Development of the Data Acquisition System for CANGAROO-III

D. Nishida, A. Asahara, H. Kubo, J. Kushida, T. Tanimori, H. Tanimura, S. Watanabe
Cosmic Ray group, Department of Physics, Kyoto University, Oiwake-cho Kitashirakawa Sakyo-ku Kyoto City, Kyoto 606-8502,Japan
S. Gunji, A. Watanabe, N. Sakamoto, Y. Doi
Department of Physics, Yamagata University, Yamagata, Yamagata 990-8560,Japan
H. Katagiri
Institute for Cosmic Ray Research, University of Tokyo, Kashiwa, Chiba 277-8582,Japan
for the CANGAROO-III collaborators

Abstract

In this paper we report the development of the data acquisition system (DAQ) of the CANGAROO-III imaging Cherenkov telescope. Multi-pixel cameras at the prime focus of the first and second 10 m telescopes consist of 552 and 427 PMTs, respectively. The charge from each PMT is measured with a ADC and the time each PMT is triggered is measured by a TDC with a time resolution of 1 ns. Since these modules are connected to a fast VME-bus and are read out by a CPU board running a Linux OS, the DAQ system of the second telescope can handle a trigger rate as high as 500 Hz. In stereoscopic observations, the DAQ of each telescope records shower events independently and these events are reconstructed in offline.

1. Introduction

An array of four 10 m imaging atmospheric Cherenkov telescopes is under construction near Woomera, South Australia (the CANGAROO-III project [1]). Observations with the first telescope started in March 2000, and these with the second one will start at the end of 2002. Here we describe the CANGAROO-III data acquisition system (DAQ) in detail.

pp. 1–6

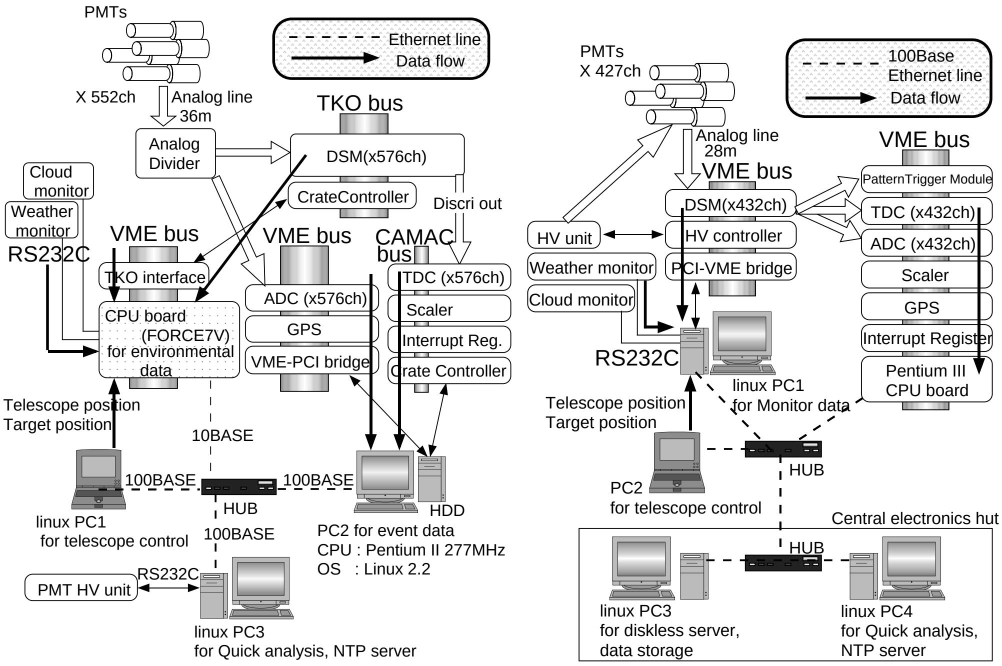

Fig. 1. Overview of the data acquisition system of the first telescope (left) and the second telescope (right)

