CHAPTER I

INTRODUCTION

I.1 The Nature of Cosmic Rays.

Cosmic rays are not really like rays at all such as light rays or radio waves. C.T.R.Wilson(1) discovered ionization caused by this kind of rays in the year 1900 in the investigations of electrical conductivity of gases. He suggested that the ionizing agency was an extremely penetrating radiation which may be of extra-terrestrial origin. Later investigations by Rutherford and Cooke(2) showed that cosmic rays are a stream of the tiniest particles pouring down from all directions into the earth's atmosphere at terrific velocities. Later investigations showed that these particles come from outer space and they are now known as the primary cosmic rays.

From the study of the latitude and east-west asymmetry effect we know that the primary cosmic rays are electrically charged. They consist of protons, alpha particles and a smaller extent of heavier nuclei. According to Glasstone(3), about 78 per cent of the primary particles are protons, 20 per cent are alpha particles and 2.5 per cent are heavier nuclei which have atomic number between 3 and 26 (Lithium to iron). The energy range of the primary cosmic rays is between 10^9 eV to 10^{18} eV, the mean being approximately 10 BeV.

Most of the primary particles interact with oxygen and nitrogen nuclei at the top of the earth's atmosphere. The result is the nuclear disintegrations in which secondary particles are produced. The secondary particles have lower energies, and are different in nature from the primary particles. They consist of alpha particles, protons, neutrons, pi-mesons, mu-mesons, electrons and photons. If τ-mesons are liberated, they will decay into pi-mesons in most instances. The following are examples of decay frequently occurred:

Particle	Character of Decay	Mean Life (sec)
$\mu^{\pm}$-mesons	$\mu^{\pm} \rightarrow e^{\pm} + \nu + \bar{\nu}$	2.1×10^{-6}
$\pi^{\pm}$-mesons	$\pi^{\pm} \rightarrow \mu^{\pm} + \nu$	2.6×10^{-8}
π^{0}-mesons	$\pi^{0} \rightarrow 2\gamma$	$\cong 10^{-16}$
$K^{\pm}$-mesons	$K^{\pm} \rightarrow \mu^{\pm} + \nu$	$\cong 10^{-9}$
τ-mesons	$\tau^{\pm} \rightarrow \pi^{\pm} + \pi^{\pm} + \pi^{\mp}$	$\cong 10^{-9}$

I.2 Cosmic Showers.

A primary cosmic ray particle of high energy can cause many of secondary particles, and a number of downward directed secondary particles sometimes accompanied by photons makes simultaneous appearance. This phenomena, having a common ultimate origin in an event caused by one primary particle, is called " Cosmic Shower".

There are two types of cosmic showers, as explained by Rossi(4), one is the cascade shower, the other is penetrating shower. The cascade shower is initiated when a high energy electron produces one or more photons of energy comparable with its own in its passage through matter. A pair production is formed by conversion of photon into electron and positron. The secondary electrons in turn produce the same effect as the primary. Thus the number of particles are increased accordingly. This cascade shower continues until the level of energy is lower than that of a pair production energy, i.e., about 1.1 MeV.

On the other hand the penetrating shower is a shower in which some particles are created so as they can penetrate into an absorber further than possible for electromagnetic radiation. This is approximately 15-20 cm of lead. Such particles are mainly mu-mesons because mu-mesons interact with nuclei very weakly. The cosmic showers are presumably initiated high in the atmosphere by a single cosmic ray particle having energy approximately 10^{15} - 10^{17} eV, extending over a large area, of the order of 300 meters in diameter, at sea level. In such a case we call it the " Extensive Air Shower" or " Auger Shower".

I.3 <u>Cosmic Ray Variations</u>

At any place in the atmosphere we find both the primary and the secondary cosmic rays. Near the top of the atmosphere they are mainly primary particles, i.e., protons and alpha particles. At the lower altitude the number of these particles decrease rapidly while the secondary particles mainly electrons and photons increase. The number of the secondaries increase to a maximum at the altitude of some where between 15 and 20 kilometres, and then decrease rapidly with decreasing altitude.

At sea level the number of mu-mesons account for more than half of the total number of charged cosmic ray particles. However, there exist also protons, electrons and neutrons at sea level.

Particles of energy lower than a certain limit can not come into the atmosphere. This phenomena is explained in Fermi(5). The limit of energy is a cut-off energy level in which particles of energy more than this energy can only pass. The cut-off energy level were studied by Störmer (6) and later developed by Lemaître and Vallarta (7). If the energy of the particle is low, it will never get to the earth and may move along one of the earth magnetic lines to end up at the one of the earth magnetic poles. For example, the cut-off energy level of protons at geomagnetic equator is about 14 BeV and that at 50° geomagnetic latitude is 1.5 BeV.

