CHAPTER VI
NFT HODOSCOPE DATA
RESULTS AND DISCUSSION

VI.1 The NFT Data

The photographs of the neon flash tube (NFT) hodoscope, obtained by triggering the neon flash tube trays with SU-7 triggers, contain the tracks of muons and accompanying particles associated with the EAS. During the operation of the EAS array, shown in Fig.II.1, in association with the UG-detector the NFT hodoscope was operated only for a short period. Preliminary results from the obtained data were presented by Chowdhuri and Saxena (1971). The TIFR group has, since, modified the EAS array at K.G.F. and the new arrangement of the detectors in the array is shown in Fig. VI.1. Using this array and the UG-detector the NFT hodoscope pictures were obtained for an effective operational period of \(1.48 \times 10^6\) secs, during which \(\sim 1760\) events, (coincidences between EAS and the UG-detector), were recorded. We have examined 740 of these events to obtain information about the muons of energy \(\geq 150\) Gev and the EAS associated with these events.

The events have been classified according to the number of particle tracks seen in the NFT hodoscope photographs and details are given in Table VI.1.
### TABLE VI.1

**NFT HODOSCOPE DATA**

<table>
<thead>
<tr>
<th>Type of the event</th>
<th>Single track events</th>
<th>Pair track events</th>
<th>Multiple track events</th>
<th>Miscellaneous</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number</td>
<td>606</td>
<td>58</td>
<td>6</td>
<td>71</td>
</tr>
</tbody>
</table>

The single track, pair track and multiple track events refer to passage of one, two, or more than two penetrating particles respectively, through the UG-detector. The events listed under "Miscellaneous" are the case where the tracks are seen only in one of the NFT trays. It may be mentioned that NFT trays do not cover the total area under the scintillator (Fig. II.3) and there were cases of single particle tracks where the inclination of the particles were such that particle passed only through one of the NFT trays and missed the other. However, the particle tracks listed under "Miscellaneous" were well within the geometry of the apparatus. These events then could be the cases where the muon, associated with the EAS, went through the scintillator without crossing the NFT trays and an accompanying electron, produced by the muon locally triggered one of the trays.
VI.2 The Single-track Events:

Majority of the examined events showed single particle tracks implying the passage of a penetrating particle through the detector. Examples of single particle tracks are shown in Fig. VI.2 where the particles are seen triggering four-tubes in each NFT tray. From a preliminary analysis of the data of the EAS associated with the single-track events it is seen that the sizes of the EAS lie in the range $5 \times 10^3$ particles to $5 \times 10^4$ particles.

Projected angles which the single-particle tracks make with Zenith in a vertical plane in N-S direction, were measured and the events were grouped in various groups of the zenith angle. Details of the classification are given in Table VI.2.
Single Particle Track
Fig. VI. 2(a)

Single Particle Track
Fig. VI. 2(b)
### TABLE VI-2

**SINGLE TRACK EVENTS**

<table>
<thead>
<tr>
<th>Projected angle</th>
<th>Number of muons</th>
<th>Incident from south</th>
<th>Incident from north</th>
</tr>
</thead>
<tbody>
<tr>
<td>0° - 5°</td>
<td>38</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>5° - 10°</td>
<td>43</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>10° - 15°</td>
<td>83</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td>15° - 20°</td>
<td>76</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td>20° - 25°</td>
<td>74</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td>25° - 30°</td>
<td>63</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>30° - 35°</td>
<td>50</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>35° - 40°</td>
<td>25</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>40° - 45°</td>
<td>13</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>465</td>
<td>86</td>
<td></td>
</tr>
</tbody>
</table>

**Tracks Along Vertical**

In addition to the events listed above there were 56 single particle events with position and inclination of the tracks such that the particles could traverse either the upper NFT tray (52 events) or the lower NFT tray (4 events). From the table one can see that in majority of the cases the particles are incident on the
UG-detector from South and projected angles of majority of the particles incident from the North are limited to angles $\leq 25^\circ$. The mean angle for the particles incident from South turns out to be $20^\circ$ with a R.M.S. deviation of $10^\circ$. The mean angle for particles from North is $14^\circ$ with an R.M.S. deviation of $8^\circ$.

