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Measurement of Shower Electrons and Muons using a Small Air Shower Array

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Abstract

A small air shower array has been used to measure the size spectrum of air showers at sea level in the size range $6.10^3 - 10^6$. The result fitted with the power law gives an index -2.79 ± 0.11 for the differential spectrum. Lateral distribution of electrons fitted with the well known NKG function results in an age parameter $s = 1.35$ for core distances less than 30m and $s = 0.8$ for longer core distances. Lateral distribution of muons follows the general shape of Greisen's relation but is much higher in intensity. Muon and electron densities at the same observation point are also compared.

1. Introduction. Cosmic rays of energy around 10^{14}eV are of particular interest with the present day availability of accelerator data. It was with this in mind that the present experiment was constructed.

The air shower array used has been described in a previous experiment (Chan et al 1979) and the accuracy of core location is typically ±6m. The present addition at the centre of the array is a flash tube assembly shown in figure 1. The upper trays of flash tubes (each 1m x 6.5mm diameter) are for measuring the total particle density, while the lower trays shielded by iron plates (threshold 0.3 GeV) are for determining the muon density simultaneously. The maximum observable density is 30m^{-2}.

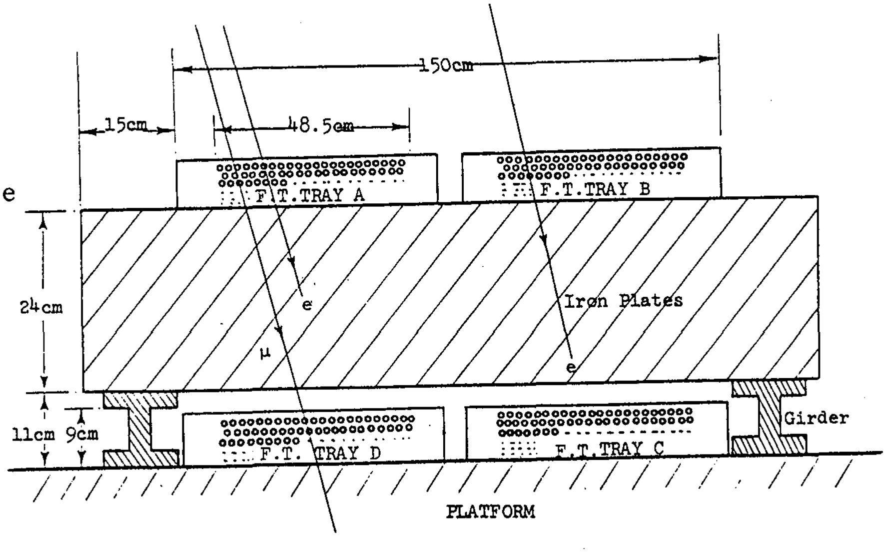

Fig. 1
Flash tube
assembly

However, as the result below reveals, most air showers observed at sea level may be just old showers with primary energies greater than 10^{14}eV, which are above the accelerator energy range. Nevertheless, it is still worthwhile to report on the measured results obtained.

2. The shower size spectra. The differential and integral size spectra in figures 2 and 3 respectively were computed from 6798 measured events taken in the period July - December, 1981. Fitting each spectrum with a power law gave agreeable slope indices, -2.79 ± 0.11 for the differential and -1.83 ± 0.1 for the integral. The latter is compared with other workers' results in figure 3.

