Expected Performance of CALET from Simulation

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Abstract

The CALorimetric Electron Telescope (CALET) is designed to observe electron from a few GeV to 10 TeV and gamma-ray from 20 MeV to 10 TeV. Its advanced design employs an imaging calorimeter and a total absorption calorimeter. The proton rejection power for electrons is about 10^6 with the detector thickness 35 r.l. by using the shower difference between electrons and hadrons, it is enough to observe electron up to 10 TeV with high precision. This paper presents the expected performance of CALET from simulation.

1. Introduction

The CALorimetric Electron Telescope (CALET) is proposed for the Japanese Experiment Module Exposed Facility of the International Space Station. Major goals of the mission are measurements of the electrons from a few GeV to 10 TeV and gamma-rays from 20 MeV to 10 TeV with low backgrounds and high angular resolution and good energy resolution. As a high energy electron and gamma-ray detector, the total weight of CALET is about 2500kg and the effective geometrical factor is about $1\mathrm{m}^2\mathrm{sr}$. The observation period is scheduled for 3 years. In this paper we present the expected performance of CALET from simulations.

2. CALET Configuration and Simulation Model

CALET is consisted of two parts: an imaging calorimeter (IMC) and a total absorption calorimeter (TASC). The IMC is stacks of 1m×1m planar scintillating fiber detector arrays with a 1.0 mm square cross section aligned in X and Y directions, interleaved with lead plates. The TASC is about 30 radiation lengths (35 cm, equivalent to about 1.5 proton interaction lengths) of Bismuth Germanate

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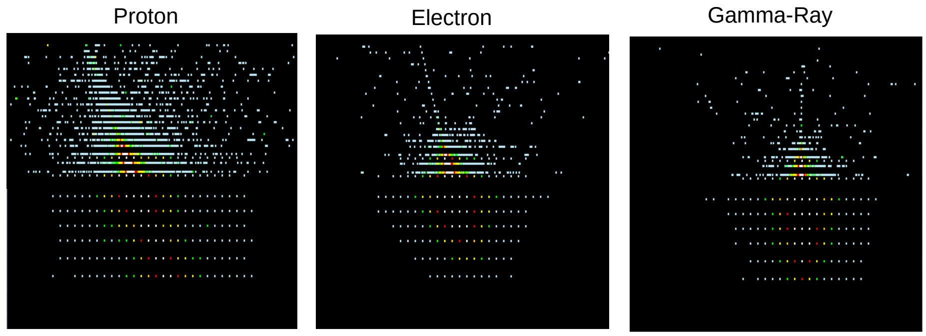

Fig. 1. The Shower image in X-direction of electron gamma-ray and proton with same energy deposit in TASC (4TeV)

(BGO) scintillator. A full description of the instrument and scientific issues can be found in the paper by S. Torii et al. in this volume.

Monte Carlo simulations were performed by using FLUKA2002 [1,2]. An isotropic event generator was developed for the CALET geometry with particles incident from the upper hemisphere. In order to optimize the thickness of the BGO log arrays with enough rejection power, the thickness is arranged in 40 cm in the simulation. When an electron enters the instrument, electro-magnetic cascade shower ensues in the lead plates and BGO logs. The direction of electron is measured by the fiber images and the energy is measured by the fiber and BGO arrays.

3. Simulated Results of Performance

3.1. Proton Rejection

By simulation we find that primary electrons deposit about 95% of their energy in the BGO calorimeter, dependent weakly on energy, while protons on average deposit about 40%. After the shower trigger, only the proton events which have the first interaction at the top of CALET can survive. Such a trigger system has been proven by several flight instruments [3]. Proton induced shower should have a wider spread than electron due to the spread of secondary particles in the nuclear interactions. This difference is clearly observed in the images of scintillating fibers. The typical shower images by electron (4 TeV), gamma-ray (4TeV) and proton (10 TeV and the energy deposit is about 4 TeV) are shown in Fig.1. By the analysis of the images, we can obtain the charge, direction of shower axis, and position of the incident particle, which are very important for the particle identification.

