Simulated and Experimental Calculation of Backscattering Area with Different Scatterers

Ikshitha Chalamalla[1,2], Shreesh Sahai[1], Sudatta Ray[1]*, A. Datta[1] and A. Goel[1]
[1]Amity Institute of Nuclear Science and Technology, Amity University Uttar Pradesh, Noida - 201305, INDIA
[2]SARENA, IMT Atlantique, Nantes - 44307, France
* email: sray@amity.edu

Introduction

In the past decade, there has been an extensive experimental investigation on gamma backscattering technique [1-3], however systematic investigation for wide range of metals is yet to be conclusively explored. The experimental measurement of the Albedo Factor is also limited to a few elements and is yet to investigate significant range of metals [3,4].

Gamma-backscattering peak analysis is a useful technique for determining the density, thickness, and composition of the backscattering material. The main features of the gamma-ray spectra are associated with the gamma rays – matter interaction processes. However, events with energy less than full energy occur rather frequently, resulting from various interactions with different energy dependences. Therefore, this technique is used to develop such an instrumental method which can have different uses. In the past, the backscattering of gamma rays from shielding materials has been the subject of an extensive experimental investigation by many studies [1-4]. The principal idea in this technique used for this experiment is the area under the backscattering peak.

The area under the backscattering peak is a factor of the scattering materials and their thickness. The simulation and the experiment use ^{137}Cs as a gamma source. The simulation used various precious and non-precious metals as the scatterers to find the area under the peak, however, due to procurement limitations associated with precious metals, the experimental setup used materials with similar Z as the precious metals. The simulation was done using *GEANT4* software, while the experimental analysis was done using *CANDLE* software.

Simulation and Experimental Details

A NaI(Tl) detector crystal of 1.5”x1.5” dimensions was simulated and was used to obtain the ^{137}Cs gamma spectrum which was further used to code the experimental setup shown in Fig 1.

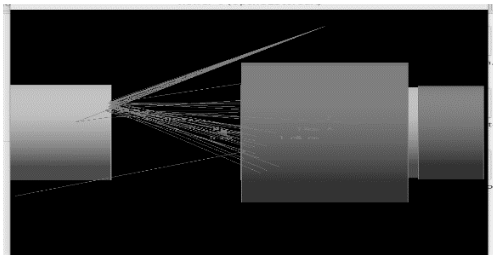

Fig 1: Detector Construction in Geant4, Detector (dark grey) and Scatterer (light grey) showing 50 events of point source under pencil beam emission {from visualization of the detector simulation through Open GUI}

For best results, approximately 50,000 incident photons were simulated at constant source activity for various thicknesses of different scattering materials to obtain the data. Although there is no strict relation between the atomic number of the material and its backscattering strength, variation in the area under the backscattered peak as a result of varying thickness is commonly observed. The area under backscattering was measured for the material of the scatterer and its varying thickness. Monte Carlo simulation allows coding a source with the desired emission at desired angles as well as the spread of the emission, and therefore the simulation was also performed using a source under 4π emission using a collimated beam at an angle similar to that in the pencil beam emission setup.

The experiment was conducted using a 1.5”x1.5” NaI(Tl) detector to match the simulation setup and used a ^{137}Cs (0.5μCi) source. The data was collected for 15 minutes and calibrated using ^{133}Ba and ^{137}Cs sources. Aluminium, Copper, and Lead scatterers were used for the experiment. The thickness of the

Aluminium scatterer ranged from 3 mm to 21 mm and for the Copper and the Lead scatterers from 3 mm to 16 mm.

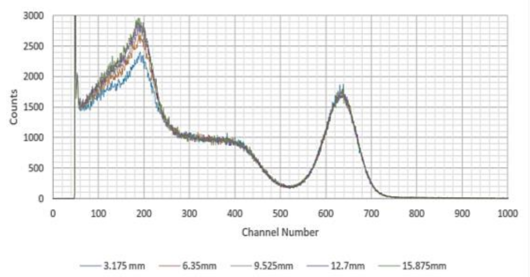

Fig 2: Variation of the area under Backscattering Peak with Cu scatterer (experimental)

Fig 2 shows the variation of the area under the Backscattering Peak using Copper scatterer obtained experimentally. Similar experimental spectra are obtained for Lead and Aluminium scatterers.

Results, Discussions and Future Scope

The simulated plots for different scatterers are shown in Fig 3 using Carbon as the lightest scatterer, Aluminium, Silver, Gold and Lead as the heaviest scatterer.

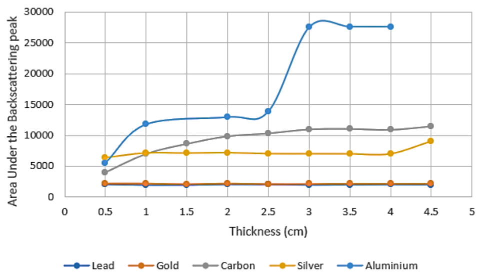

Fig 3: Area Under Backscattering Peak vs Thickness for different scattering materials (pencil beam emission source, simulated)

A similar plot is obtained for the experimental data as shown in Fig 4

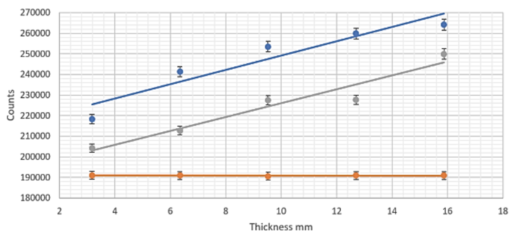

Fig 4: Area Under Backscattering Peak vs Thickness for different scattering materials (point source, experimental)

As seen in Fig 3 and Fig 4, it can be concluded that the trends in both plots are similar in the given range. The result depicts that the backscattered peak intensity provides information on the material and its thickness.

In the simulation, Copper absorbers may be further analysed for comparison and confirmation. In the experiment, the thickness of the scatterers may be increased for more data points. Since this technique has found application in the field of landmine site detection [5] presently, it finds future applications in the field of medical, industrial, agricultural industries and security domains.

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References

[1] M. Biswas, A. K. Sinha and S. C. Roy, Nuclear Instruments and Methods, 159 (1979) 157.
[2] H. Fujita, K. Kobayashi and T. Hyodo, Nucl. Sci. Eng. 19 (1964) 437.
[3] D. B. Pozdneyev, J. Nucl. Energy 21 (1967) 197.
[4] J. J. Steyn and D. G. Andrews, Nucl. Sci. Eng. 27 (1967) 318
[5] Gerl, J., Ameil, F., Kojouharov, I. and Surowiec, A., (2004), Nuclear Instruments and Methods in Physics Research Section A, 525(1-2), pp.328-331