# Measurement of coherent bremsstrahlung from $^{252}$Cf spontaneous fission at the Jaduguda Underground Lab

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One of the fundamental and debated problems of nuclear fission physics has been the emission of high-energy $\gamma$ rays (> 25 MeV) accompanying the spontaneous fission. The emission probability from the excited fission fragments of such high energy is negligibly small. These high-energy $\gamma$ rays, if exists, are therefore conjectured to be originated from the coherent bremsstrahlung process in the Coulomb field of the fission fragments [1-6]. The measurement of the $\gamma$-rays above 25 MeV is challenging due to low probability of emission as well as due to large cosmic-ray background which has significant contribution in the region of interest. In order to overcome the problems arising due to cosmic rays, we have measured the $\gamma$-ray spectrum from $^{252}$Cf at the underground laboratory located at UCIL, Jaduguda, India.

The underground facility at the 555 meters depth level of the mine has a flat overburden having an average rock density of 2.8 g/cc. This provides a natural reduction of the cosmic muon flux, as measured, by a factor 2 x $10^4$ [7,8]. The cosmic muon rate at the underground lab was measured to be 2.79 x $10^{-7}$ cm$^{-2}$ s$^{-1}$ sr$^{-1}$ [7]. The experimental setup for measuring the $\gamma$-rays from $^{252}$Cf is shown in Fig. 1. The LAMBDA array [9] arranged in 5x5 matrix along with four multiplicity filters [10], arranged in 2x2 matrix, were used to detect high-energy $\gamma$ rays from the $^{252}$Cf source (12$\mu$Ci) in the $\gamma$-$\gamma$ coincidence mode. The approach is based on the fact that several low energy $\gamma$ rays are emitted from the excited fission fragments, and thus, the coincidence establishes the correlation between fission events and high energy $\gamma$-rays. The source was placed as close as possible to the multiplicity detectors to detect the fission events as well as to get the fast start trigger, while the LAMBDA array was placed at a distance of 25 cm from the source to detect the high-energy $\gamma$-rays. A master trigger was generated by taking a coincidence (70 ns) between the start trigger and any one of the 25 detectors in the LAMBDA array above 4 MeV. The neutron-gamma discrimination of the events in the high energy spectrometer was achieved through the time of flight (TOF) measurement. The pile-up events were rejected by measuring the charge deposition over two integrating time intervals (50 ns and 2 $\mu$s) in each of the detectors. The data was recorded in this mode for 920 hours, in which a total of 2.5 x $10^{10}$ fission events were observed. In order to get an idea about the cosmic events, the background events were also recorded for 920 hours by replacing the $^{252}$Cf source with the $^{22}$Na source having similar activity.

Fig. 1. The experimental setup during the experiment. The LAMBDA array (blue) arranged in 5x5 matrix and the multiplicity filter (red) in 2x2 matrix.

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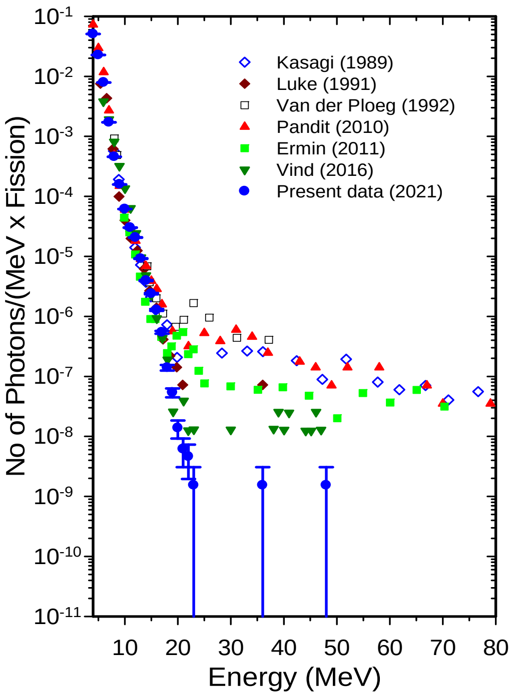

Fig. 2. Measured γ-ray spectra for photon emission from the spontaneous fission of $^{252}$Cf. The data has been compared with the previous measurements

It was observed that the accidental coincidence count of the cosmic rays was nil. However, cosmic ray induced background was observed when the cosmic shower triggered both the multiplicity filter and the LAMBDA array leading to an event in the prompt time gate as well as the two dimensional PSD gate. Owing to the high granularity of the LAMBDA detectors, the muon events can be easily identified as they produce track in the detector whereas the high energy gamma rays produce cluster [11].

A total of 26 events were observed above 25 MeV in the background run. All the events produced track in the detector and were identified as cosmic muon events. As a matter of fact, in most of the cases, the total energy deposit was well over 187 MeV (the experimentally measured total kinetic energy from $^{252}$Cf). Similarly, during the $^{252}$Cf source run 29 events were recorded above 25 MeV in the raw data, out of which 27 were identified as cosmic muon events owing to their hit pattern. Only two events generated cluster like event in the detectors with total energy deposit of 36 and 48 MeV which could therefore be regarded as real events. The high-energy γ-ray spectrum measured in the present experiment is shown in Fig. 2. The result has been compared with the previous measurements of γ-ray spectrum accompanying spontaneous fission of $^{252}$Cf.

As could be seen, the γ-ray spectrum in the medium energy region 8-20 MeV is in good agreement with the data from the previous measurements. However, the γ-ray spectrum above 25 MeV measured in this work is about two orders of magnitude lower than Kasagi [1], Van der Ploeg [3] , Pandit [4] (our previous measurement at surface level), and more than an order lower compared to Ermin [5] and Vind [6]. As it appears, the relevant difference between the present measurement and the previous measurements is probably due to the incomplete rejection of the cosmic ray background leading to an overestimation of the γ-ray emission probability. The sensitivity of the present experiment was highly augmented by the measurement at the underground laboratory which naturally reduces the cosmic ray background. We provide an upper limit of 5 x $10^{-11}$ photons/(fission x MeV) for the production of γ-rays in the energy range 25-180 MeV at 95% confidence level. It was calculated considering a constant γ-ray emission probability in the 25-180 MeV energy regions. The new upper limit is about two orders smaller than the previous measurements.

## References

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