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OPTIMIZATION STUDIES OF A NEW DESIGN ARRAY DETECTORS USINGMONTE CARLO SIMULATIONS

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Abstract

A development using different gamma spectrometers was constructed for enhancing detection and verification tools of nuclear materials and radioactive source. The array design consists of HPGe detector and three different NaI detectors; one of them represents the annual detector and the others represent the guard detector. The aim of the present work is studying designs in which the perfect position for the detectors with respect to each other as well as the sample by changing the guard detectors position along the x-axis. Where the Ge detector placed, to get the best position which givesthe highest performance for the array. The Monte Carlo code (MCNP5) is used to get the optimum conditions to the design at which the systematic error is being as low as possible. The calculations require the knowledge and data of the internal dimensions of the used detectors and samples and the distances between them. The estimated results proved that the perfect position for the array when the guard detectors placed at zero angle from thex-axis where the Ge-detector placed.

Key Words: MCNP (Monte Carlo Code), SNM (standard Nuclear Material), HPGe, NaI.

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1. Introduction

The precision of gamma spectrometry is partly related to the efficiency calibration of the detector system. The detector efficiency is usually much less than 100% on account of the loss of gammaraysthrough interactions either within the sample itself, thedetector or other inactive regions (e.g. detector packaging, electricalcontacts, semiconductor deadlayer) [3].Germanium detectors are often used as the primary detector due to theirefficiency and energy resolution which is surrounded by three NaI detectors one of them represented as annual detector and the two others guard detectors.further challenges to reach the optimum positions for such detectors with the sample

Monte Carlo simulations are a set of computational algorithmswhich rely on repeated random sampling and are utilizedextensivelyin predicting the interaction of radiation with materials [3].

2. Monte Carlo Simulation

MCNP is a powerful tool used for calculating of energies and positions of different types of particles (for instance electrons, photons, neutrons and positrons) during their interaction with specific materials which have unique shape. The main problem of defying parameters for simulationin MCNP is to define sufficiently geometry of experimental setup to get as realistic model as possible.The input file of this code is created in which geometry, materials, particle source, type of results and numbers of histories are defined [9].

F8 tally is used in the input file which estimate thepulse height tally in each cell will be important and TRCL card is used as well which responsible for the transformation of the cell to different solid angles.The TRCL card makes it possible to describe just once the surfaces that bound several cellsidentical in size and shape but located at different places in the geometry.

TRn Coordinate Transformation Card

Form: TR*n O1 O2 O3 B1 B2 B3 B4 B5 B6 B7 B8 B9 M*

n = number of the transformation: 1 *n 999*.

∗TRn means that the *Bi* are angles in degrees rather than being the cosines of theangles.

*O1 O2 O*3 = displacement vector of the transformation.

B1 to *B9* = rotation matrix of the transformation.

M = 1 (the default) means that the displacement vector is the location of the origin of the auxiliary coordinate system, defined in the main system.

= −1 means that the displacement vector is the location of the origin of the main coordinate system, defined in the auxiliarysystem.

The *B* matrix specifies the relationship between the directions of the axes of the two coordinatesystems. *Bi* is the cosine of the angle (or the angle itself, in degrees in the range from 0 to 180, ifthe optional asterisk is used) between an axis of the main coordinate system *(x,y,z)* and an axis ofthe auxiliary coordinate system as follows:
Element *B1 B2 B3 B4 B5 B6 B7 B8 B9*

Axes *x,x'y,x' z,x' x,y' y,y' z,y' x,z' y,z' z,z'*[10].
The model of the HPGe detector was based on the manufacturer specificationsand design drawings. However, discrepancies between the real and simulated system can occur if technical information from themanual is omitted e.g. the deadlayer thickness. Limited accuracy inthe actual set-up in the detector (e.g. errors in the distance of thecrystal to the front window, misalignment of the crystal and itshousing occurring during the manufacturing phase etc.) or fromchanges to the size of the detector components after cryogeniccooling can also be responsible for errors. Additionally, the deadlayerthickness may vary considerably over the detector surfaceand can also increase with time [3].

