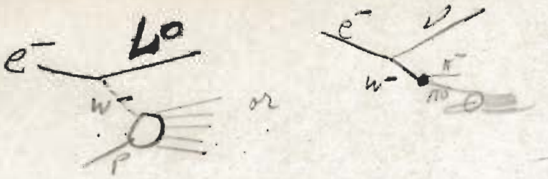

SLAC Proposal No. 56-A

(New Version of Proposal No. 56)

January 5, 1970

(This version replaces the initial submission of July 3, 1969)

I. Title

A Search for Unknown Sources of Neutral Particles Having No Strong Interactions.

II. Experimenters

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$\gamma + Z \rightarrow \left\{ \text{neutral} + \ldots \text{(including } \mu \text{ which scattered} \right\} \rightarrow$ weak decay to charged ensemble

$1\,\text{BeV} > m_N > 500\,\text{MeV}$

Budgetary delay

III. Description of the Experiment

We propose herewith a speculative experiment which has a high probability of yielding no significant result. Nevertheless we feel that the total investment involved in both money and effort is sufficient small and the

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possibities sufficiently exciting to warrant its implementation.

The basic aim of the experiment is to search for unknown short-lived sources of neutrinos or neutrino-like objects which can be produced at SLAC. The full electron beam will be allowed to enter a beam dump in front of enough steel to stop all muons. Behind the steel shield we will set up a twenty ton spark chamber array with forty tons of iron and lead interspersed and search for energetic charged particles which arise from either decay or interaction. The detailed arrangement of experimental equipment will be described shortly.

We are aware of the difficulty in trying to provide more than an intuitive justification of such an experiment. Nevertheless, it is a tenable hypothesis that there exist unknown sources of neutral, non-strongly interacting particles which may be produced either directly or indirectly through the interactions of high energy electrons at SLAC. Furthermore, the background of known kinds of neutrino events which would be detected in our apparatus is small and measurable and a signal above this background in either quality or quantity would be easily observed.

In order to fully understand the potential of the experiment, it is useful to make some observations about the background. From long experience with neutrino experiments we know that there are no known particles other than muons, neutrinos and their by-products that can penetrate the shield and give any appreciable counting rate. Furthermore, the neutrino events themselves are characteristic in appearance, almost always involving one muon. Hence, the only real concern is the extent to which "ordinary" neutrino events can obscure the unknown phenomena we are searching for.

We have two ways of approaching this point. Firstly, as we said before, we can look for events which do not appear to involve an energetic muon. Secondly, we can examine the rate of obtaining events as a function of the distance from the beam dump to the shielding wall. The minimum distance is of the order of one meter, yielding about 15 events per day in our detector. By moving the dump back by about 10 meters, this can be increased to about 150 events per day. It is possible to extrapolate down to zero decay length with an accuracy of one or two events per day. Hence, we feel that we can certainly detect a signal of the order of five per day if the events are indistinguishable from conventional neutrino events and as few as one in two or three days if the events are readily distinguishable from conventional neutrino events.

It may be of interest to review briefly the motivation in our initial consideration of this experiment, that is, the possible existence of leptons heavier than the muon, as an example of a possible short-lived source of neutrinos. There have been a number of conjectures about such leptons in the literature; see, for instance, Rothe and Wolsky, Nuclear Physics B10, 241 (1969) and Gershtein and Folomeshkin, Soviet Journal of Nuclear Physics 8, 447 (1969). Suppose, for the purpose of discussion here, that there exists at least one such charged lepton L having its own neutrino ν_L associated with it.

It seems likely that the L, if it exists, has a mass $m_L \gtrsim m_K$. For $m_K \leq m_L \leq 1$ GeV, the L will have a lifetime $10^{-11} \leq \tau_L \leq 10^{-10}$ sec and decay predominantly by the mode $L^{\pm} \rightarrow \pi^{\pm}+\nu_L$. There is no known particle that can decay into an L if $m_L > m_K$. L pairs with $m_L = 0.5$ GeV/c^2 will be photoproduced at SLAC at a rate of about 5×10^6 per sec, assuming 10^{14} incident electrons per sec on 5 r.l. of Be; for $m_L = 1.0$ GeV/c^2, the production rate is 5×10^4 per sec. The neutrinos from about one half of these will be intercepted by our detector. Assuming an average laboratory neutrino energy of 4 GeV from the decay of an L, we might hope for as many as 5 events per day for $m_L = 0.5$ GeV/c^2 and 0.05 events per day for $m_L = 1.0$ GeV/c^2. The interaction of a $\nu_L(\bar{\nu}_L)$ in the detector will lead to the production of an L and possibly one or more energetic hadrons; the L will in turn decay rapidly to π and $\nu_L(\bar{\nu}_L)$. Hence the visible particles in the final state of a reaction produced by a ν_L will be only energetic hadrons, a fact which can be determined with reasonable accuracy by their subsequent interactions in the detector. We would consider events of this type, i.e., without visible leptons in the final state, as possibly arising from the chain we have just described. Even with a small number of events ($\gtrsim 10$) we might hope as a consistency check to estimate the mass m_L from the transverse momentum distribution of the energetic pions in events showing only single pions.

