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A NEW DATA ACQUISITION SYSTEM FOR THE NBU EAS ARRAY.

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ABSTRACT:

A new data acquisition system developed for detection of Extensive Air Shower (EAS) events is described and the characteristics of the system relating to particle density measurement and particle arrival time measurement are presented.

Introduction:

The NBU Extensive Air Shower (EAS) array has been operating since 1980. Since the original construction of the array, a number of modifications and improvements have been made. The array currently consists of 24 scintillation detectors for the measurement of particle density of EAS at various points , 8 fast timing detectors for determination of the arrival direction of each shower event and two muon magnetic spectrographs for the study of muon component of EAS. One of the main purpose of the array is to search for discrete point sources of ultra high energy Cosmic Rays. For this a large air shower statistics is required which demands lowering of the shower size threshold of the array and small dead time of the data acquisition system. Moreover in a number of EAS observations it has been found that occasionally EAS are coming within short time interval (few ms.) (Klebesadel R.W. et. al.,1973,Smith G.R. et. al.,1983, Hillas A.M.,1984) having similarity with low energy gamma ray burst. To observe such phenomena ,each shower event need to be recorded within few μs. Considering these aspects , a new data acquisition system for the NBU EAS array has been developed. In the original data acquisition system of the NBU EAS array (Basak D.K. et. al.,1984) a 32 channel multiplexed ADC was used to digitised the analog pulse carrying the information of charged particle density in EAS. In the present system analog pulse heights are digitised simultaneously for all the 32 channels and these digitised density data and particle arrival time data are automatically recorded in an external 32 k-byte memory and subsequently stored in the Computer hard disk. In this paper the recording system , calibration of the read out system and instrumental errors are briefly described.

Recording System:

Fig-1 shows the schematic block diagram of the NBU EAS array data recording system. In the present form of the recording system , fast timing detector pulses are discriminated through a Lecroy discriminator. Discriminated output converted to TTL through Level adapter of Lecroy for coincidence. Out of eight fast timing detector we used three fixed and another one from remaining five for coincidence pulse generation.

The Particle Density Detector(PDD) pulses are amplified by an 'OPAMP' of gain 10 and the output is discriminated through a comparator to provide for a switching of time 4μs. These pulses are also fed to a Sample and Hold (S/H) circuit. A hold pulse is generated from coincidence circuit. If a coincidence pulse comes within that 4μs, the hold capacitor is isolated from discharging for a time of 150μs. The output pulses of S/H are connected to the input of the Analog to Digital Converter(ADC) to scan the pulse heights. All the PDD channel scan these pulses simultaneously . The maximum time required to complete the scanning is 100 μs. There is a FET switch in each input of the S/H to disconnect the input channels from the S/H unit until the completion of total process. When a coincidence pulse is generated, a pulse of width 150μs is fed to the ADC-Hold and a 1 μs delayed pulse of width 150 nano second is generated in the coincidence circuit for the digital conversion of input analog pulse. We used a real time clock to get the shower arrival time and the date of individual shower.

Time to Digital Conversion (TDC) of fast timing detector pulse starts through a common start pulse of Lecroy model 2228A by a coincidence pulse . As common start comes , a capacitor is charged up by a constant current source until a stop pulse from an individual channel of fixed delay.

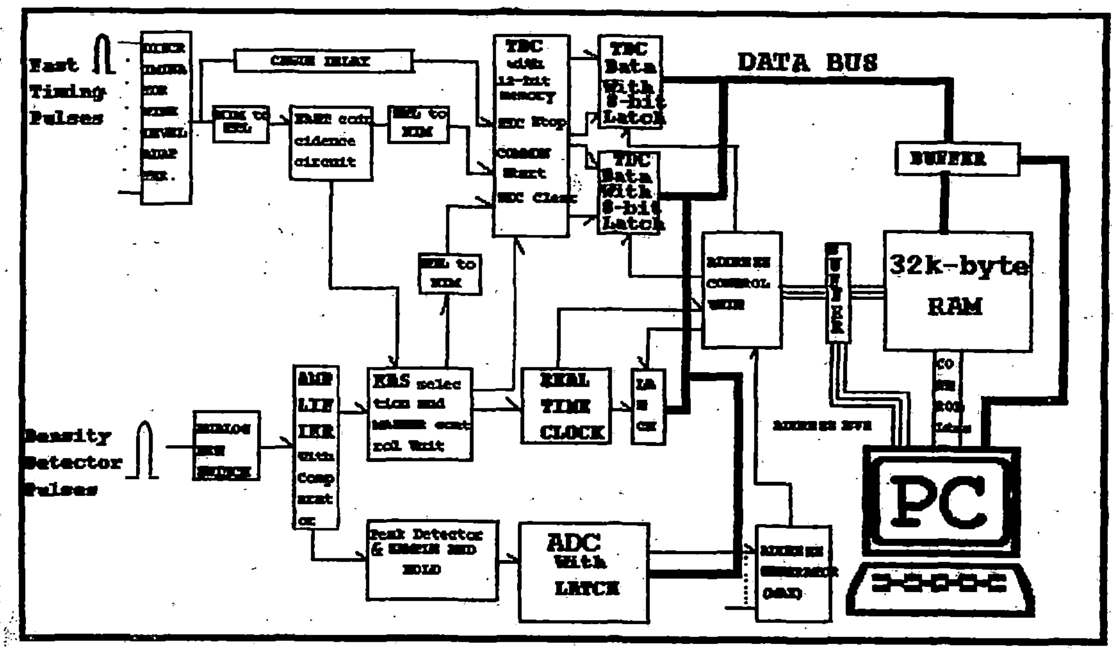

Fig-1. Block Diagram of the New Data Acquisition System.

When a coincidence pulse is generated , arrival time and date of the shower from the real time clock are stored into 8-bit latches and all the PDD data are stored into the individual ADC latch and 8-channel TDC data stored into TDC memory. After completion of these, a write pulse generated from the Master Control Unit (MCU) and an up counter of 15-address line start to increase the memory address for storing the data of arrival time , date , digital data of all PDD channels and the relative time difference for all TDC channels into the 32k-byte memory through 8-bit data bus.

The time between the arrival of individual shower and completion of data storage into the memory is about 200μs. After 200 μs, the system is ready for the next event. The memory has nearly 1000 event data storing capacity. After completion of 1000 events ,we start transfer all these data into the hard disk of a PC through parallel port. For the storage into hard disk from the external memory we use a software which is developed by us.The system has the provision to increase any number of PDD channels only by the addition of S/H and ADC.

Calibration of the Read Out System:

All the ADC are calibrated first using a standard dc source. In the next step a square wave pulse generator of variable amplitude was used as a standard source. The width of the pulses was taken comparable with the output analog pulses of the density detectors. Fig-2 shows an actual calibration

curve of a particular ADC. From the calibration curve it is found that digitised output pulses are linear to the input voltage upto 5 volt. The maximum error in ADC is 19.6 mv.
The TDCs are calibrated using a standard timer.