Figure 2 shows the scatter plots of shower energy deposits of individual events *vs.* widths of showers at 3 different depths in the BGO calorimeter. On the

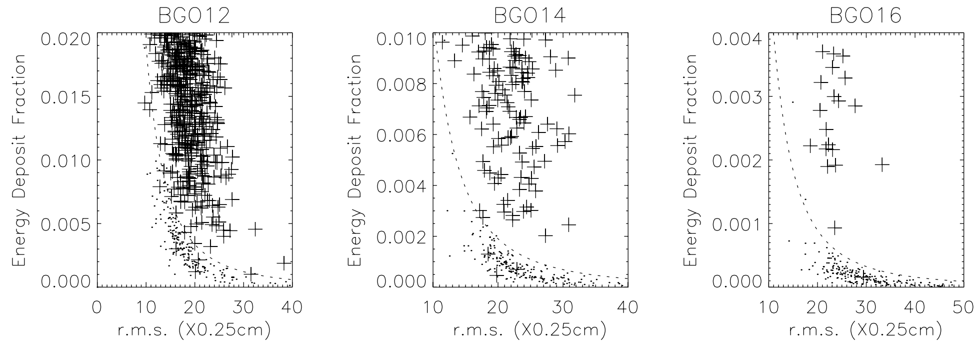

Fig. 2. Scatter plots for incident electrons and protons in 30cm, 35cm and 40cm BGO layer from simulation (+ proton events, . electron events).

Table 1. Rejection power as a function of BGO thickness

BGO Thickness ($\times 2.5cm$)	12	13	14	15	16
Rejection Power ($\times 10^5$)	1	3	6	10	15

ordinate the energy deposit in a particular BGO layer is expressed as a fraction of the total of that event and the lateral spread is expressed as the r.m.s. on the abscissa. The average spread is calculated at each individual layer around the BGO bar with the highest energy deposit. The plots in Fig.2 are simulation results of 4 TeV electrons and 10 TeV proton events with energy deposit close to that of 4 TeV electrons. Combining the total performance of IMC and TASC, the total rejection power is shown in Table 1 in the different BGO depths under the condition that the electron detection efficiency is above 95%.

3.2. Gamma-ray detection

For gamma-rays below 10 GeV, we set another trigger condition: 1): Events which give hits at least 4 consecutive fibre planes (X and Y view). 2): Enery deposit in the anticoincidence which surrounds the imaging calorimeter is smaller than 0.3 MIP. We simulated 1 million events of earth albedo gamma-rays (above 10 MeV) and cosmic gamma-rays (above 10 MeV). The trigger efficiency is 3.3% for earth albedo gamma-rays; the trigger efficiency is 16% for cosmic gamma-rays. Figure 3 presents the CALET effective area, angular resolution, energy resolution and relative area as a function of energy. In plots we make a comparison with GLAST capabilities. Detail discussions can be found in the paper by Yoshida K. et al. in this volume.

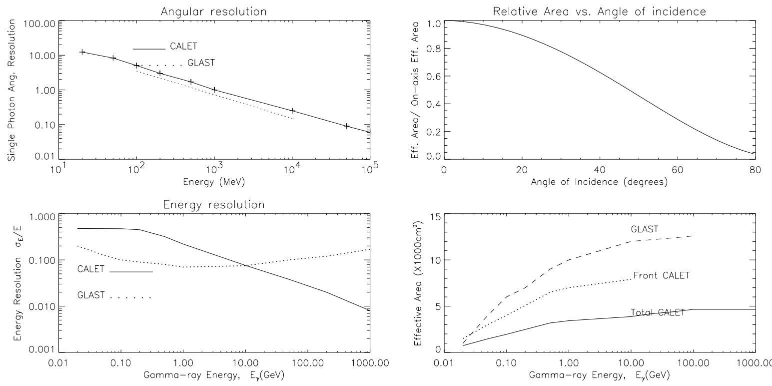

Fig. 3. CALET gamma-ray observation performance: angular resolution, relative area, energy resolution, and effective area as a function of energy

4. In flight Calibration

For high energy electron observation, one very important thing is in-flight calibration. Up to now no beam test above 1 TeV is available to check the instrumnet rejection power and other performance. We have found from simulation that there is almost no difference of shower between gamma-ray and electron in TASC. Fig.1 shows a typical shower image of 4 TeV gamma-ray in the CALET. As clearly seen in this figure, there are many back-scattered particles. However the possibility that the particles are mistaken as the incident one is less than 0.01%, assuming the position resolution at the top two layers is better than 0.5mm. Secondary gamma-rays from cosmic-ray interaction with space station material can be used as in flight calibration of CALET.

5. Summary

The preliminary simulated performance estimations given in this paper demonstrate that the CALET has a capability to observe electron from several GeV to 10 TeV with low background rate.

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