

Construction of New 7m Imaging Air Čerenkov Telescope of CANGAROO

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Abstract

CANGAROO group has constructed the new large imaging Air Čerenkov telescope to exploit hundred GeV region gamma-ray astronomy in March 1999 at Woomera, South Australia. It has a 7m parabolic mirror consisting of 60 small plastic spherical mirrors, and a fine imaging camera with 512 PMTs covering the field of view of 3 degree. Observation will start from July 1999.

1 Introduction:

In this decade Very High Energy(VHE) gamma-ray astronomy has been dramatically advanced due to the appearance of an imaging Air Čerenkov Telescope, and about ten TeV gamma-ray emitters have been found so far. Nowadays VHE gamma-ray astronomy is just proceeding to the next stage in exploiting hundred GeV or sub-hundred GeV region. For example Whipple group promotes the construction of the array of eight 10m imaging telescopes. German groups also propose two main projects: HESS consisting of 16 X 10m imaging telescope and MAGIC of one big 17m imaging telescope looking for several ten GeV gamma rays. In this manner, new stage of VHE astronomy will certainly begin at the opening of 21st century.

CANGAROO group has also pushed ahead the next project consisting of four 10m imaging telescopes. In 1995 the construction of one imaging telescope was approved (CANGAROO II project). Due to the limit of the approved fund, we decided to construct the telescope with a 7m mirror, of which frame and base however can sustain a large mirror of a 10m diameter. Therefore, in near future, this telescope will be easily extended to the 10m mirror by adding more mirrors.

In December 1998, all components of the telescope and the gamma camera were prepared in Japan and shipped to Australia. In the middle of March 1999, the telescope construction was completed at Woomera as shown in Fig.1. After then the short observation for studying the performances of the telescope was done. Here we present the overview of this new telescope and the brief report of its performance as an imaging Čerenkov telescope.

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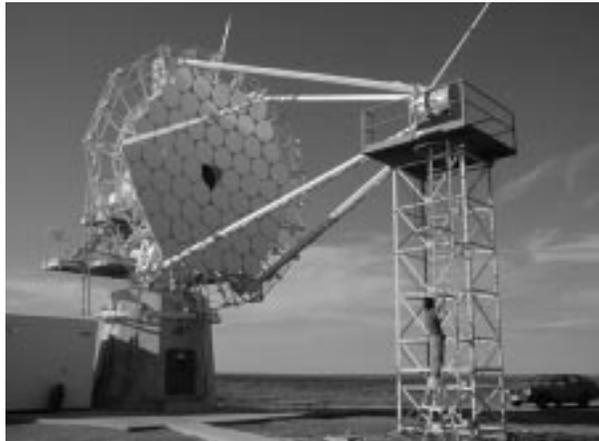


Figure 1: Photo image of new CANGAROO 7m telescope at Woomera

2 Performance of Mirror:

The design concept and features of the 7m telescope were already presented in Tanimori et al. 1995 and Matsubara et al. 1997. We adopted a 7m parabolic mirror with a 8m focal length, which consists of sixty spherical-composite mirrors with a 80cm diameter (total light-collection area of 30.1 m²), in order to keep the duration of the arrival times of Čerenkov photons within a few ns. For the extension to a 10m mirror, an additional fifty-four mirrors will be attached on the outer frame around the present mirrors. One of challenges in this telescope was to use plastic as a material of the composite mirror. The mirror consists of mainly Carbon Fiber Reinforced Plastic(CFRP) sheets and thin aluminum foils. By our long endeavor, the accuracy of the mirror surface was achieved within about 20 μ m, which corresponds to the blur of 0 $^\circ$.08(FWHM) for a parallel beam. The weight of this mirror is only one fifth of that made by glass. The reflectivity of this mirror can be kept \sim 80% in several years by washing its surface by water. The blur of the 7m parabolic mirror consisting of 60 small plastic mirrors was measured using star images taken by the CCD camera, and obtained to be \sim 0 $^\circ$.15(FWHM). This resolution is within an allowable range, but not satisfactory, considering the fine resolution of the imaging camera. The blurs of about 10 mirrors were found to be much worse than others. It will be improved by replacing those bad mirrors in next year. The details about the performances of the 7m mirror and the composite mirror are presented in Kawachi et al. 1999.

Also using star images, the tracking accuracy and the deformation of the 7m mirror due to the camera weight were estimated by changing the azimuthal and zenith angles. The results obtained were 0 $^\circ$.006 and 0 $^\circ$.007 respectively, which are much smaller than a blur of the mirror.

3 Performance of Camera & Electronics:

Figure 2 shows the front view of the camera attached in the focal plane, where that of 3.8m telescope is also presented. This camera consists of 512 pixels to covers a field of view (FOV) of diameter \sim 3 $^\circ$, Each pixel covers 0 $^\circ$.115 \times 0 $^\circ$.115 (16mm \times 16mm), and 13 mm ϕ photomultiplier (PMT: Hamamatsu R4124UV) was used as a pixel detector. The photocathode of this PMT has an area of 10 mm ϕ and cover about 35% of the FOV. The Array of hollow light collectors were attached in front of the PMTs in order to increase the collection area of the camera by twice. Sixteen PMTs are housed in one module unit with a common bleeder circuit. PMTs are operated with a low gain of \sim 10⁵ to avoid the long-gain drop (more than a few ten minutes) due to the passage of bright stars.

