PROGRESS REPORT ON A NEW SEARCH FOR FREE e/3 QUARKS IN THE CORES OF $10^{15}-10^{16}$ eV AIR SHOWERS

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ABSTRACT

The Leeds 3 m^2 Wilson cloud chamber is being used in a new search for free e/3 quarks close to the axes of $10^{15}-10^{16}$ eV air showers. A 'ratio trigger' circuit is used to detect the incidence of air shower cores; the position of the shower centre and the axis direction are determined from photographs of current-limited spark chambers. It is thus possible, for the first time, to know "where we have looked" for quarks in air showers and to select for scanning only those cloud chamber photographs where we have good evidence that the shower axis was close to the chamber. 250 g cm^{-2} of lead/concrete absorber above the cloud chamber serve to reduce particle densities and make a quark search possible very close to the shower axes. This paper gives the current status of the search.

1. Introduction. We report on a new search for free e/3 quarks in the core region of cosmic ray air showers. That is the very region where, if free quarks exist, they are most likely to be found but one which it has not been possible to explore properly in the past because of high particle densities and low rates of shower core 'hits'.

The 3 m^2 Leeds cloud chamber is ideally suited for such a search and this is now operating under absorber in conjunction with an array of discharge chambers which give information on the positions and directions of shower axes relative to the cloud chamber. Since the stereo scanning of cloud-chamber photographs for lightly-ionizing e/3 quark tracks is very time-consuming and tedious we can now be much more selective regarding which photographs are scanned; currently we scan only those events in which a shower core fell on a 35 m^2 discharge chamber array above the cloud chamber so that we know that the shower axis either passed through the cloud chamber or was in the close vicinity

Many improvements in technique and in the experimental arrangement have been made since a previous quark search with this cloud chamber (Hazen et al., 1975; Kass, 1977).

2. Experimental arrangement. Information on the shower cores is derived from a 7 m × 5 m close-packed array of 1 m^2 (2 cm gap) discharge chambers with Georgian-wired glass faces. This is mounted directly on the underside of a thin sandwich-panel roof ($\sim 2 \cdot 2$ g cm^{-2}), some 6·5 m above the cloud chamber (Figure 1), and is photographed from below. The direction of incidence of the showers may be derived (within $\sim 1-2^{o}$) from the mean projected 'track' angles in two 1 m^2 (4 cm gap) orthogonal vertical discharge chambers and one 1 m^2 (8 cm gap) horizontal discharge chamber beneath the array.

Beneath the 'discharge chamber room' and under 15 cm of lead ($2 \cdot 10^4$ kg) and 25 cm of concrete ($1 \cdot 1 \ . \ 10^4$ kg) is located the Leeds 3 m^2(× 1 m deep) Wilson cloud chamber (Hodson et al., 1965) with its 'front' window

