TARGET INVESTIGATION DRIVEN BY A 10 MeV ELECTRN LINAC FOR BREMESSTRAHLUNG PRODUCTION*

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Abstract

IPM E-Linac is a 10 MeV electron linear accelerator presently under construction at Institute for Research in Fundamental Sciences (IPM). It will accelerate electron from 45 keV to 10 MeV along the 160 cm accelerating tube. One of the beam energy measurement devices is designed based on the production of bremsstrahlung radiation. Target of the electron linac presents a key role in the production of bremsstrahlung. In this paper, we present the simulation results for an investigation on the bremsstrahlung radiation production based on target thickness, radius and atomic number, Z. We have applied Fluka Monte Carlo code for collecting the dose equivalent of generated bremsstrahlung along the target central axis at 30cm located downstream the target.

INTRODUCTION

IPM E-Linac as the first attempt for manufacturing an electron linac in Iran is under the construction [1], [2], it accelerates electron to 10 MeV along 160 cm accelerating tube and the main parameter of the machine is presented in Table 1. It consists of a 45 keV thermionic rf gun, a pre-buncher cavity and the accelerating section: accelerating tube, buncher and the couplers shown in Figure 1.

The accelerated electrons expose the target downstream of the end-coupler, while for feasibility of changing and examining different target, a 0.1 mm titanium window closes the end-cap of the pipe to save the vacuum level of structure. The produced bremsstrahlung at an angle and distance downstream the target are affected by the beam energy, beam distribution, target material, geometry (surface and thickness) of the target, distance and angle of detection regarding the target. In this paper we report radiation production result of an investigation on thickness, diameter and material of the target driven by the 10 MeV electrons beam with transverse Gaussian distribution to obtain the maximum generation of photon out of the target at 30 cm downstream the titanium window. Monte Carlo simulations were performed by Fluka [3] to detect the photon dose equivalents.

METHODOLOGY

The structure was used in Fluka simulation is in Figure 2. The titanium thickness is constant, 0.1 mm, as the first layer while the atomic number, Z, and thickness of the second layer and the both of the layers diameters were scanned for generation of the bremsstrahlung radiation. The 10 MeV electron beam with the transverse Gaussian beam distribution of 1mm as FWHM, Figure 3, incidents on the center of the target, perpendicularly. Keeping the less than 1.2% relative error was provided by initiating the simulations with 3×10^{7} as the number of incident electrons.

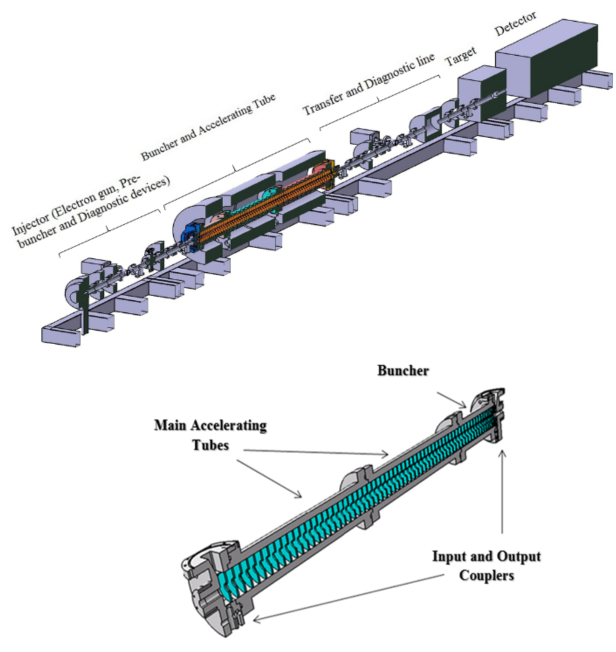

Figure 1: Layout of IPM E-Linac [1].

