A Summary of the Search for Free Quarks*

Lawrence W. Jones†
University of Michigan, Ann Arbor, MI 48109

In spite of twenty years of effort only one experimental group reports positive evidence for fractional charge, the Stanford group of W. Fairbank. Other recent negative experiments have been reported, and several new searches in stable matter are planned or in progress. It is possible to concoct a "theory" relating free quark abundance to proton lifetime and the age of the Universe.

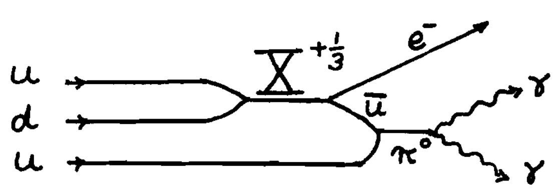
In three successive Physical Review Letters, W. Fairbank and his students have reported evidence for fractional charge on niobium spheres of about 100 μ gm. From over 40 measurements on at least 15 niobium balls he has numerous values of net charge $q=\pm 1/3$ e, although most measurements give $q=0$ (all measurements are modulo $\pm 1/2$e). The error is small and no measurements are reported at other than 0 and $\pm 1/3$ e within error. A most perplexing aspect of the data is that repeated measurement of the same ball often show a charge change of $\pm 1/3$ e. The total quantity of matter studied has been about 1.5 mg, or about 10^{21} nucleons.

Morpurgo has found no evidence for fractional charge in iron samples totalling 2-3 mg (about 2×10^{21} nucleons). R. Bland and co-workers have studied mercury droplets with a computerized Millikan oil drop apparatus, and find no fractional charge among 200 μg of Hg (about 1.2×10^{20} nucleons).

Other stable matter searches are in progress or planned by Hirsch and Hagstrom (falling droplets), W. Fairbank, Jr. (single atom laser spectroscopy), Olson (Van de Graaf charge spectrometer), Perl, Douglas, and Ziock. At the PEP collider at SLAC a limit has been set on pointlike quarks produced through understood EM processes which disallows production of quark pairs with m_q<15 GeV. Gustafson at Fermilab has reported more recent negative results from a hadronic production experiment.

Zweig and Lackner have developed a quark chemistry which helps them identify a most probable crystal matrix in which a particular quarked nucleus might most probably be found. One observation, for example, is that whatever the quarked nucleus found in a niobium crystal, it is almost surely not a niobium nucleus.

It was amusing to notice that Fairbank's reported quark abundance, about 10^{-21} quarks per nucleon, is numerically equal to the probability of a proton decay since the big bang ($10^{-31}\times 10^{10}$), using the most popular guess of the proton lifetime. This coincidence suggested a possible model, to wit: the conventional proton decay scheme is sketched as follows:



If the $\overline{u}$ from X decay produces a π° with a u from a second nucleon rather than that from the parent nucleon, two nucleon fragments with fractional charge remain. This might happen in a heavy nucleus, and the energy release from the nucleon decay could lead to fissioning of the nucleus, perhaps leaving two fission fragments each with fractional charge. It may further be true that unpaired quarks in a large nucleus might be stable against spontaneous quark pair production in vacuum, but below some nuclear radius or mass number this would fail. Hence there might be a natural explanation for the failure of the other experiments to see quarks in light nuclei or as single particles produced by an accelerator. Of course this argument is flawed by Zweig's arguments, by the fact that proton decay is not yet proven, and that Fairbank's quarks seem to come and go so capriciously.

In any event the search for free quarks provides an amusing chapter in elementary particle physics. I do not expect an early, definitive resolution to the current uncertain situation.

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