Development of Microdosimetric Detectors for Radiobiology in Hadron Therapy Facilities

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Introduction

The interest in hadron therapy for cancer treatment is increasing as it offers much better results compared to conventional radiation therapy. Though, it can have adverse effects. The study of how particles spread their energy at the microscale contributes to the description of dose effects at a cellular level. Still, the ability to measure microscale radiation effects is a huge challenge, as most tools are unable to do this due to their size.

Aim

This project targets the development of scintillators and crystals to be used as active and passive microdosimeters, namely:

- Micrometric scintillating plastic optical fibres (mSPOF) on a plastic base with different doping combinations
- Fluorescent neutral tracking detector (FNTD) based on Al_2O_3 crystals with diferent doping agents

Micrometric Scintillating Plastic Optical fibres (mSPOF)

The active dosimeter (i.e., provides a signal in real-time) is based on a polystyrene (PS) mSPOF produced by electrospinning, process that uses electrostatic forces to produce micro/nano polymer fibres. The obtained cross-sections are closer to those of human cells (~30 µm) and smaller than commercially available fibres (~250 µm).

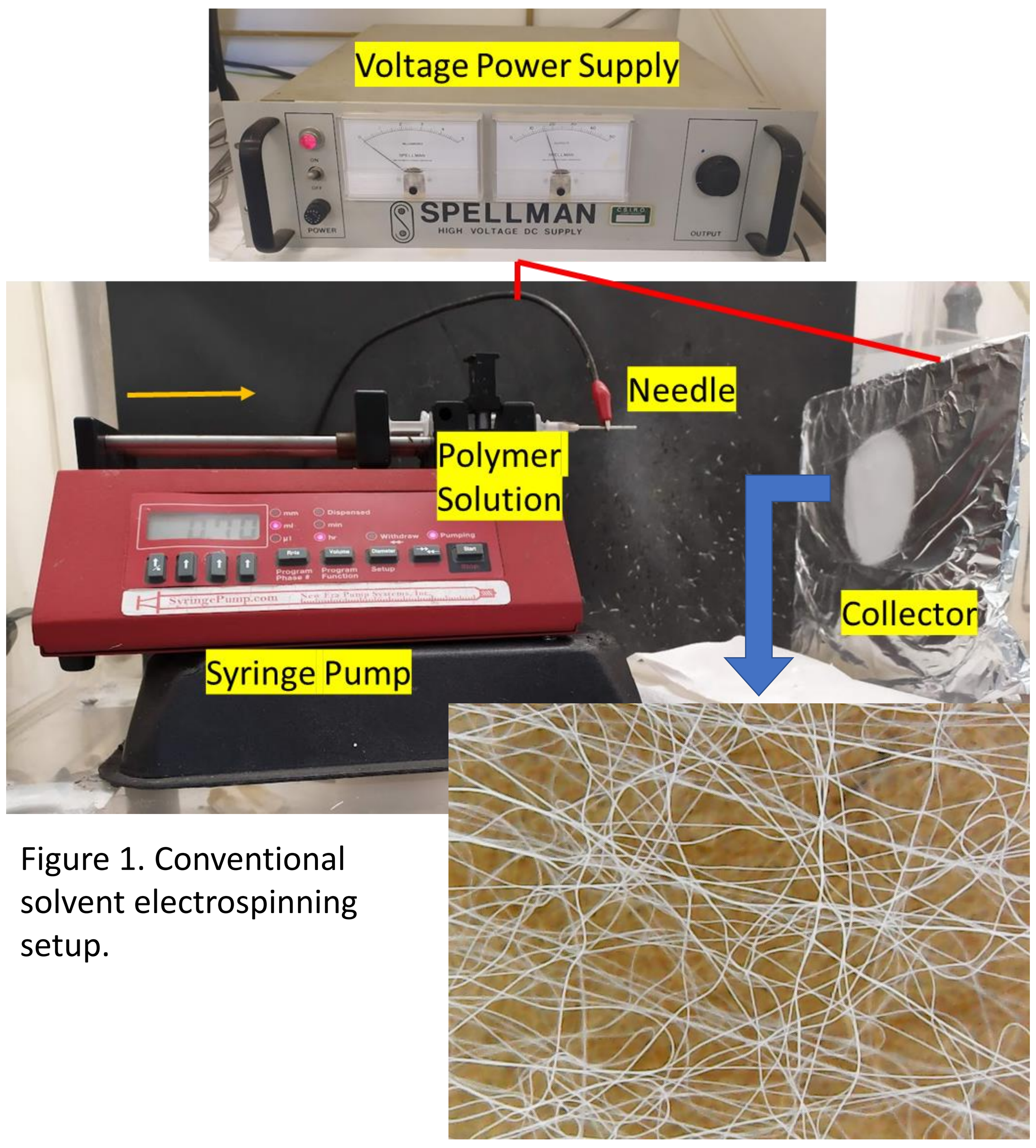


Figure 1. Conventional solvent electrospinning setup.

Goal for final product: infinite single fibre to be organized in several oriented and parallel fibres to be connected to an array of photodetectors.

Fibre Alignment

Figure 2. Colector used to obtain aligned electrospun fibres.

