NAL PROPOSAL No. 44

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PROPOSAL TO STUDY NEUTRINO INTERACTIONS WITH PROTONS AND NEUTRONS USING THE 14-FOOT BUBBLE CHAMBER AT NAL

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ABSTRACT

We propose a detailed channel study of neutrino interactions on protons and neutrons. To accomplish this we request a run using at least 200 BeV internal machine energy to obtain 50,000 events in a deuterium-filled track sensitive target surrounded by neon. Using current flux estimates from a double horn focusing system and assuming 10^{13} interacting protons per pulse, the run of 50,000 events in deuterium would be obtainable with 500,000 pictures of the 14-foot bubble chamber. The neutrino flux is limited by the acceptable event rate in the neon.

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I. Physics Justification

An exposure of 500,000 pictures of neutrinos in the 14-foot bubble chamber fitted with a deuterium filled track-sensitive target surrounded by neon will supplement quantitatively the neutrino-hydrogen exposure (NHE) previously reported.[1] The physics justification of the NHE proposal is also the basic justification of this proposal, however with the neon blanket around the target, quantitative studies can now be made of those final states involving neutral pions. The total cross section and $\frac{d^2\sigma}{d\nu dq^2}$ should be measurable to about 50 BeV to test scale invariance and search for intermediate vector boson production. By using deuterium in the track sensitive target, neutrino interactions with neutrons can be studied and the form factor for the elastic channel determined at high q^2 allowing CVC and second class current tests. CVC and PCAC can be tested using the Adler test. This exposure is viewed as the first major run of the 14-foot chamber with an internal track-sensitive target. A 500,000 picture exposure using an $5.5m^3$ track sensitive deuterium target will yield about 50,000 events on neutrons and protons.

An exposure to a track sensitive target filled with deuterium will supplement the NHE experiment in several ways. It will allow us to measure channels with π^0 mesons and to add to the detailed channel study. We can clearly separate the inelastic channels, look for ρ, A_1, and higher N^* branching ratios, and also perform a better search for neutral current interactions. In addition σ_{total} and $\frac{d^2\sigma}{d\nu dq^2}$ (or $\frac{d\sigma}{dM^{*2}}$) should be measurable up to beyond 50 BeV before bias and normalization problems become too severe. If an intermediate boson exists the total cross section should not rise linearly with energy but should turn over. In fact, an intermediate boson causes a term $(M_W^2/(q^2 + M_W^2))^2$ to multiply $d^2\sigma/dq^2d\nu|_{\text{no boson}}$. Calculations[2] indicate that a measurement of σ_{total} up to 40 or 50 BeV with about 10% error should be sufficient to detect a turnover in the cross section corresponding to a 10 BeV boson at about the 3σ level. This is a one-way test. If there is a boson, there is a turnover. If there is a turnover there is either a boson or some sort of weak interaction cutoff or violation of scale invariance. An intermediate boson can be searched for directly by looking for dimuon events, muon positron events or resonances in the strong particles up to a mass of about 9 BeV or 14 BeV for a 200 Bev or 500 BeV exposure respectively.[3] This search can be made in the neon blanket as well as in the deuterium target.

A determination of $d^2\sigma/dq^2d\nu$ is necessary for studies of the deep inelastic region. In addition to having more energy than SLAC the neutrino experiments have the advantage of a basically <u>flat</u> q^2 dependence rather than a $1/q^4$ dependence which holds for electron interactions.

In addition, the very important neutrino reactions on neutrons can be measured. This will allow us to look at the elastic cross section at high energies and high q^2 with good discrimination against $1_\pi^{\,0}$ events. At high energies (assuming locality) the cross section is governed by:[4]

$$W_2 = |g_A|^2 + |g_V - 2Mf_V|^2 + q^2(|f_V|^2 + |f_A|^2)$$

where g_V, f_V are obtained by CVC from electron scattering data, g_A is the axial vector form factor and f_A is an axial vector second class current. At high q^2 the last terms will dominate giving only mild sensitivity to g_A but allowing CVC and second class current tests. The comparison of $\sigma_{\nu p}$ with $\sigma_{\bar{\nu}p}$ and $\sigma_{\nu n}$ have been discussed by many people[5] and are of great interest in distinguishing various high energy strong interaction theories. This experiment should allow a comparison using uniform methods of analysis on p and n reactions.

We can perform the Adler test[6] which relates low q^2 neutrino events to pion interactions. This is a test of CVC and PCAC. If we make very stringent cuts, i.e., ask that the transferred energy be greater than 1 BeV and that $q^2 < m_\pi^2$, we should obtain of the order of 40 events. Hence, a 20% test of this relation appears reasonable.

