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Towards parameter-free nanodosimetric quantities in the impact of highly ionizing radiation

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Cosmic Rays, in particular the high charge and high energy (HZE) particles and eventual secondary low energy protons, are high Linear Energy Transfer (LET) radiation, i.e. they transfer a high amount of energy to the target per unit path length travelled in the target itself, leaving behind a dense track of ionization and atomic excitations. Understanding the radiation physics and the biology induced by the impact of high LET radiation is of importance for different fields of research, such as radiation therapy with charged particles, space radiation protection of astronauts and of human explorers on Mars and eventually also survival of any bacterial, plant cell on other planetary/small bodies. While data for low LET radiation such as X-ray have been studied in the survivors of the atomic-bombs, medical patients and nuclear reactor workers, for high LET radiation there is no relevant collection of human data for risk estimates, and experiments with nuclei created at accelerators are necessary.

At present we still do not have an understanding of how the radiation interaction with a single nanometric target (units of DNA), the so-called track structure [1], should decide the fate of the irradiated cell. Monte Carlo (MC) track structure codes essentially work only with the physics given by impact cross sections on the sole water, there is no real consideration of the electronic/chemical characteristics of the hosted biomolecule [2]. Limitations given by such an approach have been highlighted [3], but on the positive side a massive effort is being done to follow the different steps of radiation effects up to biological damage [4].

In this contribution we would like to highlight how a chain of models from different communities could be of help to study the radiation effects on biomolecules. In particular, we will present how ab-initio (parameter-free) approaches from the chemical-physics community can be used to derive in detail the energy loss of the impacting ions/secondary electrons on water and small biological units [5,6], either following in real time the ion or based on perturbative theories for low energy electrons, and how the derived quantity can be given as input to Monte Carlo track structure codes, extending their capabilities to different relevant targets. Given the physical limitations and high costs of irradiation experiments, such calculations offer an efficient approach that can boost the understanding of radiation physics and consolidate existing MC track structure codes.

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