The Event Trigger System for CALET

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Abstract: The CALorimetric Electron Telescope, CALET, is a mission to study high energy phenomena in the universe by observing high energy cosmic rays (electrons, gamma rays, and nuclei) on the International Space Station. The instrument consists of a segmented plastic scintillator charge-measuring module, an imaging calorimeter consisting of 8 scintillating fiber planes interleaved with tungsten plates of 3 radiation length, and a total absorption calorimeter consisting of orthogonal PWO logs of 27 radiation length. It is necessary to eliminate the background events, mostly low energy protons that prevent efficient observation of high energy cosmic rays. Therefore, CALET has an on-board trigger system to select events which are 1) high energy showers, 2) low energy showers and 3) non-interacting protons or heavy nuclei. These triggers are generated by a combination of the signals from the charge detector, the imaging calorimeter, and the top layer of PWO in the total absorption calorimeter. A CERN-SPS beam test of the CALET prototype detector was carried out by using muons, electrons, and hadrons. We introduce the CALET trigger system and present its performance verified during the beam test.

Keywords: CALET, electron, gamma-ray, ISS, trigger system, beam test

1 Introduction

The CALorimetric Electron Telescope (CALET) mission aims to reveal high energy phenomena in the universe by the space-based observation of high-energy cosmic rays. The detector is planned to be placed on the Japanese Experiment Module (JEM) Exposed Facility of the International Space Station (ISS). The main detector of the CALET consists of 3 components [1]. The top part is the Charge Detector (CHD), the middle part is the Imaging Calorimeter (IMC), and the lower part is the Total Absorption Calorimeter (TASC).

The CALET detector will use a shower trigger system with three modes which adopt different threshold levels. To evaluate the perfomance of CALET, we developed a prototype detector, and an accelerator beam experiment was carried out at CERN-SPS in 2010.

2 Trigger system for CALET

The CALET detector will use a shower trigger system which is an effective method to detect the development of the cascade in the detector of a high-energy particle.

2.1 CALET detector

The CALET detector consists of the Carge Detector (CHD), the Imaging Calorimeter (IMC) and the Total Absorption Calorimeter (TASC). The CHD is composed of 2 layers by which the charge number of incoming particles is measured. Each layer consists of 14 plastic scintillators. For the readout, PMTs (R7600, Hamamatsu) are used.

The IMC is composed of 8 layers by which the track of incoming particle is traced. Each layer consists of a tungsten plate and 2 scintillating fiber (SciFi) belts aranged in the x and y direction. Each belt is composed of 448 fibers with cross section of 1 mm square in each. The total thickness of tungsten plates is 3.0 radiation length (r.l.). The signal of SciFi is read out with multi-anode PMTs (R7546, Hamamatsu) and the front-end circuits installed in VA chips (VA32HDR14.3).

The TASC is composed of 12 layers, each of which consists of 16 PWO ($PbWO_4$) scintillator logs (19mm$\times$20mm$\times$326mm). The total tickness of TASC is 27 r.l.. The first layer is coupled to PMTs (R7400, Hamamatsu) and the others are coupled to dual APD/PDs (S10937-9351, Hamamatsu). A Dual APD/PD is a 2-in-1 package of APD (S8664-1010) and PD (S1227-33BR).

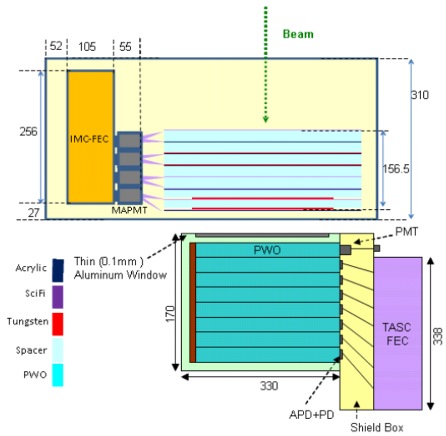

Figure 1: Side view of the CALET detector and a simulated shower development (100 GeV electron).

2.2 Trigger source

To generate a trigger signal used in CALET, we will use three signal sources which are the followings:

- The summation of PMT signal of CHD each layer (CHD)
- The summation of dynode signal of IMC each layer (Dy1∼Dy4)
- The summation of PMT signal of TASC first layer (TTop-SUM)

In Fig.1, the side view of CALET with an example of simulated shower is presented.

2.3 Trigger modes

During observation, CALET will be operated either in Low-Energy Trigger mode (LE) and High-Energy trigger mode (HE). The LE mode is optimized for the observation of particles with energies as low as or higher than 1 GeV, while the HE mode is optimized for particles above 10 GeV. Single mode is also available for calibration purpose. The trigger thresholds of LE and HE are determined based on the simulation as shown in Table 1.

