Performance of the Atmospheric Cherenkov Imaging Camera for the CANGAROO-III Experiment

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Abstract

A Cherenkov imaging camera was developed and installed in the second telescope of the CANGAROO-III project for observing gamma-rays having energies above 10^{11}eV. The camera consists of 427 pixels, arranged in a hexagonal shape at 0.17° intervals, each of which is a 3/4-inch diameter photomultiplier with a Winston-cone–shaped light guide. The camera discussed in this paper offers a wider field of view, a better photon collection efficiency, and a larger dynamic

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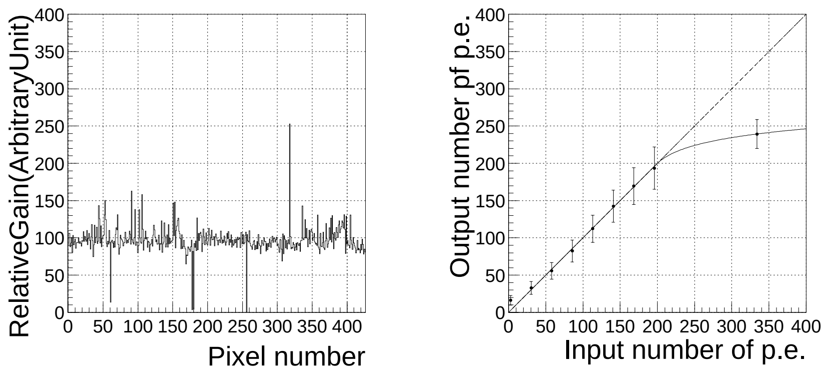

Fig. 1. Left: Hardware gain distribution. We can estimate the absolute number of incident photoelectrons (p.e.) by assuming a Poisson distribution. Right: output p.e. versus input p.e. The linearity is maintained up to about 200 p.e. and the dynamic range after software corrections is about 250 p.e.

range for signal linearity than that of the CANGAROO-II telescope, resulting in a lower energy threshold. The preliminary performance of the camera will be reported.

1. Introduction

The camera is contained in a cylindrical vessel 800 mm in diameter and 1000 mm in length. Inside the camera vessel, 427 PMT modules, regulator circuit panels, and several instruments were contained. The PMT modules are cylindrical, with a diameter of 20.5 mm and length of 173.5 mm. Each module consists of a 19 mm (3/4 inch) PMT (Hamamatsu R3479UV), with bleeder circuits and a pre-amplifier (MAX4107) attached to the base of the PMT. The pixels were arranged in a hexagonal shape in order to maximize the collection efficiency of the Cherenkov light. The pixel size of 0.17 degrees was determined from a simulation study [1], taking into account the spot size of the reflector [2]. The detailed design of this camera is described in Ref. [4].

2. Calibration and performance

The gain of each pixel was calibrated using an LED light source [4] in the following way. We estimated the gain by assuming that the output ADC distribution has a Poissonian distribution. The measured "gain" versus serial number of the pixel is shown in Fig. 1 (left). The mean value of relative the "gain" was ∼100 ADC counts per p.e. with an R.M.S. of ∼10%. After off-line corrections, the deviation among the pixels was at the one percent level. The

