GEANT4 simulations on shielding materials for neutrons

G. Kekre, V. Ranga*, S. Panwar and G. Anil Kumar
Radiation Detectors and Spectroscopy Laboratory,
Indian Institute of Technology Roorkee, Roorkee-247667, Uttarakhand, INDIA
** email: vranga@ph.iitr.ac.in*

Introduction

It is well known that in the design of accelerators, nuclear reactors or a shielding container of neutron emitting sources, an accurate estimation of the neutron shielding capabilities is essential for safety requirement. Several research groups have studied neutron shielding capabilities of various shielding materials [1]. Some of the Monte Carlo codes that are widely in use for studying shielding properties of materials are MCNP, MCNP4B2, SAS, SCALE and GEANT4. In the present work, we aim to study the shielding designs for sources ^{252}Cf and ^{226}Ra-^{9}Be using GEANT4 simulations.

^{252}Cf and ^{226}Ra-^{9}Be are widely used as natural neutron sources. The average energy of neutrons from ^{252}Cf is 2.35 MeV. The energy distribution of neutrons from ^{226}Ra-^{9}Be source extends up to a maximum of 13 MeV with a broad peak at 4 MeV and there are indications of many intermediate neutron groups. Due to its large gamma background, ^{226}Ra-^{9}Be source has not been studied in detail. The energy distribution is similar to that of ^{210}Po-^{9}Be source except at the low energy side where there are indications of neutron groups [2]. We have a 50 mCi ^{226}Ra-^{9}Be source at IIT Roorkee and it is being in use for the past more than 40 years to study the half-life of Indium and Silver foils using G-M counter as part of post graduate teaching experiments. The present work also aims to study the properties of this source and to have new shielding design for this source with the help of realistic GEANT4 simulations. The shielding materials under study are concrete, paraffin, borated polyethylene and Boron Carbide. We have used a 3″×3″ BC501A liquid scintillation detector to generate the response for mono energetic and poly energetic neutrons.

Simulations and measurements

In order to estimate the neutron shielding capabilities of various materials using simulations, it is necessary to simulate the response of detector for neutrons with and without shielding materials. For this, we have first simulated the response of BC501A detector considering a beam of monoenergetic neutrons. We have used G4HPModel in the physics list. The energy distribution of neutrons from 252Cf has been incorporated in the simulations using the following function:

$$f(x) \propto exp\left(-\frac{E}{1.025}\right) sinh(2.926E)^{1/2}$$

The energy distribution of neutrons from ^{226}Ra-^{9}Be source has been taken from Ref. [2]. The particle gun's source was placed at a distance of 10 cm from the detector. The conversion of deposited neutron energy to the visible detector light output was estimated using the relations [3]:

$L(E_p) = 0.83E_p - 2.82(1-exp(-0.25E_p^{0.93}))$

$L(E_\alpha)=0.41E_\alpha - 0.59(1-exp(-0.065E_\alpha^{1.01}))$

$L(E_{Be}) = 0.0821E_{Be}$

$L(E_B) = 0.0375E_B$

$L(E_C) = 0.017E_C$

$L(E_{e-}) = E_{e-}$

Experimental work is done at RDS lab, IIT Roorkee by using a 3"×3" BC501A detector (supplied by Saint Gobain company).

Results and Discussion

Figure-1 shows the simulated spectrum for 2.5 MeV neutron beam. The shape of the spectrum is in very well agreement with the data reported in the literature [4]. Figure-2 shows the simulated as well as measured spectrum of neutrons from ^{252}Cf source. An excellent agreement between both spectra validates our simulations.

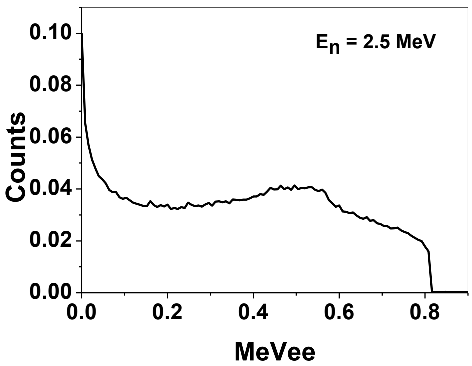

Fig. 1: Simulated response of BC501A to 2.5 MeV neutrons

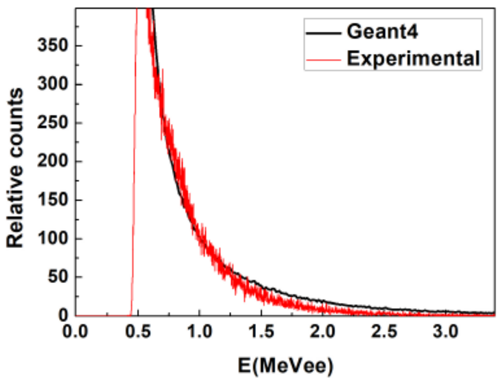

Fig.2: Simulated as well as measured spectrum of neutrons from ^{252}Cf source, recorded using a 3″×3″ BC501A detector.

Investigations are in progress to optimize the design of shielding with different materials for neutrons by simulating the neutron dose equivalent rates.

Acknowledgements
This work was supported by Council of Scientific and Industrial Research, Government of India through the CSIR-JRF fellowship under Grant 09/143(0907)/2017-EMR-I.

References

[1] K. Ueki *et al.*, Nucl. Sci. Eng. 124 (1996) 455.
[2] K. R. Alvar and R. A. Peck, Nucl. Instr. and Meth. 84 (1970) 195
[3] R.A. Cecil *et al.*, Nucl. Instr. and Meth.161 (1979) 439.
[4] Zimbal *et al.*, Proceedings of Science (FNDA2006) 035.