GEANT4 simulation of scintillation response of Xenon gas to low energy γ-rays

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Introduction

Noble gases, namely, Helium, Argon, Krypton and Xenon have long been used for radiation detection. They are used to operate either as ionization detector or as scintillation detector. Liquefied noble gases have been used in ionization detectors since early 1950s. The performance of Liquid Xenon has been found to be most satisfactory both as an conventional ionization detector and also in proportional mode. Xenon counters have variety of applications, namely, low energy gamma-ray spectroscopy, X-ray astronomy, medical imaging etc. [1]. The high atomic number (Z=54) of Xenon makes it an ideal choice for detection of gamma-rays due to very large photo-electric absorption. In more recent time Xenon counters are widely considered for detection of dark matter and neutrino less double beta decay [2]. The real challenge in using liquid Xenon counter is the attainment of a very high level of purity. Xenon can also be used to build scintillation counters. The primary emission of Xe due to scintillation is at 175 nm in the very Ultra Violet region. It is to be noted that considerably more work has been reported in literature about the working of Xenon ionization chambers than Xenon gas scintillation detector. It has also been reported that the energy resolution in Xenon gas proportional chamber is much better than what is achieved in liquid Xenon [3]. It is therefore, quite interesting to have better understanding of Xenon as scintillator vis-a-vis as an ionization detector in both liquid and gaseous forms.

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Simulation and results

We have initiated a programme to carry out in-depth studies of Xe as ionization and scintillator detector. Xe gas scintillator detector is much simpler to construct and operate compared to liquid Xe counter that requires considerable cryogenic arrangement. As a first step we want to carry out a comparative study of the efficiency of Xe gas as scintillator with Xe ionization chamber. We have designed and constructed a a Xe gas scintillator chamber that can operate up to 5 Atm pressure. The chamber has been couple to 2" PMT (ET9266QB) that can operate at 175 nm with high quantum efficiency. Special glass windows have been used for transmission of the scintillation photons to the PMT.

In order to have better understanding of the response of Xe gas as scintillator we have carried out very detailed, realistic GEANT4 simulations for low energy gamma-rays from 10 to 100 keV. In the preliminary simulations we have considered a cubical Aluminium chamber of dimensions 16cm X 40cm X 100cm filled with Xe gas at 2 Atm pressure. The gamma-rays enter the main volume through a .05mm thick mylar window. The gamma rays are allowed to fall vertically all over the entrance window. For each energy we consider hundred thousand events to generate the final spectrum. Figures 1 and 2 show the response of the detector to 100, 70, 50 and 30 keV gamma-rays. The initial GEANT4 outputs have been folded with finite resolutions to get the final spectra. The photo-peak efficiency increases from 18% at 100 keV to 74% at 30 keV. The photo-peak efficiency at 50 keV is higher than at 30 keV. This can be understood in terms of the variation of the photo-electric cross section of Xe with photon energy. The initial results are encouraging enough to carry out more realistic simulations for the exact design of our detector chamber. The data taking and further analysis are underway and will be presented in the meeting.

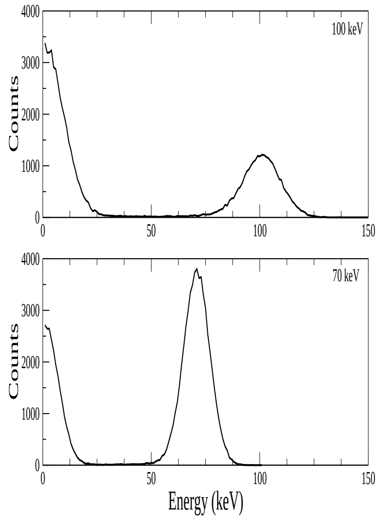

FIG. 1: The GEANT4 simulated spectra for 100 (top) and 70 keV (bottom) gamma-rays.

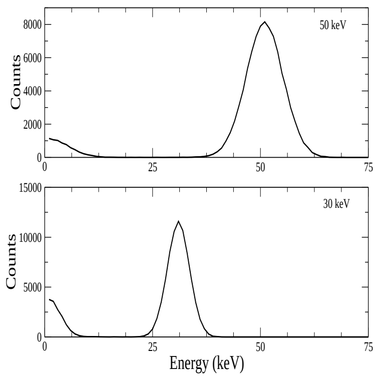

FIG. 2: The GEANT4 simulated spectra for 50 (top) and 30 keV (bottom) gamma-rays.

References

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