Bull. Astr. Soc. India (2003) 31, 411–412

Analysis System for GRAPES-III Extensive Air Shower Data

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Abstract. GRAPES-III experiment [Tonwar S.C] consists of 271 scintillators of 1 m^2. area each and a large area (560 m^2) muon detector to record Extensive Air Showers (EAS) produced in the atmosphere by high energy cosmic rays (> $3X10^{13}$ eV). A comprehensive set of software modules have been developed to analyze this vast amounts of data (> 3 Giga byte/day). A brief description of this is presented here.

Keywords : EAS, pair-production, bremstrahlung

1. The EAS Phenomena and Data Analysis Procedure

When a primary charged cosmic ray is incident on top of the atmosphere, it strongly interacts with the atmospheric nuclei, and produces a shower of secondary particles, mainly charged and neutral pions (π^+, π^- and π^0) nucleon-antinucleon pairs and other hadrons. The π^0s decay into two high energy γ rays which materializes into an electron-positron pair *(pair-production)*. The electrons undergo *bremstrahlung* process and radiate part of their energy into gamma rays which in turn undergo *pair-production*. The repetition of this cycle produces a shower of particles, spread out over an extensive area of several tens to hundreds of meters; the phenomenon called Extensive Air Shower. The lateral spread of the density of particles can be represented by the Nishimura-Kamata-Greisen(NKG) function $\Delta(N_e,s,r)=(N_e/2\pi r_0^2)G(s)(r/r_0)^{s-2}(1+r/r_0)^{s-4.5}$, where Δ is the density/m^2 of the charged particles at a distance r (in meters) from the shower core, N_e is the shower size , r_0 is the Moliere unit of scattering, s is the age parameter which is representative of the steepness of the lateral distribution and $G(s)=\Gamma(4.5-s)/(\Gamma(s)\Gamma(4.5-2s))$. The procedure for obtaining the shower parameters is to have a least square fit by minimizing the expression, $\chi^2=\Sigma w_i(\Delta_i^o-\Delta_i^e)^2$ where Δ_i^o and Δ_i^e are the observed and expected densities respectively in the i^{th} detector and w_i is the statistical weight factor for it [Sinha S.]

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2. Tests using Simulated Data and Analysis of Real Data

Several sets of 100,000 simulated(NKG) showers were analized. The distributions of the difference (log of ratio in the case of *size*) between the true and estimated values of different parameters showed mean values which are very close to zero as expected and with acceptable standard deviations. Figure-1 shows the x-coordinate difference distribution. The broader curve in Fig. 1 is the distribution based on a crude estimate of the core position using the centre of gravity of the densities and it can be noticed that the minimization algorithm refines this crude estimate effectively and pulls it to the more accurate value reducing the spread considerably. The zenith angle (Θ) distribution (Fig. 2) showed the expected shape which peaks around 22^0. Analysis of 32 million Real showers showed acceptable agreement with simulations. The distributions of x-coordinates exhibiting nearly uniform pattern and the zenith angle distribution showing fairly identical shape as that of similated showers are shown in Fig. 3 & Fig. 4.

3. Conclusions

We have developed a comprehensive Software System, well optimized in time and space, for analysis of GRAPES-III data. This comprises of three stages of processing, each stage requiring a main program module and several sub modules within it. The computing time to preprocess, filter and estimate the shower parameters of a day's data (1.2 million showers) is about 42 minutes for the currently operating array with 271 detectors, and will be about 2 hours for the projected maximal configuration of the GRAPES-III array with 721 detectors. In addition to this, the preprocessing and filtering process reduces the input data volume itself by almost eight times. Various tests discussed above using simulated data on showers have shown the analysis system to perform well yielding reliable values of shower parameters which can be used for studies on energy spectrum and composition of high energy cosmic rays.

References

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