Let us examine these observations taking the geometry of the experimental set up into account. It is to be noted that the UG-detector is located $\sim 70$ m North-East of the vertical projection of the centre of the EAS array. The line joining UG-detector to the centre of EAS array makes an angle of $19.5^\circ$ with the vertical. Thus the observation that majority of the particle tracks are incident from South with an average angle of $20^\circ \pm 10^\circ$ implies that in most of the cases the particle enters ground very near the centre of the EAS array. The detection efficiencies for the EAS, having cores near the centre of the EAS array, are high and the efficiency drops off with increasing distance of the core from the centre. Thus we note that the NFT hodoscope records particles which form part of EAS and which are in neighbourhood of the respective EAS cores.
Taking account of the solid angles involved and detection efficiencies of the EAS the number of single track - events in various zenith angle bins has been corrected. The zenith angle distribution of the particles is as shown in Fig. VI.3. The correction factors for various zenith angle bins have been expressed in terms of the correction factor for $40^0 - 45^0$ bin so that the number of events in this bin remains unaltered. The distribution can be expressed by a power law of the type

$$I(\theta) = I_0 \cos^n \theta \quad \ldots(6.2.1)$$

where $n = 7.6 \pm 1.4 \quad \ldots(6.2.2)$

As shown earlier the muons recorded by the UC-detector in association with EAS are in the vicinities of the respective EAS cores. Thus if the directions of these muons may be taken as the representatives of the directions of the EAS cores than eqn. (6.2.2) indicates a steep zenith angle distribution of the recorded EAS.

At a comparable depth of 816 m.w.e. Achar et al. (1965) measured the angular distribution of all cosmic ray muons which penetrate that depth. Operation of their experimental apparatus does not require association with an EAS at the surface level. The angular distribution
was found to be well represented by an expression of the type

\[ I(\theta) = I_0 \cos^n \theta, \]

with \( n = 1.93 \pm 0.22 \). This distribution is much flatter than the results of the present experiment for muons, at 580 m.w.e., associated with EAS. This discrepancy is due to the difference in triggering system in the two experiments. In the present experiment angular distribution of UG-muons, associated with EAS at surface, actually gives angular distribution of the EAS cores.

Measurements on angular distribution of EAS, by means of cloud-chamber and G.M. counter techniques, by various workers show that the value of 'n' lies in the range 6-9. Bassi et al. (1953) have obtained the angular distribution of air showers at sea-level by measuring the space angles of air-shower axes. The measurement yields a distribution of the type

\[ I(\theta) \propto \cos^n \theta; \quad n \approx 8.3 \]

This value is slightly larger than the value 7.6 obtained in the present experiment. Though the present distribution is obtained on the basis of the projected angles, we do not think that this will effect the value of the exponent 'n' significantly. The slightly flatter distribution may be due to the fact that in this
VARIATION OF NUMBER OF SINGLE-TRACK EVENTS 
WITH PROJECTED ZENITH ANGLE

FIG XI. 3
experiment an EAS is recorded only when it is associated with a muon at U.G. level. Thus the probability of recording larger zenith angle showers in this experiment is expected to be higher, as the muon density increases with the increasing zenith angle. In an experiment at sea-level, Earl (1959) found that even near the shower cores (20-150 m) the muon density (for \( E \geq 1 \text{ Gev} \)) increased by a factor of 1.3, as the zenith angle of EAS changed from 0° to 40°.

VI.3 Pair-tracks Events:

About 7.8% of the total events were pair-tracks events exhibiting simultaneous passage of two penetrating particles through UG detectors. In most of these cases the particles were parallel to each other (Table VI.3 a).

<table>
<thead>
<tr>
<th>Nature</th>
<th>Parallel pairs</th>
<th>Convergent pairs</th>
<th>Divergent pairs</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of Events</td>
<td>47</td>
<td>7</td>
<td>4</td>
</tr>
</tbody>
</table>

TABLE VI.3 (a)

PAIR TRACKS EVENTS
The criterion adopted for the parallelism was that the angle between the two tracks be $< 1^0$. The distribution of the parallel-pairs in the separation between the pairs is shown in Fig. VI.4 (a). The minimum projected separation is 4 cm. Fig. VI.4 (b) shows the angular distribution of the parallel-pairs. It is seen that the distribution is having a rather sharp peak between $20^0 - 30^0$. These Parallel Pairs might have originated either in the atmosphere or in the rock beyond 5 - 6 m from U.G. detector. In order to get a better idea about the origin of these particles we have analysed these events further.