The annulus detector is positioned with alignment with the HPGedetector.The guard detectors placed at both sides of annual detectors, SNM and Ge detector as shown in the figures. The annulus NaIdetector is dimensioned as 3x3 inch contained in a thin aluminum holder. One of The guard detectors dimensioned as 3x3 inch and other 2x2 inch. The detailed information are showed as in the figure (2.1)

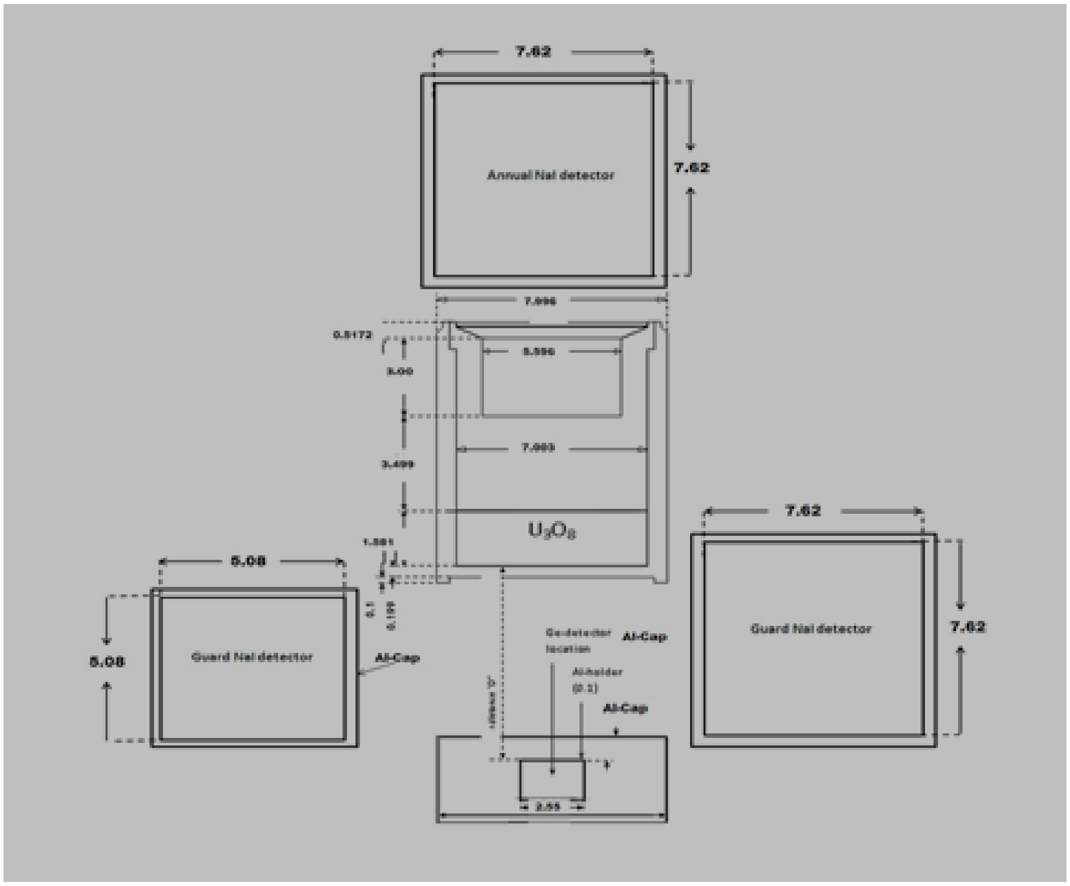
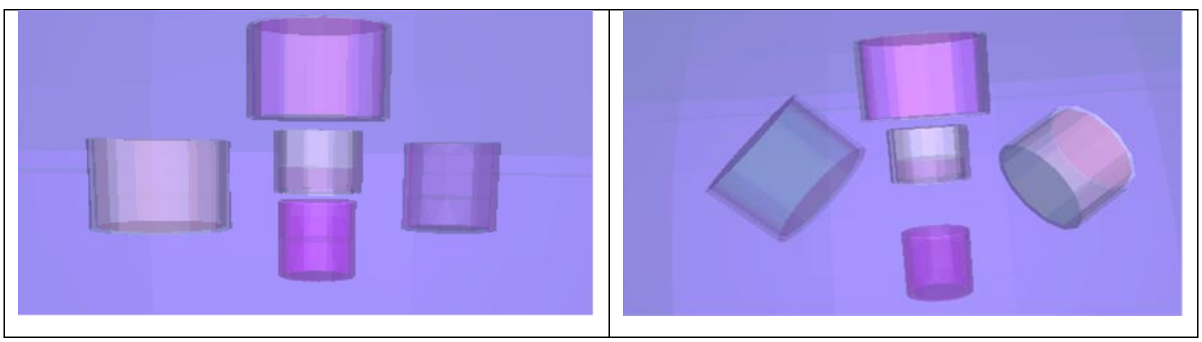


