Compton imaging with a two fold clover HPGe detector

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The imaging capability of a two fold clover detector is explored for ^{137}Cs and ^{60}Co sources with a Compton back-projection imaging algorithm. Such a method enable to reconstruct the image of a given gamma-ray source in the image plane. The method project the Compton cone in the image plane reconstructed from the position and energy distribution of a γ-ray interactions. Such distributions are obtained from the simulation of the clover detector under Geant4 environment. The preliminary results of position centroid and resolution obtained from the Compton image reconstruction are presented.

Introduction

The composite HPGe detector (viz. clover, cluster detector etc.) system has a high resolving power with large detection efficiency compared to a single crystal of same geometry. The main disadvantage of such detector system is its large Doppler broadening effects, due to geometry of the crystal and the velocity of the ions involved in the experiment [1]. The position-sensitive composite HPGe detector offers an alternative solution to this problem by Compton tracking of the event of interest in the crystal volume [1]. The tracking principle allows to identify the Compton cone deduced from the ensemble of position co-ordinates (from Pulse Shape Analysis [1]) in a three dimensional space. The back-projection cone obtained from a tracked sequence in the image plane leads to the image of a localized source. In addition, the tracking procedure would enable to identify the events which originate from the target and from background. Using the concept of γ-ray tracking the background suppression factor up to 100 can be achieved [3]. Such a procedure would be realised in practice in the planned FAIR-DESPEC germanium array [3].

In the present paper we have presented the results of the Compton imaging performed with a two fold Clover HPGe detector. The preliminary analysis of Compton imaging is discussed.

Image back-projection algorithm

A simple back-projection method [4] has been used to generate the Compton image of a two fold clover detector. The Compton imaging involves the calculation of first scattering cone angle via most probable scattering sequence provided by the γ-ray tracking algorithm [1]. To fulfill the purpose, the source image plane needs to be divided into a large number of pixels/voxel (2D or 3D) of finer bin size into which the image is reconstructed. Let $\overrightarrow{X}_1(x_1, y_1, z_1)$ and $\overrightarrow{X}_2(x_2, y_2, z_2)$ be the position vectors (from reference origin) of the first two interaction points provided by the gamma-ray tracking algorithm. Let the angle between the two position vectors be θ. This angle can be treated as an emission angle viewed from the source. Therefore, it forms a semi-vertical angle of the cone with all the line passing through $\overrightarrow{X}_2$ inclined at an angle of θ. In general the intersection of the cone on the image plane located at a distance $Z = Z_s$ generates an equation of ellipse whose parameters depend on $\overrightarrow{X}_1, \overrightarrow{X}_2$ and θ given as :-

$$[n_x(x - x_1) + n_y(y - y_1) + n_z(z - z_1)]^2 = \cos^2\theta[(x - x_1)^2 + (y - y_1)^2 + (z - z_s)^2] \quad (1)$$

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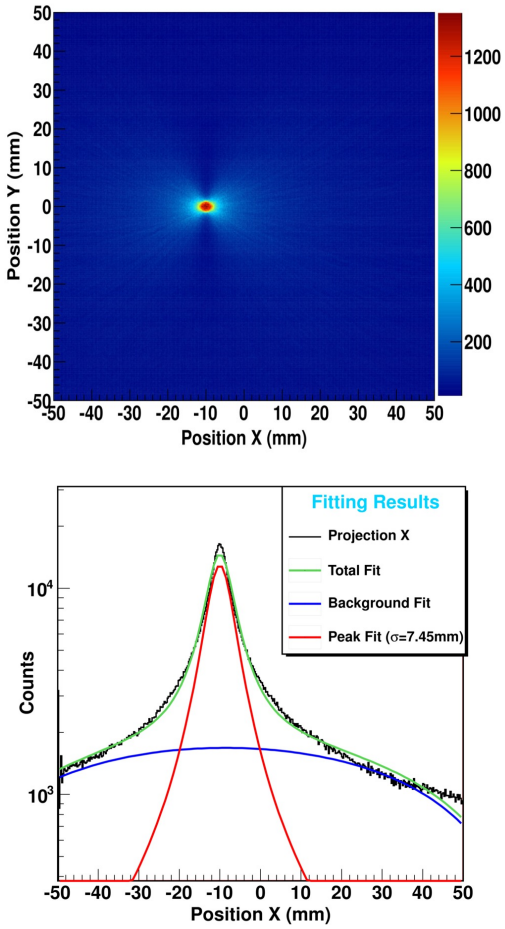

FIG. 1: (top) Compton image of ^{137}Cs source placed at the co-ordinate (-10 mm,0) with respect to the centre of the clover detector, (bottom) the profile of a projected strip of 20 bins along X-axis with fitted curves.

here, n_x, n_y and n_z are the direction cosines along the cone axis. Above equation can be converted into quadratic form as

$$A(y - y_1)^2 + B(y - y_1) + C = 0 \qquad (2)$$

where A, B and C are the constants. Equation (2) can be solved on event-by-event basis. Superposition of large number of such cones intersect at a common point resulting in the Compton image formation.

Results

The Compton images with two fold clover detector has been generated with ^{137}Cs and ^{60}Co sources respectively. The experimental data of both the sources are collected by full illumination of the clover detector surface with a VME based data acquisition system [5]. Both the sources are placed at a distance of 25 cm from the clover surface. The position coordinates for ^{137}Cs and ^{60}Co are (-10 mm, 0, 250 mm) and (0, 0, 250 mm) respectively, with respect to the centre of clover detector. The events are simulated with Geant4 based code with similar experimental conditions and are stored under ROOT environment [5]. The calculation of most probable scattering sequence has been performed by comparison of geometric and kinematic angles via γ-ray tracking principles. A good gamma-ray tack is obtained under the condition $0 \leq \chi^2 < 6$ for both photo-absorbed and Compton scattered events. The result of a back-projection algorithm implemented on event-by-event basis with 80,000 Compton cones for Compton scattered events is shown in Fig. 1. The resulting distribution is fitted with Lorentzian funtion superposed on the quadratic background. The obtained FWHM along X and Y directions are 14.9 ± 0.0027 mm and 5.22 ± 0.075 mm respectively. Similar results obtained from fitting would be presented in the symposium.

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