Density Detector Calibration:

For the measurement of particle density, each density detector must be calibrated in terms of single particle pulse height. This was done by placing each scintillation detector within a telescopic arrangement of three G.M. counter, two of which were placed above the detector with their axis mutually perpendicular to each other and the third G.M. counter was placed below the detector. For the measurement of pulse height, the coincidence pulse from the telescope is used to trigger the MCU of the data acquisition system and the output from the detector is connected to each of the channels of the pulse height measuring circuit one after another.Most coincidences correspond to single particles. Fig-3 shows the single particle pulse height distribution of a particular detector. The Full Width at Half Maximum (FWHM) of single particle pulse height distribution for each of the channels is found to be within 27% of the average single particle pulse height of that channel.
During the operation of the array, the differential pulse height spectrum for all the detectors has also been measured sequentially and from the pulse height spectrum the average single particle pulse height was estimated.

Instrumental Uncertainty in Timing Measurements:

Instrumental uncertainty is measured in the following way.A coincidence of a vertical fast timing scintillation detector telescope is taken and this coincidence pulse starts TDC. Pulses of two detectors are fed to discriminator and the discriminated output pulses pass through with the same cable delay. These delayed pulses are used to stop the channels of the TDC..The distribution of the quantity $d = t_d - t_o + (d/c)$ is shown in Fig-4 ; where t_d is the time recorded by the lower detector , t_o is the time recorded by the upper detector, d is the vertical distance between the two detectors and c is the velocity of light. Assuming that the distribution is Gaussian , the standard deviation σ of the distribution gives the uncertainty in arrival time measurements and the uncertainty in timing measurement for a single detector is $\sigma/2^{0.5}$ which is (1.84 ± 0.05) nano second.

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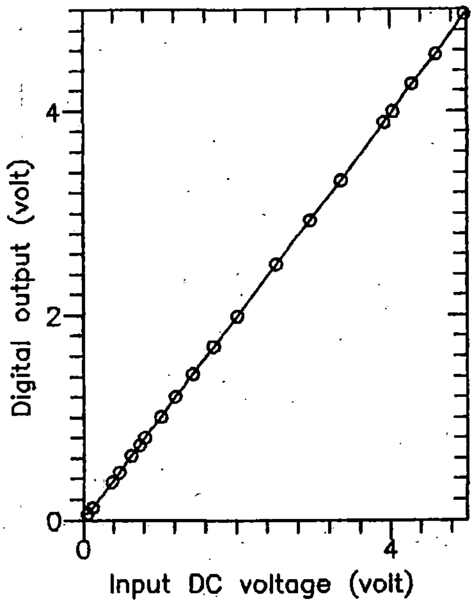

Fig-2. ADC Calibration.

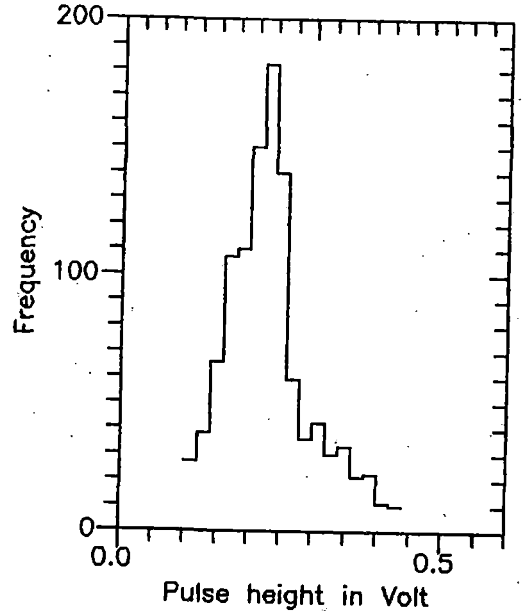

Fig-3. Single Particle Pulse Height Distribution.

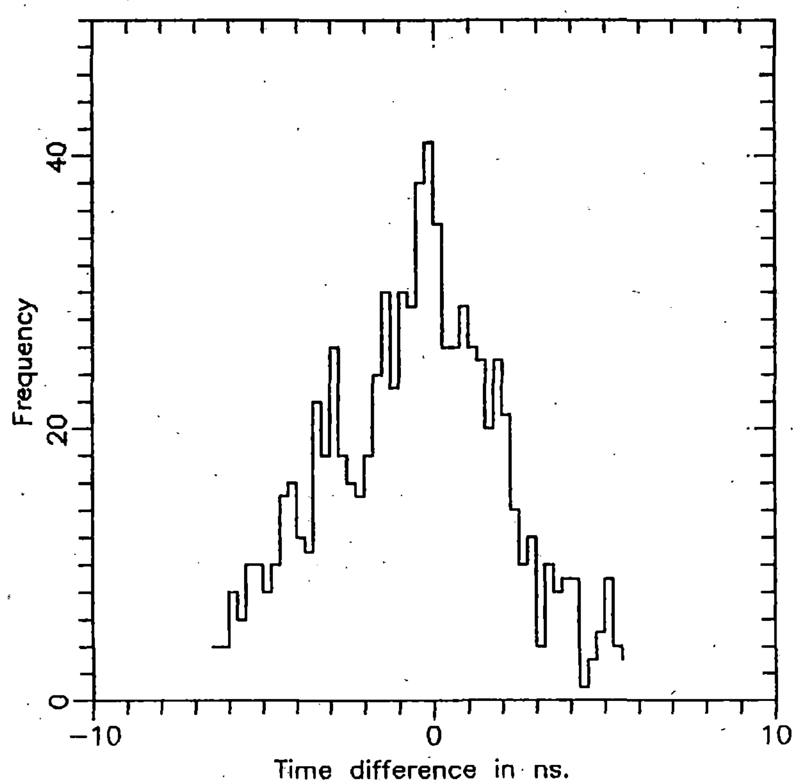

Fig-4. Instrumental Uncertainty in Timing Measurements.

The Zenith Angle Dependence of Shower Age

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ABSTRACT

The variation of shower age parameter with zenith angle for different shower size ranges is studied . The observed variation is in agreement with the electron-photon cascade theory and with the other EAS observations. It is found that upto zenith angle 30^0, shower 'age' is practically independent of zenith angle . So it is difficult to correlate the observed high 'age' value of the directional excess showers with zenith angle.

