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Calculation of Detection Efficiency for the Gamma Detector using MCNPX

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Radiation detection has been a main interest for researchers as all kind of produced particles in atomic and subatomic physics based on the measurement systems so-called detector. Detection efficiency is one of the main parameter in detection system besides many other different parameters of the detector. The absolute efficiency of the gamma detector system will be used at Turkish Accelerator and Radiation Laboratory at Ankara (TARLA) is simulated using MCNPX code (version 2.4.0). The MCNP is the general purpose MC code that can be used for neutron, photon, electron or coupled neutron, photon, electron transport. The results have been obtained for NaI(Tl) detector system and compared with the experimental results. A good agreement was found between calculation and experiment.

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1. Introduction

Gamma detection techniques are widely used in gamma spectroscopy for nuclear physics [1]. Especially scintillation detectors have been widely used in many fields [2]. Radiation loses all or part of the energy by making interactions since enter into material environment. If photon sweep away an electron from the atom of material environment, this atom become ionized atom. Excitation condition is a condition that exists for the atomic nucleus. Degradation of equilibrium in the nucleus causes the excitation. During the excitation, nucleus trend to return to the ground state. This trend is a natural process of nucleus and causes the radiation release. This radiation release is the basic principle of the detection. The detection systems most widely used for gamma spectrometry are NaI(Tl) and HPGe based detectors [3]. One of the most important characteristics of a detector is the efficiency of the detector. Important advantage of NaI(Tl) is high detection efficiency of NaI(Tl) crystal at much lower cost [4]. Detection efficiency definition covers some parameters as (i) Absolute efficiency (ii) Intrinsic efficiency (iii) Full-energy peak efficiency (FEPE). Calculation of efficiency by using Monte Carlo simulation became widely used method in recent years [5]. Absolute efficiency of gamma ray detectors has been calculated in previous studies by using monte carlo simulations [6]. In this study absolute efficiency of $3'' \times 3''$ Na(Tl) detector has been calculated by using the MCNPX code.

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2. Material and method

One of the general-purpose monte carlo code is MCNP that can be used for the electron, neutron and photon or coupled neutron-photon-electron transport. With the great data base of cross section MCNP can simulate these particles from 1 keV to 100 MeV [7]. In this work, MCNPX was used to simulate NaI(Tl) detector efficiency. The efficiency was obtained by using F8 tally. F8 is the pulse height tally without any variance reduction. The detector geometry definition about cells and surfaces given in MCNPX input file.

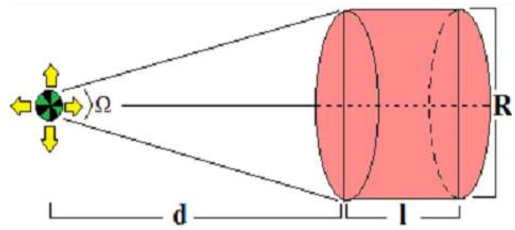

Fig. 1. Source-detector geometry.

Figure 1 shows the definition of the geometry in MCNPX simulation. In this figure d is the distance between source and $3'' \times 3''$ NaI(Tl) detector, l is the length of the detector, Ω is the solid angle between source and detector and R is the diameter of the detector. Absolute efficiency calculated in this study given by the below equation [8].

$$\varepsilon_{\text{abs}} = N_c/N_s. \quad (1)$$

Equation (1) gives the value of absolute efficiency. In this equation ε_{abs} is absolute efficiency value, N_c is number of counts recorded by the detector and N_s is number of photons emitted by the source. To obtain absolute efficiency, the photon must be radiate in the Ω solid angle [8]. Efficiency of the detector can vary depending on several factors. One of these factors is distance between source and detector [9]. Different radiation sources (^{22}Na, ^{54}Mn, ^{60}Co and ^{137}Cs) were placed at two different distances (0,5 cm–10 cm) from the source and performed for each isotope. These four isotopes give the 511, 662, 835, 1173, 1275 and 1332 keV gamma ray energies. Simulations have been done for the period of 10 hours in MCNP to reduce error rate.

3. Conclusion

In this study we calculated the absolute efficiency of modeled $3'' \times 3''$ NaI(Tl) detector and compared the results with previous studies [9]. Detector efficiencies have been calculated and variation of efficiency depending on distance has been obtained. Figure 2 shows the variations of efficiencies as a function of photon energy.

