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The CALET Mission on International Space Station

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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 the nearby cosmic ray sources and dark matter by carrying out a precise measurement of the electrons in 1 GeV - 10 TeV and 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 can be better than 10^5 and the energy resolution better than a few % over 100 GeV. The detector consists of an imaging calorimeter, SciFi and W, and a total absorption calorimeter, BGO. CALET has also a capability to measure protons and nuclei up to 1000 TeV, and it will have a function to monitor solar activity and γray 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. Details of each part of CALET will be presented in accompanying papers in this conference.

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 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.

Scientific Objectives

Electron Sources and Propagation

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 10^5 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]. The diffusion process in the Galaxy strongly affects the electron flux. The energy spectrum could, therefore, give a direct evidence of nearby cosmic ray sources and 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 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].

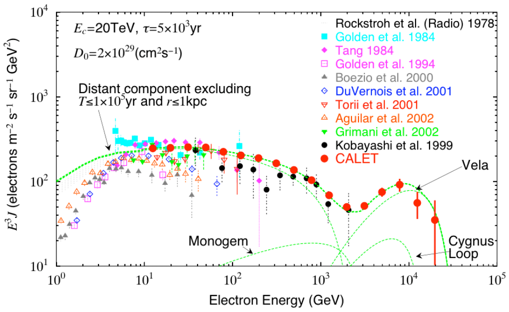

Figure 1: Comparison of the present data of electron energy spectrum and the expected by CALET with a diffusion model which show contributions from nearby sources in the TeV region.

Gamma-ray Sources

Since CALET has a large field of view (~2 sr) and a wide effective area (~m^2@10GeV) for γ 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 γ rays from point sources to fill the energy gap between the EGRET and Air Cherenkov observations. The point source sensitivity (in one year) of CALET is nearly 1×10^{-8} cm^{-2}s^{-1}, which is considerably 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 γ ray bursts. In particular, the diffuse Galactic component of γ rays above 10 GeV is strongly related to the electron energy spectrum since the γ rays are mainly produced by inverse-Compton scattering with electrons near the source region [8].

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.

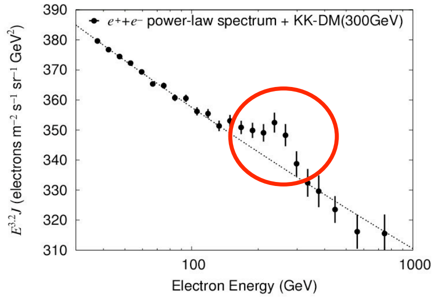

Figure 2: Simulated energy spectrum of e^- + e^+ spectrum with Kaluza-Klein dark matter annihilation for 300 GeV in mass.

Because the energy resolution improves at higher energies, CALET can precisely measure the γ 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. Finally, observations of γ ray lines from the annihilation of SUSY particles [10] are also feasible if such particles exist with an abundance as shown in Fig. 3.

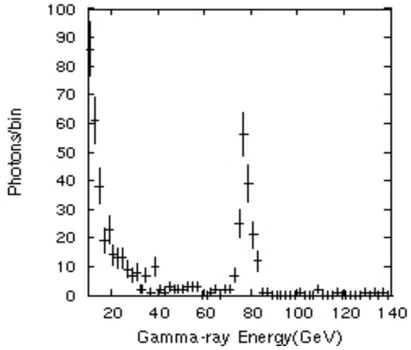

Figure 3: Expected γ ray line spectrum with neutralino annihilation with a mass of 78 GeV.

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.

Solar Physics

The CALET measurement of long-term variations of the electron energy spectrum in 1-100 GeV will produce a wealth of data to investigate electron propagation in the heliosphere. CALET is not able to distinguish positive charge from negative. However, we can evaluate the charge sign dependence of solar modulation using correlation with the neutron monitors, since most particles are negative electrons in this energy range. We can also estimate transport parameters, and, in particular, the energy dependence of diffusion coefficient in the heliosphere. CALET will also have a capability of measuring the short-term variation of around ten Forbush decreases (Fds) for three years. Precise measurement of the energy spectral variation of Fds will give a conclusion of the energy dependence of Fds.

Detector Concept

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 ~ 1 m^{2}sr. A schematic structure of detector is presented in Fig. 4. In addition to the calorimeter, a γ ray burst monitor will be put together. The IMC consists of 17 layers of tungsten plates each separated by 2 layers of 1mm square cross section scintillating fibers (SciFi) belts arranged in the x and y direction and is capped by an additional x, y layer pair. The dimension of IMC is about 90 cm by 90 cm. While the total thickness of IMC is 4 radiation length (X_0) , and about 0.13

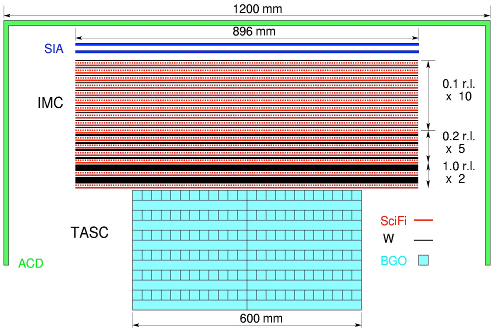

Figure 4: Schematic side view of CALET detector.

proton interaction lengths (λ). This 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 readout for SciFi layers is currently planned to consist of multi-anode photomultiplier tubes, Hamamatsu R5900 with a front-end electronics based upon a high density ASIC, the 32 ch Viking Chip [11]. 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. It is composed of 12 layers of Bismuth Germanate (BGO) logs where each log has dimension of 2.5 cm × 2.5 cm × 30 cm. There are 24 such logs in each layer. Alternate layers are oriented 90 degrees to each other to provide an x, y coordinate for tracking the shower core. The total area is 60 × 60 cm^2 and the vertical thickness 28 X_0 and 1.4 λ . It is anticipated that each BGO log will be read by a multi-photodiode for measuring in a high dynamic range.

At the top of IMC, two layers of silicon pixel array (SIA) are placed to improve the charge resolution of incident particles and to eliminate effectively the back-scattered particles. The whole detector is covered by an anti-coincident detector (ACD) of segmented plastic scintillators to reject charged particles for low energy γ ray observation.

Accommodation Study for JEM

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 5 shows a schematic view of the CALET payload which is attached to the port. The main structure of CALET is designed by adopting an interface structure of a usual exposed facility.

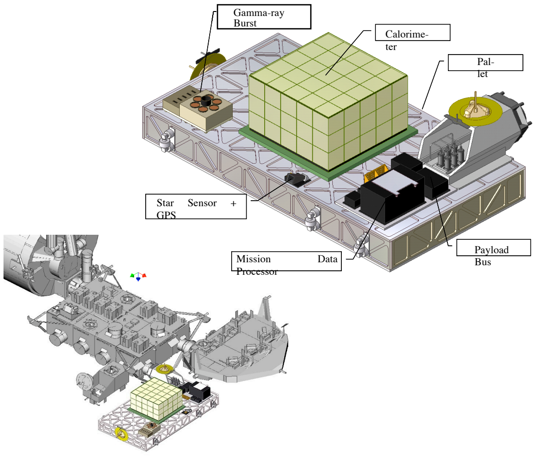

Figure 5: Overview of CALET at JEM-EF.

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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