Let us consider the Parallel Pair-tracks events with pairs having projected angles within $35^0$. There are in total 40 such events and we can write

$$(D_{\mu})_{\text{obs}} = (2.02 \pm 0.32) \times 10^{-5} \text{ Sec}^{-1} \ldots (6.3.1)$$

for the observed rate of the events. Number of such events expected, on the basis of the assumption that the observed particles are muons produced in the atmosphere as part of the EAS and that the number of muons in EAS is subjected to Poissonian fluctuations, may be written as

$$(D_{\mu})_{\text{exp}} = F (\geq N) \frac{\text{A}_{\text{eff}}}{\ell^2} \times P_{\mu^2} \times 2\pi \text{ rdr}$$
Figure VI. 4

(a) Separation between the particles (cm)

(b) Projected angle of the particles
where \((\lambda_{\text{eff}}/L^2)\) is the effective solid angle for the EAS, \(F(N)\) is the integral flux of the EAS and \(P_{\mu 2}\) is the probability that the underground detector will record two muons for showers having cores within \(r\) and \(r + dr\) from the detector. \(P_{\mu 2}\) may be written as

\[
P_{\mu 2} = \frac{e^{-X} \exp(-\frac{\Delta_{\mu}}{\lambda_{\text{eff}}}}}{2!} \left(\frac{\lambda_{\text{eff}}}{2}\right)^2 \quad \text{..(6.3.3)}
\]

where \(S\) is the effective area of the detector.

In order to estimate the expected number we have assigned unique average values to \(\langle \lambda_{\text{eff}}/L^2 \rangle\) and \(\langle r \rangle\) for the observed events as explained below.

Approximate distances of the core from the Parallel-Pair particles were obtained by calculating the distance between the intercept of one of the particles, with surface, and the point of incidence of EAS core. The distances were found to lie within 40 m. A weighted mean value of 11 m was obtained and we may then assign

\[
\langle r \rangle = 11 \text{ m}
\]

to all the events under consideration.

Muon density at distance \(r\) may be written as

\[
\Delta_{\mu}(r) = \frac{N_{\mu}}{2\pi \gamma_0^2} e^{-\frac{r}{\gamma_0}} \quad \text{..(6.3.4)}
\]
and from Chapter IV, we may write

\[ r_0 \lesssim 12 \text{ m.} \]

\[ N_{\mu} = 27 \left( \frac{N}{10^5} \right)^{0.47} \]

The sizes of EAS associated with the events under consideration lie in the range $8.7 \times 10^3 - 5 \times 10^5$ particles. The integral flux $F(\geq N)$ turns out to be $\lesssim 10^{-4} \text{ m}^{-2} \text{ St}^{-1} \text{ Sec}^{-1}$. A weighted mean size $\langle N \rangle \simeq 5.10^4$ particles may be assigned to the events. We then have $N_{\mu} \simeq 20$ particles. Equation (6.3.4) then yields

\[ \Delta_{\mu} \simeq 0.01 \text{ m}^{-2} \]

which in conjunction with equation (6.3.3) gives

\[ P_{\mu^2} \simeq 2.25 \times 10^{-4} \]

In order to obtain the values of $\langle \text{eff/} L^2 \rangle$ we have classified the observed events in various zenith angle groups and calculated the solid angles for each group as given in table VI.3 (b). The triggering efficiency ($\varepsilon$) is taken into consideration. From
TABLE VI.3 (b)

PARALLEL - PAIRS EVENTS

<table>
<thead>
<tr>
<th>Projected zenith Angle</th>
<th>Number</th>
<th>( \frac{A_{\text{eff}}}{2\pi {^2} )</th>
<th>( \frac{A_{\text{eff}}}{2\pi l^1} )</th>
<th>( \langle \frac{A_{\text{eff}}}{l^2} \rangle )</th>
</tr>
</thead>
<tbody>
<tr>
<td>10° - 15°</td>
<td>3</td>
<td>0.53 x 10^{-2}</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15° - 20°</td>
<td>10</td>
<td>1.34 x 10^{-2}</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20° - 25°</td>
<td>14</td>
<td>1.05 x 10^{-2}</td>
<td>1.04 x 10^{-2}</td>
<td>6.53 x 10^{-2}</td>
</tr>
<tr>
<td>25° - 30°</td>
<td>9</td>
<td>0.85 x 10^{-2}</td>
<td></td>
<td></td>
</tr>
<tr>
<td>30° - 35°</td>
<td>4</td>
<td>1.08 x 10^{-2}</td>
<td></td>
<td></td>
</tr>
<tr>
<td>35° - 40°</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>40° - 45°</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>45° - 50°</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Not considered for the present calculations.

