SMARTPHANTOM: INSTRUMENTED WATER PHANTOM BASED UPON SCINTILLATING-FIBRES

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INTRODUCTION

Protons therapy is based on a constant radiobiological effectiveness (RBE) value of 1.1. However, it is known that this value is not a constant and depends on many variables, including tissue characteristics, linear energy transfer (LET), and energy. This dependence on various physical and biological properties is even greater for heavy ions like carbon.

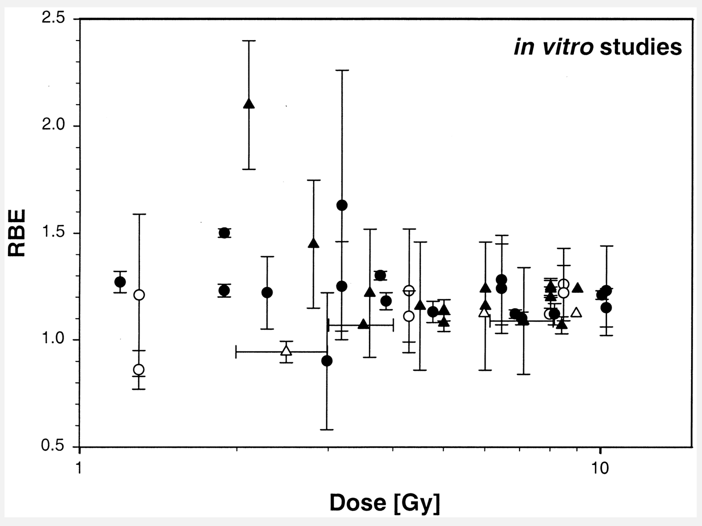

FIGURE 1: RBE of protons in relation to ^{60}Co, as a function of the dose [1]. Circles represent RBEs for <100 MeV proton beams, and triangles for >100 MeV beams, with the open and closed symbols representing different cell lines.

SmartPhantom is proposed as an instrumented phantom made up of multiple scintillating-fibres layers placed within a water phantom. The aim is to provide researchers at MedAustron real time determinations of LET, dose-measurements, and distribution of the proton and carbon-ion beam irradiating a cell sample.

OUTLINE OF DESIGN

Five scintillating fibre stations will be situated within the phantom. Each station containing two layers oriented 90° with respect to each other. Each individual layer consists of 250 µm scintillating fibres.

