CALCULATION OF THE ABSORBED DOSE IN PHANTOMS USING THE DOSXYZNRC SOFTWARE PACKAGE

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Abstract. *Based directly on the DOSXYZ code created for the EGS4 code system, DOSXYZnrc is a Monte Carlo simulation code for determining dose distributions in a rectilinear voxel phantom. The OMEGA-BEAM system of codes created at NRC includes DOSXYZnrc. Every voxel may have a different density and substance. A variety of beams, including complete phase-space files from BEAMnrc and beams described using Beam Characterization models, may be incident on the phantom. A CT data set of Hounsfield numbers may be read in and converted by the companion application ctcreate into the details required by DOSXYZnrc to simulate transport in a phantom (i.e. the appropriate material and density are specified in each voxel)[1]. This CT phantom can be incident on any of the available beams. The code has a restart feature and may be executed on platforms for parallel computing.*

Keywords: *Monte Carlo, phantom, absorbed dose, simulation, dose distribution, shielding.*

Introduction

It is known that one of the most important factors of radiation therapy is the destruction of a malignant tumor and the protection of healthy tissues from radiation. Excessive exposure to radiation leads to the destruction of living tissues in the body. Therefore, various protective devices are used to avoid radiation. According to the ALARA principle, protection is based on three principles: time, distance and shielding[1].

DOSXYZnrc is the Monte Carlo code. Its general purpose is to calculate the absorbed radiation dose in three dimensions. EGSnrc/DOSXYZnrc models the transport of photons and electrons in Cartesian coordinates and calculates the energy distribution in given voxels. This program works in a semi-offline mode and allows saving the dose distribution in ASCII format. There is also a graphical user interface (GUI) that allows us to create input files in graphical mode[2].

Theory

A common batching method was used to do the statistical analysis in the original DOSXYZ code. The statistics on the doses are calculated starting with DOSXYZnrc by grouping scored quantities (i.e., energy deposited) on a history-by-history basis, and then figuring out the uncertainties. For the majority of sources, this only entails classifying quantities by incident particle. Quantities are classified by primary history for phase space sources, when it is possible to link several incident particles to a single primary history. It's important to point out that the technique utilized considers the latent variance in any phase space file being used as a source (i.e. the uncertainty introduced by the statistical variations in the phase space file)[1].

As a result, repeatedly recycling the data won't be able to lower the uncertainty in any dosage calculation below that threshold. If the phase space source is permitted to restart the phase space file instead of using the recycle option, the statistical result will be artificially low and overlook this latent variation. Restarting the phase space file should thus be avoided in order to get correct uncertainty estimations[1].

The following rules should be followed for radiation protection.

The principle of justification. Any alteration brought on by radiation exposure ought to be beneficial rather than detrimental.

The principle of protection optimization. When taking into account economic and social aspects, the likelihood of exposure, the number of people exposed, and the size of each individual dosage should be as low as possible.

The principle of using the dose limit value. When radiation exposure is intended, the overall dose that people receive from regulated sources shouldn't be more than the stated limit value.

To protect against ionizing radiation, you need to know the following characteristics of the source[3]:

- radiation type (n, p, γ, β)
- geometric parameters of the radiation source:
  - point - the size of the source, very small ($\square \ll \square$) than the distance from it to the target
  - linear - $d \ll L$
  - surface - $d \ll S$
  - volumetric - $d \approx r$
- source power - Q (particles/sec per point charge)

Model

The distribution of doses produced when a 25 MeV electron beam strikes a tantalum plate has been studied using the DOSXYZnrc software program. To do this, the input file contained the principal dimensions, beam attributes (source), medium parameters (medium), and geometric dimensions of the phantom (geometry).

Figure 1: Choosing the beam's settings

```
###############################################
#### SOURCE
###############################################
:start source definition:
    :start source:
        name = pencil_beam
        library = egs_parallel_beam
        charge = -1
        direction = 0 0 1
        :start spectrum:
            type = monoenergetic
            energy = 25 #MeV
        :stop spectrum:
        :start shape:
            type = point
            position = 0 0 -10 #cm
        :stop shape:
    :stop source:

    simulation source = pencil_beam
:stop source definition:
```

Figure 2: The phantom's geometrical characteristics

```
##########################################
#### GEOMETRY
##########################################
:start geometry definition:
    :start geometry:
        name = slab
        library = egs_ndgeometry
        type = EGS_XYZGeometry
        x-planes = -5, 5 #cm
        y-planes = -5, 5 #cm
        z-planes = -10, 0, 0.1, 10 #cm
        :start media input:
            media = vacuum tantalum
            set medium = 1 1
        :stop media input:
    :stop geometry:

    simulation geometry = slab

:stop geometry definition
```

The monochromatic beam with a 25 MeV energy is shown in Figure 1. The source is decided upon as a point source.