Using the neutron interactions, better $\Delta S/\Delta Q$ tests appear possible. For instance, limits on $\nu n \to \mu^- \Sigma^+$ can be set and a new amplitude test of $\Delta S/\Delta Q$ using $\nu n \to \mu^- K^0 p$ is available in this experiment. A large fraction of the K_2^0 will interact in the neon blanket making this three body strangeness changing channel interesting in its own right. Also new interesting associated production channels become available such as

$\nu n \rightarrow \mu^- K^+ \Lambda^o$ or Σ^o, $\nu n \rightarrow \mu^- K^+ K^+ \Xi^-$, etc. A comparison of the various N^* production ratios on n or p will afford tests of the $\Delta I = 1$ rule for non-strange weak interactions, perhaps even as a function of energy and q^2. In this comparison the effect of non-resonant background must be considered.[7]

Reactions in the neon part of the chamber may also be of interest. $\nu + Ne \rightarrow \mu^- + Na$ is a process which should be calculable and may serve as an additional means of flux normalization.[8] Based on theoretical results for carbon, a yield of about 600 events can be expected for 50,000 events in the target. In addition, diffraction processes such as $\nu + Ne \rightarrow Ne + \mu^- + X$ may occur and would be quite interesting although a specific calculation[9] has yielded a small result.

II. Experimental Arrangement

The neutrino beam and detector configuration is the same as requested in the NHE proposal except that the bubble chamber is fitted with a $5.5m^3$ track sensitive target.

Using 10^{13} 200 BeV protons per pulse interacting in the neutrino target, a two-horn focusing system and $5.5m^3$ track sensitive deuterium target, we obtain a yield of about 50,000 events on neutrons and proton for a 500,000 picture exposure. The energy distribution of these events is given on Table 1. Here it has been assumed that the total neutrino-nucleon cross section rises linearly with neutrino energy. This is known to be true experimentally[10] to approximately 10 BeV and should be true theoretically if scale invariance holds and there is no intermediate boson or cut-off in the weak interaction.[11] If the cross section saturates at 20 BeV then the total number of events expected is reduced by about 13%. The background of events in the neon surrounding the target is about 3 per picture at 200 BeV operation. A study of this background may lead to a request for more pictures using a lower neutrino flux.

This proposal requests 50,000 events of neutrinos on protons and neutrons. Using the present flux predictions these 50,000 events can be obtained in 500,000 accelerator pulses by using 10^{13} interacting protons per pulse on the neutrino target. For an accelerator cycle of 4 seconds this exposure could be obtained in 550 hours, or using a total experimental arrangement efficiency of 30% the exposure time would be about two and one-half months. The exposure could be longer if the neon induced background were so serious to force the reduction of the neutrino beam flux.

The exposure to yield 50,000 events is considered a minimum exposure because of event limited experiments. For example, the Adler test consists of only about 40 events. It is clear that we would not want less. The reaction $\nu + Ne \rightarrow \mu^- + Na$ which can serve as an additional flux normalization method gives only about 600 events. Dividing the flux into several energy ranges one gets only a 10% to 20% normalization due to limited statistics with the present exposure.

III. Apparatus

This exposure is viewed as a first major run of the 14-foot chamber with an internal track-sensitive target. Members of this collaboration have played a major role in the invention and development of this device. The major asset of this exposure is to have an ability to detect gamma rays. A track-sensitive target gives the largest solid angle for gamma detection. The detailed design of the target is now under study but depends both on bubble chamber technical considerations and on whether a spark chamber array, such as the one that Peterson and Stevenson[12] have proposed, is installed and works. If the spark chamber does work, then the target may go completely through the chamber. If we do not depend on that we estimate a target of $5.5m^3$ can be built and with the same assumptions as in the NHE experiment 50,000 events in deuterium can be obtained with about 500,000 pictures if $\sigma_{\nu p} = \sigma_{\nu n}$.

Deuterium is the easiest liquid to use in a track-sensitive target since its thermodynamic properties are a better match to neon than those of hydrogen. In addition, the event rate is double that of hydrogen if $\sigma_{\nu p} = \sigma_{\nu n}$.

The analysis of this experiment will be dominated by scanning time. It is probable that every event will be examined by a physicist. This seems quite feasible with the present group. The measurement load is modest by today's standards, especially when divided between our two groups. This is true even assuming that one might measure double the actual numbers of events eliminating fake events with the aid of track reconstruction information. The University of Michigan and NAL are currently building POLLY devices and the measurement load is easily managed. We anticipate having the NHE and this exposure spaced about a year or so apart and hope to have initial results from each run within a year of the time the pictures are taken.