Annealing to enhance transparency

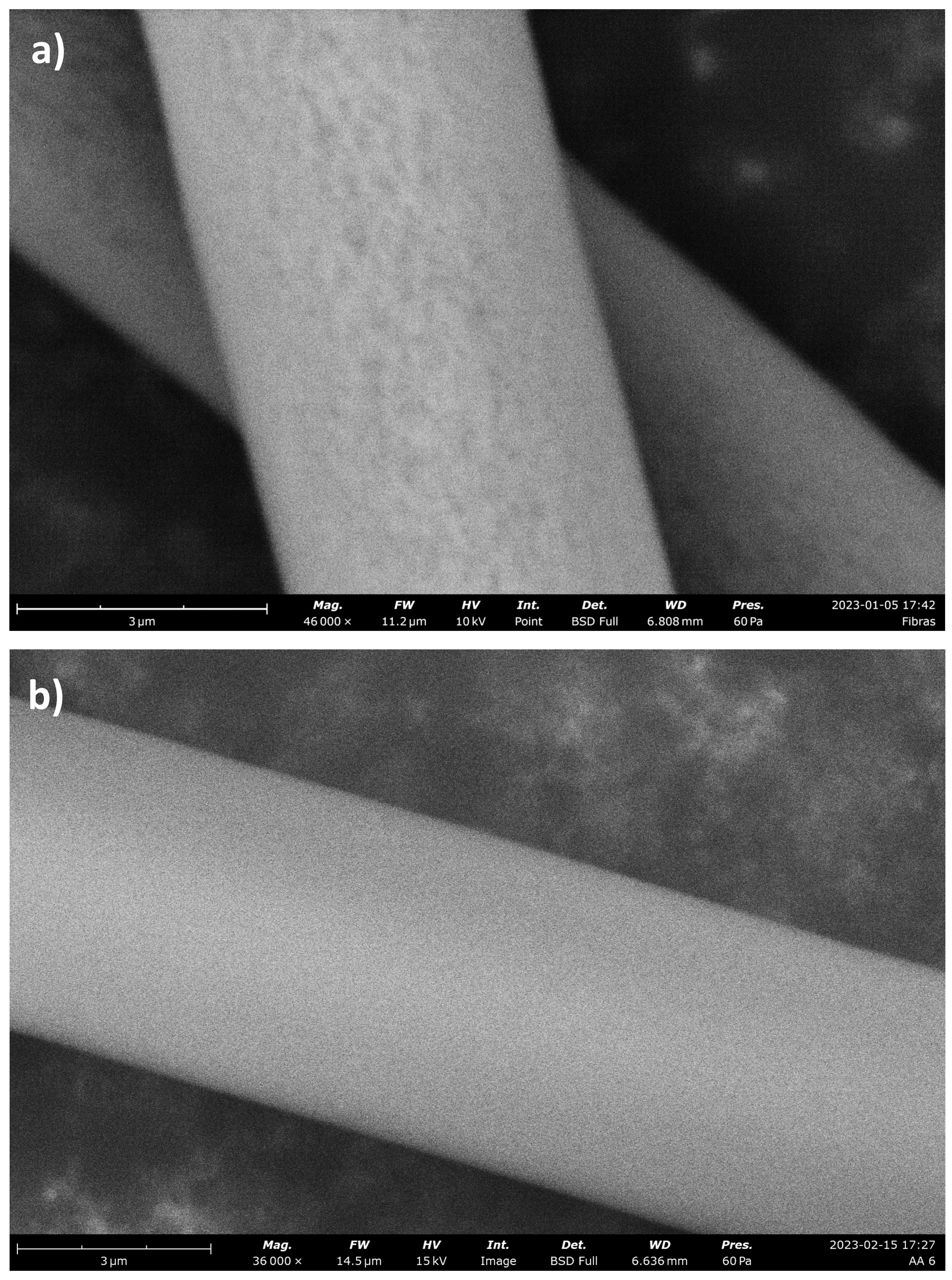
