Measurement of gamma radiation background in a low energy accelerator facility

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Introduction

Measurement and reduction of the background events in the gamma ray spectrum are essential to improve the minimum detection level. This improvement is needed in case of detection of rare gamma events. In nuclear astrophysics, all the relevant reactions take place far below the Coulomb barrier and thus the reaction cross sections are very small (typically in the nanobarn range). Suppression of events arising from background radioactivity is essential for these measurements.The energies of gamma rays coming from natural radioactive elements are generally upto 3 MeV. At energies above 3 MeV, the background in the γ spectrum is primarily due to cosmic radiation. So, to detect a rare event where gamma energy lies well above 3 MeV - it is advantageous to work in an underground laboratory to have enough thickness of shielding. Moreover, these radiations beyond 3 MeV don't originate from the shielding overburden, unlike those below 3 MeV. Thus, if gamma rays of interest have less than 3 MeV, working underground does not provide additional advantage [1].

Nuclear radiation shieldings are of two types - active shielding and passive shielding. For passive shielding of gamma rays, one generally encloses the detector system with high-Z elements, like lead (say) along with inner layers of graded shielding of elements with gradually decreasing atomic numbers for absorption of X-rays generated from the outer layers. Low Z materials, like paraffin, high-density polyethylene (HDPE) and concrete wall work as passive shielding to stop the neutrons. Active shielding methods require the use of other detectors to distinguish between background and the counts of interest and reject the un-wanted events.

Saha Institute of Nuclear Physics is setting up a low energy accelerator-based Facility for Research in Experimental Nuclear Astrophysics (FRENA). The accelerator is in the process of installation. The accelerator hall as well as the beam hall are shielded by thick concrete wall ($\simeq$ 1.2m) which has been designed to reduce the radiation dose outside these rooms to permissible limits. These walls acts not only as a shielding material but also may act as a source of gamma ray background itself. In this work we are presenting the results of experimental measurements of the gamma background at different positions of the accelerator building to test the quality and effectiveness of the concrete shielding.

The gamma radiation field inside a building with thick concrete wall is also simulated using Monte Carlo code Geant4 [2]. To understand the effectiveness of this shielding further, the experimental spectrum inside the shielded building is compared with a spectrum acquired in our nuclear physics laboratory which is enclosed by normal brick walls.

Experimental procedure

An HPGe detector with 20 % relative efficiency is used for the measurement of gamma ray background at different positions of the building. The data is acquired using 14 bit DT5780M CAEN digitizer. The experimental spectrum is compared with the background spectrum taken at our nuclear laboratory. The acquired spectra at two different places - building with thick concrete shielding and

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our lab are shown in Fig.1. We have also compared the yields of background gammas of various energies at different positions of the accelerator building to check the variation in background.

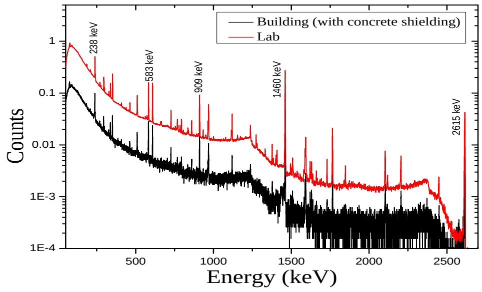

FIG. 1: Comparison of experimental spectra at two different positions - building with thick concerete shielding and our nuclear physics laboratory.

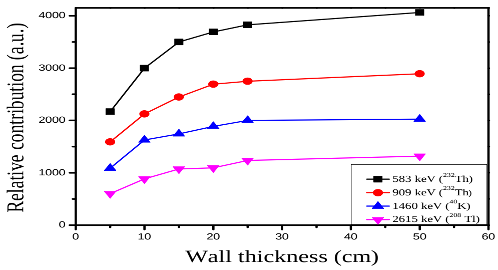

FIG. 2: Variation in the yield of gamma rays originated from long-lived radioisotopes as function of the concrete wall thickness.

Geant4 Simulation

Monte Carlo GEANT4 [2] simulation calculations have been done for understanding the shielding effect. A hollow cylindrical concrete wall has been generated and a detector with same specification as used in the experiment is placed at the middle [3]. We considered that the radioactive nuclei are isotropically distributed within the cylindrical concrete wall. The gamma photons are generated using GPS (General Particle Source) and thrown randomly from the concrete wall. Different wall thicknesses are taken and the photon energy spectra are simulated for intense gamma rays of long-lived radioactive nuclei, like ^{40}K (1.28×10^{9} y), ^{232}Th (1.4×10^{10} y) and ^{226}Ra (1600 y) decay series etc, which are typically found in room background spectra. The variation of photopeak areas of gamma rays of various energies are plotted as a function of wall thickness (Fig.2).

Results and Conclusion

Fig.1 indicates the effectiveness of concrete shielding compared to brick walls. Moreover, the comparison also shows difference in the ratio of ^{232}Th to ^{226}Ra in our lab compared to the accelerator building.

From Fig 2., we have seen that as the wall thickness becomes more than 25 cm the photopeak count saturates. The concrete wall thus shields the gammas ($\simeq 3MeV$) coming from the environment and also acts a radiation source. The gamma rays coming from the wall behind 25 cm do not contribute in the indoor spectrum as they are scattered and absorbed within the wall. Similarly, the gamma rays coming from outside environment till 3 MeV, at least, are also totally absorbed. From the Fig.2, it is clear that the saturation in photopeak area is achieved earlier at smaller wall thickness as the photopeak energy increases. The wall acts as an infinite thickness wall at nearly 25 cm. We have also compared the experimental background spectra for different detector positions in the building. We noticed that the beam hall background is nearly 1.2 times greater than the accelerator room count rate. This observation can be explained well if we consider the ratios of the concrete wall volumes in the beam hall to that in accelerator hall ($\simeq$ 1.2). From Fig 2. we have seen the reduction in gamma background due to concrete shielding.

Our study thus clearly indicates that the concrete shielding in the FRENA accelerator building will be helpful for low cross-section reaction studies.

References

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