International Journal of Innovation and Applied Studies
ISSN 2028-9324 Vol. 6 No. 3 July 2014, pp. 635-641

http://www.ijias.issr-journals.org/

Implementation of the EGSnrc / BEAMnrc Monte Carlo code - Application to medical accelerator SATURNE43

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ABSTRACT: The Monte Carlo method is the most accurate method for the simulation of radiotherapy equipment. Linear accelerator (Linac) is currently the most widely used in radiotherapy center's machines. In this work we run the Monte Carlo code EGSnrc under the platform BEAMnrc to calculation of important photon beam parameters by modeling the head of the linear accelerator SATURNE43.The aim of this study was to calculate the dosimetric functions, namely: the dose profile and Percentage depth dose (PDD) for a 12 MV photon beam generated by Linac SATURNE43 and delivered in a water phantom. Photons are generated by the bremsstrahlung effect of electrons during interaction with the tungsten target. All calculations are done by considering a square field dimension 10x10cm² at a depth z = 100 cm from the target. Analysis of the data stored in the phase space is performed and photons spectrum is extracted. The PDD and the 10cm depth dose profile distributions are compared to experimental data by the Monte Carlo code EGSnrc under the platform BEAMnrc. A good agreement is obtained for both distributions and a reasonable computing time is obtained by use of the following fundamental parameters of the simulation: ECUT = 0.4MeV, PCUT = 0.12MeV, FWHM = 0.17cm and ESAVE = 1MeV.

KEYWORDS: SATURNE43, Monte Carlo, EGSnrc, dose distribution, TPS.

1 INTRODUCTION

The aim of using external radiotherapy in cancer treatment using high radiation doses from photon or electron beams. Healthy tissues and organs at risk surrounding the tumor should be preserved during treatment by the optimization of the irradiation parameters using a convenient Treatment Planning System (TPS).

However, a quality control program should be implemented to compare the results provided by the TPS with experimental data. The experimental data are obtained by measurement of dosimetric parameters such as dose profile and percentage depth dose (PDD) [8].

There are innumerable dosimetry techniques already available that compare experimental results with Monte Carlo simulations. Also the precise prediction of the absorbed dose distributions in patients irradiated by clinical beams plays an important role in radiotherapy treatment. A Monte Carlo method is the most accurate way to calculate it [4]. In this work we use the EGSnrc / BEAM code for modeling the head of a linear accelerator SATURNE43 and calculate the dose distribution across the phantom.

BEAMnrc is a Monte Carlo code system for simulating radiation therapy sources. It was developed as part of the OMEGA project a collaboration between the National Research Council of Canada and a research group at the University of

Wisconsin–Madison. It is based on the EGS code system for the coupled transport of electrons and photons BEAMnrc is a package of codes for building accelerator geometries and for evaluating the results of simulations through those geometries. The geometry of the accelerator to be simulated is built up from a series of predefined “component modules“(CMs), BEAMnrc can model all types of medical linear accelerators, using the code component module system [1, 9].

The OMEGA project can be divided into three stages: an accelerator simulation, characterization and representation of the beam and the dose calculation. The modeling of the head of a medical linear accelerator is the most important part of the program (BEAMnrc) [1, 7].

The code BEAMnrc can produce a so called phase space file of the beam at specified scoring planes on the model, these planes are to be placed at the back of an already defined CM and the planes have to be perpendicular to the central-axis. A phase space file contains full information (charge, energy, position and direction) about the particles crossing the scoring plane. BEAMnrc also offers a variety of radiation sources (point source, a source that emits radiation isotropic ally over a specified volume, phase space file as source, etc...) and some so called variance reduction techniques to speed up the calculations.

BEAMnrc is considered as a reference in radiation therapy where they are compared to the results of other codes with this code.

2 MATERIALSA ND METHODS

2.1 MEASUREMENT DATA

Measurement data of depth dose or off-axis lateral dose was obtained from EURADOS group [5].

2.2 MONTE CARLO SIMULATION PARAMETERS

The Simulate linear accelerator Saturn 43 by method of Monte Carlo was done in two steps:

2.2.1 SIMULATION THE HEAD OF THE LINEAR ACCELERATOR SATURNE 43

We constructed the model of the LINAC Saturne 43 geometry using Monte Carlo code BEAM/EGSnrc.