We require:

1. Neutrino focusing system.
2. Neutrino flux monitoring system.
3. 14-foot bubble chamber fitted with a deuterium track sensitive target surrounded by neon.

These pieces of equipment which are to be built by the people involved in this proposal are to be available as NAL facilities.

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TABLE 1.

Distribution of 50,000 Events from a 200 BeV Exposure.

Neutrino Energy Interval (BeV)	Number of Events
0 - 10	12,200
10 - 20	21,700
20 - 30	7,900
30 - 40	2,900
40 - 50	1,400
50 - 75	2,200
75 - 100	1,200
100 - 150	500

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PROPOSAL TO STUDY NEUTRINO INTERACTIONS WITH PROTONS AND NEUTRONS USING THE 14-FOOT BUBBLE CHAMBER AT NAL

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PROPOSAL TO STUDY NEUTRINO INTERACTIONS WITH NUCLEONS USING THE 15-FOOT BUBBLE CHAMBER AT NAL

ABSTRACT

We propose a detailed channel by channel study of neutrino interactions on nucleons. We propose to detect neutral particles from these interactions by using a track sensitive target surrounded by a neon-hydrogen mixture in the 15' Bubble Chamber.

Among the topics we intend to examine are intermediate boson production, pseudoelastic interactions, single pion production, multiple pion production and deep inelastic scattering, associated production and strangeness changing reactions, four fermion interactions, conservation laws, ν_e interactions, and a neutral current search.

We have been and continue to be active in the design and construction of the beam and detector components needed for this experiment e.g. meson focusing system, neutrino monitoring system, 15' bubble chamber and track sensitive target.

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PREFACE

The advantages of a hydrogen or deuterium filled track-sensitive target in a neon-hydrogen bubble chamber have been documented in the NAL Summer Study Reports of 1969 and 1970.

The following proposal assumes a deuterium fill of the track sensitive target. However, much of the physics can be done with a hydrogen fill and we do not wish to commit ourselves to hydrogen or deuterium at the present time.

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I. INTRODUCTION

An exposure of 750,000 pictures of neutrinos in the 15-foot bubble chamber fitted with a deuterium filled track-sensitive target surrounded by neon will supplement quantitatively the neutrino-hydrogen exposure (NHE) previously reported.[1] The physics justification of the NHE proposal is also much of the basic justification of this proposal, and we will not repeat those arguments in detail. However, with the neon blanket around the target, quantitative studies can be made of those final states involving neutral pions. The total cross section and $\frac{d^2\sigma}{d\nu dq^2}$ should be measurable to about 50 BeV to test scale invariance and search for intermediate vector boson production. By using deuterium in the track sensitive target, neutrino interactions with neutrons can be studied and the form factor for the elastic channel determined at high q^2 allowing CVC and second class current tests. CVC and PCAC can be tested using the Adler test. This exposure is viewed as the first major run of the 15-foot chamber with an internal track-sensitive target. A 750,000 picture exposure using a $4.7m^3$ track sensitive deuterium target will yield about 50,000 events on neutrons and protons.

II. PHYSICS CONTENT OF THE EXPOSURE

We use the same neutrino flux calculation as in our NHE proposal. With 10^{13} 350 BeV protons per pulse incident on a one interaction length target and a TST volume[2] of $4.7m^3$ we calculate a yield of about 50,000 events in a 750,000 picture exposure. The energy distribution of these events is given in Table I. The neutrino flux distribution is given in Figure 1.

It has been assumed that the total neutrino-nucleon cross section rises linearly with energy $\sigma_{total} = 0.8\ E_{\nu} x 10^{-38} cm^2$. The justification for this is discussed in the NHE proposal and we note again that if the cross section saturates at 30 BeV then the total number of events is reduced by about 18%.

For most of the objectives of this experiment an external muon identifier (EMI) is not necessary although it would be used if available. Often when there is more than one muon candidate (except in the intermediate vector boson (IVB) productions) we can use the fact that the fast negative particle is usually the muon. Exceptions to this method of muon selection are given in the individual physics sections below. .

1. New Particle Search

As in the NHE we can search for heavy leptons, quarks, magnetic monopoles or other exotic new particles. We have the advantage here of having many more events (including the 1.5×10^6 events in the neon blanket), good gamma ray detection efficiency and a large amount of neon to allow secondaries to interact or be ranged out.

