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THE APPLICATION OF GEANT4 SIMULATION CODE FOR BRACHYTHERAPY TREATMENT

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ABSTRACT

Brachytherapy is a radiotherapeutic modality that makes use of radionuclides to deliver a high radiation dose to a well-defined volume while sparing surrounding healthy structures. At the National Institute for Cancer Research of Genova a High Dose Rate remote afterloading system provides ^{192}Ir endocavitary brachytherapy treatments.

We studied the possibility to use the Geant4 Monte Carlo simulation toolkit in brachytherapy for calculation of complex physical parameters, not directly available by experimental measurements, used in treatment planning dose deposition models.

1 What is brachytherapy?

Brachytherapy is a medical therapy used for cancer treatments in which radioactive sources are used to deposit therapeutic doses near tumors while preserving surrounding healthy tissues.

Our μSelectron HDR brachytherapy unit uses an ^{192}Ir source for endocavitary treatments. To have a certain dose distribution in the target volume the source moves along catheters inserted in natural cavities of the body e.g. vagina or bronchi.

Fig.1 shows a typical dose distribution of an intra-uterine treatment with source moving along three catheters (obtained with PLATO [1] treatment planning brachytherapy system).

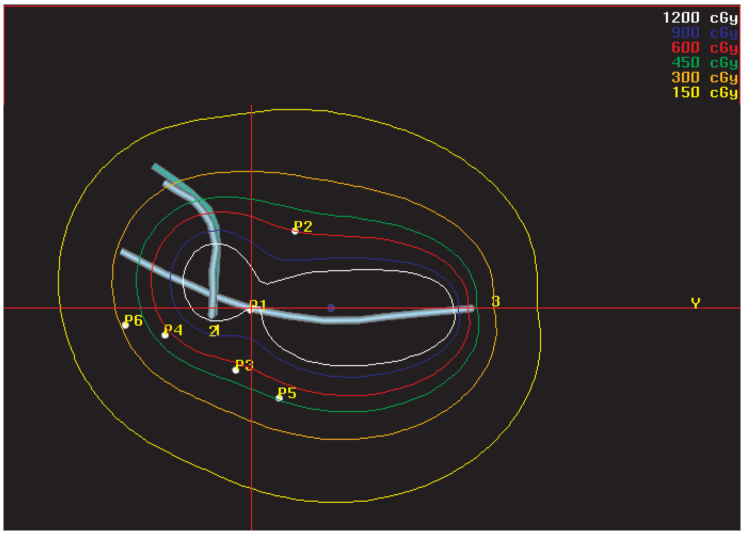

Figure 1: *Isodose distribution for an intra-uterine treatment.*

2 Monte Carlo simulation in brachytherapy

Monte Carlo simulation code applied in brachytherapy can give an important help in the clinical practice. It can enhance dose calculation with:

- computation of dose deposition kernels for treatment planning dose calculation algorithms based on convolution/superposition methods;
- separation of primary, first scatter and multiple scatter components for complex dose deposition models;

- simulation of other complex model-dependent parameters. e.g. the anisotropy function;
- accurate calculation of dose deposition in high gradient regions.

In addition Monte Carlo simulations have proven to be very useful to verify experimental calibration procedures.

3 The Geant4 Simulation Toolkit

The Geant4 Toolkit [2] is a general purpose Monte Carlo code for the simulation of the passage of particles through matter. It provides a wide set of tools to address the various domains of simulation: geometry and material description, particles tracking within any geometry, material and field, run, event and track management, an ample variety of physics processes over an extended energy range, response to particle interactions, visualisation and user interface.

Geant4 provides various features relevant for medical applications:

- the Object Oriented design allows to achieve the transparency of physics, therefore contributing to the validation of the results, that is of fundamental importance in such sensitive applications as the medical ones;
- the code is freely available from a public distribution source;
- a large international Collaboration is responsible for the development and maintenance of the code and for the user support;
- the toolkit relies on the use of standards, both ISO and de facto ones;
- the code is independent from any system of units;
- the toolkit does not depend on any external software packages, but can be interfaced to a variety of software tools, such as graphic drivers, object databases, histogramming and analysis packages etc.;
- evaluated physics databases, acknowledged as the state of the art in their domain, are utilized.

Powerful and unique physics functionalities of medical interest are available in Geant4, such as extensions of electromagnetic interactions [3] down to low energies (250 eV for electrons and photons, < 1 KeV for hadrons and ions) [4, 5, 6], a module to handle the full radioactive decay chain [7], an abundant set of hadronic processes and models, a package of neutron physics interfaced to all the available evaluated neutron databases.

4 Our simulation results

We have simulated dose energy deposition in water considering the full geometry (core + capsule) of our ^{192}Ir source and a simplified photon spectrum model in which photon energy is equal to the mean energy (356 keV).

We consider:

- the simulated source placed at the center of a 30 cm water box;
- dose deposition investigated in the longitudinal plane;
- plane partioned in 1 million 1 mm^3 voxels.

We generate a minimum of 10 millions photons on the 4π solid angle. The dose deposition is not isotropic due to source geometry and auto-absorbtion, encapsulation and shielding effects. In fig.2 there is our simulated anisotropy distribution at 6 cm axial distance.

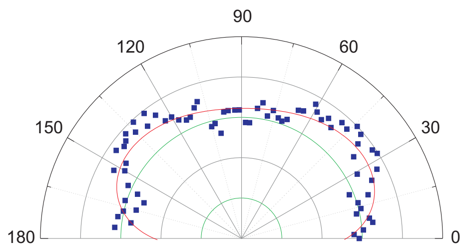

Figure 2: *Simulated anisotropy function at 6 cm.*

From our simulation we also obtain isodose distribution in the longitudinal plane. Fig.3 shows 100% and 50% isodoses.

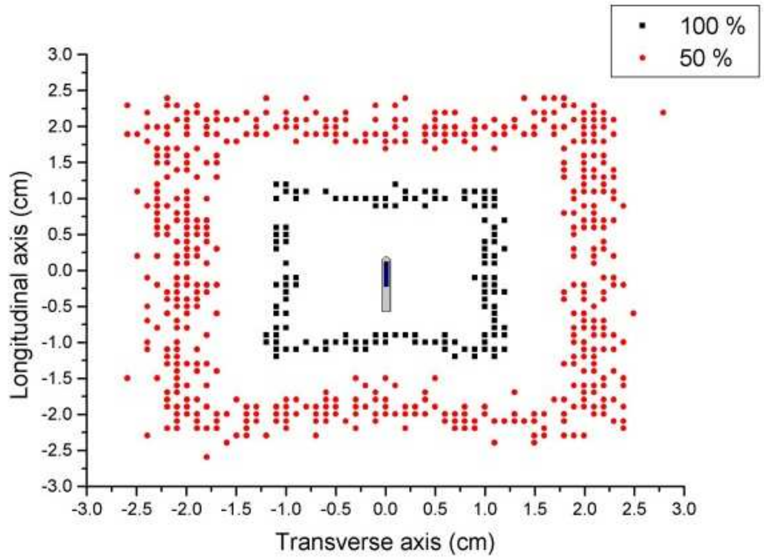

Figure 3: *Simulated isodose distribution.*

5 Acknowledgements

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