As another possibility consider the production of neutral particles without strong interactions through either a very small magnetic moment, a modest charge distribution, or some other mechanism. [See, for example, Bernstein, Ruderman and Feinberg, Phys. Rev. 132,1227 (1963); Bernstein and Lee, Phys. Rev. Lett. 11, 512 (1963); Meyer and Schiff, Physics Letters 8, 217 (1964); Cheng and Bludman, Phys. Rev. 136, B1787 (1964)]. Observe that there is no astrophysical evidence on the electromagnetic properties of such particles if their mass is greater than about 1 Kev since there is generally insufficient energy in stellar interiors to make a pair of 1 kev particles electromagnetically. Furthermore, weakly interacting neutral particles with mass less than about 2 or 3 MeV would not be apparent in the decays of pions or kaons even if they were coupled with the same strength as other leptons; they would not be distinguishable from the normal neutrinos.

Such neutral particles would traverse the muon shield in our experiment with negligible interaction and be attenuated only by decays in flight if they were unstable. Roughly, a photoproduction cross section on Be greater than 10^{-42} cm^2 in conjunction with a mean lifetime τ in the region $3 \times 10^{-8} \leq \tau \leq 3 \times 10^{-6}$ sec would yield at least one decay of a neutral per day in the detector.

It is worth emphasizing that the properties of the particles discussed above make it difficult to produce them except in a high energy electromagnetic interaction. An experiment such as we have described - as tenuous as it may sound - is one of the few ways in which a search for particles of this or similar type can be made. Experiments using protons to produce neutrinos have so far not exceeded an incident beam current of 10^{12} protons/sec on target and experiments in the near future are unlikely to go above 10^{13} protons/sec. We must stress again, however, that this experiment is intended primarily to be a survey in a region which has never been explored. The initial cost in dollars to the laboratory - \$$10^5$ - is relatively small as high energy physics experiments go. All of the experimental equipment needed is in hand and the experiment can run largely parasitically whenever end-station A is at high intensity and high energy.

IV. Experimental Set-up

Extensive study has been made of the logistics and cost of setting this experiment up with the conclusion that the following is fairly optimal in cost and convenience.

A series of holes, ranging from 12 feet to 16 feet in diameter would be excavated behind ESA. The first three of these holes would be packed with steel and refilled to provide a 15 meter shield for the fourth hole. Total cost for the excavation and set-up has been estimated in great detail and should come to about $107,000. A sketch of the arrangement is shown in Figure 1.

Within the excavation itself we propose to mount existing Spark chambers (20 tons) and lead or iron blocks (40 tons) as shown in Figure 2. Camera equipment, film, counters and all of the paraphenalia needed to run the experiment are in hand.

V. Accelerator Operation

We would like to run the machine at as high an energy, with as much intensity, in as poor a duty cycle as is possible. We realize however that there is a real advantage to running this experiment as a parasite and are prepared to do so over a long period of time.

VI. Timetable

We will be ready to run as soon as the excavation can be completed and the shielding put into place. All of the experimental equipment, from chambers to camera to film is in hand and ready to use.

VII. Machine Time

We would like to be sure of a total of 500 hours of running at optimum conditions - full intensity, highest energy, shortest pulse length. If these can be secured parasitically then no time request is necessary for the major part of the running. We would like about 200 hours as "prime user" during which time we can vary the beam energy and explore background.

VIII. Analysis

Analysis requires no special equipment and no large amount of computer time.