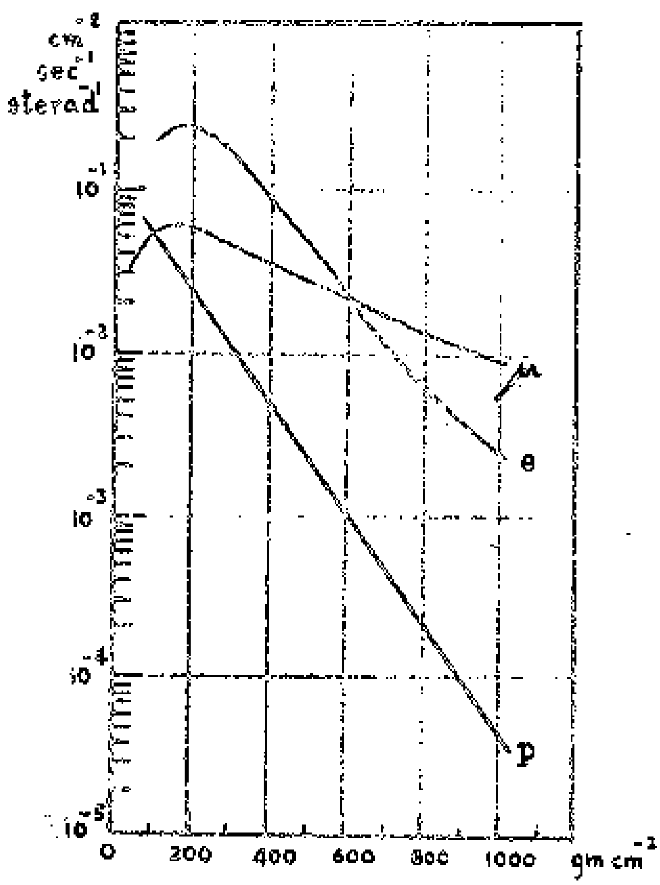

Fig.E. Vertical intensities of various cosmic ray components at 50° geomagnetic latitude, as the functions of atmospheric depth [after Rossi(4)]

From the study of absorption of cosmic rays in matter, as shown by Rossi(8), Street, Woodward and Stevenson(9) it is known that there are 3 types of radiation, soft component and hard component of cosmic rays. The soft component consists mainly of electrons, positrons, photons, a small number of slow mesons, neutrons, protons and heavier particles that are absorbed rapidly by 10 cm of lead. The hard component consists mainly of highly energetic mesons, mostly μ-mesons, fast protons, neutrons, electrons and photons of extremely high energy which are able to pass through 10 cm of lead. The other type, causing nuclear reactions, resulting sometimes in the formation of cosmic ray stars in nuclear emulsion plate, is called nuclear interaction component of cosmic rays.

The variation of intensity of cosmic rays due to the deflection of electrically charged particles in the earth magnetic field is called "Latitude Effect". The intensity is least at the geomagnetic equator and increases as the high latitude is approached. Most of the primary cosmic rays are found to be positively charged, because we find a greater intensity of particles approached from the westerly than from the easterly direction. This effect is called "East-West Asymmetry Effect".

I.4 <u>Properties of Mesons.</u>

Mesons are observed as secondary particles in cosmic rays. They are unstable particles of mass greater than that of electron but less than that of nucleon. Some of them are charged, but some of them are neutral.

It is probable that in most of nuclear disintegrations resulting from the collisions of primary particles with target nuclei, several pi-mesons, positive, negative and neutral, are produced. When this pi-mesons pass through a matter, most of the positive pi-mesons undergo pi-mu decay into mu-mesons of positive charge. The majority of negative pi-mesons are captured by the atomic nuclei resulting in star producing disintegrations. However, some of the negative pi-mesons decay into negative mu-mesons, and neutral pi-mesons decay into photons.

The mean life of charged pi-mesons is about 10^{-8} sec., and that of mu-mesons is about 10^{-6} sec. The pi-mesons will probably decay at high energy into high energy mu-mesons. If pi-mesons slow down before decaying, the positive and negative pi-mesons should behave differently after coming to rest. The positive pi-mesons, slowed down by inelastic collisions with nuclei along its path, and is repelled by atomic nuclei, simply come to rest and decay. The slow negative pi-mesons will be attracted and then absorbed by nuclei, forming the spallation reactions. In such a case stars are formed.

Mesons whose masses lie between that of pi-meson and the nucleon mass are called K-mesons in which τ-mesons are included. τ-mesons are produced directly in high energy nuclear interactions. They will decay normally into charged pi-mesons.

F.5 <u>Cosmic Ray Components Causing the Formation of Stars at Ground Level.</u>

According to Mason(10), the star producing particles are mainly neutrons and protons secondary to the primary cosmic rays. The particles are the nuclear interaction components. Protons lost energy by ionization and can penetrate through the atmosphere less than neutrons. Neutrons lost energy only by nuclear interactions. Therefore at ground level the radiation responsible for the low energy stars (i.e. 200 MeV) are predominantly neutrons. For high energy stars, the initiating particles are fast neutrons and protons.

In recent years, C. Kaumaphonija and J. Suttipongse (33) have observed the ground level cosmic ray stars and the east-west asymmetry effect of nuclear interaction component at latitude 13°46' N. Their experimental results showed that the great part of cosmic rays at ground level, that caused the formation of stars, are non-ionizing particles, i.e., neutrons at low energies. The frequency distribution of the stars are relatively maximum at 3-group stars. The results are similar to that of other authors, notably of Rose(34).

In studying the absorption of ground level cosmic ray components, there were small data reported by different authors. The inconsistency in the various measurements could perhaps be due to many causes such as, different geometries employed, the placement of the absorbers, the different latitudes and altitudes, where such observations were made. For example, P.S. Gill(35) have observed the lead absorption of cosmic rays at low altitude by using a set of cosmic ray telescope whilst M.P. George and A.C. Jason(22) were using nuclear emulsions. The method of observations in the two cases were different.

In the year 1963 and 1964, an attempt was made at the Department of Physics, Chulalongkorn University, to measure lead absorption of cosmic ray stars using nuclear emulsions similar to that of George and Jason (22) in order to determine the absorption curves for low energy and high energy stars. The results are shown in this thesis.