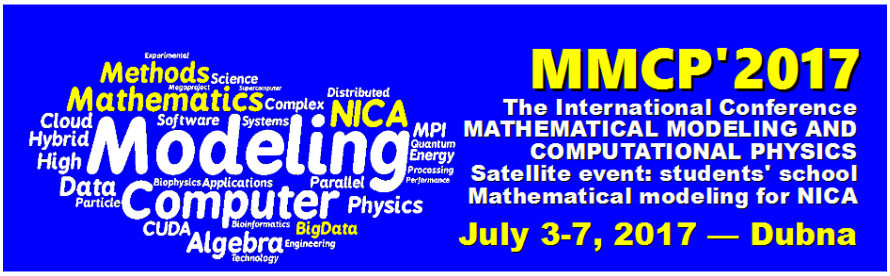

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Simulation of radiation damage to neural cells

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Radiation damage to the central nervous system (CNS) has been an on-going challenge for the last decades primarily due to the issues of brain radiotherapy and radiation protection for astronauts during space travel. Although recent findings revealed a number of molecular mechanisms associated with radiation-induced impairments in behaviour and cognition, some uncertainties exist in the initial neuronal cell injury leading to the further development of CNS malfunction. As usual, these initial stages of neuronal injury are hardly accessible to experimental measurements. Many events cannot be investigates experimentally at all. In this regard, development of computation methods for assessing these early stages of radiation damage to CNS is of great interest.

To help in understanding the physical and biological mechanisms underlying effects of cosmic and therapeutic types of radiation on CNS, we have developed an original microdosimetry application based on the Monte-Carlo Geant4 toolkit, in particular, its biophysical extension of Geant4-DNA [1, 2]. The applied simulation technique provides a tool for simulation of physical, physico-chemical and chemical processes (e.g. production of water radiolysis species in the vicinity of neurons) in realistic geometrical model of neuronal cells exposed to particle radiation. The present study is performed to evaluate microscopic dose depositions and water radiolysis species yields within a detailed structure of individual neurons taking into account such cell components as soma, dendrites, axon and spines. To demonstrate benefits of the developed approach, the calculations were made for proton, 12C and 56Fe of different energy within a relatively wide range of linear energy transfer values from a few to hundreds of keV/μm. Simulation results indicate that the neuron morphology is an important factor determining the accumulation of microscopic radiation dose and water radiolysis products in neurons. The estimation of the radiolytic yields in neural cells suggests that the observed enhancement in the levels of reactive oxygen species may potentially lead to oxidative damage to neuronal components disrupting the normal communication between cells of the neural network.

[1] M. Batmunkh, O.V. Belov, L. Bayarchimeg, O. Lkhagva, N.H. Sweilam, Estimation of the spatial energy deposition in CA1 pyramidal neurons under exposure to 12C and 56Fe ion beams, // J. Radiat. Res. Appl. Sci. 2015. 8:498-507.
[2] O.V. Belov, M. Batmunkh, S. Incerti, O. Lkhagva, Radiation damage to neuronal cells: Simulating the energy deposition and water radiolysis in a small neural network // Physica Medica 2016. 32:1510-1520.

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