Introduction

The longitudinal development of Cosmic Ray Extensive Air Shower (EAS) is an essential feature that reflects the gross feature of particle interaction at high energies. The stage of development of an air shower is described by shower age parameter (s). Showers that develop early in the atmosphere have on the average larger 'age' than late developing showers of equal primary energy. Discrimination of gamma-ray initiated showers from the large background of charged cosmic ray initiated showers based on shower 'age' has been used in several observations (Samorski and Stamm 1983 ; Protheroe et al 1984) on the assumption that , for same shower size , photon induced showers are older . But the Monte Carlo simulation results (Fenyves 1985 , Hillas 1987 , Cheung and Mackeown 1988) show that in 'age' the gamma-ray induced showers are not older than that of normal showers, though in several observations it is found that the excess showers from the direction of discrete point sources are characterised by high 'shower age' value (Samorski and Stamm 1983 , Protheroe et al 1984 , Fomin et al 1987 ,Tonwar et al 1988). In most of the observations the showers from point sources were observed at large angles during most of the observation time due to high angle of transit of the sources at the arrays .As for example, Cygnus X-3 is observed at Kiel at zenith about 14^0,the same source is observed at Ooty at zenith angle nearly 26^0 at the transit.Though in the search for evidence of UHE emission the source and backgrounds events are collected during the same time in the same zenith angle intervals still there is a remote possibility (because of small statistics) that the source events had higher zenith angle than the background events . And with the increase of zenith angle the atmospheric thickness increases , so showers with high zenith angles are expected to have high shower 'age' values. To better understand the problem in the present work the dependence of shower age on zenith angle in the range 0^o - 55^o for three different shower size range is examined .

Experimental Set-up :

The air shower array at North Bengal University campus (latitude $26^o42'$ N, longitude $88^o21'$ E, 150 m a.s.l.) , INDIA , is operating since 1980 . At present it is composed of twenty four plastic scintillation counters , each of area 0.25 m^2 , for the measurement of particle density of air shower , eight fast timing detectors , each having also an area of 0.25 m^2 , for the determination of the arrival direction of the air showers . Two magnet spetrographs of maximum detectable momentum 220 GeV/c, each of an area 0.25 m^2, under a concrete shielding absorber are also operated in conjunction with the air shower array for the study of muon component of EAS . Each spectrograph consists of a solid iron magnet in between four neon flash tube trays (used as muon track detector) . The effective shower size threshold for the array is 2×10^4 particles . Details of the experimental system and data acquisition are described elsewhere (Basak et al 1984 , Bhadra 1996 , Chakrabarty et al 1997) .

Data Analysis :

The recorded showers have been analysed for core position (X_0 , Y_0) , shower size (N_e) , shower age (s) and arrival direction (l,m,n) . Shower size , shower age and core position were determined by a least square fit of observed particle density to NKG (Greisen 1960) lateral distribution. Showers with cores landing within 30 m from the centre of the array (approximately the array boundary) were only accepted . The resolution of the core position is $\pm$ 2.8 m and that of shower age and shower size are $\pm$ 0.11 and $\pm$ 17% respectively (Bhadra 1996) .

The arrival direction were obtained by measuring the relative arrival times (t) of the shower particles at different points . Using conical shower front and radial distance dependent weight factors the arrival direction of each shower event was calculated by a least square fit to the timing data . Deviation from the plane shower front was taken through the empirical equation (as measured by the array , Bhadra 1996)

$$dt = 0.19\, r - 2.12$$

To incorporate the variation of shower front thickness with core distance the weight factor used in the analysis is given by

$$w_i = 1/(\sigma_t^2 + \sigma_{inst}^2)$$

where σ_t is the spread of the arrival of the shower front paricles and was taken as (Linsley 1986)

$$\sigma_t = \sigma_0 / \sqrt{n}\, (1 + r/r_t)^b$$

with σ_0 = 1.6 ns , r_t = 30 m and b = 1.65 , n is the number of particles that hit the detector . σ_{inst} is the instrumental error of the timing detector . Instrumental uncertainty of the timing detectors of the array was found around 1.25 ns .

The angular resolution of the array has been estimated by the conventional 'split the array' method and is nearly 1.1^0 in zenith .

Results :

The results of the present work are based on a sample of nearly 10000 EAS events which were collected by the array during Jan 1994 to June 1994 . The general features of the EAS (e.g. lateral distributions of electrons and muons , shower age distribution , N_μ -N_e relation etc.) observed by the array were reported earlier (Basak et al 1987 , Sarkar et al 1991, Bhadra 1996) and are consistent with the well known characteristics of air showers .

The age distribution of the observed showers for the showers in the size range $6 \times 10^4 < N_e < 1 \times 10^6$ is shown in fig 1. The mean age of the observed showers is 1.31 which is close to the theoretical estimate (1.33 for proton showers) of Fenyves(1985) but differs with s = 1.45 measured at Haverah Park (Idenden 1990) and s = 1.1 measured at Kiel (Samorski 1983) at the same observation level . The zenith angle distribution of the observed showers in the same shower size range is given in figure 2. The peak of the distribution is observed at around 20^0 .

The variation of mean shower 'age' with zenith angle for three shower size range , (7.5 - 8.5) x 10^4 (1.5 - 2.5) x 10^5 and (5.5 - 6.5) x 10 , are shown in figure 3. The Figure shows that the nature of the variation does not vary much with shower size . The variation of s with zenith angle (z) is found slow and up to zenith angle 30^0 the shower age is practically found to be independent of zenith angle . In the shower size range (1.5 - 2.5) x 10^5 the mean shower age is 1.29 at z = 2.5^0 and at z = 52.5^0 the mean 'age' reaches only 1.44 though at zenith angle 52.5^0 the atmospheric overburden is nearly double . The observed variation can be expressed by the relation

$$s = s_0 + A \, \mathrm{Sec}\,(z) \qquad ....(1)$$

where the value of s_0 and A for different shower size range are given in table 1 .

