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An enriched ^{100}Mo powder measurement by an array of HPGe detectors

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Abstract

Advanced Mo-based Rare process Experiment (AMoRE) – II led by Center for Underground Physics (CUP) will search for neutrinoless double beta (0νββ) decay of ^{100}Mo, using molybdate crystals such as $^{40}Ca^{100}MoO_3$ (CMO) crystals [1]. Because the theorized 0νββ decay would happen rarely, it is important to reach zero-background level around the region of interest near 3 MeV. Therefore, it is necessary to check the raw material of the crystal, the $^{100}MoO_3$ powder, for trace levels of radioactive contamination. The High Purity Germanium (HPGe) detector group operates an array of 14 HPGe detectors, referred to as CUP Array of Germanium (CAGe), at the YangYang underground Laboratory (Y2L) in Korea. By measuring $^{100}MoO_3$ powder samples in the CAGe, we obtained activity levels of ^{226}Ra (1.6 $\pm$ 0.3 mBq/kg), ^{40}K (12 $\pm$ 3 mBq/kg), ^{228}Ac (344 $\pm$ 71 μBq/kg), ^{228}Th (244 $\pm$ 50 μBq/kg), and ^{88}Y (33 $\pm$ 8 μBq/kg). Data analysis and experimental methods are discussed in this report.

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1. Introduction

The raw material of molybdate crystals, $^{100}MoO_3$ powder, should have low levels of radioactive contamination for use in a $0\nu\beta\beta$ experiment. The CAGe system with ultra-low background radiation is available with a coincidence capability. Each detector element in the CAGe has a relative efficiency of 70 % and an endcap diameter of 8.5 cm. The array is shielded with 10 cm thick copper and 30 cm thick lead [2].

Fig. 1. The CAGe with ^{100}Mo powder bags installed

2. Experiment

Six bags with 3.847 kg of the powder were arranged in a square configuration on an acrylic plate and were installed between the top and bottom arrays. Eight other bags with a weight of 5.771 kg surrounded the CAGe as shown in Fig. 1. Two Vikuiti sheets sealed two sides of the shielding so that the detection volume can be efficiently flushed with clean boil-off nitrogen gas. The data with the powder were collected for 1919 hours, and background data without the powder were also taken for 1578 hours.

Decay chain	Isotope	Peak (keV)	Decay chain	Isotope	Peak (keV)
^{226}Ra	^{226}Ra	186	^{228}Ac	^{228}Ac	911
	^{214}Pb	295			969
		352	^{228}Th	^{212}Pb	239
	^{214}Bi	609		^{212}Bi	727
		1120		^{208}Tl	583
		1764			801
^{88}Y		898			2615
		1836	^{40}K		1461

Table 1. Gamma emission peak energies used for activity analysis in this study

3. Analysis

The energy calibration of the sample data was performed using 609 keV and 1461 keV peaks. The one for the background data was done with ^{137}Cs (662 keV) and ^{60}Co (1173 keV and 1332 keV) source data. Two of the detectors in the bottom array were excluded in the analysis because of their bad resolutions (> 3.0 keV) during the data taking period. All the peaks used in the analysis are summarized in Table 1. Peaks were fitted using three different sets of functions, a Gaussian plus exponential function, a Gaussian plus linear function, and a Gaussian function plus a constant. The fit having the best chi-square was chosen for each peak. The Geant4 Monte Carlo simulation tool was used to calculate the efficiencies of the CAGe detectors.

4. Result and Discussion

We measured radioactive contaminants in $^{100}MoO_3$ powder for AMoRE-II crystals. The measured activities are 1.6 ± 0.3 mBq/kg for ^{226}Ra, 12 ± 3 mBq/kg for ^{40}K, 344 ± 71 µBq/kg for ^{228}Ac, 244 ± 50 µBq/kg for ^{228}Th, and 33 ± 8 µBq/kg for ^{88}Y. As a next step, we plan to reduce systematic uncertainties in estimation of the detection efficiencies.

References

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