ICMP 2011
April 17-20 · Porto Alegre - RS - Brazil

PDD´s Reconstruction of the Linear Accelerator Varian 2100C for Photons Beams of the 6MV and 10MV Using MCNP-4C Code

M. Giglioli[1], M.A.R. Fernandes[2] and H. Yoriyaz[1]

[1] Instituto de Pesquisas Energéticas e Nucleares/Centro de Engenharia Nuclear, São Paulo, Brasil
[2] Universidade Estadual Paulista (UNESP)/Faculdade de Medicina de Botucatu/ Departamento de Dermatologia, Botucatu, Brasil

Abstract— **A great challenge in simulations in the area of radiotherapy is to character the source, since the equipment's manufacturers don't provide specifics information about this. This work presents an empiric method for characterization of the ray-X beams of 6,0 MV and 10 MV originating from a linear accelerator of the mark Varian model 2100C. The experimental values of the percentage of deep dose (PDD) were used for reconstruction of the energy spectrum and analysis of the angular distribution of the beam simulated with Monte Carlo's Method, using the code MCNP-4C. The results were shown solid could be used for the space reconstruction of the beam.**

Keywords— **PDD reconstruction, Monte Carlo method, MCNP, medical physics.**

I. INTRODUCTION

The Monte Carlo method has been widely applied in areas of medical physics through simulations treatments Radiotherapy, Nuclear Medicine, Radiation Protection, Radiology, among others. These simulations should contain data on the specific characteristics of the problem being studied, such as geometry, composition and arrangement of elements of simulation and specifications of the font used [1][2][3].

In simulations in radiotherapy, one challenge is to determine the spectrum of the radiation source, since the specific information of the geometry, composition and location of the components are not provided by equipment manufacturers [2][3].

In order to obtain the characterization of the energy spectrum of a source, without simulating the equipment used, are made experimental measurements of percentage depth dose (PDD) and plain, for different depths in a water phantom, following the procedures dosimetry adopted in the hospital [4][5]. After obtaining the experimental measurements, the method of construction of this spectrum consists of a mathematical representation of the photon beam, which is determined in the energy part, by a linear combination of monoenergetics beams given by the following equation:

$$S(E) = \sum_{i=1}^{N} w_i . E_i \qquad (1)$$

Where:

Ei represents the monoenergetics components of clinical beam and;

wi are the weighting factors.

Since that weighting factors wi are determined by comparing the simulation results with the results of experiments, the energy spectrum of clinical beam is completely characterized by any of the equation (1) [2]. Since the energy part of the beam is adjusted based in experimental PDD, it is necessary to adjust the spatial part of the beam. The geometric characterization is performed by dividing the radiation field in various regions, each is assigned a weight of source which represents its intensity in that region. This geometric weighting causes the radiation source has the same energy spectrum in the whole field, but different intensities, according to the weights assigned to each region. With this empirical procedure, the radiation beam of the linear accelerator is quite characterized [2].

Thus, this work aims reconstruct, through the empirical method, the experimental PDDs' photons beams of the 6 MV and 10 MV of the linear accelerator Varian, model 2100C, using Monte Carlo method by simulations realized wit MCNP code, version 4C.

II. METHODOLOGY

A. Experimental Measurements

Experimental values of the PDD of photons beams of the 6 MV and 10 MV were transferred by Technical Sector of Radiotherapy of the Faculty of Medicine of the UNESP, Botucatu (HC-FMB), and they are represented by Table 1. Depth values are in centimeters (cm) and PDD are in percentage (%).

B. Monte Carlo Method: MCNP-4C

The Monte Carlo method can be defined as a statistical tool, which uses a sequence of random numbers to simulate and reproduce events that can be represented by stochastic processes. In contrast to conventional methods of discrimination, statistical simulations in the physical process need not be described by mathematical equations to be solved, just that this process can be described by a probability density function (pdf), which characterizes the phenomenon observed [1][6].