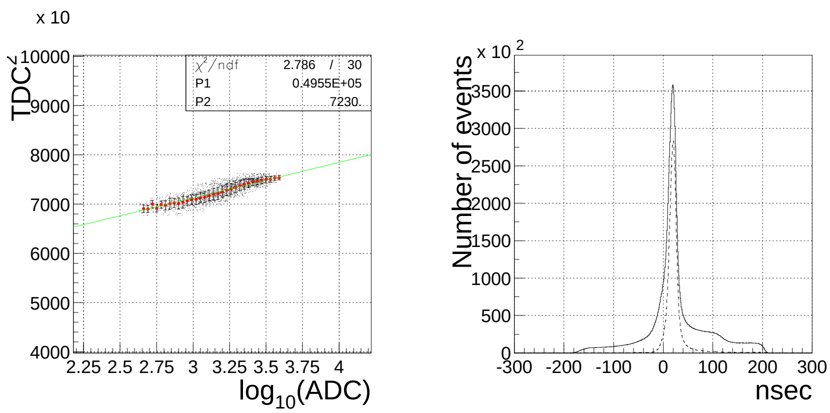

Fig. 2. Left: $(TDC)^2$ versus $\log{(ADC)}$. This distribution was fitted with a line. Right: timing distributions of a pixel in a typical observation. After the time-walk correction, the solid line is for all triggered pixels and the dotted line is after a further off-line selection (dotted line).

PMT and the ADC modules were designed to have a large dynamic range, up to 250-p.e. The relation between the input number of p.e. and the output number of p.e. is shown in Fig. 1 (right). A good linearity was maintained up to about 200-p.e. and the deviation was about 10% at 250-p.e. The reflector of the telescope is parabolic so as to provide the accurate arrival timing of photons [5,6]. The timing resolution of the camera was measured after time-walk correction. We approximated the pulse shape with a Gaussian [4], and analytically solved the relationship between the timing and the signal as shown in Fig. 2 (left). The averaged time resolution of the pixel was obtained to be 0.94 nsec at 30-p.e. After this correction, the arrival timing distribution in a typical observation is shown in Fig. 2 (right). All data (the solid line) and those after a further off-line analysis (the dotted line) are shown, where the pixel threshold was set to 3-p.e. and five adjacent hits (“t5a”) were required in each event. A detailed analysis of this method is described in Ref. [3]. In Fig, 2 (right), the dispersion (1σ) of the distributions is 14 nsec (1σ) and 8 nsec (1σ), respectively (the solid and dotted curves), which were consistent with expectations. The observed event rate during a typical observation is shown in Fig. 3. The solid line shows the hardware trigger rate and the dotted line shows the rate after the off-line selection. Using the rate of randomly triggered events, the Night Sky Background (NSB) level of the CANGAROO-III telescope was estimated to be 100 MHz. In contrast, the NSB of the first telescope (CANGAROO-II) was 16 MHz [6]. Therefore, the light correction efficiency of the second telescope (CANGAROO-III) is several times better than that of the first telescope, even taking into account the increase in the field of view. We roughly estimated the energy threshold as follows. In

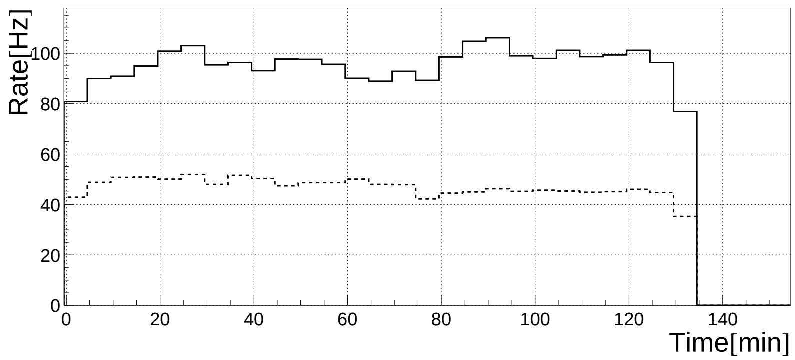

Fig. 3. The solid line shows the hardware trigger rate in an on-source run. The dotted line shows that after software-selection.

CANGAROO-II, the shower rate was about 2.2 Hz, and the energy threshold of a cosmic ray was 800 GeV [6]. In CANGAROO-III, because the shower rate was around 40 Hz the energy threshold of a cosmic ray was estimated to be about 320 GeV. A detailed study of the energy threshold of the CANGAROO-II telescope is described Refs. [3,6].

3. Conclusion

The performance of the Cherenkov imaging camera for the second CANGAROO-III telescope was improved compared with the first (CANGAROO-II) telescope concerning the uniformity of the gain, dynamic range, time resolution, and energy threshold.

4. References

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