The different components of the irradiation head were modeled using the modules (CM) Code. The model of the accelerator is comprised of a succession of planes perpendicular to the z axis in a module which is horizontal planes. Each CM is independent of the others and is distinguished by its numbering. The same CM can be used several times without interacting with the previous ones. It is the user who connects to each other. A module can be considered as a block having an input surface and an output surface. CMs are composed of elements that are numbered in the double direction of increasing z. BEAMnrc uses a local numbering according to the CM and a second global numbering based on the entire accelerator. This allows the code to follow the path and interactions experienced by the particles in the accelerator head. The components were applied to model the target, primary collimator, flattening filter, monitor chamber and jaws. Thereafter, a compilation is necessary to allow verification of the geometric model of overlap between components, it allows the generation of the necessary files to the code execution, as mortjob.mortan file that contains the definition of the different parameter simulation [1, 6, 7].

At the end of this step, the components of a linear accelerator for a 12MV photon beam are shown in Figure (1)

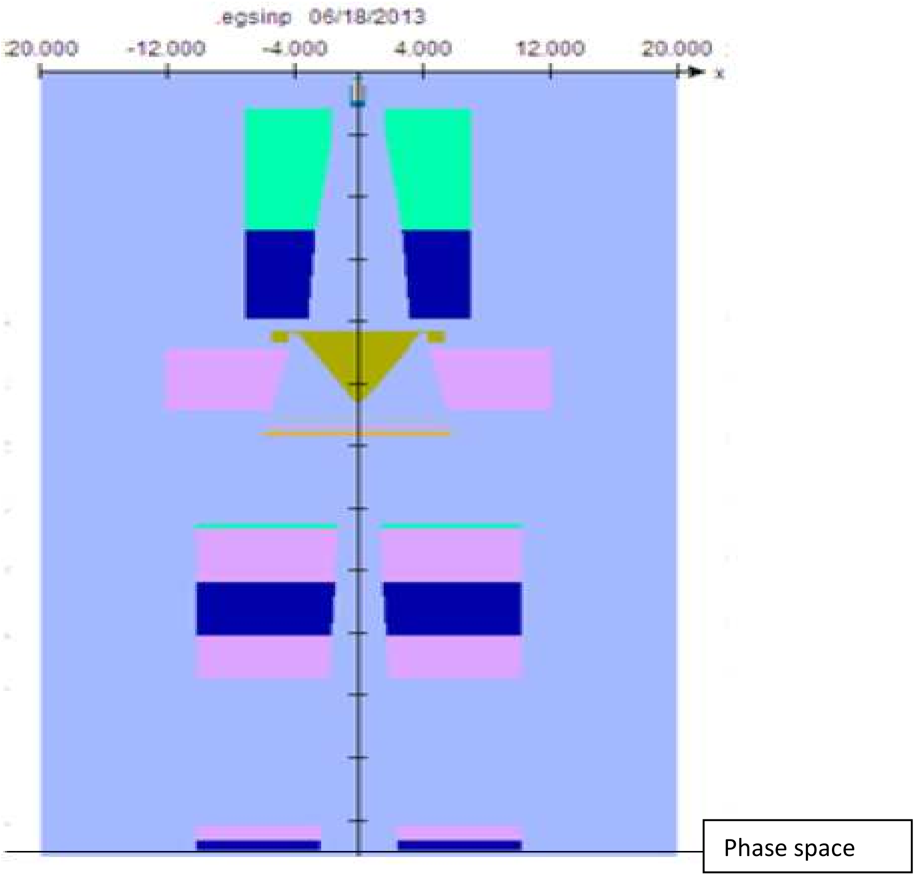

Fig. 1. Saturne 43 Linac head modeling by BEAMnrc code in 2D geometry

During this study the variance reduction techniques used are:

- The energy Cutoffs for photons and electrons respectively were set to 120 keV,400keV
- Bremsstrahlung splitting is DIRECTIONAL
- ESAVE =1MeV (Energy in MeV below which electron will be discard in range rejection)

The parameters of the source of electrons:

- Source number. 19 define a source with Gaussian distribution in the X and Y plane incident from the front. for mono energetic beam Equal 11.4MeV
- Gaussian distribution (x-y plane) with origin on beam axis for FWHM =1.7mm and BEAM SIGMA= 0.0722 cm

In our study the phase space obtained for these parameters is calculated at -50 cm from the tungsten target by simulating 60 x 106 mono-directional incident electrons. A phase space file of roughly 4GB is created and it contains about 32.106 photon tracks and 2 x 105 electron tracks.