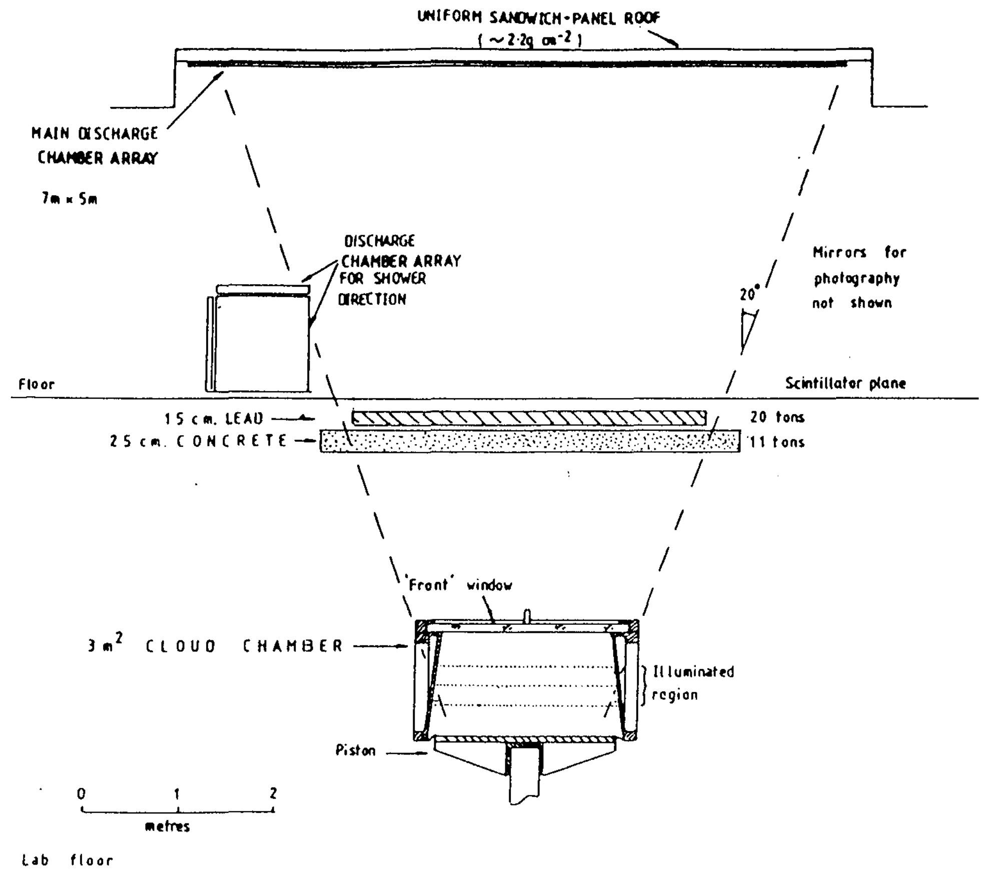

Figure 1: Elevation of Leeds Discharge Chamber/Cloud Chamber Installation

horizontal (and its original internal plates removed).

The discharge chambers and cloud chamber are triggered by pulses from an array of 7 plastic scintillators. A new trigger circuit, based on *ratios* of pulse heights following the work of Green and Hodson (1979), has recently been introduced to select showers whose cores fall within the 35 m^2 discharge chamber array and to exclude, as far as possible, those falling outside the array.

Four cameras are used to take stereo photographs of the cloud chamber, four views on 68 mm wide film and two on 200 mm wide film (Kodak Technical Pan 2415). A 40 cm deep section of the chamber is illuminated by four linear flash tubes (135,000 joules total flash energy). The photographs are taken effectively from above, via a mirror, so that the tracks appear foreshortened and a lightly-ionizing track (such as is expected from a relativistic e/3 quark) is more readily visible. Each track passes, at some point, through the region of best focus and good illumination; the photographic conditions are such that droplets on individual ions are recorded. The expansion time of the cloud chamber is