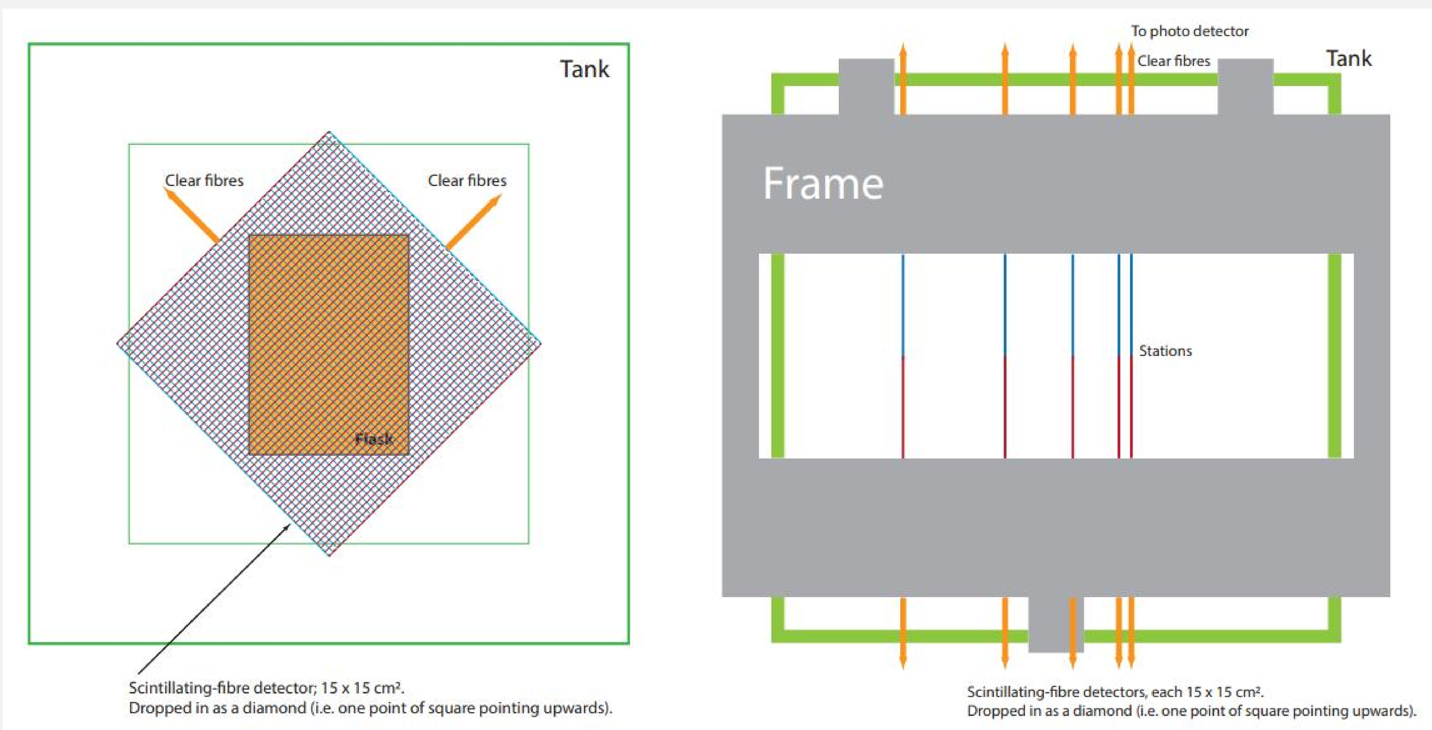

FIGURE 2: Schematic diagrams for SmartPhantom. Left Panel: Transverse plane view of the water phantom indicated by outer green square, with the inner square representing the beam window. The scintillating fibres are positioned in a rotated diamond orientation covering the area being irradiated (flask). Right Panel: View of the phantom from above with a beam incident from the left.

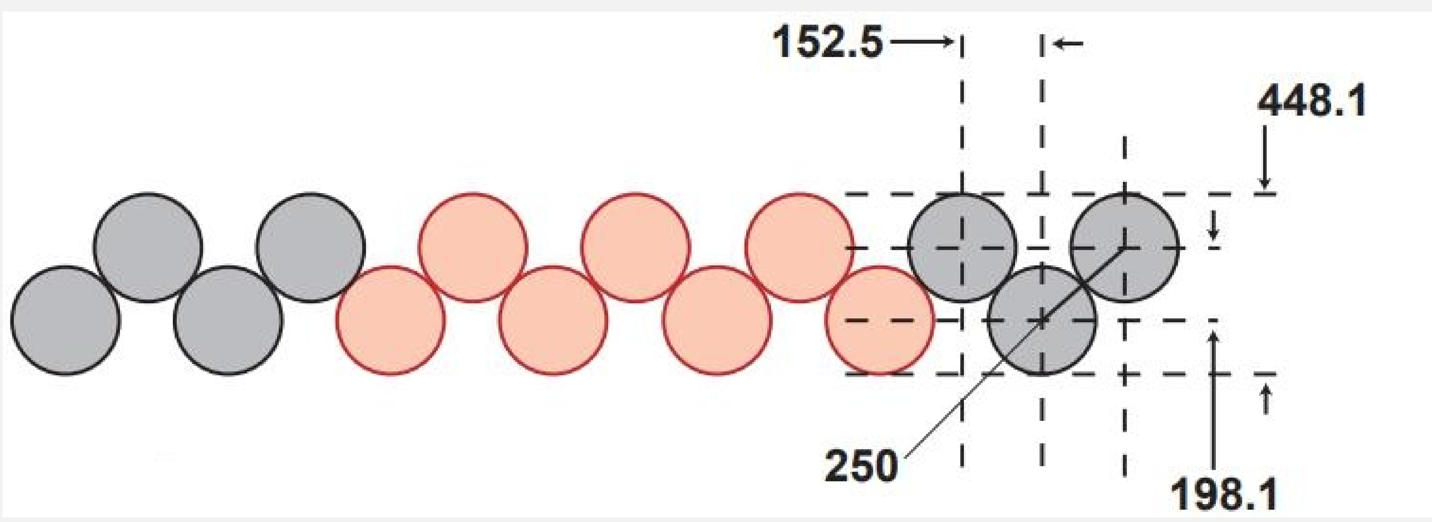

FIGURE 3: Arrangements of the scintillating fibres for a layer with the spacing and pitch specified in µm.

Clear-fibre light guides will transport the scintillation photons to photodiodes. At the moment, it is planned that the fibres will be read-out using a silicon image-capture sensor. The clear-fibres length will be minimized but still of sufficient length in order for the photodiodes, digitiser boards and readout to be located behind the phantom.

ION-BEAM

Currently, protons at clinical energies have been commissioned to reach the research room at MedAustron, with ongoing work by the Therapy Accelerator group at MedAustron to bring carbon-ions into the research room.

