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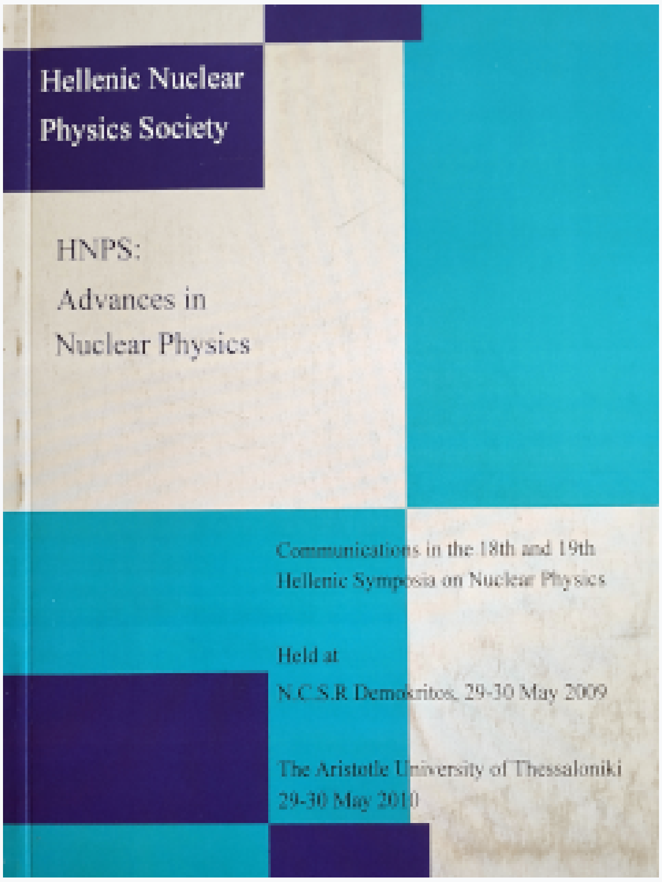

Electron fluence determination per Monitor Unit of a linear accelerator used for radiation therapy

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Electron fluence determination per Monitor Unit of a linear accelerator used for radiation therapy

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Abstract

About 20% of patients in Greece undergoing radiotherapy were irradiated by electron beams with energies ranged between 4 to 20 MeV. The correct determination of electron beam, leads to the proper treatment planning. In this study electron fluence at the isocenter was determined for a linear accelerator ELECTA SL 20 for nominal electron energy of 20 MeV. Two methods have been applied using (a) an ionization chamber in the frame of monthly quality assurance and activation detector (^{238}U). The experimental estimated electron flux, which was in good agreement with the applied calculations using the data of irradiation procedure, ranged between 3.5 up to 4.3 x 10^8 electrons per cm ^{2} per sec or 6.1 ±0.7 x 10^7 e. cm $^{-2}$ per MU.

1. Introduction

Cancer is a leading cause of death worldwide, accounting for 7.6 million deaths (around 13% of all deaths) in 2008 [1]. According to the National Statistical Service, Greece presents an upward trend in deaths from cancer in both males and females during the last 20 years; only the last five years, 148.712 people died from cancer. These figures drive to improve treatment techniques used today. In Greece, 60% of cancer patients undergoing radiotherapy and 20% of them undergoing radiotherapy with electron beams.

The fast electron beam radiotherapy has been used since 1950, initially by Van de Graff generator and after 1970 by linear accelerators. The clinical features of the electron beam are also associated with the type of accelerator producing them. The electron beam is suitable for treating superficial tumours up to five to six cm from the surface of the skin, because unlike photons, the percent depth dose (PDD) decreases rapidly with distance from the skin surface. Both the maximum absorbed dose and its distribution in the tissue varied depending on the initial energy of electrons. In the figure 1 the difference in depth dose distribution of photons at 4 MV and 12 MeV electron beam is shown. Because electrons scatter in the air, the irradiation field should be located close to the skin of the patient. For this reason, secondary collimators or specific cones (electron applicators) are used. Electron applicators operate in the linear accelerator head and create square field's size from 2 × 2 cm^2 to 25 × 25 cm^2.

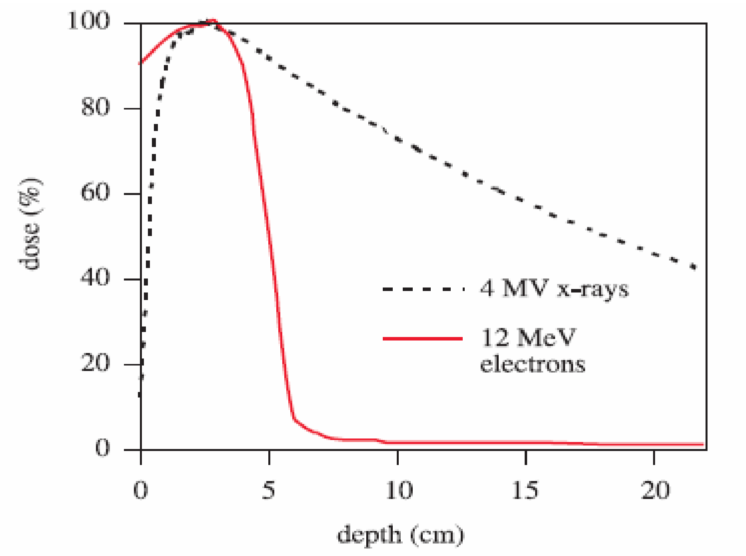

Figure 1: Depth dose curves for a 4 MV photon and 12 MeV electron beam.

