{h_{Tc}} \frac{\mathrm{KeV}}{\mu\mathrm{m\ mV}}$. This yields the frequency distribution of the lineal energy y which has been extented down to $y = 0.01$ KeV μm^{-1} through the fit of a complementary cumulative distribution function of a log-normal distribution, in order to obtain $\int_{0.01}^\infty f(y)\, dy = 1$.

The last steps are the esteem of the frequency-mean lineal energy $\overline{y}_{\mathrm{F}}$ and of the dose-mean lineal energy $\overline{y}_{\mathrm{D}}$ explained in Eq. 3 and Eq. 4.

$$\overline{y}_{\mathrm{F}} = \int_{0.01}^\infty y f(y)\, dy \tag{3}$$

$$\overline{y}_D = \int_{0.01}^\infty y d(y)\, dy = \frac{1}{\overline{y}_F} \int_{0.01}^\infty y^2 f(y)\, dy \tag{4}$$

where $d(y)$ is given by Eq. 5.

$$d(y) = \frac{y}{\overline{y}_F}\, f(y) \quad \text{for which} \quad \int_{0.01}^\infty d(y)\, dy = 1 \tag{5}$$

4. Mini-TEPC

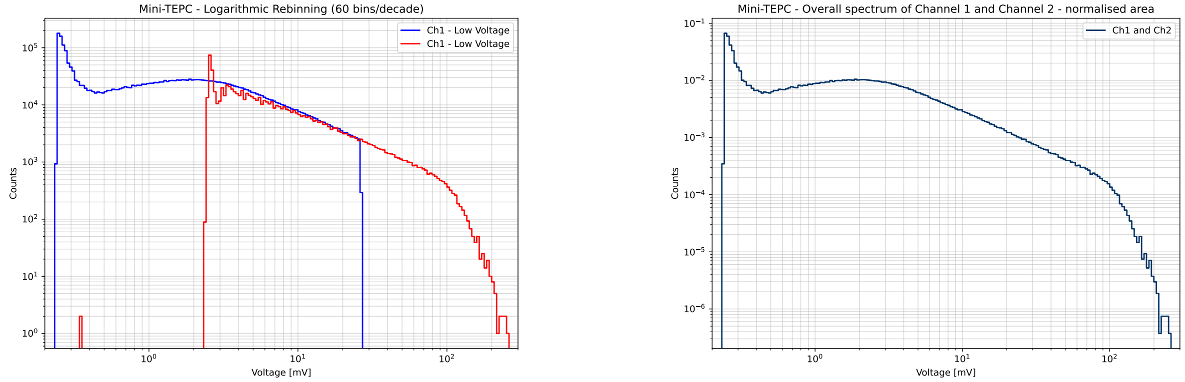


Figure 2. On the left: logarithmic rebinning of the two spectra. On the right: overall spectrum with normalised area

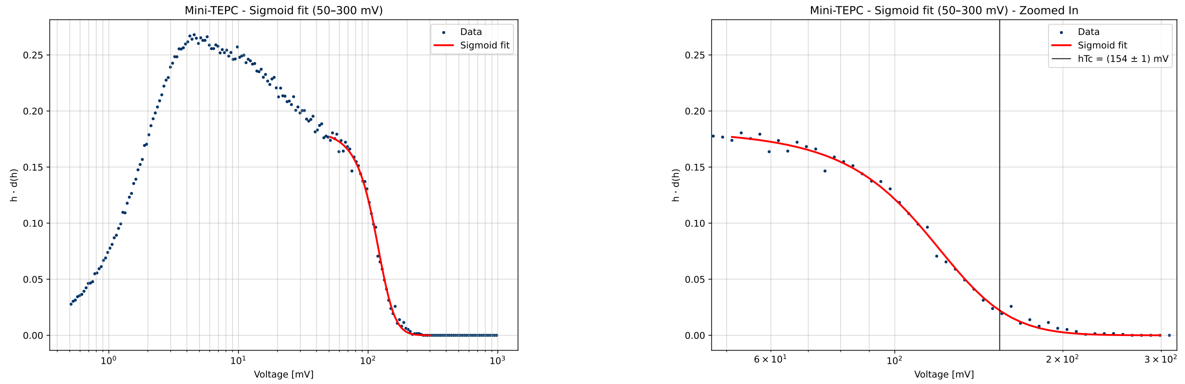


Figure 3. On the left: Sigmoid fit of the $h \cdot d(h)$ distribution. On the right: zoomed fit with h_{Tc}

