Systematic Approach to On- Line Calibration of the Scintillation Detectors of GRAPES-3 Experiment.

Sonali Bhatnagar [1], S.K. Gupta [2]

[1] *Department of Physics and Computer Science, Dayalbagh Educational Institute, Agra.*

[2] *spokesman for GRAPES Collaboration, High Energy Cosmic Ray Group, Mumbai.*

Introduction.

The observable characteristics of extensive air showers provide indirect information on two important areas of high energy physics and astrophysics, namely, some characteristics of particle interactions in the very forward region and the energy spectra and relative flux of various nuclear groups present in the primary cosmic rays, at ultra-high energies. These information's are obtained from the nuclear detectors after their output passes through systems which alter their forms to interpret the information required. The detailed description of the calibration system is given below. This on-line calibration is done for all the 400 plus scintillation detectors by ROOT software package.

GRAPES3 Experiment.

The main aim of this experiment is to
a) Study nuclear composition and energy spectrum around knee region.
b) Search for gamma ray point and diffuse source.
c) Study on solar modulation.

This experiment is located in South India, 76.7 ˚E and 11.4˚ N at 2200 m above sea level where atmosphere is $800 g/cm^2$. GRAPES-3 is a high density air shower array designed to measure both densities and relative arrival times of shower particles to determine the energy and incident direction of primary cosmic ray particle which initiates a shower in the atmosphere. The details of the experiment with shower detectors, shower trigger and data acquisition is described elsewhere [1]. At present the array records 2.2 million showers per day with TDCs for arrival time and ADCs for particle density measurement in the primary energy range 10^{13} - 10^{16} eV. Monte-Carlo simulation shows that the GRAPES-3 array has trigger efficiency ~90% at E. ~30 TeV for γ-ray primaries [1]. With its high trigger efficiency for lower energy γ-ray showers, it has potential to study γ-ray sources. Besides this, the other unique advantage of the array is, its association with a large area (560 m^2) muon tracking detector which can distinguish primary γ-rays from charged cosmic ray particles through the muon content of the shower [2].

Systematic Data Flow Diagram for Calibration.

The calibration of detectors is the essential part of any experiment i.e. to calculate the single particle gain of the detector and hence know the performance. The single particle gain is used to estimate the number of particles passing through the detector. The scintillation detector has been calibrated by using a double muon paddle, mounting below the detector. The detectors are calibrated at regular intervals of time to update the gain information of each detector, as the variation in gain occurs due to different factors like aging of the scintillators, PMT, change of temperature, pressure and other environmental parameters. The number of detectors being large so each detector has been calibrated once in a month. The system of calibration or the code has been developed to make a complete automation in the extraction of calibration information of scintillation detectors from binary data files and also to develop a proper database.

The data flows from the scintillation detectors to the pre-analysis systems and then calibration and monitoring systems. After the triggering criteria for the GRAPES3 detector setup is satisfied, the calibration information have been recorded in binary data format together with air shower, pedestal and other useful data with distinct trigger mark for each case in a single data file. The present data recording time per file is around 5 minutes and hence per day around 300 binary data files are recorded by the automated data recording system of this experiment. This code has been developed to make a complete automation in the extraction of calibration information of scintillation detectors from binary data files and also to develop a proper database with this information for later work.
The selection of the calibrated detectors from the binary data files is the aim of this code. For this purpose we have calculated the mean and RMS of the