Table 1: The main IPM E-Linac Parameters

Parameters	**Values**
Output energy	10 MeV
Max. Peak current	10 mA
Bunch frequency	2997.92 MHz
Pulse Length	7 μs
Accelerating tube length	160 cm
Operational mode	π/2-TWπ
Max. Pulse Repetition Frequency (PRF)	250 Hz

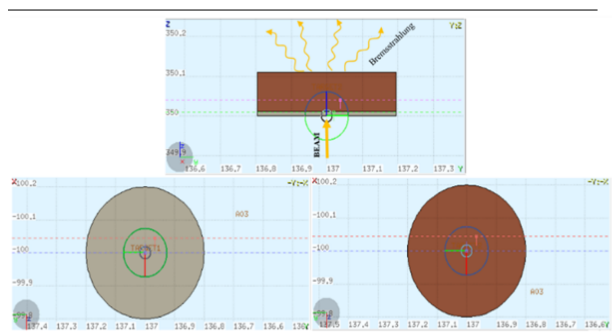

Figure 2: Schematic view of the simulation model.

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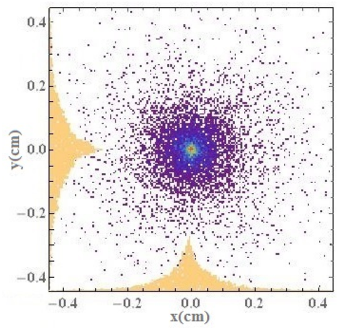

Figure 3: Transverse beam distribution at exposed target location.

RESULTS

The Dose equivalent estimations by changing the thickness and diameter of the cylinder target for the high Z target (tantalum) is shown in Table 2 and Figure 4, for the low Z target (carbon) are show in Table 3, Figure 5 and aluminium, iron, copper and silver in Figure 6. The dose equivalent of bremsstrahlung for a given cylinder increases as the target atomic number Z increases was expecting from the yield evolution with Z [4].

As the above mentioned Tables and Figures show the evolution of the generated radiation as the function of target diameters too. Figures 4, 5 and 6 present: changing the target diameter has efficiency on the generated radiation for low targets (Z≤13 in this study). The carbon target with 5.2 cm and 1.3 cm as diameter and thickness, respectively, and the aluminium target in an area around 1.2 to 5.8 cm and thickness 0.7 to 0.9 cm have the maximum radiation production.

The generated dose equivalent of the incident beam on the high Z targets (Z>13) has ignorable dependency on the target diameter especially for the thickness less than 1 cm.

Comparing the data and plots indicate the tantalum target with the thickness less than 0.2 cm and the 0.4 to 6 cm as diameter (according to this study) generates the maximum radiation among the rest of material.

Table 2: Dose equivalent per incident electron (pSv/primary) generated by a high Z target (tantalum) exposed by a 10 MeV electron beam as a function of target thickness and diameter at 30 cm from central axis of the target

Target thickness (cm)	Target diameter (cm)							
	0.4	1.2	2.0	2.8	3.6	4.4	5.2	6.0
0.1	1.28×10^{-2}	1.28×10^{-2}	1.28×10^{-2}	1.28×10^{-2}	1.28×10^{-2}	1.28×10^{-2}	1.28×10^{-2}	1.28×10^{-2}
0.3	1.12×10^{-2}	1.12×10^{-2}	1.12×10^{-2}	1.14×10^{-2}	1.13×10^{-2}	1.13×10^{-2}	1.13×10^{-2}	1.14×10^{-2}
0.5	9.44×10^{-3}	9.47×10^{-3}	9.60×10^{-3}	9.53×10^{-3}	9.62×10^{-3}	9.56×10^{-3}	9.53×10^{-3}	9.57×10^{-3}
0.7	7.92×10^{-3}	8.02×10^{-3}	8.07×10^{-3}	8.16×10^{-3}	8.20×10^{-3}	8.08×10^{-3}	8.12×10^{-3}	8.05×10^{-3}
0.9	6.86×10^{-3}	6.90×10^{-3}	6.91×10^{-3}	6.97×10^{-3}	7.01×10^{-3}	6.95×10^{-3}	6.98×10^{-3}	7.03×10^{-3}
1.1	5.80×10^{-3}	5.94×10^{-3}	5.99×10^{-3}	6.10×10^{-3}	6.07×10^{-3}	6.02×10^{-3}	6.01×10^{-3}	5.98×10^{-3}
1.3	4.91×10^{-3}	5.16×10^{-3}	5.11×10^{-3}	5.19×10^{-3}	5.18×10^{-3}	5.14×10^{-3}	5.13×10^{-3}	5.17×10^{-3}
1.5	4.27×10^{-3}	4.43×10^{-3}	4.49×10^{-3}	4.50×10^{-3}	4.47×10^{-3}	4.51×10^{-3}	4.47×10^{-3}	4.53×10^{-3}
1.7	3.69×10^{-3}	3.86×10^{-3}	3.89×10^{-3}	3.91×10^{-3}	3.90×10^{-3}	3.91×10^{-3}	3.92×10^{-3}	3.90×10^{-3}
1.9	3.15×10^{-3}	3.31×10^{-3}	3.35×10^{-3}	3.35×10^{-3}	3.40×10^{-3}	3.42×10^{-3}	3.37×10^{-3}	3.41×10^{-3}

