PARTICLE DISTRIBUTIONS IN $\sim 10^{14} - 10^{16}$ eV AIR SHOWER CORES AT SEA LEVEL

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ABSTRACT

At the Bangalore Conference we reported experimental evidence for the 'steepening' of the differential density spectra for known fixed distances (0, 1·0, 2·5 and 4·0 m) from the shower centres and for 'core flattening', the cores becoming flatter, on average, as the shower size (primary energy) increases. With improved statistics on 4192 cores, the previous results are exactly confirmed.

1. Introduction. At the Bangalore Conference we reported the first measurements of the differential density spectra for cosmic-ray air showers at known fixed distances from the centres of shower cores (Hodson et. al., 1983a) and also evidence that as the shower size increases the cores, on average, become flatter (Hodson et.al.,1983b). In this paper we report data on a total of 4192 shower cores, increasing the statistics previously available. The conclusions regarding 'steepening' of the density spectra and 'core flattening' given at Bangalore are confirmed and it is shown that the flattening effect extends to at least 2·5 m radius from the shower centre.

2. Data and results. The data on particle distributions near to the cores of $10^{14} - 10^{16}$ eV air showers at Leeds (80 m above mean sea level, 1020 g cm^{-2}) were obtained from a 7 m × 5 m array of discharge chambers. A particular feature of the apparatus is the precision (usually $\sim$0·1 m) with which the centres of symmetry of the shower cores can be located. The experimental arrangement, triggering system, and data analysis were exactly as described in the above 1983 papers. An additional 1589 shower cores have now been analysed and the combined data are given in Figures 1 and 2.

Figure 1 shows the differential spectra for densities $\rho(r)$ measured at r = 0, 1·0, 2·5, and 4·0 m from the shower centres. All four spectra are of a similar shape which may be approximated by two power law lines; all four spectra are consistent with a power law index of ~ -2 at low densities before steepening to an index of $\sim -3{\cdot}5$ at high densities. Deviations from the −2 power law at the lowest densities shown in Figure 1 are attributed to trigger and scanning bias. The 'central density' spectrum (Figure 1a) steepens at $\rho(0) \sim 800\,m^{-2}$; for r = 1·0, 2·5, and 4·0 m the spectra steepen at lower density values. The 'join point' between the two power law lines occurs at about the same differential rate in each of the four spectra (horizontal dashed lines).

Figure 2 expresses the data on core flattening. The quantity $\langle\rho(r)\rangle$ is defined as the average density for all shower cores in a particular interval of $\rho(4{\cdot}0)$. The closer the ratio $\langle\rho(r)\rangle/\langle\rho(r')\rangle$ is to unity, where $r' < r$, the flatter is the particle distribution in the region between r' and r from the shower centre. In the absence of data on the

