Validation of a NaI(Tl) detector's model using Monte Carlo method

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This report presents a methodology aiming at the calculation of the photon detection efficiency and energy resolution curves of a planar a 1.5"x 1" NaI(Tl) scintillator detector exposed to gamma rays in the energy range from 20 keV to 662 keV. The relationship between resolution and energy were determined experimentally for the correction of the spectra obtained by simulation. The parameter used for the experimental validation of the detector's model was the experimental photopeak efficiency curve - which was compared with the calculated efficiency curve by the MCNP-X code - while the energy resolution curve was used to improve the response of the mathematical simulation of the detector in code. Two sources were used to determine the actual dimensions of the detector's crystal: ^{241}Am and ^{137}Cs, representing low and one high energy, respectively. The activities of the point radiation sources were measured with the NaI(Tl) detector, in an appropriate distance between source and detector, in the same axial direction of the detector, and, after that, the same geometry was reproduced in the code. This geometry was reproduced by simulation, and the results were compared with experimental values. The procedure consists of an interactive process between counts in the simulation and variations in the thickness and diameter of the crystal. New calculations were performed, gradually decreasing the thickness and diameter of the detector's crystal, until the value of the total count was in agreement with the experimental value. Fig. 1 shows the comparison between the experimental and the simulated data by the MCNP-X code. The distributions of pulse height (PHD), obtained by simulation, considered the energy resolution, with special treatment of broadening. An acceptable agreement on the photopeak from both sources can be noted, however, for ^{137}Cs source, the Compton continuum below 400 keV, all the calculated results are a little lower than the experimental data, due to the uncertainty of the simulation of low-energy electrons by code and to the photons scattered by shield and detector support. For ^{241}Am, in comparison with the experimental data, a small discrepancy can be seen because the effect of the scintillation efficiency increase in low-energy regions where the scintillation efficiency is not linear and not considered in code.

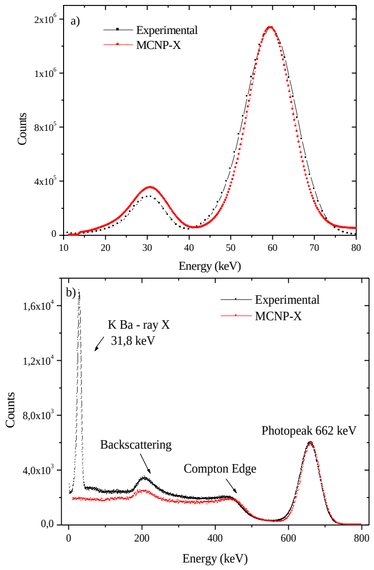

Figure 1. Experimental and simulated PHDs to sources: a) ^{241}Am; b) ^{137}Cs.

The experimental and simulated points showed good agreement. The discrepancies found are due mainly to the quality of the adjustment of the photopeak performed by the user and, probably to the fact that the scintillation efficiency of the NaI(Tl) detector is not considered by the MCNP-X code. The largest discrepancy of 5.54% was presented for the energy of 59.45 keV from ^{241}Am. The code has simulated the PHD for NaI(Tl) detector with good agreement. With the experimental photon detection efficiency curve it was possible to perform experimental validation of the mathematical model developed in the code. The sensitive volume of the detector had to be modified so that the values of the experimental photon detection efficiency and simulated curve reached a better agreement. Another possibility is that the detectors used are very old and some degradation in the crystalline lattice of the scintillator may be occurring. Whatever the case, it is necessary to conduct further studies, especially with the use of new detectors.

References

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