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Microtrack: the new Geant4 example for calculations on microdosimetry.

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The spatial distribution of energy deposition events produced by the different types of ionizing radiation is a key factor to determine their radiobiological effects at the cellular scale. The theoretical framework provided by microdosimetry has been widely employed to describe these stochastic interactions, particularly in studies addressing the characterization of Linear Energy Transfer (LET) and Relative Biological Effectiveness (RBE) of ion beams in the context of hadron therapy. Such quantities are typically calculated through Monte Carlo simulations.

To fulfill the purpose of calculating these energy distributions, a new track-structure Monte Carlo application has been developed to incorporate it as a new Geant4-DNA example of the Geant4 toolkit. The code, named Microtrack, is designed to study the energy deposition in spherical sensitive volumes, known as sites, whose diameter sizes may vary from nanometer to micrometer scale. These sensitive volumes are sampled within a cubic water volume. This geometry is defined by two input parameters: the site radius and the maximum electron range.

A flexible primary generator controls particle type (protons by default), energy, and beam source position, enabling reproducible irradiation setups relevant to microdosimetry, LET and RBE studies.

Scoring is implemented through a dedicated sensitive detector that records per-step energy deposition and aggregates event-level observables. Simulation outputs are handled by the Geant4 analysis manager and written to a ROOT file, containing useful histograms for the aforementioned studies, including distributions of single-event energy imparted up to the second moment to calculate weighted quantities such as dose-mean lineal energy.

Microtrack emphasizes transparency and flexibility: default options, such as the volume material, particle, beam energy, or physics list, can be modified through Messenger classes and macro files, while multithreading enables faster simulations by distributing runs across multiple threads and merging results.

In summary, the future Geant4-DNA example Microtrack constitutes a versatile Monte Carlo tool for the calculation of microscopic energy deposition patterns and assists research on microdosimetry for hadron therapy.

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