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The CALET Mission for the International Space Station

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Abstract. The CALorimetric Electron Telescope, CALET, mission is proposed for the Japanese Experiment Module Exposed Facility, JEM-EF, of the International Space Station. The major goals of the mission are to reveal the origin of cosmic-ray electrons and the diffusion characteristics in the Galaxy. The instrument will be composed of an imaging calorimeter of scintillating fibers and a total absorption calorimeter. The total thickness of absorber is 45 r.l for electromagnetic particles and 2.1 m.f.p for protons. Total weight of the payload is nearly 2,200 kg, and the effective geometrical factor for the electrons might be larger than 0.5 m^2sr. The hadron rejection power should be 10^6 in order to observe the electrons up to 10 TeV. The detector has also capability of measuring gamma-rays from 0.1 GeV to 1 TeV, keeping the energy resolution within a few % over 10 GeV. We are expecting to launch the CALET around 2007 by the Japanese H-II Transfer Vehicle, HTV.

1 Introduction

As predicted by several calculations, the electrons in the TeV region are indispensable to resolve the long-term questions on the acceleration cites and the diffusion characteristics in the Galaxy. High-energy electrons lose their energy in proportional to the square of the energy by synchrotron radiation and inverse-Compton scattering. Therefore, when the energy of electron, E increases, the life time of electron becomes shorter in proportion to $1/E$ and the propagation distance in the diffusion process reduces by $1/\sqrt{E}$. In the TeV region, only the electrons from the sources at a distance within 1 kpc and with an age less than $\sim 10^5$ years, can reach the Earth. Since the number of such possible sources is very limited, the energy spectrum of electrons should have a structure (Nishimura et al., 1980; Atoyan et al., 1995), and the arrival directions are expected to show an anisotropy (Shen and Mao, 1971; Putsukin and Ormes, 1995). Also, the diffusion process can have effects on the electron flux. The electron energy spectrum might, therefore, give direct knowledges of the diffusion coefficients (Nishimura et al., 1997).

Precise measurement of the gamma-ray energy spectrum over 10 GeV is very important to know the origin and the propagation process. The point sources observed by EGRET up to $\sim$10 GeV were not always detected over several 100 GeV by ground-based detectors. We will try to detect gamma-rays from point sources to fill the energy gap between the space observations and the ground experiments. The diffuse Galactic component of gamma-rays over 10 GeV is strongly related to the electron energy spectrum since the gamma-rays are produced by inverse-Compton scattering with electrons (Paul and Esposito, 1998).

The CALET has a proton rejection power $\sim 10^6$ and a sufficient discrimination power of electrons from gamma-rays, and the energy resolution is better than a few % over 10 GeV (Torii et al., 2000a). We shall simultaneously observe the electrons and the gamma-rays by using a multi-triggering system. The CALET is now proposed to be put on the Japanese Experiment Module Exposed Facility (JEM-EF) of the International Space Station. In following, we will briefly report on the concept of CALET mission and the scientific objectives.

2 Mission Concept

2.1 Japanese Facility of ISS

The status of CALET mission is now under the concept study for the development of the key devices and the review of sci-

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entific objectives. The National Space Development Agency of Japan (NASDA), which is responsible for the scientific program of ISS, has selected four missions which will be launched on the JEM-EF around 2004. In the next AO scheduled around the end of 2001, some missions will be selected for the Phase A/B study aiming to launch in the year of 2007.

The JEM-EF is a unique facility for detectors exposed to cosmic radiation, and 10 attached payloads with a size of 1.85 m $\times$ 0.8 m $\times$ 1.0 m are available for detectors (Shimizu, 1999). A schematic structure of the JEM-EF is presented in Fig. 1. The weight limit for the standard payload is 500 kg, and that for the heavy payload, which can be mated to either EFU #2 or EFU #9, is 2,500kg. We are proposing to put the CALET at the EFU #9, which has a wider field of view.