Table 1 Experimental Measurements of PDD for 6 MV and 10 MV beams.

6MV		10MV	
Depth	**PDD**	**Depth**	**PDD**
1	98.3	1	90.0
1.5	99.9	2	99.8
2	98.6	2.2	100
3	94.6	3	98.6
4	90.2	4	95.2
5	85.8	5	90.9
6	81.6	6	87.1
7	77.7	7	83.7
8	73.8	8	79.9
9	69.9	9	76.7
10	66.1	10	73.2
11	62.7	11	69.8
12	59.3	12	66.6
13	56	13	63.7
14	53	14	60.8
15	50.1	15	57.9
16	47.4	16	55.5
17	44.7	17	52.9
18	42.4	18	50.6
19	39.9	19	48.2
20	37.6	20	45.9
21	35.6	21	43.9
22	33.6	22	41.9
23	31.9	23	40.1
24	30.2	24	38.2
25	28.5	25	36.5
26	26.9	26	34.8
27	25.3	27	33.2
28	24	28	31.6
29	22.7	29	30.2
30	21.4	30	28.8

Thus, in simulations of the interaction of radiation with matter, the set of events that happens to a particle, since it leaves the source until the moment it is completely absorbed or leaves the system (history of the particle), is generated by sampling of the pdf. So, any calculation that uses Monte Carlo starts with real system reproduction, which will be sampled the pdfs and monitored the histories of particles, in order to estimate the average value of quantity to be measured with the smallest possible statistical uncertainty. The greater the number of simulated histories, the smaller the uncertainty and therefore the average value is more representative, however, the computational expense is greater, which explains the increasing use of this technique occur as technological advances in computational area [1].

The MCNP code, version 4C was used in performing the simulations responsible for reconstruction the PDD. The basic structure of this code consists of three blocks, through of these is reproduced the real experiment (Fig. 1) [6]:

- 1º Block: Title simulation and description of cells involved in trouble, this is, real system reproduction by surfaces like plans, spheres, cylinders, among others;
- 2º Block: description of the surfaces used in the first block;
- 3º Block: description of the materials that compose the system, the quantities to be measured, determination of the number of stories to be simulated, among other information.

```
Reconstruction of PDD ----
c Cells
c DETECTORS
101 1 -1 -10 imp:p,e=1
102 like 101 but TRCL=(0 0 -1)
...
c world
150 0    41:-42:43                imp:p,e=0

c Surfaces
c Phantom plans
2 px -15
3 px 15
...
c Limits surfaces
41 cz 50
42 pz -40
43 pz 101

c MATERIALS
c Water
m1 1000. 2 8000. 1
c Air
m3 6000. -0.000125 7000. -0.755267 8000. -
0.231781
      18000. -0.012827
c SOURCE
mode p e
sdef erg=d1 sur=1 x=d2 y=d3 z=100 vec=0 0 -1
dir=d4 par=2
...
c TALLIES
*F8:p 101 102 103 104 105 106 107 108 109
nps 2e8
```

Fig. 1 Sample input of MCNP code.

C. Geometric Reproduction of real system

Geometric modeling, shown in Fig. 2, consists of a flat source of photons (plane cuts the z axis) located 100 cm from the surface and a cubic water phantom 32cm^2, starting at 0 cm and centered on the axis z , which contains in its interior, 31 ellipsoids with volumes equal to 0.6 cm^3, also centered at z, each located at a depth where the dose is measured (every 1cm, from -30cm to -1cm, including the depth of the build-up regions (region of electronic equilibrium, corresponding to the region between the surface and the depth at which the dose reached the maximum value) - being -1.5 cm and -2.2 cm, respectively, for 6 MV and 10MV). This whole scheme is surrounded by a large air cylinder, in order to delimit the area of interest of the problem and optimize the simulation time.