Fig.(2.1) Schematic view for optimization studies



(2.3) configuration for the array geometryby Visual Editor

3. Equipment and Methods:

The low-energy part of the spectrum is dominated by the cumulative Compton plateaus of the high-energy peaks. The Monte Carlo method is possible to calculate the detector response at arbitrary gamma-ray energy. The geometrical dimensions provided by the manufacturer of the

HPGe detector were used as an initial guess in the simulations. Several parameters are important, including dead-layer thicknesses, to get closer agreement with the measurements [1].

Although employing the beta/gamma coincidence measurement technique significantly increases the sensitivity ofthe detection system and improves the measurement of ultra-low radioactivity in a high background field, there is still some probability for high-energy gamma-rays to be scattered through Compton scattering in the gamma detector. These interactions will add unwanted background for regions of interest at lower energies [6].

The main objective of this research is to integrate an ideal design array mechanism to further advance the detection and measurement by reducing the Compton background in theregions of interest of gamma-ray spectra.

This paper described a new method for gamma ray analysis by using radioactive source ^{137}Cs at energy line 661.7 KeV and SNMwith enrichment 2.95% at energy line 185.7 KeV. The guard detectors are placed where the Al- caps are front of the Ge detector on the x-axis and then the angle between the guard detectors and the center of Ge detector will be increased gradually (0^o,10^o,20^o,…..,90^o). Each time, the net area is recorded as shown in the figure (4.1).

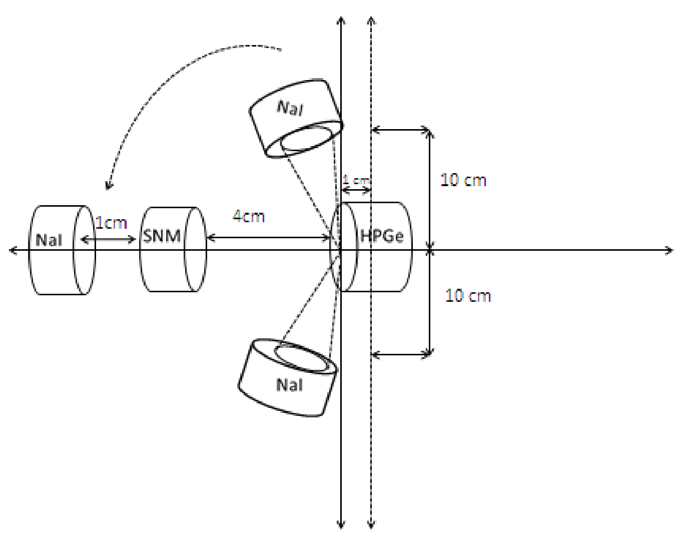


Fig.(4.1) the changes of guard detectors positions in the array

4. Results:

The detailed dimensions of the used detectors and the sample,as well as, the distances between the detectors and each other are used in the input files of MCNP code. The simulated array is shown as in the figure (4.2)