2. First telescope

2.1. Electronics

An overview of the DAQ of the first telescope is shown in Fig. 1. The first telescope has a multi-pixel camera which consists of 552 PMTs (Hamamatsu 4124UV, 1/2″ in diameter) at the prime focus. The camera covers a field of view $2.7^\circ \times 2.7^\circ$. The signal from each PMT is transmitted through a 27 m twisted cable to the electronics hut, and divided to both VME9U-bus 32ch-12bit-charge sensitive ADC (Hoshin 2637) and TKO-bus Discriminator & Summing amp Module (Hoshin 2548; hereafter DSM) shown in Fig. 2.

In the DSM, the signal from each PMT is amplified with a fast shaping amplifier, and the signals of 16 channels are summed (hereafter ASUM). The amplified signal is fed to two discriminators; one is for measurement of the trigger ('hit') time by a CAMAC-bus 32ch TDC (LeCroy 3377) with a 0.5 ns resolution in time window of 256 ns, while the other is for measurement of the counts over the threshold level during about 1 ms with a 12-bit scaler. Both act to monitor and reduce the night sky background; the former based on the fact that the telescope is parabolic and the time propagation of a shower can be reproduced with an accuracy of less than 1 ns, and the latter is used to reject PMTs hit by starlight

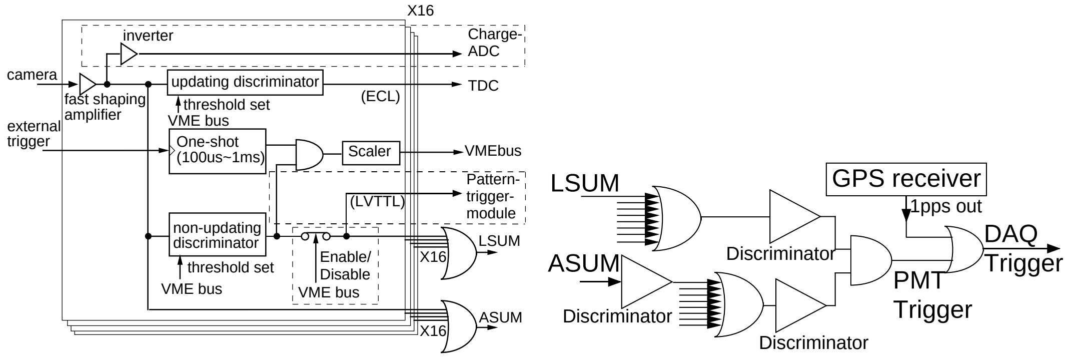

Fig. 2. Discriminator and Summing Module (DSM) and DAQ trigger logic. In the first telescope the areas enclosed by the dashed lines are not included, and a TKO-bus is used instead of a VME bus. Each module contains two units.

in the off-line analysis. The thresholds of both discriminators are adjustable via the TKO-bus. The window of the latter discriminator is set to be about 20 ns, the same as the time dispersion of showers, and a pulse with a voltage proportional to the number of PMTs hit at same time is generated (hereafter LSUM).

The DAQ trigger is generated as shown in Fig. 2. LSUM signals from DSMs connected to the inner 256 PMTs are summed, and discriminated to determine the number of PMTs hit within ∼20ns. The threshold of the discriminator is set to be 4 or 5 PMTs. On the other hand, the ASUM signal is discriminated to select a concentrated hit pattern. PMT triggers are generated from the coincidence of the outputs from the two discriminators, and then DAQ triggers are generated. In order to check the DAQ system, a pulse from a GPS receiver is added to a DAQ trigger every second. The DAQ trigger promptly opens an ADC gate of between 50 and 100 ns width, which converts the amplified signal from the DSM after a 150 ns delay provided by a delay-line chip onboard the ADC. The DAQ trigger also latches the time of the VME-bus GPS receiver and generates an interrupt to a CAMAC-bus interrupt register module. All signals shown in Fig. 2. are counted by a CAMAC-bus scaler.

