Geant4 Simulation of ancillary charge particle detector array for detection efficiency

Jasmeet Kaur[1]* and R. Kumar[2]
[1] *Ferozepur College of Engineering and Technology, Ferozepur, INDIA and*
[2] *Inter University Accelerator Centre, Aruna Asaf Ali Marg, New Delhi 110067, INDIA*

Introduction

Ancillary charged particle detector arrays has become essential nowadays to support the large gamma-ray spectrometers that may enable the study of nuclei far from stability valley. The exotic nuclei close to the proton drip line can be reached at Inter University Accelerator Center (IUAC) with the availability of higher energy beam from LINAC using fusion evaporation reaction of nuclei of nearly equal mass. The senitivity for studying these weakly evaporated channels at high spin can be enhanced by suppressing the competing channels. The incorporation of ancillary detectors like charged particle detector array (CPDA) can greatly improve the capabilities of γ-ray detectors. An array consisting of CsI scintillators coupled to a Si-PIN photodiode S3590-08 is under development at IUAC for the detection of light charged particles such as protons and α-particles. The array will be coupled as an ancillary device to Indian National Gamma Array (INGA), providing the opportunity to select reaction channels of interest by gating on emitted light charged particles. This will enable selection or rejection of reaction channels, rejection of random events and will also enhance gammas [1]. The absolute measurement of crossections of particles emitted in the nuclear reactions requires the efficiencies of detectors inorder to correct the measured yields. Thus, before passing to the real simulations, we must define the general properties of detection system, like efficiency, energy and time resolution. The present contribution reports preliminary results of alpha particle efficiency of upcoming CPDA by reviewing important aspects of detector geometry using Geometry and Tracking 4 (Geant4), Monte Carlo code [2].

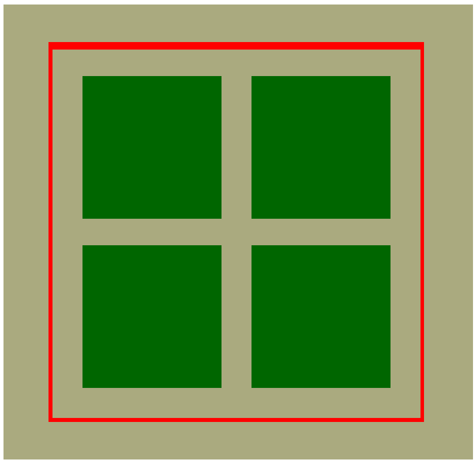

FIG. 1: Quad CsI Crystals

Simulation

Using Geant4, square shape (60 mm$\times$ 60 mm) PCB boards were created and are arranged in Rhombicuboctahedron geometry. The CsI crystal having dimension 20 mm $\times$ 20 mm with 3 mm thickness assembled as quads in 2×2 configuration on each PCB. Fig. 1 shows the placement of 4 CsI crystals on single PCB where former is called as daughter volume and latter is the mother volume. Fig. 2 shows arrangement of 18 PCB in rhombicuboctahedran geometry.

A total of 72 crystals are implemented in present simulations, subsequently 8 triangular shape crystals will be added to get efficiency of 4π CPDA. The entire array is designed to be housed inside a hollow quasi-spherical alu-

*Electronic address: `jasmeet48@gmail.com`

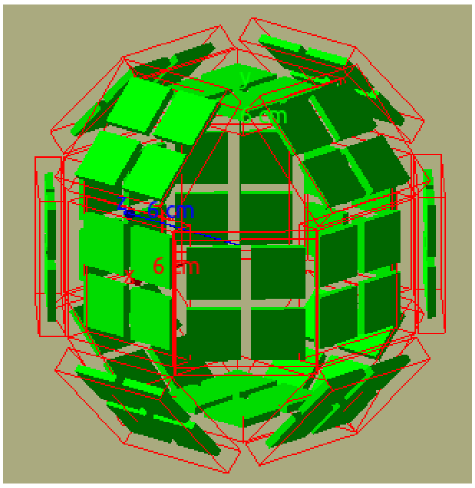

FIG. 2: Simulated Rhombicuboctahedron geometry of CPDA

minium chamber of thickness $\sim$ 3mm. The chamber has an outer diameter of $\sim$ 10”, so that it can be well placed inside the INGA array. In addition to constructing geometry, various physics processes like electromagnetic and hadronic proceses are included in Physics List class. These processes can occur when the particles travel through the detector materials. The radioactive source, Am^{241} is modeled as general particle source and set to emit decaying particles isotropically by implementing standard G4 radioactive decay model. The source is placed at the center of array and source to PCB distance is approximately 6 cm. The efficiency of simulations is increased by implementing G4UserStacking Action in such a way that secondary ions from the decay are not further treated and the decay is interrupted for daughter nucleus Np^{237}.

The simulation output consisted of the total energy per event deposited in the sensitive detector CsI volume, the energy deposited by alpha, electrons and gammas. The more detailed output includes information about all processes, particles involved and their geometrical origin. The main processes in which alpha particles lose energy are excitation and ionization. The information is collected and analysed event by event using Root

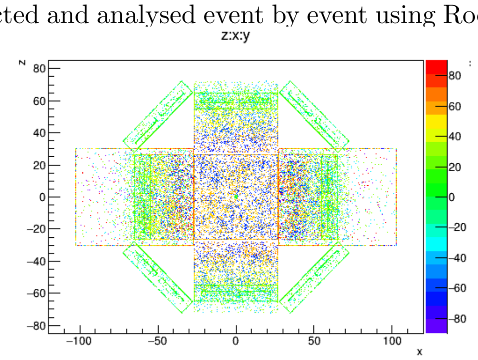

FIG. 3: simulated distribution of $\alpha-$ particles

libraries[3]. Fig. 3 shows the distribtion of alpha particles along x-y-z axes.

Simulation Results

The detection efficiency of array for 5.486 MeV $\alpha-$particles is $\approx$ 50% with the simulated array. The efficiency of array is optimized by varying different geometrical parametes of array. The next step is to estimate the full efficiency of array including triangle detectors and after accomplishing this objective we will move to the real simulations for different charged particles by implementing fusion-evaporation reactions in simulations and also to evaluate the transparency of array to gamma rays. The results of simulations can be further verified by experimentally measuring efficiency of array using different monoenergetic charge particle beams.

References

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