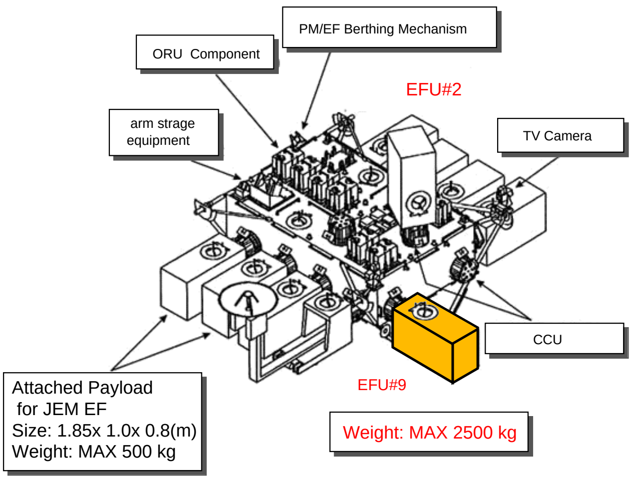

Fig. 1. A schematic view of the JEM-EF. Among 10 attached payloads, two of them are for the heavy payload, 2,500 kg, and the others are for the standard, 500 kg.

2.2 Detector Concept

The design concept of CALET is to measure electrons from a few GeV to 10 TeV and gamma-rays from 0.1 GeV to 1 TeV. The weight of detector is nearly 2,200 kg and the effective geometrical factor is 0.5$\sim$1 m^{2}sr. The observation period is scheduled for 3 years.

The baseline detector is combination of an imaging calorimeter, IC, and a total absorption calorimeter, TASC. The IC is used for the identification of the incident particle and the energy measurement below 10 GeV, and the TASC for the proton rejection in the TeV region and for the energy measurement over 10 GeV. In Fig. 2, an overview of the CALET instrument as an attached heavy payload is illustrated.

The IC is a sampling-type calorimeter using scintillating fibers, SciFi, for sensitive layers and lead for absorber. The configuration of IC has been studied from an experience of the BETS instrument in 10$\sim$100 GeV (Torii et al., 2000b, 2001; Tamura et al., 2000), and the performance over 100 GeV is estimated by the simulation study (Yoshida et al., 2001). Since back-scattered particles in an electro-magnetic shower increases when the incident energy becomes higher,

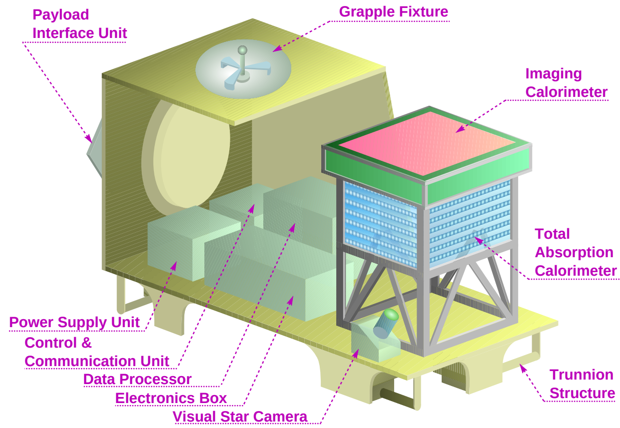

Fig. 2. An overview of the CALET instrument as an attached payload at JEM-EF.

a highly-granulated imaging capability is necessary for identification of the incident particle at high energies. Therefore, the IC has 46 layers of SciFi belts which are set in x and y direction alternatively. The cross section of SciFi is 1 mm square. The energy-sampling rate in the beginning stage (< 2 r.l. depth) of shower development is as dense as one per 0.2 r.l to measure precisely the shower starting point and to separate an incident particle from copious back-scattered particles. The area of detector is 70 $\times$ 70 cm^2, and the total thickness of lead is 13 r.l. The number of SciFi is 32,200. Examples of shower images in IC obtained by the simulation are presented in Fig.3 to make clear the capability of particle identification.

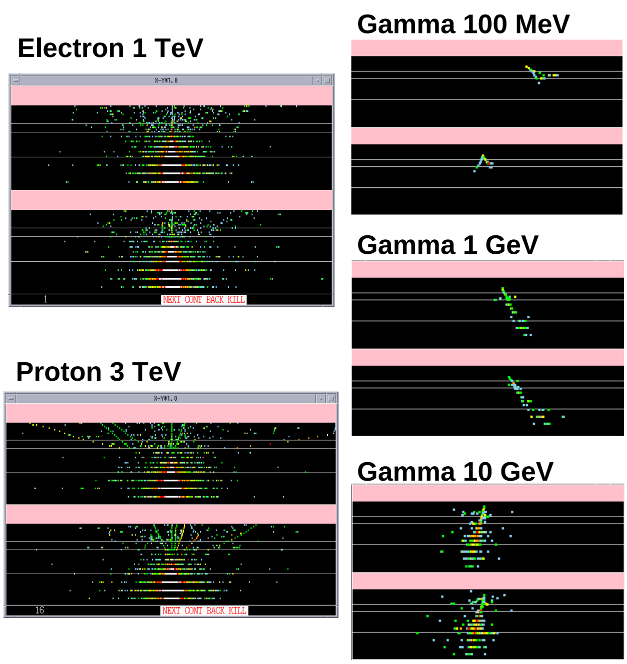

Fig. 3. Examples of shower images by simulations. The upper and the lower figure presents the x and y image, respectively.

