Bull. Astr. Soc. India (2002) 30, 381–384

Towards absolute gain calibration of the TACTIC Imaging element

A.K.Tickoo[1], V.K.Dhar[1],K.Venugopal [2],K.K.Yadav[1],S.K.Kaul[1],R.Koul[1], M.Kothari[2], H.C.Goyal[2], P.Chandra[2], N.Bhatt[1] and C.L.Bhat[1].

[1] *Bhabha Atomic Research Centre, Nuclear Research Laboratory, Mumbai- 400085,India.*

[2] *Gurushikhar Observatory for Astrophysical Sciences, Mount Abu- 307501, India.*

Abstract The imaging element of the 4-element TACTIC telescope array has been in operation at Mt. Abu since 1997, for carrying out detailed investigations of γ-ray sources in the TeV energy range. In order to characterize the progenitor particle (γ-ray / cosmic ray), a relative gain calibration system, based on a high intenstity LED, has been in operation. However, for calorimetric purposes, an absolute gain calibration system is necessary and has been developed for on-line calibration of 4 out of 349- pixels of its imaging camera, using Am^{241} -based light pulsers. The details of the scheme followed and the results obtained so far are presented in this paper.

Key words: PMT detectors, Absolute gain calibration , TACTIC telescope

1. Introduction

After the discovery of quite a few γ-ray sources with high statistical significance [Ong, 1998], lot of efforts have been directed towards the measurement of their fluxes and energy spectra. One of the most crucial inputs required for obtaining the energy spectra is the absolute gain of the PMT detectors so that event size measured in CDC counts can be converted accurately into number of photoelectrons. Several methods have been used to find out this conversion factor, viz., single photoelectron peak detection using pulsed LED [Mirzoyan et al ,1995], identifying Cerenkov images produced by local muons [Vacanti et al , 1994] and using the variance in the relative calibration data itself [Biller et al, 1995]. Although the method proposed by us also employs the principle of detecting the single photoelectron peak, it has the added advantage of gain monitoring on a continuous basis to account for any possible gain drift of the PMTs.

TACTIC, standing for TeV Atmospheric Cerenkov Telescope with Imaging Camera, is a compact array of 4 atmospheric Cerenkov telescopes [Bhat, 1997], which are placed at the corners and the center of an equilateral triangle of side 20m(Fig.1a). All the telescope elements use 9.5 m^2 surface area, tessellated light collectors, which are placed on altitude-azimuth mounts, having computer controlled 2-axes movements [Tickoo et al, 1999].The central telescope, called the Imaging Element (IE), carries a 349- pixel imaging camera at its focal plane, which covers a field of view (FoV) of $\sim 6^o \times 6^o$ (truncated square) with a uniform pixel- resolution of $\sim 0.31^o$ (Fig. 1b).The event trigger is generated by demanding that Nearest-Neighbour Non-Collinear (3NCT) pixels should fire simultaneously within $\sim$ 20 ns. The recent results of our observation campaigns on the Crab Nebula and Mkn-421, carried out with its full 349-pixel camera are discussed in [Tickoo et al ,2001]. Detailed simulation for the full TACTIC array, using CORSIKA air-shower simulation regarding its collection area, energy threshold and sensitivity estimates are presented in [Koul et al, 2002; Sapru et al, 2002].

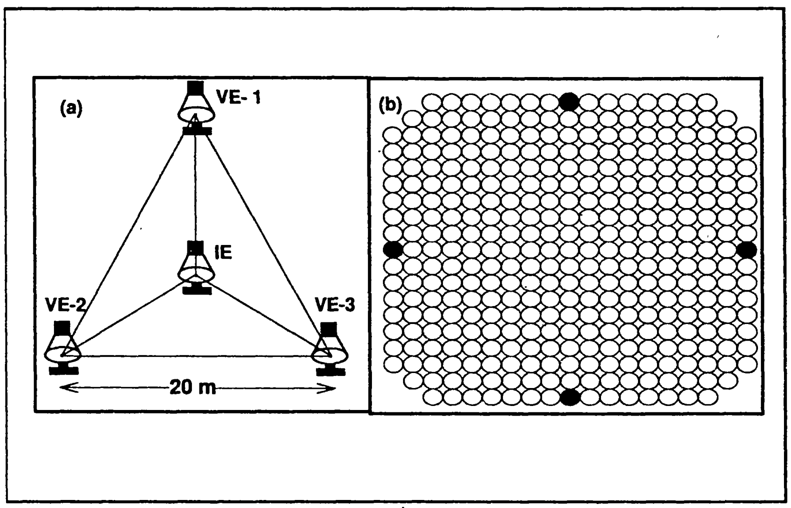

Figure 1. (a) Schematic layout of the TACTIC telescope elements. (b) Layout of the TACTIC IE camera pixels. Filled circles in the figure indicate pixels mounted with radio-active light pulsers.

2.Gain-calibration scheme followed for TACTIC IE

The PMT calibration scheme employed for TACTIC has two parts, viz., Relative Gain calibration (RGC) and Absolute Gain Calibration (AGC). In the RGC scheme, we use a high intensity LED at a distance of 2m from the camera to determine the relative gain of the imaging camera pixels. The LED has been provided with a light-diffusing medium in front of it to ensure the uniformity of the photon field within is $\sim \pm$ 7%. The mean light recorded from the pulsed LED by each pixel , in respose to 2000 light flashes are subsequently used for off-line relative gain calibration of the imaging camera.