Particle	Energy	# Particles	Spot Sizes
Proton	Min: 60 MeV	$\sim 1.8 \times 10^{10}$ particles/spill	Min: 7×7 mm^2
	Max: 250 MeV		Max: 20×20 mm^2
Carbon (C^{6+})	Min: 120 MeV/u	$\sim 4.5 \times 10^{8}$ particles/spill	Min: 6×6 mm^2
	Max: 400 MeV/u		Max: 10×10 mm^2

TABLE 1: Table of beam specifications which will be used for the SmartPhantom at MedAustron.

SIMULATION

Geant4-based simulations will guide the design of the SmartPhantom. Simulations will begin within the MedAustron High Energy Beam Transfer Line (HEBT) and track the beam through the medical nozzle and into the SmartPhantom. The results provide the number of scintillation hits and energy deposition in each scintillating fibre.

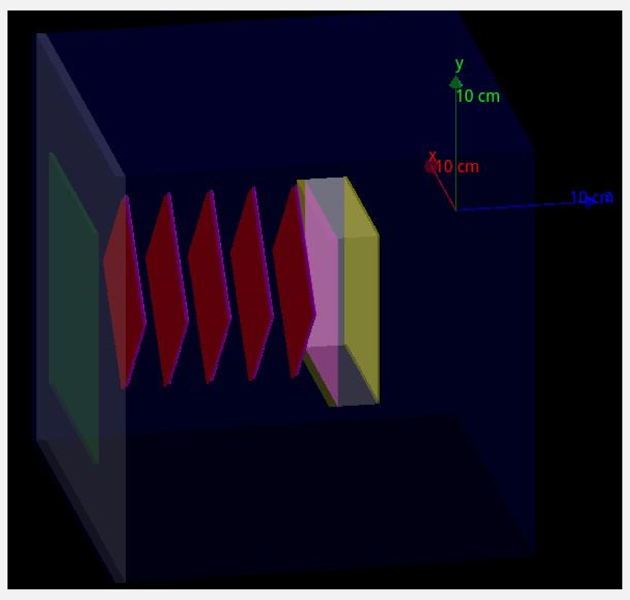

FIGURE 4: Visualization of the SmartPhantom in Geant4 with a beam incident from the left. The square in green represents the beam window, with the red and purple alternating layers representing the scintillating fibre stations, with a sample flask placed at the end.

The results of the simulations will also be used to develop the analysis scripts to fit a Bragg peak to the measurements and estimate the amount of dose delivered, LET, beam distribution and beam profile.

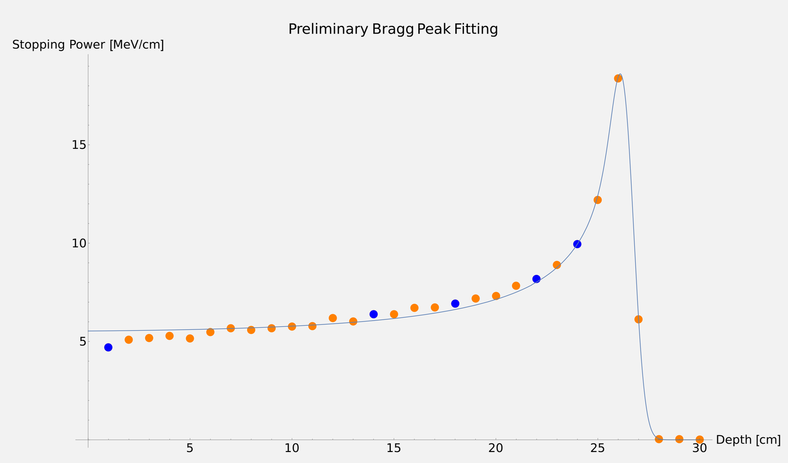

FIGURE 5: Example of fitting a Bragg curve [2] to simulated data of a 200 MeV proton beam through 30 cm of water. The points in blue were the data points used to perform a fit and the orange points represent the full dataset.

CONCLUSION

SmartPhantom was conceptualised in order to provide researchers information regarding the dose, beam distribution, and LET when a cell sample is irradiated by an ion-beam. The key emphasis is deriving these results from measurements taken shot-by-shot as opposed to being derived purely through Monte Carlo simulations.

[1] H. Paganetti, A. Niemierko, M. Ancukiewicz, L. E. Gerweck, M. Goitein, J. S. Loeffler, and H. D. Suit, "Relative biological effectiveness (rbe) values for proton beam therapy," *International Journal of Radiation Oncology*Biology*Physics*, vol. 53, no. 2, pp. 407 – 421, 2002.

[2] T. Bortfeld, "An analytical approximation of the bragg curve for therapeutic proton beams," *Medical Physics*, vol. 24, no. 12, pp. 2024–2033, 1997.