Monte Carlo simulations of microdosimetry and radiolytic species production for preclinical proton beam using GATE and Geant4-DNA as part of the FLASHMOD project

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Background: In FLASH radiotherapy (dose rate > 40 Gy/s) healthy tissues appear to be spared while the anti-tumor efficiency is maintained. The FLASHMOD project aims to develop an end-to-end environment for ARRONAX 68 MeV proton beam in ultra-high dose rate (UHDR) conditions: dosimetry, microdosimetry, physico-chemistry and radiobiology studies.
Monte Carlo track structure codes have an important role to play in the understanding of radiolysis mechanisms involved at UHDR.
Material and Methods: ARRONAX cyclotron enables the production of macro-pulses of proton bunches with mean dose rate ranging from 0.2 Gy/s (100 Hz, pulse dose rate about 1 Gy/s) to 60000 Gy/s (single macro-pulse).
The beamline has been modeled with the GATE platform. Simulated dose distributions were validated through comparisons with experimental measurements.
A Geant4-DNA example application named "UHDR" (under development and to be released soon) has been tested using a long-time reaction scheme to model water radiolysis at different dose rates in aerated and de-aerated conditions.
N_2O scavenger reactions were added to the code to study the impact of solvated electrons.
Fricke dosimeter was also modeled implementing the reactions involving iron and water radiolysis products.
Preliminary results: Simulations were conducted to take into account intertrack reactions between chemical species that may affect water radiolysis chemistry in UHDR irradiation. A preliminary comparison to experimental results is proposed.