In the present study the electron flux from an electron linear accelerator ELECTA SL 20 was determined for nominal electron energy 20 MeV and field size 4x4 cm^2. The fluence was determined experimentally by using an ionization chamber, in the frame of monthly quality assurance and activation detector (^{238}U). The experimental results were compared to nominal data of the irradiation system.

2. Experimental

The specifications of ELECTA SL 20 linear accelerator are: maximum nominal electron energy 20 MeV; target W; primary collimator W; y-backup collimator W; x collimator W/Pb; flattening filter Fe and leaves W/Pb. For electron beam measurements, plane parallel ionization chamber was used (Markus type 23 343 - PTW). The Model N23343 plane-parallel ionization chamber is designed specifically for electron measurements with energy above 100keV, according to the Bragg-Gray principle. The ionization chamber was connected to a MULTIDOS electrometer with high measuring accuracy and good long-term stability (Fig. 2).

Figure 2: Markus ionization chamber – MULTIDOS electrometer

Electron fluence was also determined using passive methods; sample of depleted U ($^{235}U/^{238}U$ = 0.18 ±0.01%) with thickness 0.75 μm were irradiated. The U radiator is used as activation detector, following the reaction $^{238}U(e,n) \rightarrow {}^{237}U \xrightarrow{(\beta-,6.75d)} {}^{237}Np......$. The counting rate of ^{237}U was determined using the two most intense γ-rays: 59.5 keV (I_γ=34.5 ±0.8%) and 208 keV (I_γ=21.2 ±0.3%). Measurements took place on a LEGe planar detector with 0.7 keV resolutions at 122 keV photons, shielded by iron and lead blocks.

3. Results and Discussion

The ionization chamber was placed in contact to the electron applicator for a cylindrical area Ø 4 cm ^{2} and irradiated with nominal electron energy and rate of 20 MeV and 400MU/min. The measurement was repeated three times and the results were corrected taken into account the beam quality (K_q = 0.899) and the correction factor for pressure and temperature ($K_{T,\ P}$ = 0.999). The estimated absorbed dose corresponds to an equal amount of effective dose equivalent since the weighted factor for electrons is unity. Taken into account the fluence-to-effective dose conversion factor H'(0.07) 270 ±0.05 pSv .cm^2 [2-4] an electron fluence 3.8 ± 0.3 x 10^8 electrons per cm ^{2} per sec was estimated.

The passive detector was placed at the same position and irradiated in the same conditions as in the case of active detector – ionisation chamber. The number of electron per cm^2 and per sec was derived from the γ-spectrometry measurements (C,cps) using the following equation: $\Phi = \frac{C}{f_{decay} \cdot f_{beam} \cdot \varepsilon \cdot I_\gamma \cdot \sigma_{eff} \cdot N}$, where

$f_{decay} = (1 - e^{-\lambda t_m}) \cdot e^{-\lambda t_a}$ corresponds to the decay process during the measurement (t_m) and the waiting time (t_a) between the end of irradiation and the begging of the measurement, λ is the decay constant. The $f_{beam} = \frac{1 - e^{-\lambda t_{ir}}}{\lambda t_{ir}}$ correction factor corresponds to the decay process during the irradiation time (t_{ir}) for the monitoring isotope, which has a half-life much longer than the beam breaks. The factors ε is the counting efficiency; $I\gamma$ is the γ-ray fraction corrected for summation effect, σ_{eff} the experimental effective cross section and N the foil nuclei. Using the effective cross section for electron-plus-photon disintegration as it is reported in the bibliography [5], for the actual electron beam energy (18.3 MeV) a mean flux value of $4.3 \pm 0.4 \times 10^8$ electrons per cm^2 and per sec was estimated.

During irradiation of ^{238}U target, the software of linear accelerator recorded average dose rate of 3.85 ±0.05 Gy/min. Taken into account the above mentioned fluence-to-effective dose conversion factors an electron flux $3.5 \pm 0.3 \times 10^{8}$ electrons per cm^{2} per sec was calculated.

4. CONCLUSIONS

Regarding to verify the electron flux of a linear medical accelerator determined during monthly quality assurance procedure using a plane-parallel ionization chamber, the activation technique was also involved to the specific measurements. The electron flux determined in the present work was ranged between 3.5 up to 4.3 x 10^8 electrons per cm^{2} per sec. The experimental results as well as the calculations applied to the nominal data of the irradiation system were presented to be in good agreement within the measurement uncertainties. According to the results each Monitor Unit delivered by the accelerator corresponds to a fluence of 6.1 ± 0.7 $e.cm^{-2}$.

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