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Simulation Study on High Energy Electron and Gamma-ray Detection with CALET

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High energy electron detection is very important to understand the cosmic ray origin, acceleration, and propagation. Until now only several electrons above 1 TeV have been observed. The CALorimetric Electron Telescope (CALET) will perform a direct measurement of electrons and gamma rays up to 10 TeV. Its advanced design employs both an imaging calorimeter (IMC) and a total absorption calorimeter (TASC). The proton rejection power for electrons is nearly 10^6 with the absorber thickness 36 r.l. By using the shower difference in development between electrons and hadrons, it is enough to observe electron up to 10 TeV with high precision. In this work, we present the Monte Carlo simulation results on high energy electron and gamma-ray detection with CALET.

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 $1m^2$.sr. The observation period is scheduled for 3 years. In September 2003, We made a prototype of CALET which was exposed to high-energy beams of protons and electrons at energies from 50 GeV to 200 GeV by CERN-SPS, We have analyzed these data and found measurements and simulations agree with each other very well. In this paper we present the expected performance of CALET from simulations.

2. Simulated Results of Performance

CALET is composed of an imaging calorimeter, IMC, and a total absorption calorimeter, TASC. Detail description of CALET can be found by separate papers [1,2]. The IMC is a sampling tracking calorimeter using scintillating fibers, SciFi, as sensitive layers and lead as absorber. The area of IMC is 100X100 cm2 and the total thickness of IMC is about is 4 r.l. It has 36 layers of SciFi belts which are set in x and y direction alternatively. The cross section of each SciFi is 1 mm square. The TASC is a totally active ionization calorimeter that consists of 14 layers of BGO bars of 2.5 cm by 2.5 cm cross sectional area and 35 cm length. Sets of 56 such bars are arranged in one layer of an area of 70 cm x 70 cm. Each layer has its bars at right angle with respect to its next layer.

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 detected by 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 Figure1. By the analysis of these images, we can obtain charge, direction of shower axis, and position of the incident particle, which are very important for the particle identification.

For studying the performance of CALET, we have simulated 2×10^6 isotropic incident proton events with power index -2.75 of spectrum which energy above 1 TeV. We define a function $\boldsymbol{F = (En/Sum) * r.m.s.^2}$ to calculate the shower development in the TASC. Here ***En*** is the energy deposit in the BGO layer n, and ***Sum*** is the total energy deposit in all BGO. Figure 2 shows two scatter plots of the F vale in 11th BGO layer *vs*. 12th BGO layer and F value in 13th BGO layer *vs.* 14th BGO layer, most of proton events are outside the plot region. It can be seen that if we set a cut as the dashed line, the electron events and proton events are separate very well. Combining the total performance of the IMC and the 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%.

Table 1. Rejection power as a function of BGO thickness

BGO Thickness (X2.5cm)	12	13	14	15	16
Proton Rejection Power ($\times 10^5$)	1	3	6	10	15

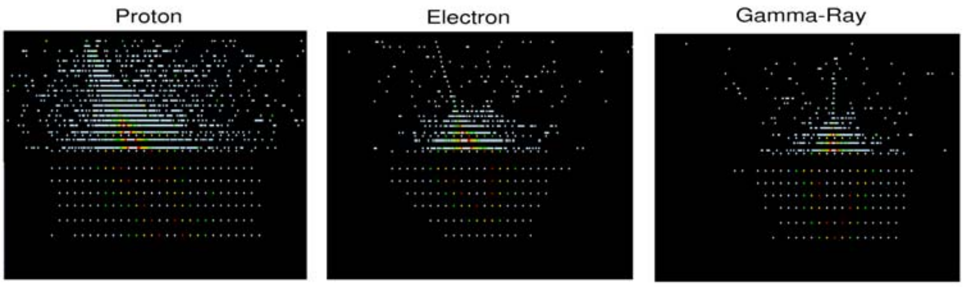

Figure 1. The Shower image in X-direction of electron gamma ray and proton in IMC and TASC, from left to right: Proton (10 TeV), Electron (4TeV) and Gamma-ray (4TeV). The energy deposits in each image are presented by gray scale. The fine points in each image show the energy deposits in the fibers and the lower sparse points show the energy deposits in BGO logs.

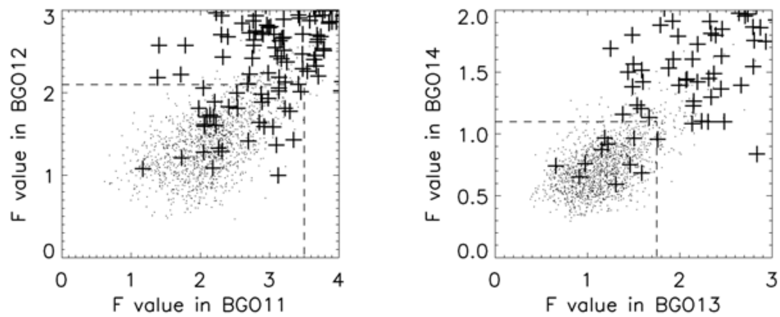

Figure 2. Scatter plots of F value in different BGO layer for isotropic incident electrons (dot signs) and protons of comparable total energy deposit in the TASC (plus signs).

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): Energy 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 the plots we make a comparison with GLAST capabilities [4].

