Monte-Carlo Method Python Library for dose distribution Calculation in Brachytherapy

R.D. Randriantsizafy
Madagascar Institut National des Sciences et Techniques Nucléaires (Madagascar INSTN), BP 4279, Antananarivo 101, Madagascar

R. Raboanary
Institut of @stro and High-Energy Physics Madagascar (@HEP-MAD), University of Antananarivo, Madagascar

M.J. Ramanandraibe
Madagascar Institut National des Sciences et Techniques Nucléaires (Madagascar INSTN), BP 4279, Antananarivo 101, Madagascar

The Cs-137 Brachytherapy treatment is performed in Madagasacr since 2005. Time treatment calculation for prescribed dose is made manually. Monte-Carlo Method Python library written at Madagascar INSTN is experimentally used to calculate the dose distribution on the tumour and around it. The first validation of the code was done by comparing the library curves with the Nucletron company curves. To reduce the duration of the calculation, a Grid of PC's is set up with listner patch run on each PC. The library will be used to modelize the dose distribution in the CT scan patient picture for individual and better accuracy time calculation for a prescribed dose.

1. INTRODUCTION

Brachytherapy is the short distance treatment of cancer using encapsulated small sources. In Madagascar, oncology department uses intracavitary treatment brachytherapy type with Cs-137 27mCi Source. It is a Low Dose Rate (LDR) treatment.

For good practice, the dose at a point of treatment (tumour) have to be known with a good accuracy, and the dose distribution in the body too. Doses can be determined using three ways: The Treatment Planning System (TPS), Manual Calculation and Standard 2D Dose distribution curves. Madagascar Oncology Department uses Dose curves and Manual calculation to determine the time treatment corresponding to the prescribed dose.

The objectif of this work is the conception of Monte-Carlo Python Library which follows the path of a photon from Cs-137 source in an homogeneous water equivalent body.

2. METHOD

For the Cs-137 brachytherapy treatment, using Nucletron Selectron LDR remote afterloaders unit, the photons come from around ten Cs-137 sources of 2mm size positioned in fletcher applicators. 1.5cm to 3cm ovoids are used to maintain the applicators inside vagina and rectum. For this model we consider one Cs-137 source as a point source. The calibration of Cs-137 sources was performed with the applicators, so the activity of the source is an apparent activity and it is not necessary to take into account the presence of the aluminium thickness of the applicators. The calibration is based on Air Kerma measurement at 1m.

From the source, the photons are considered as interacting directly with the body which is water equivalent material. As the photon energy from Cs-137 is 662 keV and Z=10 for the water, the curve of proportion interaction effect (see Figure 1) shows that the Compton effect is dominant in front of Photoelectric effect and Pair production effect.

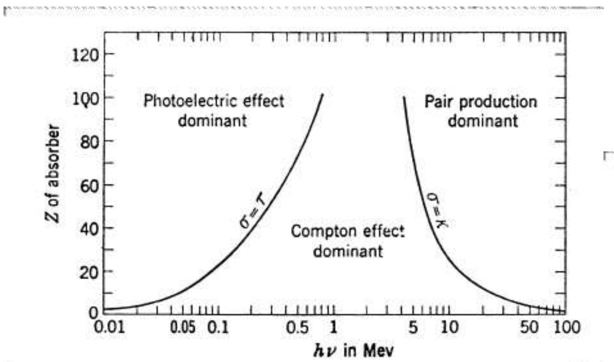

Figure 1: Interactions proportion

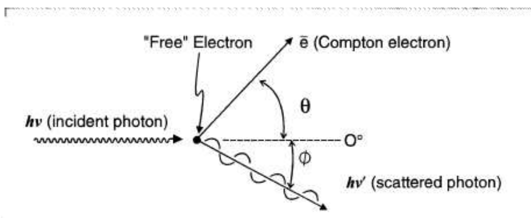

Figure 2: Compton interaction

After travelling a random free path (see Figure 2) the incident photon (hν) interacts with on free electron. The interaction produces one Compton electron and one scattered photon (hν').

