Monte Carlo and Practical Study of a Novel Microdosimetric Diamond Detector

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Introduction:
Hadron therapy offers a **higher dose conformity** and **increased radiobiological effectiveness**, compared to conventional radiation therapy [1]. However, the main challenge is the determination of the biological effectiveness of radiation. It is not only important to develop a way that could accurately represent the dose delivered to the patient, but that could also specify the **radiobiological effectiveness** in clinical conditions [1] - [3].

As can be seen in figure 1, difference can clearly be observed between **low-LET** (sparsely ionising) radiation (figure a, b and c) and **high-LET** (densely ionising) radiation (figure d and e).

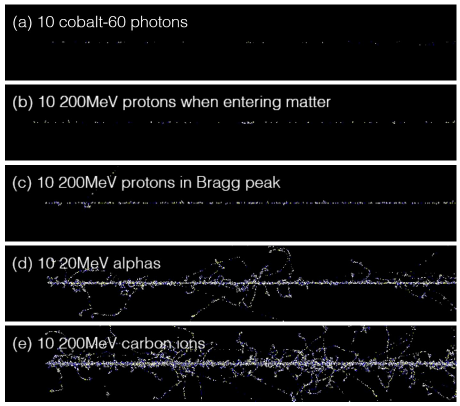

Fig. 1: particle track structures in water vapour over 1 μm (courtesy of prof. dr. Brigitte Reniers)

Microdosimetry studies the entire energy deposition process. It is a technique that allows for the measurement of stochastic energy deposition distributions in a micrometre size sensitive volume [2], [4] - [7].
Radiation quality can be specified in terms of spectra of the **lineal energy.**
The lineal energy y is defined as the quotient of the **energy deposition** in a **single event** ε_s and the **mean chord-length** $\bar{l}$, as given by the following equation [8]:

$$y = \frac{\varepsilon_s}{\bar{l}}$$

The lineal energy can be measured by **microdosimeters** [1].

High-purity single crystal diamond

produced by chemical vapour deposition

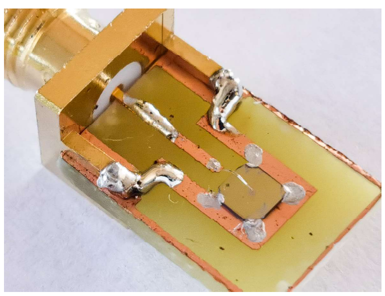

Fig. 2: diamond microdosimeter

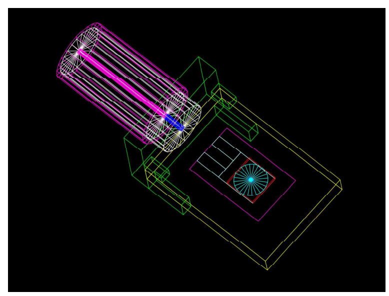

Fig. 3: Monte Carlo model diamond microdosimeter

Monte Carlo model

TOPAS Tool For Particle Simulation

Results lab experiments:
- determination of the experimental setup and working parameters (fig. 4)
- calibration in terms of lineal energy (keV/μm)
- lineal energy spectrum of a ^{241}Am alpha source at multiple source-detector distances (fig. 5)
- noise level: < 10 mV rms and < 40 mV pp
- lower detection limit: 10 keV/μm
- resolution: 10 keV/μm

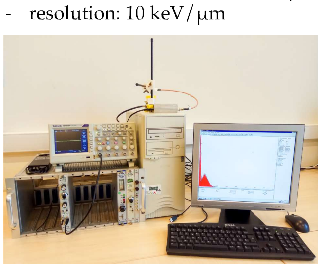

Fig. 4: experimental setup

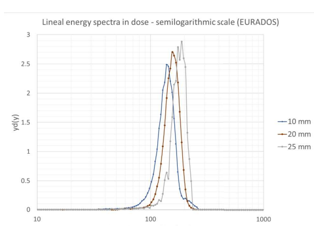

Fig. 5: lineal energy spectra in dose

Results Monte Carlo simulations:
- good agreement between experimental data and simulation data (fig. 6)
- dose mean lineal energy in function of source-detector distance (fig. 7)
- Bragg peak can be clearly recognised

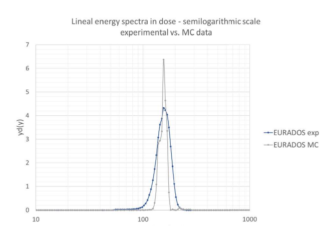

Fig. 6: lineal energy spectra in dose (exp vs. MC data)

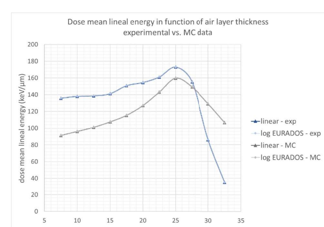

Fig. 7: dose mean lineal energy (exp. vs. MC data)

Conclusion: This Master’s thesis highlights the possibilities of a **new and promising research line** concerning **experimental microdosimetry** at NuTec, UHasselt. The **initial steps,** within the framework of this Master’s thesis, have been **successfully taken.**

Various improvements and extensions to the experiments and simulations performed can be achieved to answer the following major research question: “**Diamond detector based microdosimetry: key solution in the determination of the radiobiological effectiveness?**”

Supervisors / Cosupervisors: prof. dr. Brigitte Reniers (Hasselt University, Belgium)
MSc Giulio Magrin (EBG MedAustron, Wiener Neustadt, Austria)

References:

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