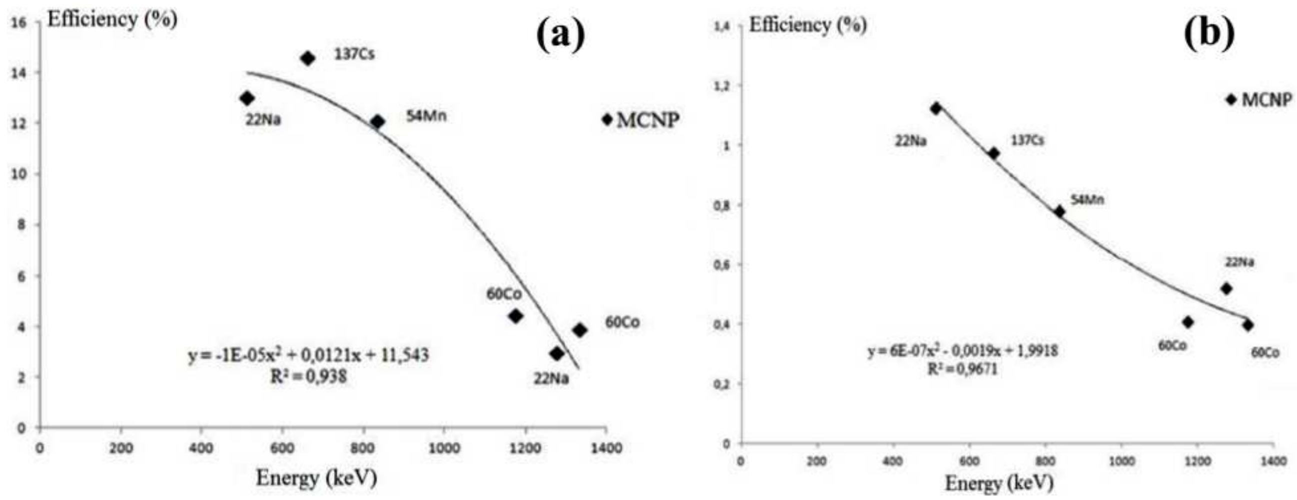

Fig. 2. (a) Variation of detection efficiency as a function of gamma ray energy for the 0.5 cm distance between source and detector (b) Variation of detection efficiency as a function of gamma ray energy for the 10 cm distance between source and detector.

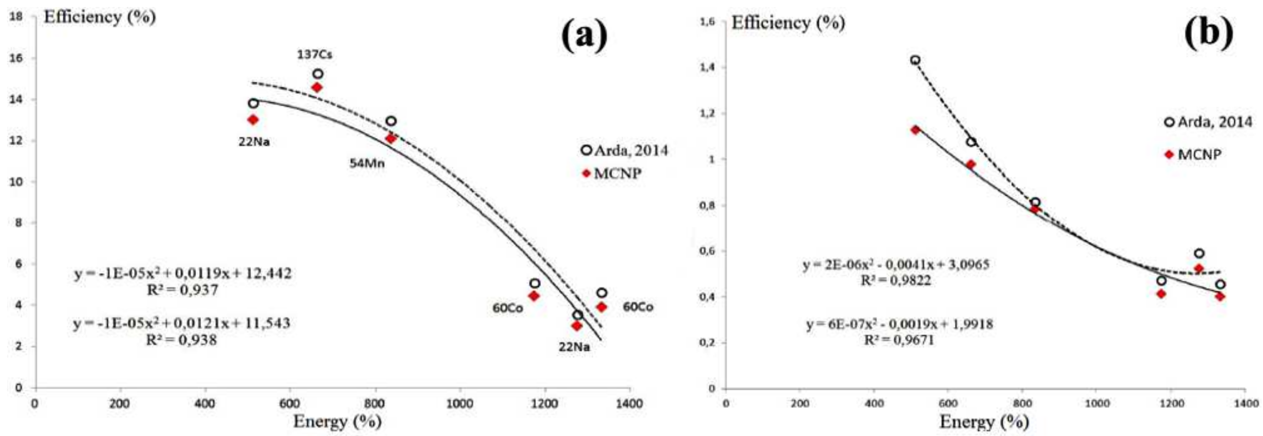

Fig. 3. (a) Comparison of measured and calculated detection efficiency of NaI(Tl) (0.5 cm distance between source and detector) (b) Comparison of measured and calculated detection efficiency of NaI(Tl) (10 cm distance between source and detector).

The comparison has been made with same isotope energies for 0.5 cm and 10 cm distances between source and detector. A good agreement has been observed between experimental results and calculated ones by using monte carlo method.

We calculated the efficiency of NaI(Tl) scintillation detector and compared with experimental results. We obtained the variation of detector efficiency by the distance and gamma ray energies. In this study we found that monte carlo simulation method is very useful method for gamma ray detector modelling and efficiency calculations. It was found from this study that MCNPX gives very consistent results by comparing with the experimental results. This consistency of calculated and experimental results showed that MCNPX can be used for future studies on various gamma ray detector modelling and particularly on efficiency calculations for any sample geometry.

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