Proceedings of the 30th International Cosmic Ray Conference
Rogelio Caballero, Juan Carlos D'Olivo, Gustavo Medina-Tanco,
Lukas Nellen, Federico A. Sánchez, José F. Valdés-Galicia (eds.)
Universidad Nacional Autónoma de México,
Mexico City, Mexico, 2008

Vol. 1 (SH), pages 3–6

Simulations of Hard X Ray and Gamma Ray Response in CsI(Tl) Scintillator Detector

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Abstract: Results of the computations of the response of the scintillator detector to high energy photons using the code GEANT-3 is presented. The dependence of efficiency on energy is obtained for a given geometry of the detector and for different angular distributions of incident flux. The estimates of the efficiency of the SONG instrument on CORONAS-F satellite are discussed.

Introduction

The SONG experiment on low altitude polar orbiting CORONAS-F satellite contained CsI(Tl) scintillator (20 cm diameter x 10 cm length) for the measurement of energetic neutral radiation from the Sun [1]. The crystal scintillator was viewed by three photomultipliers and was entirely surrounded by a 2-cm thick plastic anticoincidence shield against charged particles. It was viewed by three other photomultipliers. The scintillation crystal had no collimator and its axis was parallel to the longitudinal axis of the satellite which was directed towards the Sun. Energy losses in the CsI were pulse-height-discriminated into twelve differential channels from 30 keV to 200 MeV.

The preliminary simulations were performed by GEANT 3.21 [2], which traces all possible interactions of particles with the instrument, and reliably takes into account deposited energy in the instrument detector.

Results

One of the basic measures of the instrument response is the detector effective area. Two kinds of gamma sources were chosen for simulation studies: an isotropic gamma source evenly distributed in the upper hemisphere and a parallel gamma beam. For each source configuration, the effective

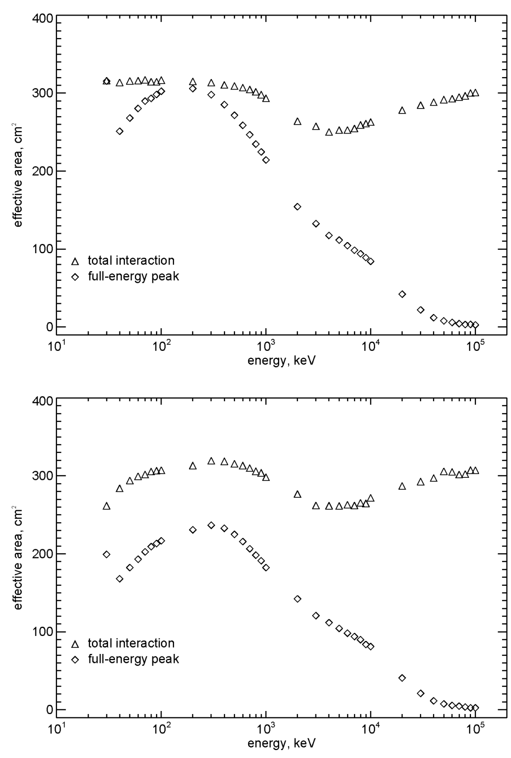

Figure 1: Effective area vs energy for CsI (upper panel) and CsI in plastic veto (lower panel)

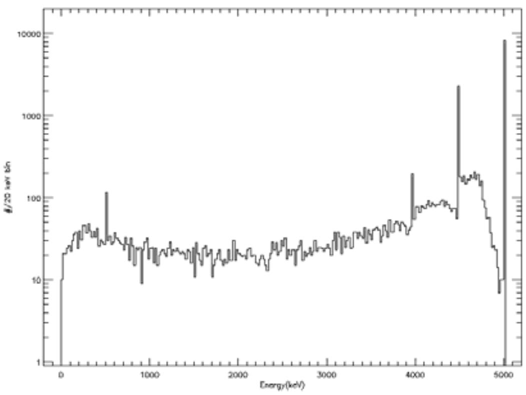

Figure 2: Energy spectrum for 5000 keV gamma rays in CsI with plastic scintillator

area was evaluated at 35 energy values between 30 keV and 100 MeV. Each photon starts in the random position on the surface of the sphere with the radius 20 cm and centered in the middle of the scintillation crystal for parallel downward beam and at the interface between plastic and CsI for isotropic source in the upper hemisphere.

Parallel beam

Fig. 1 (upper panel) shows simulated SONG /CORONAS-F effective area as a function of the incident photon energy. Mono-energetic beams of 10^5 photons – parallel (zenith angle equals to zero) with detector (circular cylinder) axis has been setup on one (upper) hemisphere. The effective area A_{eff} has been calculated according to $A_{eff} = \varepsilon A$, where A presents the projected geometric area, which is πr^2 for normal incidence with r=20cm. Detection efficiency ε for full energy peak (total interactions) has been calculated as ratio of number of photons at full-energy-peak (number of photons which interact within crystal volume) and number of photons sent on the hemisphere above the CsI. Note for total interaction the efficiency refer to probability of interaction not detection. Fig. 1 (lower) depicts results for CsI in 2-cm thick plastic veto. The effective area for full energy peak is lowered due to losses of some portion of energy in the veto.

Simulated energy spectrum of mono-energetic photon beam of 5000 keV is shown in Fig. 2. Several features can be drawn from this figure (from right to left): the full-energy photopeak, which arises from the full-energy interactions in the detector, Compton edge (at 4757 keV) - maximum energy loss through the Compton scattering, single escape peak (at 511 keV below full-energy peak) and double escape peak (at 1021 keV below full-energy peak) due to pair production and escape one or two 511 keV annihilation photons. Then follows Compton continuum from interactions involving only partial energy loss and 511keV annihilation peak. More details can be found in [3].

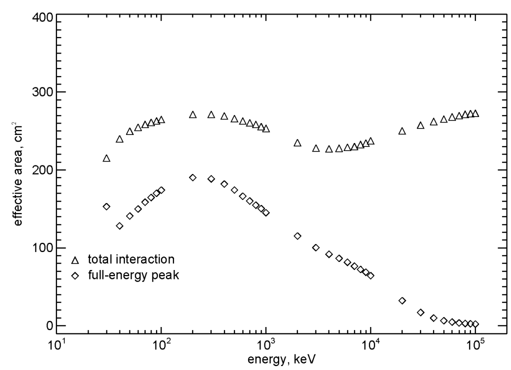

Figure 3: Effective area vs energy for CsI in plastic veto for isotropic source

Isotropic source

For isotropic source in the upper hemisphere, zenith (azimuth) angle is chosen randomly from uniform distribution between 0 and $\pi/2$ (0 and 2π). Mono-energetic beams of 10^6 photons have been used for simulations. Fig. 3 shows effective area as a function of the incident photon energy for CsI in 2-cm thick plastic veto. Here the values are lower since photons see lower projected area as for parallel incidence. One can multiply effective area by factor 2π to have a quantity in units of $cm^2 sr$. Statistical error for photopeak efficiency is <1% for energies below 40 MeV and <3% for higher energies.

Conclusions

In the simulations we have used parallel particle beam which is equivalent to isotropic source in infinity. This geometry can be useful for solar energetic particle data analysis. For the study of detector response to the local gamma rays produced in the Earth's atmosphere or in the satellite material we have used isotropic distribution of incident photons.

For more reliable results, the matter around the scintillation crystal must be considered. The simulations in the simplified mass model, developed in [4] are being undertaken.

Acknowledgements

This work was supported by the Slovak Research and Development Agency under the contract No. APVV-51-053805.

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