Since we are aware that the rest energy of electrons is 511 keV, the minimum value for the total energy of electrons was established at 521 keV. The "medium" or "carrier" is made of tantalum plates. The program automatically selects density values for tantalum, lead, and water from the NGS library.

Figure 3

Setting up the media.

```
####################################################################################
#### MUHIT
####################################################################################
:start media definition:
    ae = 0.521 #elektronlar uchun minimal energiya, kinetik energiya + 0.511 (MeV)
    ap = 0.01 #fotonlar uchun minimal energiya (MeV)
    ue = 50.511 #elektronlar uchun maksimal energiya, kinetik energiya + 0.511 (MeV)
    up = 50 #fotonlar uchun maksimal energiya


#### Tantal
:start tantal:
    density correction file = tantalum
:stop tantalum:


#### Qo`rg`oshin
:start qo`rg`oshin:
    density correction file = lead
:stop qo`rg`oshin:


#### Suv
:start suv:
    density correction file = water_liquid
:stop suv:

:stop media definition:
```

When all the necessary information had been supplied, the program was launched by entering the following command in the terminal:

```
$myapp -i slab.egsinp
```

Figure 4. The simulation.	Figure 5. Dose distribution on a tantalum plate.

Results and conclusions

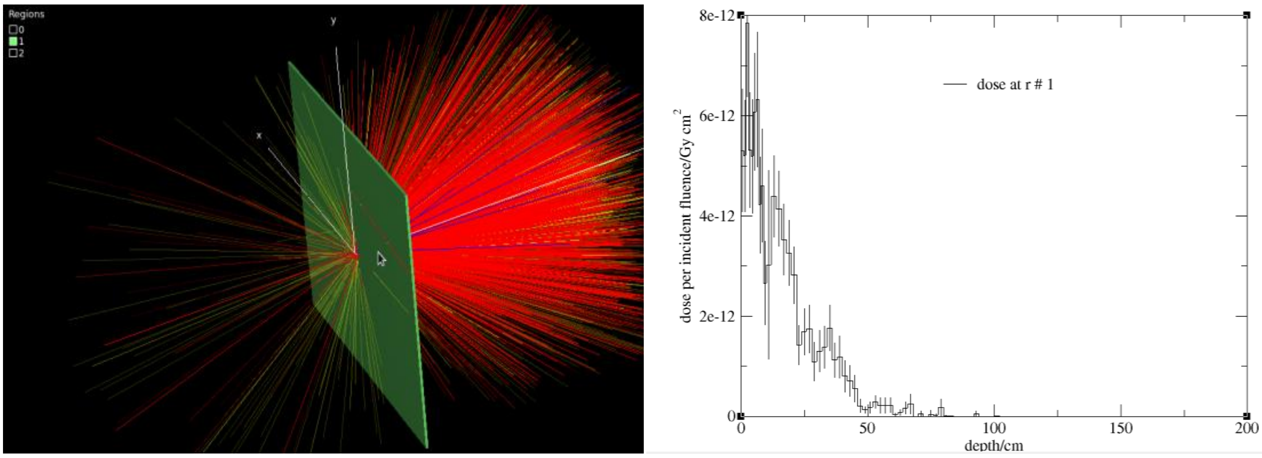

Figure 6.

The value of the radiation dose generated on the tantalum plate.

```
==> Summary of region dosimetry (per particle)
ir medium rho/[g/cm3] V/cm3 Edep/[MeV] D/[Gy]
---------------------------------------------------------------------------
1 tantalum 16.654 10.0000 2.5506e+00 +/- 1.828 % 2.4535e-12 +/- 1.828 %
---------------------------------------------------------------------------
```

After running the simulation, a graph was drawn using the xmgrace program based on the obtained results (Figure 5). As can be seen from the graph, the absorbed radiation dose is higher near the surface of the plate.

The energy delivered to the tantalum plate was equal to 2.5506 ± 1.828% MeV, and the absorbed radiation dose was equal to 2.4535 × 10−12 ± 1.828% Gy (Fig. 6). It means that it is possible to use a beam of electrons to destroy cancer cells located close to the surface of the skin [4].

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