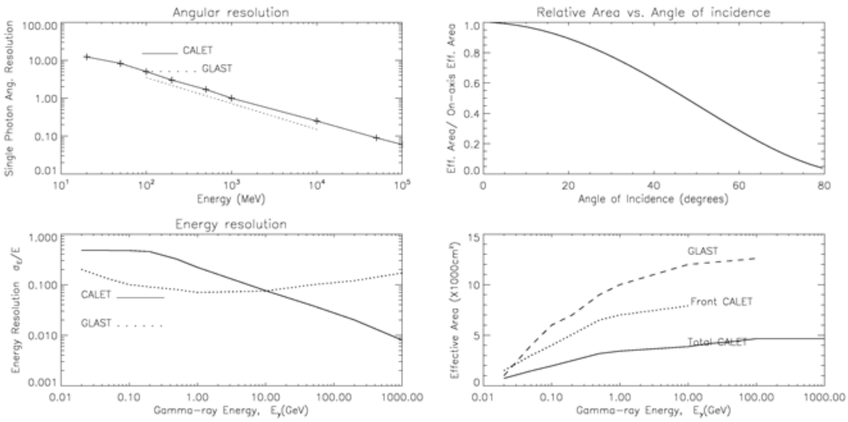

Figure 3. CALET gamma-ray observation performance: angular resolution, relative area, energy resolution, and effective area as a function of energy

3. Signature of SUSY dark matter expected by electron observation

One of goals of physics in the CALET is a search for dark matter. In recent years the existence of dark matter has become widely accepted, but what is the 'dark matter' is still a mystery. Over the last several decades experimental and theoretical work has essentially eliminated all known particles as dark matter candidates leaving only a few exotic species as possibilities. Such candidates include weakly interacting particles from supersymetric theories, such as neutralinos, which can annihilate and produce electrons and

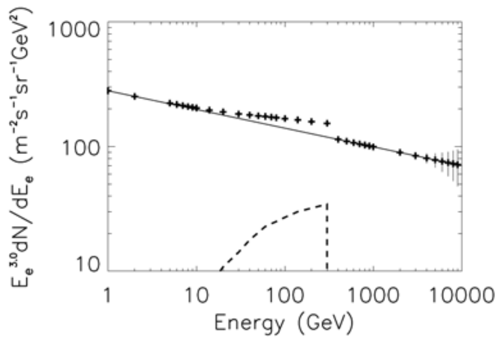

Figure 4. Simulated electron flux enhancement due to dark matter particle signal (Annihilation of 300 GeV dark matter particle produce equal fraction of $\tau^+\tau^-$, $\mu^+\mu^-$ and e^+e^- pairs, a NFW dark matter distribution with a boost factor 5 and ρ_{local}=0.4GeV/cm^3 [5], solid line is fitted from present electron observation data.)

positrons as a signature. As an example, Figure 4. shows an increase of electron flux (including positron) due to the 300 GeV dark matter particle annihilations into electron pairs. It can be seen that the electron spectrum has the prominent feature around the energy of dark matter particle mass.

4. CERN beam test

We have carried out the beam test of the prototype detector of CALET which is consisted of small size imaging calorimeter and BGO calorimeter. Figure 4 presents the cross section view of a scale model of CALET used for the beam test at CERN. The size of IMC is only about 5% of CALET flight model. The TASC is consisted of 10 layers of BGO, and each layer has 4 bars including a dummy material of iron as shown in Figure4. Figure 5 shows the result of proton rejection power compared with simulation results. It can be seen that experimental results agree with simulation very well. If we set a cut around 25, we only lose several percent of the electrons but reject about 99% of the protons. The IMC beam calibration have been made several times, detail comparisons with simulation can be found in separate papers [3,6].

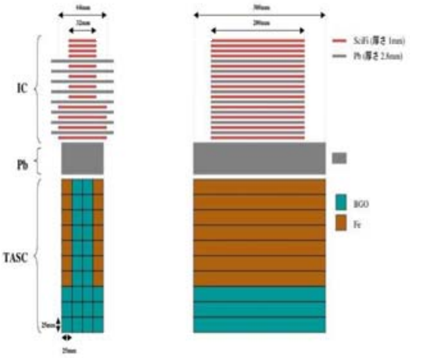

Figure 4. A cross section of CALET calibration configuration (left is in X-Z plane, right is in Y-Z Plane).

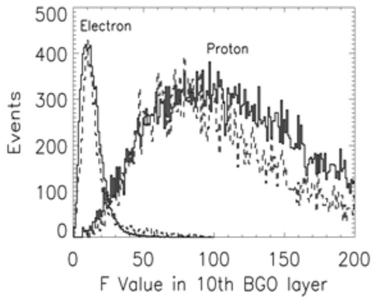

Figure 5. F value distribution (see text) in 10th BGO layer for 50 GeV incident electrons (left peak) and 150 GeV incident protons of comparable total energy deposit in the TASC (right peak). Solid line is from CERN exposure and dashed line is from simulation.

5. Summary

We have described the results of simulation calculations and have compared them with actual exposures to high energy electrons and protons at CERN. We find that CALET has a capability to observe electron from several GeV to 10 TeV with low background rate and high energy resolution. For gamma-ray observation, the angle resolution and total effective area is a little worse than GLAST, but it has better energy resolution than GLAST in high energy. It is very useful for dark matter search.

References

[1] S. Torii et al., 28th ICRC, Tsukuba, 2177, (2003)
[2] J. Chang et al., 28th ICRC, Tsukuba, 2185, (2003)
[3] S. Torii et al., ApJ 559, 973 (2001)
[4] J. E. McEnery et al., AAS, 205 (2004)
[5] E. A. Baltz, D. Hooper,hep-ph/0411053 (2004)
[6] H. Kitamura, et al., 28th ICRC, Tsukuba, 2089, (2003)