NAL PROPOSAL No. 3

Correspondent: P. H. Eberhard
Lawrence Radiation Lab
University of Californi

FTS/Commercial 415 843 2740

PROPOSAL FOR A SEARCH FOR MAGNETIC MONOPOLES AT NAL

L. W. Alvarez, P. H. Eberhard, R. R. Ross

Lawrence Radiation Laboratory

R. D. Watt

Stanford Linear Accelerator Center

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"A Monopole Detector For Search In Lunar Material"
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L. W. Alvarez, P. H. Eberhard, R. R. Ross - LRL

R. D. Watt - SLAC

ABSTRACT

It is proposed that an experiment be performed to search for magnetic monopoles based on their electromagnetic properties at macroscopic distances only.

A ferromagnetic trap would be exposed in a beam dump at NAL and monopoles would be searched for using an existing detector.

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Introduction

The discovery of a magnetic monopole would be an important experimental result. It would give a reason for the phenomenon of exact electric charge quantization that is not explained yet any other way.[1] Schwinger's dyon theory makes monopoles even more important because they would also be the quarks, i.e., the building blocks of the hadrons. Schwinger's scheme[2] requires the electric charge of the monopoles to be a multiple of 1/3 of the electron charge while all magnetically neutral particles must have electric charges equal to an integer times the electron charge. Monopoles would be also responsible for CP violations.

Properties of Monopoles

If monopoles exist, few of their properties would be known. For their magnetic charge, there is a minimum value g_o.

$$g_o = 3 \times 10^{-8} \text{ e.m.u.} \qquad (1)$$

and their charge g is a multiple of g_o

$$g = \nu \quad g_o \qquad (2)$$

where ν is an integer. ν is not known but even for its minimum value, 1, the coupling constant is about 68.5 times larger than the electric coupling constant e. It follows that reliable calculations can be used to predict properties of the monopoles for interactions at large distances only.

From Maxwell's equation completed by its "missing terms," a reliable computation, involving only large distances, shows that a monopole of charge g traveling inside a coil along its axis will generate a known electro motive force. Another reliable computation shows that monopoles would be trapped by ferromagnetic material with a binding energy W expressed in eV

$$W = 3 \times 10^4 \frac{\nu^2}{r} \frac{\mu-1}{\mu} \qquad (3)$$

where μ is the permeability of the ferromagnetic material, ν is the integer that defines the charge in equation (2) and r is a distance, expressed in Å beyond which calculations are considered to be reliable. Of course, r should be large enough also so the field at distance r does not saturate the ferromagnetic material.

$$r \gtrsim 170\sqrt{\nu} \qquad (4)$$

Even if r is of the order of 1000 Å, and the charge is minimum ($\nu = 1$), the binding energy is as large as 30 eV, large enough to withstand thermic agitation.

However, 3 parameters are not known, the integer ν , the mass M and the cross section σ of production of a monopole pair by proton-proton collision. Any search for monopole covers a given range of the parameters M, σ, and ν .

Experimental Situation

In the domain accessible to a monopole search at NAL i.e., for masses M less than 15 GeV, the previous experiments[3] have explored ranges that are all included in the range of one of the latest publications.[4] This experiment involves known properties of the monopoles only, such as trapping in ferromagnetic material and electric induction in a coil by a moving monopole. From its negative result, one can conclude that there are no monopoles of any charge g equal or greater than the minimum charge g_o, i.e. for any integer ν , for a mass M less than 15 GeV, that would be produced with a production cross section above 10^{-40} cm^2 (95 °/o confidence level). The limit for the cross sections is even lower for lower masses.

However, there is no theoretical lower limit for the cross section σ^5. The range of smaller cross sections is worth exploring and we think a search for monopoles is worthwhile as long as the new range covered is sizeable. A reduction by at least a factor of 10 in the experimental upper limit for σ in the case of finding no monopole, seems to us to be a reasonable requirement on a new experiment. The experiment also should cover all values of the integer ν and rely only on known properties of the monopoles such as induction and trapping in ferromagnetic material.

We propose to perform an experiment at NAL that would satisfy the above conditions.

Description of the Experiment

1) A cylinder of ferromagnetic material would be interposed in the beam dump for the extracted beam. The length of the cylinder should be computed by adding one collision length for proton interaction (about 100 g/cm^2) to the maximum range that a monopole produced at NAL could have (50 g/cm^2). A cylinder of iron should be approximately 30 cm long. Its diameter depends on the geometry of the beam at the beam dump.

2) When the irradiation is sufficient for the experiment, the ferromagnetic cylinder would be taken out and shipped to Berkeley. The question raised from the health hazards due to handling ratioactive material should be discussed with the experts in NAL and Berkeley.

3) The cylinder would then be ground, mixed thoroughly and the powder would be separated in different samples so the north and the south poles would not likely be in the same sample. This operation should probably be done in Berkeley.

4) Each sample would be run in the same equipment that was used in reference 4 for the lunar sample. This detector measures the magnetic charge of a sample to an accuracy better than the minimum charge g_o. Description of this equipment is attached to this proposal.

Time of irradiation

The longer the irradiation, the more chance we have to find a monopole. To be reasonable, the exposure time should be of the order of a few months, so one may expect to collect 10^{18} protons (assuming an intensity of 10^{12} protons/pulse.)

Even if no monopole is found in the search, a new upper limit would be established for p-p production cross section σ and for masses $M \lesssim 15$ GeV. The new upper limit at 95 °/o confidence level would be about 10^{-43} cm^2.

Even the lunar experiment[4] does not have any comparable limit for the cross section unless one considers $M < 1$ GeV.

Possible variants of the proposal.

Targets

There are many ways to design a ferromagnetic trap for monopoles. The iron cylinder described here is the least sophisticated one. Of course more complicated systems may turn out to be necessary if this simple design does not receive the agreement from the NAL staff responsible for the beam dump or the staff in charge of health and safety.

Placement of the target

Irradiations may be performed at the beam dump used in the early time of running the machine, or in the beam dump used later when the experimental areas are functioning or in both beam dumps. We would like to use every opportunity to produce and trap a monopole. However, irradiations of less than 10^{16} protons are too small to justify a reasonable experiment.

FOOTNOTES AND REFERENCES

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