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Performance of the Imaging Atmospheric Cherenkov Telescope System of CANGAROO-III

T. Yoshikoshi[a], Y. Adachi[a], A. Asahara[b], G.V. Bicknell[c], R.W. Clay[d], Y. Doi[e], P.G. Edwards[f], R. Enomoto[a], S. Gunji[e], S. Hara[a], T. Hara[g], T. Hattori[h], Sei. Hayashi[i], Y. Higashi[b], R. Inoue[h], C. Itoh[j], S. Kabuki[b], F. Kajino[i], H. Katagiri[b], A. Kawachi[h], S. Kawasaki[a], T. Kifune[k], R. Kiuchi[a], K. Konno[e], L.T. Ksenofontov[a], H. Kubo[b], J. Kushida[h], Y. Matsubara[l], Y. Mizumoto[m], M. Mori[a], H. Muraishi[n], Y. Muraki[l], T. Naito[g], T. Nakamori[b], D. Nishida[b], K. Nishijima[h], M. Ohishi[a], J.R. Patterson[d], R.J. Protheroe[d], Y. Sakamoto[h], M. Sato[e], S. Suzuki[o], T. Suzuki[o], D.L. Swaby[d], T. Tanimori[b], T. Tanimura[b], G.J. Thornton[d], K. Tsuchiya[a], S. Watanabe[b], T. Yamaoka[i], M. Yamazaki[i], S. Yanagita[o], T. Yoshida[o], M. Yuasa[a], Y. Yukawa[a]

(a) Institute for Cosmic Ray Research, University of Tokyo, Kashiwa, Chiba 277-8582, Japan
(b) Department of Physics, Graduate School of Science, Kyoto University, Sakyo-ku, Kyoto 606-8502, Japan
(c) Research School of Astronomy and Astrophysics, Australian National University, ACT 2611, Australia
(d) Department of Physics and Mathematical Physics, University of Adelaide, SA 5005, Australia
(e) Department of Physics, Yamagata University, Yamagata, Yamagata 990-8560, Japan
(f) Institute of Space and Astronautical Science, Sagamihara, Kanagawa 229-8510, Japan
(g) Faculty of Management Information, Yamanashi Gakuin University, Kofu, Yamanashi 400-8575, Japan
(h) Department of Physics, Tokai University, Hiratsuka, Kanagawa 259-1292, Japan
(i) Department of Physics, Konan University, Kobe, Hyogo 658-8501, Japan
(j) Ibaraki Prefectural University of Health Sciences, Ami, Ibaraki 300-0394, Japan
(k) Faculty of Engineering, Shinshu University, Nagano, Nagano 480-8553, Japan
(l) Solar-Terrestrial Environment Laboratory, Nagoya University, Nagoya, Aichi 464-8602, Japan
(m) National Astronomical Observatory of Japan, Mitaka, Tokyo 181-8588, Japan
(n) School of Allied Health Sciences, Kitasato University, Sagamihara, Kanagawa 228-8555, Japan
(o) Faculty of Science, Ibaraki University, Mito, Ibaraki 310-8512, Japan
Presenter: T. Yoshikoshi (tyoshiko@icrr.u-tokyo.ac.jp), jap-yoshikoshi-T-abs1-og27-poster

The imaging atmospheric Cherenkov telescope system of CANGAROO-III has been in full operation with four 10 meter diameter telescopes since March 2004 near Woomera, South Australia. The system is used to study gamma-ray astrophysics at sub-TeV energies in the southern hemisphere. The performance of the stereoscopic system such as gamma-ray energy resolution, effective detection area for gamma rays and accuracy of reconstructed shower parameters, has been investigated using Monte Carlo simulations, which are based on various calibration results, e.g., calibration of light collection efficiency using muon ring images. We present the estimated performance of the CANGAROO-III system as well as the reliability of our simulation code, comparing simulation results with observed data.

1. Introduction

The atmospheric Cherenkov technique has dramatically improved the signal-to-noise ratio in detecting Very High Energy (VHE, $\sim$ TeV) gamma rays by utilizing the imaging technique, which was first demonstrated by the Whipple 10 meter telescope in 1989 detecting gamma rays from the Crab Nebula at the 9 σ level [1]. Sensitivity to VHE gamma rays has further been improved by the HEGRA group by adding the technique of stereoscopic observations [2], in which two major backgrounds, local muon events and hadronic shower events, are greatly reduced owing to their locality (muons) and poor reconstruction accuracy due to more irregular shower patterns (hadronic showers). Another important advantage of the stereoscopic system compared to a single Imaging Atmospheric Cherenkov Telescope (IACT) is its ability to reconstruct air shower parameters such as the arrival direction and the core location more accurately. As a result, we can expect to have better angular and energy resolutions using stereoscopic observations.

