

## Monte Carlo Simulation Study on Prompt Gamma Activation Imaging System Based on Coincidence Detection

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*For the 2D elemental analysis of the bulk sample, in the present study, a new imaging system for the neutron based prompt gamma activation imaging was proposed. The imaging system measures the 2D prompt gamma image based on the coincidence detection with a calorimeter and a position sensitive detector. The simulation results show the feasibility of the proposed imaging system for the 2D elemental analysis by measuring the prompt gamma imaging.*

### I. Introduction

For the 2D elemental analysis of the bulk sample, the neutron based prompt gamma activation imaging method has been widely used in archeology and cultural heritage researches<sup>1</sup>. To measure the prompt gammas emitted from the irradiated sample with high spatial and energy resolutions, the scanning method using a high-purity germanium detector and a slit collimator is currently used<sup>2</sup>. Although this approach can measure the 2D elemental distribution, it requires a time consuming process. Therefore it is need to improve the detection system for effective measurement.

For this purpose, in the present study, we proposed a new prompt gamma activation imaging system. The imaging system measures the 2D prompt gamma distribution with energy information based on the coincidence detection with two different detectors. One detector, a calorimeter, is to determine the energy, and the other, a position sensitive detector, is to determine the emission position. To estimate the feasibility of the proposed system, in the present study, the Monte Carlo simulation using the Geant4 toolkit<sup>3</sup> was performed.

### II. Methods

The imaging system proposed in this study consists of a calorimeter for the energy determination, and a position sensitive detector with an 8 x 8 scintillation array coupled with a parallel-hole collimator for the position determination. To correlate the energy information with position information, a coincidence detection was employed. To estimate the feasibility of the proposed imaging system for the 2D elemental analysis, we performed the Monte Carlo simulation using the Geant4 toolkit.

Figure 1 shows the geometrical setup in the Geant4 simulation. In the present study, we used the rectangular iron sample with the “L” shaped nickel. The sample dimension was 50 (W) x 50 (H) x 6 (T) mm<sup>3</sup>. For the coincidence measurement, one detector was located on the opposite side of the other. The distance between the detector and sample was 50 mm. The diameter and length of the calorimeter were 80 mm and 63 mm. The hole size, thickness, and septal thickness of the collimator were set to be 5 x 5 mm<sup>2</sup>, 30 mm, and 2 mm, respectively. The dimension of the scintillator was 6 x 6 x 50 mm<sup>3</sup>. These dimensions were not optimized. To shield the neutrons scattered from the sample, the lithium-6 enriched glass with the 0.3 mm-thickness was located in front of the calorimeter.

To measure the 2D distribution using the imaging system, the cold neutron beam of  $7 \times 10^8$  was delivered to sample. For the uniform irradiation, the sample was rotated by 30 degree in clockwise. The simulation was performed under the perfect detection condition where incident gammas are fully absorbed in the detector.

### III. Results

In the present study, the feasibility of the proposed imaging system was predicted for the nickel mixed iron sample irradiated with the cold neutron beam. To estimate the performance for the elemental analysis, we estimated the energy spectrum obtained by the calorimeter for coincidence events. The characteristic gamma ray's peaks of 352, 7631, and

7645 keV for the iron and 465, 8998 keV for the nickel can be identified. Based on the result, it was confirmed that the proposed system can identify the elements in the sample. Figure 2 shows the 2D prompt gamma image obtained by the proposed imaging system. For the coincidence events where 465 keV gamma rays were absorbed in the calorimeter, the position information in the position sensitive detector was selected. As shown in figure 2, the locations of the nickel elements in the iron plate can be determined by the proposed imaging system. Based on the results of the energy spectrum and 2D distribution, we expected that new imaging system can be applied for the neutron induced prompt gamma activation imaging analysis.

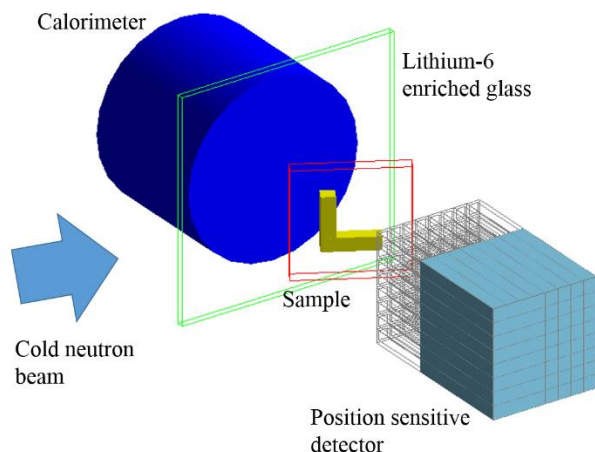


Fig.1. Geometrical setup of prompt gamma activation imaging system in the Geant4 simulation

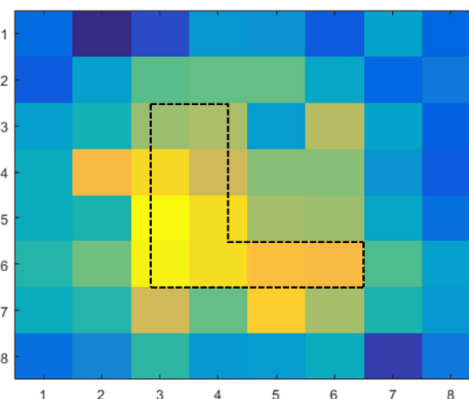


Fig.2. Prompt gamma imaging obtained by the imaging system. “L” shaped box indicates the nickel element in the iron plate

#### IV. CONCLUSIONS

In the present study, we estimated the feasibility of a new prompt gamma activation imaging system based on the coincidence measurement using the Monte Carlo simulation. The imaging system consists of a calorimeter and a position sensitive detector for the energy and position determination, respectively. For coincidence events, the iron and nickel elements can be identified by the energy information of the calorimeter, and the location of the nickel element in the iron plate can be visualized by using the position sensitive detector. Based on the simulation results, it was expected that the proposed imaging system can be used for 2D elemental analysis using the neutron beam by measuring prompt gammas. For optimal dimensions and detector materials, the performance of the imaging system will be estimated for various samples, and these simulation results will be presented.

#### ACKNOWLEDGMENTS

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