Development of Geant4 based simulation package for neutron array facility at IUAC

Davinder Siwal,* N. Saneesh, and P. Sugathan
Inter University Accelerator Centre, Aruna Asaf Ali Marg, New Delhi-110067, INDIA

Fusion-Fission dynamics would be investigated with state-of-the-art **N**ational **A**rray of **N**eutron **D**etectors (NAND) facility at IUAC, New Delhi. The array consist of hundred spectator cells of BC501 elements, arranged in 4π configuration, for the measurement of neutrons. In order to understand the single cell and array response, a *Geant4* based simulation package has been developed.

Introduction

Though 75 years has been passed since the discovery of fission [1], the field is still active with many interesting experiments. Among the many probes used in heavy ion induced reaction, measurement of pre (post) scission neutrons is an important and sensitive tool used to explore the fission dynamics. The neutron multiplicity (M_n) can be used as a clock to measure the time delay involved in the dynamical process [2]. The neutron Time-Of-Flight (TOF) with ancillary detectors provide scope to explore the said signatures to explore the dynamical processes.

The experimental facility, National Array of Neutron Detectors (NAND) [3] at Inter University Accelerator Centre, New Delhi focuses in this direction. The present detector array, aiming 100 elements of liquid organic scintillation based neutron detectors, arranged in 4π configuration would provide state-of-the-art facility for the study of nuclear reaction dynamics. The detector response would play the vital role to extract the fission dynamics parameters. Therefore, a detailed study of the detector involving Monte-Carlo based *Geant4* [4] simulations are required to understand the response towards the incident flux of neutron and gamma radiation.

Simulation package development

In order to address the above mentioned properties, a dedicated monte carlo simulation package based on *Geant4* framework (version 4.9.6, patch-02) has been developed. The package can be used to simulate a single unit placed at different radial distances from the source, as well as multiple detector cells arranged in 4π configuration at a fixed radial distance. Each of the cell comprises of liquid scintillation based BC501 neutron detector of dimension 5"x5". The two options has been isolated in the package with the help of preprocessor directives in C++, can be invoked independently during runtime via compiler macro option. Each of the single crystal with a jacket of aluminum casing, has been constructed with *G4VSolid* and *G4SubtractionSolid* class with a thickness of 1.5 mm. The distance between centre of the array and surface of the crystal is of 175 cm. The rear part of the crystal has been supported by iron structure of thickness 55 mm followed by 5 mm thickness of steel flange. Both the iron structure and detector flange has been generated by using *G4VSolid*, *G4SubtractionSolid*, and *G4UnionSolid* classes.

The array geometry has been constructed in *Geant4* framework, consisting of eight rings having geodesic dome configuration with partial symmetry of hexagons and pentagons. Different rings of the array has been interconnected with iron rod having outer (inner) diameter of 20 mm (12 mm). These rods are generated with *G4SubtractionSolid* class, their spatial co-ordinates have been calculated with the help of section formula involving the co-ordinate of the two adjacent detector. The rod length are adjusted appropriately to avoid the overlapping volumes. The centre of the array consist of target chamber with stainless steel material of 4 mm thickness having inner

*Electronic address: dev84sonu@gmail.com

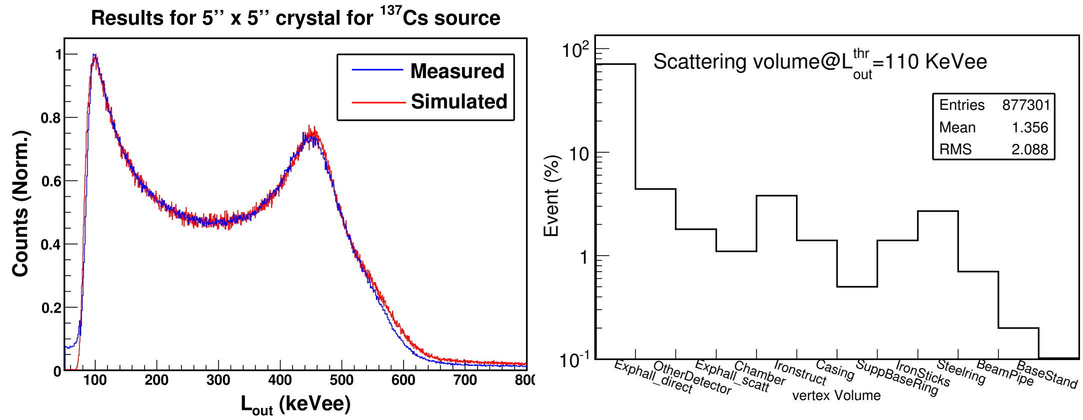

FIG. 1: Comparison between simulated and experimental light output (left), scattering volume distribution of the full array events at 110 keV light threshold for ^{252}Cf source.

diameter of 1 m, generated with *G4Sphere* class. In addition, the beam pipe having stainless steel material, and array stand having iron material has been implemented in the geometry construction.

The physics list has been included with various particle transport models. In order to simulate gamma-rays more accurately, the low energy electromagnetic package $G4EMLOW$ (version 6.32) has been implemented. The package include different options such as : $G4EmStandard, option1, option2, option3, G4EmLivermore, G4EmPenelope$. Standard gamma-ray sources has been implemented with *G4RadioactiveDecay* class (version 3.6). In the case of neutron radiation, a high precision particle transport model (G4NDL4.2) has been used. The primary particle generator class has been implemented with three different options, including single particle, ion (for radioactive decay), and radiation from the fission fragments. The radiation from the standard fission sources has been implemented by interfacing the package with $Geant4$ based external library from $LLNL$ [5].

In order to study the light output, the energy deposited by the incident particles inside the detector volume is collected on event-by-event basis. The history of particle interaction is tracked by collecting vertex volume label, position, momentum direction etc. The corresponding light output of different particles produced by incident radiation has been implemented by the standard formalism [6]. The events generated in the simulation are stored in a standard ROOT Tree, by invoking libraries during simulation run-time under ROOT environment [7].

Preliminary results

In order to compare the experimental response with the simulated outcome, the experimental spectra for the ^{137}Cs source is recorded with a single detector, collected at 70 $keVee$ threshold. Single cell unit has been simulated with the package with appropriate background correction is shown in Fig. 1 (left). Further, the scattering volume distribution obtained for ^{252}Cf source is shown in Fig 1 (right). The distribution obtained with full array at 110 $keVee$ threshold including both gammas and neutrons. Similar results, and interesting findings would be discussed during the symposium.

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