From the sigmoid fit of the $h \cdot d(h)$ distribution we got $a_{\mathrm{TEPC}} = \frac{15.5}{h_{Tc}} \ \frac{\mathrm{KeV}}{\mu\mathrm{m\ mV}} = (0.1006 \pm 0.0007) \ \frac{\mathrm{KeV}}{\mu\mathrm{m\ mV}}$

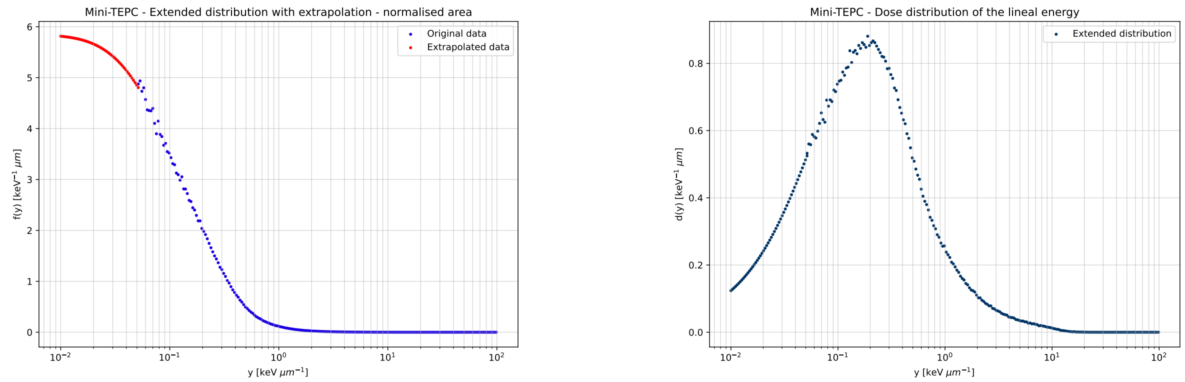


Figure 4. On the left: Frequency distribution of the lineal energy. On the right: Dose distribution of the lineal energy

The frequency-mean lineal energy and the dose-mean lineal energy are respectively:

$$y_{\mathrm{F}} = 0.39\ \mathrm{keV}\mu\mathrm{m}^{-1} \tag{6}$$

$$y_{\mathrm{D}} = 2.22\ \mathrm{keV}\mu\mathrm{m}^{-1} \tag{7}$$

5. FWT

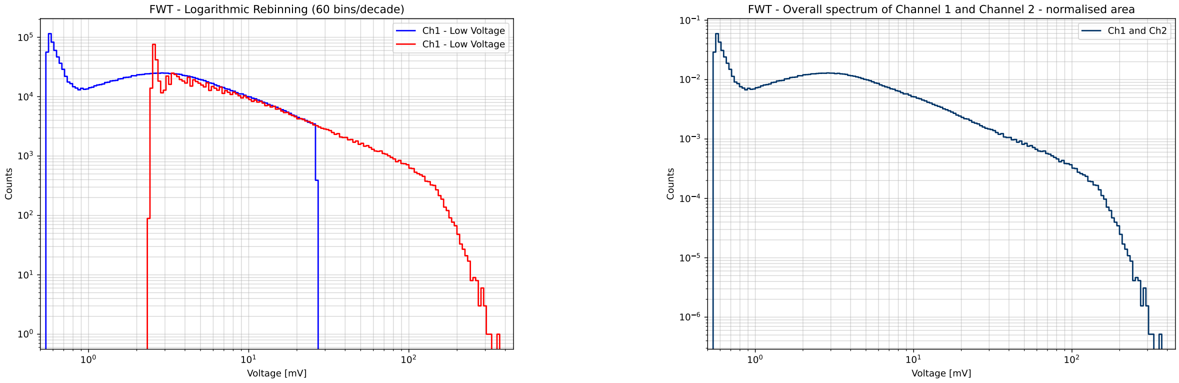


Figure 5. On the left: logarithmic rebinning of the two spectra. On the right: overall spectrum with normalised area

