PREFACE

The quest for understanding the basic nature of matter, which began in the earlier days of Greek philosophers about 2500 years ago with a purely speculative concept of four eternally existing elements viz., Earth, Water, Air and Fire, has witnessed a lot of changes till it came to the present days of most organized researches in Particle Physics. In its evolutionary path, the discovery of atomic and molecular structure of matter was an important step forward as it gave birth to the concept of 'elementary particles' to be the fundamental constituents of matter. But again, as the inner and inner strata of matter was reached and investigated, this label of 'elementary particles' declaring the prestigious status of being the fundamental blocks for building the whole material universe, too, has changed its bearer a number of times starting from the Dalton's 'indivisible atom' to the so called 'quarks' of the modern days. And possibly, nothing could have served this quest better than the discovery of 'Cosmic Rays' in the second decade of this century.

Ever since their discovery, 'Cosmic Rays' have been a subject of serious scientific research. When it was understood that the incidence of a single cosmic ray particle at the top of the atmosphere initiates a cascade of secondary particles resulting into what is popularly known as 'Extensive Air Shower' (EAS) that could be studied at ground stations, a number of air shower arrays have been constructed to study the different properties of EAS. Numerous experiments have been performed at these air shower arrays, large & small, situated at different altitudes to investigate different components of EAS. These investigations have gathered a lot of information by interpreting the observed EAS properties in terms of the nature of primary cosmic ray (PCR) and characteristics of particle interactions at high energies. However, in the absence of direct observations which become more and more difficult owing to the decreasing flux of PCR at high energies, the detailed knowledge of these two aspects- the composition of PCR and the characteristics of particle interaction at cosmic ray energies ($E_0 > 10^{14}$eV), are still far from complete. Hence, the study of the characteristic properties of different components of EAS and their correct interpretation is a subject of contemporary interest, which is being pursued by different group of investigators around the world. The present experiment whose results are being reported in this thesis was also a part of an ongoing investigation of electron and muon components of EAS being performed with NBU air shower array situated at near sea level.

The experiment on cosmic ray EAS with the NBU air shower array was started in the year of 1982 with a research project funded by Department of Atomic Energy, Government of India. The array, initially commissioned with 16 plastic scintillation detectors for the measurement of electron density and two magnetic spectrographs along with one neon flash tube chamber for the recording and energy measurement of muons with minimum threshold energy of 2.5 GeV associated with EAS of sizes 10^4 to 10^6 particles, at present consists of 29 scintillation detectors among which 8 are fast timing detectors for the determination of arrival direction of the recorded showers. But, when the present experiment was performed, the array was operational with 21 scintillation detectors and the two magnetic spectrographs. The details of the experimental arrangement are presented in section–I of chapter III.

The author of this thesis joined the research project in 1987 as a Junior Research Fellow of Department of Atomic Energy and participated in all the activities of preparing for the experiment and also during the actual performance of the experiment. But, just after the completion of the experiment, the author had to leave with a teaching assignment offered by Government of Sikkim. Then, the subsequent analysis of the data collected in the experiment was continued by the author working as a part-time scholar of the laboratory during the vacations. Some of the results of preliminary analysis are reported in some published papers whose list along with reprints of the papers is enclosed here. However, the various responsibilities associated with the Government assignment and inevitable long gaps between the vacations did not help much in the completion of analysis. But, fortunately, again in 1996-97 the author got an opportunity of joining the laboratory for one year as a Teacher Fellow sponsored by University Grants Commission, India, under its Faculty Improvement Programme. It was then, the pending part of the analysis was undertaken and completed. That explains the delay in reporting the results of the experiment, which, otherwise, has no reflection regarding the commitment of the author. If, in any way, the completion of the project has anything to reflect, then it is the firm persuasion with kind assurance and whole hearted co-operation of Prof. N. Chaudhury, the Principal investigator of the project and the supervisor of the author for his Ph.D. assignment.

The contribution of the author during the performance of the experiment and the subsequent analysis of the data can be listed as below:

1. The calibration of all the 21 scintillation detectors before the starting of the experiment.

2. Checking the alignment of the two magnetic spectrographs.

3. Rechecking the stability of the magnetic field inside the magnet and measurements of leakage field outside the magnet. (Reported in section 3.1.2 of Chapter III).

4. The determination of the maximum detectable momentum (m.d.m.) of the magnetic spectrographs and the estimation of the error in deflection measurement caused by multiple coulomb scattering and the loss of energy by muons in the material of the magnet. (Reported in section 3.6.2 of Chapter III)

5. The analysis of the artificially simulated air showers, the determination of detection efficiency of the array and the uncertainties in the determination of the shower parameters. (Reported in section 3.7 of Chapter III).