Table 3: Dose equivalent per incident electron (pSv/primary) generated by a low Z target (carbon) exposed by a 10 MeV electron beam as a function of target thickness and diameter at 30 cm from central axis of the target

Target thickness (cm)	Target diameter (cm)							
	0.4	1.2	2.0	2.8	3.6	4.4	5.2	6.0
0.1	6.33×10^{-3}	6.34×10^{-3}	6.32×10^{-3}	6.33×10^{-3}	6.31×10^{-3}	6.31×10^{-3}	6.30×10^{-3}	6.31×10^{-3}
0.3	7.85×10^{-3}	7.84×10^{-3}	7.79×10^{-3}	7.81×10^{-3}	7.78×10^{-3}	7.80×10^{-3}	7.81×10^{-3}	7.82×10^{-3}
0.5	8.53×10^{-3}	8.53×10^{-3}	8.51×10^{-3}	8.52×10^{-3}	8.55×10^{-3}	8.54×10^{-3}	8.49×10^{-3}	8.48×10^{-3}
0.7	8.97×10^{-3}	8.91×10^{-3}	8.94×10^{-3}	8.86×10^{-3}	8.90×10^{-3}	8.86×10^{-3}	8.91×10^{-3}	8.93×10^{-3}
0.9	9.10×10^{-3}	9.12×10^{-3}	9.05×10^{-3}	9.06×10^{-3}	9.09×10^{-3}	9.14×10^{-3}	9.20×10^{-3}	9.09×10^{-3}
1.1	9.03×10^{-3}	9.14×10^{-3}	9.14×10^{-3}	9.11×10^{-3}	9.16×10^{-3}	9.19×10^{-3}	9.12×10^{-3}	9.15×10^{-3}
1.3	8.97×10^{-3}	9.11×10^{-3}	9.14×10^{-3}	9.19×10^{-3}	9.07×10^{-3}	9.08×10^{-3}	9.21×10^{-3}	9.14×10^{-3}
1.5	8.88×10^{-3}	9.00×10^{-3}	9.00×10^{-3}	9.02×10^{-3}	9.05×10^{-3}	9.08×10^{-3}	9.04×10^{-3}	9.06×10^{-3}
1.7	8.70×10^{-3}	8.93×10^{-3}	9.04×10^{-3}	8.95×10^{-3}	8.96×10^{-3}	9.00×10^{-3}	8.96×10^{-3}	8.94×10^{-3}
1.9	8.44×10^{-3}	8.75×10^{-3}	8.85×10^{-3}	8.84×10^{-3}	8.81×10^{-3}	8.82×10^{-3}	8.85×10^{-3}	8.88×10^{-3}

