Effective solid angle calculation using MCNP6 code

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The methodology to calculate solid angle (Ω) for a point isotropic source and a hypothetical detector with a circular aperture is well established [1]. Therefore, the aim of this report is to study effective solid angle (Ω_E), considering now the attenuation in the medium and others effects of the radiation interaction with matter. Simulations were carried out using Monte Carlo method by means of MCNP6 code [2]. Solid angle and effective solid angle calculations were performed using a 2 × 2 cm NaI(Tl) detector. The detector model is simplified and it considers the NaI(Tl) crystal as a homogeneous cylinder with a cylindrical aluminum casing. In order to observe behavior of the study solid angle and effective solid angle in different energies, two point isotropic sources were studied: ^{137}Cs (662 keV) and ^{241}Am (59.5 keV). The sources were placed in six positions (P), as follows Figure 1.

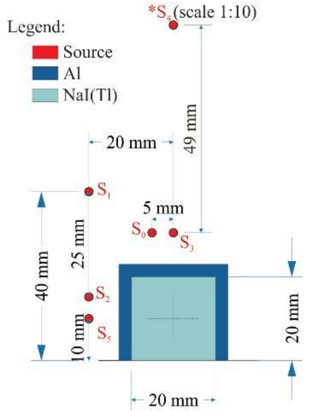

Figure 1. Positions used to calculate effective solid angle.

Moreover, to study the importance of materials used in the simulation in the effective solid angle calculations, frontal and lateral thickness of the aluminum casing of the detector were varied (1 mm and 3 mm). Results of Ω_E using 3 mm of Al thickness are presented in Table 1 and the comparison between Ω and Ω_E were made using relative error (RE%).

Table 1. Effective solid angle subtended by a NaI(Tl) detector with 3 mm of Al thickness.

P	3 mm of Al thickness			
	^{241}Am		^{137}Cs	
	Ω_E	RE(%)	Ω_E	RE(%)
S_0	1.3820	15.56	1.6003	2.22
S_1	0.3027	20.17	0.3694	2.58
S_2	1.0581	16.18	1.2389	1.86
S_3	1.5605	15.17	1.8003	2.13
*S_4	0.0011	8.33	0.0012	0.00
S_5	1.1682	15.96	1.3643	1.86

* S_4 is 500 mm away from the detector and significant changes in Ω and Ω_E were beyond fourth decimal place.

Results show that the greater the thickness of the detector casing, higher the radiation attenuation, which led to an increase in the relative error when comparing the solid angle with the effective solid angle. In addition, it is possible to highlight that for low energies the difference between the solid angle and the effective solid angle is greater than for high energies. Moreover, this study showed that the difference between solid angle and effective solid angle reached 20.17% for ^{241}Am (59.5 keV) and 2.58% for ^{137}Cs (662 keV) (both at position S_1), which means that it is highly necessary to consider the effective solid angle mainly at low energies. This result could be explained because, as the source is displaced from the collinear axis of the detector, the path taken by the radiation in the attenuator material is greater. The same effect is noticed observing positions S_0 and S_3. Considering low energy, when moving the radiation source from position S_3 to position S_0, effective solid angle is reduced from 1.5605 (S_3) to 1.3820 (S_0), which means approximately 11% of reduction. For position S_1, this attenuation is higher, probably due frontal and lateral contributions in the solid angle and effective solid angle calculations. Solid angle values and more information can be found in DAM et al., (2019) [1].

References

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