CHAPTER VII

SUMMARY

A study on muons of energy \( \geq 150 \text{ Gev} \), associated with EAS, has been made for showers in the size range \( 10^5 - 5 \times 10^6 \). The study was made using an air shower array at the surface in coincidence with a muon detector placed at a depth of 194 m underground in Kolar Gold Fields, India. The investigation was carried out in collaboration with TIFR, Bombay.

The results presented in the thesis are based on the analysis of \( \sim 4000 \) showers recorded in coincidence with underground detector and \( \sim 10,000 \) showers recorded without the requirement of coincidence with the underground detectors. The results presented in the thesis are:

1) the differential spectrum for the showers recorded in coincidence with a muon of energy \( \geq 150 \text{ Gev} \), is a power law expressed as

\[
\frac{d\Phi}{dN} = (1.15 \pm 0.2) \times 10^{-13} \left( \frac{N}{10^5} \right)^{-2.30 \pm 0.09} \text{ dN m}^{-2} \text{ Sec}^{-1}
\]
ii) the differential spectrum for all the showers recorded by the array is given by
\[ F(N) \, dN = (1.01 \pm 0.10) \times 10^{-10} \left( \frac{N}{10^5} \right)^{-2.78 \pm 0.04} \, dN \, m^{-2} \, \text{Sec}^{-1} \]

iii) the number of muons \( n_\mu (\geq 150 \, \text{Gev}) \) varies with the shower size \( N \) as
\[ n_\mu (\geq 150 \, \text{Gev}) = (27 \pm 7) \left( \frac{N}{10^5} \right)^{0.47 \pm 0.05} \]
in the size range \( 10^5 \leq N \leq 5 \times 10^6 \),

iv) the energy spectrum of muons in the energy region \( 150 \leq E_\mu \leq 640 \, \text{Gev} \), may be expressed as a power law \( (E_\mu^{-\beta_\mu}) \) with a power index \( \beta_\mu = 1.30 \pm 0.16 \).

Number of muons, with threshold energies \( \geq 150 \, \text{Gev} \), has been calculated on the basis of four different models of the nuclear-interaction. The calculations have been carried out both for the proton primaries as well as for a mixed primary composition which remains constant throughout the primary energy range considered. The model calculations predict a \( n_\mu -\text{Ne} \) variation, which goes as \( \text{Ne}^{0.6-0.8} \), and the assumed models do not reproduce the observed variation. Two possibilities for obtaining the
observed n-Ne variation are considered. It is shown that if one assumed a primary composition, which is varying with energy and is subjected to galactic rigidity cut-off in the relevant energy range, it is possible to reproduce the observed variation by selecting a proper model. However, the second possibility, viz. that of a possible change in the characteristic of the nuclear interactions at high energies ($\geq 10^{14}$ eV), cannot be ruled out.

Experimental data, on the particles detected at underground level in association with EAS, obtained by means of a NFT hodoscope are presented. It is shown that majority of the particles, recorded by the UG detector in association with EAS, are located in the vicinities of the respective cores. The distribution of the muon directions with the zenith is found to be of the type

$$I (\theta) \propto (\cos \theta)^{7.6 \pm 1.4}$$

This distribution is indicative of a steep zenith angle distribution for the recorded EAS. Order-of-magnitude calculations are given to show that the parallel-pair particles detected in association with EAS form part of EAS and are produced in the atmosphere. The electromagnetic interactions of the muons with matter are found to be consistent with the theoretical predictions. Some cases of large bursts, of high energy particles, recorded during the investigation have been presented.