The CALET mission for detection of cosmic ray sources and dark matter

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Abstract. We are developing the CALorimetric Electron Telescope, CALET, mission for the Japanese Experiment Module Exposed Facility, JEM-EF, of the International Space Station. Major scientific objectives are to search for nearby cosmic ray sources and dark matter by carrying out a precise measurement of the electrons in 1 GeV - 10 TeV and the γ rays in 20 MeV - several TeV. CALET has a unique capability to observe electrons and γ rays over 1 TeV since the hadron rejection power is more than 10^5 and the energy resolution better than a few % over 100 GeV. The detector consists of an imaging calorimeter by SciFi and W, and a total absorption calorimeter by BGO. CALET has also a capability to measure protons and nuclei up to 1000 TeV, and will have a function to monitor solar activity and γ ray bursts with additional instruments. The phase A study has started on a schedule of launch in 2013 by H-II Transfer Vehicle (HTV) for 5 years observation.

1. Introduction
CALET is developed as an instrument to observe very high energy electrons and γ rays on the Japanese Experiment Module Exposure Facility, JEM-EF, on the ISS. The objective of the CALET mission is to explore a new frontier at higher energies for the origin of cosmic-rays (CR), the propagation of CR and to search for dark matter. We will measure electrons from 1 GeV to 10 TeV and γ rays from 20 MeV to several TeV, free from the hadron backgrounds, with an excellent energy resolution beyond 100 GeV. CALET has also a capability to measure protons and heavy nuclei from several 10 GeV to 1000 TeV and to monitor solar activity and γ ray bursts.

CALET is designed on the basis of experience in balloon observations [1-4]. It is a calorimeter, combining an imaging part and a total absorption part, and it will have an excellent capability for proton rejection, 10^6, which is necessary to select electrons and γ rays in the TeV region. It is also suitable for a precise measurement of the energy spectrum, since the energy resolution is better than a few % for energies greater than 100 GeV.

2. Scientific Objectives
2.1. Electron sources and propagation in our Galaxy
High-energy electrons lose their energy in proportion to the square of the energy, by synchrotron radiation and inverse-Compton scattering. Therefore, in the TeV region, only the electrons at a distance within 1 kpc from the sources and with an age less than 10^7 years, can reach the Earth. Since the number of such possible sources are very limited, the observed energy spectrum might have a characteristic structure [5], and the arrival directions are expected to show a detectable anisotropy [6].

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The diffusion process in the Galaxy strongly affects also the electron flux. The energy spectrum could, therefore, give a direct evidence of nearby cosmic ray sources and a knowledge of diffusion characteristics in interstellar space. Vela is the most promising as an observable nearby source since both the distance, \(~0.25\) kpc, and the age, \(~10^4\) years, satisfy the constraints listed above. Figure 1 shows an expected energy spectrum calculated by a diffusion model. Several parameters assumed in the model calculations are chosen to reproduce a spectrum consistent with the present data below 100 GeV. These include the injection spectrum of \(E^{-2.4}\), the total energy of \(10^{48}\) erg per SN, the size of the Galactic disk, the diffusion coefficient and the energy loss rate [7].

2.2. Gamma-ray sources

Since CALET has a large field of view (~2 sr) and a wide effective area (~0.5 m\(^2\)@10 GeV) for \(\gamma\) rays, it can observe the whole sky without any attitude control. The coverage per day is \(~70\) % and the entire sky can be observed in 20 days. The observation period for point sources is 48 days on average per year. Most of the GeV sources detected by EGRET have not been observed in the TeV region by Air Cherenkov observations although the detection efficiency should be enough for the case of no break in the spectrum. CALET will have the ability to detect \(\gamma\) rays from point sources to fill the energy gap between EGRET and Air Cherenkov observations. The point source sensitivity (in one year) of CALET is nearly \(1 \times 10^{-9}\) cm\(^{-2}\)s\(^{-1}\), which is worse than GLAST, but the energy resolution is as good as a few \% over 100 GeV. CALET might also be useful as a follow-up observation after GLAST. The important targets of observation include: Galactic and extra-Galactic diffuse components, supernova remnants, pulsars, AGNs, and \(\gamma\) ray bursts. In particular, the diffuse Galactic component of \(\gamma\) rays above 10 GeV is strongly related to the electron energy spectrum since the \(\gamma\) rays are mainly produced by electrons near the source region [8]. Because the energy resolution improves at higher energies, CALET can precisely measure the \(\gamma\) ray energy spectrum from 10 to ~100 GeV. Such changes might be a consequence of the decrease of acceleration power and/or the absorption by starlight photons in the extra-Galactic space.

2.3. Dark matter

There are some expectations that positrons have a line signature around several 100 GeV from the dark matter candidates: neutralinos in the SUSY theory [9] and Kaluza-Klein (extra dimensional) particles [10]. Although CALET has no capability to distinguish positive and negative charges, an excess of positron and electrons might be detected due to the excellent energy resolution of the instrument and with very high statistics as shown in Fig. 2. Observations of \(\gamma\) ray lines from the annihilation of SUSY particles are also feasible if such particles exist with an expected abundance.
2.4. Protons and Nuclei
Although CALET is an electromagnetic calorimeter, it can detect protons up to 1000 TeV as the absorber thickness corresponds to 1.8 mean free path for protons as described in next section. Determining the energy spectrum of protons in proximity of the Knee region is very important for resolving the acceleration limits of protons and heavy nuclei. Further, validity of the leaky box model will be tested up to the energy region of 10 TeV by measuring the cosmic ray secondary to primary ratio energy dependence.

3. Detector Concept and Accommodation Study
The CALET consists of a combination of an imaging calorimeter, IMC, with a total absorption calorimeter, TASC. Total detector weight is nearly 1430 kg, and the geometrical factor (for electrons) is ~ 0.7 m^2 sr [11]. A schematic structure of detector is presented in Fig.3. The IMC provides the precision necessary to 1) separate the incident particles from backscattered particles, 2) precisely determine the starting point of showers, and 3) identify the incident particle. The TASC measures the development of the electromagnetic showers to 1) determine the total energy of incident particle and 2) separate electron and γ rays from hadrons. SIA is a silicon pixel detector for charge measurements. ACD is an anti-coincidence detector for low energy γ rays. CALET will be launched by Japanese carrier, HTV, and attached to a port of JEM-EF, EFU#9, which is capable to maintain a heavy payload and a wider field of view. Figure 4 shows a schematic view of the CALET payload which is attached to the port. In addition to the calorimeter, a γ ray burst monitor will be put together. The main structure of CALE is designed by adopting an interface structure of a usual exposed facility.

4. Summary
The CALET mission is approved for a phase A study aiming at the launch around 2013 for 5 years observation. We mainly expect to detect nearby electron sources and dark matters by a precise measurement of electron and γ ray energy spectrum up to the TeV region.

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