Development of the Trigger Module for CANGAROO-III

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In order to lower the energy threshold for very high energy gamma-ray observations with the CANGAROO-III imaging air Cherenkov telescope to around 100 GeV, we undertook Monte Carlo simulation studies to find the optimum trigger conditions, and manufactured the trigger module for our new camera using complementary programmable logic devices (CPLD).The results of the simulation studies and the characteristics of newly developed trigger module are presented.

1 Introduction

One of the important factors preventing the reduction of the energy threshold is the chance coincidence rate due to the night sky background light. Our DAQ system requires the maximum trigger rate to be less than 1 kHz. Therefore, first of all, we select the trigger conditions which satisfy this requirement, then we investigate the trigger efficiency of gamma-ray events.

2 Monte Carlo Simulation

Event generation and analysis has been done using *FULL*, which is our simulation and analysis tool based on GEANT. Power law energy spectra with indices of –2.0, –2,2, –2.5, and –3.0 are assumed for gamma-rays in the energy range between 100 GeV and 500 GeV. Considering the parameters for the CANGAROO-III telescope summarized in table 1, the night sky background (NSB) is estimated to be about 170 photoelectrons/event. We assume three cases (170, 250, and 350 p.e./event) for the NSB.

Diameter of each spherical mirror facets	0.8 m
The number of spherical mirrors	114
Reflectivity of each mirror	70 %
Collection efficiency of the light guide	70 %
Quantum efficiency of PMTs	20 %
Field of view of imaging camera	3.9 deg.
Gate width	10 nsec

Table 1

We investigate two types of trigger patterns. One is the *Tna* trigger where adjacent *n* PMTs have signals over threshold. Examples for *T3a* are shown in Fig.1(a)-(c). The other is the simple *any n* trigger where any *n* PMTs have signals over threshold (Fig.1(d),(e)). The threshold for each PMT is set by the number of photoelectrons, which was varied between 1.0 and 6.0.

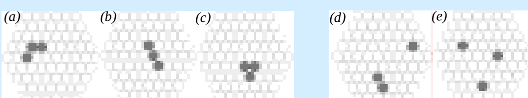

Fig. 1

3 Results of the Trigger Simulation

We first investigate the trigger rate and select trigger conditions which give a trigger rate less than 1 kHz as required by our DAQ system. The trigger conditions satisfying this are listed in table 2.

NSB (p.e./event)	Threshold (p.e.)	*Tna*	*any n*
170	3	*T5a=<*	-
	4	*T3a=<*	*any 6 =<*
	5	*T2a=<*	*any 3 =<*
250	3	*T6a =<*	-
	4	*T4a =<*	*any 8 =<*
	5	*T3a =<*	*any 4 =<*
	6	*T2a =<*	*any 3 =<*
350	4	*T4a =<*	-
	5	*T3a =<*	*any 5 =<*
	6	*T2a =<*	*any 3 =<*

Table 2

Then we investigate the energy dependence of trigger efficiency for gamma-rays. Fig.2(a) and (b) show the results for the case of NSB=170p.e./event (standard NSB), threshold = 4p.e., and spectral index = 2.2 for (a) *any n* and (b) *Tna* triggers, respectively. It is clear that the *Tna* trigger is more effective than the *any n* trigger in lowering the energy threshold for the same PMT threshold. Fig.2(c) shows the differential energy spectrum of triggered gamma-rays for the same conditions as above. For a *T3a* trigger, the energy threshold is expected to be less than 100 GeV.

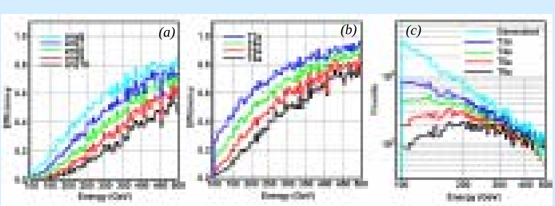

Fig. 2

Fig.3 shows the trigger efficiency of gamma-ray events for the case of *T3a* trigger in three NSB cases. In the case of 350 p.e./event as NSB which corresponds to the expansion of gate width twice as long, the trigger efficiency decreases about 10% compared to the standard NSB case. However it is still enough for our purpose. We found that *T2a* with a 6 p.e. threshold and *T3a* with a 4 p.e. threshold are expected to realize trigger efficiencies of about 20% and 85% for around 100 GeV and 500 GeV, respectively even if twice of standard NSB is assumed.

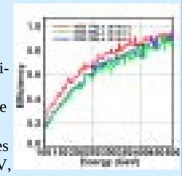

Fig. 3

4 Selection of Trigger Device

Our requirements for the trigger module are that the decision should be made within 60 nsec using signals within a 30 nsec gate width. We chose a CPLD manufactured by ALTERA as the logic device, because we can set any trigger logic by configuring the CPLD. First, we simulate the function and timing for the *T3a* trigger pattern for several CPLD families using the development tool "MAX+plus II". Then we tested some of these using a CPLD mounted on a test board to confirm the reliability of the simulation. As a result, a combination of four EPF10K130EQC240-1 is expected to give the best performance for a decision time less than 30 nsec. Its fluctuation is less than 15 nsec which is sufficient for our requirements.

5 Trigger Module

We manufactured the new trigger module using four CPLDs on a single board. The camera is divided into four areas corresponding to each of the CPLD devices (Fig.4). There are 427 TTL inputs from the front-end modules. Considering the overlap at least for *T3a*, those signals are distributed into four CPLDs. Trigger logic is set through configuration of the ROM. Trigger outputs (NIM signals) are transmitted to the interrupt register and scaler. A schematic block diagram of the trigger module is shown in Fig.5. In Fig. 6, pictures of the trigger module are shown.

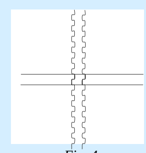

Fig. 4

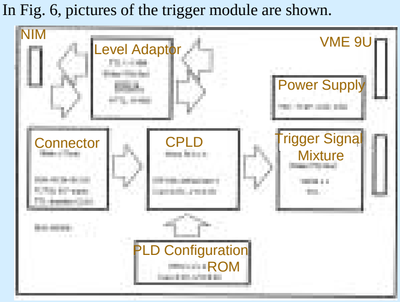

Fig. 5

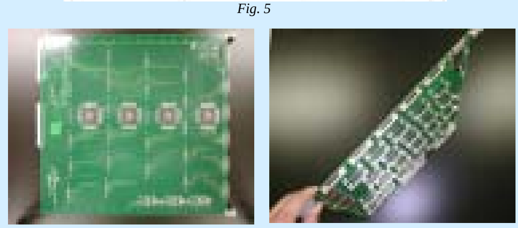

Fig. 6

6 Summary

We developed the new trigger module using CPLDs. The first trigger module is set to *T3a* logic and its function and timing have been tested in the laboratory. The results are consistent with expectations. The final test at the observation site will be done this November.