Educational project

Computer Modeling of Radiation Biophysics using the Geant4

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1. Description of the project

The study of biological risks from therapeutic radiations for brain tumors and galactic cosmic rays to cosmonauts during space travel is challenging topic in modern radiation research, as well as radiobiology. Computer simulation of radiation transport in biological structures with the use of Monte Carlo techniques can be of great help in order to predict and understand damaging actions of charged particles including protons, alpha particles and heavy ions. This project presents for simulation of stochastic nature of particle track structure in biomolecules and cells at the physical, physico-chemical and chemical stages, and calculation of early radiation damage using the Geant4/Geant4-DNA Monte Carlo toolkits [1]. Frequency distribution of energy deposition in nano/micro-meter targets provides a method of interpretation of initial mechanisms of radiation effects at the molecular and cellular levels.

2. Purpose of the project

The aim of the presented project is to enable all students to gain practical experience and modern methods of computer simulations in radiation biophysics, and with a better understanding of nanodosimetry and microdosimetry calculation techniques using Geant4-DNA models. Practical work of students is related with investigation of initial DNA damage induced by space radiation with different qualities.

3. Short description of the practical work

1. Track structure simulation of physical, physico-chemical and chemical stages of charged particle interactions with biological media: spatial distribution of energy depositions, interaction types (ionization, excitation, elastic scattering, charge changes, etc.), and diffusion of water radiolysis.
2. Scoring energy and dose depositions, counting ionizations and free radicals in sensitive targets of cells caused by different types of ionizing radiation.
3. Modeling complex geometry of DNA molecules and cells.
4. Estimating clustered DNA lesions following exposure to charged particles with different linear energy transfers (LET).
5. Analyzing and comparing simulation results with experimental data (published).

4. Enter requirements

1. Basic knowledge of the physics of ionizing radiation interaction with matter and biological tissues.
2. Experience in computer simulation.

5. An example of particle track structures in biological media

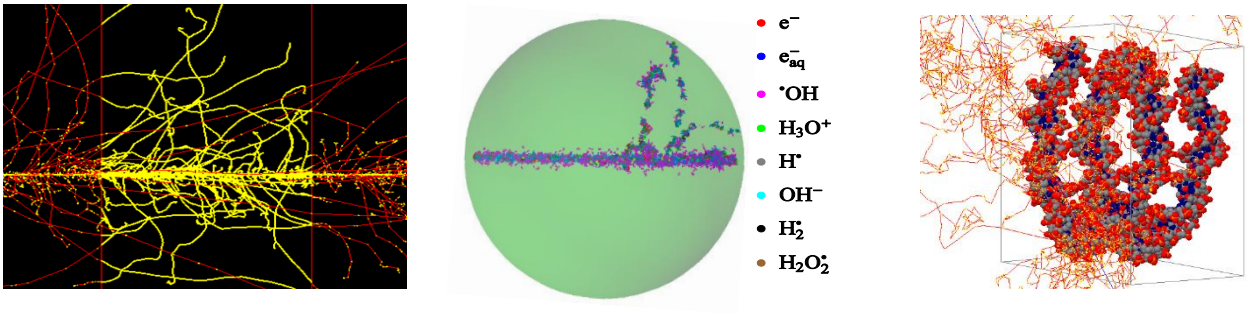

Figure 1. A track segment of 600 MeV/u iron ion in liquid water of 200 μm (left). Diffusion of water radiolysis in solid sphere of 200 nm (medium). Energy depositions in a segment of DNA nucleosome of 20 nm (right).

6.The number of participating students is limited to 4.

7. References

1. GEANT4 HOME PAGE and http://geant4-dna.org/ .
2. M. Batmunkh et al., "Cluster Analysis of HZE Particle Tracks as Applied to Space Radiobiology Problems", Particles and Nuclei Letters, 2013, 10(184):854-859. DOI: 10.1134/S1547477114010075.
3. L. Bayarchimeg et al., "Simulation of radiation damage to neural cells with Geant4-DNA", EPJ-WoC, 2017, 173(2):05005. DOI: 10.1051/epjconf/201817305005.

8. Contacts of the project coordinators

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