Other files can be saved for the dose and the statistical uncertainty in the various components of the treatment head these files have an extension egslst.

2.2.2 SIMULATION OF DOSE DISTRIBUTION IN THE WATER PHANTOM

In this step we calculate the dose distribution in water Phantom by Code dosxyz. DOSXYZnrc is an EGSnrc-based Monte Carlo simulation code for calculating dose distributions in a rectilinear voxel phantom and is based directly on the DOSXYZ code developed for the EGS4 code system. DOSXYZnrc is part of the OMEGA BEAM system of codes developed at NRC. Density and material in every voxel may vary. A variety of beams may be incident on the

phantom, including full phase-space files from BEAMnrc, In order to calculate the dose distribution must be defined Phantom of water, the source of the particles, the parameters of code Dosxyz and The EGSnrc Parameters [2].

In this step the phase space file is used as a source and is put at 40cm from the water phantom, a water phantom with dimensions of 40 cm × 40 cm × 40 cm was simulated under the gantry with a source-surface distance (SSD) of 90 cm. The phantom was divided into voxels, with each voxel's dimensions being 5 mm × 5 mm × 5 mm, in which we collected the energy deposited to calculate the relative dose absorbed in the phantom. The percentage depth dose (PDD) and beam profiles were calculated in a water phantom a square field dimension 10x10cm² at a depth z = 100 cm from the target. We simulated 5.108 particles with the module DOSXYZnrc. We then compared them with measurements for validation of our Monte Carlo model.

3 RESULTS

The curves of PDD are normalized at 10cm depth and are obtained for a field size of 10x10cm2 and a SSD= 90cm, and lateral dose profile normalized at 10cm in water.

In Fig. 2, 3 we show experimentally measured data and EGSnrc/BEAMnrc Monte Carlo simulation results. (2) Shows the depth-dose curves, (3) shows lateral dose profile at 10 cm depth, for the 10 × 10 cm2 field, And (3) we show laterals dose profiles at 0, 5, 10, 15, 20 cm depth, with the 12MV beam (SSD = 90 cm)

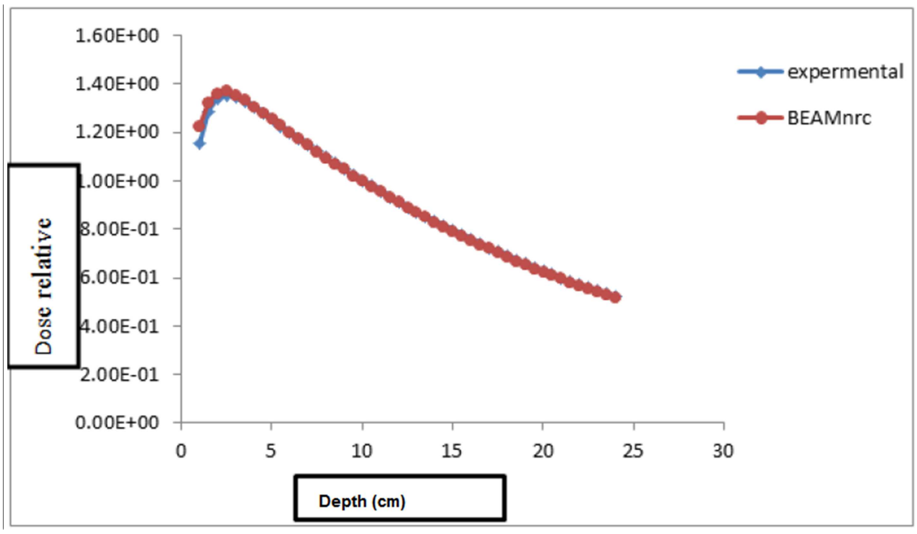

Fig. 2. PDD comparison between measurement and MC simulation for 12MV, filed size 10 × 10 cm2

X (cm)

