NAL PROPOSAL No. 22

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EXPERIMENTAL PROPOSAL TO THE NATIONAL ACCELERATOR LABORATORY FOR A SEARCH FOR MULTIGAMMA EVENTS FROM MAGNETIC MONOPOLE PAIRS

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The failure of numerous attempts to find isolated Dirac magnetic monopoles is well known. Ruderman and Zwanziger have speculated that monopole pairs may be created by high energy photons. Because these pairs would have an extremely strong, as well as long range attraction for each other, they would quickly annihilate. This whole process would give rise to a great number of photons both from annihilation radiation and bremsstrahlung. Observation of a few anomalous pure photon cosmic ray showers, which display characteristics explainable only by this model, were in part responsible for this theoretical speculation. Thus motivated, we propose to survey multigamma events emerging from a thin target bombarded with protons at the highest accelerator energy attainable. We propose also to search, by conventional methods, for the possible production of free monopoles.

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II. Physics Justification

The prediction of the existence of magnetic monopoles by Dirac (Proc. Roy. Soc. (London) Sec.A, 133, 60 (1931)) has initiated many experimental searches over the past third of a century. All have looked for free monopoles and none have found them (see R.L. Fleischer *et al.* J. Appl. Phys. 41, 958 (1970)). However, very low upper limits on free monopole production cross sections and high lower limits on the monopole's mass have been established. Recently, Ruderman and Zwanziger (Phys. Rev. Letters 22, 146 (1969)) have put forward a very reasonable explanation for the negative results, assuming that monopoles exist. Based on largely classical electrodynamics, they point out that due to the strong long range force between monopoles, they must be produced with relativistic velocities in their own center-of-mass system to escape their self-attraction. Furthermore, bremsstrahlung processes associated with this production process will greatly exceed the pole's rest energy. Except for extremely high incident energies, the result will be annihilation of the monopoles, resulting in additional radiation. The authors estimate that at incident energies of 10^{13}ev, this transitory production of a monopole pair will result in about 10^{2} gamma rays, with laboratory energies of a few hundred MeV to a few GeV.

In support of this model, Ruderman and Zwanziger point to the observation of a number of very peculiar energetic narrow cosmic ray photon showers, reported by A. Debenedetti *et al.*, (Nuovo Cimento 12, 954 (1954)), and Nuovo Cimento 2, 220 (1955), M. Schein, *et al.*, (Phys. Rev. 95, 855 (1954), and Phys. Rev. 99, 643 (1955)), M. Koshiba and M.E. Kaplon, (Phys. Rev. 100, 327, (1955)).

Figure 1 is a reproduction of one of the Schein events.