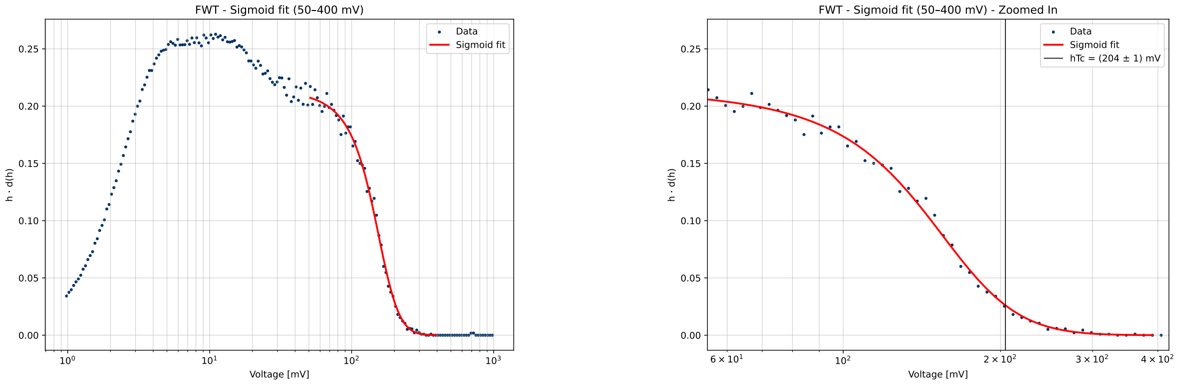


Figure 6. On the left: Sigmoid fit of the $h \cdot d(h)$ distribution. On the right: zoomed fit with h_{Tc}

From the sigmoid fit of the $h \cdot d(h)$ distribution we got $a_{\mathrm{FWT}} = \frac{15.5}{h_{Tc}} \; \frac{\mathrm{KeV}}{\mu\mathrm{m\ mV}} = (0.0758 \pm 0.0005) \; \frac{\mathrm{KeV}}{\mu\mathrm{m\ mV}}$

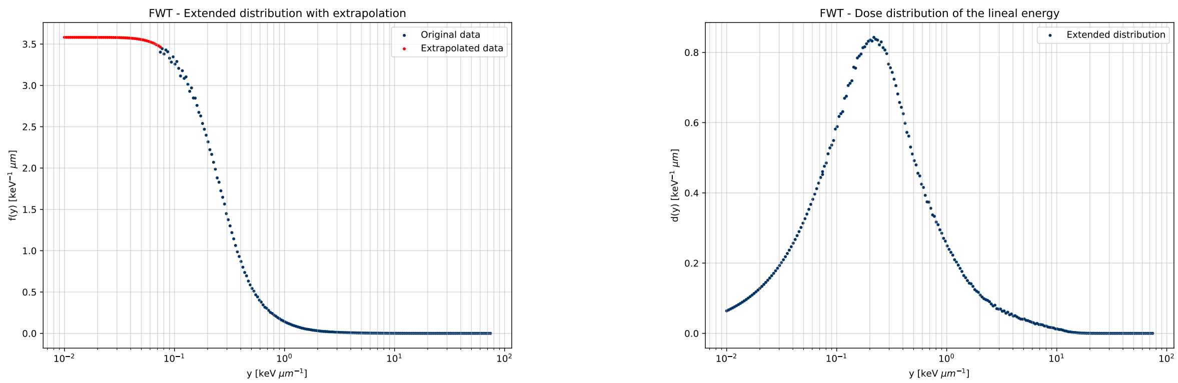


Figure 7. On the left: Frequency distribution of the lineal energy. On the right: Dose distribution of the lineal energy

The frequency-mean lineal energy and the dose-mean lineal energy are respectively:

$$y_{\mathrm{F}} = 0.46 \ \mathrm{keV}\mu\mathrm{m}^{-1} \tag{8}$$

$$y_{\mathrm{D}} = 2.36 \ \mathrm{keV}\mu\mathrm{m}^{-1} \tag{9}$$