6. The operation and routine checkups of different units of the array during performance of the experiment.

7. Data taking and making them ready for further analysis.

The analysis of data after the performance of experiment undertaken by the author includes:

1. The analysis of electron density data for the determination of the shower parameters. (Section 3.5 of chapter III).

2. The reconstruction of the trajectories of the muons recorded photographically by the magnetic spectrographs for determination of the deflection suffered by muons to estimate their energy. (Section 3.6 of chapter III).

3. The study of distribution of electrons in EAS. (Reported in section 4.2 of chapter IV)

4. The study of distribution of muons for different muon energy thresholds (2.5 to 100 GeV) associated with EAS by studying the variation of its density with the distance from the shower core (r), the size of the shower (Ne) and the threshold energy ($\geq E_{\mu}$). (Reported in section 4.3 of chapter IV)

5. The study of variation of total number of muons for different muon energy thresholds ($\geq E_\mu$) with the size of the air showers and the integral energy spectrum of the muons in EAS of different sizes. (Reported in section 4.4 of chapter IV)

6. The comparative study of the measurements of present experiment with those of the other experiments. (Reported in section 4.5 of chapter IV)

7. The comparative analysis of the results of present experiment with those obtained by theoretical simulations of EAS events using various models of high energy particle interactions as reported by different authors. (Reported in section 4.6 of chapter IV.)

Furthermore, a brief introduction of cosmic rays and the phenomenon of EAS as a whole and introductory remark on the different techniques of theoretical simulation of air shower events and the models used thereby, in general, are presented in Chapter I. A brief review of the different experimental works investigating the electron and muon components of EAS are presented in sections 2.1 & 2.2 of Chapter II. Similarly, a review of different theoretical calculations of EAS performed by various authors using different theoretical models of high-energy particle interaction is presented in section 2.3 of chapter II.

The results obtained from the measurements of present experiment and the important conclusions drawn from them are discussed and summarized in section 4.7 of Chapter IV. The measurements of present experiment are seen to be consistent with those of the other experiments and their comparative analysis with the results of theoretical calculations, as reported by different authors, show that they are fairly well represented by the calculated results of Quark Gluon String (QGS) model of high energy particle interaction with normal mixed composition of primary cosmic ray.

Lastly, for the support of the candidature of the author, the list of the previously published papers in which the author had contributed is given here. The reprints of some of these papers are attached at the end of this thesis.

1. A NEW MULTIDETECTOR SYSTEM FOR HIGH ENERGY COSMIC GAMMA-RAY WORK

   N. Chaudhuri, G. C. Goswami, B. Ghosh, S. K. Sarkar, N. Chaudhuri, R. Chhetri and S. Sanyal

   Proc. IEEE (1989) *Nucl. Sci. Symp.*,.Livermore, U.S.A.

2. ENERGY SPECTRUM OF PRIMARY COSMIC RAYS FROM AIR SHOWER OBSERVATIONS AT SEA LEVEL.

   B. Ghosh, S. Sarkar, N. Chakrabortrty, D. K. Basak, B. Bhataacharya, R. Chhetri, S. Sanyal and N. Chaudhuri.

   Proc. 21st ICRC (Adelaide 1990) **3** 133

3. NEW MEASUREMENTS AND ANALYSIS OF HIGH ENERGY MUONS IN COSMIC RAY EXTENSIVE AIR SHOWERS

   S. K. Sarkar, B. Ghosh, N. Mukherjee, R. Chhetri, S. Sayal, D. K. Basak and N. Chaudhuri

   J.Phys. G: Nucl. Part.Phys. **17** (1991) 1279

4. LOW AND HIGH ENERGY MUONS IN EXTENSIVE AIR SHOWERS OF SIZE 10^4 TO 10^6 PARTICLES

   C. Chakraborty, D. Chanda, G. Saha, A. Mukherjee, A. Bhadra, S. Sanyal, R. K. Chhetri, S. K. Sarkar, B. Ghosh and N. Chaudhuri

   24th ICRC (Rome 1995) **1**, 569

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

   C. Chakraborty, D. Chanda, G. Saha, A. Mukherjee, A. Bhadra, S. Sanyal, R. K. Chhetri, S. K. Sarkar, B. Ghosh And N. Chaudhuri

   24th ICRC (Rome 1995) **1**, 462