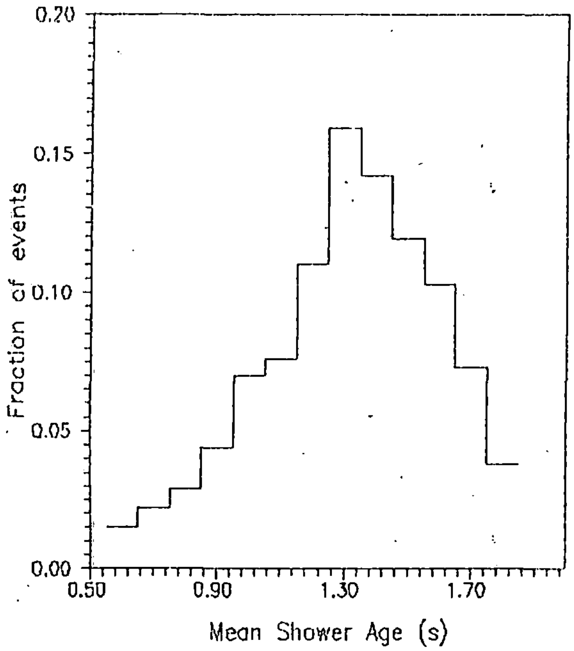

Fig. 1. Age distribution of the observed showers

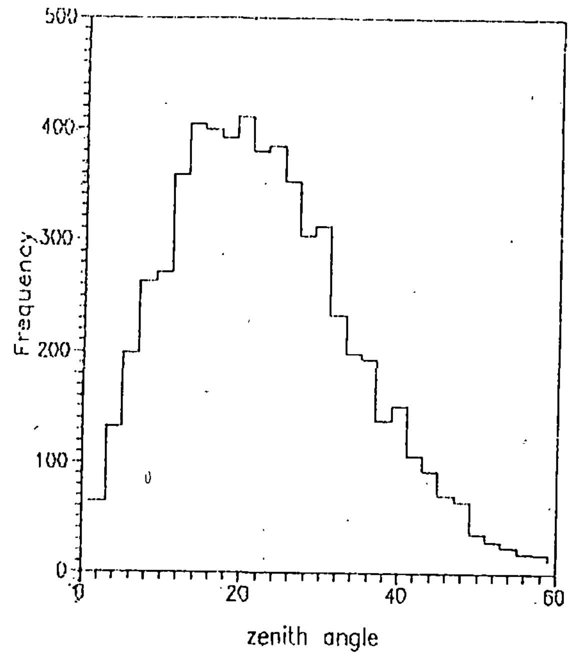

Fig. 2. Zenith angle distribution of the observed Showers

The development of electron-photon cascade is approximately described by the equations (Greisen 1960)

$$s = 3t/(t + 2w) \quad \text{....... (2)}$$

and

$$Ne = (0.31/\sqrt{w}) \exp[\, t\,(1 - 1.5 \ln s)] \quad \text{.......... (3)}$$

where $w = \ln E/\varepsilon_0$ and t is the atmospheric depth in radiation length . Using eqns (2) and (3) and expressing the variation of s with z for three different shower size range through the relation as given in eqn.(1) the values of s_0 and A for different N_e are also given in table (1). The result shows that the observed variation is in accordance with the cascade theory .

Table 1. Comparison of the observed variation of age parameter with zenith angle with the cascade theory for three different shower sizes.

Ne		8×10^4	2×10^5	6×10^5
Observed	s_0	1.10	1.03	0.98
	A	0.22	0.26	0.27
Theory	s_0	1.15	1.11	1.05
	A	0.27	0.28	0.30

Discussion :

Present result of the variation of shower age with zenith angle agrees with the prediction of cascade theory . In a number of EAS observations (Aguirre et al 1973, Miyaki et al 1981, Clay et al 1981 ,Idenden 1990) similar trend of variation was observed . In the Kiel observations, showers with zenith angle less than 30^0 only were accepted for the analysis . So it is difficult to correlate the high 'age' value of the directional excess showers with zenith angle.

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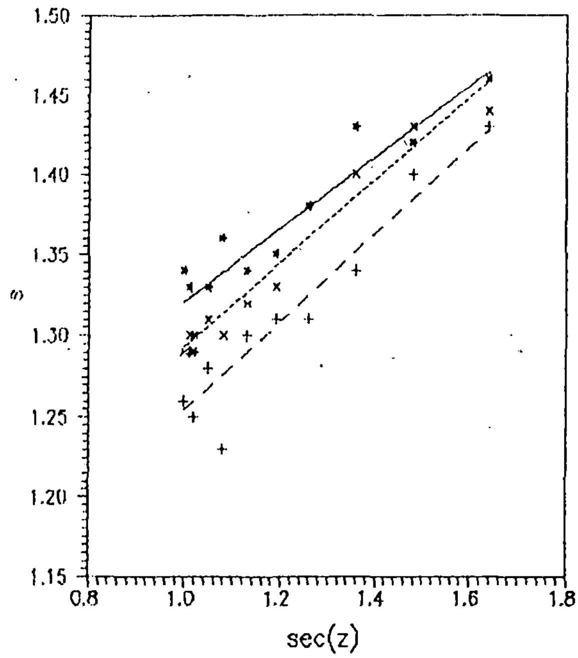

*Fig. 3. Variation of shower age with zenith angle for three different shower size range (* -- N_e = (7.5 - 8.5) x 10^4* , x -- N_e = (1.5 - 2.5) x 10^5 , + -- N_e = (5.5 - 6.5) x 10^5 .

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Study of electrons simultaneously with muons in Extensive Air Showers (EAS) initiated by Primary Cosmic Rays of energy $10^{14}-10^{16}$ eV

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Abstract.

An air shower experiment performed with the provision of direct measurement of both low and high energy muons simultaneously by magnet-spectographs has yielded radial muon density distributions at various measured muon energies and radial electron density distributions as a function of known shower size of measured age. The characteristics of these distributions in terms of the measured shower parameters have been determined to draw conclusions about the mass of the primaries of EAS.

1.- Introduction:

The initial results of the first set of measurements of both the electron and muon distributions in EAS in the size range 10^4 - 10^6 particles (primary energy range 2.2×10^{14} - 4.8×10^{15} eV) have been presented in the previous ICRC sessions (1983, 1985, 1987, 1990) by the NBU group. The direct measurements of muon energies by two magnet-spectographs of the NBU EAS array provide accurate data to form a base for comparison with the predictions of different EAS models for various primary compositions. The present report presents the final results of our first experiment.

2.- Method:

The method was same as we described in previous reports (1983, 1985, 1987, 1990). The magnet-spectographs for recording muons were operated in coincidence with the EAS array of particle density detectors and timing detectors under a fixed set of selection criteria. The average electron and muon densities in each of various narrow shower size bins in the shower size range 10^4-10^6 particles was obtained as a function of r and muon energy E_μ (not exceeding E_μ). These results yield radial distributions for muon density with energy not exceeding E_μ as well as the muon energy spectrum at various muon distances r over the range 0-120 m .

3.-Results:

3.1:-The measured muon energy spectrum.
The muon energy spectra have been measured for various average shower sizes. For average shower size $\bar{N}_e = 2.2 \times 10^4$ particles($\bar{s}$ = 1.25) in the radial range 0-100 m the muon energy spectrum fits to :

$$N_\mu(\geq E_\mu) \sim E_\mu^{\alpha_\mu(r)} \qquad --- \quad (1)$$

where $\alpha_\mu(r)$ changes from 0.26 at about 5 m to 1.01 at about 90 m showing the degree of dependence of energy spectrum of muons on the distances from the EAS axis .

3.2:-Muon density dependence on average shower size $\bar{N}_e$.
For different threshold muon energies and the radial distances from the EAS axis, the results of muon density dependence on shower size fit to :

$$\rho_\mu(\geq E_\mu, r) \sim N_e^{\beta(E_\mu, r)} \qquad --- \quad (2)$$

The exponent β is weakly dependent on r and the threshold muon energy E_μ. For example for muons of energy exceeding 10 GeV at r between 16 and 32 m, the value of β is 0.72 whereas for E_μ > 100 GeV for the same value of r between 16 and 32 m, the value of β is 0.68 .