Both weather and cloud monitors are connected to a VME-bus CPU board (FORCE 7V; TurboSparc 170MHz; Solaris 2.6) with RS232C lines, which reads the data every minutes. The VME-bus CPU also collects the scalers onboard the DSMs via a VME-TKO interface every 10 seconds, and the pointing direction of the telescope via a 100-Base network from the PC (PC1 in Fig. 1.) which also controls the telescope. PC1 runs KURT, a linux operating system with a real time extension.

2.2. Software

As shown in Fig. 1. a PC workstation (Pentium II 277MHz; PC2 in Fig.1.) collects data from the ADCs and the GPS via a PCI-VME bridge while the TDCs and the CAMAC-scaler are read via a ISA-CAMAC bridge. This is done when a DAQ trigger, shown in Fig. 2., is generated and the CPU of PC2 is interrupted by the CAMAC interrupt register. PC2 runs a linux operating system, and a portable DAQ system "UNIDAQ" [2] is installed for collecting and storing all data on a hard-disk. Although the DAQ trigger rate is below 30 Hz in most observations, the DAQ system can accept triggers at a rate of 80 Hz with a dead time of 20%. The UNIDAQ system is also used on the VME-bus CPU board in the left side in Fig. 1. The total size of data recorded in an event is 1.5 kbytes, and at most 45 kbytes/sec.

For real-time quick analysis, part of data is transmitted via the 100-Base network to a PC (PC3 in Fig.1.) on which linux is running, and both ADC and TDC distributions of all PMTs are displayed on event monitor windows. PC3 is connected to the high voltage controller of PMTs via RS232C lines, and both applied voltage and measured current are displayed on the window. PC3 also calculates the positions of stars in the field of view of the camera and displays them on the map of PMTs in order to compare their positions with PMTs with high DSM scaler values. If the positions are different, observers are alerted to check for telescope drive problems or discharge of PMTs. PC3 also plays a part in serving the system clock to all other CPUs via the network as an NTP server.

3. Second telescope

The mirror of the second telescope and the camera is improved, and the energy threshold is expected to be lower than that of the first telescope. Therefore, as the event trigger rate is expected to be higher than that of the first telescope, the DAQ system of the second telescope has been improved based on the experience of the first telescope. The biggest difference of the DAQ between the first and second telescopes is the kind of data-bus. The read-transfer speeds of both CAMAC and TKO data-buses are at most 1 Mbyte/sec, while that of the VME (VME32 type) is $\sim$8 Mbytes/sec. Thus the readout of second telescope's DAQ system, which consists of only VME modules, is faster than that of the first telescope.

3.1. electronics

The overview of the DAQ of the second telescope is shown in Fig. 1. The second telescope has a camera which consists of 427 PMTs (Hamamatsu

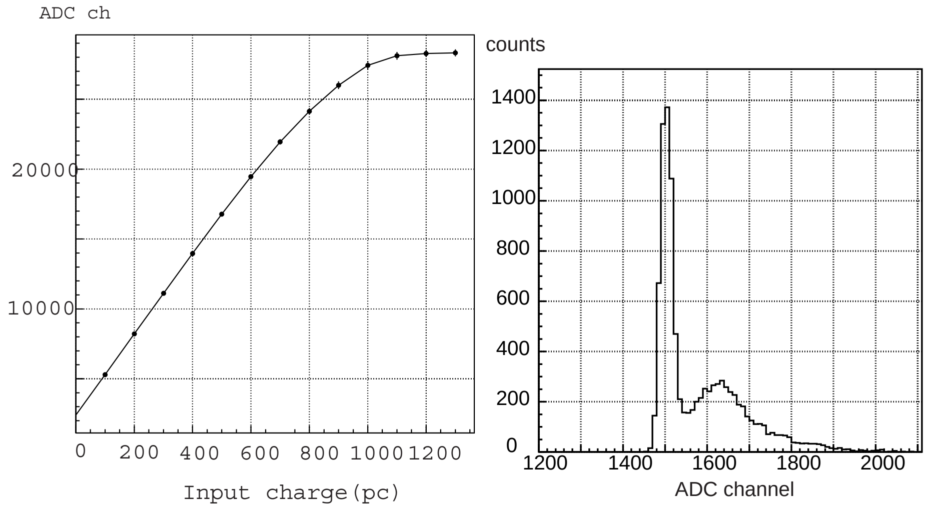

Fig. 3. Performance of the charge ADC and DSM. (left) the linearity (ADC). (right) single photoelectron spectrum (DSM + ADC).

