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The first outcome on the 3-D feature of Forbush decrease events from large muon telescope of GRAPES III at Ooty

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Abstract

We have observed several Forbush decrease events during 2000 and 2001 with Large Muon Telescope of the GRAPES III shower array at Ooty (800g/cm^2). Our telescope is rather unique in its very large detection area, total area of 560m^2 (16 units of 35m^2 each) and rather good angular resolution, less than 8 degrees. We present the 3-D structure of Forbush Decrease (FD) events and their time profiles in great details. We found some distinct features in their structures. Some of the CME (Coronal Mass Ejection) from the Solar flares can cause these peculiar type of FD events. We discuss these results in connection with the energy spectrum of the cosmic rays during the passage of CME directed toward the Earth.

1 Introduction

Each detector has its own characteristics such as neutron monitors, scintillation detectors, proportional counters and so on. Our muon telescope in Ooty GRAPES III experiment has an excellent statistics because of its large detection area, 560m^2. This is a great advantage for the study on short term variation of both the galactic cosmic rays and solar cosmic rays. Short time feature can be only clarified with large area and direction sensitive detector.

One of our main aim is to study the 3-D structure (in time and space) of Forbush event rather precisely and to understand the effect of solar magnetic field. We are hoping to clarify the nature of Forbush Decrease in connection with Solar flare and Interplanetary Magnetic Field.(IMF) The satellite observation can perform point observation very well, but our ground level detector has a great advantage to study the global feature of IMF and shock front associated with the solar flare events.

Another aim is to make a detailed study on time profile of the solar proton and neutron in the occasion of Grand Level Enhancement (GLE) Kawakami et al (1999) If there would be the rapid change in GLE, it would give the clue to understand the mechanisms of particle acceleration in their early stage which would be difficult to study by the conventional small size neutron monitor.

We report here the time and space structure of several FDs and would like to discuss their behavior.

2 Detectors and Experimental Conditions

The detector element is 6m long proportional counter with cross

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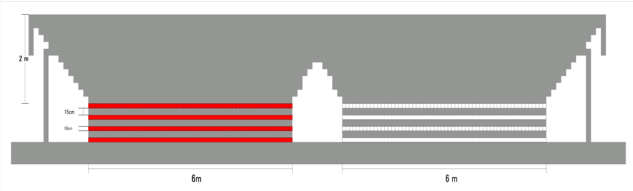

Fig.1 Side view of GRAPES III Muon detectors.　Figure of 2 modules.

section of 10cm by 10 cm. 58 counters are placed side by side on a concrete platform and covered with 15cm thick concrete slabs. Four layers of counters are arranged in crossed configuration to obtain the track and angle of individual muon. Top of the counter layer thick concrete were put and total thickness of the detector is 550g/cm^2 (about 20 r.l.), so the minimum energy of a penetrating muon is about 1 GeV. Total number of modules for muon detector is 16. Area of each module is around 35 m^2 and its total area is 560 m^2 . They have been fully operational since February 1998. Figure of the Muon Telescope is shown in Fig.1.

Omni directional observation has been started for 16 modules from April 1998 and the directional measurement of the muons has been started from April 1999 by one module and now 12 modules (total area 420m2) are operational. In principle the angle of individual muon is recorded in each 10 seconds.

The ambient condition of these muon detectors is quite stable. Though outside daily temperature varies around 15 degrees for fine weather, temperature of the muon detector deviate only one to two degrees per day. Maximum temperature variation in a year near the detectors is within 5 degrees. The atmospheric pressure changes

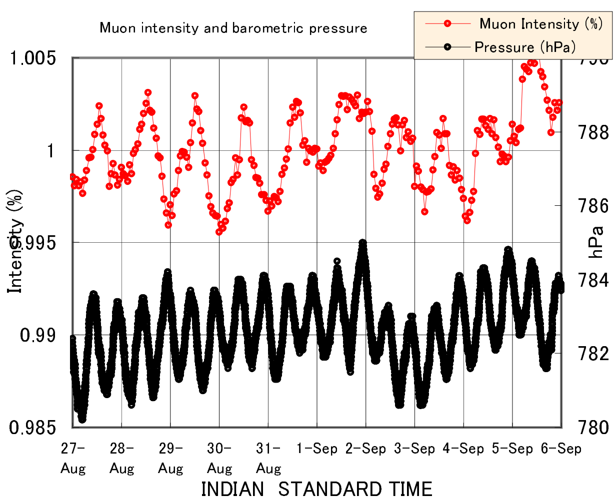

Fig.2 Red: variation of muon intensity
Black: barometric pressure

periodically with cycle of 12 hours. Fig.2 shows a typical example of the variation of muon intensity, variation of atmospheric pressure.