It is further seen (fig.1) that for low energy muons in showers of size less than $10^{5.25}$ particles the exponent β decreases with r increasing whereas in larger showers of size greater than $10^{5.25}$ particles, β increases with r. For high energy muons β decreases with r in showers of size below and above $10^{5.25}$ particles. At different radial distances and for different low muon thereshold energies β changes around the shower size $10^{5.25}$ particles. Such variation of β implies that the muon radial distribution function changes with the primary energy. The measured muon lateral distribution for each shower size and muon energy exceeding E_μ in the radial range between 0 and 120 m shows a fit to the form

$$\rho_\mu(\geqslant E_\mu, r, N_e) \sim r^{-k(\geqslant E_\mu)} \exp(-r/r_o) \quad --- \quad (3)$$

This shows that the muon lateral distribution function depends on muon energy threshold. The exponent k has the values in the range 0.26 - 1.22 .

The measured data of muon density also fit to a single parameter form :

$$\rho_\mu(\geqslant E_\mu, r, N_e) \sim r^{-\alpha(\geqslant E_\mu)} \quad --- \quad (4)$$

values of α within an error range 8-10 % from the fit of the data for $E_\mu \geqslant 2.5$ GeV. are shown as a function of N_e in fig.2 . The trend of α vs. E_o (the conversion of shower size to primary energy E_o is in accordance with the energy scaling factor of Aliev et. al.[1] and Trzupek et. al.[2]) curve shows that α is a function of energy up to 2×10^{15} eV and becomes constant at higher energies. Such a variation of α with E_o implies that the effective primary mass is decreasing with increasing energy over the range 10^{14} - 10^{15} eV and becomes constant at higher energies.

3.3-Radial distribution of electrons compared with radial distribution of muons:

The radial muon density distribution in young developing showers ($s \leqslant 1.0$)as well as in old decaying showers ($s \geqslant 1.0$)is flatter compared to the radial electron density distribution which is shown in fig.3 for $N_e = 3.3 \times 10^5$.The muon densities in old showers are high than those in younger showers of the same size by a factor two.

4.-Discussion.

The properties of the measured radial distribution of muon density in EAS as a function of primary energy in the range 10^{14} -10^{15} eV indicate continuously decreasing primary mass composition. The measured value and shape of the radial distribution for muons and electrons at small and large distances from the EAS axis are similar to the Monte Carlo results obtained for primary proton initiated EAS (Poirier et al.[3])

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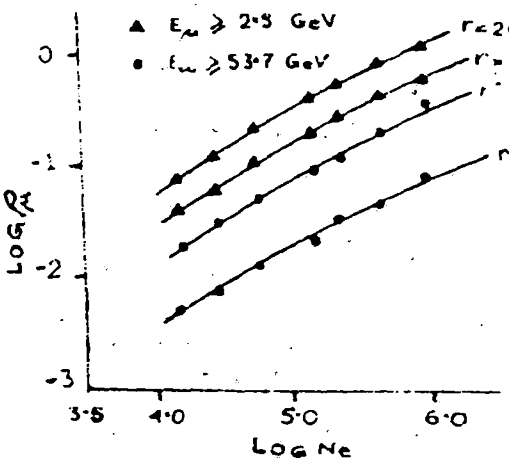

Fig 1

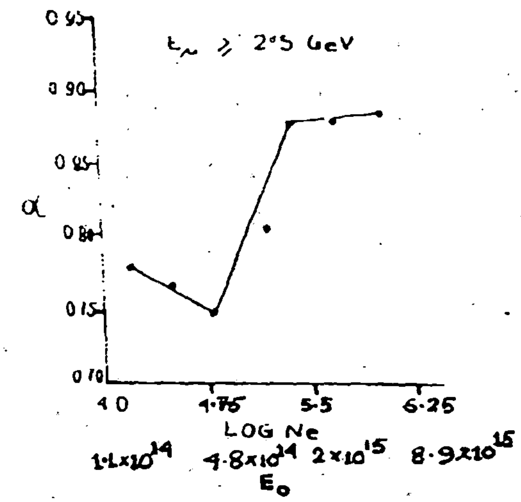

Fig 2

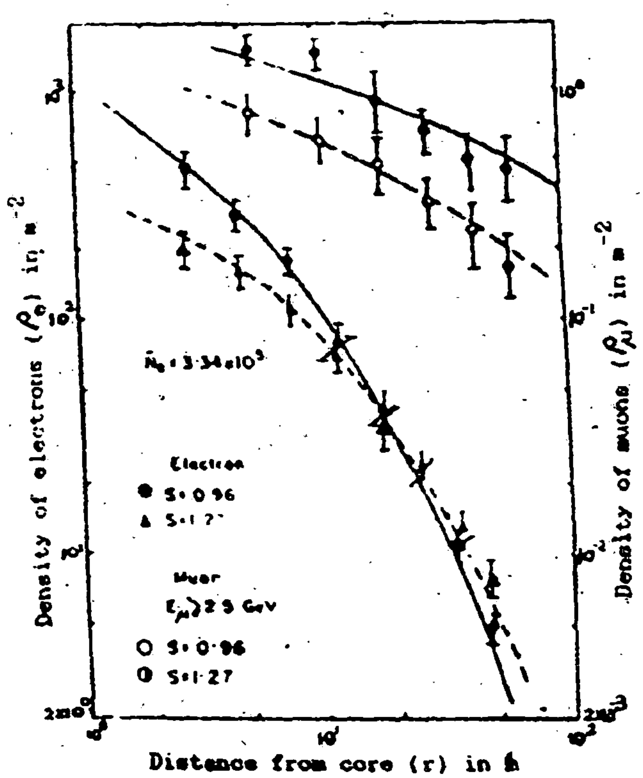

Fig 3

Figure Captions :

Fig.1. Variation of muon density at radial distances 20 m & 50 m with shower size (vertical showers) at $E_\mu \geq 2.5$ & 53.7 GeV

Fig.2. Variation of α with N_e at $E_\mu \geq 2.5$ GeV

Fig.3. Electron and muon lateral density distributions for old decaying and young developing vertical showers.

Low And High Energy Muons In Extensive Air Showers Of Size 10^4 To 10^6 Particles

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Abstract

Accurately measured energy spectra and radial distributions of low and high energy muons in Extensive Air Showers (EAS) are presented and compared with Monte Carlo calculations assuming specific hadronic interaction characteristics of primary protons with air nuclei in the primary energy range $2.2\text{X}10^{14}$ - $4.8\text{X}10^{15}$eV.

I-Introduction:

Knowledge of radial distribution together with energy distribution of muons in EAS is of fundamental importance as such data have explicit energy dependence and are expected to be sensitive to both the primary cosmic ray composition and the characteristics of hadronic interaction with air nuclei.

This paper contains accurately measured data on low and high energy muons detected in association with EAS at sea level. By direct and accurate measurement of muon energy over a wide range of energy and radial distance from the EAS axis, the present experiment provides a firmer base for comparing with the theoretical predictions for different primary compositions.