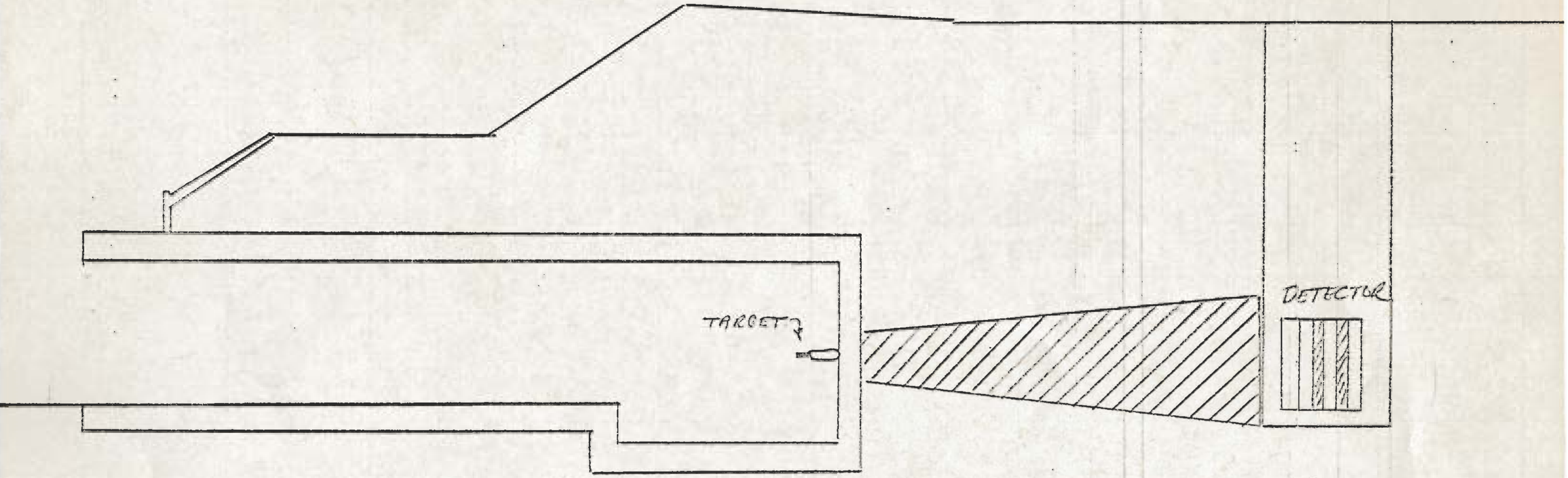
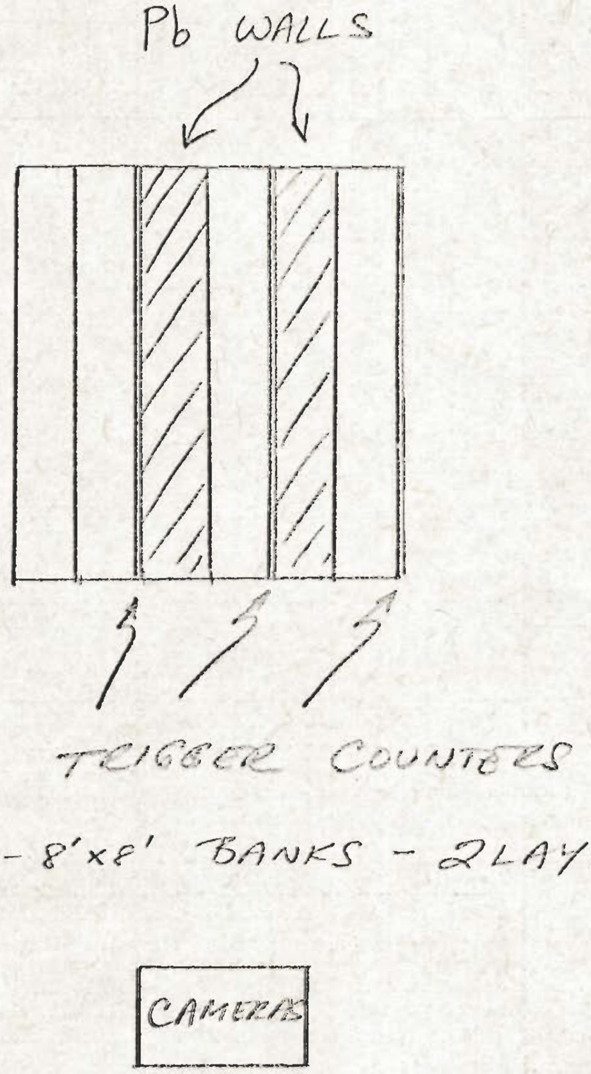


FIGURE 1. SET-UP FOR NEUTRAL PARTICLE SEARCH.



3 - 8'x8' BANKS - 2 LAYERS PER BANK.

FIG 2- EXPERIMENTAL CONFIGURATION.