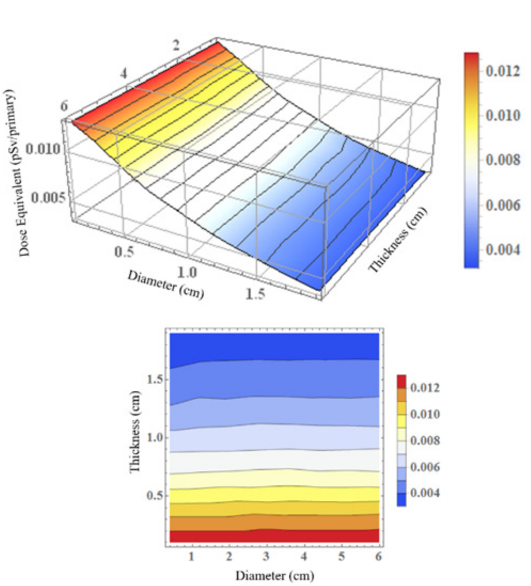

Figure 4: Dose equivalent of generated photon with tantalum target as function of diameter and thickness.

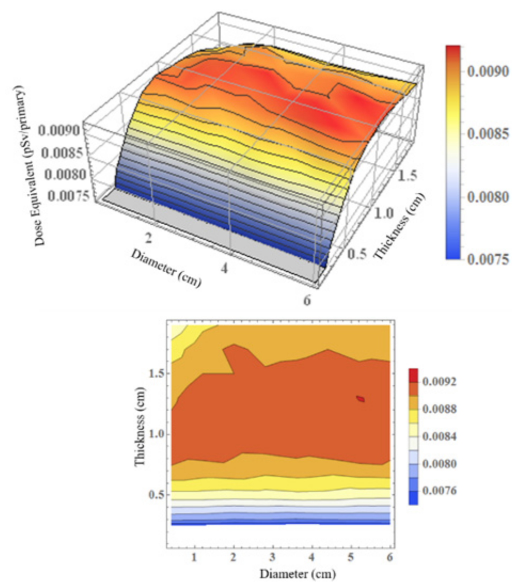

Figure 5: Dose equivalent of generated photon with carbon target as function of diameter and thickness.

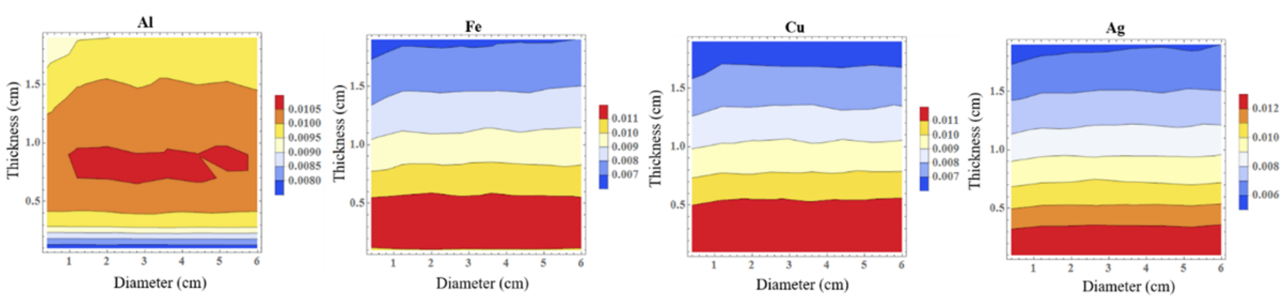

Figure 6: Dose equivalent of generated photon with Al, Fe, Cu and Ag as function of target diameter and thickness.

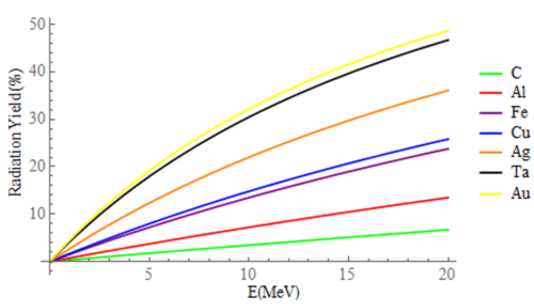

Figure 7: Radiation yield as a function of material atomic number and the kinetic energy of incident electrons.

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