These values of solid angles a weighted mean is evaluated which may then be taken as the effective solid angle \( \langle \frac{A_{\text{eff}}}{l^2} \rangle \) for the events.

\[ \langle \frac{A_{\text{eff}}}{l^2} \rangle \simeq 6.53 \times 10^{-2} \text{ St.} \]

Substituting the values of various parameters obtained above in equation (6.3.2) we have

\[ (D \mu ) \exp \simeq 0.74 \times 10^{-5} \text{ Sec }^{-1}. \]
Though the observed result is nearly three times the one expected on the assumption that parallel-pairs are part of the incident EAS, it is approximately within three standard errors of the observed value.

It may, however, be noted that we can measure only projected zenith angles of the trajectories in a vertical plane in N-S direction and the actual space angles are not known. Moreover, information about the arrival directions of the associated EAS is not available. Thus the estimated core distances are very rough and $\Delta \mu$ is calculated only for an average $r$ value because of a limited number of events. The effective aperture estimate is also based on the projected angles and events associated with EAS of various sizes (having a large size range) are lumped together. Further the muon number - EAS size relation used here may not be very accurate in the size range under consideration. Considering all these approximations the agreement between the observed and expected rate may not be very unsatisfactory.

Thus we conclude that most of the parallel pairs originate in the atmosphere as part of EAS. However, the possibility that a small fraction may be due to local production in the rock at heights $\gtrsim 10$ m can not be ruled out. It will be possible to get more definite
information if space angles of the particles are known and if events could be classified in various size-groups.

There are seven cases of parallel pairs with projected zenith angle $\geq 35^\circ$. Out of these we have the surface EAS data for three events only. Core distances in these cases were found to be $\geq 50$ m. These are most probably the particles accompanied by very much inclined showers and hence these are not included in the analysis.

The convergent pairs appear to converge in the rock above the detector and the convergence in these cases is $\geq 1^\circ$. These pair events, which converge in the rock at angles greater than the limit of parallelism, seem to be produced in the rock by single muons of EAS. Particles in these events penetrate 10 cm lead absorber without undergoing the multiplication and hence they can not originate in electromagnetic interactions. These particles have to be non-electronic in nature and hence must have originated in photo-nuclear interaction of fast muons accompanying the EAS. As the number of observed events is small attempt has not been made to derive production cross-section due to nuclear interaction. For divergent pairs, the divergence appears too large to be accounted for by the multiple scattering suffered by the particles in the rock. Moreover, the accidental coincidence rate for such event is too small to account for the observed number.
VI.4 Multiple - Tracks Events:

In addition to the single-track and pair-tracks events six events, each showing three tracks, and one event showing five tracks were also observed. The particles in these events appeared to be parallel to each other and details of the separations between the tracks are given in Table VI.4.

<table>
<thead>
<tr>
<th>Nature</th>
<th>Projected angle</th>
<th>Separations between the tracks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1 &amp; 2</td>
</tr>
<tr>
<td>Three Parallel Particles</td>
<td>34°S</td>
<td>46 Cm</td>
</tr>
<tr>
<td></td>
<td>16°S</td>
<td>5 &quot;</td>
</tr>
<tr>
<td></td>
<td>28°S</td>
<td>7 &quot;</td>
</tr>
<tr>
<td></td>
<td>30°S</td>
<td>74 &quot;</td>
</tr>
<tr>
<td></td>
<td>23°S</td>
<td>76 &quot;</td>
</tr>
<tr>
<td></td>
<td>25°S</td>
<td>20 &quot;</td>
</tr>
<tr>
<td>Five Parallel Particles</td>
<td>30°S</td>
<td>37 &quot;</td>
</tr>
</tbody>
</table>
Four of the particles in the five-particles event are close to each other, the fifth one being separated quite a bit from this group. In the present sample of the data events containing four-particles were not seen.

