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The CALET Instrument for Experiment on the ISS

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We propose the CALorimetric Electron Telescope (CALET) mission for Japanese Experiment Module, Exposed Facilisty (JEM-EF) on ISS to address some of the most profound questions in particle astrophysics. CALET is composed of two kinds of calorimeter, an imaging calorimeter, IMC, at upper part and a total absorption calorimeter, TASC, at lower part. The IMC is employed to detect the shower profile by using scintillating fibers with 64-anode PMT read-out system. The TASC is consisted of BGO logs to measure the energy deposits in each shower. Total weight of the payload is nearly 2,500 kg and the geometrical factor for electrons is about 1 m^2 sr. CALET has a unique capability to measure electrons and gamma-rays beyond 1 TeV since it can have a superior hadron rejection power of 10^6 for electrons and much better for gamma-rays. It can also measure protons and heavy nuclei in proximity of the Knee. The energy resolution for electromagnetic particles is better than a few % above 100 GeV. We will present a baseline design of the detector, and report the present status of detector development. Compatibility of the detector with the JEM Exposed Facility will also be discussed.

1. Introduction

The Calorimetric Electron Telescope, CALET, dedicated to the study of high energy cosmic rays (CR), is designed to identify the primary particle and to record electronically in flight its charge and energy. We are planning to measure electrons in 1 GeV - 10 TeV and gamma-rays in 20 MeV ~ several TeV , free from the hadron backgrounds with an excellent energy resolution over 100 GeV. It is also considered to detect protons and heavy nuclei in 1- 1000 TeV. The objective of the CALET Mission is to explore a new frontier at high energies and to reveal the origin of cosmic-rays, the early universe and the dark matter [1].

The low CR fluxes at high energy impose to maximize the geometric factor of the instrument within the limitations imposed by the available weight and power. We have contrived CALET on the basis of the experience of balloon experiments. It is a calorimeter in combination of the imaging part and the total absorption part, and it could have an excellent capability of the proton rejection power, ~10^6, which is necessary to select electrons and gamma-rays in the TeV region. It is also suitable to a precise measurement of the energy spectrum since the energy resolution is better than a few % above 100 GeV. Since CALET has a capability both to identify the particle kinds and to measure the energies with the imaging calorimeter, we need not any additional detector other than a light weight Silicon Pad Detector for precise charge identification of relativistic particles. Therefore, it might have a larger geometrical factor comparing to the weight. The observation on ISS has advantage to the satellite experiment in reducing the weight of payload because the station could provide the common faciliities of power, telemetry, and thermal control and so on. Meanwhile, demerits caused by the station are not serious for the CALET observation.

2. Detector Concept

A schematic of the CALET detector concept is shown in Figure 1. The detector consists of two major components: the Imaging Calorimeter (IMC) and the Total Absorption Calorimeter, TASC. The IMC consists of 17 layers of lead plates each separated by 2 layers of 1mm square cross section scintillating fiber (SciFi) belts arranged in the x and y direction and is capped by an additional x,y SciFi layer pair. The dimension of the IMC is about 100 cm by 100 cm. While the total thickness of the IMC is 4 radiation length (X_0) , and about 0.13 proton interaction lengths (λ), the first 10 lead – SciFi layers sample the particle at 0.1 X_0, followed by 5 layers that are 0.2 X_0 thick and finally 2 layers that are 1 X_0 deep. This provides the precision necessary to 1) separate the incident particle from backscattered particles, 2) precisely determine the starting point for the electromagnetic shower, and 3) identify the incident particle. The readout for the SciFi layers is currently envisioned to consist of multi-anode photomultiplier tubes (MA-PMT), such as the Hamamatsu R5900 [2]. Each R5900 MA-PMT has 64 anodes and, consequently, about 16 MA-PMTs will be needed to read each belt. The front-end electronics for the IMC will be based upon a high density ASIC such as the 32 channel Viking (VA32HDR2) chip [3]. Current work involves developing readout electronics with the dynamic rang and low noise characteristics needed by CALET.