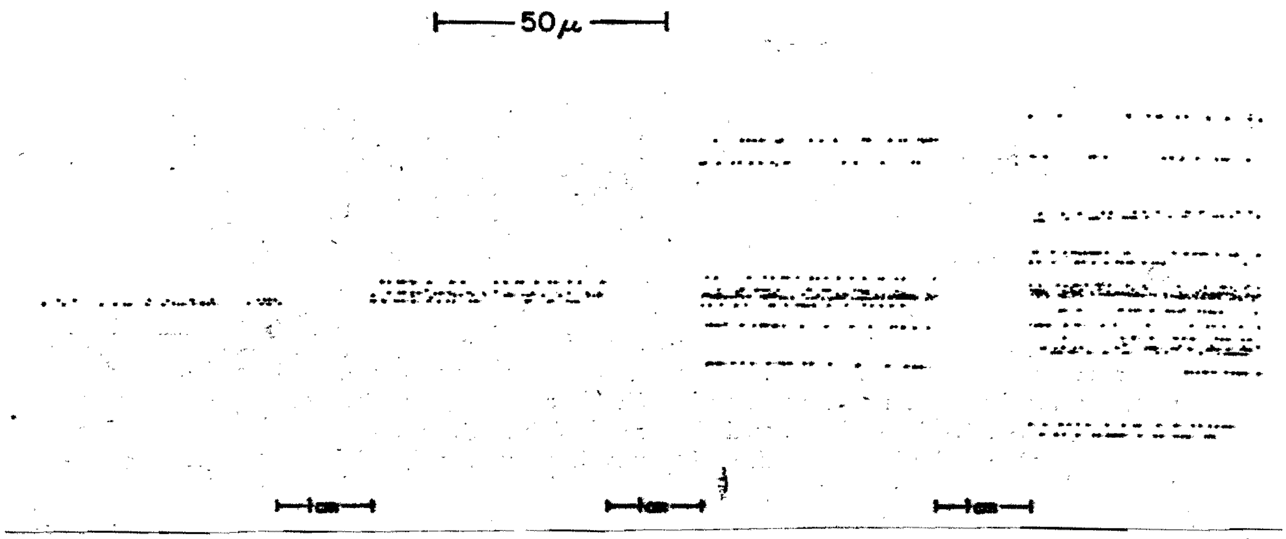

Fig. 1. Narrow shower of pure photons. Sections at arbitrary intervals to show development of shower. Note pair starting in last section.

Table I lists the angular spread and energy of each detected gamma ray which was observed in a similar shower by Debenedetti.

Table I. A Narrow Shower Event.

Pair no.	Angle 10^{-3} rad	Energy GeV	Radial distance μm	Distance from the first pair (μm)
1	0.2	10	—	—
2	0.2	10	6	760
3	1	2	2	2 200
4	1	2	< 1	5 630
5	1	2	2.5	6 800
6	10	0.2	35	11 820
7	0.6	3.3	1.5	12 160
8	10	0.2	28	16 580
9	0.6	3.3	30	18 670
10	1	2	3	19 500
11	2	1	35	19 850
12	1	2	2	20 000
13	< 1	> 2	3.5	21 000
14	8	0.25	22	24 500

All these authors claim that, for a number of reasons, the events are not conventional electromagnetic showers originating from a single high energy gamma, but result from some tens of independent gamma rays. Ruderman and Zwanziger point out that the similarities of these anomalous showers are consistent with the results of annihilation of magnetic monopole pairs.

III. Experimental Arrangement

We propose a search for multigamma events produced in proton-nuclei interations at the highest energy available at the National Accelerator Laboratory. If such multigamma events could be established, a systematic investigation of their characteristics could lead to a verification of the Ruderman-Zwanziger model and thus to evidence for the existence of monopole pairs.

The key to this experiment is the ability to identify a shower of 10 or more simultaneous gamma rays with $E_\gamma \geq 100$ MeV, each from a background of simultaneous gamma rays originating from multiple π^0 production and conventional showers initiated by a single gamma ray. We propose to use, for this purpose, a rather simple combination of lead converters (~ 1 radiation length thick) sandwiched between proportional wire chambers. This array will be placed in a swept 0° beam at a considerable distance (~ 50 meters) from a thin target bombarded with protons of the highest available energy.

The proportional wire chambers with their good time resolution (~ 10 ns) will reduce accidental coincidences. The chambers will also have a spatial resolution of 0.5 cm or less for gamma ray produced showers. Thus this array will record the arrival of simultaneous gamma rays with angular divergences from 0.1 to 10 mr. A multigamma event will be established by the presence of many small showers produced in coincidence at distinct transverse locations across the array. No attempt will be made initially to determine the energy of the individual showers.

The identification of the monopole pair induced multigamma events will be based on their unique spatial and multiplicity distributions. Gamma rays from π^o's have an estimated spread of 20 to 50 mr while from Table I it can be seen that angular spreads for the anomalous cosmic ray photon showers is between 0.2 and 10 mr.

Proportional wire chambers permit one to set any lower limit desired on the number of simultaneous gammas per event (n_γ). By raising this lower limit data can be obtained leading to a normalized frequency plot of n_γ. For π^o and shower produced gammas the distribution of n_γ will have a maximum at low n_γ and fall off rapidly as n_γ is increased. For monopole pair produced gammas the distribution should have a maximum at $n_\gamma \geq 10$. If the Ruderman and Zwanziger scenario is correct one might expect a plot of n_γ to look like that shown below in Fig. 2.

