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Performance Test of the Compton Suppression System (CSS)

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1. Introduction

Environmental sampling has considered a part of verification tool on North Korea nuclear activities since 2006. Collected samples undergo gamma screening at the Korea Institute of Nuclear Nonproliferation and Control (KINAC) before detailed analysis is carried out. The Compton Suppression System (CSS) is widely used for screening because of its high resolution.

KINAC had designed the CSS with three secondary detectors. These detectors are designed to collect and subtract the Compton scattered events. This article will discuss the performance of the each secondary detector and the effect of the source location to the resolution of the whole system.

2. The configuration of the CSS

The CSS at the KINAC is composed by four detectors; the primary detector and the secondary detectors. The secondary detectors are used to collect and subtract the events from scattered photons. Before scattering, the each incident photons have energy ranging from low-medium to high. This encountered energy affects the angle of scattered photons.

The three secondary detectors, which include the annulus, plug and back-catcher NaI(Tl) were designed and had arranged with consideration to the direction of scattered photons as shown on the Fig. 1.

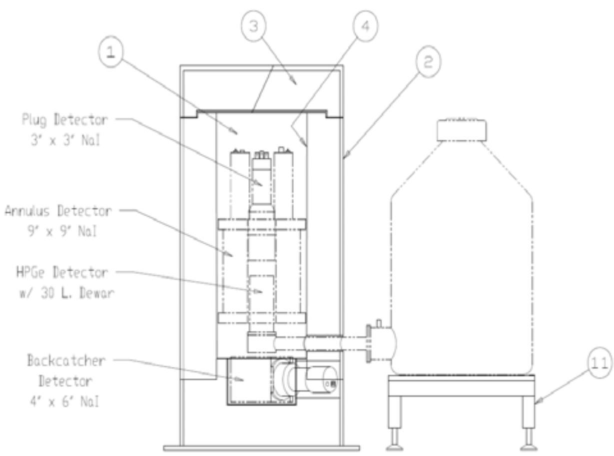

Fig. 1. The configuration of the CSS in the KINAC

3. Method

3.1 The performance test of the secondary detectors

Experiments were conducted in order to check the performance of each secondary detector. Four detectors had been repeated operating alternately as shown in Table I. The HPGe detector has been operated in every experiment to insure the accurate comparison. A ^{137}Cs (662 keV) point source was used for calculating the Peak to Compton ratio (P/C) indicating the resolution of the system. After detecting the source 20 times, the average P/C was derived as showed in table I.

3.2 The effect of the source location

The source geometry is the factor causing the resolution difference in a system. Every swipe sample collected by the inspectors has difference composition and densities of radioactive material. This means that the method of collecting or detecting of swipe samples can cause a difference in the source location.

For deriving the effect of the source location, ^{137}Cs (662 keV) source was used in substitution for the swipe sample. The location of the ^{137}Cs point source was shifted in each experiment, as shown as Fig. 2. The source was located on the surface of the HPGe detector inside the annulus NaI(Tl). Each location of the source is same distances from the center.

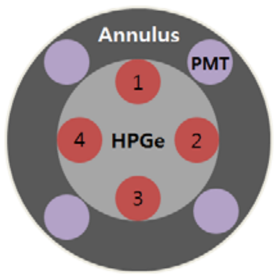

Fig. 2. The source location on the HPGe detector

4. Results

4.1 The performance test of the secondary detectors

The right column of Table I shows the ratio between the P/C using NaI(Tl) detector with the HPGe and P/C using only HPGe, unsuppressed any Compton scattering events.

Experiments 1, 2 and 3 show the P/C using only one secondary detector. In these experiments, the annulus detector provided the best P/C. The plug detector has more P/C, meaning that it can subtract the Compton scattered events better that the back-catcher detector. Experiments 4, 5 and 6 show the P/C using two secondary detectors. The best P/C is shown from a combination of the annulus and plug detector. Comparing the results from experiments 2, 3, and 5, the effect of the back-catcher derived that was not significant in the detection of ^{137}Cs sources.

Table I: The Peak to Compton Ratio [P/C] in several secondary detector conditions

	Annulus	**Plug**	**B.C.**	**P/C**	
1	×	×	×	**126.3**	1
2	×	×	○	**143.4**	1.1
3	×	○	×	**151.9**	1.2
4	○	×	×	**598.3**	**4.7**
5	×	○	○	**152.2**	1.2
6	○	×	○	**654.0**	5.2
7	○	○	×	**796.1**	**6.3**
8	○	○	○	**915.1**	7.2

These results caused by the direction of the scattered photons. The incident energy of the ^{137}Cs source is 662 keV. According to the Klein-Nishma formula [1], the ^{137}Cs source has a tendency not to maintain its own direction after the Compton scattering. The back-catcher detector was less able to collect the Compton scattered photons because most of the scattered photons lose their own direction.

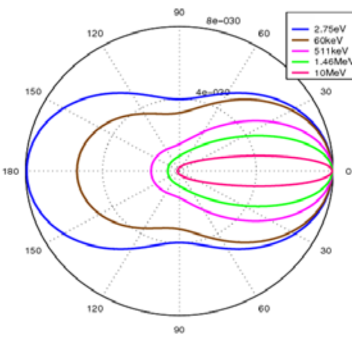

Fig. 3. The distribution of scattering-angle cross sections over a range of commonly encountered energies

4.2 The effect of the source location

According to the results of four experiments, P/Cs have differences depending on the source location. P/C was the least when the source was on the left side of the HPGe detector. The peak count was similar to that in experiment 1; the source was on the top side. Nevertheless, the Compton continuum counts of experiment 4 were higher that of experiment 1.

Table II: The Peak to Compton Ratio [P/C] in several source locations

	Source location	**P/C**	**Uncertainty**
1	Top	**824.49**	**1.50**
2	Right	**822.92**	**3.41**
3	Bottom	**828.45**	**1.00**
4	Left	**812.20**	**2.11**

5. Conclusion

Most of the radioactive materials in the swipe samples have similar or higher energy levels than the ^{137}Cs [2]. The encountered energy from the samples has a high probability of back scattering. Hence, the plug detector is more dominant over the P/C than the back - catcher detector. Studies have shown that the importance of the back-catcher detector is not as significant as was originally expected in the design.

According to the results, the resolutions show differences depending on the locations of the sources. The characteristics of the swipe sample such as composition and density might influence the source location. Therefore, further simulation is needed to derive the theoretical resolution in the condition of each swipe sample's characteristics.

REFERENCES

[1] Glenn F. Knoll, Radiation Detection and Measurement.
[2] V.Maiorov, Y.Kuno, W.Raab, V.Jansta, D.Donohue, Gamma Screening of Swipe Samples at the IAEA, IAEA.