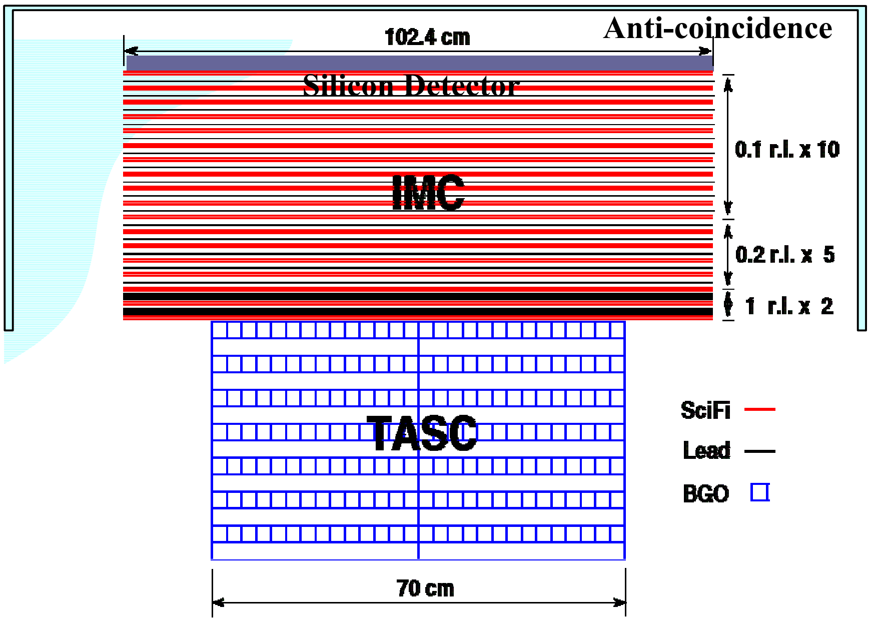

Figure 1: Schematic side view of CALET detector structure.

The TASC measures the development of the electromagnetic shower to 1) determine the total energy of the incident particle and 2) separate electrons and gamma-rays from hadrons. The TASC is composed of 14 layers of Bismuth Germanate (BGO) "logs" where each log has dimensions of 2.5 cm x 2.5 cm x 35 cm. There are 56 such logs in each layer. Alternate layers are orientated 90^0 to each other to provide an x,y coordinate for tracking the shower core. The total area of the TASC is about 0.5 m^2 and the vertical thickness is 32 X_0 and 1.6 λ. It is anticipated that each BGO log will be read by a photodiode and laboratory tests have confirmed that such a system is capable of detecting 0.5 MIP (minimum ionizing particle) and work is currently underway to develop electronics with a high dynamic range [4].

For low energy gamma-rays (<10 GeV), the IMC is covered by plastic scintillators for anti-coincidence with hadrons. A pixelated silicon detector module will be placed at the top of the IMC for having sufficient charge separation capability and dynamic range to identify relativistic nuclei in the range from proton to Iron and above. It can also afford to identify precise position of an incident particle among the copious backscattered particles at higher energies.

A concept instrument design for CALET is shown in Figure 2. The IMC in the top part of the figure shows the SciFi belt assembly interfacing with an array of MA-PMTs and front end electronics (FEC). Two such belts, oriented 90^0 to each other, are shown being placed on a lead plate. The remainder of the IMC layers is assembled in a similar fashion. Below the IMC is the TASC with its stack of BGO logs. The logs are wrapped on five sides for optical isolation and, for each layer, are assembled next to each other in two rows with the unwrapped face outward. The photodetectors (PD) are then attached to the unwrapped log faces. Layers are then assembled on top of each other with each layer rotated by 90^0 relative to the previous layer. Finally, the PD readout electronics (PreAMP + AMP) boxes are assembled on each face of the TASC. Details of this assembly, as structural support for the individual BGO crystals, position calibrations for the SciFi belts and analysis of launch loads, still needs further work.