The random free path ***d*** of the incident photon between two interaction is determined with the following formula.

$$d = -\frac{1}{\mu}(1-\xi) \qquad (1)$$

where ξ is a random number and μ the linear attenuation coefficient depending on the incident photon energy and the target material. We consider that the Compton electron energy and the difference between incident photo energy and scattered photon energy are absorbed by a voxel of 1cm^3 at the interaction point. The energy of the scattered photon is given by

$$h\nu' = \frac{h\nu}{1+\frac{h\nu}{m_0}(1-\cos\theta)} \qquad (2)$$

The scattered photon which is the new incident photon after interaction will continue in the same way until it leaves the volume of 20cmx20cmx20cm or until its energy is below 100keV. The probability distribution function (PDF) used by the method is based on Klein Nishina cross section

$$\frac{d\sigma}{d\Omega} = \frac{\alpha^2}{2\mathrm{m}_0}\left(\frac{\omega'}{\omega}\right)\left(\frac{\omega}{\omega'}+\frac{\omega'}{\omega}-\sin^2\theta\right) \qquad (3)$$

from which a database of a cumulative probability distribution function (CPDF) for each diffusion angle (0 to 2π radian) and for each photon energy (From 100 to 662 keV) is pre-calculated (see Figure 4). The incident photon from the source are fixed as a packet of 1000 photons.

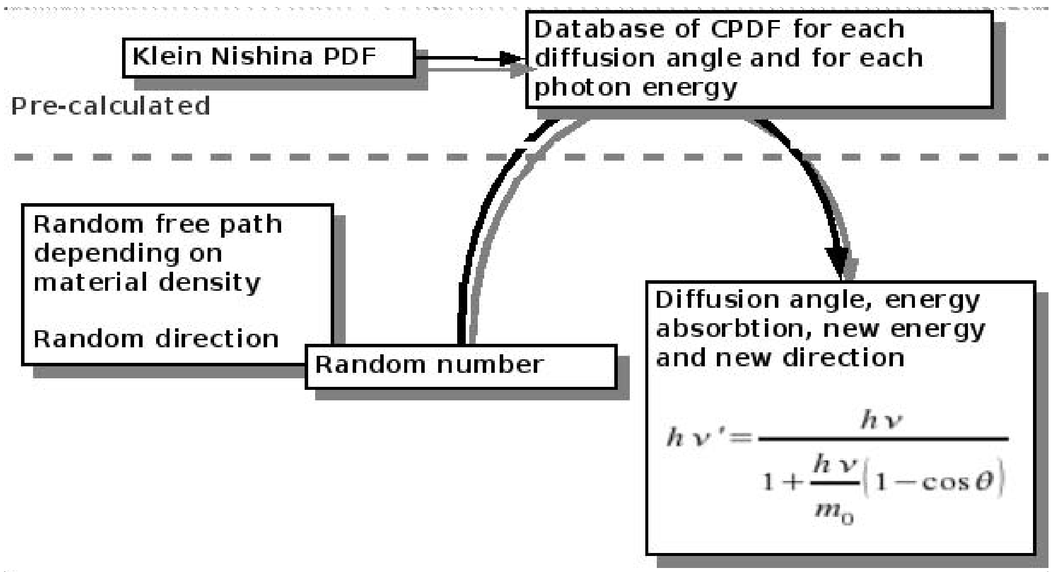

Figure 4: The model

Table I: Margin specifications

CPU	Random Memory	Number of Photons	Voxel size	Duration
Pentium 733MHz	256 MBytes	5900000	1 cm	1000 sec

3. RESULTS

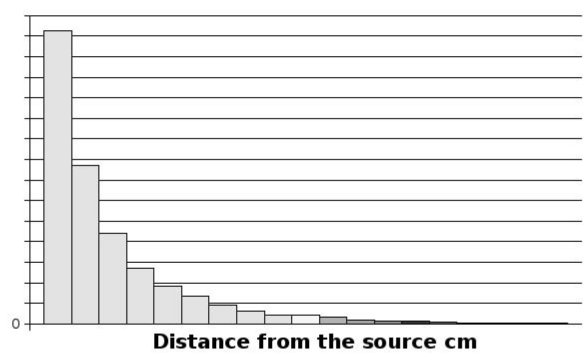

Figure 5: Dose proportion around the source

We validate the model by comparing the Monte Carlo distribution dose curve with the Nucletron curves furnished by the Nucletron Company.

