ICRC'07 Mérida, México

Balloon observation of electrons and gamma rays with CALET prototype

Y. SHIMIZU[1], S. TORII[1], K. KASAHARA[1], Y. AKAIKE[1], Y. FUKUTA[1], K. HIDAKA[1], K. TAIRA[1], T. TAMURA[2], K. YOSHIDA[3], Y. KATAYOSE[4], H. MURAKAMI[5]
FOR THE CALET COLLABORATION
[1]*Research Institute for Science and Engineering, Waseda University, Japan*
[2]*Faculty of Engineering, Kanagawa University, Japan*
[3]*Department of Electronic and Information Systems, Shibaura Institute of Technology, Japan*
[4]*Department of Physics, Yokohama National University, Japan*
[5]*Department of Physics, Rikkyo University, Japan*
y.shimizu@waseda.jp

Abstract: We carried out a balloon observation of cosmic rays using a prototype of the CALET at the Sanriku Balloon Center of the Japan Aerospace Exploration Agency. The prototype detector consists of 1024 scintillating fibers for track imaging and 24 BGO scintillator "logs" for total absorption of showers. The observation was carried at an altiude between 35 and 37 km for about 3.5 hours. We measured electrons and gamma rays in the energy region between 1 to 100 GeV, and 20 MeV to 1 GeV, respectively. In addition to verification of the prototype system, we have obtained preliminary results of the electrons and the γ-ray. Final results will be presented at the conference. Now we are planning a series of balloon experiments with larger-scale detectors and longer-duration flights, which includes one-month observation by a super-pressure balloon.

Introduction

The CALorimetric Electron Telescope (CALET) mission aims to reveal high energy phenomena in the universe by space-based observation of the high energy cosmic rays [4]. The detector is intended to be placed on the Japanese Experiment Module (JEM) of the International Space Station (ISS). We have researched and developed elemental components of the CALET such as BGO scintillator, scintillation fiber and readout electronics for them. For the verification of observation capability, a balloon-borne experiment with a prototype of the CALET was carried out. We report the results of the balloon experiment and obtained electron and γ-ray events.

Prototype detector

As described in the reference [3], the major part of the CALET detector consists of a large-mass calorimeter, which is divided into two parts. The upper part is an imaging calorimeter (IMC), and the lower part is a total absorption calorimeter (TASC). A structure of the prototype is shown in Fig 1. While the prototype is not covered with anticoincidence detector, two layers of plastic scintillator is installed for the trigger.

The IMC of the prototype is composed of four layers for track imaging. Each layer consists of a tungsten plate and two scintillation fiber belts arranged in the x and y direction. Each belt is composed of 128 of 1 mm square cross section fibers, so that the total number is 1024. The dimension of the IMC is about 128 mm by 128 mm. The total thickness of the tungsten plates is 1.3 radiation length (r.l.). The image measured by the IMC is used for estimation of the incident direction and the shower development of cosmic rays. Signals of each fiber are detected by 64ch multi-anode PMTs.

The TASC is composed of 6 layers of BGO scintillator. Each layer consists of 4 of 25mm square cross section BGO logs. Alternate layers are orientated 90 degrees to each other to provide an x and y coordinate. The total thickness of the TASC is 13 r.l. The TASC is used for the measurement of the shower development to determine the total energy of the incident particle and to discriminate electrons and γ-rays from protons. To measure BGO signals, a single photodiode is attached to each log. The peak corresponding to the minimum ionizing particle (MIP) is clearly seen in measurement of cosmic-ray muons.

Two layers of 20mm-thick plastic scintillators and the top layer of the TASC are used to generate a trigger signal. To obtained both of electron and γ-ray events, we provide two trigger modes. The trigger condition shown in Table 1 is set to eliminate effectively the background proton events.

	S1	S2	B
e	>0.7 MIPs	>0.7 MIPs	>5 MIPs
γ	<0.7 MIPs	> 0.7 MIPs	>0.5 MIPs

Table 1: Trigger mode. The pulse height is normalized to the peak of the minimum ionizing particle (MIP).

The detector performance is calculated by Monte-Carlo simulations with the EPICS code [1]. The acceptance of the prototype is estimated to be about 20 cm^{2}sr.