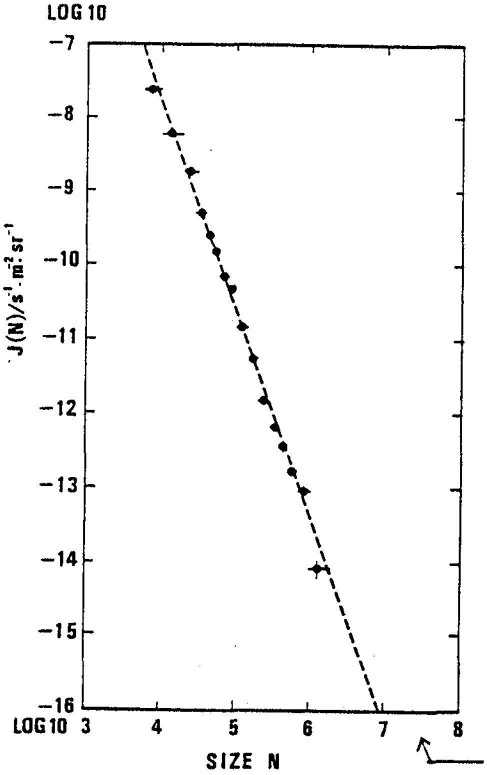

Fig.2 Differential size spectrum

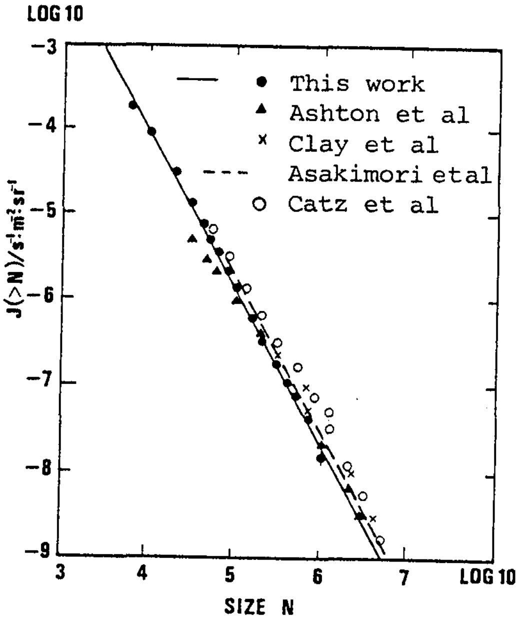

Fig.3 Integral size spectrum.

3. Lateral distributions of electrons and muons. Results in the figures 4 and 5 are based on particle tracks observed from the flash tube assembly. Difference in track intensity between the upper and lower flash tube trays provides the electron density at a known location and known size of a shower. For showers in the size range 10^4 - 4.10^4, the results can be fitted with the well known NKG function with a single age parameter $s = 1.3$. Those in the size range 4.10^4 -2.10^6 are more complicated, giving a fairly large age parameter($s \sim 1.35$) at smaller core distances, but a very small parameter ($s \sim 0.8$) at larger core distances. A straight forward interpretation is that those falling close to our detection assembly were in fact old showers well

passed their point of maximum development, and those further away were developing young showers.

The data presented in figure 6 for the muon lateral distribution are based on the track count in the lower flash tube trays. Local bursts in the iron absorber were rejected since they were mostly hadron events. The distribution follows the general shape of the classical relation (Greisen 1960), but the intensity is about three times as large.

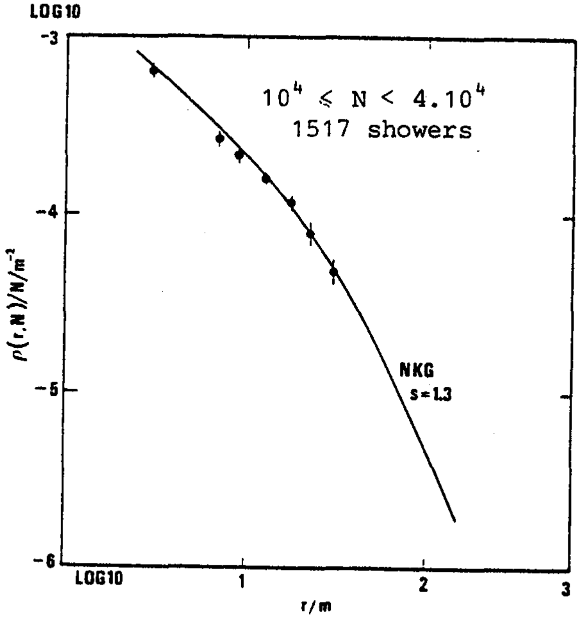

Fig. 4
Lateral distribution of electrons.

