RECENT STATUS OF CANGAROO-III PROJECT

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In 2000 CANGAROO-II 7m telescope has been improved to a 10m telescope, and the CANGAROO-III project has been begun. The CANGAROO-III is a project to study celestial gamma rays above 0.1 TeV with an array of four 10m Imaging Air Čerenkov Telescopes (IACTs) in the southern hemisphere. Here we report on the status of CANGAROO-III project including the observations using the first telescope

1 Introduction

The CANGAROO-III is a project to study celestial gamma rays in the sub TeV region utilizing a stereoscopic observation of Čerenkov light with an array of four 10m IACTs [1], following the CANGAROO-I 3.8 m telescope[2] and the CANGAROO-II 7 m telescope constructed in March 1999 [3,4] in Woomera, South Australia (136°47′E, 31°06′S, 160m a.s.l.). It has officially started since April 1999 and is planned as a five-year program. In February 2000 the 7 m telescope has been expanded to a 10 m telescope by doubling the number of small mirrors as shown in Fig. 1, which is the first telescope of the CANGAROO-III array. Subsequently we are making the second telescope system in Japan, which will be installed in 2001. Other two telescopes will be installed successively in the fourth and fifth years. Figure 1 shows the arrangement of the four telescopes set on a corner of a diamond of about 100 m side. The simulated performances of the angular resolution and effective area (sensitivity) at this arrangement are less than 0.1 degree and the good sensitivity of $\sim 10^{-13} cm^{-2} s^{-1}$ around 1 TeV. These results are consistent with other studies for the next generation IACTs. The first stereoscopic observation will be done in early 2002.

The most mark point of this telescope is the first use of plastic mirrors for an IACT so far. The details of this plastic mirror and the total structure of the 7 m telescope are described

	10m telescope
Focal length	8m Prabola
80cm CFRP mirrors	114 (57m²)
Number of PMTs	552 (1/2") FOV ~ 3° (4°)
Electronics	TDC & ADC
Point image size	0.20° (FWHM) (< 0.15°)

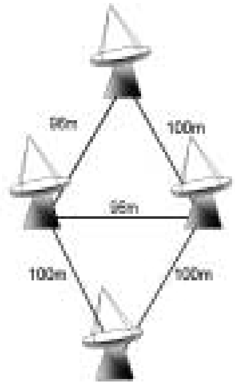


Figure 1: The 10 m telescope completed in February 2000 and the arrangement of CANGAROO-III four telescopes.

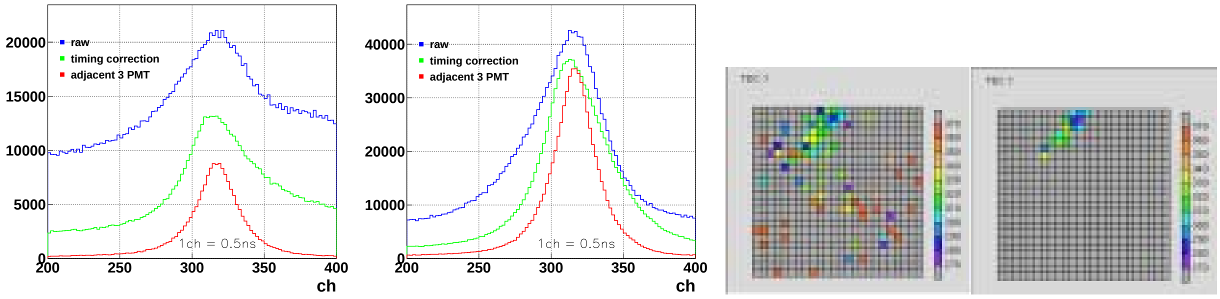


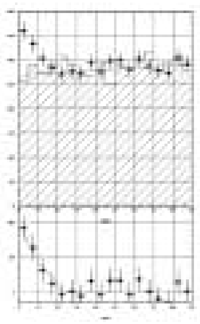
Figure 2: On (1st from the left) and Off (2nd) Timing distributions of all hit PMTs in cases of raw data (top line), after corrections of time walk and the timing center of each event (middle), and after requirement of at least 3 adjacent hit PMTs(bottom). Also images on the camera before (3rd) and after the noise reduction (4th) are presented.

elsewhere [5]. Although the ability of focusing is a little worse than that of a glass mirror, it has many advantages such as light weight, hardness, and durability. The image of a star was measured with a CCD camera and its size (FWHM) is 0.20°. This is a little larger than the pixel size and also the design value which is a little smaller than the pixel.

The camera consists of 552 PMTs of half-inch diameter and subtends about 3 degrees in octagon shape. On each PMT a light guide made of plastic coated by aluminum is attached to collect photons focused on the focal plane more efficiently. The inner part within 2 degrees are used for the trigger decision to optimize the figure of merit of the detection efficiency of gamma-ray showers. Signals from the PMTs are fed into analog-buffer amplifiers. One output goes to the existing front-end module (discriminator and scaler) and the other goes to newly developed VME-based ADCs (150 ns internal delay, 50 ns gate width). The discriminated signals are sent to TDCs to measure timing with 1ns resolution, which enable us to reject almost all the accidental photons due to the night sky background despite of the wide ADC gate; actually ~20 ns gate is achieved at the off-line analysis.

2 Observation and Analysis

Observations have been carried out using both the 7m and the 10 m reflector in 1999 and 2000. Target objects were primarily selected from our list of TeV gamma-ray sources: SN1006, PSR1706-44, RXJ1713.7-3946, Crab and Vela in order to reconfirm our previous detections with the 3.8m telescope. Also nearby X-ray selected BL Lacs (some type of blazars): PKS2005-489, PKS2155-304, and PKS0548-322 were observed along with multi wavelength campaigns.