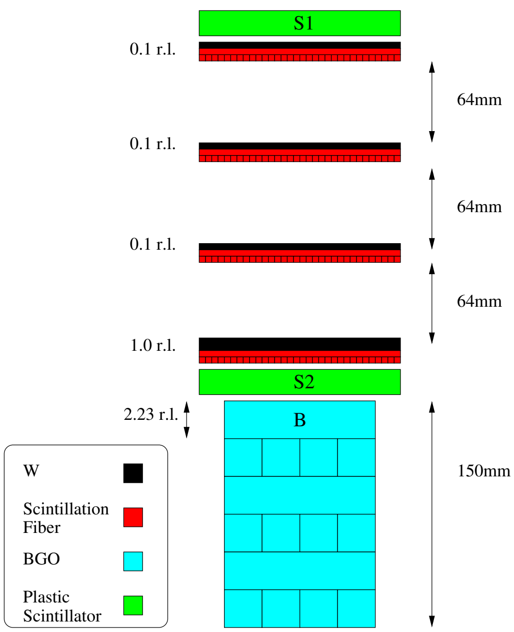

Figure 1: Schematic side view of the CALET prototype detector.

Balloon observation

The balloon observation was carried out at the Sanriku Balloon Center of the Japan Aerospace Exploration Agency on 31 May 2006. The CALET prototype was successfully launched from the center at 6:00 and drifted toward the Pacific Ocean. The flight was terminated after the duration of about 6 hours. The payload was recovered on the ocean. The variation of the altitude is shown in Fig. 2. The duration of the level flight above 35 km was 3.5 hours. The trigger rate was observed at each altitude during the flight as shown in Fig. 3. At the level flight, the rate for the electron and γ-ray modes are 0.35 and 2.1 Hz, respectively. We collected about 3 $\times$ 10^3 electron trigger events and 4 $\times$ 10^4 γ-ray trigger events in the level flight.

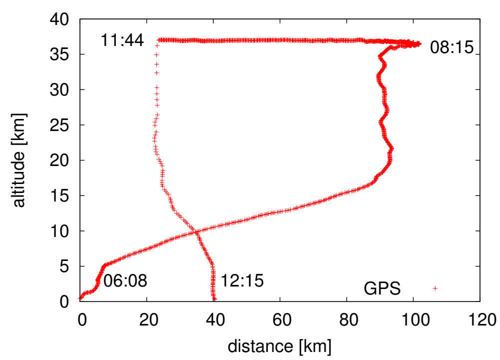

Figure 2: Balloon altitude in the flight.

Data analysis

The data observed in the level flight was employed for analysis of electrons and γ-rays. Using the shower image measured by the IMC and the TASC, we obtained the incident energy and the incident direction and separated the electromagnetic shower by electrons and γ-rays from the hadronic shower by protons. Figure 4 shows an example of an observed event with the energy of 7 GeV.

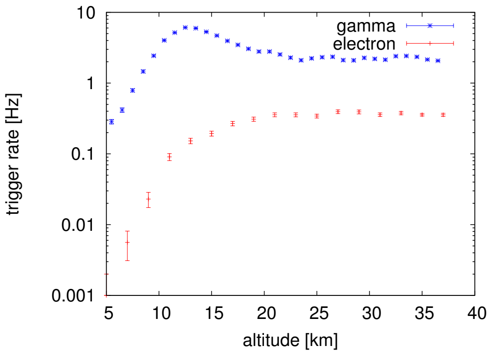

Figure 3: Variation of the trigger rate for the electron and γ-ray modes.

Incident energy

The incident energy was estimated by the sum of the deposit energy in the TASC. The energy calibration curves were calculated by the simulation of electrons and γ-rays. While most of the particle energy is deposited in TASC since the thickness of the IMC is only 1.3 r. l, energy loss in the IMC was calculated by the simulation and considered in this analysis.

Incident direction

The incident direction was obtained by the best-fit straight line of hit points and shower cores in the shower image. For the tracking in the IMC, we used the positions of the scintillation fiber that has the highest signal in each layer. For the TASC, we assumed the energy weighted center of four BGO scintillators in one layer was the position of the shower core.

Proton rejection

The vertical and transverse development can be used to discriminate the electromagnetic showers from the hadronic showers. The difference of the vertical development was identified by the trigger described in the previous section. The difference of the transverse development was distinguished by the standard deviation from the energy weighted center of the BGO array.