2. Intermediate Vector Boson Search.

An intermediate boson can be searched for directly by looking for dimuon events, muon positron events or resonances in the hadrons up to a mass of about 10 BeV for a 350 BeV exposure.[3] This search can be made in the neon blanket as well as in the deuterium target. If an intermediate boson is found, then we will be able to examine the decay mode branching ratios, and determine the mass or spectrum of masses using the peculiar production kinematics as a signature for boson production as described in our NHE proposal. The neon blanket will enable us to examine many modes unavailable in hydrogen.

σ_{total} and $\frac{d^2\sigma}{d\nu dq^2}$ (or $\frac{d\sigma}{dM^{*2}}$) should be measurable up to beyond 50 BeV before bias and normalization problems become too severe. If an intermediate boson exists the total cross section should not rise linearly with energy but should turn over. In fact, an intermediate boson causes a term $M_W^2/(q^2+M_W^2)^2$ to multiply $d^2\sigma/dq^2d\nu|_{\text{no boson}}$. Calculations[4] indicate that for a 350 BeV exposure a measurement of σ_{total} up to 50 BeV with about 10% relative error should be sufficient to detect a turnover in the cross section corresponding to a 8.5 BeV boson at about the three standard deviation level. This is a one-way test. If there is a boson, there is a turnover. If there is a turnover there is either a boson or some sort of weak interaction cutoff or violation of scale invariance. For this part of the experiment an EMI would be useful to help identify dimuon events. However, the search for $W^+\to e^+\nu$ events which should have the <u>same rate</u> as $W^+\to\mu^+\nu$ would be unimpaired if the EMI did not exist.

3. <u>Pseudo Elastic Scattering</u>

The very important neutrino reactions on neutrons can be measured in this experiment. This will allow us to look at the pseudo elastic $\nu n\to\mu^- p$ cross section at high energies and high q^2 with good discrimination against $1\pi^0$ events. At high energies (assuming locality) the cross section is governed by:[5]

$$W_2 = |g_A|^2 + |g_V - 2Mf_V|^2 + q^2 (|f_V|^2 + |f_A|^2)$$

where g_V, f_V are obtained by CVC from electron scattering data, g_A is the axial vector form factor and f_A is an axial vector second class current. At high q^2 the last terms will dominate giving only mild sensitivity to g_A but allowing CVC and second class current tests.*

The use of the low q^2 elastic events as a possible method to determine the incident neutrino flux has been described in the past.[8,9] It appears that if CVC is valid it should be feasible to normalize the neutrino spectrum to about 10% before deuteron wave function problems become severe. The flux measurement is quite crucial to all neutrino experiments and any new handles we can get on it are very useful. We expect a total of about 2000 elastic events distributed in energy as shown in Table I if the elastic cross section[10] is about $2 \times 10^{-38} cm^2$. These events will probably peak at low q^2 but the amount of peaking depends on the details of the form factors. We would expect that there will be of the order of several hundred events in a region useful for extrapolation to $q^2 = 0$. If we assume the total elastic cross section is constant as a function of energy as required at high energy by locality, then all 2000 events are available for use in normalization.

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* This particular second class current is the one currently favored to explain the Wilkinson[6] anomaly. However, it is possible that this anomaly may be due to effects other than second class currents.[7]

$\nu + Ne \rightarrow \mu^- + Na$ is another pseudo elastic process which may be calculable and serve as an additional means of flux normalization.[11] Based on theoretical results for carbon, a yield of about 600 of these events in the neon blanket can be expected for 50,000 events in the target. The muon will be very strongly forward peaked. These events must be distinguished from $\nu_\mu + e \rightarrow \nu_e + \mu$ events as discussed below in Section 4.

4. <u>Four Fermion Interactions</u>.

We expect about 800 $\nu_\mu + e \rightarrow \nu_e + \mu$ events in the neon:[12] For these events as for the $\nu\ Ne \rightarrow \mu^-\ Ne$ events the muon will be strongly forward peaked. For the neon events the muon will carry almost all of the neutrino energy. Hence, some separation should be possible and some subtraction based on the expected 35 four fermion events in the deuterium and the 70 events in the hydrogen exposure can be made. The 800 extra four fermion events should give us considerable further information on the spectrum of these events.

