Estimation of energy imparted from ionization-based measurements at the nanometer scale

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Background: Microdosimetric measurements of energy imparted are generally performed by means of ionization-based techniques, using the W-value (i.e., the mean energy expended in a gas per ion pair formed) as conversion factor. However, when the site size is below 100 nm, this procedure fails [1]. This work aims therefore at defining an alternative procedure to calculate the energy imparted from measurements of the ionization yield, applicable when the site size is as small as 1 nm. Since calorimetric techniques cannot be applied at the nanometer scale, this problem can be studied by Monte Carlo simulations only.

Material and Methods: Simulations were done with the Geant4-DNA track structure code [2], using the Physics List "Option 4". Liquid water spheres with diameter 1, 10 and 100 nm were uniformly irradiated by a beam of either protons or carbon ions with energy 1, 10 or 100 MeV/u. The beam diameter was two times that of the sensitive sphere. At the passage of each primary ion, both the energy imparted and the number of ionizations were scored. The ratio of the mean energy imparted and the mean ionization yield was calculated and defined as new conversion factor $\tilde{\omega}$. Variations of $\tilde{\omega}$ were studied as a function of volume size, particle type and energy.

Preliminary results: As it can be seen in Table 1, the ratio $\tilde{\omega}$ depends only weakly on particle type (the difference between protons and carbon ions is about 7%), while the dependence on ion energy is negligible (less than 1%). The dependence on sensitive volume size is stronger: $\tilde{\omega}$ increases up to 17% if the sphere size increases from 1 nm to 100 nm. In this respect, the different contribution of secondary electrons plays a crucial role.

SV diameter	Protons	Carbon ions
1nm	19.6 eV	18.3 eV
10nm	23.0 eV	21.4 eV
100nm	23.0 eV	21.7 eV

Table 1: values of the ratio $\tilde{\omega}$ for different primary beams and sphere sizes.

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