PREFACE

The characteristic features of primary cosmic radiation (PCR) such as wide energy spectrum (from $\sim10^9$ to $\sim10^{20}$ eV), a "knee" at around $5X10^{15}$ eV and an "ankle" at around 10^{19} eV, nuclear charge composition at higher energies, the directional distribution, and the problem of origin of PCR atomic nuclei have been the subject of investigation for more than 30 years now. Some of the sources of PCR nuclei may also be the sources of ultra high energy (UHE) ($\geq10^{14}$ eV) gamma rays. Determination of the origin of PCR nuclei and a search for UHE gamma ray sources by the detection of UHE gamma rays through atmospheric shower of particles [Extensive Air Shower(EAS)] and the investigation of the "knee" and "ankle" features of the PCR spectrum by the EAS technique have been the thrust in the current research in this field.

The North Bengal University (NBU) EAS programme was started in 1980. I joined the NBU programme holding the University Grants Commission (UGC) junior research fellowship in 1994 when the experiment on detection of both low and high energy muons in EAS was being carried out by two muon magnetic spectrographs in conjunction with the air shower array. I participated in this experiment for about a year and then started developing a new air shower array set up for observing discrete point sources of cosmic gamma rays. In the part "A" (chapter- 2, 3 & 4) of this thesis , my work on the development and use of new air shower telescope set up for cosmic gamma ray observation is described. In part "B" (chapter-5) of the thesis, a summary is given of the work done (and published) on low and high energy muons in EAS.

My contribution to the work included in part "B" is the following-

(1) Calibration of the scintillation detectors.
(2) Operation and day-to-day maintenance of the magnetic spectrographs.
(3) Data taking and analysis.

My contribution to the work included in part "A" is the following-

(1) Development of a new Computerised data acquisition system (Chapter-2).
(2) Re-arrangement of the detector array and resetting the individual detectors (Chapter-2).
(3) Calibration of the detectors (Chapter-2).
(4) Calibration of Analog-to-Digital Converter(ADC) and Time-to-Digital Converter(TDC) (Chapter-2).
(5) Instrumental uncertainty measurement (Chapter-2).
(6) Operation and day-to-day maintenance of the set up.
(7) Data taking.
(8) Development of Computer programmes for the determination of shower parameters from the observed shower data(Chapter-3).
(9) Development of Computer programme for the determination of direction of observed showers(Chapter-3).
(10) Estimation of errors in shower parameters(Chapter-3)
(11) Estimation of angular resolution (Chapter-3).
(12) Determination of sensitivity (detection efficiency and triggering probability) of the telescope (Chapter-3).

The design and construction of the new EAS telescope is the main work done here during the last three years for observing from a new site (latitude $26^{o}42'$ N, longitude $88^{o}21'$ E) in the northern hemisphere several gamma ray sources e.g. Cygnus X-3, Hercules X-1, Crab nebula, which have been under observation by Cerenkov telescopes and EAS telescopes from a number of other sites. To detect reliably UHE particle emission from specific directions and to search for clustering of arrival directions, the characteristics of the EAS telescope such as angular resolution, sensitivity of the array telescope have been determined using the normal EAS events due to the charged primary cosmic ray nuclei, which form the background for the UHE directional showers. The characteristics of the telescope have been determined for accurate measurements of important shower parameters and shower characteristics which in very early EAS experiments were studied with less precise measurement technique. The fundamental aspects and requirements in EAS measurements have been given attention to for reliable shower identification and for ensuring that the inefficiencies and inaccuracies in the measurements do not affect the final results and conclusion inferred from these measurements. The present study using the new EAS telescope includes-

(13) Study of the fundamental properties of EAS(Chapter-4).

(i) Lateral distribution of Electrons , (a) dependence of lateral structure function for electrons on zenith angle and (b) dependence of lateral structure function of electrons on shower size.

(ii) Shower size distribution and shower age distribution .

