Radioactivity and Nuclear Measurements
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Laboratory Report

Dosimetry

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1 Abstract

Dosimetry studies the energy absorbed by matter when radiation passes through it. This branch of Physics finds an application on Medicine, in particular on the tumors treatment. The technique consists in bombarding the tumor cells with a focused ion beam but it is necessary to take into account also the damage on the healthy cells which is related to the energy absorbed. That analysis is done in the laboratory with inorganic substances, propane in this case, and results are compared with the human tissues (water equivalent).

2 Instrumental Apparatus

The dosimetric study is performed using a proton beam against a propane gas chamber.
A coaxial anode wire is located in the center of the chamber while its walls work as cathode. After the collisions, the gas is ionized and the produced charges are collected. The signal is then splitted so it is possible to obtain both low and high amplification gains which refine on the energy spectrum. Then the two signals pass through preamplificators and finally through the ADC converter. Two different sets of data are taken corresponding to an applied voltage of $750V$ and $830V$.

3 Analysis

At the laboratory the gaseous propane is used but, since we are interested on biological damage, the water equivalent thickness can be evaluated from:

$$\Delta x_{H_2O} = \Delta x_{Prop} \frac{\rho_{Prop}}{\rho_{H_2O}} \left(\frac{dE}{dx}\right)_{Prop_{Electronic}} \left(\frac{dE}{dx}\right)^{-1}_{H_2O_{Electronic}}$$

The $\left(\frac{dE}{dx}\right)_{Prop_{Electronic}}$ and $\left(\frac{dE}{dx}\right)_{H_2O_{Electronic}}$ values are taken from the NIST site using the PSTAR program which provides the stopping power and range tables for protons in the interested materials. The

$\Delta x_{H_2O} = 1.11\mu m$ is obtained by an average on the electronic stopping powers for protons from $10keV$ to $250MeV$ energy.

The two channels histograms are fixed in the point where the higher resolution histogram finishes (after making sure that the number of events in the intersection of the two channels is the same). We merge the 750V and 830V histograms in the point where they overlap, since the 830V data should reproduce well the low energy part, while the 750V the higher one.

Then frequency distribution is gained using the formula:

$$f(h_i) = \frac{n_i}{\sum_{i_{min}}^{i_{max}} n_i \Delta h_i} \qquad \sum_{i_{min}}^{i_{max}} f(h_i)\Delta h_i = 1$$

Where n_i is the number of counts and Δh_i is the bin width.

The dose distribution is obtained using :

$$d(h_i) = \frac{h_i f(h_i)}{\sum_{i_{min}}^{i_{max}} h_i f(h_i)\Delta h_i}$$

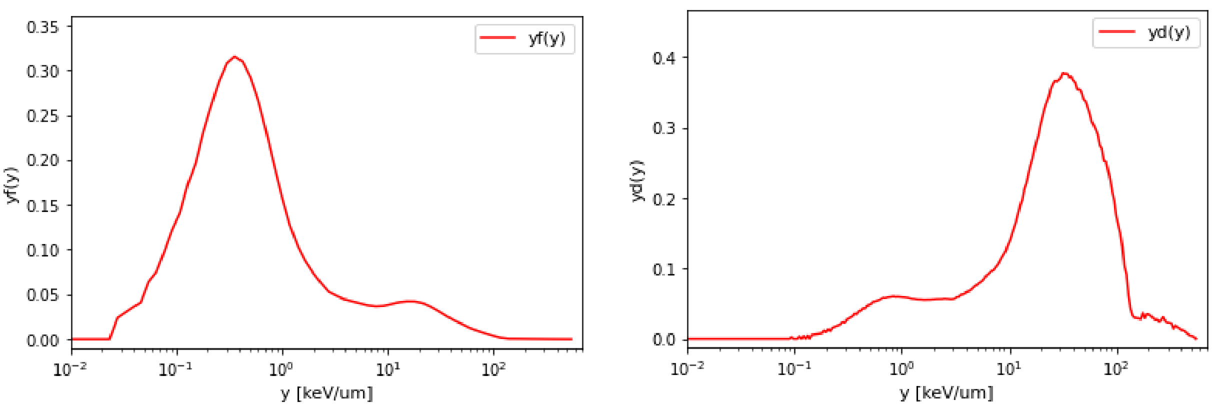
The falling region after the highest peak of the hd(h) distribution corresponds to the proton edge (the maximum stopping power of protons released in 1.11 μm in water), and the equivalent thickness in water is smaller than the proton range at the correspondent energy ($R_P = 1.39 \pm 0.04\mu$m). This ensures that the proton edge effectively corresponds to the maximum stopping power and is not shifted to lower energies. Those points are fitted with a Fermi function :

$$hd(h) = \frac{A}{1 + e^{B(h-C)}}$$

It is now useful to work with the lineal energy (in KeV/μm), using the relation $C(mV) = \frac{\epsilon_{max}}{\bar{l}}(\frac{KeV}{\mu m})$ where $\bar{l}$ is the medium cord ($\bar{l} = \frac{2}{3}$d, and E_{max} is the maximum energy released estimated as $d(\frac{dE}{dx})_{max}$ where d is the equivalent thickness in water).
The behaviour in the empty space at really low energies is extrapolated with a linear fit (since the power fit $y = mx^k$ returns a k value compatible with 1).

We obtain the calibrated and normalized frequency and dose distributions and the corresponding mean energy values: $\bar{y}_F = 2.78\frac{keV}{\mu m}$ and $\bar{y}_H = 39.98\frac{keV}{\mu m}$

It is useful to make a $yd(y)$ and $yf(y)$ plot for a visual aim. Moreover the plots have been re-binned in order to have a better visualization in logarithmic scale. The so-obtained plots for frequency and dose linear energy distributions are shown in figure 1.


yf(y)
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
10^{-2}
10^{-1}
10^{0}
10^{1}
10^{2}
y [keV/um]
yd(y)
0.4
0.3
0.2
0.1
0.0
y [keV/um]

(a)

(b)

Figure 1