Multiplicity measurement of prompt fission gamma rays in spontaneous fission of ^{252}Cf

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Introduction

Information gained from studies in prompt fission neutrons and gamma rays are relevant not only for nuclear technologies but also in better understanding of the fission process. While a lot of effort has been put in measurements and understanding towards average properties of prompt fission neutrons, studies towards prompt fission gamma spectrum (PFGS) has gained momentum only in recent times. The OECD organization's Nuclear Energy Agency has expressed the need for more accurate measurements of the characteristic features of prompt fission gamma-ray spectrum such as mean total energy and multiplicity within a 7.5% uncertainty [1]. But an underestimation of prompt gamma heating by 10% to 28% for ^{235}U and ^{239}Pu came in light in recent benchmarking exercises on nuclear reactors [2]. This has resulted into a renewed interest worldwide in measurements of the PFGS characteristics for providing improved accuracy data within the stipulated limit.

The motivation of this work is to unfold the prompt gamma multiplicity distribution from the experimentally measured fold (number of gamma detectors fired simultaneously in an event in coincidence with fission) distribution and benchmark it with the well known ^{252}Cf multiplicity distribution. The unfolding technique once benchmarked will be used in studies related to neutron induced fission reactions in actinides and minor actinides to unfold prompt fission gamma multiplicity spectrum. A preliminary report in this regard describes the experimentally measured prompt gamma fold distribution in spontaneous fission of ^{252}Cf using 14 bismuth germanate(BGO) detectors.

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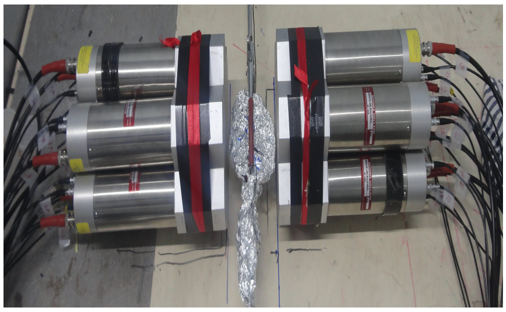

FIG. 1: Photograph of experimental setup consitiong of BGO array and fission trigger chamber.

Experimental Details

Measurement of prompt gamma rays was done using multiplicity detector array consisting of 14 hexagonal BGO detectors, each 8.6 cm thick with a face-to-face distance of 5.9 cm. These were configured in two close-packed groups with 7 detectors in each group. These 7x7 arrays of closely packed hexagonal BGO detectors were kept symmetrically at a distance of 5 cm from ^{252}Cf source. For each BGO detector a bias of -1100 Volt was applied. The ^{252}Cf source was mounted in the cathode of an ionization chamber operating in air and covering $\sim 2\pi$ solid angle for fission fragments emitted during spontaneous fission of ^{252}Cf. The anode and the cathode having $\sim$6 cm diameter each, were kept separated by a distance of 3 mm using a Teflon insulator ring. A positive voltage of 450 V was applied to the anode. Photograph of the experimental setup is shown in Fig. 1.

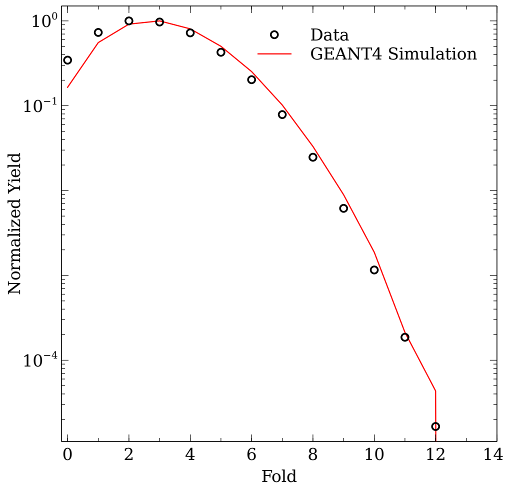

FIG. 2: Comparison of measured prompt gamma fold distribution (open circles) and GEANT4 simulation(red line).

Each BGO detector was kept at electronic threshold of ∼100 keV using CAEN CFD. The BGO timings were generated after processing anode signal via CAEN CFD and dynode signals were processed through Mesytec-MSCF module to get energy information. The full scale energy range for each BGO was set to be ∼4 MeV. A VME based data acquisition system LAMPS was used to acquire the processed signals data via an ADC and a TDC module. The trigger for the data acquisition system was obtained from the energy loss signal in the ionization chamber produced by the fission fragments. Fission triggers were also used as the reference for the timing of each BGO detector.

Analysis

For each BGO detector a prompt time window was determined. In the energy loss spectrum of ionization chamber a region of fission like events were selected. A condition for energy threshold on each BGO was put ∼100 keV. With these conditions imposed, a fold value was generated for each event whenever a fission like event occurred. For example a fold value of zero is associated with events where fission occurred but none of the BGO recorded events within the prompt time window and beyond the ∼100 keV threshold. The normalized fold distribution spectrum obtained is depicted in Fig. 2 by open circles. The GEANT4 toolkit along with ^{252}Cf spontaneous fission source from FREYA(Fission Reaction Event Yield Algorithm)[3] library was utilized to simulate the fold distribution in similar experimental setup and is shown as comparison in Fig. 2. Here, it is worth mentioning that due to the short flight path length of 5 cm , it was not possible to separate neutron and gamma in the time of flight spectrum. But a contribution of ∼5-6% by the neutrons in the fold distribution was estimated experimentally as well as by GEANT4 simulations. Further analysis is in progress to extract the multiplicity distribution from the measured fold spectrum.

Acknowledgments

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References

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