Experimental verification of angular dependence of 0.662 MeV scattered gamma photons in iron

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Introduction

Multiple scattering is a process in which incident gamma photons collide with the targets of finite dimension more than once, which acts as a noise when one measures accurately the Compton cross-sections. For the radiation shielding calculations, the quantification of multiple scattering photons is must, therefore it is important to estimate accurately the intensity and spectral distribution of multiply scattered photons.

In the present experimental study, measurements on multiple scattering are conducted for iron targets as function of thickness and scattering angle, using 0.662 MeV incident photons at various possible scattering angles. The optimum thickness at which the multiply scattered events saturate is also evaluated. The scattered photons are detected by properly shielded 76 mm × 76 mm NaI (Tl) scintillation.

Method of Measurements

Fig. 1 shows the diagram of the experimental set-up for measurement of scattered γ-rays. For the present measurements, gamma photons are obtained from the radioactive source of ^{137}Cs of strength 0.215 GBq. The experimental data were accumulated on a PC based gamma NaI (Tl) scintillation spectrometer with a fully integrated *dMCA*. A software program using *winTMCA32* was written for the present experimental set-up in order to evaluate parameters such as multiple scattering events and single scattering events.

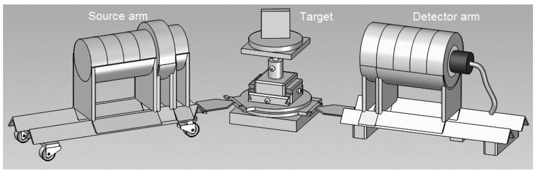

FIG. 1: Experimental setup.

Using the number of counts at peak position and FWHM of the detector, the number of photons of the Gaussian distribution for each energy can be calculated. The total number of photons at desired energy is obtained by numerically integrating. This results in an analytically estimated single scattered spectrum as registered by the detector [1].

A typical spectrum obtained by irradiating an iron sample for 1000 seconds is presented as Fig. 2 (curve-a). Background spectrum is also recorded for same period of time to permit registration of events unrelated to target (curve-b of Fig. 2). Observed experimental spectrum obtained by subtracting events under curve-b from those under curve-a, consists of both single and multiple scattered events (curve-c of Fig. 2). Subtraction of reconstructed single scattered spectrum (curve-d of Fig. 2) from experimental spectrum in range the range 183 to 229 keV results in only multiple scattered photons. This procedure is repeated for different thicknesses of iron samples.

A plot of scattered photons versus target thickness is shown in Fig. 3 for different scattering angles. From the graph, saturation thicknesses of iron for scattering angles of 55°, 75°, 95°, 115°, 125° and 135° are found to be 21mm, 28 mm, 31 mm, 32 mm, 34 mm and 31 mm respectively.

The scattered photons are estimated by

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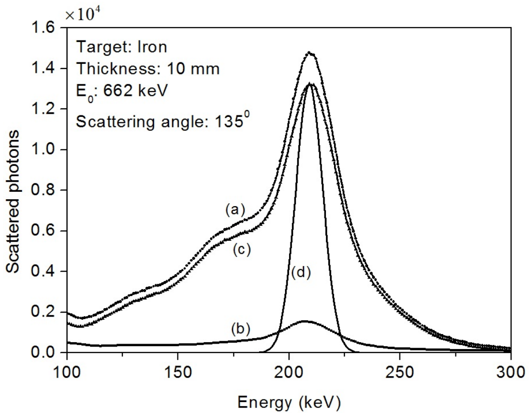

FIG. 2: Experimental pulse height distribution.

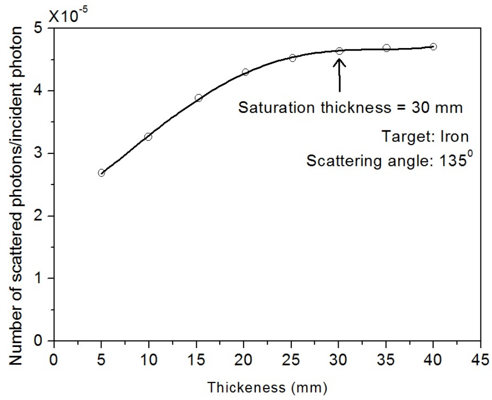

FIG. 4: MCNP simulation for Iron.

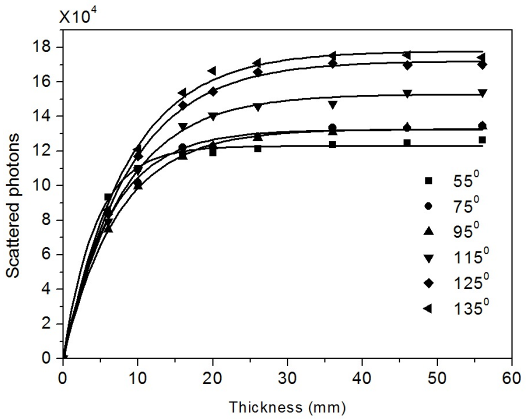

FIG. 3: Saturation thicknesses for different angles.

Monte Carlo calculation using MCNP4A code [3] for a backscattering angle of 135° and a plot of backscattered photons versus thickness for iron is shown in Fig. 4. As many as 15,00,000 histories were run in order to produce reliable confidence intervals [4]. Saturation thickness of iron through simulation is found to be 30 mm. This behaviour supports the present experimental data.

Results and conclusions

The present measurements also support the work carried by Singh et al [2] that the saturation thickness behaves differently in the two hemispheres. In the backward hemisphere, number of multiply scattered events saturate after a particular thickness known as saturation thickness and further increase in scatterer thickness does not result any change in the count rate while on the other hand in the forward hemisphere, the number of multiply scattered events decreases because self- absorption in the scatterer becomes more predominant.

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