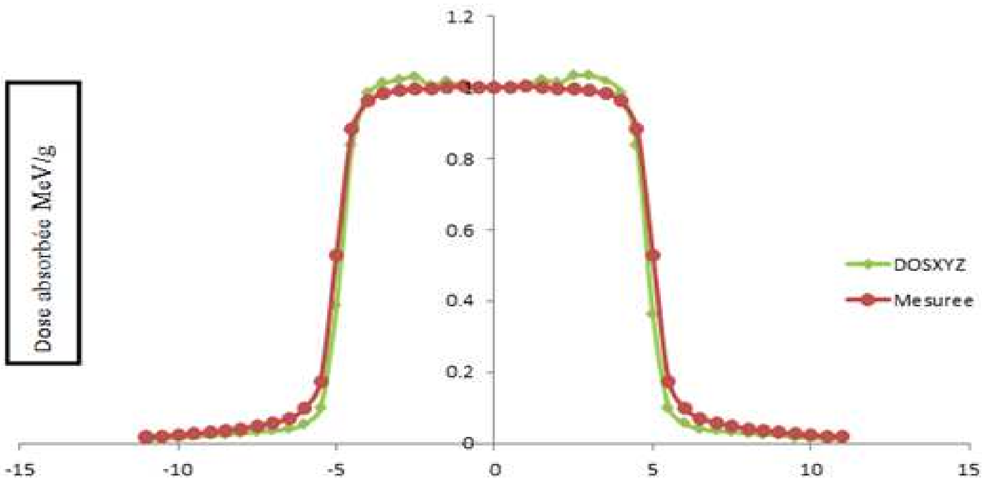

Fig. 3. lateral profile comparison between measurement and MC simulation

X (cm)

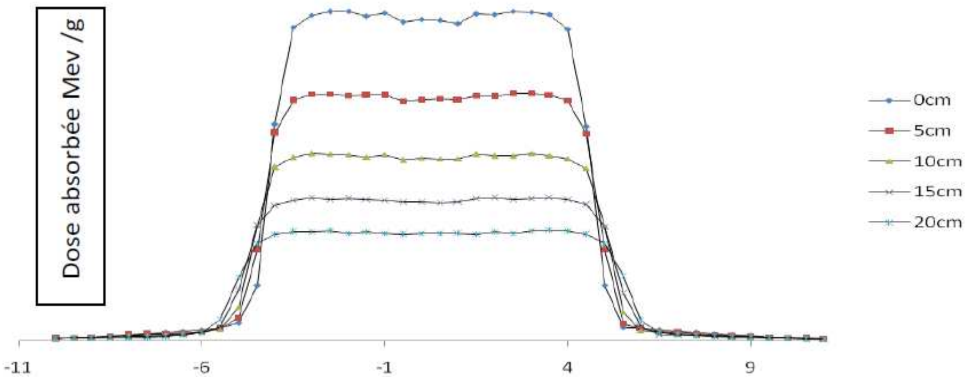

Fig. 4. Lateral dose profiles at 0, 5, 10and 20 cm depth for 10 × 10 cm^2 field with a 12MV beam.

In Figure (2, 3) We note there is good agreement between calculated and measured results, In (2) depth dose matched perfectly with a few of the disagreement around the dose build- up point, In (3) lateral dose profile the values so close with a very slight statistical difference in central plateau may fade with time simulation or increase the number of particles simulated

In Figure (4) Lateral dose profiles are very sensitive to the depth in a phantom. The results show that increasing the depth tends to reduce the dose in two areas: central plateau and darkness. As against, lateral dose profiles outside the field is less sensitive than the depth.

To analyses of the data stored in the phase space and photons spectrum Performs by BEAMDP Code, BEAMDP (BEAM Data Processor) is a program developed for the OMEGA (Ottawa Madison Electron Gamma Algorithm) project[3], the phase space file was generated by BEAMnrc at z =50cm, for 12MV. These file was analyzed, and the characteristics of the particles they contained were plotted. The graphs that were taken from BEAMDP were Mean Energy, Energy Fluence vs. position, Energy Fluence distribution and distribution the Particle in x-y plane, As shown in Figures 5,6,7and 8

