The CALorimetric Electron Telescope, CALET, Mission for the International Space Station

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Abstract

We are proposing the CALET mission for the Japanese Experiment Module (JEM), Exposed Facility (EF) of the ISS. Major goal of the mission is the investigation of high energy phenomena in universe by observing the electrons in a few GeV $\sim$ 10 TeV and the gamma-rays in 20 MeV $\sim$ 10 TeV. The detector consists of an imaging calorimeter (IMC) and a total absorption calorimeter (TASC). It has a proton-rejection power of $\sim 10^6$ for electrons, and the geometrical factor is nearly 1 m^2 sr. As a heavy payload of JEM, the total weight of payload is 2,500 kg and three-years observation is expected.

1. Introduction

Observation of the TeV electrons is indispensable to resolve the long-term questions on the acceleration cites and the diffusion mechanism in the Galaxy. The expected electron flux is, however, very small over 1 TeV ($\sim$ 2 / m^2 sr day) due to the energy loss rate in proportion to E^2, and the amount of background protons exceeds electrons in flux by more than 1000 times. As a result, the

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detector should require a large (and heavy) scale as 1 m^2 sr and an excellent rejection power better than 10^5 against the background protons. The observation must, also, be done for long term and in very low backgrounds. For the purpose, it is unique to employ CALET for three years observation on ISS.

The CALET detector is a calorimeter in combination of imaging part and total absorption part, and it has the proton rejection power to select effectively the electrons and the gamma-rays up to the TeV region. It is also suitable to precise measurement of the energy spectrum since the energy resolution is better than a few % over 100 GeV. We shall simultaneously detect the electrons and the gamma-rays by using a multi-triggering system [1].

The status of our mission program is now under the concept study to confirm the feasibility of detector in the performance and the compatibility as a suitable mission on JEM-EF. We will briefly report on the scientific objectives of the CALET mission and the detector concept.

2. Detector Concept

The detector is composed of an imaging calorimeter, IMC, and a total absorption calorimeter, TASC. The IMC is used for the identification of the incident particle and the energy measurement at lower energies, and the TASC for the proton rejection in the TeV region and for the energy measurement. A schematic configuration of the CALET detector is presented in Fig.1. The IMC

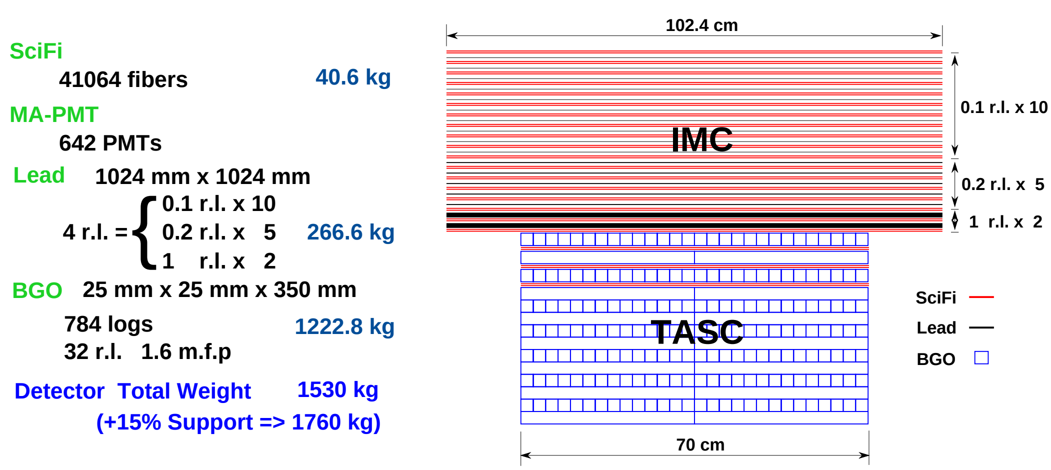

Fig. 1. The schematic side view of CALET. The anti-coincidence system covering IMC is not presented.

is a sampling-type tracking calorimeter using scintillating fibers, SciFi, as sensitive layers and lead as absorber. The configuration of IMC has been studied from an experience of the balloon experiments in a few $\sim$100 GeV, and the performance over 100 GeV is estimated by simulations. Since back-scattered particles in shower increases considerably when the incident energy becomes higher, a highly-granulated imaging capability is crucial for identification of the incident particle. Therefore, the IMC 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 sampling rate in pre-shower stage ($<$ 1 r.l. depth) is as dense as one per 0.1 r.l to measure precisely the starting point and to separate an incident particle from the back-scattered particles. The area of detector is 100 $\times$ 100 cm^2, and the total thickness of lead is 4 r.l. The total number of SciFi is nearly 40,000. The read-out system is being successfully developed by using the 64-anode PMT and the front-end processor made of ASIC [2,3].