Mode	CHD	Dy1	Dy2	Dy3	Dy4	TTop-SUM
Single	0.7	0.7	0.7	0.7	0.7	0.7
LE	0.7	0.7	0.7	0.7	2.5	4
HE	-	-	-	-	7.5	52

Table 1: The trigger threshold of each layers. The numerical value is converted with Minimum Ionization Particle (MIP) signal.

3 Configuration of the prototype trigger system

We have developed a prototype detector for the accelerator beam experiment. The prototype detector has been composed of CALET components such as PWO scintillators, scintillating fibers [2],[3], readout electronics, and the trigger system. The detector geometry is shown in Fig. 2. The configuration of detector materials along the beam direction has been reproduced as same as possible with the CALET fligh model.

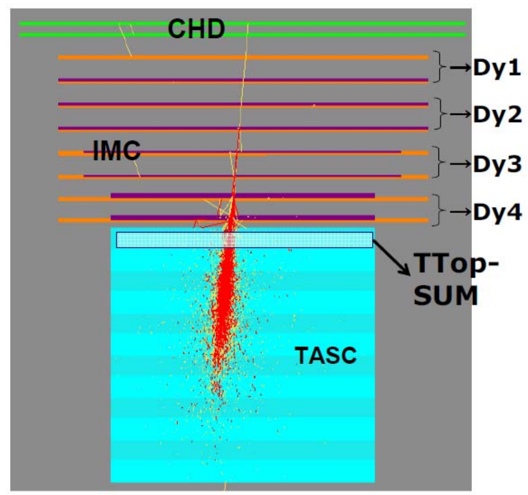

Figure 2: The schematic view of the prototype detector.

While the signals of CHD constitutes the trigger of CALET, the prototype trigger system is composed of the followings:

- The summation of the dynode signals of each IMC layer (Dy1∼Dy4)
- The summation of the PMT signals of the first TASC layer (TTop-SUM)

The circuit system that reads the trigger signal of IMC is shown in Fig. 3. In CALET, the dynode signals of 14 multi-anode PMT are added by an analogue-adding circuit, and a Charge Sensitive Amplifier reads it. Aftar that, to make a trigger signal of IMC, Charge Sensitive Amplifier signals are read out by wave form shaping amplifiers (fast shapers) and pulse height discriminators. For measurment of the pulse heights, they are read out by wave form shaping amplifiers (slow shapers) and Peak-hold ADC (PHADC). The adding circuit is omitted in the prototype because it reads IMC with one multi-anode PMT each layer.

The circuit system that reads the trigger signal of TASC is shown in Fig. 4. Almost same as IMC's circuit. Two slow shapers with different gains are coupled to the Charge Sensitive Amplifier to achive a wide dynamic range. The ratio of the higher gain to the lower is 30:1.

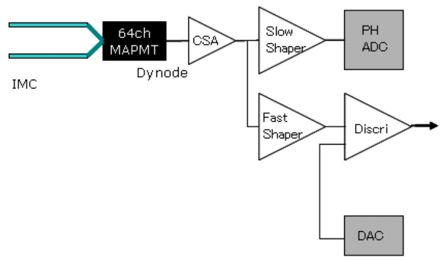

Figure 3: The block diagram of the readout circuit for IMC's MAPMT dynode.

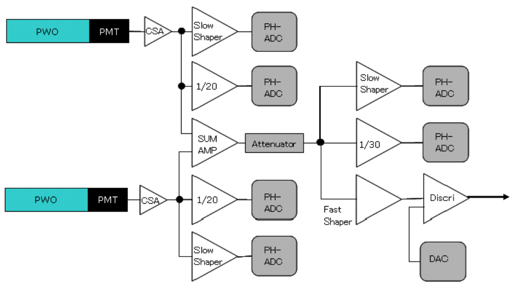

Figure 4: The block diagram of the readout circuit for TASC's PMT.

4 Performance test of trigger system at CERN-SPS

We used the Super Proton Syncrotron (SPS) accelerator at CERN in September, 2010. We carried out the tests by using positron and hadron beams in the energy region from 6 to 200 GeV, and from 30 to 150 GeV, respectively, and 150 GeV muon beams for calibration. The detector setup for the beam test is shown Fig. 5. The trigger efficiency is estimated by comparing prototype trigger system with the trigger scintillators in front of the detector.

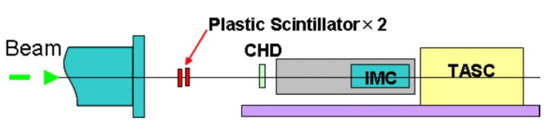

Figure 5: The side view of the detectors setup.

4.1 Performance evaluation for trigger system

To determine the thresholds, the beam muon was irradiated. An example of signal distributions for muons is shown in Fig. 6 and Fig. 7.