If the parallel particles, observed in the data, are produced in air as part of the EAS then the observed numbers in various categories appear to suggest a very steep number-density spectrum for these particles in EAS. However, any further conclusions about the nature of the spectrum of these particles, in EAS, must await the availability of a much larger sample of the data.

VI.5 Electromagnetic interactions of the high energy muons

From a study of the particles accompanying the muons, detected underground one may hope to derive information about the interactions of the muons with matter. In the present case where the muons, of energy $> 150$ Gev associated with EAS, are being studied the interactions will correspond to interactions of muons having an average energy $\sim 500$ Gev. This estimate of the average energy is based on the energy spectrum of muons in EAS, of the type $E^{-1.3}_\mu$ (Chapter IV). It is to be noted here that Chowdhuri and Saxena (1971) gave an estimate of 330 GeV for the average energy of the muons for the present experiment on the basis of the muon spectrum $E^{-1.5}_\mu$. 
With a better estimate of $\beta_{y,3}$ the average energy is found to be larger.

The particles accompanying the muons have been classified in different categories as shown in Table VI.5.

<table>
<thead>
<tr>
<th>Nature</th>
<th>Number</th>
<th>Percentage Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) Showers produced in rock</td>
<td>30</td>
<td>0.040 ± 0.008</td>
</tr>
<tr>
<td>b) Showers produced in lead</td>
<td>40</td>
<td>0.055 ± 0.009</td>
</tr>
<tr>
<td>c) Knock-on Electrons produced in rock</td>
<td>19</td>
<td>0.026 ± 0.006</td>
</tr>
<tr>
<td>d) Knock-on Electrons produced in lead</td>
<td>30</td>
<td>0.040 ± 0.008</td>
</tr>
<tr>
<td>e) Knock-on Electrons produced in surrounding material</td>
<td>6</td>
<td>----</td>
</tr>
<tr>
<td>f) Electrons incident from rock</td>
<td>36</td>
<td>----</td>
</tr>
<tr>
<td>g) Electrons incident from lead</td>
<td>35</td>
<td>----</td>
</tr>
<tr>
<td>h) $\delta$ -rays in upper tray</td>
<td>13</td>
<td>----</td>
</tr>
<tr>
<td>i) $\delta$ -rays in lower tray</td>
<td>13</td>
<td>----</td>
</tr>
</tbody>
</table>

The events listed in category f) and g) correspond to the "Miscellaneous" category of Table VI.1 and for these events penetrating particles were not seen. In
addition to the events listed above there were 7 cases where electrons showers, incident from rock and hence seen only in upper tray, were not accompanied by a penetrating particle. Similar cases for showers incident from the lead numbered-five. One event showing the electron-showers in both the upper and the lower tray was also recorded. The probability for such a double-process can then be written as \((0.0013 \pm 0.0013)\).

The results given in table VI.5 may be compared with those of Creed et al. (1965). Creed et al. (1965) have studied the probabilities of a muon accompanied by electrons from the rock or generating them in the lead absorber, at three different depths at Kolar Gold Mines viz 816, 1812 and 4160 m.w.e. The mean energies of the muons observed at these depths were 130 Gev, 220 Gev and 300 Gev respectively. The probability of electrons accompanying a muon from the rock was found to increase with increasing depth as expected from the increasing average energy. The probabilities obtained in present experiment for various categories turn out to be greater than those observed by Creed et al. (1965) for muons of average energy 300 Gev. This is consistent with the fact that the average energy in the present experiment is greater than the average muon energies in the experiment of Creed et al.
The probabilities of electron-showers accompanying a muon from the rock and for the electron-showers produced by muons in 10 cm. lead absorber have been calculated for muon energy $E = 500$ Gev. The cross-sections for knock-on, Bremsstrahlung and Pair-production processes, as given by Bhabha (1938), Christy and Kusaka (1941) and Bhabha (1935) respectively, have been used. The probabilities in the rock and the lead turn out to be 4.5% and 6.7% respectively. The calculated probability for lead is in reasonable agreement with the observed value. However the observed probability in lead appears to be slightly smaller than the predicted one.