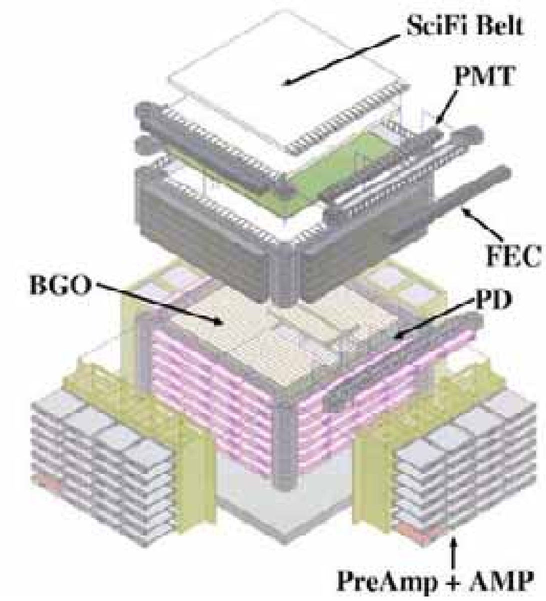

Figure 2 : Concept instrument design of CALET.

3. Performance of Detector

In 2003, we carried out a beam test of the prototype of CALET (in smaller scale) at CERN-SPS [5]. In this prototype, the detector has similar structure in longitudinal direction with the baseline structure of CALET for measuring the energy resolution, the angular resolution and the hadron rejection power. We confirmed the performance is very consistent with expectations from the simulations for electrons at energies of 50 GeV and 100 GeV and for protons of 150 GeV. Simulation study has been done at higher energies which are not attainable by accelerators [6]. Since the simulation results are proved by the beam tests, the extrapolation to higher energies might be reliable to examine the performance. In Table 1, we summarize the expected performance of the baseline detector for the electron observation.

Table 1: Expected performance for electrons by simulation.

Energy Range	1 GeV ~ 10 TeV
Geometrical Factor	~ 1 m^2sr
Proton Rejection Power	~ 10^6
Energy Resolution	9.2 % /√ E(10 GeV)
Angular Resolution (>10 GeV)	0.03 ~ 0.1 deg.

4. Accommodation study for JEM

The CALET will be launched by a Japanese carrier, HII Transfer Vehicle (HTV), and attached to the EFU #9, which is capable to maintain a heavy payload up to 2.5 tons in mass and has a wider field of view, 45 degrees. The main structure of CALET is designed by adopting an interface structure of a usual exposed facility. The structure, therefore, includes a pallet to sustain the detector, which is used both for launching by HTV and for attaching to JEM. The structure was optimized to meet the requirements from the ISS for the vibration condition. Also, the heat condition was analyzed in several phases of the experiment. The mission life is supposed to be three-years.

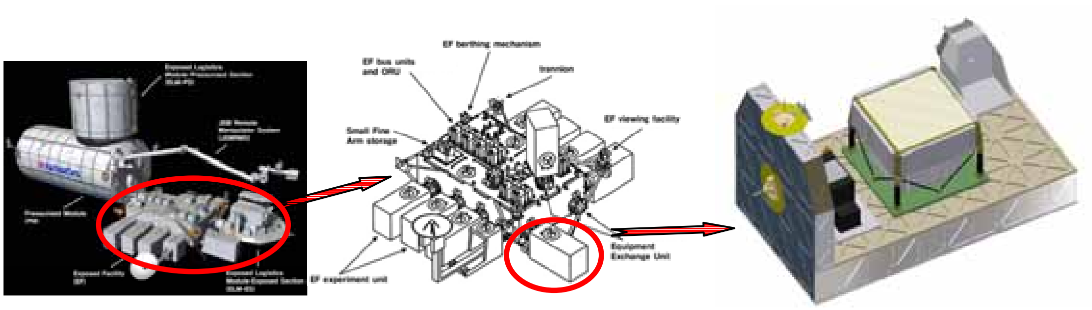

Figure 4: CALET on JEM platform.

5. Conclusions

We have successfully been developing the CALET detector for JEM-EF on the ISS. The capability expected by the simulations and the beam tests is excellent to measure electrons and gamma-rays in the TeV region and protons to Iron in the proximity of the Knee region. We will have further development to apply the Mission Opportunity for launching around 2012, which will be scheduled in near future.

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