The history of the CANGAROO experiments is similar to the development mentioned briefly above, but they have played a pioneering role in the southern hemisphere. The stereoscopic IACT system of CANGAROO-III was completed in March 2004 and has been in operation since then. Study of the total performance of the system is still underway and some preliminary results will be shown in this poster presentation.

2. CANGAROO-III Stereoscopic IACT System

The CANGAROO-III stereoscopic IACT system is located near Woomera, South Australia. It consists of four 10 meter diameter IACTs, which are placed at the corners of a diamond shape with a 100 meter span. The data acquisition system is triggered if any two telescopes are fired within 650 ns and raw trigger rates in this condition are about 20 Hz. The details of the optical system, the imaging cameras and the data acquisition system are described elsewhere [3, 4, 5].

3. Simulations

Our Monte Carlo simulation code consists of the following three parts: 1) primary particle injection and secondary particle generation in the atmosphere, 2) Cherenkov light emission from the particles and tracing it to the imaging cameras, and 3) response of the electronics. The air shower generation is based on GEANT3 [6] and the target atmosphere is approximated by uniform 80 layers of the same atmospheric depth, densities of which are calculated using the U.S. standard atmosphere. Only Rayleigh scattering is incorporated as a scattering process for Cherenkov photons in the atmosphere. Light collection efficiency of the telescope including electronics response is adjusted on the basis of the results from muon ring analyses [7]. In the simulations used here, gamma rays of various energies are vertically injected into the atmosphere inside of a circular area of the 500 meter radius at random.

4. Stereoscopic Reconstructions

4.1 Arrival Direction

The arrival direction of a stereoscopic event is simply estimated as the intersection of major axes of individual Cherenkov images. If more than two shower images are successfully obtained in an event, a weighted mean of the intersections, in which the weight is $\sin^2(\text{angle between axes})$, is calculated as the arrival direction.

4.2 Core Location

Let (EL_0, AZ_0) be the horizontal coordinates of the image centroid in the field of view and ϕ be the angle shown in Figure 1, where M, S and Z are the centroid, source and zenith directions, respectively. Then, the azimuthal direction of the core location viewed by the telescope (indicated by C in Figure 1) is represented as:

$$AZ = AZ_0 + \tan^{-1}(\sin EL_0 \tan\phi) \quad (1)$$

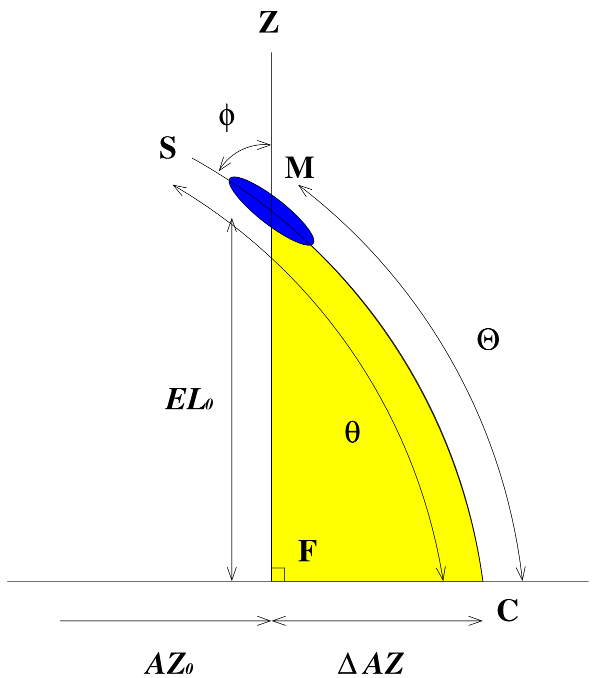

Figure 1. Schematic diagram representing the relation between Cherenkov image and core directions. The blue ellipse indicates an image and all of the lines are great circles in the celestial sphere.

The core location is obtained as an intersection of lines pointing to this direction and passing through the telescope locations. Treatment when more than one core location are reconstructed in an event is the same as the case of the arrival direction.

5. Results

The results will be presented in the Conference.

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