Numerical characterization of a novel ΔE-E telescope microdosimeter on ^{12}C beam lines

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Successful radiotherapy treatments with ^{12}C depend on accurate knowledge of the mixed radiation field, contaminated by nuclear fragmentation, and of the radiobiological effectiveness (RBE) of the beam and its components [1]. One of the proposed methods to calculate the RBE_{10} is the microdosimetric kinetic model (MKM) applied to measurements of microdosimetric spectra [2]. Unfortunately, detectors able to characterize the radiation field with sub-mm resolution and simultaneously measure microdosimetric spectra are not currently commercially available.

One such proposed devices, is the silicon-based ΔE-E telescope (Politecnico di Milano, Italy) [3], a $25\ \text{mm}^2$ detector composed of a $1.9\ \mu\text{m}$ thick ΔE stage and of a $500\ \mu\text{m}$ thick E stage. In a previous study, it was reported that the device could be used to characterize the radiation field produced by a $290\ \text{MeV/u}$ ^{12}C clinical beam at the HIMAC facility (Japan) with high spatial resolution, while simultaneously being able to measure microdosimetric spectra [4]. In that study, good agreement was found between experimental and numerical characterizations performed with a GEANT4 tool-kit.

In the present study, we report on the numerical modelling of the response of the ΔE-E telescope in a modulated (328.1 to $361.5\ \text{MeV/u}$) clinical ^{12}C scanning beam and in a low-energy monochromatic ($5.95\ \text{MeV/u}$) ^{12}C beam. The first beam line was modelled after that at the CNAO facility (Pavia, Italy), while the second one was modelled after that at the 14UD facility at ANU (Canberra, Australia). The latter study is an important step in the quest for a comprehensive understanding of the side effects of particle therapy, its significance stemming from the information it provides on the fragments present in the distal part of the Bragg Peak. Simulations were performed adapting the application originally developed in [4], and adopting EM option 3 to model electromagnetic physics and QMD to model ion physics [5].
We show that, owing to its potential for distinguishing different fragments in a mixed radiation field produced by clinical and low-energy ^{12}C beams, the ΔE-E telescope can be used for sub-mm resolution measurements of microdosimetric spectra both in- and out-of-field. Spectra were obtained by correcting for tissue equivalence the energy distribution imparted in silicon, as recently suggested in [6]. In the future, numerical results will be compared to experimental data currently being collected.

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