

The Geant4-DNA project: overview and status

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Understanding and prediction of adverse effects of ionizing radiation at the cellular and sub-cellular scale remains a challenge of today's radiobiology research. In this context, a large experimental and modeling activity is currently taking place, aimed at better understanding the biological effects of ionizing radiation at the sub-cellular scale. The "Geant4-DNA" project was initiated by the European Space Agency [1]. It aims to develop an experimentally validated simulation platform for the modeling of early DNA damage induced by ionizing radiation, using modern computing tools and techniques. The platform is based on the general-purpose and open-source "Geant4" Monte Carlo simulation toolkit, and benefits from the toolkit's full transparency and free availability [2].

This project proposes to develop specific functionalities in Geant4 allowing:

1) The modeling of elementary physical interactions between ionizing particles and biological media, during the so-called "physical" stage.

2) The modeling of the "physico-chemical and chemical" stages corresponding to the production, the diffusion and the chemical reactions occurring between chemical species. During the "physico-chemical" stage, the water molecules that have been excited and ionized during the physics stage may de-excite and dissociate into initial water radiolysis products. In the "chemical stage", these chemical species diffuse in the medium surrounding the DNA. They may eventually react among themselves or with the DNA molecule.

3) The introduction of detailed biological target geometry models, where the two above stages are combined with a geometrical description of biological targets (such as chromatin segments, cell nuclei...). The Geant4-DNA physics processes and models are fully integrated into the Geant4 toolkit and can be combined with Geant4 geometry modeling capabilities. In particular, it becomes possible to implement the geometry of biological targets with a high resolution at the sub-micrometer scale and fully track particles within these geometries using the Geant4-DNA physics processes. These geometries represent a significant improvement of the geometrical models used so far for dosimetry studies with the Geant4 toolkit at the biological cell scale.

The current status of the project will be presented, as well as on-going developments.

[1] S. Incerti et al., "Comparison of Geant4 very low energy cross section models with experimental data in water", *Med. Phys.* **37**, 4692-4708 (2010)

[2] S. Agostinelli et al., "Geant4-a simulation toolkit", *Nucl. Instrum. Methods. Phys. Res. A.* **506**, 250-303 (2003)