Study of the effective volume sensitive NaI (TI) detectors using MCNP-X code

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This report aims to model, validate and estimate the effective sensitive volume of a detector using the MCNP-X code, which is used for simulation of radiation transport. In this work, the gamma radiation sensing element is a crystal composed of sodium iodide doped with thallium - NaI(Tl). These detectors are hygroscopic, "aging" and fragile and the properties of the photomultiplier tube vary with temperature [1]. However, they present many important features and one that stands out is their high counting efficiency for gamma rays in a wide energy range. A model of this crystal was developed using the MCNP-X code [2]. An estimate of the effective sensitive volume was made, considering that its aging, as well as the other effects mentioned, could cause a decrease in efficiency. The effective sensitive volume of the detector was calculated using standard sources Am^{241} and Cs^{137} positioned frontally to the detector. A real NaI (Tl) detector with 3,175 in diameter and 1.905 cm thick was simulated [2].

The sources were positioned on the central axis at a distance of 5.45 cm from the detector. Experimental measurements were made and it was found that the values obtained were below those obtained by simulation [2]. Considering that the crystal efficiency in the mathematical model was greater than the one in the-experimental, model, the decision was to decrease the crystal volume NaI(Tl) detector. Then, an interactive process between the counts obtained in the simulation and the thickness variation and the crystal diameter was performed. New calculations were gradually performed, decreasing the crystal volume until the value of the total counts became in accordance with the experimental value. The values of efficiencies can be seen in Table 1. Considering the new value of the effective sensitive volume of the crystal, - which now has 3.175 cm in diameter and is 1.757 cm thick - there was a decrease in the volume of 7.95%.

Table 1: Experimental and simulated efficiency values.

Source	Experimental (%)	MCNP-X (%)	Error (%)
^{241}Am	1,256	1,174	6,49
^{137}Cs	0,141	0,146	-3,5

The calculated photopeak absolute efficiency in the energy range 40-1000 keV was calculated using MCNP-X code, considering a new value of the effective volume of the detector. The results were compared with the experimental efficiency of the detector for sources of Am^{241} and Cs^{137} and the results are shown in Figure 1.

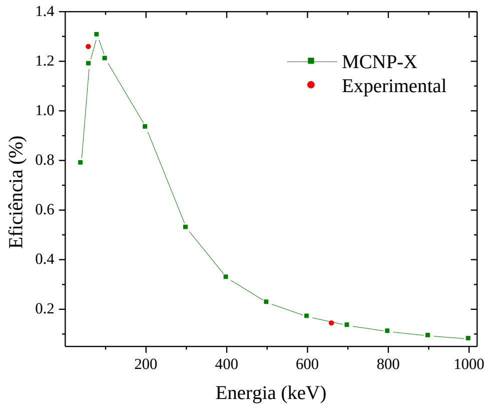

Figure 1. Photopeak efficiency curve.

An automated source and detector positioning system, which is in the design phase, will also perform measurements with the source positioned laterally to the detector, which will allow for a more complete model and expand the application of these detectors.

References

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