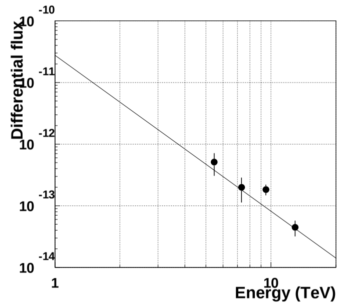


Figure 3: Preliminary alpha plots of the Crab (on source: dotted and off: hatched), and differential flux of the Crab with the average flux of the world data, which were obtained by 7m CANGAROO-II telescope in 1999.

Since many sources observed by CANGAROO are located in the galactic plane, brighter region in the sky, on-source observations ordinarily suffer from the night sky background. Figure 2 shows the timing distributions of all hit photomultipliers for on-source and off-source observations respectively. The peaks in both figures correspond to the real shower events and flat distributions below the peaks are due to the accidental hit by the night sky background. By correcting the time walk of each timing and adjusting the center of the timing distribution of every event, the timing distribution of the peaks are reduced to $\sim$ 14ns at FWHM, which is well consistent with the simulated timing spread of Čerenkov photons from hadron showers. In order to remove the accidental events, the following clustering are required: at least three adjacent PMTs are hit in the event. After this requirement, almost all accidental hits are clearly removed, because the ratios of the peak to the residual flat distribution for the on-source and off-source are quite similar. Also Fig.2 shows the rejection of the night sky background and the appearance of the shower in the event image. Thus the timing of PMTs is very useful for the background rejection. Then the ordinary image parameter cut are applied for the data.

Preliminary results of the Crab in 1999 are shown in Fig.3. The spectrum of the Crab obtained from the alpha peak is well consistent with the previous data of the CANGAROO-I and also other data above 4 TeV. Preliminary differential flux of PSR1706 and the reconfirmation of TeV gamma-ray emission form supernova remnant RXJ1713 are described elsewhere[6,7]. Those preliminary data compared with a Monte Carlo simulation suggests the threshold energy of the 7m telescope is 600$\sim$700 GeV depending on their power indices.

3 Work in Progress for Subsequent Telescopes

Mirrors

The refinement of the focusing of plastic mirrors is intensively underway. Figure 4 shows the comparison of the focusing power between the mirror used for the first 10m telescope and that being developed for the second telescope. We expect the image size of the 2nd telescope will be improved about two thirds of that of the first telescope. This improvement will reduce the energy threshold for gamma rays from $\sim$300 GeV to $\sim$150 GeV. In addition, some important improvements are being carried out as follows.

Camera

The new design of a camera will be in hexagonal shape so that the dead space between PMTs is minimal. The field-of-view will be enlarged to 4.3° with 427 3/4" PMTs (Hamamatsu R3478) to optimize the efficiency of stereo observation. Light guides to increase the light collection are redesigned to match the new PMT arrangement. Signals from PMTs are amplified (gain of $\sim$20) at the camera and sent to the electronics via twisted-pair cables. High voltages are supplied

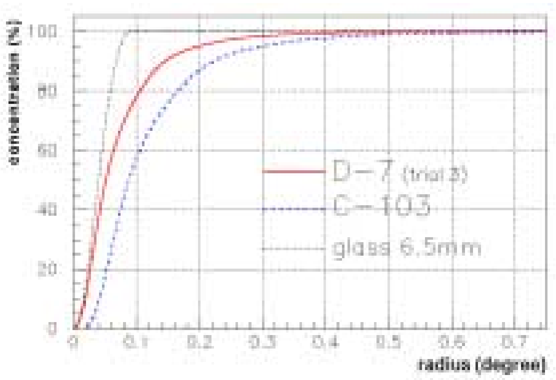


Figure 4: Concentration ratios of light on the focus as a function of radius for glass mirror(dotted), plastic mirror that is being developed (solid) and plastic mirror used in the 1st telescope (broken).

to PMTs individually from the ground electronics so that the gain of each PMT can be tuned remotely. Positive high voltages are supplied to PMTs to solve the discharging problem.

Electronics

The new electronics system will be all VME-based. The front-end circuit (under development, 16 ch/VME-9U) amplifies the signal and feeds to an ADC (the improved type of those used in the CANGAROO-II with faster conversion), discriminates it and feeds to a TDC, an internal scaler and a trigger circuit.

In order to decrease the energy threshold, huge number of accidental coincidence of hit PMTs in the camera has to be excluded at the trigger level. The pattern trigger is considered as a fairly effective method, and recently has been adopted for several IACTs. The pattern trigger circuit using Programmable Logic Device are under development, which will be expected to decide the trigger within 100ns. Increased data size requires faster data acquisition. Now we are testing several possibilities including VME-based Pentium CPU board running a Linux operating system, which shows faster task switching, reducing dead time of data acquisition.

Those developments will be adopted for the second telescope.

4 Summary

The second 10m telescope is constructed in 2001, and the stereo observation will be begun from 2002. The third and fourth 10m telescope will be constructed in 2002 –2003. Final goal of the ability of the CANGAROO-III four 10m telescope array is followings: the energy threshold of $\sim$ 100 GeV, the sensitivity of $\sim 5 \times 10^{-13} cm^{-2} s^{-1}$ at 500 GeV, and the angular resolution of $\leq$ 0.1 degree.

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