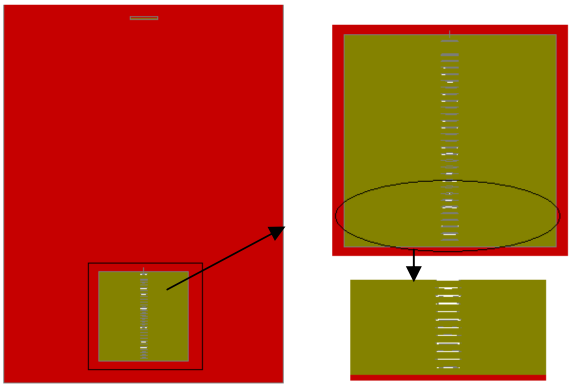

Fig. 2 Geometric representation of real system for PDD measurement.

D. PDD simulation

Several simulations were performed until they were found the best values for the energy spectrum and angular distribution of the sources. Subsequently, two simulations were carried stories of 2x10^8 particles, and both with the same geometric schema, differing among themselves only in relation to the energy spectrum and angular distribution of particles emitted by the source.

III. Results

Fig. 3 illustrates the energy spectra of the photon beams of 6 MV and 10 MV, reconstructed using the experimental values of the PDD. The Fig. 4 shows the angular distribution of particles emitted by the source, simulated with the Monte Carlo method and used for reconstruction of the PDD curve.

After several attempts to determine the energy spectrum and angular distribution, to find the best values of these parameters, this is, values that characterize the source so that the PDD simulated most closely matches the experimental, curves for reconstruction of the photon beams' PDD of 6 MV and 10MV were obtained and are presented in Fig. 5 and 6.

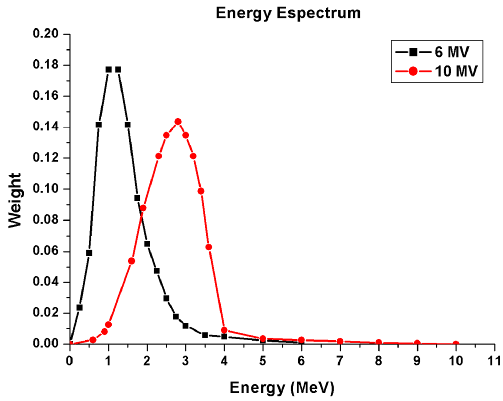

Fig. 3 Energy spectrum of source used in PDD reconstruction of the 6 MV and 10 MV photon beams.

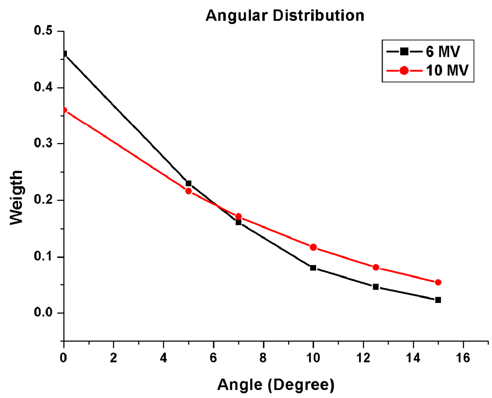

Fig. 4 Angular distribution of particle leaving the source used in the reconstruction of PDD of the 6 MV and 10 MV photon beams.

The adjustments made by the simulations, presented in Fig. 4 and 5, showed values very close to experimental. The propagation of errors was performed by considering uncorrelated measurements of energy deposition taken in each ellipsoid. The values of the deviations were found for each point at most 1%, proving the consistency of measurements obtained by simulation using the code MCNP-4C. Since the percentage difference between experimental and simulated curves, reached a peak of 3.7% for 6 MV beam and 4.6% for 10mV, disregarding the first point, which showed 9.6% difference in percentage ; once that corresponds to the build-up region, suffer greater variation of measures and is not worth reading obtained at this depth used for normalization of the curve of the PDP, this is, the dose value obtained at the point of maximum dose is considered the 100% point, normalizing the values for PDP subsequent depths.