Buffer amplifiers (LeCroy TRA402) are also installed in the module box to sustain the total gain

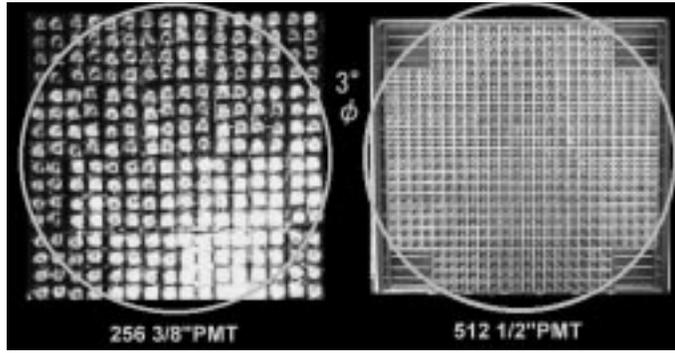


Figure 2: Front view of both the cameras of the 3.8 telescope (left) and the new 7m telescope (right).

of $\sim 10^7$ (after amplification) and to feed signals through long twisted cables(36 m). The whole camera consists of 32 module units.

Signals were fed to electronics circuits in the hut located by the base of the telescope. Here all timings and pulse heights of hit PMTs are measured, where a hit PMT means that its pulse become larger than the preset value (usually three or four photoelectrons). The detail is described in Mori et al. 1999. Triggers are generated when both the number of a hit PMT (H-sum) and the linear sum of all PMT signals (L-sum) exceed the preset values. Inner-most 16 of 32 modules are concerned with the trigger, which covers a $\sim 1^\circ.8$ diameter of the FOV. The observation for studying the camera and electronics was done during few days in March. When requiring the H-sum $\geq \sim 4$ and L-sum $\geq \sim 1.2\times$ of the linear sum of the night sky background fluctuation, triggers were generated at ~ 11 Hz.

In this condition, the timing distribution of hit PMTs accumulated for all events are shown in Fig.3, where no correction for the time jitter was not applied. Timings of hit PMTs almost concentrates within 50ns (1bin = 0.5 ns), which indicates that more than 90% of events are triggered not by an accidental coincidence due to the night sky background but by a muon or a shower.

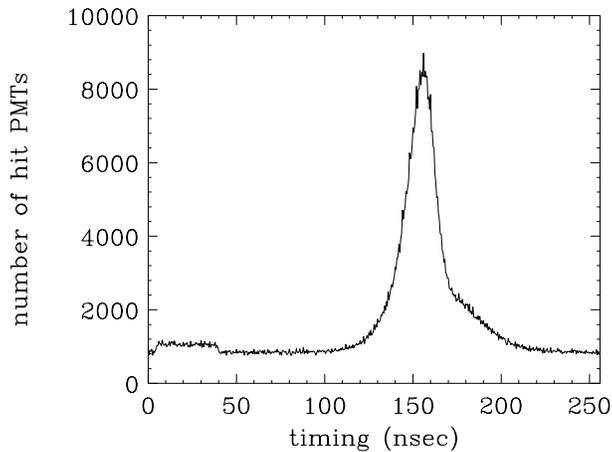


Figure 3: Plot of arrival timings of all of hit PMTs

Figure 4 shows the distribution of the L-sum for those events. Note that most events including in this figure are not accidental but physical events. The higher part of the distribution ($\sim 45\%$)

clearly corresponds to those triggered by showers (power law). Note that the slope becomes flatter as energy decreasing. This might be due to the decrease of the detection efficiency at the trigger level for hadrons below ~ 1 TeV, which was expected for the large telescope having a fine imaging pixels from the simulation study (Aharonian et al. 1994; Tanimori et al. 1994). On the other hand, the dominant peak near 400 counts is considered due to single muons from the narrow-timing concentration and the hit pattern on the camera. In 3.8m telescope, muon events were rarely detected since its detectable energy was relatively high (~ 1.5 TeV). We are now estimating the threshold energy by comparing the simulation for hadrons and muons.

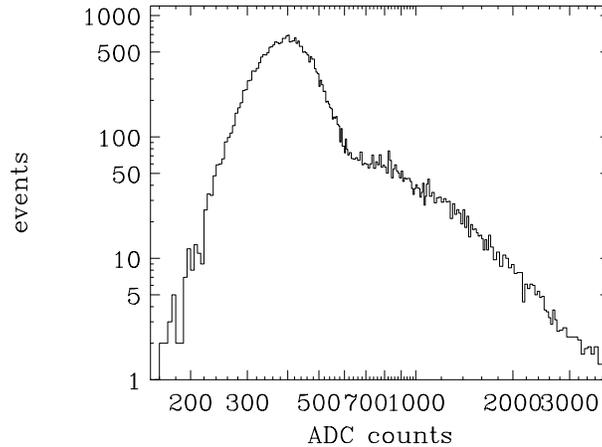


Figure 4: Distribution of the linear sum of all PMTs for triggered events

4 Summary:

The construction of New CANGAROO 7m telescope has been completed in March, and the telescope has detected many shower and muon events. Now the detailed study of the trigger condition is ongoing. In May and June, the tuning of electronics and trigger condition is being carried out. In particular the each L-sum of a module unit including will be individually discriminated from the L-sum due to the night sky background in one module unit, by which the threshold energy will be expected to be decreased. Then we will start the normal observation from July. Also the fast pattern trigger using the hit pattern of 32 module units will be applied late of this year.

Finally we are now about to start the construction of another three 10m imaging telescopes (CANGAROO III project), which has been approved by Japanese government in April 1999. CANGAROO III includes the extension of the 7m telescope to 10m. The array of four 10m imaging telescopes for the stereo observation will be completed by 2003 at Woomera.

References

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