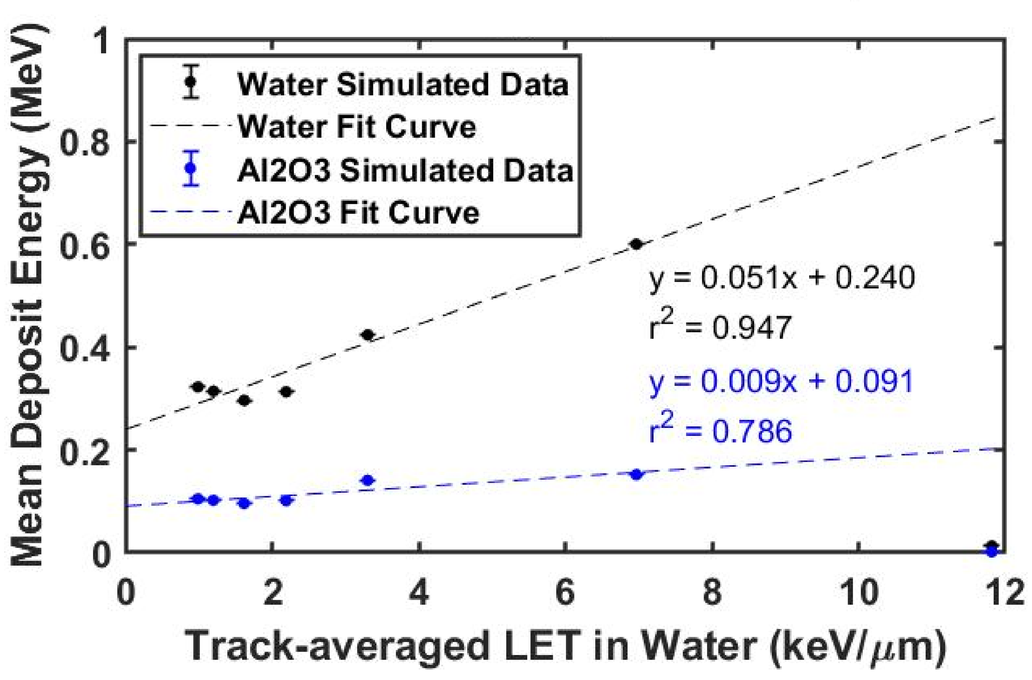
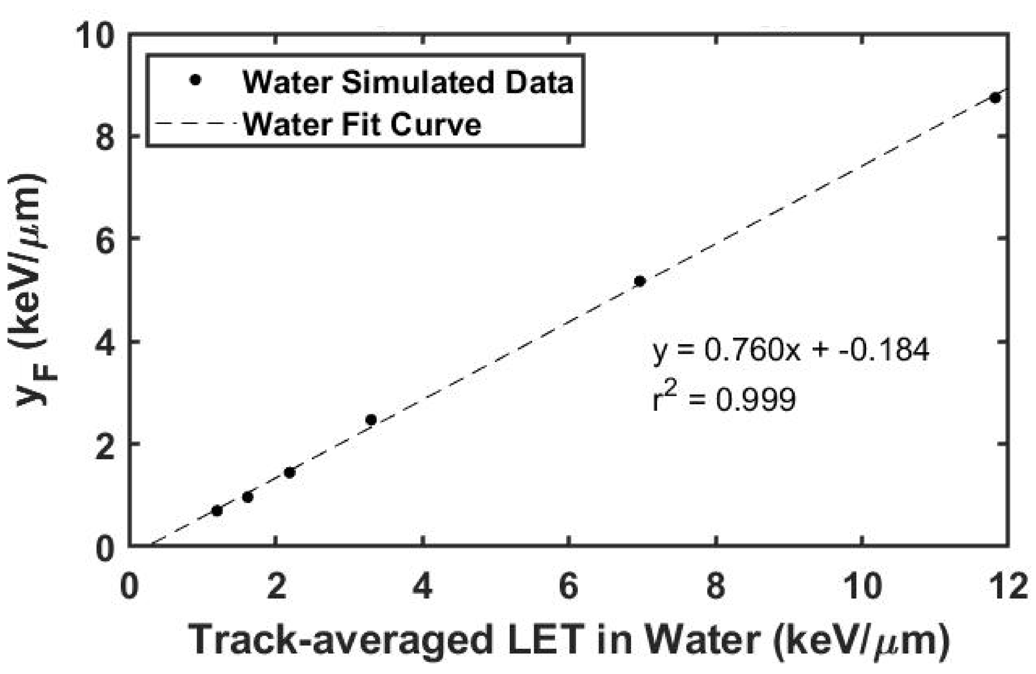


