Application of Monte Carlo Simulation for the Medical Linear Accelerator in Radiotherapy

Thesis Submitted
to
Physics Department
Faculty of Science, Ain Shams University
In
Partial Fulfillment of the Requirements
for the Master Degree in Science

By
Ahmed Sayed Hamed Ali

Supervisors

Prof. Dr. Amr Radi

Physics Department, Faculty of Science,
Ain Shams University

Prof. Dr. Noha Emad

Ionizing Radiation Metrology Lab,
National Institute for Standards

Dr. Elsayed Salama

Physics Department, Faculty of Science,
Ain Shams University

2014

Ain Shams
University
Faculty of Science
Physics Department

Degree: Master Degree in Science (MSc. degree in Physics)

Title: Application of Monte Carlo Simulation For the Medical Linear Accelerator in Radiotherapy

Name: Ahmed Sayed Hamed Ali

Thesis Advisors	**Approved**
Prof. Dr. Amr Radi Physics Department, Faculty of Science, Ain Shams University	……………..
Prof. Dr. Noha Emad Ionizing Radiation Metrology Lab, National Institute for Standards	……………..
Dr. Elsayed Salama Physics Department, Faculty of Science, Ain Shams University	……………..

Ain Shams
University
Faculty of Science
Physics Department

Name: Ahmed Sayed Hamed ALi

Titled: Application of Monte Carlo Simulation For the Medical Linear Accelerator in Radiotherapy

Degree: MSc. degree

Submitted to: Physics department, Faculty of science, Ain Shams University.

بِسْمِ اللّٰهِ الرَّحْمَنِ الرَّحِيمِ

وَقُلْ رَّبِّ زِدْنِي عِلْمًا

In the Name of Allah, the Most Gracious, the Most Merciful

"..**And Say: My Lord! Increase me in Knowledge"**

"TAHA/114, the Glorious Quran"

To

Mother

Father in God's mercy

Brothers

Sisters

And

My fiancee Ola

CONTENTS

CHAPTER 1
INTRODUCTION

CHAPTER 2
THEORETICAL ASPECTS

CHAPTER 3
SIMULATION SETUP

CHAPTER 4
RESULTS AND DISCUSSION

ACKNOWLEDGMENT

The author likes to express his deepest gratitude to Prof. Dr. Amr Radi the professor in physics department, faculty of science, Ain shams university, Prof. Dr. Noha Emad the professor in radiation measurements department, National Institute for Standards and Dr. ElSayed Salama in physics department, faculty of science, Ain shams university, for their valuable supervision, and grateful cooperation creative discussions.

Deep thanks and sincere gratitude to Physicist Mostafa Abd Al Moez, Kasr El Aini, Cairo University, for his valuable discussions and creative cooperation.

I would like to thank the family of Centre for theoretical physics for their continuous support.

Ahmed Sayed Hamed Ali

ABSTRACT

ABSTRCT

GATE (Geant4 Application for Tomographic Emission) is a general purpose simulation platform for PET, SPECT and radiotherapy applications. Built on top of the Geant4 simulation toolkit, it provides multiple new features with the objective to ease use of Geant4 in the field of medical physics. Handling Gate is carried out by scripting via a command language instead of C++ coding. In this study, gantry of a 6 MV photon beam of medical linear accelerator (LINAC), based on the manufacturer's detailed information was simulated using GATE/GEANT4. This simulation was performed by using more than 2x 10^9 primary electrons. The simulation process is divided into two main stages. The first stage is to run the code to simulate photons and electrons transport through the Linac head, and record the information of the simulated hits crossing a scoring plane above the secondary collimator in a phase space file (PhS). The second stage is to generate hits histories from a given phase space file, and calculate dose distributions in a phantom relative to reference depth 1.5 cm at the isocenter. Evaluation of percentage depth dose distribution (PDD) and flatness symmetry (lateral dose profiles) in water phantom were performed. Comparison between experimental data and simulated were carried out for three field sizes 5 × 5, 10 × 10 and 15 × 15 cm^2. Results show good agreement between computed and measured PDD, Moreover the lateral dose profiles at 15, 50, and 100 mm depth are compatible with the measured values. Overall, GATE/GEANT4 code is a promising applicable Monte Carlo program in radiotherapy applications.

SUMMARY

SUMMARY

Most of commercial Treatment Planing Syatem (TPS), use an analytical calculation for estimating dose to patient, Such methods are less accurate in practice. In alternative, Monte Carlo calculation using GATE/GEANT4, can be used for accurate dose calculation. This technique represents a powerful tool for simulation of complex geometrical shapes and material composition by using different physics models.

In the present work, a Monte Carlo simulation for 6 MV high energy photon medical linear accelerator (Linac), using GATE/GEANT4 was introduced. The gantry of a VARIAN 600C LINAC was simulated according to the manufacturer's detailed information was simulated. The simulation processes were performed on two stages. The first stage includes simulation of the accelerator gantry resulting to phase space file (PhS) formation, the phase space file (PhS) was generated by using more than 2x 10^9 primary electron. Such a phase space file records all information of the simulated hits crossing a scoring plane, such as energy, orientation, type, charge and position of the particles crossing the scoring plane. While the second stage was executed by interactions of recorded hits from a given (PhS) file, with a water phantom of dimensions 48cm×48cm×35cm at source-surface distance (SSD) = 100 cm, were the percentage depth dose (PDD) and the flatness symmetry for different field sizes were calculated relative to reference depth 1.5 cm at the isocenter. A macro files were created for the purposes analysis of beam characteristic at two stations in the treatment head.

During the physics sitting construction, the geometrical specification of the accelerator , as well as the beam energy were taken into consideration. A 6 MV circular electron beam with a gaussian energy distribution accelerated down to hit the tungsten and cupper target were bremsstrahlung photons are generated. These photons and secondary particles are interacting with the flattening filter, monitor chamber, mirror and a pair of Jaws.

Experimental dose measurements were carried out by the aid of a dosimetry system include computerized welhofer WP 700 water phantom version 3.5. This phantom consisting of a water-filled tank with a scanning volume of 48 × 48 × 48 cm^3 and two cylindrical water proof ion chambers each of sensitive volume 0.147 cm^3 and wall thickness of 0.4 mm (RFA 300 Scanditronix) were used.

The computed percentage depth dose (PDD) for three field sizes 5 × 5, 10 × 10 and 15 × 15 cm^2 and the flatness symmetry for each fiels size at 15, 50, and 100 mm depths in water phantom , are compared with experimental measurements. Results show good agreement between computed and measured PDD. Moreover the lateral dose profiles at 15, 50, and 100 mm depth are compatible with the measured values.

LIST OF TABLES