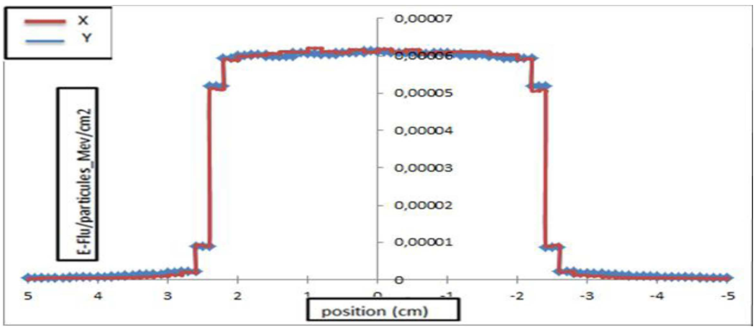

Fig. 5. Energy Fluence vs. Position for 12MV on X and Y axis

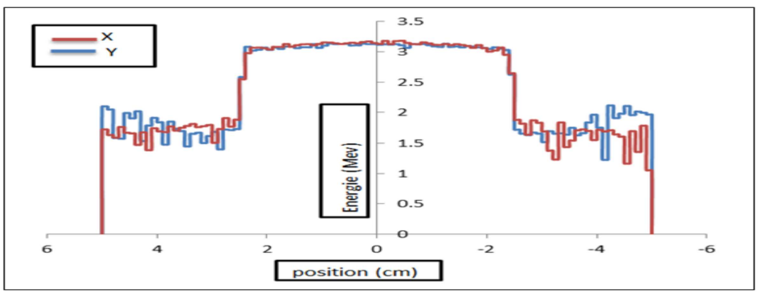

Fig. 6. Mean Energy

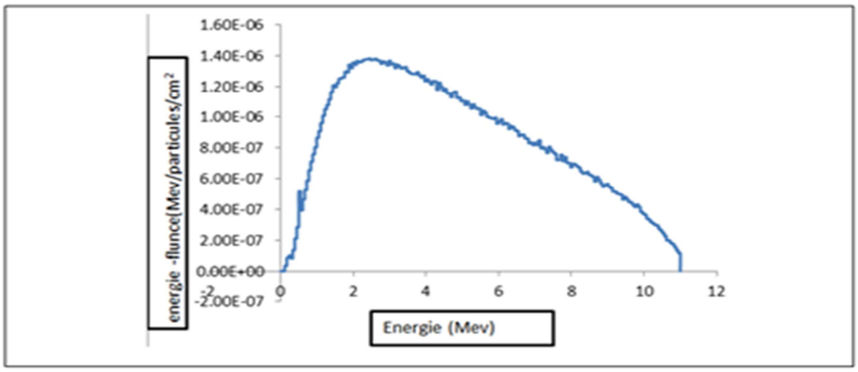

Fig. 7. Energy Fluence Distribution

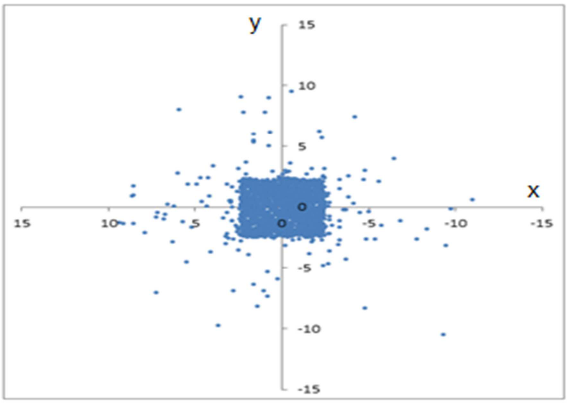

Fig. 8. distribution the Particles in x-y plane

In Figures 5, 6, 7 and 8, we note that BEAMDP is very effective for spectral beam analysis and validation of the field that we use in the simulation and it is necessary to analyze the errors that may be associated with simulation. So it is very important in the planning of radiotherapy.

4 Conclusion

in this work, we have modeled the medical linear accelerator Saturn 43 by EGSnrc/BEAMnrc Code, the results which obtained by EGSnrc simulation are acceptable and shows Excellent agreement and a slight statistical difference with the experimental results, so we mastered the installation and operation of this system for the simulation of linear accelerator used in radiotherapy. Accuracy of this method in the calculation of the dose distribution and analysis of the data stored in the phase space file so we can use this code in the treatment planning system of radiation therapy, to improve the statistical simulations, we see, firstly study the effect of certain components of the head SATURN 43 of dose distributions and the energy spectrum of photons as the flattening filter and jaws Secondly the different variance reduction techniques for Optimizing simulation in terms of time.

Acknowledgments

I want to thank my supervisor pr. Tarek EL Bardouni for guiding me and I thank him very much for welcoming me in his laboratory, its availability and for his invaluable assistance in the completion of this work and especially for the supervision of this work, also extend my sincere thanks to Prof E. Chakir, H. Boukhal and M. Azahra for their collaboration and technical support to this work.

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