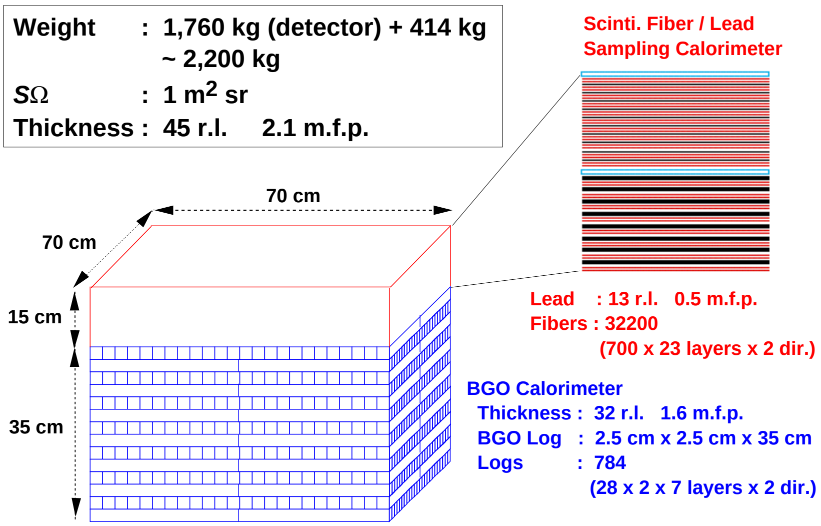

Fig. 4. The configuration of the CALET detector. The IC consists of SciFi belts inserted between lead plates; the TASC of BGO logs. The geometrical factor is $0.5 \sim 1\text{m}^2\text{sr}$ depending on the incident energies.

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. Since the background protons is 1000 times more than the electrons in the TeV region, the rejection power against the protons should considerably larger than this. The thickness of BGO must be optimized in order to save the weight as much as possible under the condition that the combined rejection power with IC is nearly 10^6. By our simulation study, it is proven that the thickness of BGO can be 35 r.l for the purpose. Therefore, the total thickness of absorber in CALET is 45 r.l. and the interaction mean free path of protons is nearly 2.1. The configuration of detector is presented in Fig. 4.

2.3 Electron Observation

The most important goal 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 since both the distance, which is revised by the recent measurement ~ 0.25 kpc (Cha et al., 1999), and the age, $\sim 10^4$ years, are very suitable for the observation.

Figure 5 showa 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 (Kobayashi et al., 1999). The size of the Galactic disc, h, the diffusion coefficient, D, and the energy loss rate, b, are assumed as presented in the figure to give a consistent result with the present data below 100 GeV. We could determine the diffusion coefficient at once, because the spectrum in the TeV region is strongly affected by the diffusion characteristics in the Galaxy.

The expected number of electrons by the observation is listed in Table 1 under an assumption that the spectrum has a simple power index of - 3.3 from the low energies. As we might expect nearly 1000 electrons over 1 TeV, it is very possible to find clearly the signature of Vela, otherwise we could expect no electrons over 2 TeV.

TABLE 1. Electrons in 3-years Observation.

Energy(GeV)	> 10	> 100	$> 1{,}000$
Expected No.	3.7×10^7	1.9×10^5	9.2×10^2

Moreover, the very precise measurement of the electron energy spectrum from 10 GeV to 1 TeV will bring the detailed knowledges of the source spectrum, the diffusion time, the distribution of sources so on (Müller, 2001). The observation below 10 GeV for many years can supply us a key to resolve the solar modulation mechanism.

2.4 Gamma-ray Observation

The IC has a capability of measuring the gamma-rays in the GeV region as proved by the BETS observation of atmospheric gamma-rays (Torii et al., 2000c). Moreover, since the energy resolution is better than a few % over 10 GeV, we can precisely measure the change of spectral index of the gamma-ray energy spectrum. The changes might be caused by the decrease of acceleration power and/or the absorption by background radiations in the extra-Galactic space. 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 in case that the spectrum has no breaking (Ong , 1998). Therefore, the precise measurement of energy spectrum between 10 GeV and 1000 GeV is certainly important.