Figure 3. SEM images of 30% (w/v) PS+DMF/THF (3:1) fibres a) as-spun and b) post-annealing at 110°C for 120 min. Largest fibres had a cross-section of around 4 um.

Fluorescent Neutral Tracking Detector (FNTD)

FNTD's can describe the 3D particles interactions with excellent spatial resolution (<1µm [1]). For the passive dosimeter (i.e., radiation-induced signal stored and read afterwards), millimetre-sized doped and undoped Al_2O_3 crystals (ρ = 3.97 g/cm³) will be grown using the flux method. TOPAS Monte Carlo simulations are being used to calculate micro/nanodosimetric quantities to correlate with the radiation-induced signal.





Single 8 x 4 x 0.5 mm³ volume
Monoenergetic 125 MeV proton beam
Irradiation field size of 8 x 4 mm²
100M events

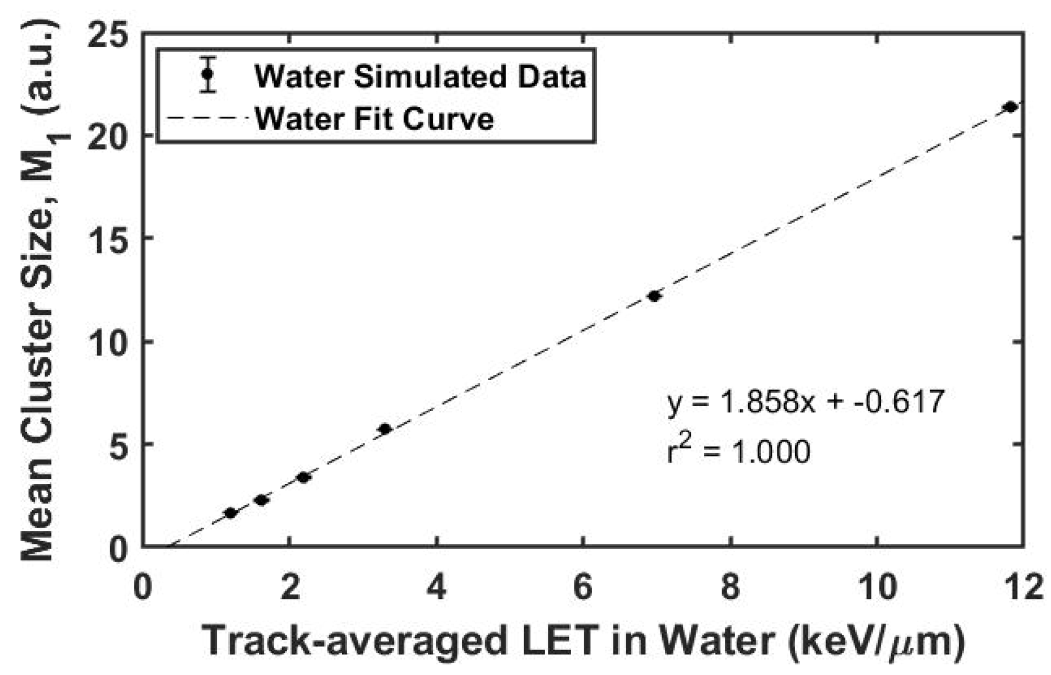
→Strong correlation between:
- Energy deposited by all particles

