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PROPOSAL

A SEARCH FOR FRACTIONALLY CHARGED PARTICLES IN WATER IRRADIATED AT THE INTERSECTING STORAGE RINGS

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If fractionally charged quarks exist as the basic triplet responsible for approximate SU(3) symmetry, we expect at least one of the quarks to be stable in ordinary matter, except for the unlikely event of annihilation against an antiquark. The stable quark will, particularly if negative, attach itself to a nucleus in matter, and since its charge cannot be neutralized by integer charge particles, a piece of matter containing a quark or antiquark will always have a charge $\pm e/3$ above respectively below the nearest integer charge value.

Such deviations from integer charge value can in principle be demonstrated by standard methods of measuring charge, provided the sensitivity is sufficiently high to separate integer and fractional charges. One such method is the Millikan oil drop method, which can detect deviations from integer charge in droplets containing about 10^{11} nucleons. However errors due to varying dropletsize, Brownian motion, and convection currents make the method of questionable value. More modern methods use a suspension of the material to be measured in a vacuum by the effect of magnetic field on a diamagnetic material [1] or superconducting material [2] to avoid many of the defects of the Millikan oil drop method and to increase the sensitivity. Such methods claim to detect a fractionally charged particle in 10^{17} nucleons, and by repeated such measurements a sensitivity of 10^{21} nucleons per quark may eventually be attained. However the limited choice of materials suitable for such methods, and the lack of knowledge about quark content originally present in the raw material and the chemical behaviour of the quarks during the complicated manufacturing process,make it very hard to estimate what the quark content should be. It is however also possible to use the magnetically suspended material as a platform on which other more suitable materials can be floated and their quark content investigated.

Many investigators [3] have made a quark search by attempting to enrich the original quark content in various materials by physical or chemical means, to a level where the quark content is more easily measurable, e.g. using a mass spectrometer. Such methods often claim very high sensitivities, of the order of 10^{24} nucleons per quark, but are subject to an uncertainty in the expected enrichment factor which depends on the unknown chemical properties of atoms in which a quark has been absorbed.

Most investigations of this kind have been made up to now in terrestrial matter, where the quark content may either be due to the remnants of free quarks present at the creation of the universe, or to production by high energy cosmic rays in the atmosphere. In both cases the distribution of the quark in the earths crust depends strongly on chemistry and geophysics, and is very uncertain. It is therefore very difficult to draw conclusions on the non-existense of quarks from the negative outcome of an experiment to measure fractional charges in terrestrial matter. If we make the assumption that quarks produced in cosmic rays have a tendency to accumulate in the sea water of the oceans, because of its high index of refraction, and that this accumulation has been going on for a substantial fraction of the age of the earth, say $2 \cdot 10^9$ years, then 1 kg of seawater is expected to contain less than 1 quark if the quark mass is above 3 GeV/c^2 and the production cross section 10^{-39} cm^2 above the threshold energy. None of the present methods have approached this sensitivity.

The cross section limit has been assumed to be 10^{-39} cm^2, as has been predicted by the statistical method or extrapolated from the known antibaryon production cross section. This limit to the cross sections has been approached experimentally in the more sensitive experimental search for quarks at accelerators [4].

THE METHOD

Work is proceeding in Lund for the development of a direct method of measuring the charge of water droplets with a sensitivity sufficient to distinguish between neutral and 1/3 elementary charge droplets. The method makes use of a vertical fountain of fine water droplets, of uniform size, in a strong electric field. To avoid spreading of the water jet it is kept in a vacuum. Tests in a forevacuum indicate that by this means the dimensions of the jet does not increase appreciably in a several meter high jet. A better vacuum has however to be achieved before a strong enough electric field will be sustained across the deflection plates, and this has not yet been attempted. With an electric field of 10 kV/cm and a transient time of 1 second in the field the expected deviation is 3 cm between neutral and e/3 droplets, large compared to the dimension of the water jet ($\ll$ 1 mm).

Assuming that this method can be made to work it should be possible to test several grams of water per hour for fractional charges, and provided that background effects can be avoided to set limits on the quark content in water of the order of 10^{27} nucleons per quark, without the need of chemical enrichment processes.

THE PROPOSAL

Although the method is not yet operational we would like to propose that one of the intersections of the ISR which are not used for other experiment be surrounded as closely a possible with tanks of water, in which fractionally charged particles originating from the interaction region would slow down and accumulate. Ideally the thickness of this water shield should be large compared to the interaction length of the quarks and to the range of the bulk of the quarks. This would correspond to a water layer of about 100 g/cm^2 thickness and a total weight of about 4 tons. With amounts of matter of this order it would be necessary to use some sort of chemical or physical enrichment process to reduce the amount by a factor of 1000 before our proposed detection method can be applied. The enrichment is however more modest that in most other methods and we would hope that theoretical studies of the chemical and physical processes performed in parallel with the development of the experimental techniques would reduce considerably the uncertainty in the enrichment factor.

We propose to expose the water during the first year of ISR operation.

As to the detailed arrangement of the water shield we would like to subdivide it into tanks both radially and in angle, so as to get information on the spatial distribution of the apparent fractional charges. Although in principle we would like to surround the intersection as completely as possible, compromises by a factor of two or so would clearly not be serious in view of the many other uncertain factors in the experiment.

SENSITIVITY

If the efficiency of the detection scheme is 100 per cent, and no background present, 200 days of the ISR runs at the design luminosity should produce one fractional charge per 10^{-42} cm^2 production cross section. A limiting sensitivity of 10^{-40} cm^2 production cross-section is therefore probably a conservative estimate. The possibility to detect a fractionally charged droplet depends to a large extent on the various background effects which can occur in our method and which as yet have only been considered theoretically. The main effect is believed to be due to the water droplets which change their charge during the transit through the electric field by picking up stray charges from cosmic ray ionization or from spurious discharges. Such droplets will however follow different trajectories from fractional charged droplets and although the deflection at one particular point may be the same, they can be identified by a more detailed study of the droplet trajectory. Droplets carrying unit charge but of higher than normal mass should also be distinguishable by their pathological trajectories.
As the detection method is limited to droplets of low charge, a few electron charges, the efficiency will be lowered, if the charge distribution is wide.

These background effects cannot be avoided entirely,but it is possible to improve the background rejection by combining our method with for example the magnetic levitation method. Droplets which from their deflection in our apparatus are judged to be fractionally charged can be collected on graphite grains for a further verification of their charge.

CONCLUSION

At the present status of the development of our method, our ISR proposal has to be tentative. It has however at least a potential sensitivity which is superior to any other method we know for detecting quarks. The necessary installations at the ISR could be very simple and would be confined to one of the 4 intersections which are not used for experiments during the initial period of ISR operation. The possible interference with the need of access to the intersection of the ISR machine group for maintenance and other purposes would of course have to be studied but we feel that suitable compromises could be arrived at if necessary.

We believe that more definite information on the feasibility of the method will be available before the ISR comes into operation. With proper planning the installations necessary for the experiment can be done in a very short time. Irrespective of our proposal it would also be of general interest to irradiate a large amount of matter for a prolonged period of the ISR, which can be searched by a variety of methods for exotic objects, such as quarks, monopoles, or as yet unsuspected particles.

REFERENCES

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