We should have about six events of $\nu p \rightarrow \mu^+\mu^-\nu p$ and four events of $\nu p \rightarrow \mu^- e^+\ \nu p$ in the neon part of the chamber. There will probably be little trouble identifying the $\mu^- e^+$ events and a very crude check of these cross sections can be made. (However, the 800 events of $\nu_\mu + e \rightarrow \nu_e + \mu$ allows us a much better test of the same coupling). The $\mu^+\mu^-$ events are very interesting but very difficult to identify because of early pion decays.[13] If the cross section for this process is anamously large[14] we may be able to detect it. An EMI would be useful to help identify the dimuon events.

5. Single Pion Production

In hydrogen only the channel $\nu p \to \mu^- p \pi^+$ is available. Here we certainly will be able to examine $\nu N \to \mu^- p \pi^o$ and, depending on the neutron background, $\nu N \to \mu^- N \pi^+$. Using the cross sections of Adler[15] a total of 3000 N^{*++} and N^{*+} events will be produced with an energy distribution as given on Table 1. The comparison of these cross sections will enable us to look at the relative amounts of $I = \frac{3}{2}$ and $I = \frac{1}{2}$ in the final state as a function of the N^* mass, the neutrino energy and the momentum transfer.

If $\nu N \to \mu^- N \pi^+$ is available then we can make a consistency test on the $\Delta I = 1$, $\Delta S = 0$ rule since it implies a triangle relation between $\sqrt{2}\,\sqrt{\sigma_{\pi^o p}}$, $\sqrt{\sigma_{\pi^+ n}}$, and $\sqrt{\sigma_{\pi^+ p}}$. This test can also be studied as a function of energy, etc.

Furthermore, we can see $I = \frac{1}{2}$ resonances. Hence we can look at the weak form factors for these resonances with appreciable πp branching fractions and generally perform the same tests indicated in the NHE for the $I = \frac{3}{2}$ resonances.

6. Multiple Pion Production and Inclusive Reactions

Here we can search for vector meson production, i.e., $\nu p \to \mu^- p \pi^+ \pi^o$ where $\pi^+ \pi^o$ forms a ρ or higher mass vector meson. This can be compared with $\nu p \to \mu^- p \pi^+ \pi^+ \pi^-$ (where $3\pi = A_1$ etc.), which can be seen here or in the NHE. In addition, the reaction $\nu n \to \mu^- p \pi^+ \pi^- \pi^o$ where $\pi^+ \pi^- \pi^o$ forms a ω or η can be studied.

These same channels will also prove very useful for studying the higher N^* resonances. Many of these higher resonances decay predominantly into $N\pi\pi$ and will be seen in the 2 pion channels, e.g.

$$\nu p \rightarrow \mu^- p \pi^+ \pi^o$$

$$\nu n \rightarrow \mu^- p \pi^+ \pi^-$$

and, if the slow neutron background is not severe, in the channel

$$\nu p \rightarrow \mu^- n \pi^+ \pi^+ .$$

In addition, diffraction processes in neon such as $\nu + Ne \rightarrow Ne + \mu^- + X$ may occur and would be quite interesting although a specific calculation[16] has yielded a small result.

The over-all pion spectra contains useful information. Soft pion theorems[17] predict that the shape of the spectrum for π^o and π^- should be different in the limit $E_\pi \rightarrow 0$.

The determination of $d^2\sigma/dq^2d\nu$ is necessary for studies of the deep inelastic region. In addition to having more energy than SLAC the neutrino experiments have the advantage of a basically <u>flat</u> q^2 dependence rather than a $1/q^4$ dependence which holds for electron interactions. Moreover it is not evident that the form factors should be the same for neutrino and electron events. We know of no strangeness changing electron scattering interaction. Furthermore, even with a parton picture the axial vector current might give different results than the vector current. In this picture the parton would be the same for both but the form factors of the interactions with different partons could be quite different.

The comparisons of $\sigma_{\nu p}$ with $\sigma_{\nu n}$ has been discussed by many people[18] and are of great interest in distinguishing various high energy strong interaction theories. This experiment should allow a comparison using uniform methods of analysis on p and n reactions. Furthermore, when $\bar{\nu}$ data becomes available a comparison of $\sigma_{\nu p}$ and $\sigma_{\nu n}$ with $\sigma_{\bar{\nu}p}$ will be of considerable importance.

Total cross section measurements were discussed under (2). The Adler test will be discussed in (8).

7. Associated Production and Strangeness Changing Channels

We again expect perhaps 5000 associated production events in the deuterium of the TST, assuming a partial cross section of 10% of the total cross section.[19] With the neutron target new interesting associated production channels become available such as

$$\nu n \rightarrow \mu^- K^+ \Lambda^o \text{ or } \Sigma^o, \ \nu n \rightarrow \mu^- K^+ K^+ \Xi^-, \text{ etc.}$$

As of now there are few theoretical predictions concerning associated production. We are sure that as this data becomes available the theorists will rectify the defect.