The TASC might be composed of BGO logs, with a cross section of 2.5 cm $\times$ 2.5 cm, which are aligned in x and y direction layer by layer. The role of TASC is measurements of the whole development of electro-magnetic showers up to 10 TeV. By simulation study, the thickness of BGO is optimized to be 32 r.l for the rejection power of nearly 10^6 [4]. In the 3 layers from top, Scifi belts are interleaved between the BGO logs to improve the position resolution. The required dynamic range of the read-out system of BGO will be established by the photo-diode and specified electronics [5].

The total thickness of absorber is 36 r.l and the interaction mean free path of protons is nearly 1.7. It is expected for electrons from simulations that the angular resolution is 0.1 $\sim$ 0.03 degree and the energy resolution is approximated by the formula, 9.2 % / $\sqrt{E(10GeV)}$. The compatibility of CALET with JEM/EF is reported in the paper by Takayanagi et al. [6].

3. Scientific Objectives

Electron: The most important target of the CALET mission is to detect directly the nearby electron sources by observing the energy spectrum in the TeV region. Among some candidates which are predicted, Vela is most promising as an observable nearby source. Figure 2 shows the expected energy spectra of electrons calculated by a diffusion model under an assumption of the injection spectrum $E^{-2.4}$ with the total energy 10^{48} erg. It is also possible to determine the diffusion coefficient since the spectrum in the TeV region is strongly affected by the diffusion characteristics in the Galaxy.

Gamma-Ray: The imaging calorimeter adopted in CALET has a capability of measuring the gamma-rays over 20 MeV as proved by simulations and balloon experiments. Since the energy resolution is better at higher energies, we can precisely measure the change of spectral index around 10-100 GeV. Some of the GeV sources detected by EGRET were not observed in the TeV region by ground-based Cherenkov observation although the detection efficiency is enough

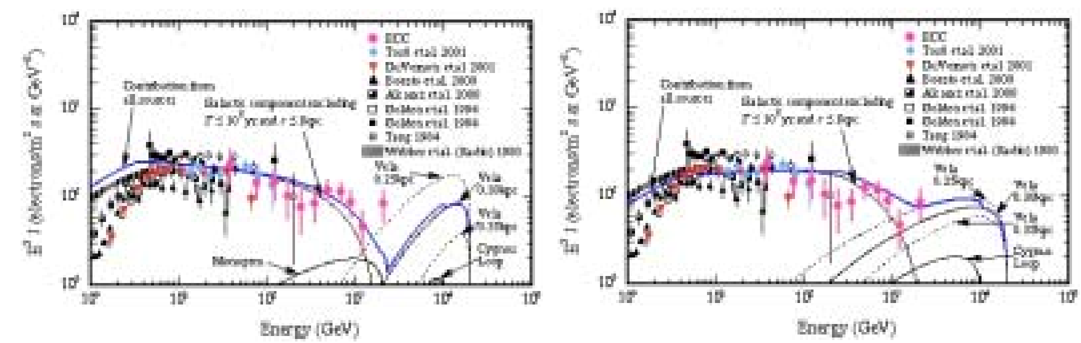

Fig. 2. Electron energy spectrum calculated by a diffusion model (the diffusion coefficient: 1×10^{29} cm^2/s in left, 4×10^{29} cm^2/s in right) and the present data.

in case that the spectrum has no breaking. Therefore, the precise measurement of energy spectrum in this unobserved region is certainly important. As the important targets of observation, the followings are expected: Galactic and extra-Galactic diffuse component, supernova remnant, pulsar, AGN, and gamma-ray burst. Gamma-rays from annihilation of SUSY particles are also expected to be observed in this region. Details of the CALET capability of observing gamma-rays are presented in the paper by Yoshida et al.[7].

4. Discussion and Summary

Although the CALET is basically an electro-magnetic calorimeter, it can detect protons and heavy nuclei up to 1000 TeV. The energy spectrum of these over 1 TeV is important to resolve the acceleration limit of cosmic rays, and the relation to the electron and gamma-rays might bring a comprehensive understanding of the high-energy phenomena.

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