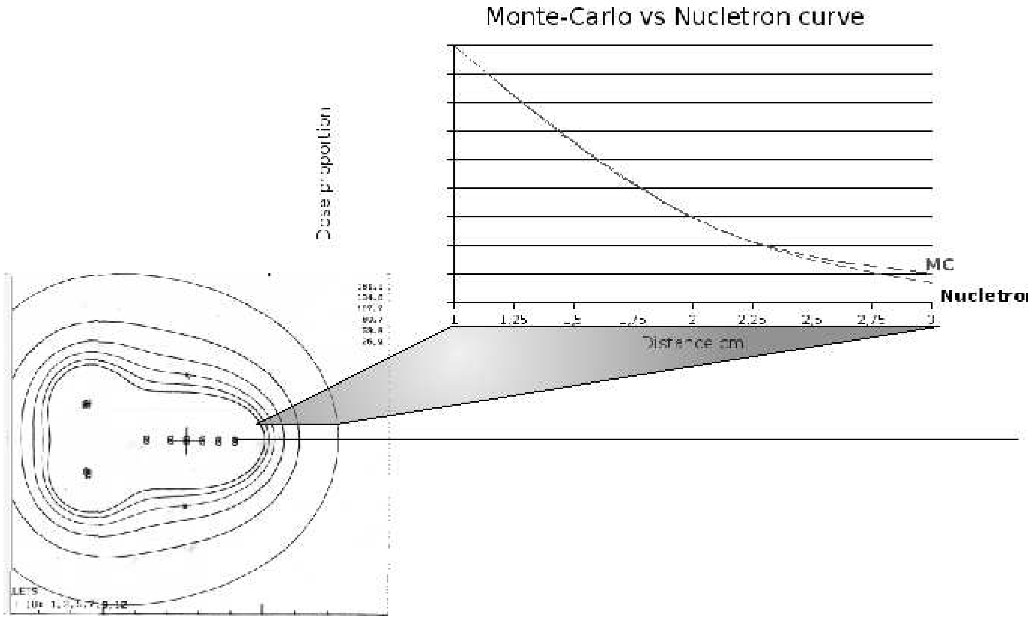

Figure 6: Dose proportion around the source

The values on the Nucletron curve are placed on the Monte Carlo (MC) curve. The MC curve fit the Nucletron curve, that means that the Monte Carlo library can be used as basis engine to calculate the dose distribution in a body. The calibration of the source is done according to the TG 43 recommendation (4)

$$\left(K_{air}(d)\right)_{air} = \frac{A_{app}\Gamma_{AKR}}{d^2} \qquad (4)$$

The dose is determined from the air kerma at 1 m of the source which is used to calculate the apparent activity of the Cs-137 source and the fluence. Then the fluence is introduced in the model.

4. DISCUSSION

The calculation is done for one source. For one treatment, around ten pellet sources will be taken into account, that means more time for the calculation. To solve this state a python patch is installed on machines listens the PC called calculation server which share the calculation packet to the PC member of the grid (Fig 7).

5. OUTLOOK

The library will be used in a GUI Tkinter for clinical application. The dose distribution visualisation will be performed with VTK library. The introduction of the code in the hospital will be done in 2 steps:

First step: Code generate 3 D dose curves which will be stored in the computer. Befor a treatment, the prescribed curve will be placed in patient radiography picture to see the dose for each organ.

Second step: When the CT Scan of the Radiotherapy service will be installed, the model will be used to draw the 3D Dose curve for one patient. The CT scan picture and the Source positions in the applicator are the inputs of the model.

6. CONCLUSION

The comparison of the Monte Carlo curve and the Nucletron Curve (see Figure 6), for validating the model, shows that the results of the model fot the values of the manufacturer (Nucletron). The energy is considered as been absorbed by the voxel of 1 cm3. But for more accuracy, the volume of the voxel has to be decreased, that means more photons and more computation time. For clinical use, the calculation has to be performed with more powerful CPU (more than 3GHz) and if it is not enough (calculation too long), through a grid of computers.

The advantage of Monte Carlo method is that it has the capability to take into account the real volume model of the patient and shape an individual 3D dose curve for each patient, wich is not not possible with the manufacturer standard curve.

Ackowledgments

We would like to express our sincere thanks to the International Atomic Energy Agency (IAEA) for all technical and scientific supports to the dosimetry department through the provision of dosimetry standard, training and expertise. We are very gratefull to High Energy Physics Madagascar (HEPMAD) for allowing us to show the first step of this work and for the fruitfull discussion we have during the HepMad 2007 conference. Many thanks to all Madagascar INSTN Staff especially the Dosimetry and Radiation Protection Department member.

References

[1] Introduction to Monte-Carlo Methods for Transport and Diffusion Equations. B.Lapeyre, E.Pardoux and R.Sentis. Oxford University Press 2003- ISBN 0-19 852592 3

[2] Radiation Oncology Physics: A Handbook for Teachers and Students. IAEA-COMP/CCPM, EFOMP, ESTRO, IOMP, PAHO, WHO. IAEA 2005. ISBN 92-0-107304-6