The Elusive Quark

The excitement generated by the paper of La Rue, Fairbank and Hebard [1]) presented to the Spring Meeting of the American Physical Society, giving evidence from Stanford of the existence of fractionally charged particles is now rather muted following the results published by Gallinaro, Marinelli and Morpurgo [2]) of their work at Genoa.

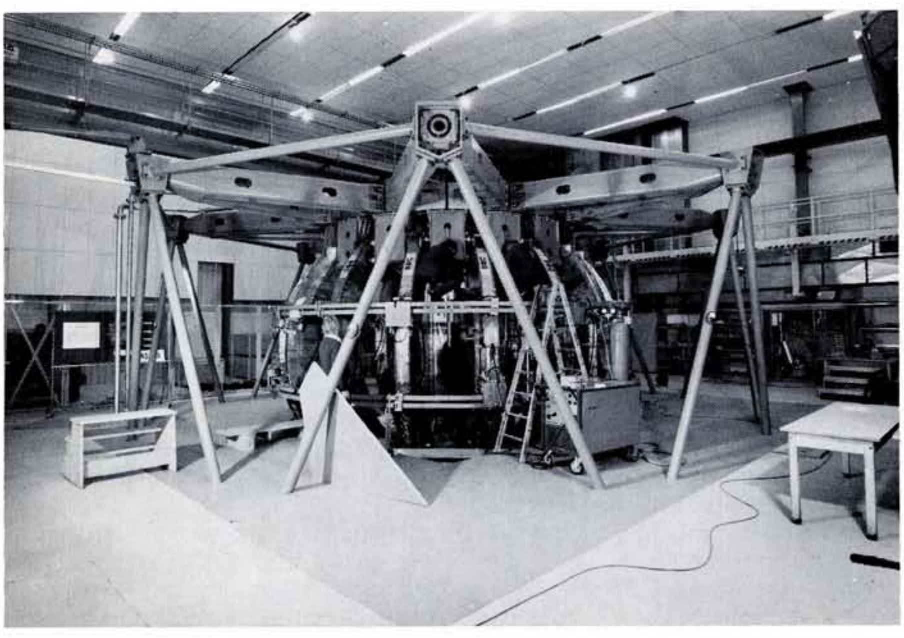
Morpurgo and his collaborators have been looking for quarks in matter since 1965. They discarded the use of the classical Millikan oil drop experiment because in each Millikan measurement not much more than 10^{-11} g of matter can be explored. This small value of the mass is due to the fact that in a Millikan experiment the object is prevented from falling by an electric field (the same as that used to measure its charge) ; moreover it is not easy to deal with big electric fields. They developed a method which consisted of levitating magnetically the grain of matter being studied and then measuring the charge by means of an applied electric field. To begin with, they used the diamagnetic properties of graphite for the suspension of a graphite grain, and measured the charge by the displacement of the grain when a static electric field was applied. This allowed the use of grains 100 times heavier than Millikan's ; another factor 100 was gained using a square wave oscillating electric field (rather than a static one) in resonance with the grain displacement to amplify the movement.

The main part of the effects arising from the electric polarization force are automatically cancelled in an oscillating field, but the secondary effects of static electric fields (Volta fields) from the electrodes remain and can only be checked by changing the distance between the electrodes. Also the symmetry of the potentials applied to the electrodes must be carefully controlled. The various Genoa apparata have all been built to allow this to be done. Without these precautions, spurious effects can easily appear and simulate a fractional charge. No evidence for fractional charges in graphite was found [3]) and the work moved on to ferromagnetic materials.

New equipment was built which, through feedback circuits, provided automatic stabilization of the suspended grain in a magnetic field gradient, frequency control of the applied alternating electric field and damping of the grain oscillation. With this equipment, the initial measurements were made on steel spheres of 3.10^{-5} g and it proved possible to determine the changes in total charge as one was lost or gained to an accuracy of about 0.02 e. Often fractional charges appeared, rather erratically. For instance, a typical sphere could show a strictly zero charge for a while (that is zero oscillation amplitude) but when that sphere was left suspended overnight, a slow increase in amplitude could begin to set in so that — without any change in charge having taken place — the next morning the apparent charge was around 1/3 e. A possible explanation was found in small rotations of the sphere. (The graphite grains were so irregular that their orientation stability was very good). This decided the Genoa group to use instead, spinning cylinders, and they were able to increase the sensitivity of the equipment to measure samples of up to 2.10^{-4} g. Since this use of spinning cylinders, no sign of fractional charges larger than 0.1 e have been observed in a total of five cylinders.

The Genoa group is certain that without the provision for changing the electrode distance and spinning their specimens they would have seen many cases of apparent fractional charge. In the Stanford experiment (which registers the time derivative of the amplitude of the vertical oscillations of superconducting specimens subjected to an alternating field), the electrode distance is fixed and the specimens are not spun. It is also significant that no fractional charges were reported on the pure niobium spheres but only on the tungsten coated niobium specimens and one of these lost its fractional charge after handling.

From a theoretical standpoint little can be said as to the implications of these results. The concentration of isolated quarks in various materials is still unknown and the Stanford experiments would show a very curious abundance of quarks in tungsten. This lack of knowledge of the expected concentration is a weak point in this kind of experiment in the same way that the lack of knowledge of the mass of isolated quarks is a weak point in accelerator quark searches since the production cross section depends heavily on the mass. The fact that the quark picture is so useful and yet isolated quarks are not found is perhaps the paradox of our days; in the long run though unravelling a paradox is always fruitful.



References

1. LA RUE, G., FAIRBANK, W. and HEBARD A., *Phys. Rev. Letters* **38** (1977) 1011.
2. GALLINARO, G., MARINELLI, M. and MORPURGO, G., *Phys. Rev. Letters* **38** (1977) 1255.
3. MORPURGO, G., GALLINARO, G. and PALMIERI G., *Nucl. Instr. and Methods* **79** (1970) 95; this paper contains a full list of references and an historical account of this kind of experiment.