Calculation of the physical proximity function t(x) for electrons, protons and carbon ions using Geant4.

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When a same quantity of energy is transfered to a biological medium, strong difference in the effects can be observed, if this energy is transfered by high or low-LET (Linear Energy Transfer) particles. This difference is mainly due to the track structure geometry and to the more substantial density of energy deposit in the case of high LET particles. This leads to complex DNA damages, much more difficult to repair by the cell. Therfore, a spatial distribution of energy seems more relevant to characterize the energy deposits in the medium, for biological purposes. Lea's work on the formation of chromosome aberrations have led to the " Dual Radiation Action " theory. In this theory, Lea suggested that the final biological "lesions" were formed by the interaction of pair of "sublesions" issued from the initial energy transfer in the medium. Later on, Kellerer and Rossi[1] proposed a general formulation of this theory using the concept of proximity functions. In their formulation, Kellerer and Rossi expressed the average number of lesions as the integral of the product of two functions: the physical proximity function t(x) that characterizes the microdosimetric distribution of energy transfers in a medium, and the biological proximity function that characterizes the biological system (cell).

In this work we calculate the physical function t(x) for electron, proton and carbon tracks simulated in water with a low energy package of the Geant4 Monte Carlo toolkit. This version of Geant4 (Geant4DNA) includes specific physical processes for low energy protons and electrons. In addition, carbon tracks are calculated by scaling with Z^2eff (carbon effective charge) the proton total cross section in water. The function t(x) is thus calculated for electron tracks of 125 eV, 1 KeV and 10 KeV, and compared to Chen and Kellerer [2] results. The function t(x) is also calculated for 0.5, 5 and 20 MeV protons and for 5 and 20 MeV/n carbons. The characteristics of this function are then analysed and discussed. Finally, the variation of the dose mean lineal energy depending on the size of the sensitive site is deduced from t(x).

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[1]:A. M. Kellerer and H. H. Rossi, A generalized formulation of dual radiation action. Radiat. Res 75, 471-488 (1978).

[2]: J. Chen and A. M. Kellerer, Proximity Functions for electrons from 100 eV to 10 MeV. Rad. Prot. Dos. 122, 1-4, pp 56-60 (2006).

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