$\nu n \rightarrow \mu^- K^o p$ is the simplest strangeness changing channel allowed for neutrinos if $\Delta S/\Delta Q$ holds. This channel is, therefore, of interest for testing the properties of the strangeness changing current. As discussed in the next section, it also afford us a test of $\Delta S/\Delta Q$.

8. Conservation Laws

a. $\Delta S/\Delta Q$ test

Using the neutron interactions, better $\Delta S/\Delta Q$ tests appear possible. For instance, limits on $\nu n \rightarrow \mu^- \Sigma^+$ can be set and a new amplitude test[20] of $\Delta S/\Delta Q$ using $\nu n \rightarrow \mu^- K^o p$ is available in this experiment. This type of test is discussed further in the NHE proposal. A large fraction of the K_2^o will interact in the neon blanket.

b. $\Delta S = 2$ test

Examination of $\nu n \to \mu^- \Sigma^+ K^o$ gives an amplitude test on $\Delta S = 2$ and $\Delta S/\Delta Q < 0$.

c. $\Delta I = 1$ test

A test of the $\Delta I = 1$ rule for $\Delta S = 0$ interactions was discussed in Section 5 under single pion production.

d. Adler test:

In this exposure we can perform the Adler test[21] which relates low q^2 neutrino events to pion interactions. This is a test of CVC and PCAC. If we make very stringent cuts, i.e., ask that the energy transfer be greater than 1 BeV and that $q^2 < m_\pi^2$, we should obtain of the order of 40 events in deuterium. Hence, a 20% test of the Adler relation appears reasonable. Using the neon events we can increase our statistics by about a factor of 30.

e. CVC

A further test of CVC is available from diffractive ρ production. This cross-section is directly related to electroproduction of ρ mesons and should provide a good ($\sim$10%) test of CVC.

9. <u>Other tests</u>

a. Locality tests:

In the limit $m_\mu = 0$ the cross-section for $\nu p \to \mu^- + \Gamma^{++}$ (Γ^{++} = anything) can be written[22]

$$d^2\sigma_\nu(\Gamma) = (4\pi E_\nu)^{-1} E_\mu \left[(E_\nu + E_\mu)^2 - p_\Gamma^2\right] \cdot \left[xA_+ + x^{-1} A_- + B\right] dE_\mu \, d\cos\theta_{\mu\nu}$$

where $x = \frac{E_\nu + E_\mu - p_\Gamma}{E_\nu + E_\mu + p_\Gamma}$

and A_+, A_-, B are positive real functions of the momentum transfer and energy transfer only. This can be transformed into:

$$d^2\sigma_\nu = (4\pi E_\nu)^{-1} E_\mu \left[a_o + a_1 E_\mu + a_2 E_\mu^2\right] dE_\mu d\cos\theta_{\mu\nu}$$

where a_1, a_1, a_2 are functions of the momentum transfer and energy transfer only.

Furthermore, it is the locality assumption[9] which requires the $\frac{d\sigma}{dq^2}$ for the pseudoelastic process $\nu N \to \mu^- p$ to approach a constant at high energy. We should, therefore, be able to make several locality tests on this data.

10. ν_e Interactions

The electron-neutrino flux was estimated from K^+_{e3} and μ^+ decays using a procedure previously reported.[23] The dominant contribution to the ν_e flux, because of the beam geometry, comes from the K^+_{e3} decays. Assuming the Hagedorn-Ranft particle production model and $\nu_\mu - \nu_e$ universality for the total cross section, about 200 ν_e events are expected. This yield is strongly dependent on the kaon to pion ratio at 350 GeV for $P_{meson}/P_{max} \sim 0.3$.

The μ-e universality and additive lepton number conservation laws can be tested from the reactions:

$$\nu_e P \to e^- P \pi^+$$
$$\to e^- P \pi^+ \pi^+ \pi^-$$
$$\nu_e n \to e^- P$$

If the lepton number conservation law is multiplicative then $\mu^+ \to e^+ \nu_e \bar{\nu}_\mu$ and $\mu^+ \to e^+ \bar{\nu}_e \nu_\mu$ producing an $\bar{\nu}_e$ flux. Approximately 180 events of the type $\bar{\nu}_e + P \to e^+ +$ anything are expected in the neon fiducial volume. This then is a very sensitive test of the additive vs. multiplicative lepton number conservation law.

