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Detector instrumentation and drive system for TACTIC gamma-ray telescope

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Abstract. TACTIC, a high sensitivity gamma-ray telescope is being set up at Gurushikar, Mt. Abu, to undertake comprehensive temporal and spectral studies of cosmic gamma-ray sources in the TeV energy range. The salient features of the system electronics and the drive-control system are discussed.

Key words : focal plane—gain calibration—drive system

1. Introduction

Most of the TeV gamma-ray telescopes in operation during the last 2 decades, operated at low flux sensitivities, necessitating very long observation-spells to establish the 'detection' of a candidate source on a firm statistical footing. To obviate this deficiency, new experiments (generation II) with a significantly enhanced sensitivity, are presently being set up. TACTIC a TeV Atmospheric Cerenkov Telescope with Imaging Camera, being set up by BARC, is an indigeneous attempt towards the realisation of this objective.

2. Experimental system

TACTIC is being set up at Gurushikar (latitude : 24° 39′N, longitude : 72° 47′E) in Mount Abu, Rajasthan at an altitude of ~ 1700m above m.s.l. (Sapru *et al.* 1993). Following a hybrid design for improving sensitivity (Bhat *et al.* 1993a), TACTIC comprises 3 conventional Trigger Units (TU) operated in a prompt coincidence mode and an Imaging Unit (IU), which generates 20 ns duration images of the Cerenkov events picked up by the TU. Deployed as shown schematically in figure 1, each unit comprises of an alt-azimuth mounted, 10.5 m^2 area, quasi-parabolic light collector made up of 34 spherical mirror facets, each of 0.6 m diameter and 8.25 m radius of curvature. These facets will be individually aligned to generate a common focus for the entire light collector, leading to an image spot size of < 0.1°.

2.1. *Focal-plane instrumentation*

As shown in figure 2, all the three Trigger Units TUi (i = 1-3) have the same focal plane instrumentation which consists of 9 Visible channels (V_{ij}, j = 1-9; Thorn-EMI 9823B) and

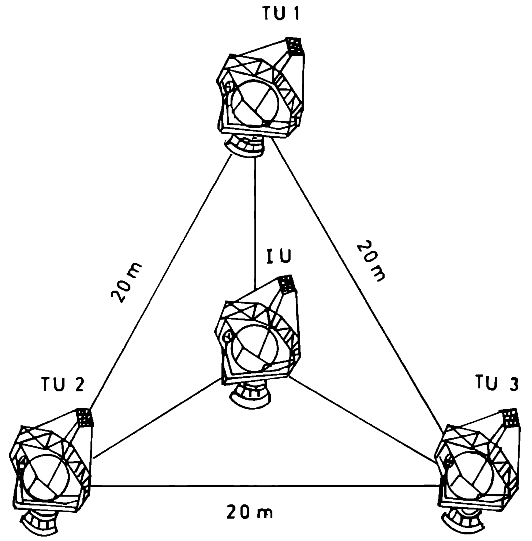

Figure 1. The layout of the three Trigger Units (TU) and the Imaging Unit (IU) of the TACTIC.

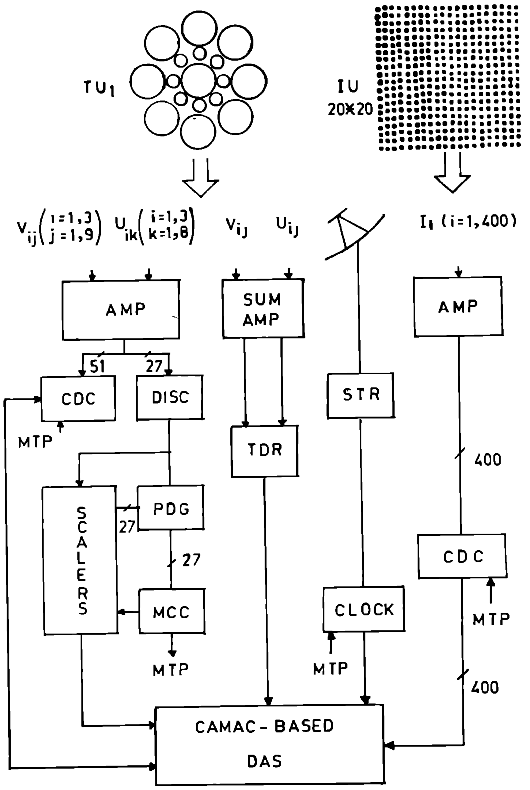

Figure 2. The block diagram representation of the focal plane instrumentation of the TU and IU.

8 Ultraviolet channels (U_{ik}, k = 1-8; Thorn-EMI 9422QB), as shown in figure 2. The three V_{i1} channels i = 1-3, centred on the telescope axes, are operated in a prompt coincidence mode to register γ-ACE and p-ACE coming from the direction of the candidate γ-ray source (on-source data). Eight independent samples of cosmic-ray background (off-source data) are

generated in an analogous manner from the remaining channels of each trigger unit (V_{ij}, i = 1-3, j = 2-9). These off-source channels are positioned symmetrically around their corresponding on-source channels in a circular ring of radius 2.5°.

