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A study on high energy gamma intensities from the ^{208}Tl decay with a ThO_2 powder

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The gamma transitions with $E_\gamma > 3$ MeV from decay of ^{208}Tl decay have not been observed and their transition intensities were known only as upper limit values. New measurements with improved sensitivity are desirable for understanding nuclear decay properties of the nucleus and high energy gamma backgrounds in rare decay experiments such as neutrinoless double beta decay searches. A ThO_2 powder sample was used as a ^{208}Tl source and was measured with a 100% High Purity Germanium(HPGe) detector in the Yangyang Underground Laboratory(Y2L) operated by the Center for Underground Physics(CUP) to obtain more accurate numbers of the high energy gamma intensities from ^{208}Tl. The experimental setup, Monte Carlo simulation studies for detection efficiencies, and preliminary results are reported in this proceeding.

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1. Introduction

Decay of ^{208}Tl is one of the main sources of natural background radiation. Most intensities of gamma transitions from the ^{208}Tl decay are already well known. However, several intensities with $E_\gamma > 3$ MeV such as 3198 keV or 3475 keV, have never been observed. The values used by the National Nuclear Data Center(NNDC) for the 3198 keV and 3475 keV gamma intensities were compiled by M. J. Martin[1] from the results of S. I. Vasil'ev[2] and represent limits of $< 7.0 \times 10^{-3}$% and $< 3.0 \times 10^{-3}$%, respectively.

2. Experiment and result

We conducted an experiment to measure the gamma intensities of 3198 keV and 3475 keV. A ThO_2 powder was used for this measurement because ^{208}Tl is included in the ^{232}Th decay chain and is supported by and in equilibrium with the longer-lived ^{228}Th. The mass of the powder is 2 kg and activities of ^{228}Ac and ^{228}Th are 23.6(24) kBq/kg and 63.1(40) kBq/kg, respectively. The 3198 keV and 3475 kev peaks are potentially from single gamma decay events or coincidence events such as 583 keV plus 2614 keV for 3198 keV peak and 860 keV plus 2614 keV for 3475 keV peak, respectively. The sample was shielded from the detector by a 10cm thick lead shelf which reduced the rate of coincidence events relative to the single gamma decays because of the decreased probability for both gammas from a single decay to simultaneously penetrate the lead, and to a lesser extent because of the larger attenuation of the lower energy gammas.

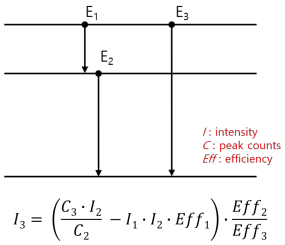

Figure 1: An example of gamma transition intensity calculation.

The powder sample was measured for 39.8 days and pileup events in the high energy region were rejected from the measurement data to reduce the background under the peaks of interest. However, peaks of interest were not observed, and only upper limits on the peaks were obtained by fitting. The count rates of 3198 keV and 3475 keV peaks are 4.40×10^6 /s and 3.59×10^6 /s, respectively. Limits on the gamma intensities were calculated from the peak rate limits using the full-energy peak efficiency(FEPE) from the Geant4 simulation by normalizing the rates to the known gamma transition intensities such as 2615 keV, as shown in Fig. 1. The preliminary upper limits of 3198 keV and 3475 keV gamma intensities are $< 1.6 \times 10^{-4}$% and $< 1.3 \times 10^{-4}$%, respectively.

3. Summary

A 2 kg ThO_2 powder was measured for 39.8 days with a HPGe detector to observe the gamma transition intensities from ^{208}Tl with $E_\gamma > 3$ MeV, especially peak transitions of 3198 keV and 3475 keV. For 3198 keV and 3475 keV transitions, representing at least a factor of 20 improvement over the accepted NNDC values.

References

[1] M. J. Martin, Nuclear Data Sheets **108** 1583-1806 (2007)

[2] S. I. Vasil'ev *et al.*, Instruments and Experimental Techniques **49** 34-40 (2006)