A.12: Bremsstrahlung source term from optimum targets

Bremsstrahlung source term is usually defined as the radiation absorbed dose rate at one meter per unit electron beam power from a high Z thick target. Conventionally, source term from a thick target is used for radiation shielding calculation of electron accelerators. As bremsstrahlung yield varies as a function of target thickness, maximum yield is obtained at a certain thickness, called as the optimum target for bremsstrahlung production. The thick target source term underestimates the dose rate compared to an optimum target (whose thickness is less than a thick target). In the present study, the optimum thickness for different target materials like aluminum (Al), copper (Cu), tin (Sn), tantalum (Ta) & lead (Pb) is determined using EGSnrc Monte-Carlo code for 450 MeV, 1000 MeV and 2500 MeV electrons. Subsequently, bremsstrahlung source term from the optimum lead targets for 450 MeV and 550 MeV are experimentally determined. The source term is also simulated using EGSnrc monte-carlo code and found to be in excellent agreement. Based on the agreement optimum target source term is simulated up to 2000 MeV and the results are presented.

The optimum target thickness was simulated using a parallel beam of electrons falling perpendicularly on the target. The obtained optimum thicknesses as a function of the atomic number are graphically shown in Fig. A.12.1.

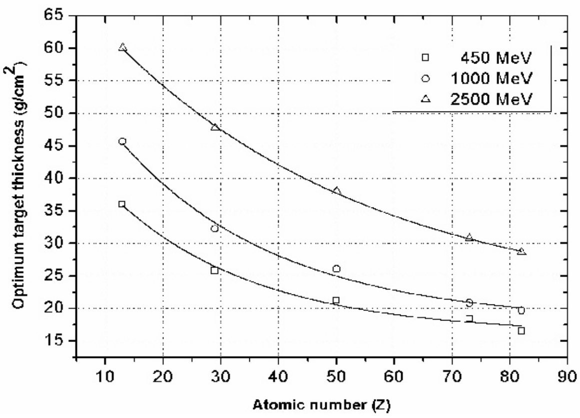

Fig. A.12.1: Optimum target thickness for 450, 1000 and 2500 MeV electrons

A curve fit equation obtained from the data for the optimum thickness, t (g/cm²) for materials (13 < Z < 82) and energy, E (MeV) within the range 450 MeV - 2500 MeV is given below.

$$t = (10.52 - 0.094Z) + \frac{5.46E^{0.412}}{Z^{0.379}}$$

For the experiments the electron beam is allowed to incident perpendicularly on optimum thick lead target (13.7 mm for 450 MeV and 14.7 mm for 550 MeV). Experiments are carried out in the booster hall of Indus facility. A water phantom of size 30cmx30cmx30cm with $CaSO_4$:Dy TLDs is placed at 1 m from the target in the forward direction (water phantom is used to simulate human body). The dose is measured inside the water phantom at various depths using the TLDs. From the maximum of the depth dose profile obtained, the optimum target source term is determined. The source term is also simulated using EGSnrc code. The experimental and simulated optimum target source term data is found to be in excellent agreement within ±3%. Subsequently, source term data is extended up to 2000 MeV and compared with thick target source term. The comparison is shown in Fig. A.12.2. It can be seen that the optimum target source term is several factors higher than the thick target source term in the energy range studied.

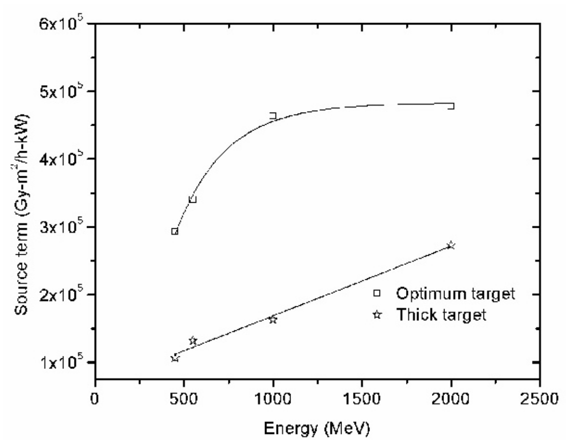

Fig. A.12.2: Comparison between optimum and thick high Z source term

It can also be seen from Fig. A.12.2 that as the energy of incident electron increases, optimum target source term increases initially and then saturates whereas thick target source term is found to increase linearly. The saturation of source term in case of optimum target at higher energies may be attributed to the reason that the photon spectrum incident on the water phantom is of similar nature though the target thickness is increased and also due to saturation of range of electrons at higher energies. Since the source term has a strong dependency on the target thickness, this aspect has to be taken care while estimating the source term for radiation shielding applications.

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