The Imaging Unit (IU) of the telescope has a 400 pixel Cerenkov Light Imaging Camera (CLIC) at its focal plane. The CLIC pixels are arranged in a square grid of 20*20 to give a total field of view of 7.2° × 7.2° with a uniform pixel resolution of 0.36° × 0.36°. The charge content produced by a particular event in each of the pixels is recorded by coupling the PMT anode outputs to Camac based CDC units. The 27 V-channels, in addition are amplitude discriminated to yield a single channel rate of ~30 kHz, which is regularly monitored to keep track of the 'system health'. All the 9 discriminator outputs of a given TU are delayed appropriately by the Programmable Delay Generator (PDG) to compensate for the inter-TU propagation-time delay. The 27 PDG outputs are next fed to a memory-based Majority Coincidence Circuit (MCC) which generates the Master Trigger Pulse (MTP) to activate the DAS for recording all the relevant event information. The MCC has a built-in feature to give a measure of the chance coincidence rates also (Bhat *et al.* 1993a).

Two high-speed (1 GHz) PC-based transient digitizers will be used to record the on- and off-source ACE waveforms. The detailed off-line examination of the time characteristics of these profiles will help in differentiating further between the γ- and p-ACE.

2.2. *Gain calibration*

To have a good image quality from the CLIC as also reliable data on the primary-particle energy, it is of paramount importance to ensure an excellent relative gain uniformity/stability of all the camera channels. After comparing the relevant features of the various available light sources, we find that a low power Nitrogen laser (lasing λ = 337 nm) is the most suitable gain calibrator. During the calibration routine, the laser flash will be directed towards the Imaging Camera and the corresponding charge content of all the channels recorded from the CDC. Data from one hundred or more such flashes, taken at the start of observations each night, will be analysed for gain variations by a computer-based system. If required, the channel gains will be adjusted by this system to within a few percent of one another by varying the amplifier or PMT gain setting. These data will be used for 'flat-fielding'—an important step in the image-processing routine.

2.3. *Drive control system*

A PC based drive system (figure 3a) controls the four units of TACTIC. Hybrid stepper motors (Evershed make FEL 23) which develop a torque of 100 NT.cm at a stepping rate of 5 KHz, power the two axes. The angular position of the two axes of each unit is monitored using 14 bit synchro-to-digital convertor type shaft encoders (CCC make SNAPTRAK) with an accuracy of 0.1°. The drives have been designed to track the source within an error range of 0.2°. After source acquisition, the drive motors move at a constant speed, determined by the computer, on the basis of the local sidereal time and the equations of motion, till the error in the tracking direction is within 0.2°. When the error crosses this limit, the new speed value is calculated by the PC for being programmed on to the Camac based stepper motor controller. As depicted in figure 3b, the required number of extra pulses corresponding to the error of 0.2° are also fed to the motor to compensate for this error. As the azimuth

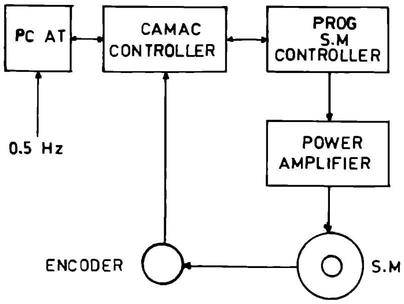

Figure 3a. Block diagram of the drive controller.

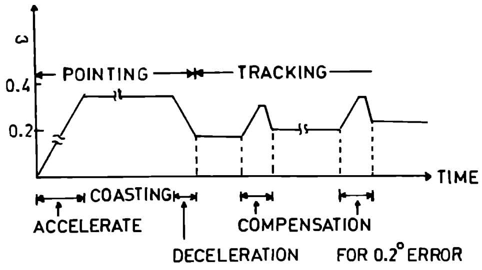

Figure 3b. Speed profile of the drive motors.

motors are capable of operating at stepping rates of 1500 Hz, the blind spot size is limited to < 2°.

The four and five-stage gear boxes used on the azimuth and zenith axes have a gear ratio of 6349 and 6631 respectively. The inherent backlash errors in the gear trains are conventionally compensated for by employing two separate gear trains and drive motors for the forward and the reverse directions, increasing the drive cost appreciably. For this reason, we propose to employ electronic backlash compensation in the drive system, thereby making it possible to use only one gear train for each drive axis. At the time of any direction reversal, the drive motor will operate unloaded for a number of steps which will vary from position to position. At such times, the TACTIC encoders will be interrogated in quick succession to keep a tab on the time during which the telescope axis did not move despite the movement of its drive motor. This information will be used in the subsequent correction cycle.

References

Bhat C. L., Koul R., Tickoo A. K., Kaul I. K., Kaul S. K., Kaul S. R., 1993a, in : Proc. Nat. Symp. on Advanced Instrumentation for Nuclear Research, BARC, Bombay.

Bhat C. L., Tickoo A. K., Koul R., Kaul I. K., 1993b, Nuclear Instruments and Methods, in press.

Sapru M. L., Bhat C. L., Kaul M. K., Kaul S. K., Kaul S. R., Dhar V. K., Kaul R. K., 1993, this conference.