R3497UV, 3/4″ in diameter) [3], with the field of view of the camera covering about 4 degrees. The signal from each PMT is fed to a DSM, as shown in Fig. 2. In the DSM the signal is fed to the VME9U-bus (CERN V430 type) 32ch-15bit-charge sensitive ADC (Hoshin 2678). The ADCs of the second telescope are improved from those of the first telescope; the simultaneous readout of 2 channels speeds up the VME-bus readout, and the number of ADC chips (BB ADS7815) is increased from 2 to 32 to convert signals in parallel, and a good linearity (ADC) is obtained up to ∼300 p.e., as shown in Fig. 3. The updating discriminator in the DSM is fed to the VME-bus 128ch TDC (CAEN V673) which has a 1 nsec resolution, and both the leading and trailing edges are recorded. The non-updating discriminator is fed to a pattern trigger module, but can be switched off via VME-bus for rejecting triggers from noisy PMTs [4]. Outputs of LSUM, ASUM, and scalers are as same as those of the first telescope.

Both weather and cloud monitors are connected to a PC (PC1 in Fig. 1.) with RS232C lines, and read once per a minute. In the first telescope the Solaris operating system was adopted, but in second one linux is used because the context switching time of linux is 2 μs while that of Solaris is at most 20 μs. PC1 also collects the scalers in the DSMs via a PCI-VME bridge every 10 seconds, and the realtime position of the telescope via a 100-Base network from a PC (PC2 in Fig. 1.) which controls the telescope. In addition, PC1 controls the VME-bus high-voltage controller.

3.2. Software

The DAQ system of the second telescope uses UNIDAQ, like that of the first telescope. Since VME-TDC and VME CPU board (Pentium III 850MHz; Linux OS kernel2.2) are adopted to collect ADCs ,TDCs, GPS, and scalers data via the VME-bus, the DAQ readout time of the second telescope is improved to be between 600 μs and 1 ms during the access to all VME-ADCs and VME-TDCs , while that of the first one is 1.2 ms during access to all VME-ADCs and $\sim$10 ms during access to all CAMAC-TDCs, respectively. Therefore the DAQ system of the second telescope can accept triggers at rates as high as 500 Hz with a dead time of 20%, while that of the first telescope can only accept triggers at a maximum rate of 80 Hz.

4. Stereoscopic observations

The CANGAROO-III project is a stereoscopic observation using an array of four 10 m imaging atmospheric Cherenkov telescopes. Stereoscopic observations with the two telescope will start at the end of 2002. In stereoscopic observations, the coincidence of DAQ triggers from two telescopes is not required, and the DAQ of each telescope records the data from that telescope, with these being reconstructed offline. For reconstructing, the DAQ of the second telescope records the GPS time of the trigger, the event number sent from the first telescope, and the time difference of the DAQ trigger between the two telescopes.

5. Conclusion

The DAQ for the CANGAROO-III telescopes has been developed. The system of the second telescope is improved from that of the first telescope, and can handle trigger rates as high as 500 Hz. For stereoscopic observations, the DAQ system of the first and second telescopes record events independently, and these events are later reconstructed offline.

References

[1] Ohishi, M. et al. 2002, in these proceedings

[2] Nomachi, M. et al. 1994, in Proc. *Int. Conf. on Computing in High Energy Physics '94, LBL-35822, p.114*

[3] Kabuki, S. et al. 2002, in these proceedings

[4] Nishijima, K. et al. 2002, in these proceedings