Neutron spectral measurements with a BSS: A Computational approach

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Ionosphere is a dense layer of charged particles and ions of earth's atmosphere, situated at about 56 km to 1000 km above the earth's surface. When primary cosmic rays and solar particles enters into the earth's atmosphere, they produce secondary cosmic rays through many cascade reactions with the atoms and molecules of the atmosphere. This results into the reduction of cosmic radiations and leading to the creation of particles with broad energy spectrum at aviation altitude of about 8 to 11 km above sea level. As shown in a report on on Cosmic-ray Neutron Spectrometry in 2008 [1], the neutrons from secondary cosmic radiation have half of its contribution in terms of the dose equivalent with energies above 20 MeV, and about 10% of neutrons reach to sea-level. Recently, it has been observed that radiation events can cause substantial data errors leads to failures in electronic devices at aviation altitudes [2]. The electronic devices or detection medium consist of silicon, ^{10}B and some other impurities, where mainly three mechanisms are responsible for the data errors viz., (i) the reaction of high-energy cosmic neutrons with the constituents of semiconductor medium (ii) the reaction of low-energy cosmic neutrons with ^{10}B impurity present in the device, and (iii) alpha particles emitted from the radioactive trace impurities in the device materials. Related to it, the knowledge of neutron spectra is essential for the radiation protection of the devices and to improve the accuracy of dose measurements which are inherent to the activation analysis and the radiation damage studies.

The multi-moderator spectrometer, commonly known as Bonner Ball or Bonner sphere spectrometer (BSS) is a reliable tool to observe neutron energy spectra in a wide energy range, i.e. from thermal to ~ 20 MeV [3]. The system consists of a detector, situated at the centre of moderating spheres of varying diameters, for thermalized neutrons detection. The efficiency of spectrometer in terms of energy range above 1GeV can be enhanced by introducing impurities such as lead, copper, iron, tungsten, etc., into the BSS [4, 5]. In the present work, an attempt has been made to perform simulations based on GEANT4 platform to understand the behavior of neutron spectra for different diameters ($1''$, $2''$, $4''$, $6''$, $8''$, $10''$ and $12''$) of Bonner ball, and to estimate the response of the ^{6}LiI(Eu) detector, localized at the center of the Bonner Balls. We have considered ^{6}LiI(Eu) crystal 4mm(dia.)×4mm(length) and with 96% enriched ^{6}Li to enhance thermal neutron absorption cross-section through the following nuclear reaction,

$$n +^6 Li \rightarrow^4 He +^3 H + 4.78MeV \qquad (1)$$

The Fig.1 (upper and lower panel) depicts a typical scene of the Bonner ball structure ($4''$) irradiation with a broad parallel beam of $\sim$ 10 MeV neutrons in GEANT4. The neutrons get moderated through elastic collisions during the interaction with the hydrogeneous material (density 0.946 g/cm^3) of the Bonner Ball. Further, the moderated neutrons are detected by the ^{6}LiI(Eu) crystal as shown by the red cylinder in the lower panel of Fig.1. It may be mentioned that the re-

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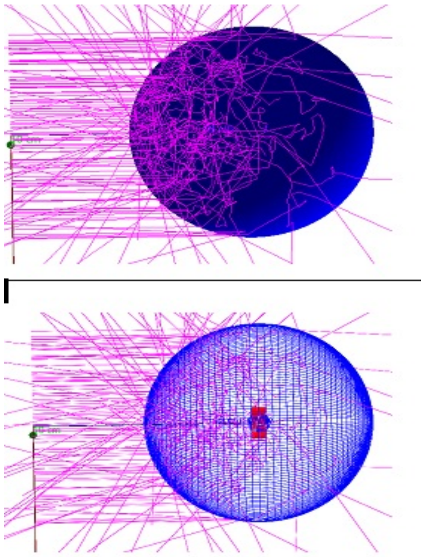

FIG. 1: The scene of neutron irradiation in Geant4, (a) Approximately 10^5 high energy neutrons falling on Bonner Ball, (b) View explaining how neutrons are elastically scattered and few of them are approaching to the crystal which is located in the centre

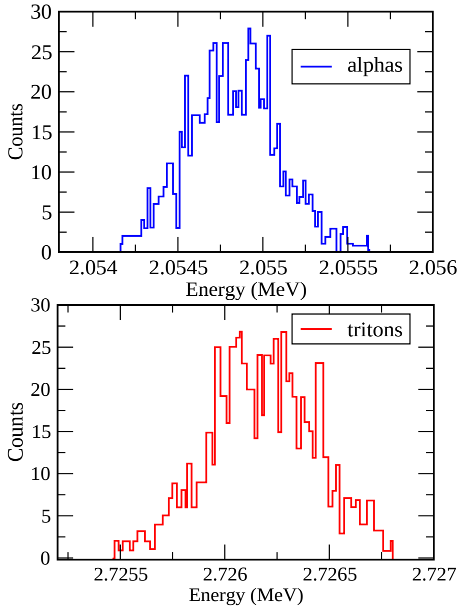

FIG. 2: Energy spectra (a) Alpha's (b) Triton's, as a result of moderated neutron capture by ^{6}Li crystal

sponse of the crystal to the neutrons is defined as the number of ^{6}Li(n,t)^{4}He reaction events taking place within the sensitive volume per incident fluence. The cross-section of the reaction is energy dependent and attains maximum value at thermal energies. As an illustration, the energy spectra of nuclear reaction products, i.e. alpha and triton are presented in Fig.2. The energy spectra appear to have a Gaussian distribution with peak maximum at ≈ 2.05 MeV (upper panel) and ≈ 2.72 MeV (lower panel) for alphas and tritons, respectively. The standard GEANT4 libraries and Physics list classes are used for the simulations. The uncertainties in the response functions may come through the cross-section libraries. It may be mentioned that the optimization of the parameters can favor the use of spectrometers in the field of radiation protection due to its relative simplicity for the on-site measurements. The calculations for the response for different diameter of Bonner Sphere at different neutron energies will be discussed during the symposium.

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