Simulations for position-sensitive tracking of γ rays in scintillators Approach for source reconstruction

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Introduction

There is a growing demand for gamma radiation detectors with imaging capability. This is relevant not only in the basic research sector, but even more in societal and industrial applications, such as medical imaging, environmental and safety investigations. Scintillation materials with position-sensitive read-out are viable candidates for this purpose and have been tested using Geant4 simulation toolkit [1].

Geant4 Simulations

The present simulation code enables easy and quick optimization of different geometries. Detailed simulations were performed with both BC404 and CsI(Na) scintillators. Here we present results with the latter detector elements, providing higher efficiency. Energy response and associated light production of the initial radiation (γ rays) has been investigated, hence including all the underlying physics processes. In addition, optical photons have been treated, with an assumption that the surface was a perfectly polished mirror. So far, $511\,keV\,e^+e^-$ annihilation radiation has been considered. First geometry simulated comprises nine $18 \cdot 18 \cdot 100\,mm^3$ scintillator bars with Hamamatsu R7600U-2000 PMTs with $2\,mm$ distance between each 2 crystal elements in the 'matrix', as represented in Fig 1. The second geometry included nine times four $\cdot 9 \cdot 9 \cdot 100\,mm^3$ scintillator bars with Hamamatsu R7600U-2000M4 PMTs with $2\,mm$ between 'submatrix' elements and $4\,mm$ between 'matrix' elements.

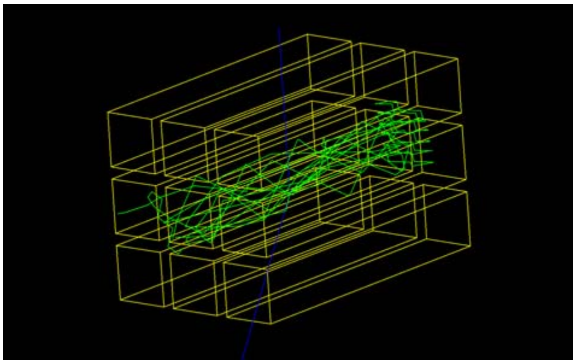

Figure 1: Geometry 1

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Analysis and Reconstruction Algorithm

We are interested in multiple Compton scattering [2, 3] in those events causing the incoming γ photon to be scattered from one detector element and then photoabsorbed in the second one. Add-back energy spectra showed Peak-To-Total approximately 50 % and 60 % in case of the first and second geometry, respectively. Compton kinematics and energy conservation law then give the scattering angle (with respect to ΔE-energy deposited in the second detector element and E_i-energy before scattering):

$$\beta = \arccos\,(1 - \frac{m_e c^2 \Delta E}{(E_i)^2 - E_i \Delta E}) \tag{1}$$

For our offline analysis it is essential to find the scattered direction, i.e. vector. Simulation gives the exact coordinates of the interaction points, so the 3D vector $(\rho,\,\theta,\,\phi)$ is easily extracted. The algorithm concentrates on the reference plane (θ, ϕ), where the centre of each circle (θ, ϕ) characterizes the scattered direction. Finally, the scattering angle is seen as a radius of the corresponding circle, as illustrated in Fig 2.

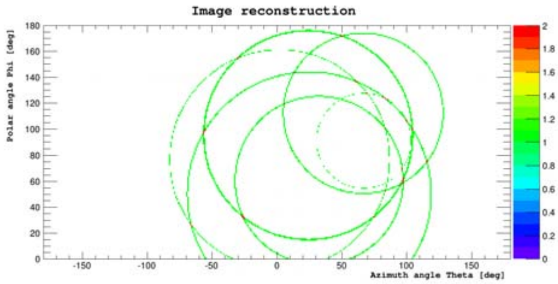

Figure 2: Representation of the reconstructing algorithm

Summary and Outlook

The simulation code has been developed providing the input data for the offline analysis and the flexibility for deploying different materials and/or geometries has been achieved. First version of the algorithm which aims to reconstruct the source position confirmed the idea of possible reconstruction of source position and is currently being tested on the larger set of data, since the preliminary results (see Fig 3.) don't yet provide an unambiguous conclusion. In addition to that, the experimental tests are ongoing and the parameters from the simulations have to be normalized with respect to the response from the realistic setup [4].

doi:10.15120/GR-2014-1-NUSTAR-GS-06

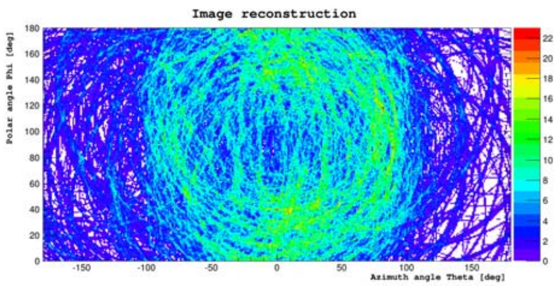

Figure 3: Reconstructing algorithm applied on a small set of data

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 doi:10.15120/GR-2014-1-NUSTAR-GS-06