II-Experiment and Method:

The experimental set up consists of an air shower array of 32 electron detectors and two magnet spectrographs for recording and measuring muon momenta accurately in association with individual EAS incident on the array. The description of the array system and spectrographs was given by Basak et al. (1). Low and high energy muons in the range of 2.5 - 200 GeV in EAS of size 10^4 to 10^6 particles (primary energy range $2.2X10^{14}$ - $4.8X10^{15}$ eV, determined by using the energy scaling factor of N.Aliev et al.(2)and A.Trzupek et al.(3)) were recorded by the two spectrographs simultaneously with the recording of the EAS events by the array. The EAS parameters such as shower size(Ne),age paramete(s), EAS axis location and the radial distance of each recorded muon were determined by the method of least squares.

The recorded muon deflection angle is converted to incident momentum of muon (momentum resolution of spectrograph 17% to 38% for energy range 2.5 - 200 GeV) by the method described by Basak et al.(1). The density of muons of energies above a threshold value in EAS of measured parameters was determined as a function of muon radial distance from the shower core.

III-Results:

Some of the representative experimental data, with typical poissonian error on a few points only, in the form of muon lateral distribution for a fixed shower size at different threshold energies (fig.1), muon energy spectrum at a fixed radial distance for two different shower sizes (fig.2) and the variation of muon density with average shower size with threshold muon energy of 2.5 GeV at two different radial distances from the shower core (fig.3) are shown.

A comparision of the measured electron lateral distribution (fig.4), muon lateral distribution (threshold energy 2.5 GeV) (fig.5) and the ratio of muon and electron density for different shower sizes (fig.6) with data calculated by Monte Carlo simulation of Poirier et al. (4) utilising simulation codes SHOWERSIM (model WOO) and EGS for proton primaries is also given. The hadron-hadron interaction model WOO (details presented by Mikocki et al. (5)) has scaling behaviour below 1 TeV but at higher energies the scaling is mildly violated in the fragmentation region and significantly violated in the central region. The hadron-air interaction cross section and the multiplicity of pions and kaons increase with energy but the inelasticity distribution (1/2 for nucleons and 2/3 for mesons) and the transverse momentum distribution (325 MeV/c for pions and 371 MeV/c for kaons) are independent of energy.

Discussion:

The present measurements of energy spectra and radial distributions of muons do not provide any evidence for heavy primaries (in the primary energy range $2.2 \times 10^{14} - 4.8 \times 10^{15}$ eV). The hadronic interaction characteristics assumed in the above mentioned model are found to be consistent with the measured data upto the fixed shower size of 10^5 particles. Using the same hadronic interaction characteristics the shape of the muon density distribution in primary iron initiated EAS is similar to that for proton initiated shower with the same primary energy but the magnitude of the distribution is higher for low energy muons in the vicinity of the EAS core (0 to 100 meter). The present experiment does not find such features in the observed muon data. The measured electron lateral distribution is in good agreement with the calculated distribution but the measured muon lateral distribution is much broader than the calculated. The same feature can be seen in the density ratio distribution (fig.6) which also shows that both the measured and calculated ratio exceeds unity beyond the distance of 100 meter from the core.

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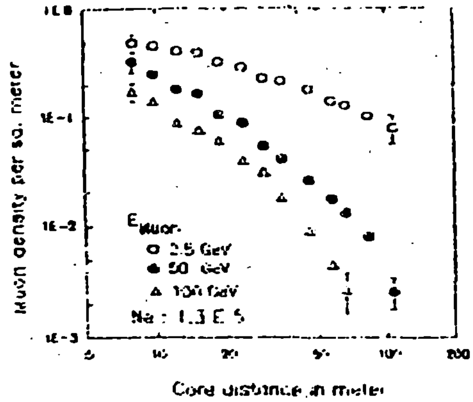

Fig. 1 Muon lateral distribution.

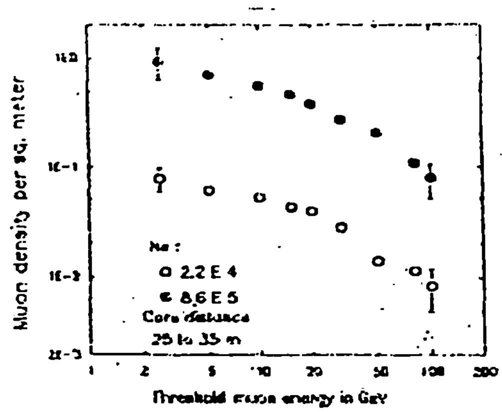

Fig. 2 Muon energy spectrum

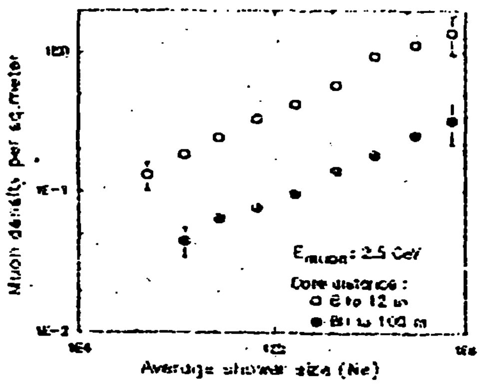

Fig. 3 Muon density and Ne distribution

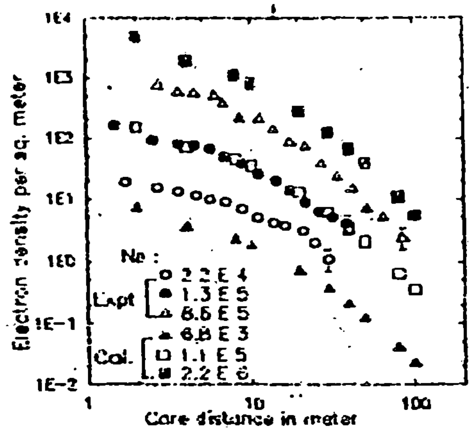

Fig 4 Electron lateral distribution

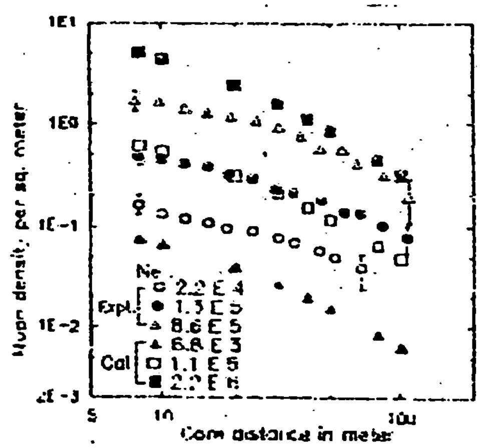

Fig. 5 Muon lateral distribution

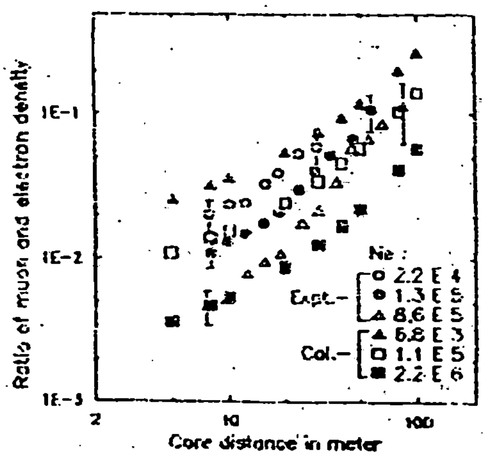

Fig. 6 Density ratio distribution

A SEARCH FOR ANISOTROPY IN THE ARRIVAL DIRECTION OF EAS BY COSMIC RAYS FROM DISCRETE SOURCES

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ABSTRACT

The NBU Cosmic Ray Telescope consisting of an EAS array of scintillation detectors and two magnet spectrographs has been operated in a search for any anisotropy in the directions of arrival of EAS events. The shower arrival directions are determined by fitting the measured shower particle arrival times. Initial results on distribution of events in declination and right ascension are given.