11. Neutral Currents

Since many of the strongly interacting particles will interact in the neon blanket we can perform a more sensitive test for neutral currents by looking for events with no muon candidates than we can in the NHE. However, as discussed there we may be limited by the neutron induced events in the chamber. Also, an EMI would be useful to eliminate the few percent of events initiated by $\bar{\nu}$ and hence having a μ^+ not a μ^-.

III. EXPERIMENTAL ARRANGEMENT

This exposure is viewed as a first major run of the 15-foot chamber with an internal track-sensitive target. Members of this collaboration have played a major role in the invention and development of this device. The major asset of this exposure is the ability to detect gamma rays in all directions with good efficiency. A track-sensitive target gives the largest solid angle for gamma detection. The detailed design of the target is now under study but depends both on bubble chamber technical considerations and on whether a spark chamber array (EMI), such as the one that Peterson and Stevenson[24] have proposed, is installed and works. If the spark chamber does work, then the track-sensitive target may go completely through the bubble chamber. If we do not depend on the EMI then we estimate a target of $4.7m^3$ can be built and with the same assumptions as in the NHE experiment 50,000 events in deuterium can be obtained in about 750,000 pictures if $\sigma_{\nu p} = \sigma_{\nu n}$.

Using 10^{13} 350 BeV protons per pulse incident in the neutrino target, a two-horn focusing system and $4.7m^3$ track sensitive deuterium target, we obtain a yield of about 50,000 events on neutrons and protons for 750,000 picture exposure as discussed in Section II. It is important to run this exposure at the highest energy compatible with the background. However, operation at less than 350 GeV would be considered.

The neutrino beam monitoring system and detector configuration is the same as requested in the NHE proposal except that the bubble chamber is fitted with a $4.7m^3$ track sensitive target.

The background of events in the neon surrounding the target is about two per picture at 350 BeV operation. A study of this background may lead to a request for more pictures using a lower neutrino flux.

The exposure to yield 50,000 events is considered a minimum exposure because of event limited channels. For example, the Adler test from deuterium events consists of only about 40 events. It is clear that we would not want less. The reaction $\nu + Ne \rightarrow \mu^- + Na$ which can serve as an additional neutrino flux normalization method gives only about 600 events. The amplitude tests of $\Delta S/\Delta Q$ will almost certainly have small numbers of events per channel as discussed in the NHE proposal.

The analysis of this experiment will be dominated by scanning time. It is probable that every event will be examined by a physicist. This seems quite feasible with the present group. The measurement load is modest by today's standards, especially when divided between our two groups. This is true even assuming that one might measure twice the actual numbers of events in order to eliminate fake events with the aid of track reconstruction information. The University of Michigan and NAL are currently building POLLY devices and the measurement is easily managed. We anticipate having the NHE and this exposure spaced about a year or so apart and hope to have initial results from each run within a year of the time the pictures are taken.

We require:

1. Neutrino focusing system.
2. Neutrino flux monitoring system.
3. 15-foot bubble chamber fitted with a deuterium track sensitive target surrounded by neon.

These pieces of equipment which are to be built by the people involved in this proposal are to be available as NAL facilities.

TABLE I

Distribution of Events From the 350 BeV Exposure.

E_ν (GeV)	Neutrino Flux /GeV.m^2.10^5p's	Total Event Rate	Elastic Scattering	One-pion Production	Associated Production
5	0.58	301	75	108	30
10	2.15	2,246	280	404	224
15	2.52	3,948	329	473	394
20	2.42	5,056	315	455	505
25	2.14	5,589	279	402	558
30	1.77	5,547	231	332	554
35	1.38	5,046	180	260	504
40	1.02	4,262	132	191	426
45	0.66	3,102	86	123	310
50	0.46	2,403	60	86	240
55	0.28	1,608	36	53	160
60	0.19	1,160	24	35	116
65	0.12	815	15	23	81
70	0.087	636	10	15	63
75	0.062	486	7	11	48
80	0.0455	380	6	8	38
85	0.037	329	5	6	32
90	0.03	282	3	4	28
95	0.026	255	3	4	25
100	0.023	240	3	3	24
110	0.020	457	6	6	45
120	0.018	447	6	6	44
130	0.017	452	3	6	45
140	0.0153	438	3	3	43
150	0.013	401	3	3	40
160	0.009	293		3	29
170	0.0063	219			21
180	0.0046	169			16
190	0.0035	134			13
200	0.0026	106			10
Total..................		46,807	2,100	3,023	4,666

