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Proposal to Search for +1/3e Stable Particles Using Cryogenic Sources

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A conceivable reason for the apparent discrepancy in the searches for stable fractional-charges between the Stanford group and those from almost all other work, is the possible stabilizing effect (on +1/3e particles) of the cryogenic temperatures used by Fairbank et al. We propose to do a cryogenic experiment, using the Fermilab 800-KV injector Cockroft Walton. Any fractional charges trapped in a cold source would be released as the temperature is raised, and then accelerated and detected. The techniques to be used are conventional and simple. A negative result would close a possible (if improbable) loophole in present measurements.

A. Introduction

The interest in searching for stable fractional charges has continued over almost two decades. The tantalizing results of LaRue et al.[1] are the only positive indications for their existence, all other experiments have negative or inconclusive results. The work of LaRue et al. involves the levitation of superconducting Nb spheres, and it has been suggested[2] that it is just conceivable that a connection may exist between the low temperatures and the observation of fractional charges, if they were +1/3e.

A simple method of searching for fractional charges is to accelerate particles in a purely electrostatic system. In such a system all charged particles will follow the same trajectory, independent of charge or mass. If a detector measures the total kinetic energy (by measuring ionization produced by stopped particles) then any integrally charged particle will have kinetic energy Vq where V is the voltage drop and q is an integral multiple of e. For a fractional charge the energy would be the appropriate fraction of Ve. Thus, in searching for +1/3e particles, one would expect to measure kinetic energies (pulse heights) exactly one third that of most sources of background.

This technique has been used[3] to look for +1/3e particles from Nb, W, and Fe filaments heated from room temperature to ~600°C with negative results. It is proposed to essentially repeat the experiment in Ref. 3, but over the temperature range of 3°-300°. The open-air feature of the Cockroft-Walton accelerators makes them especially attractive for such cryogenic measurements. Most electrostatic machines with pressurized terminals, would present problems in allowing one to design and instrument a cryostat in a pressurized environment.

B. Experimental Apparatus

(i) The Cockroft Walton

There are two Cockroft Walton pre-accelerators at Fermilab operating at −750 kV for H^- beams. These are alternated at approximately 2-month intervals, with one machine always in reserve. During summer and fall months when no high-energy physics program is in operation, there is not the imperative need for beam at all times. Beam is required a few days per week only for cancer therapy and occasional beam studies in the booster and cooling ring. It becomes possible therefore to consider assigning the reserve accelerator to another project for a time of up to several months, if necessary, during the summer.

The diodes in the high-voltage rectifying stack will be reversed to provide a positive voltage on the terminal. The present negative ion source, together with its supporting flange assembly, refrigerator and vacuum pump, will be removed. The cryostat source on an appropriate supporting flange for the quark search experiment will be installed on the accelerating column. All existing electronic equipment racks and cabling in the terminal can be left intact as the new equipment is added. No vacuum pumps are required in the terminal.

(ii) The Cryostat Source

As presently envisioned, the source assembly would consist of a copper block cooled by a continuous flow of 4.2 K liquid helium with a heater and thermometers attached. The source itself would be a Nb ribbon filament thermally attached to the block, with provision to pass a 60 Hz heating current through the filament. This will allow the filament to be heated to ~1200°K for alignment purposes. It will be necessary to place a 25 liter liquid helium storage dewar and possibly a 25 liter liquid nitrogen dewar in the terminal. Terminal controls and interfacing required will be two or three solenoid operated valves, two thermometer readouts and control of two heater voltages. It will be possible to raise the filament temperature from 4.2°K to

~300°K in a few seconds. If the experiment is approved the source assembly will be designed in about one month, fabrication assembly and testing should be complete in another three months, and the experiment would proceed anytime after June 1.

(iii) Terminal Controls

Control and monitoring of equipment in the injector terminal will be handled by the existing microprocessor-based system which uses optical-fibre coupling between ground and high-voltage terminal. There are about 20 signal channels available in excess of those needed for injector operation, out of which we need about 12 (2 thermometric readouts, 2-3 solenoid actuating controls, 1 dc heater voltage control, 1 ac heater voltage control, 2 for einzel lens control and readout, 1 liquid He level readout, 2 general voltage readouts).

(iv) Focusing and Alignment

The cryostat and ion source will be constructed to allow a few millimeter motion to ion-optically align the filament. An auxiliary electrode (einzel lens) near the source will allow us to optimize beam transport through the Cockroft Walton accelerator. This additional focussing is necessary since the space-charge effects that are utilized under normal high beam current operation in the injector will be absent under the "zero beam" conditions of the present experiment. Focussing and ion-optical transport to the detector chamber will be tested and optimized visually with a charged-particle beam emitted from the heated source (~6-800°C) and a quartz screen in the detector location.