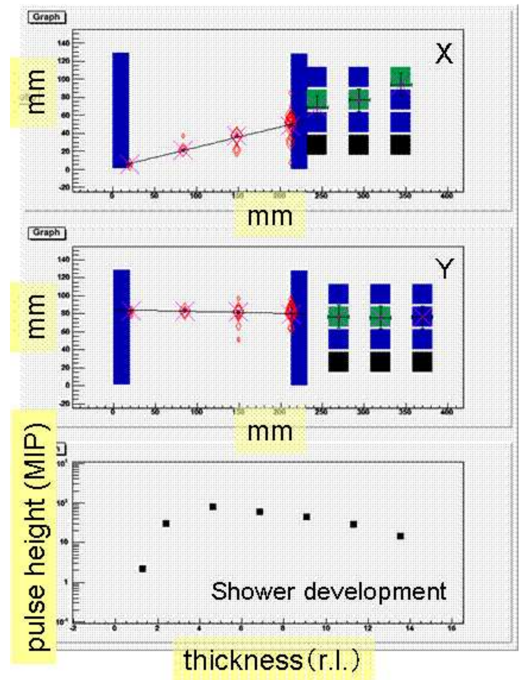

Figure 4: Example of an observed electron-like event with the energy of 7GeV. Pulse hight of a scintillation fiber is described by size of the red diamond. BGO logs are represented by colored boxes. Light color indicates larger pulse hight.

Preliminary results

To derive energy spectra of electrons and γ-rays, actual electron and γ-ray events was selected from among the obtained trigger events. The trigger events include large amount of background protons. Furthermore, accidental trigger events in which particles enter from the side of the detector need to be eliminated. First, we selected contained events, where an extrapolated line of a particle track crossed both of the top of the IMC and the bottom of the TASC, from the trigger events (the light blue points in Fig 5). Second, proton-like events were eliminated by considering the difference of the transverse shower development (the blue points in Fig 5). Preliminary results of the event selection are presented in Fig. 5. The remaining events are electron-like and γ-ray-like events observed at the altitude between 35 and 37 km.

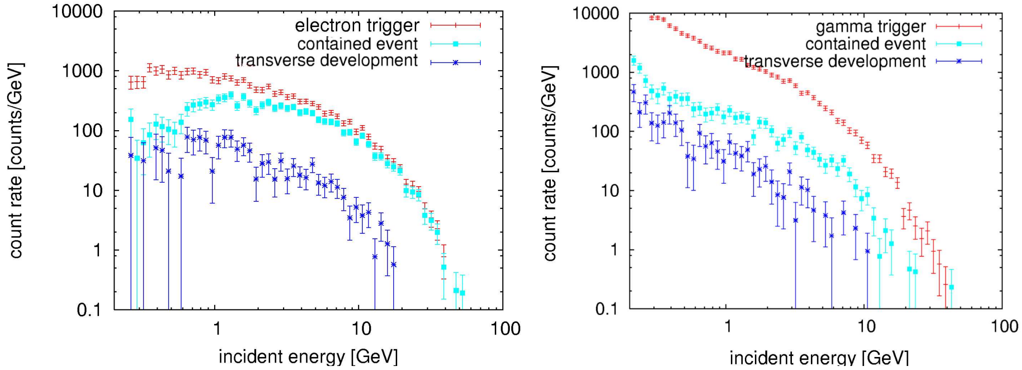

Figure 5: Preliminary results of selection of electron-like (left) and γ-ray-like (right) events from the trigger events.

Future plans

To achieve more precise measurement, more statistics is required. We need a larger scale detector and a longer flight. To extend flight duration and add BGO logs, a low power consumption readout for the TASC is developed [2]. Then, a series of longer duration balloon experiments is proposed. At first, we are preparing for one-day flight with a detector which has four times larger area than the prototype in 2008. It will be carried out in Taiki-cho, Hokkaido. For the next step, we are planning one-month flight with a super-pressure balloon that is developed by the balloon center. The balloon will be launched from Brazil and landed in Australia. The detector for this flight is 16 times larger than the prototype. The statistics of the observation with the super-pressure balloon is expected to be 2000 times larger than that of the prototype. This observation might make it possible to measure TeV electrons and high energy γ-rays.

Summary

The first balloon experiment with the CALET prototype is carried out. We obtained thousands of electron and γ-ray trigger events at the altitude between 35 and 37 km. The shower image of cosmic rays were clearly observed by the calorimeter. To derive energy spectra of electrons and γ-rays, data analysis is on going. Furthermore, we are planning longer balloon experiments by a super-pressure balloon as a precursor flight of the CALET mission.

References

[1] http://cosmos.n.kanagawa u.ac.jp/.

[2] Y. Katayose *et al.* Development of a high dynamic range rend-out system using multi-photodiode for the total absorption calorimeter of CALET. In *International Cosmic Ray Conference*, 2007.

[3] S. Torii *et al.* CALET Mission on the International Space Station. In *International Cosmic Ray Conference*, 2007.

[4] S Torii *et al.* The CALET experiment on ISS. *Nucl. Phys. B (Proc. Suppl.)*, 166:43–49, 2007.