VI.6 Large Size Bursts:

Besides the events discussed in proceeding section we have observed some cases of rather large number of particles (Bursts) triggering either the upper-tray or the lower tray or both the trays of the neon flash tube hodoscope. Some examples of such events are shown in Fig. VI.5 - Fig. VI.10.

Out of these three categories, bursts which are detected simultaneously in both upper and lower n.f.t. trays, (separated by 10 cm. lead absorber) are most interesting. Number of the particles detected in the lower tray varies from 4 to 7. However, in some cases
the bursts are very dense. These bursts could be generated in the rock by a highly energetic Bremsstrahlung process or in some other different type of interaction in the cores of EAS. Further investigation will be able to give more definite explanation about this phenomenon. We have not included detailed analysis of these events here as further investigation is being continued.

VI.7 Conclusion and Summary:

Distribution of zenith angles of single penetrating particles at 580 m.w.e associated with EAS, is found to be of the form

$$I(\theta) = I_0 \cos^n \theta$$

with $n = 7.6 \pm 1.4$. This is a steeper distribution than obtained for all cosmic ray muons at 816 m.w.e by Achar et al. (1965). However, the distribution obtained in present experiment gives the angular distribution of EAS core. Other experiments indicate an exponent $\sim 8-9$. The discrepancy between these results and the result from present experiments can be explained on the basis of the difference in the recording systems. In the present experiment the EAS are recorded only when accompanied by a muon at underground level. Thus the
the present recording system has a natural bias for larger angle showers.

The probabilities of small shower production by muons in rock and in the lead are found to be (4.0 ± 0.8)% and (5.5 ± 0.9)% respectively. These values are in good agreement with the expected probabilities, for muons of average energy ≈ 500 GeV, calculated on the basis of the cross-sections given by Bhabha and Christy and Kusaka.

The rate of double parallel penetrating particles, associated with EAS, is found to be of the order of (2.02 ± 0.32) x 10^{-5} per sec. The value, expected on the basis of the assumption that these particles are produced in atmosphere as a part of the EAS, is found to be 10^{-5} Sec^{-1}. The observed value thus appears to be larger than expected value. Since it has not been possible from the present data to classify the events in various EAS size groups, and further as the information is limited to the projected zenith angles of these tracks, the difference between the observed and expected values is not unreasonable. We, thus, conclude that the parallel pairs are particles produced in the atmosphere in the EAS cores.
A few cases of convergent pairs have also been observed. It is felt that these pairs are produced by the interaction of the incident muon in the rock through photo-nuclear interaction. Apart from those double penetrating particles a few multiple particle events have also been observed.

Some cases of very large bursts detected simultaneously in both the n.f.t. trays are reported. Such events are being investigated further.

VI.8 Suggestions for further investigation:

The large bursts observed in the present experiment represent a phenomenon which is hard to understand on the basis of present quantity and quality of the data. It is, therefore, desirable to look for these type of events in an improved way. At present the information about the spread of the bursts is available only in the projected plane. Use of a crossed-tray N.F.T. hodoscope can provide further information which may be useful in a better understanding of these events. Another tray of neon flash tubes under the lower tray separated by at least 5 cm of lead absorber will also be useful in understanding the nature of the detected particle.
'Burst' Produced in Lead
Fig. VI. 5

'Burst' Produced in Lead
Fig. VI. 6
'Burst' Incident from Rock
Fig. VI. 7

'Burst' Incident from Rock
Fig. VI. 8
Double Burst

Fig. VI. 9

Double Burst

Fig. VI. 10
These events have been observed for muons associated with the EAS. For a better understanding of these events it is desirable to know the location of the particles, observed in these events with respect to the core of the associated EAS. One may, therefore, use an EAS array which provided information about the direction and inclination of the EAS core.

It will, also, be interesting to look for these types of events in the underground experiments where association with the EAS is not a requirement. A comparison of the rates of these events in both these types of experiments (associated with EAS, and without EAS association requirement) will give useful clues about the nature of the particles in these events.

Parallel double and multiple penetrating particles, observed in present experiment, can give much important information about the production process and about the nature of primaries which generate the associated ultra high energy EAS. For this purpose it is necessary to know distances, of these particles from EAS cores, very accurately. To get these information a future investigation may be carried out to measure the space angles of these penetrating particles as well as arrival directions of the associated EAS. This will not only yield the accurate core distances but also the proper separation between the tracks in the parallel multiple events.