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SLAC Proposal No. 25

PROPOSAL FOR AN EXPERIMENT TO SEARCH FOR FRACTIONALLY CHARGED PARTICLES

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The purpose of the proposed experiment is to make a search for fractionally charged particles produced by the SLAC electron beam. The motivation of the proposal is based not only on the possible existence of charged 'quarks,' with charges e/3 and 2e/3, but on the phenomenological possibility that particles with much smaller charge may exist. The fact that the energy loss of such particles passing through material decreases according to the square of the charge would have made it difficult to observe such particles in the past.

Many experiments have been performed since the proposed existence of 'quarks,' to search for the latter*. Experiments on proton machines, mainly using bubble chambers, have failed to find quarks with production ratios compared to π's of the same momenta of $\sim 5 \times 10^{-9}$ for charge e/3, and $\sim 4 \times 10^{-8}$ for charge 2e/3. The most recent cosmic ray experiments place limits of $\sim 10^{-8}$ of the μ flux. Experiments at C.E.A. (D. A. Garelick, private communication) have failed to find weakly interacting quarks to one part in 10^7 of the muon flux.

The detecting system in the proposed experiment would consist of four similar five inch thick NaI(Tl) crystals as energy loss detectors, each viewed by four photomultipliers. Minimum ionizing particles of charge e will lose on the average about 70 MeV on passing through each of these crystals. These crystals can easily resolve the Co^{60} peaks at 1.17 and 1.33 MeV, and energy deposition, in a single pulse, as low as 100 keV is easily recognizable above noise and measurable with good resolution. This would be the ionization loss of a fast particle of charge e/25 passing through the crystal. These crystals would be placed at the final focus of the muon beam tuned to maximum rigidity (at present 12.75 BeV/c muons) with the energy of the electron beam incident on the target just below this value. No particles of unit charge can then pass through the beam system. Particles with charge $Ze(Z < 1)$ of momentum 12.75 x Z BeV/c will be focused on the detector. The four crystals will be placed in coincidence (resolving time $\sim$ 20 ns) opening a gate allowing the pulses from each crystal to enter an analogue to digital converter. After each coincidence, the pulse heights registered by the A.D.C.'s will be read out via a typewriter and the units reset. One-hundred kilowatts of beam power would be required.

For particles of low charge, the limit on detection is likely to be set, not by the detection capabilities of the NaI(Tl) crystals, but by the decrease of yield at low momenta, since all particle yields below 0.5 BeV/c (corresponding to particles with charge e/25 being focused by the beam magnets) are likely to be small. For the yield of leptonic pairs, calculation of Tsai and Van Whitis modified by a Z^4 factor indicate that 10^{-8} and 10^{-10} yields with respect to μ's would occur for 1 BeV and 1.5 BeV mass particles respectively, each of charge e/3. With 18 GeV incident electron an increase by factors $\sim$ 3 or 5 respectively in the flux would be expected for such particles, but the muons would then have to be stopped in an absorber of $\sim$ 30 feet of steel.

Although backgrounds are expected to be small on the basis of our present experience with lower intensity beams, these are best determined with a short run during setting up. We accordingly request 2 shifts for aligning, testing and setting up, to be followed, assuming a satisfactory performance, by 3 shifts for taking data at 12.5 BeV electron beam energy. The muon beam as at present existing would suffice for this experiment. We would also like to request a further 2 shifts for runs at 18 BeV electron beam energy with absorber inserted to stop the muons. If fractionally charged particles were detected by this technique, it would be desirable to incorporate a visual detector and to make a mass determination using a short pulse technique and time of flight measurements.

The equipment is ready, and data analysis time is expected to be a few days.

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Addendum: Background Run at 10 ma and 120 p.p.s.

The four large NaI crystals were placed at the third or final focus of the μ beam and a 3" diameter 3" long NaI crystal was mounted at the second focus. The thresholds were set so as to accept particles of charge about e/20 or greater. With the electron beam hitting the muon beam target, no background coincidences between the 3" crystal and the large NaI crystals were recorded in two (2) hours of running. Coincidences between the four (4) large crystals alone were about 50/hour. These latter seemed to be μ particles but were not coming down the beam line. When the beam was dumped in the straight ahead dump, this rate increased by an order of magnitude, so that the slow readout system (3 seconds/event), was jammed when triggered on these coincidences.

Running at 20 ma and 180 p.p.s., true beam coincidences would therefore be expected to be between 0 and 50/16 hour run, assuming our zero counts might have arisen from a true mean of 0 to 2.

The following table gives the number of counts expected/16 hour run at 180 p.p.s. and 20 ma, for various masses and charges assuming no production via strong interactions, but only via electro-magnetic pair production.

Charge \ Mass (BeV)	.1	.5	1.0	1.5
2 e/3	10^9	3.10^4	5.10^2	3
e/3	2×10^7	3.10^3	50	0.3
e/10	10^5	10	----	----
e/25	10^2	----	----	----

One shift would correspond to 10^{10} muons produced at 7 BeV/c in the beam and to 10^{11} π's at 7 BeV/c in the beam.

Assuming that a statistically significant count for real fractionally charged particles would be 5, then in a 16 hour run mass limits would be charge 2 e/3 about 1.5 BeV

charge e/3 about 1 BeV

charge e/10 about 0.5 BeV

charge e/25 about 0.1 BeV

Since the dynamic range of the equipment for accurately recording the pulse heights from the counters is about 10:1, then two such runs would cover from e/10 to e (100:1, in pulse height), three such runs would cover from e/25 to e (625:1, in pulse height).

We therefore request six 8 hour shifts at 20 ma and 180 p.p.s. or three 8 hour shifts at 20 ma and 360 p.p.s.

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