



HAL
open science

Requirements of modelling tools for the understanding of radiation-induced biological damage at the cellular level

Yann Perrot, Carmen Villagrasa

► **To cite this version:**

Yann Perrot, Carmen Villagrasa. Requirements of modelling tools for the understanding of radiation-induced biological damage at the cellular level. Technical Meeting on New Trends and Advances in Microdosimetry and its Applications (Virtual Event), AIEA, Oct 2020, Vienne (E-conference), Austria. irsn-04134012

HAL Id: irsn-04134012

<https://irsn.hal.science/irsn-04134012v1>

Submitted on 20 Jun 2023

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



Distributed under a Creative Commons Attribution - NonCommercial - NoDerivatives 4.0 International License

Requirements of modelling tools for the understanding of radiation-induced biological damage at the cellular level.

Yann Perrot*¹ and Carmen Villagrasa*¹

¹ Institut de Radioprotection et de Surêté Nucléaire.31, Av. du général Leclerc. B.P. 17. 92262 Fontenay aux Roses Cedex. France

*Members of the Geant4-DNA collaboration: <http://geant4-dna.org/>

Introduction:

Modelling the biological impact of the effect of ionizing radiation is of crucial importance for understanding the mechanisms involved but also for exploring the consequences of complex exposures. Our group at the French Institute for Radioprotection and Nuclear Safety (IRSN) is working on the development of a method in order to improve knowledge of the risks of complications during radiotherapy treatments. It combines a Track Structure Monte Carlo (TSMC) simulation tool of the interactions of ionizing radiation and radiolytic species [1] based on Geant4-DNA [2, 3, 4, 5] with a multi-scale modeling tool of the exposed cell population based on new functionalities implemented in the DNAFabric software [6]. The benchmarking with experimental data [7] and the integration of mathematical functions derived from experimental biological data on cell fate in a broad sense is ongoing. As with any modeling tool, continuous benchmarking is required to adapt to improvements in the simulation codes involved or to the availability of experimental data.

Materials and Methods:

DNAFabric was first developed to generate geometrical models of nuclear DNA that can be exported to Geant4-DNA (TSMC) with the intention to be able to calculate the amount of early DNA damage (direct and indirect) within a particular nucleus for a given radiation quality. The parameterization of the simulation is carried out in accordance with the available experimental data. This tool was then extended to provide the essential framework for modeling the fate of a cell layer from the early simulated early DNA damage as well as other biological data that may be relevant.

Results:

As a first step, we will show how our simulation could be benchmarked against experimental data for induction of early radiation-induced DNA damage up to some biological endpoints (survival, DSBs repair). Improvements under development will be presented: more refined target geometries, new methods for modelling the chemical stage (Independent Reaction Time method based), inclusion of the cellular layer. Each element being a source of uncertainty, it will make it possible to present the prerequisites for benchmarking in general terms. Nevertheless, we will see that a complete benchmark must be based on experimental data obtained under controlled conditions.

Conclusion and perspectives:

Modeling tools of the risks for ionizing radiation effects are indispensable to better anticipate the effects of ionizing radiation on living organisms. With the example of DNAFabric new feature developments, we emphasize the indispensable and obvious complementarity of experimental and modelling activities. Developments of each activity must be linked. To achieve this, the standardization of experimental and simulation data should be the first prerequisite.

References:

- [1] Meylan, S., et al., 2017. Simulation of early DNA damage after the irradiation of a fibroblast cell nucleus using Geant4-DNA. *Scientific Reports*, 7(1), 11923.
- [2] Incerti, S., et al., 2018. Geant4-DNA example applications for track structure simulations in liquid water: a report from the Geant4-DNA Project. *Medical Physics*, 45, e722-e739

- [3] Bernal, M. A., et al., 2015. Track structure modeling in liquid water: A review of the Geant4-DNA very low energy extension of the Geant4 Monte Carlo simulation toolkit. *Physica Medica*, 31, 861-874
- [4] Incerti, S., et al., 2010. Comparison of Geant4 very low energy cross section models with experimental data in water. *Medical Physics*, 37, 4692-4708.
- [5] Incerti, S., et al., 2010. The Geant4-DNA project. *International Journal of Modeling, Simulation, and Scientific Computing*, 1, 157–178.
- [6] Meylan, S., et al., 2016. Geant4-DNA simulations using complex DNA geometries generated by the DnaFabric tool. *Computer Physics Communications*, 204, 159-169.
- [7] Tang, N., et al., 2019. Assessment of Radio-Induced Damage in Endothelial Cells Irradiated with 40 kVp, 220 kVp, and 4 MV X-rays by Means of Micro and Nanodosimetric Calculations. *International Journal of Molecular Sciences*, 20(24), 6204.