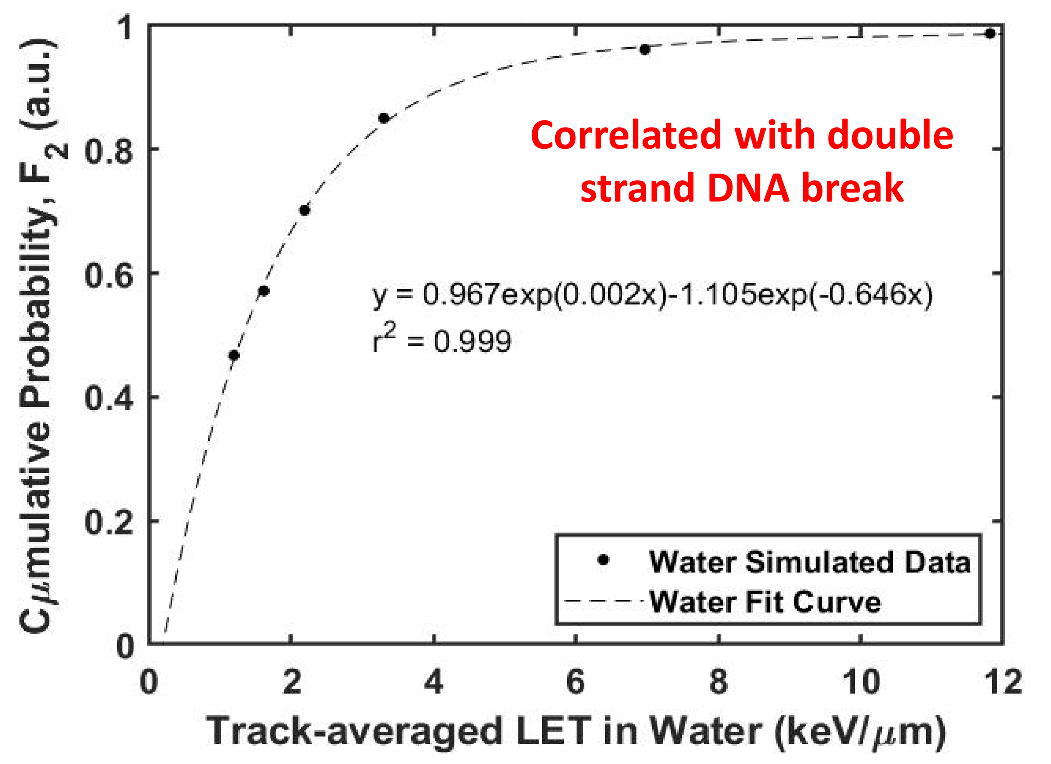
with track-averaged LET in water **< 6.97 keV/um**.

→Very strong correlation between:
- Frequency mean lineal energy, y_F
- Mean ionization cluster size, M_1
- Cumulative probability of occurring more than one ionization, F_2

with track-averaged LET in water **< 12 keV/um**.

These quantities may be correlated with track brightness but experimental data is needed!





[1] M.S. Akselrod; G.J. Sykora (2011). Fluorescent nuclear track detector technology – A new way to do passive solid state dosimetry. , *46(12), 1671–1679*.

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