(v) The Detector

The simplest form of the detector would be a Si surface-barrier detector a few cm^2 in area. The range of a particle with +1/3e charge and 800/3 = 267 keV energy is somewhat uncertain, since such a particle, unlike protons, deuterons, α's or other integrally-charged particles would not be neutral, even at low velocities. Roughly, the range should be ~100 μ and we would plan on using a 200-μ thick detector. A large number of such detectors are in our possession now and used in standard fashion in many of our nuclear-physics charged-particle experiments at the Argonne tandem-linac facility.

We will actually use a two-element telescope, ~1 cm^2 in area consisting of a 20 μ transmission detector in front of a 200 μ one. The fractional energy loss in the first detector would identify the charge of the particle--since a 1/3e particle would have a uniquely low dE/dx. This will place a severe cut on any background, if present. We also plan to provide for the possibility of introducing a ~10-cm gap between the two elements of the telescope. We have used such telescopes to provide time-of-flight information with time resolution of 50 psec under normal circumstances but at higher particle energy. For the present systsem we expect approximately 0.5 to 1 nsec resolution, which should give a mass resolution of $\leq$ 20% for a +1/3e object with mass $\geq$ 300 MeV/c^2. The detector system will be housed in a small scattering chamber provided by us, and pumped by the vacuum pumps on the injector system.

A weak ^{241}Am α source (0.1)C) will be used to calibrate the energy response of the detector system.

(vi) Background Rates

The number of background counts seen in the detector from cosmic rays should be << 1/min. From the experience in the previous quark search experiments, the background rate with the source at room temperature may be < 1/min., but can also be 10–100/min., if the accelerator tube is not properly conditioned. Small sparks or discharges can cause charged particles to be released from surfaces in the accelerator—and these may be accelerated into the detector. The nature of such background at the Fermilab injector is difficult to predict, however the use of a ΔE-E telescope will quickly eliminate any such background. Particles will be stopped in the front (ΔE) detector, even 800-keV protons will stop in ~11 μ of Si—half the thickness of the proposed ΔE detector. Thus there will be no accelerator-induced backgrounds. Some cosmic-ray-induced shower may trigger both the ΔE and E detector and give a false signal. The probability of such events is many orders of magnitude too low to give even a single event in the total measurement time of a few minutes. And background observations over hours or days will be carried out. The most serious source of background may be electronic noise and some care will have to be taken to eliminate such effects—but this problem has been solved before.

(vii) Electronics

Standard commercial (and to some extent ANL-built) fast-slow electronics for pulse-height analysis will be used, connecting to a CAMAC interface that feeds into a PDP 11/45 computer. All electronics will be available from Argonne.

(viii) Computer and Trailer

We propose to use a PDP 11/45 computer with ~128K memory presently installed in an Argonne-owned trailer. The trailer is 43 ft. long × 8 ft wide and 12 1/2 ft. high; it is expected to be back at Argonne by ~March 1 and available for the rest of 1982. This computer system has been used extensively at LAMPF in Los Alamos, and is identical to ones in use for data acquisition at the Argonne superconducting linac and at the dynamitron. A well-developed software system (SNAP) has been used by a number of us for data acquisition in closely-analogous experiments (e.g. Ref. 3), it records data on magnetic tape for off-line analysis and at the same time allows for on-line analysis and monitoring of the data. Maintenance of the hardware will be carried out by personnel from the Argonne Physics Division. The electronics will be interfaced to the computer through standard Camac modules.

C. Measurements

(i) Approximate time sequence and total time requirements:

a) Polarity change of injector	~2 days
b) Installation of ion source plus detector chamber and cryogenic tests of ion source	1-2 weeks
c) Ion-optical alignment with low beam current	1-2 weeks
d) Measurements	2-3 weeks
Total	~6 weeks

D. Collaborators

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K. W. Shepard, IEEE Trans. Nucl. Sci. NS-28, 3248 (1981)

Kenneth W. Shepard, IEEE Trans. Nucl. Sci. NS-26, 3659 (1979)

E. Required Support

Reversal of polarity of the Cockroft Walton accelerator and removal of negative ion source.....(5 man days)

Installation of cryogenic source, beam line and detection chamber..............................(6 man days)

Operation and maintänance of accelerator system....(2 technicians on call, will average one half technician during the remainder of running period.)

Cryogenic supplies (~500 ℓ of liquid He, and a similar quantity of liquid N_2.)

Space for 43 x 8 ft trailer within ~200 ft cable distance of experiment; 440V, 3-phase, 60A power for trailer; pathway for cables from trailer to experiment.

References

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