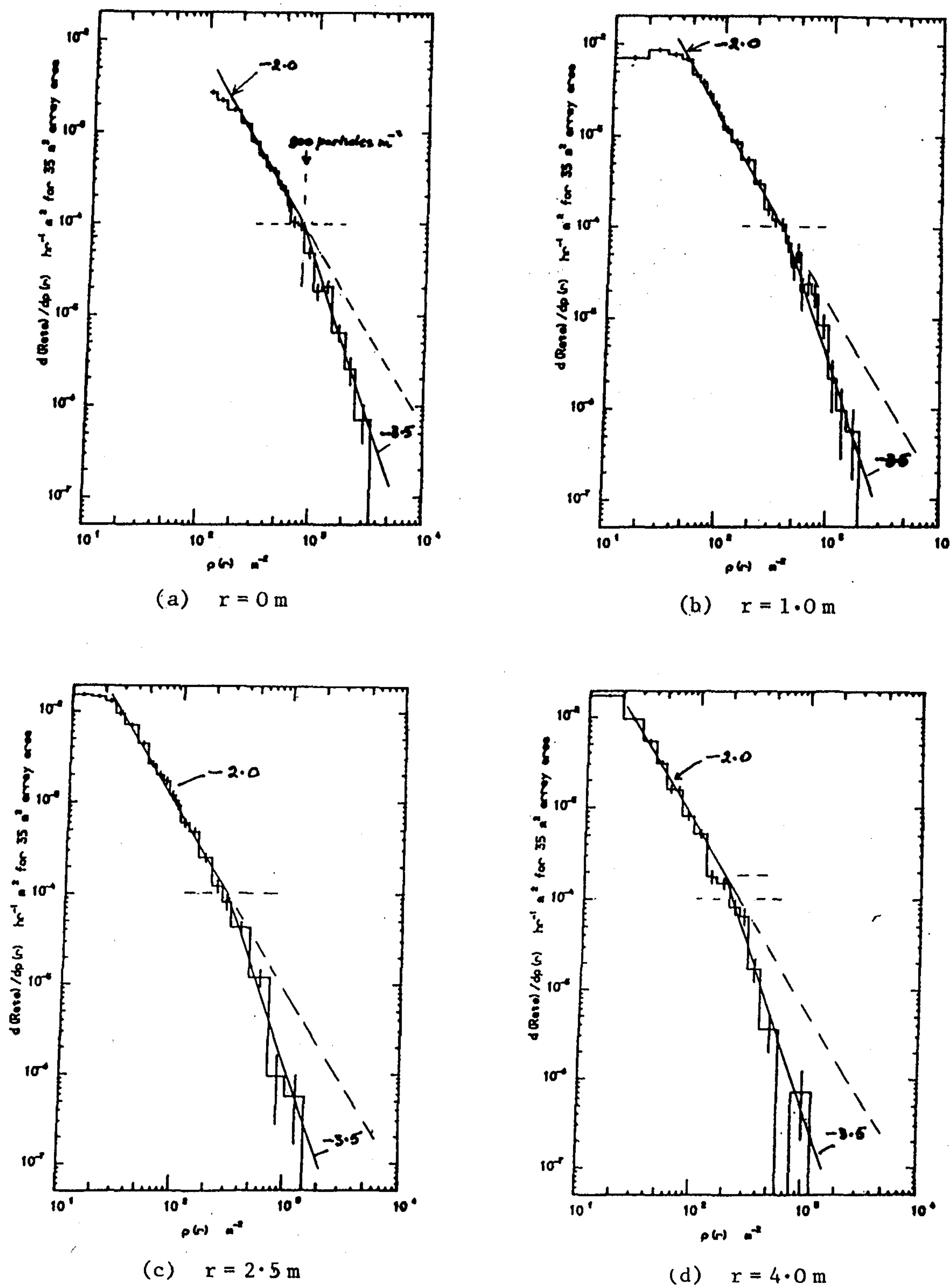
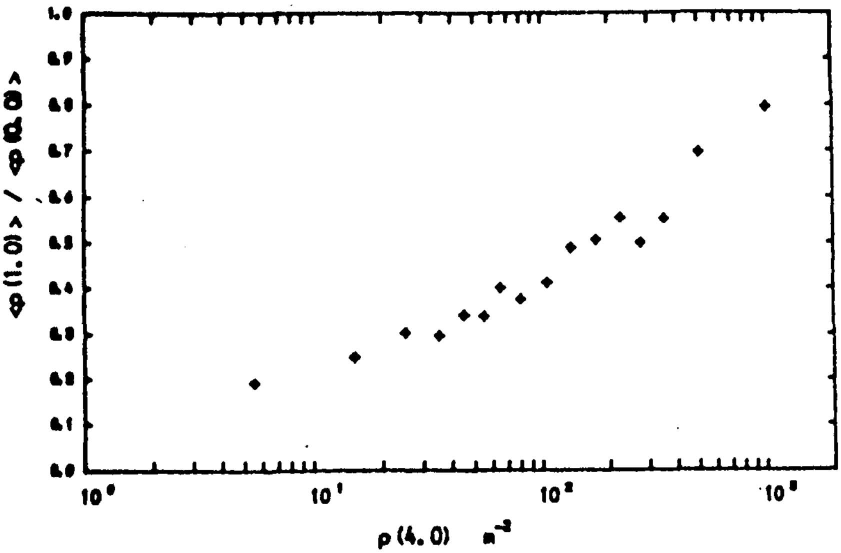
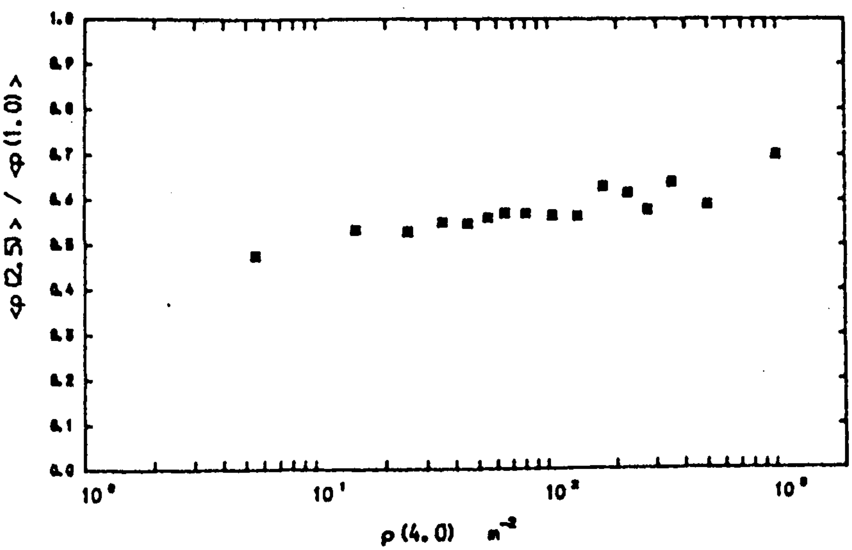