The Gamma-ray Large Area Space Telescope, GLAST (Allen et al., 2000), is expected to extend the gamma-ray observation in this energy region. The CALET might carry out a complementary observation with a higher energy resolution over 10 GeV. In Fig.6, we summarize the detection limit of gamma-rays from the point sources and from the diffuse components.

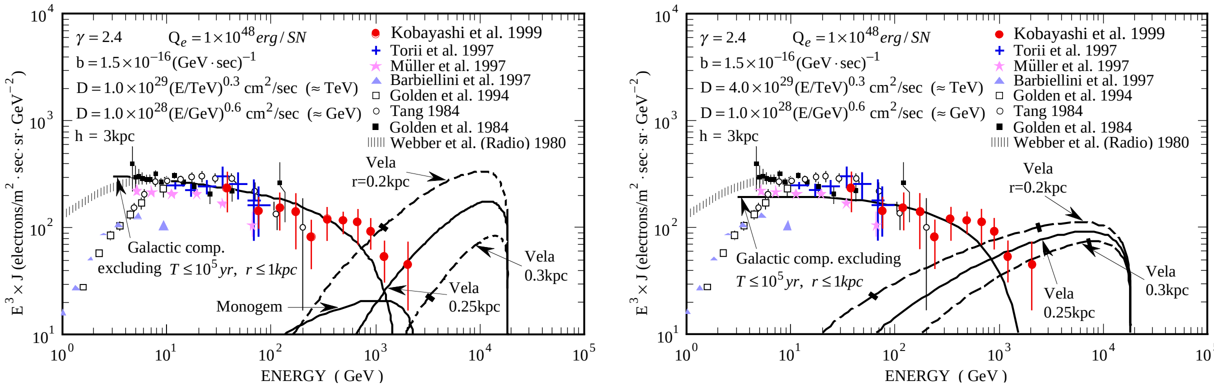

Fig. 5. Expected energy spectrum of electrons from a diffusion model calculation comparing with the present data. The spectrum from Vela is calculated for different distances; two cases of diffusion coefficient are assumed in the right and left figure. See the text for other assumptions in the calculation.

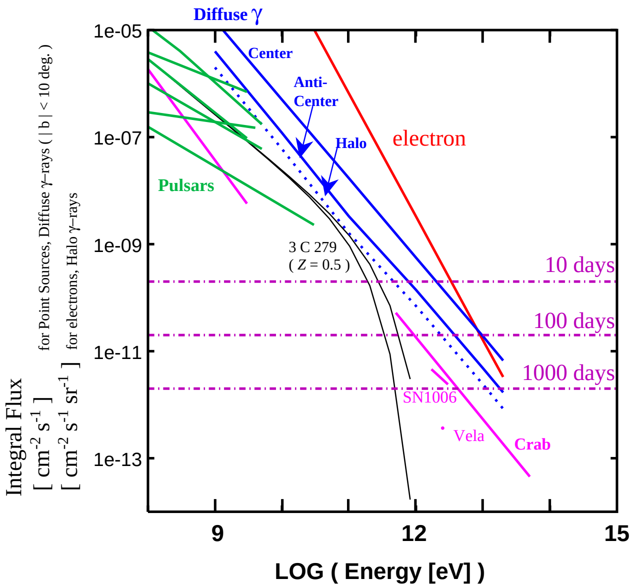

Fig. 6. Estimated detection limits for point sources and diffuse components. The observation time is 10-100 days for the point sources and more than 100 days for the diffuse components.

3 Discussion and Summary

The CALET mission is planned to perform a crucial observation of electrons up to 10 TeV. By observing the energy spectrum and the distribution of arrival directions in the TeV region, the nearby sources will be revealed with the diffusion characteristics of electrons in the Galaxy. In the gamma-ray observation, we might know features of the electrons in the source region from the diffuse component and the origin and propagation from the point sources.

The key technology of the CALET is the read-out system of scintillating fibers. We have successfully developed a space-borne image intensifier and a system of multi-anode PMT and VLSI, Viking Chip (Tamura et al., 2001). We will decide the hard-ware setup including the read-out system in the Phase A/B study.

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