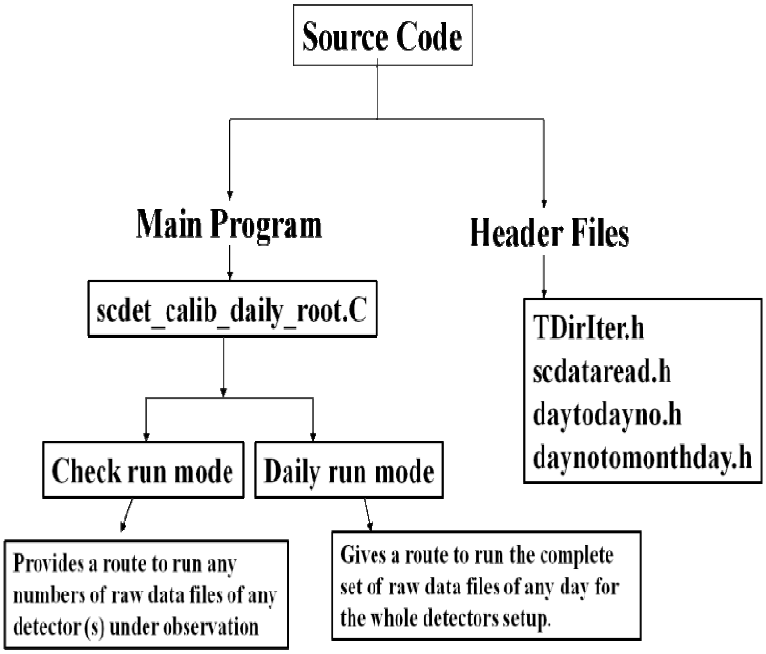

Figure 1: The basic data flow diagram of Calibration Systems for all detectors.

signal and pedestal ADC counts of each detector, and recorded it for the calibration and pedestal triggers. The detector which i.e. actually calibrated in that run must have large differences between the signal and the pedestal's mean (call it the net mean) than the rest of the detectors. In principle, non calibrated detectors should have zero net means, but in real they are not zero in most cases for many other factors. Hence we apply a condition that, the calibrated detector must have the net mean value greater than or equal to 15, as no detector should have gain less than 10 (since the net mean 15 is equivalent to a gain of 10 which is usually taken from the median or peak value of signal ADC distribution of the detector). On further observation it was found that this condition is not sufficient to select the calibrated detector because of chance coincidence effect in some of the detectors nearby the calibrated detector and also due to large pedestal variation of some bad detectors. As a result, those detectors also appear as calibrated detectors together with a truly calibrated detector. Consequently we have applied the following two additional selection criteria to select a calibrated detector from the set of operating detectors i.e.

(a) The ratio of the net mean to signal RMS of the calibrated detector must be greater than 0.2.This condition is justified after observing the pattern of distribution of the ratio of net mean to signal RMS with respect to net mean of all detectors and is effective to reject the chance coincidence effect.

(b) The pedestal RMS must be less than the signal RMS of the calibrated detector. This condition ensures the rejected of a non calibrated detector, which has very large pedestal distribution, from appearing as a calibrated detector.

All these three conditions together, more effectively and efficiently select the calibrated detectors from the binary data files containing the calibration trigger mark.

Algorithm of Check Run Mode and Daily Run Mode.

This analysis tool has two modes of operation :(a) Check Run mode where we run any number of binary data files of any detector to check its performance or other parameters while the same are under observation, without affecting the database outputs.

(b) The daily run mode serves the main function of this code as it runs the complete set of binary data files of any day for the whole detector setup.

The two separate run modes have been written in C++ language in the ROOT framework. ROOT is an object-oriented data analysis framework developed at CERN [3] aimed at solving the data analysis challenges of high energy physics. The daily run mode serves the main function of this code as this mode gives a route to run the complete set of binary data files of any day for the whole detector setup.

Conclusion.

This analysis tool has been tested for the year 2005 and 2008 binary data in Linux operating system and is presently being run for all the coming data. The performance is found to be quite satisfactory.

The outputs of these systems are in the form of data files which carry the calibration information and history of each calibrated detector. Another file generated contains the parameters of the Gaussian fit to the signal ADC and pedestal ADC histograms of each calibrated detectors in a day. These parameters are TDC peak, TDC sigma; signal peak, signal sigma, pedestal peak and pedestal sigma with the corresponding calibrated detector and TDC type.

References.

[1] GRAPES3 Collaboration, Nuclear Instruments and Methods in Physics Research A 540 (2005) 311–323.
[2] GRAPES3 Collaboration, Nuclear Instruments and Methods in Physics Research A 545 (2005)643-657.
[3] CERN homepage (http://root.cern.ch/).