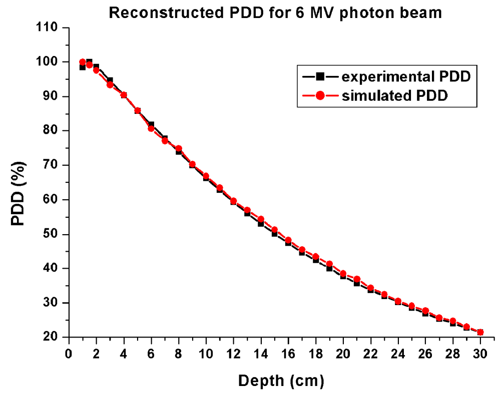

Fig. 5 Comparison between the experimental PDP and rebuilt by the empirical method for the 6 MV beam.

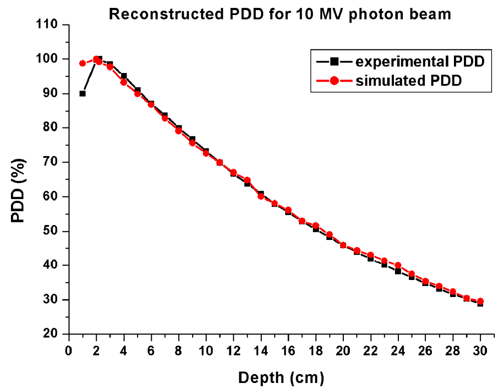

Fig. 6 Comparison between the experimental PDP and rebuilt by the empirical method for the 10 MV beam.

IV. Discussion and conclusion

The calculations for determining the PDD, for the beams of 6 MV and 10 MV linear accelerator Varian 2100C model, were performed using the code MCNP-4C and showed consistent values, this is, with maximum deviation of 1%. When compared to the experimental data yielded by HC-FMB, the percentage differences were at most 3.7% and 4.6% for each beam, respectively. These figures show that despite the PDD curves obtained empirically are still liable to a fine tuning in order to become even closer of the experimental curves, they are already ready to be used in the sequence of the procedure for characterizing the source: the determination of this flatness. Thus, the agreement between the results for the photon beams validates the proposed methodology.

Acknowledgment

The authors acknowledge CNPq for financial support. Process: 145293/2009-2.

References

1. Yoriyaz H (2009) Método de Monte Carlo: princípios e aplicações em Física Médica. Revista Brasileira de Física Médica 1:141-149
2. Yoriyaz H, Poli MER, Furnari L, Rubo R, Rodrigues LN and Fonseca GP (2007) Clinical electron beam characteristics investigations using the Monte Carlo method for absorbed dose determination, AAPM 49th Annual Meeting, Medical Physics, Minneapolis, 2007, pp. 2424-2424
3. Hinson HW, Kearns WT, Deguzman AF and Bourlamd JD (2008) Photon spectral characteristics of dissimilar 6 MV linear accelerators. Med Phys 35(5):1698-702
4. IAEA (2000) Absorbed Dose Determination in External Beam Radiotherapy - An International Code of Practice for Dosimetry Based on Standards of Absorbed Dose to Water. Technical Reports Series no. 398. Vienna
5. International Atomic Energy Agency (2005) Radiation Oncology Physics: A Handbook for Teachers and Students. Vienna.
6. Briesmeister JF (2000) MCNP: A General Monte Carlo N-particle Transporte Code. Version 4C, LA-13709-M. Los Alamos Scientific Laboratory, Los Alamos. New Mexico

CORRESPONDING AUTHOR:

Author: Milena Giglioli
Institute: Instituto de Pesquisas Energéticas e Nucleares
Adress: Av. Lineu Prestes, 2242
City: São Paulo
Country: Brasil
Email: milenagiglioli@gmail.com