Introduction : A cosmic ray air shower telescope has been installed at a new location (latitude $26^{o}42'$ N, longitude $88^{o}21'$ E) to look for any anisotropy in the directional intensity of primary cosmic rays in the energy range 10^{14}-10^{16} eV. The set up consisting of plastic scintillation detectors for electrons, two shielded magnet spectrographs for muons and eight fast timing scintillation detectors for shower particles arrival time measurements has been in operation for some time now. Preliminary results from the measurements of shower arrival directions are presented in this report.

Method of analysis : Some 13 thousands EAS events have been registered by the EAS array so far. For each event the shower parameters : the shower size (N_e), the shower age (S) and the shower core location (X_o, Y_o) have been determined using a fitting function to fit the measured electron density data by an iterative procedure for minimizing chisquare using gradient search method. The analysis on a selected group of showers in the size range $10^{4.3}$-$10^{6.2}$ has led to

the following error estimates:
(i) core location error is within ± 1 m,
(ii) shower size error is $\pm 0.1\ N_e$,
(iii) age parameter error is within ± 0.06.

The arrival direction of the shower is determined fron the measured relative arrival time delay data by minimizing the quantity,

$$\chi^2 = W_i\ [lx_i + my_i + nz_i + c(t_i - t_o)]^2,$$

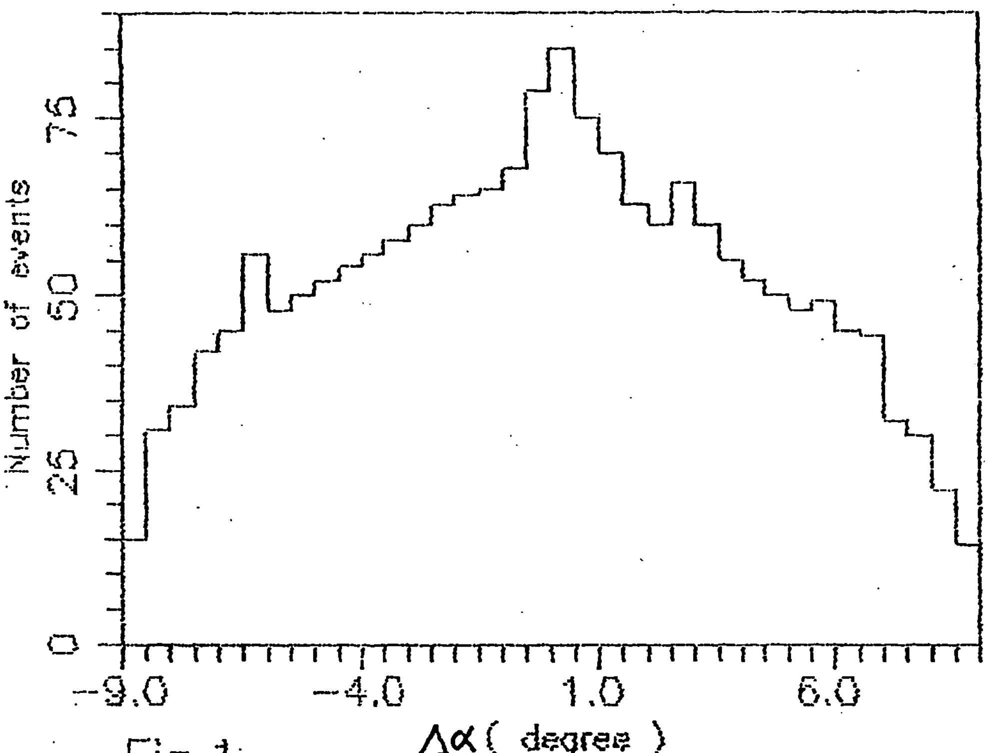
where t_i is the actual time measured by the ith detector, W_i is the statistical weight factor, c is the velocity of the EAS front which passes through the origin at t_o and l, m, n are the direction cosines of arrival.

From the best fitted values of direction cosines the direction of arrival of each EAS event has been determined in local coordinate system (zenith angle, azimuth angle). Finally the EAS arrival direction angles are transformed into right ascension (α) and declination (δ). The resolution of the EAS array has been determined by the divided array method using those events in which all the timing detectors yielded information about the arrival time of the EAS front. The systematic and statistical uncertainties in the measurement of arrival direction have been determined and taken into account in the analysis. The estimated resolutions are 1.1° in declination and 1.6° in right ascension.

Results : Preliminary results from a small sample of shower arrival time data are given. The measured data on resolution of the EAS array are given in figures 1 and 2. The distribution of all the EAS events in declination (δ) is given in figure 3. The observed declination range is within -40° and $+88^\circ$ with a peak at 32°-34° bin. Similar declination distribution of Mitsuishi EAS data (Fujita et al.,1993) showed a peak within 30°-40°. The right ascension (α) distribution is shown in figure 4. This distribution in right ascension has not been corrected for any effect arising out of occasional discontinuities in running time.

