

NAL PROPOSAL No. 170

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Search for Electromagnetic Production of Fractionally Charged
Particles at NAL

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1. Introduction

One of the most important investigations to be conducted during the early operation of NAL is the search for quarks. Several experiments have been proposed which will investigate quark production via the strong interaction. As we discuss below, however, there are serious arguments to suggest that the mass limits obtained will not be significantly higher than the current limits of 4 to 5 GeV. To circumvent these objections we propose a simple experiment based on electromagnetic production of quarks. It would run inside the main ring with photons produced in the rotating C-O target. No presently approved quark experiment is sensitive to such production without modification of its proposed set-up.

2. Quark Production

In any quark search, an upper limit on the differential production cross section is achieved by a straight forward measurement. The interpretation of this cross section in terms of a quark mass, however, requires the use of a production model. The usual approach⁽¹⁾ employs the statistical model⁽²⁾ which is known to predict fairly well, at conventional energies, secondary particle production from incident hadrons. A characteristic of this model, however, is that the production of very massive secondaries is strongly suppressed in favor of less massive particles. The dramatic suppression of high masses

is not significantly off-set by the center of mass energies now available at NAL or the ISR.

To circumvent this problem we have tried to estimate the cross section for quark production via the electromagnetic processes. Drell has proposed a scheme to calculate the electromagnetic pair production of spin zero objects. His relation which is known to work well for pion production is:

$$\frac{d\sigma(k, E, \theta)}{d\Omega dE} = \frac{\alpha Z^2}{2\pi} \frac{E(k-E)}{4\pi k^3} \frac{4\theta^2}{[\theta^2 + (M/E)^2]^2} \sigma_T(k-E)$$

k photon energy

E, M energy and mass of produced particle

θ angle of produced particle in the laboratory

To estimate the quark production we use:

$$\sigma_T = 12 \text{ mb. independent of energy (quark, nucleon total cross section)} = 1/3 \text{ nucleon nucleon cross section}$$

Z = charge of quark

This expression appears to be as reasonable an estimate as any for electromagnetic quark production. (3)

An interesting feature of electromagnetic production is that the yield is zero at zero angle with respect to the photon direction and reaches a maximum at $\theta = M/E$. Thus one must perform observations at a relatively large angle with respect to the photon direction. This implies that experiments at small

angles will be insensitive to the effect and, on the other hand, that the backgrounds from strong interactions will be significantly reduced in the angular region of observation.

3. The Detector

A schematic of the experimental layout is shown in Fig. 1. Photons, produced by π^0 production and decay in the rotating C-O target, impinge on a beryllium collar around the beam pipe about 70 feet downstream. The beryllium forms the photon target where quarks are produced. A multi layer, dE/dx measuring, gas proportional counter is positioned at about 100 mrad. with respect to the photon direction and is used to identify the quarks. This same counter provides angular information on the quark direction and thus is an important element in the rejection of background sources. Such multi-layer gas proportional counters are now being built by some of us for an experiment at the CERN-ISR. Their technology is well understood.

The electronics and data acquisition system would be the same as is currently set up for experiment 120 at the C-O service building.

4. Yields and Mass Limits

To estimate the sensitivity of the experiment we have first calculated the photon flux into the beryllium collar on the basis of the Hagedorn-Ranft statistical model for π^0 ⁽²⁾

production. The Drell formula is then integrated over the resulting photon spectrum and gives the quark yields as a function of mass shown in Table 1.

On the basis of a 10^{-3} ster solid angle detector (~4inx4in at 10 ft.) and 10^9 interacting protons per second we find 200 events per day at the kinematic mass limit of 9 GeV (200 GeV machine operation). If one includes the Fermi motion of the target nucleon this mass limit can be increased to 12 GeV at 200 GeV machine operation, and 18 GeV at 450 GeV operation with a corresponding reduction in rate of 10^3 . Thus electromagnetic production allows one to explore the quark mass range up to the kinematic limit of the accelerator and with rates of several hundred events per day. In view of possible uncertainties in the quark production mechanism this high yield is an important safety factor.

5. Schedule

This quark search would represent only a modest extension of the present experiment 120. The dE/dx counters could be installed by mid-May. We would like to demonstrate the feasibility of this experiment by conducting background studies as soon as experiment 120 is given permission to begin.

6. Conclusions

We feel that this experiment on electromagnetic quark production represents an important compliment to the quark

experiments already approved by the laboratory. On such a fundamental issue as fractionally charged particles all production mechanisms must be exploited. The experiment is extremely simple and could be carried out in the next few months.

References

1. Yu. M. Antipov et al., Physics Letters 29B, 245 (1969);
Physics Letters 30B, 576 (1969).
2. R. Hagedorn and J. Ranft, Suppl. Nuovo Cimento 6, 311
(1968).
3. L. Van Hove, private communication.

Table 1

<u>Quark Mass</u> <u>(GeV)</u>	<u>Quark Yield (per int. proton, sterad.)</u> <u>at 100 mrad.</u>	
	<u>200 GeV</u> <u>Operation</u>	<u>350 GeV</u> <u>Operation</u>
2	1.0×10^{-6}	3.0×10^{-6}
3	5.1×10^{-7}	1.7×10^{-6}
4	2.8×10^{-7}	1.0×10^{-6}
5	1.7×10^{-7}	7.0×10^{-7}
6	1.0×10^{-7}	4.7×10^{-7}
7	0.7×10^{-7}	3.3×10^{-7}
8	0.5×10^{-7}	2.4×10^{-7}
9	0.3×10^{-7}	1.8×10^{-7}
10		1.4×10^{-7}
11		1.0×10^{-7}
12		0.8×10^{-7}

ELECTROMAGNETIC QUARK PRODUCTION EXPERIMENTAL LAYOUT