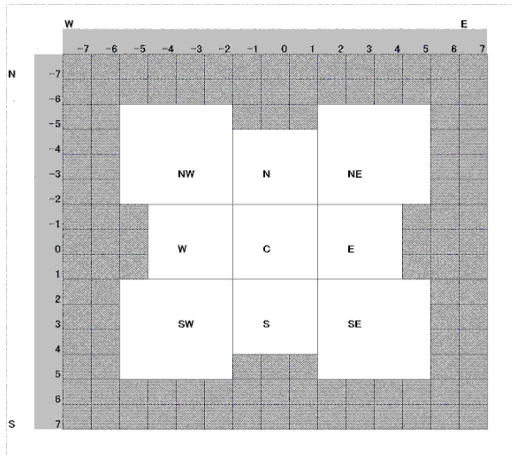

Fig. 3. groups of the muon direction

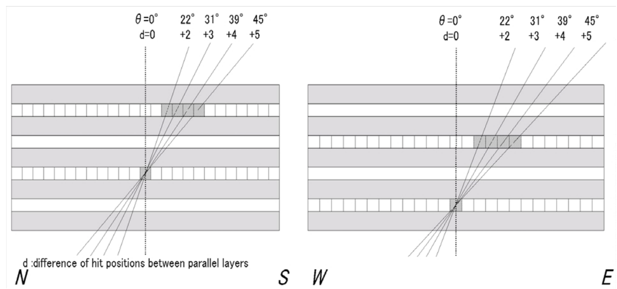

Fig.4. schematic diagram for NE direction

3 Analysis of Forbush Decrease Events

We have categorized the data by the angle of muons, the example of combination of angle is shown in Fig.3.

There are 9 categories of muons in total, North, North East, East, South East, South, South West, West, North West and Vertical. (Fig.4) All the raw data (each one minute interval) have been checked up thoroughly. After confirming that there is no misbehavior due to hardware problems and then summed up all the modules together. We adopted one hour count rate for analysis of FD through directional observation.

Fig.5 shows typical variation of galactic cosmic rays in FD. Phase shift of anisotropy is clearly seen through out FD period. It indicates that the anisotropy arising from Solar magnetism is maintained somehow during FD period and only the intensity of all the direction is disturbed equally. This feature is rather difficult to understand, since some shock front must have passed when the cosmic ray decrease sharply. The natural consequence of it would be the mixing of cosmic rays after the shock front.

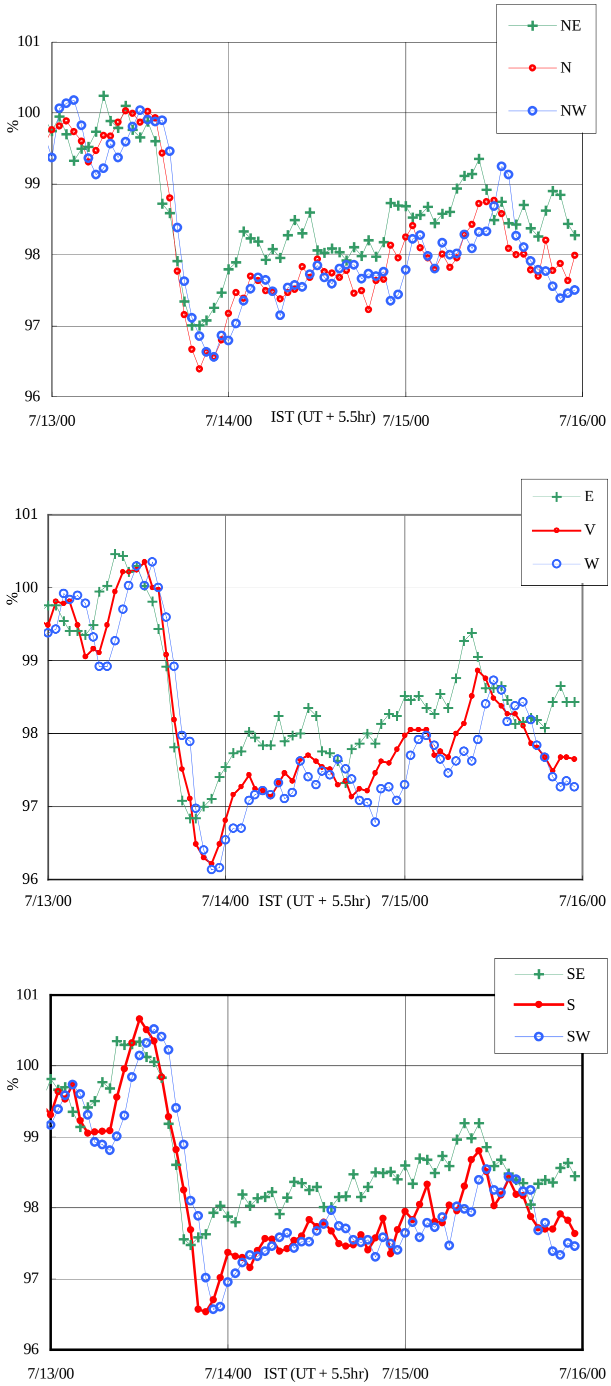

Fig.5 Example of typical Forbush Decrease

Contrary to this FD, another type of Forbush decrease shows the complete mixing of cosmic rays for all the direction. It is clearly seen in Fig.6, there is a peak at around 04:00 for all the direction. (Indian Standard Time (IST). IST is UT + 5.5 hours.) It should mean that the cosmic ray intensity for all the direction varies