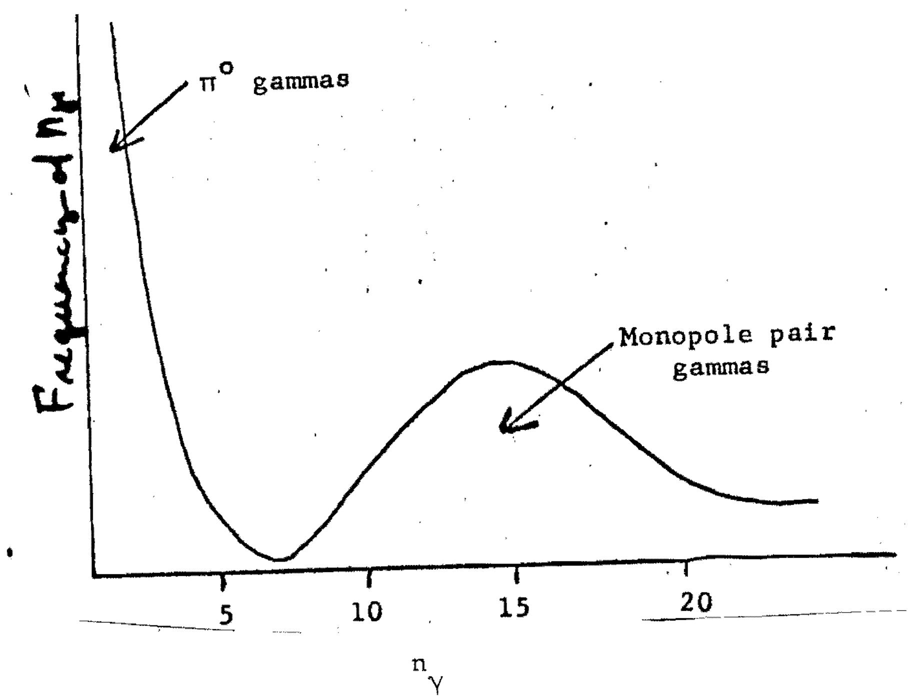

Figure 2. Anticipated frequency spectrum for high energy gamma rays from various sources.

What are the chances of observing multigamma events? Above the threshold energy the cross section for producing monopole pairs from high energy gammas from decaying π^o mesons should be quite large, on the order of that for the photoproduction of electron-position pairs. The cross section for producing monopole pairs by strong interactions processes cannot be estimated. Our experimental arrangement would have a high probability of recording the simultaneous arrival of multiple gamma rays. This is a consequence of a very favorable Jacobian. The short resolving time of proportional wire chambers would make the system resistant to the background due to single gamma rays and neutron induced showers. We are concerned that the accelerator's energy of 2 to 5 x 10^{11} eV is considerably below the value of 10^{13} eV estimated by Ruderman and Zwanziger as being necessary for the photoproduction of monopole pairs. This estimate is based on an assumed monopole mass of 10 GeV and an incident energy high enough to permit the target nucleus to interact coherently, as a whole. Thus it is at best uncertain. We are encouraged by the fact that the total energy in the shower listed in Table I is only 45 GeV.

IV. Apparatus

Our requirements are minimal. We need to view, at zero degrees and from a distance of about 50 meters initially a 0.1 radiation length target (later a series of targets less than 1.0 radiation length) bombarded by high intensity, high energy protons. This channel must be contained in a vacuum pipe, have a sweeping magnet to remove charged particles and have a collimator to limit the opening to $\pm$ 10 mr. We would require a total of one hundred (100) hours of running time given in three periods to make our search.

We propose to bring the proportional wire chambers, lead converters, and associated electronics to the National Accelerator Laboratory.

V. Supplemental Preliminary Search

Some of us have carried out, at the AGS, a search for free magnetic monopoles. With little effort and cost to the National Accelerator Laboratory we could, using much of the same equipment, carry out a similar search when the accelerator begins 500 GeV operations. It could be done as one of the first experiments in the experimental program since it involves only a magnetically shielded target exposed to high energy protons. This should be considered as a supplement to our main proposal.