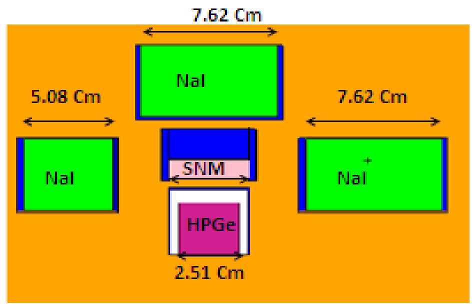


Fig.(4.2) the simulated array by MCNP5 where the guard detectors at angle 90^{o} with x-axis

Because there are a great number of assumptions and approximations made to model array detector and attempts to reach perfect position of guard detectors in the array. Many different predictions are executed MCNP transport model and comparing the results with each other for one sample. The results give highest count at the angle 0 as shown in the figures (4.3) for radioactive source and (4.4) for SNM.

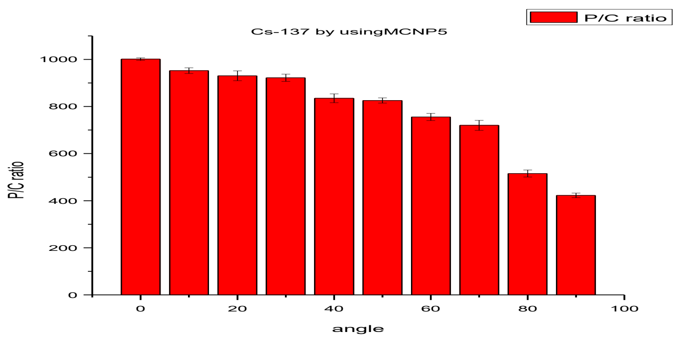


Fig.(4.3) the simulated results by MCNP5 by using radioactive source Cs-137

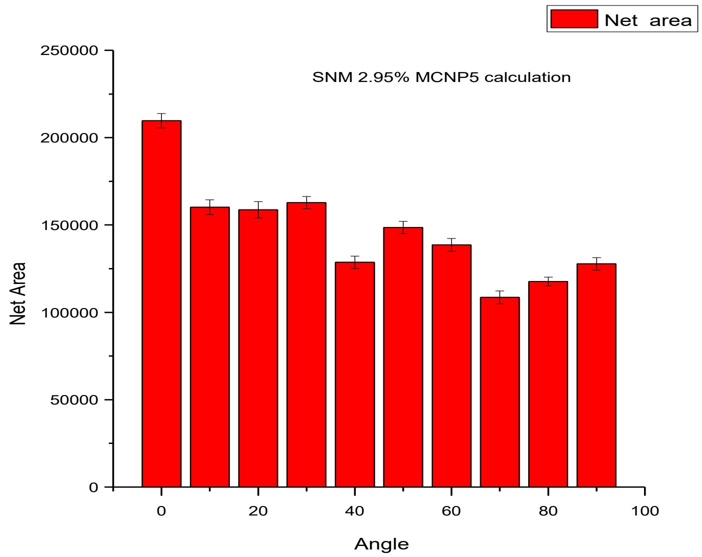


Fig.(4.4) the simulated results by MCNP5 by using SNM

5. Conclusion

In this paper,It was determined the bestarray parameters optimizationusing MCNP transport calculations. The height optimization demonstratesa maximum net peak area was obtained by the MCNP simulations.Tally F8 (detector tally) was used to calculate detector response in the active area. The results proved that the perfect position for the array is when the guard detectors (NaI) placed at zero angle fromthe x-axis, where the HpGe-detector is placed.

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