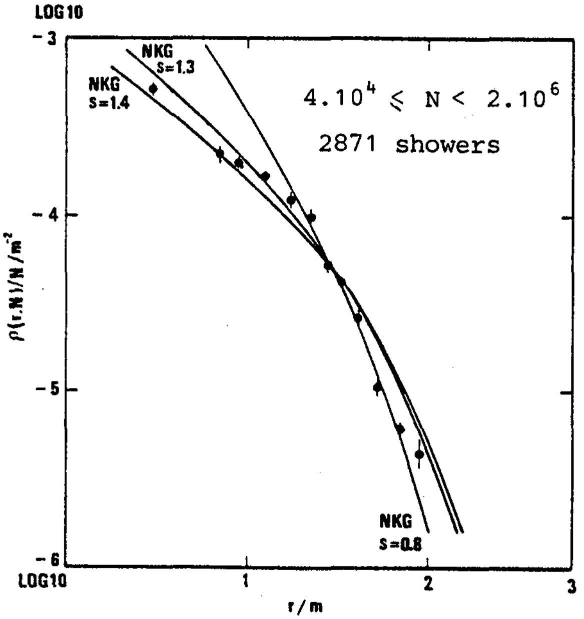

Fig. 5
Lateral distribution of electrons.

4. Density ratios of muons to electrons. Figure 7 presents the density relation between shower muons and electrons at the same location from each core. The pioner results due to Cocconi (Hayakawa 1969), and rough estimates based on Greisen's relation and the NKG function with mean shower size $2.23.10^4$ are also shown for comparison. Again our ratios are expected to be much higher.

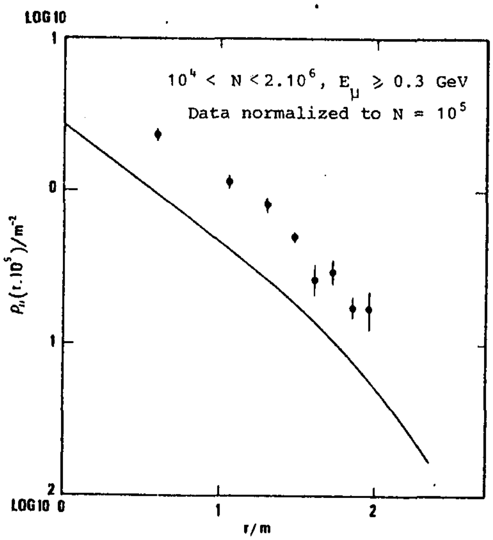

Fig.6 Lateral distribution of muons.

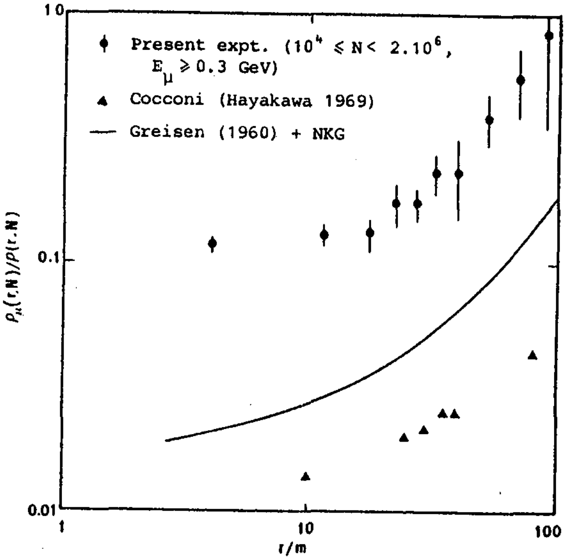

Fig.7 Density ratio of muons to electrons.

5. Discussions. If the observed shower events are either old declining showers $(s \sim 1.3)$ or very young developing showers $(s \sim 0.8)$, the smallness of the size is only phenomenological and may not have been initiated by primaries of small energies ($\sim 10^{14}$eV). High intensity of muon component in the showers supports that they were initiated by higher energy primaries.

Alternatively, if the richness in muon content is not due to the phenomenological factor, then this result would suggest that the primary cosmic rays at the energy range concerned are dominated by heavier components $(A \sim 15)$ and that p-p interaction at this energy range should possess multiplicity which rises with energy at least as fast as $n_s \alpha E^{\frac{1}{4}}$.

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