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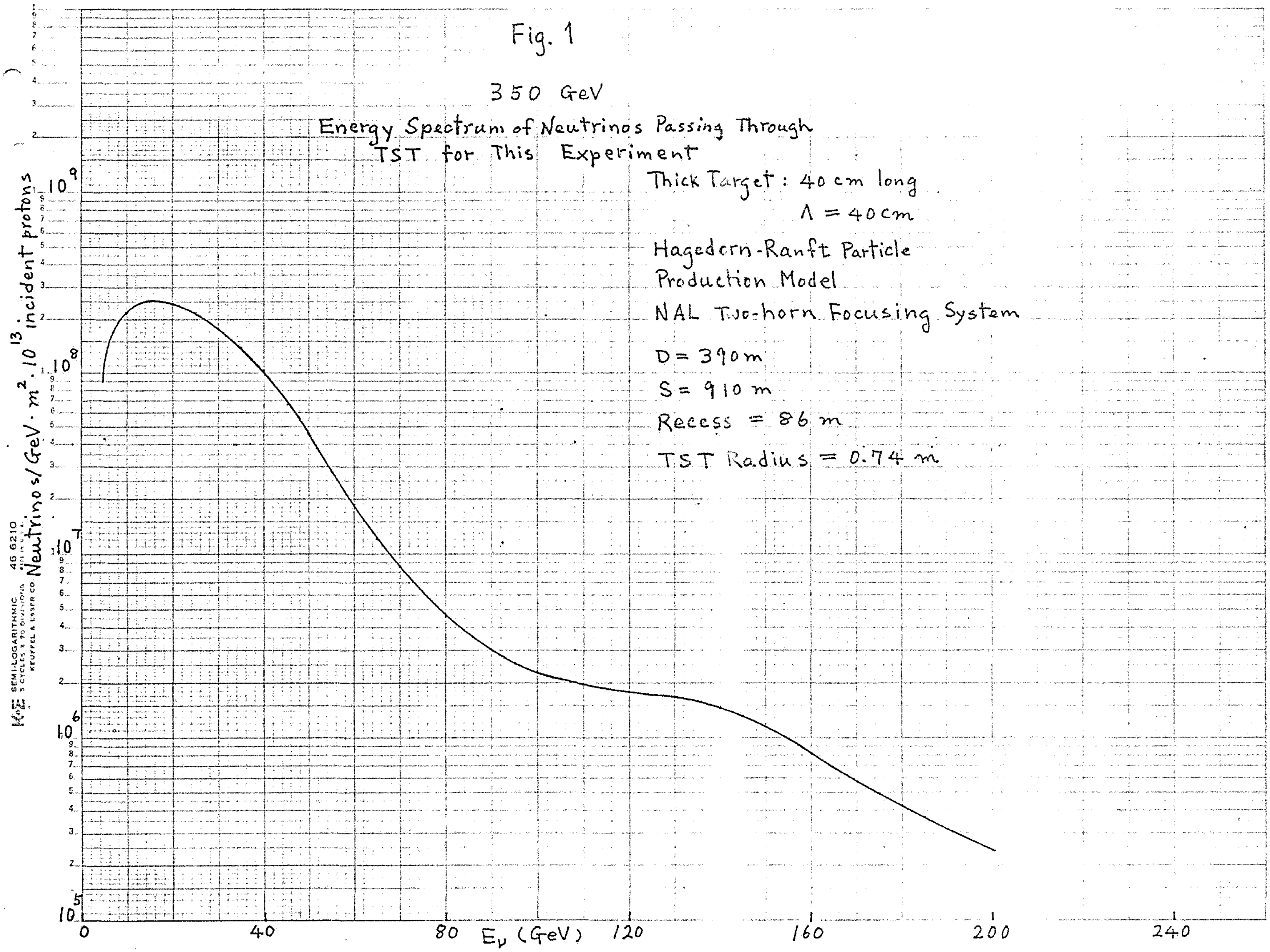
Fig. 1
350 GeV
Energy Spectrum of Neutrinos Passing Through TST for This Experiment
Thick Target: 40 cm long
Λ = 40 cm
Hagedorn-Ranft Particle Production Model
NAL Two-horn Focusing System
D = 390 m
S = 910 m
Recess = 86 m
TST Radius = 0.74 m
Neutrinos/GeV · m² · 10¹³ incident protons
Eν (GeV)
0
40
80
120
160
200
240
10⁵
10⁶
10⁷
10⁸
10⁹
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