Figure 1. Experimental differential density spectra at known fixed distances (r) from the shower centre.

Total no. of shower cores: 4192; Run time: 7033 hours



(a) 'Core flattening' between 0 and 1·0 m from the shower centre



(b) 'Core flattening' between 1·0 and 2·5 m

Figure 2. Data showing that the particle distribution in shower cores becomes flatter, on average, as the shower size increases.

(The ordinate is a measure of the flatness of the distribution; the abscissa is an approximate measure of shower size.)

densities of our showers at large distances, we take $\rho(4{\cdot}0)$ as a rough measure of shower size N. (Data from the Kiel air shower array (Bagge et al., 1979) suggest $N \sim 2000 \times \rho(4{\cdot}0)$, where $\rho(4{\cdot}0)$ is expressed in particles m^{-2}.)

The dependence of $\langle\rho(1{\cdot}0)\rangle/\langle\rho(0)\rangle$ on $\rho(4{\cdot}0)$ is given in Figure 2a, that of $\langle\rho(2{\cdot}5)\rangle/\langle\rho(1{\cdot}0)\rangle$ in Figure 2b. The upward trend towards unity in both Figures 2a and 2b shows that, on average, as the shower size (primary energy) increases the cores become flatter; the trend is less marked in Figure 2b but still clearly indicates a significant flattening out to at least 2·5 m from the shower centre.

The data given in this paper are well suited to comparison with predictions from Monte Carlo simulations. Details of such simulations and conclusions drawn are given by Ash (1985a,b).

Complementary to the present data are the results of a similar analysis by Ash (1985c) of photographs of air shower cores observed in the 20 m^2 discharge chamber array operated by Hazen et al. (1981) at Sacramento Peak (730 g cm^{-2}), New Mexico.

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References

Ash, A.G., 1985a, paper HE 4.2-15, this Conference
Ash, A.G., 1985b, paper HE 4.2-16, this Conference
Ash, A.G., 1985c, paper HE 4.2-18, this Conference
Bagge, E.R., Samorski, M., and Stamm, W., 1979, Conference Papers, 16th International Cosmic Ray Conference (Kyoto), 13, 260
Hazen, W.E., Hendel, A.Z., and Hazen, E.S., 1981, Conference Papers, 17th International Cosmic Ray Conference (Paris), 11, 350.
Hodson, A.L., Porter, M.R., Ash, A.G., and Bull, R.M., 1983a, Conference Papers, 18th International Cosmic Ray Conference (Bangalore), 6, 23
Hodson, A.L., Porter, M.R., Ash, A.G., and Bull, R.M., 1983b, *ibid.* 11, 201