Recent results from CANGAROO-II&III

Masaki Mori* and the CANGAROO-III team†

*Institute for Cosmic Ray Research, The University of Tokyo,
5-1-5 Kashiwanoha, Kashiwa, Chiba 277-8582, Japan
†http://icrhp9.icrr.u-tokyo.ac.jp

Abstract. Recent results from CANGAROO-II, the first 10m atmospheric Cherenkov telescope, and status of CANGAROO-III, the array of four 10m telescopes, are presented. The former one has been operating since 2000 and the latter one was completed in March 2004.

INTRODUCTION

CANGAROO is an acronym for the Collaboration of Australia and Nippon (Japan) for a GAmma Ray Observatory in the Outback. After successful operation of the 3.8m imaging Cherenkov telescope (CANGAROO-I) for 7 years, which was the first of this kind in the southern hemisphere, we constructed a new telescope of 7m diameter (CANGAROO-II) in 1999 [1] next to the 3.8m telescope near Woomera, South Australia (136°47′E, 31°06′E, 160m a.s.l.). Then the construction of an array of four 10m telescope (CANGAROO-III) was approved and as the first step the 7m telescope was upgraded to 10m diameter in 2000, which is the first telescope of the CANGAROO-III array [2, 3, 4, 5, 6]. In the following years, we have constructed an additional three 10m telescopes located at the corners of a diamond of 100m side with improved mirrors, cameras and electronics. After tuning, we have started observation with the full system in stereo mode in March 2004 (Fig.1).

CANGAROO-III

Basic specification

The major parameters of the CANGAROO-III telescopes are summarized in Table 1. The detailed design of reflectors [7, 8], cameras [9, 10, 11], electronics [12, 13], and telescope control system [14] are described elsewhere.

Star tracking accuracy

Telescopes are driven by commands specifying elevation and azimuth angles sent to telescope controllers every 100 ms. Those values are computed from the celestial

FIGURE 1. The CANGAROO-III telescopes as of March 2004. The telescope seen at right is the CANGAROO-II.

position of a target object by a control PC synchronized to a master PC equipped with a GPS receiver via `ntp` protocol.

Tracking accuracy of telescopes are monitored using CCD cameras mounted at the center of reflectors and faced to cameras. We can observe stars through the telescope focal ring when cameras are not installed and around the ring when cameras are installed with a wide camera lens. The root-mean-square deviation of displacement between observed and commanded positions is less than one arcminute, which is small enough compared with the size of a camera pixel (0.115° [T1] or 0.168° [T2, T3, T4]).

Optical quality

Each spherical mirror, made of laminates of fiber-reinforced-plastic and aluminium sheet [7], can be adjusted their direction by two stepping motors. Mirrors of the first telescope were tuned using a distant light source [7]. For later (T2, T3, T4) telescopes

TABLE 1. Parameters of the CANGAROO-III telescopes.

	T1	T2, T3, T4
Mount	Alt-azimuth	
Focal length	8m	
Number of mirrors (area)	114 ($57m^2$ in total)	
Reflector type	Parabola	
Number of PMTs	552 (1/2")	427 (3/4")
Camera pixel size	0.115°	0.168 °
Readout	TDC(CAMAC) & ADC	TDC(VME) & ADC
Point image size (FWHM)	0.20°	0.14 $\sim$ 0.21°
Completion	2000.3	2002.3 (T2), 2002.11 (T3), 2003.7 (T4)

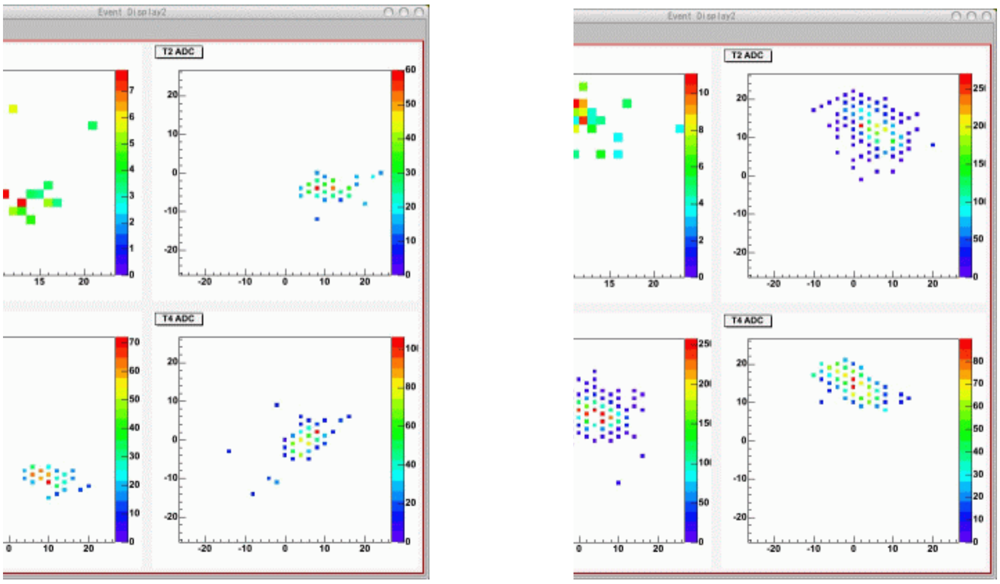

FIGURE 2. Examples of four-fold coincident events.

we tuned mirrors to a common focus while stars under tracking [8]. Focal images are captured by a CCD camera mounted at the center of the reflector before and after movements of motors and we can identify the displacement of each mirror by subtracting those images. By repeating this procedure on each mirror, we could tune all mirrors in a few nights per telescope. The point spread functions measured at the construction time are 0.20°, 0.21°, 0.14°, and 0.16° (FWHM). They are not as good as those of glass-made mirrors, but are comparable with the size of camera pixels.

