Measurement of high-energy γ-rays in spontaneous fission of ^{252}Cf

R.P. Vind[1], D.C.Biswas[1], N. Kumar[1], Y.K. Gupta[1], Reha Grover[1,2],Shradha Dubey[1] ,R.V. Jangale[1], A.L. Inkar[1], D.R. Chakrabarty[1]

[1]Nuclear Physics Division, Bhabha Atomic Research Centre, Mumbai – 400085, India.
[2]Physics Department, Indian Institute of Technology, New Delhi - 110016 , India.
email: dcbiswas@barc.gov.in

Introduction:

The dynamical evolution of fission process is quite complex due to the dissipation of energy during the massive rearrangement of nucleons in a short time scale. Various charged particles, neutrons and gamma rays are emitted from the excited fission fragments and also during the journey from saddle to scission of the fissioning nucleus, which carry crucial information of the fission process. In nuclear fission very large energy (~180 MeV) is available and several experimental groups have carried out investigations to explore the release of the energy by measuring the decay products. One of the decay channel is the emission of high energy gamma (HEG) rays in nuclear fission [1]. Previously four regions of gamma rays emitted in ^{252}Cf have been reported [2-4]. These are: (i) $E_\gamma \leq 3.5$ MeV statistical and rotational gamma rays (ii) $8 \geq E_\gamma \leq 20$ MeV giant dipole resonance (GDR) region and (iii) HEG tail $20 \geq E_\gamma \leq 40$ MeV (iv) extreme HEG due to coherent bremsstrahlung $40 \geq E_\gamma \leq 80$ MeV. It is very difficult to measure the high-energy part of the γ-spectrum coming from spontaneous fissioning nuclei due to its low cross-section. Moreover, the presence of background radiation due to other sources of background gamma rays and also interference of the cosmic muons, make it a challenging task. To investigate further, we report here the experimental results of the measurement of the energy spectrum of the gamma rays in coincidence with fission fragments produced in spontaneous fission of ^{252}Cf.

Experimental details:

The fission fragments emitted from the spontaneous fission of ^{252}Cf (5μCi) were detected by using a multi-wire proportional counter (MWPC) of dimension 17.5 x 7.0 cm, mounted inside a scattering chamber at a distance 18 cm from the source. The gamma rays were detected by using a Bismuth Germanate (BGO) detector, 7.6 cm long with a hexagonal cross section of inner circular diameter of 5 cm, mounted at a distance of 1.0 cm from the source. We have not separated the neutrons from the gamma rays, as the main purpose of the present experiment is to measure the very high energy gamma rays ($E_\gamma \geq 20$ MeV). The BGO detector output was fed to a shaping amplifier. The shaping time of the amplifier was 1 μs and the gain was set to a value for measuring the energy of the photons up to 90 MeV. For measuring the coincidence timing information, we have processed the fast signal of the BGO detector using a timing filter amplifier and CFD to obtain logic signal, which has been used as the 'start' signal for the time to amplitude converter (TAC). The 'stop' signal has been obtained from the MWPC anode and the TAC range was kept 200 ns. Both x and y position signal as well as cathode energy signals were measured to select fission events just above the threshold energy of the detection of 6 MeV alpha particles emitted from the source.

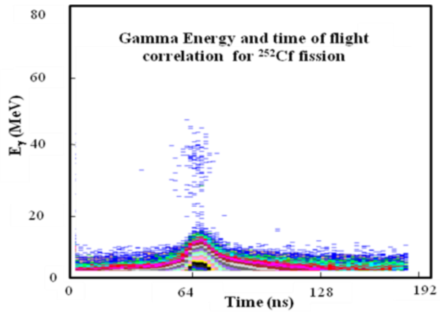

Fig.1. Two dimensional plot of TOF vs gamma ray energy (threshold energy, E_g = 1 MeV) in spontaneous fission of ^{252}Cf.

Results and discussions:

In Fig. 1 we have shown a two dimensional plot of gamma energy (E_γ) from the BGO detector vs the time of flight (TOF) between the prompt gamma rays (detected by BGO detector) and the fission events detected by the MWPC. The projected gamma ray spectrum (Fig.2) gated by the prompt time window extends up to 56 MeV. The most intense gamma rays up to 20 MeV are produced due to statistical as well as the GDR emission of the photons in the fission process. It is observed that the gamma rays beyond 20 MeV have a peak-like structure at 41 MeV (shown in the inset of Fig.2) which is close to the calculated energy loss of the cosmic muons in the BGO detector. The projected TOF spectrum is shown in Fig.3. The two peaks in the spectrum are due to light and heavy fragments emitted in the spontaneous fission.

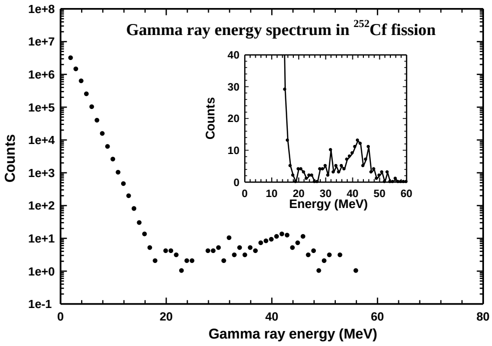

Fig.2. γ-ray energy spectrum observed in the BGO detector. In the inset the high energy part of the spectrum is shown.

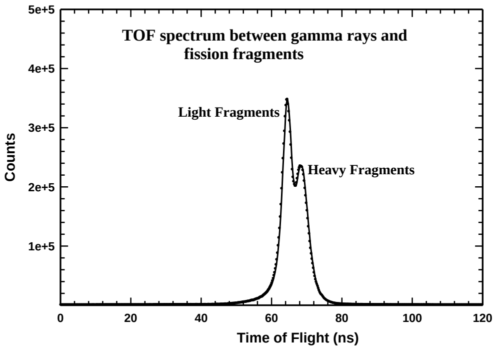

Fig.3: The TOF spectrum between the BGO detector (γ-rays) and MWPC (fission fragments).

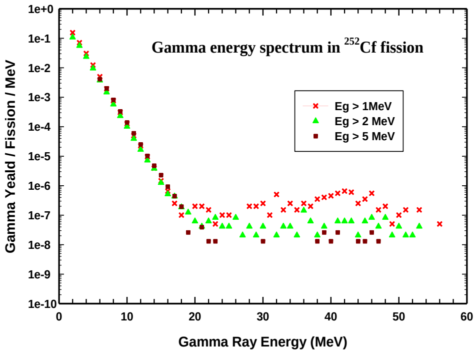

Fig.4: Normalized gamma energy spectrum for different threshold energy (E_g).

In Fig.4, normalized gamma energy spectrum for different threshold of gamma energy (E_g) is plotted. It is seen that gamma yield beyond 20 MeV decreases with increase of threshold (E_g). The cross-section of the HEG rays strongly depend on E_g and it implies that these are not emitted from fission fragments. In high energy part of the gamma energy spectrum, there can be contamination due to the cosmic muons piling up with the prompt low energy gamma rays emitted from the fission fragments. Further investigation is required to understand the source of these HEG rays.

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References:

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