(iii) EAS angular distributions.

(iv) Barometric coefficient from zenith angle distribution.

(v) Absorption length of EAS from zenith angle distribution.

(vi) Integral shower size spectrum measurement.

(14) Study on shower age parameter (Chapter-4)

(i) Variation of shower age with shower size.

(ii) Dependence of shower age on zenith angle.

(iii) Study on local age parameter.

The various properties of EAS studied by early workers as well as the facts found have been re-examined and the following features have been found in the present work.

(1) Structure of the lateral distribution of electrons in EAS is independent of shower size and zenith angle in the shower size range $7X10^4$ to $1X10^6$.
(2) Barometric coefficient obtained from the zenith angle distribution increases with the increase of shower size. This is an indication for the increase of the primary spectrum index with the increase of primary energy.
(3) Absorption length of EAS has been determined from the zenith angle distribution and is consistent with result obtained by other method.
(4) The "knee" of the integral size spectrum changes its position at the different observation levels by about two times the present result.
(5) The " knee" of the primary spectrum obtained is around $3X10^{15}$eV.
(6) The average age parameter slowly decreases with the increase of shower size upto 10^6 particles (variation within 15%).

(7) The local age parameter decreases as radial distance increases from the shower core and reaches a minimum at around 32m from the shower core beyond which it increases again.
(8) Variation of shower age with zenith angle is slow and is in accordance with the photon-electron cascade theory.
(9) The effective PCR nuclear mass decreases in the "knee" energy region between $3.4X10^{14}$eV and $4.6X10^{16}$eV.

I have contributed to a number of papers (published and under publication).
I submit the list of these papers and some reprints & preprints as annexture to the thesis as an additional support to the candidature.

(1) An experimental study of primary cosmic rays at the knee energy region by observation of Extensive Air Shower (EAS).
G.Saha, A.Bhadra, C.Chakrabarti, S.K.Sarkar and N. Chaudhuri.
IL NUOVO CIMENTO, 1997 (date of acceptance - Oct. 2,1997; Ref. No. 7106 NCC).

(2) The NBU extensive air shower telescope for observation of UHE point sources.
A. Bhadra, S.K. Sarkar, C.Chakrabarti, B. Ghosh and N. Chaudhuri.
Accepted for publication on 13.03.1998 in *Nuclear Instruments and Methods in Physics Research*, Section - A.

(3) A new data acquisition system for the NBU EAS array.
C. Chakrabarti, A. Bhadra, S.K.Sarkar and N. Chaudhuri.
25th International Cosmic Ray Conference, 1997, HE 2.6.

(4) Zenith angle dependence on shower age.
A. Bhadra, C. Chakrabarti and N. Chaudhuri.
25th International Cosmic Ray Conference, 1997, HE 2.1.18.

(5) Study of Electrons simultaneously with Muons in Extensive Air Shower (EAS) initiated by primary cosmic rays of energy 10^{14}-10^{16} eV.
C. Chakrabarti, D. Chanda, G. Saha, A. Mukherjee, A. Bhadra, S.Sanyal, S. Sarkar, B. Ghosh and N. Chaudhuri.

24th International Cosmic Ray Conference, Rome, 1995, **1**, 387.

(6) Low and high energy muons in Extensive Air Showers of size 10^4 to 10^6 particles.
C. Chakrabarti, D. Chanda, G. Saha, A. Mukherjee, A. Bhadra, S.Sanyal, S. Sarkar, B. Ghosh and N. Chaudhuri.
24th International Cosmic Ray Conference, Rome, 1995,**1**, 569.

(7) A search for anisotropy in the arrival direction of EAS by cosmic rays from discrete sources.
C. Chakrabarti, D. Chanda, G. Saha, A. Mukherjee, A. Bhadra, S.Sanyal, S. Sarkar, B. Ghosh and N. Chaudhuri.
24th International Cosmic Ray Conference, Rome, 1995, **1**, 462.

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