In the AGC scheme we perform the necessary calibration in the following two steps: (i) 4 PMT pixels, placed symmetrically at the edges of the 349-pixel imaging camera in the IE (shown by filled circles in Fig. 1b), have been selected and their single-photoelectron peaks measured at a High Voltage (HV) value of 1250 V. To obtain the single photoelectron peaks, we illuminate the calibration pixel PMT's with a very low flux of steady-light so that the resulting shot-noise voltage pulse at the anode is mainly due to emission of 1 photoelectron from the photocathode . A representative example of differential spectrum obtained for one of the PMT's is shown in Fig.2a. The mean amplitude of the single photoelectron peak along with its P/V (Peak/Valley) ratio is then determined by fitting a Gaussian distribution function to the differential rate curve. After this operation the 4 calibration pixels are mounted permanently with Am^{241} isotope (alpha-emitter) based light-pulser. Representative example of the pulse height distribution obtained with one of the radioactive light pulser is shown in Fig.2b. These 4 calibration channels are then used for an in-situ monitoring of their gains and also for evaluating gains for rest of the 345 uncalibrated channels from their relative calibration data. It may be worth pointing here that measuring the light pulser yield on a continuous basis for in-situ gain monitoring is relatively much more straight forward as compared to the more time consuming procedure of determining the single photoelectron peak. Several measurements of single photoelectron peak and the Radio Active Pulser (RAP) yield were taken under dark room conditions to validate the reproducibility of the masurements and for preparing the reference data base. Any change in the RAP yield measured during actual observations, is then attributed to actual gain change of the pixel possibly due to variations in the night sky backgrond light seen by the pixel and the ambient temperature .

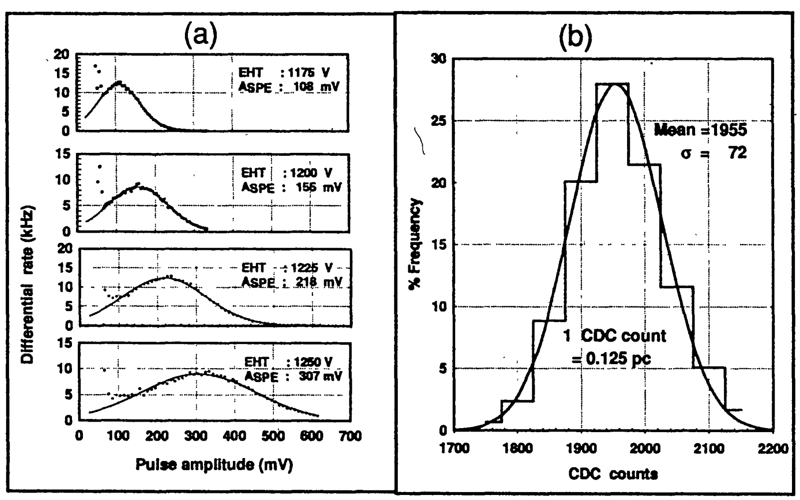

Figure 2. (a) An example of single photoelectron peak obtained for one of the calibration pixels at different values of HV. (b) Representative example of the pulse height distribution obtained with one of the radioactive light pulsers.

3. Conversion of CDC counts to number of photoelectrons

The charge content of an ith uncalibrated pixel recorded in terms of CDC counts (C_i) in response to a Cerenkov event has been converted into photolectrons (K_i) by using the following formula:

$$K_i = \frac{C_i}{(4Q_i)} \sum_{j=1}^{4} \frac{P_j \delta_j N_j}{A_j} \tag{1}$$

where (A_j) and (P_j) are the CDC counts recorded under actual conditions by the jth calibration channel during the most recent absolute and relative calibration run respectively; (N_j) is the RAP yield (in number of photoelectrons) measured under dark room conditions; (Q_i) is the CDC count recorded by the ith uncalibrated pixel during the relative calibration run; (δ_j) is the correction factor (>1) to take into account the reduction in the photocathode of the jth calibration pixel due to obstruction caused by the light pulser itself when the pixel sees light flashes from the LED. The underlying principle behind this formula uses the fact that the calibration pixels are also exposed to the light flashes from the LED during the relative calibration run and hence it becomes possible to obtain the conversion factors for all the 345 pixels of the camera. On using the coversion factor (3 CDC counts $\equiv$ 1pe) obtained through the above procedure, we were able to convert the image size recorded in CDC counts into number of photoelectrons. This informtaion along with relevant inputs from our simulation studies has been seccessfully used to derive the energy spectra of γ-rays from the Crab Nebula and Mkn-421.

4. Conclusion

The absolute gain calibration system of the TACTIC telescope has been in operation for about one year, and the data obtained so far suggests that PMT gain does change by $\pm$ 20 % during the course of an observation night. Detailed procedure to account for this change in being incorporated in our data analysis procedure so that the conversion ratio can be determined more accurately. A detailed comparision of our calibration procedure with already existing ones is also being undertaken for cross checking purposes.

References

Bhat C.L ., 1997, Proc. Perpectives in the High Energy Astronomy and Astrophysics , TIFR India.
Biller S. D., et al, 1995 , Proc. 24th ICRC, Rome , Italy, 3, 412
Koul M.K., et al , 2002, This proceedings.
Mirzoyan R., et al, 1995, Proc. Towards a Major Atmospheric Cerenkov Detector IV, Padua, 230
Ong R.A., 1998, Phys.Rep., 305, 93
Sapru M.L. et al, 2002 , This proceedings
Tickoo A.K. et al, 1999, Exp. Astron, 9, 81
Tickoo A.K. et al, 2001, Proc. 27th ICRC, Hamburg , Germany
Vacanti G. et al, 1994, Astroparticle Physics, 2, 1