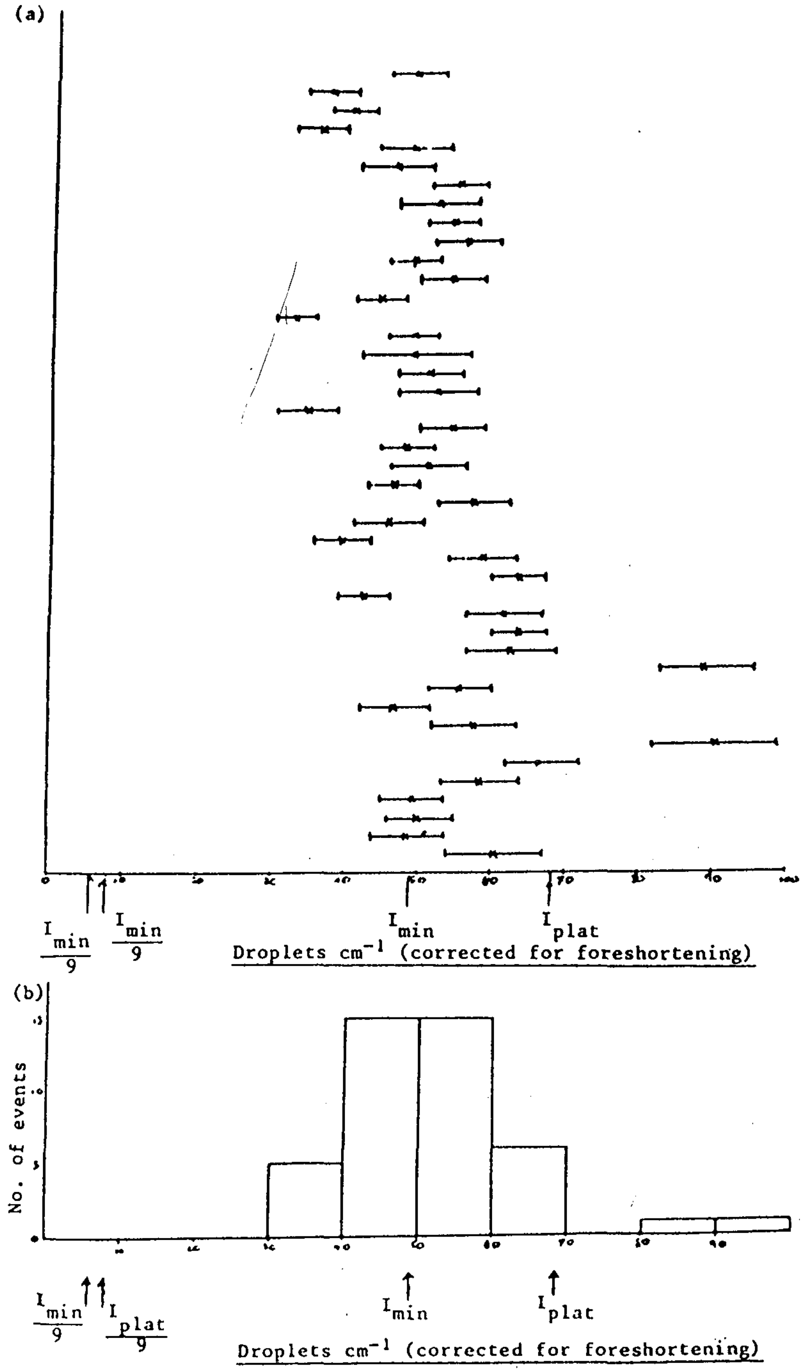

Figure 2: Individual drop count measurements (a), and preliminary distribution (b), for recent film.
The arrows indicate expected values for charge e particles and e/3 quarks at "minimum ionization" and at relativistic plateau ionization ($\approx 1\cdot4\ I_{min}$)

slowed to ~200 ms to allow the ions to diffuse and give track widths in the chamber ~3·5 mm wide suitable for the counting of resolved droplets.

The absorber above the cloud chamber removes the soft component of air showers and enables a search for free e/3 quarks to be made near the shower axes. After locating the position of the incident shower core at roof level in the discharge-chamber array it is then possible to trace the shower axis down through the absorber to the cloud chamber level using the directional information on the shower. The distance between the centre of the cloud chamber, in which the search is made, and the shower axis can then be found.

Voltages applied to horizontal planes of wires, 20 cm apart, within the cloud chamber serve to remove background ionization. By using electric fields of alternating directions between these planes and removing these fields promptly when a shower is detected, we are able to distinguish unambiguously between a genuine quark track and possible artefacts due to low condensation on separated negative ion columns still present in the chamber from pre-shower particles.

3. Current status of the search. The equipment is being run on as near as possible a continuous basis. Between January 1984 and May 1985 we photographed over 5400 events (~ 1200 with cores) at trigger rates of ~0·5 - 1 hr^{-1}. To date, ~650 core-related events have been scanned in stereo; no e/3 quark 'candidates' have yet been found.

Droplet counts on charge e shower tracks show a preliminary distribution as expected and demonstrate good discrimination between charge e ionization and the one ninth levels expected from free e/3 quarks (Fig.2).

We are currently refining our technique for superimposing 'artificial quark tracks' on occasional photographs to check observability and scanning efficiency.

4. Acknowledgements. We wish to thank the Science and Engineering Research Council for financial support. We are also indebted to our film scanners, Mrs J.Barker and Mrs P.A.Young, and former scanner, Mrs J Wilson, for their invaluable assistance.

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