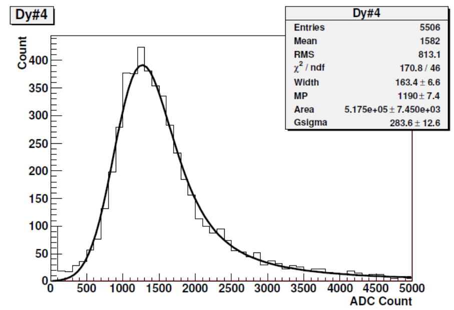

Figure 6: The distribution of the muon signals from Dy4 (IMC 7th and 8th layer).

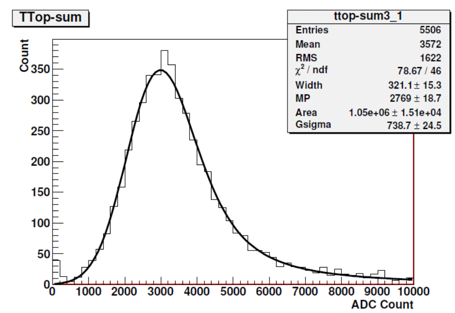

Figure 7: The distribution of the muon signals from TTop-SUM (sum of TASC 1st layer).

4.2 Trigger efficiency for electrons

To study the trigger efficiency, electrons with energy of 6 - 200 GeV have been irradiated to the center of the detector surface. The number of triggered events by the prototype (internal) trigger system is compared with that mesured by the (external) plastic scintillators. Fig. 8 shows the distribution of TTop-SUM signals of 10 GeV electrons.

The threshold level has been set to 40 MIPs and 65 MIPs, and the setting with 52 MIPs (HE trigger) is reproduced in off-line analysis. The comparison between these results and simulation is shown in Fig. 9.

4.3 Trigger efficiency for hadron events

When we set trigger threshold to more than a few MIPs, most of hadron events are not be triggered, because of a small percentage of occurrence of cascade. In the same way with electrons, we have made a comparison between the experimental trigger efficiency with the simulations for protons. In HE trigger mode, hadrons are experimentally triggered 5.3%. In the simulation, it is predicted as 5.5%. They are consistent within in statistical error. This trigger system is able to reject 94% or more hadrons at energies less than 30 GeV by adopting the trigger condition. Effect of π contamination in protons will be investigated in future analysis.

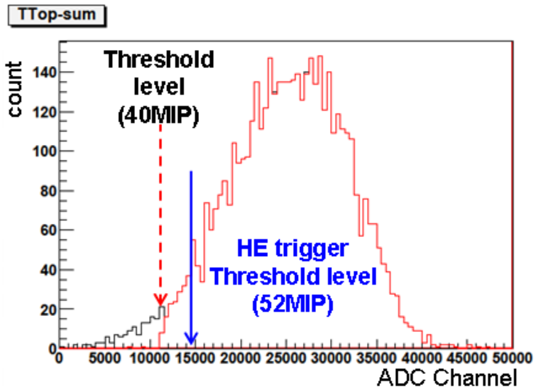

Figure 8: The distribution of TTop-SUM signals by 10 GeV electrons irradiated. Black line shows all events. Red line corresponds to the events detected by prototype trigger system (at 40 MIPs threshold level). Blue arrow shows HE-trigger threshold level (52 MIPs) used for offline analysis.

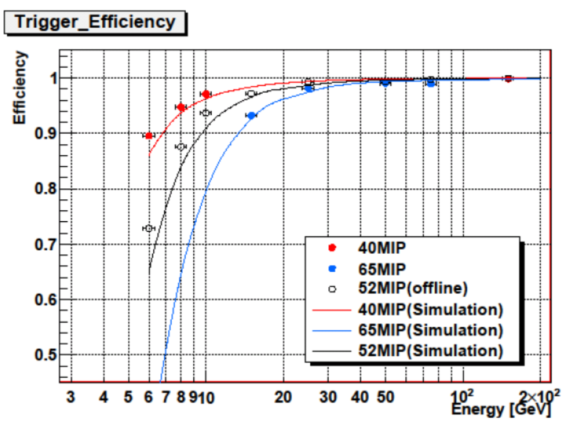

Figure 9: The trigger efficiency of HE-trigger. Solid lines are the efficiency by simulation. Red and blue dots present the efficiency obtained by the experiment. Open circles give the efficiency calculated by offline analysis.

5 Summary

In order to effectively detect high-energy particles , the CALET detector adopts a shower trigger system which detects the development of cascade shower in detector. To evaluate the perfomance of trigger system, we carried out a beam test at CERN-SPS with a prototype detector. Performance of the trigger system has been evaluated by using muons, electrons and hadrons. It is confirmed that the trigger efficiency of 90% (or more) for electron at 10 GeV and an on-board rejection factor of 95% for hadrons at 30 GeV. We are planning to carry out the CERN-SPS beam test in 2011 to develope an extended prototype detector and a trigger system including CHD with futher study by simulations.

6 Acknowledgments

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