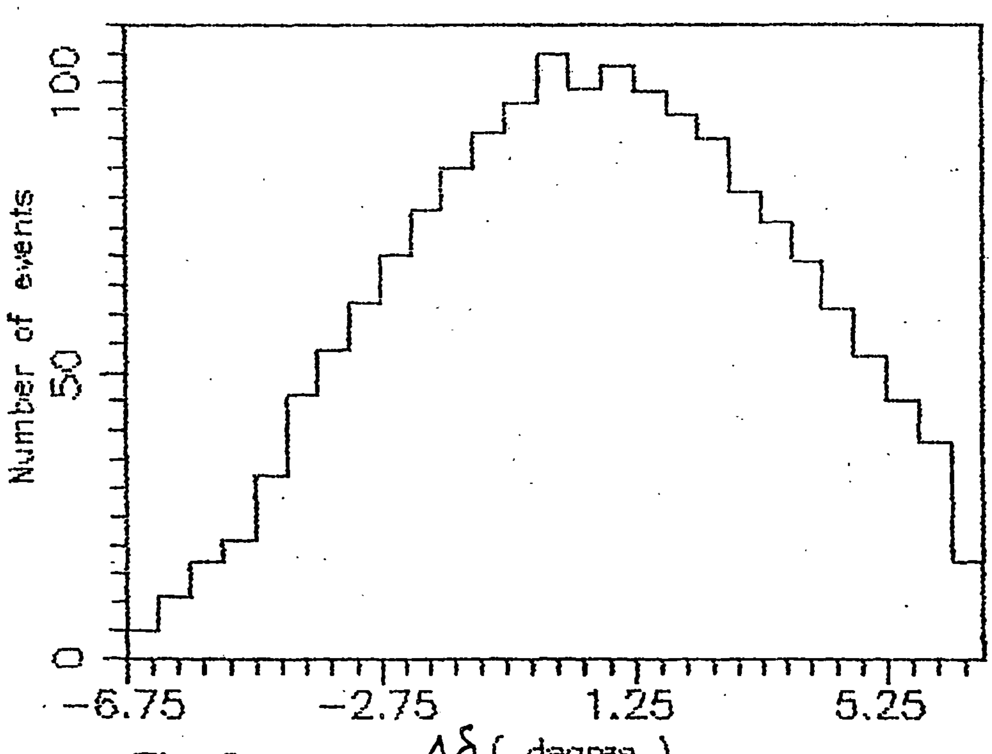
Reference :

Fujita K. et al, Proc. 23rd ICRC, Calgary, 1(1993)376



Number of events
0
25
50
75
-9.0
-4.0
1.0
6.0
Δα (degree)

Fig.1



Number of events
0
50
100
-6.75
-2.75
1.25
5.25
Δδ (degree)

Fig.2

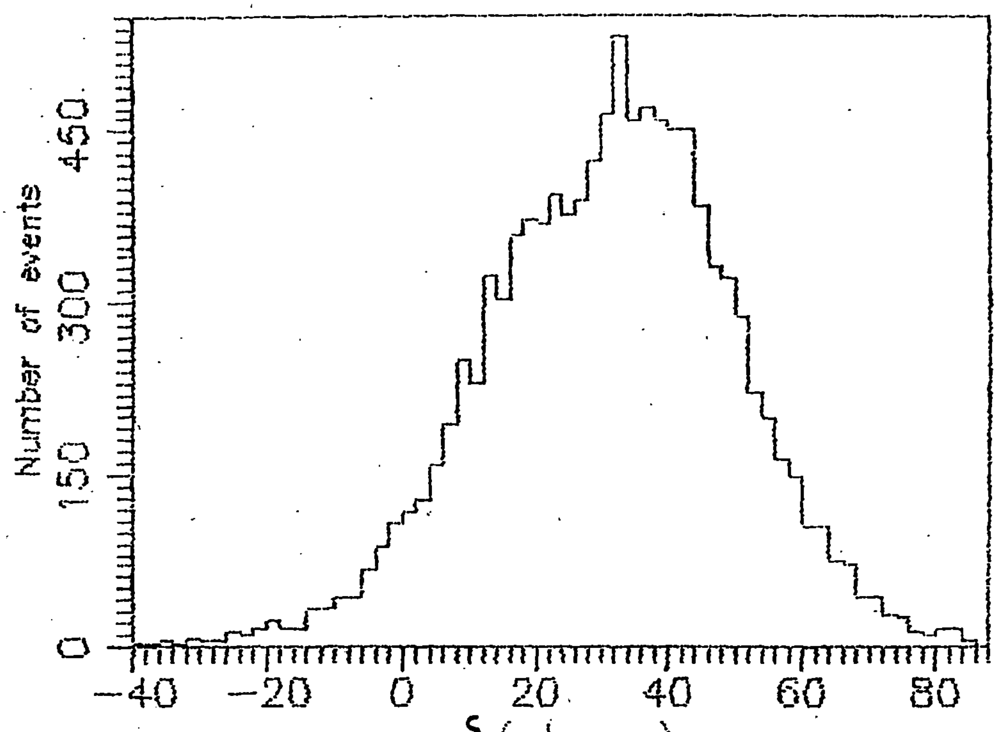

Number of events
0
150
300
450
−40
−20
0
20
40
60
80
δ (degree)

Fig.3

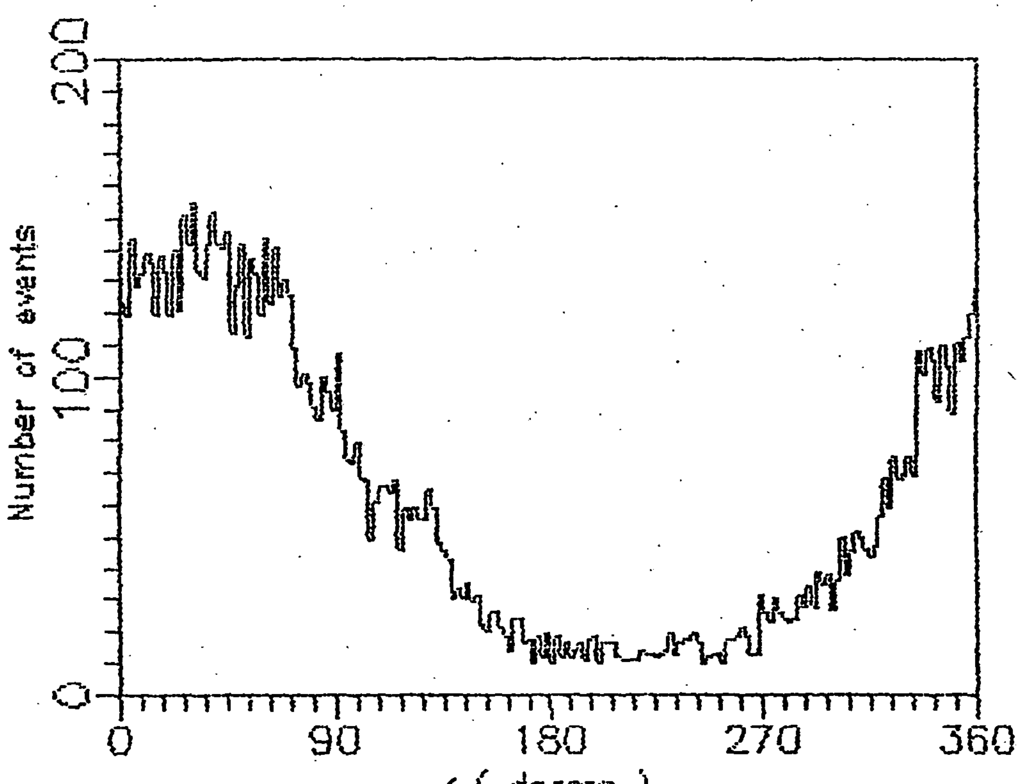

Number of events
0
100
200
0
90
180
270
360
α (degree)

Fig.4