Stereo observation

Figure 2 shows examples of four-fold coincident events. Note that the T1 camera has different configuaration from others.

Data analysis in stereo mode follows basically the method that has been reported by the HEGRA group and others: cross points of major axes of ellipse-like Cherenkov images point to the direction of incoming primary particles. In our case, the stereo event rate is limited by the first telescope which has a higher energy threshold, and we are trying to study stereo events with newer telescopes taken after March 2004 which corresponds to more than 200 hours of data (till July 2004) . We are doing our best to present these results soon.

Muon rings

We selected 'good muon' events to study the performance of our telescopes in the following criteria: 1) there is a cluster with enough number of adjacent hits in the image;

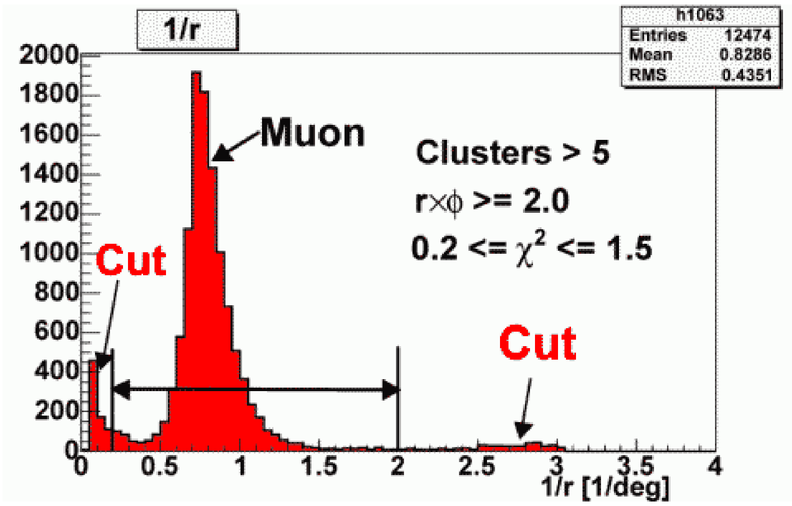

FIGURE 3. An example of curvature distribution of events selected as muon candidates. (T4)

2) *arclength*, or ring radius times arc angle, is larger than 2 deg·rad; 3) the ring fit is fairly good (small χ^2). An example of curvature distribution is shown in Fig.3. There is a clear peak around $1/1.2^\circ$, which corresponds to local muons. We are studying these muon events further and will report on the performance of our telescopes.

RECENT RESULTS FROM CANGAROO-II

The Galactic center

We observed the Galactic Center in 2001 and 2002 with the 10m telescope. The total observation time after selection of data under good weather condition was 66 hours (on source) and 57 hours (off-source), respectively. The image analysis showed a statistically significant excess at energies greater than 250 GeV, which is roughly one-tenth of the gamma-ray flux from the Crab nebula. Details of the results are described elsewhere [15, 16].

Recently, the Whipple group [17] and the H.E.S.S. group [18] reported detection of gamma-ray signal from the Galactic Center. However, these results do not seem to be consistent with each other and consistency of analysis should be checked further.

Pulsar binary PSR1259-63/SS2883

This is a nearby binary consists of a 48 ms radio pulsar in a highly eccentric orbit around a Be star and offers a unique laboratory to investigae interactions between outflows of the pulsar and the Be star at various distances. The orbital period is 1236.72 days and there are some theories which predict time-variable, enhanced gamma-ray emission near the periastron. Our observation with the 10m telescope in 2000 and 2001,

~ 47 and ~ 157 days after the October 2000 periastron, did not show a gamma-ray signal and upper limits at the $0.13 - 0.15$ Crab level were obtained. Details of the results are described elsewhere [19, 20].

Recently, the H.E.S.S. group reported detection of gamma-ray signal from this binary in the March 2004 periastron [21]. Comparison with their data with our model calculation is on-going.

SUMMARY

We have started observations of celestial gamma-rays in four-telescope stereo mode in South Australia since March 2004. Data analysis in stereo mode is on-going and will be reported soon.

In this conference new results from the H.E.S.S. group were presented [22]. Some of the results we have published using the CANGAROO-I telescope and some of the preliminary results using the CANGAROO-II telescope were not confirmed by their initial results and their upper limits are inconsistent with our reported fluxes. However, their detections of the supernova remnant, RX J1713.7-3946, and the Galactic Center are encouraging, although their reported power-law indices of energy spectra differ from ours significantly. We have a fairly large amount of observational data and are concentrating upon accumulating data in stereo mode on the sources which H.E.S.S. has not confirmed, and we would like to speed up our analysis to resolve the issues. Also we will observe the Crab nebula as the established standard source at top priority in the coming season in order to verify our analysis procedure.

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