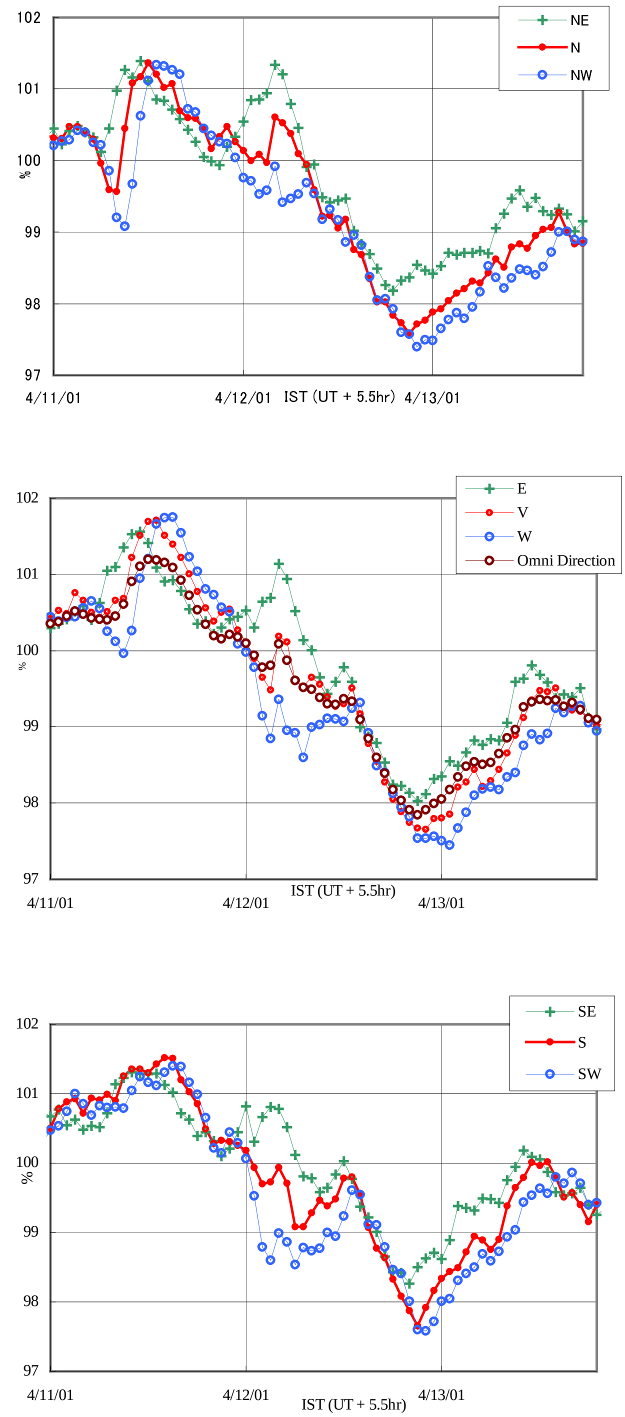

Fig.6 Examples of Forbush Decrease where mixing have happened

simultaneously in this period. So, there could have been some mixing of cosmic rays by the shock front. As a consequence of this mixing, anisotropy is lost for about 1 to 2 hours at least. This might have happened because of over-up of two successive Coronal Mass Ejection (CME). We estimate two CME (UT 15:34 9th April and UT 05:26 10th April) which are responsible for this complicated FD. Another distinct feature of this FD is that it shows quite different peak intensity between East direction and West. We have categorized E-W groups and shown in Fig.6 and N-S combination in Fig.7. As it can be seen in Fig..6, peak intensity of the east direction is always bigger than the west during this FD. If the energy spectrum of the cosmic rays becomes soft during this FD, cosmic rays from east is easy to penetrate the earth's magnetic field. It could be the cause of these differences.

3 Summary

It seems we might consider the flows of north-south direction of GCR to explain the complicated up and down during the FD event. The energy spectrum of GCR would become softer behind the shock front.

We could not spend enough time to estimate the possible behavior of the interplanetary magnetic field which must have caused the FD shown above. We hope to be able to analyze them soon thoroughly. So far we have been able to complete the analysis of 3 modules only for this FD of April 12th, the data of another 9 modules still to be analyzed for this FD. We are hoping to complete the analysis of remaining data by the conference time and to bring more concrete conclusion.

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