NAL Proposal No. 459
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FTS 608-262-2281

Search for New Phenomena Associated with High Energy Neutrinos Using the Quadrupole Triplet Beam

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Abstract

We propose to take one million pictures of high energy neutrinos in an approximately 20% mixture of Neon and Helium using the FNAL 15 foot bubble chamber exposed to the quadrupole triplet focussed neutrino beam with the EMI. Our experience in E-28A has shown that the capability of recording and analyzing high multiplicity, multiple gamma conversions, secondary neutron interactions, and high energy electrons makes this instrument uniquely useful in searching for new phenomena in neutrino interactions.

The principle advantage in using the quadrupole triplet beam is

1. A greater proportion of the events occur at high energy (i.e. >35 GeV) allowing a fast and more efficient analysis of the characteristics at high energy. The results of the counter neutrino experiment indicate that new phenomena are very likely to occur at high energy.
2. A 20% Ne/H_2 mixture makes possible the detection of high energy electrons from the primary vertex. For a substantially higher density of Ne, this detection efficiency will be much worse due to a confusion of the primary with secondary vertices from interactions and radiation losses.

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I. Introduction

This proposal is for an exploratory experiment concentrating on new phenomena at high energies, using the 15' bubble chamber with a 20% Ne/H_2 filling and a quadrupole triplet neutrino beam optimized for an energy range of 30-200 GeV.

The main emphasis will be on:

1. phenomena with electrons in the final state
2. a detailed study of dilepton events (with both electrons and muons in the final state) observing their hadronic features such as their association with strange particles.
3. recently observed anomalies in the deep inelastic region at small $x = Q^2/2M\nu$.

These phenomena appear to have a threshold at about 30 GeV neutrino energy. For their investigation the broad band beam neutrino spectrum with its large flux of low energy neutrinos provides a large "background" of low energy neutrino events. The analysis of high energy interactions is prolonged because of the large number of low energy neutrino events. There is a difficulty of interpretation because of the corrections necessary with a rapidly falling neutrino spectrum. The analysis is greatly simplified for the neutrino spectrum from the quad triplet beam. This beam suppresses the low energy neutrinos and somewhat enhances the high energy neutrino spectrum as is seen in Fig. 1. The main advantage lies in the ease of analysis. Essentially all neutrino interactions are in the region of the new phenomena while the background due to low energy neutrons from low energy neutrino interactions is suppressed. We anticipate far fewer cuts necessary on the data since most of the interactions will have an energy in the region of the new phenomena. Finally the relatively long spill of the beam should allow for the detection of dimuon events using a coincidence of two penetrating tracks in the EMI.

II. Detailed Description

A. Dilepton

Experiment E310 or E1A has evidence from their investigation of dimuon events that the new phenomena occur at the hadron vertex. This implies a possible new particle of sufficient lifetime and stability so that it must decay via the weak interaction. E310 proposes to investigate the properties of leptons produced in dimuon events, with rather course sampling of the hadronic component. The 15 foot FNAL bubble chamber with an enriched Ne-H_2 mix also provides an excellent tool for investigation of the hadronic component of neutrino interactions. The direction and multiplicity of the hadron component is seen visually and the electro-magnet component from pi-zero or other neutral decay is seen because of the conversion to gamma rays in the neon. If, in fact, there is a new particle with new quantum numbers, of sufficient lifetime, it may be visible in the bubble chamber along with its subsequent decay. The search for dimuon events using the EMI is greatly aided by the use of a 1 millisec spill. The structure in the time distribution of events for multiple turn extraction along with the timing information available for the EMI allows a correlation in time of the 2 muon tracks of a dimuon. The many buckets in 1 millisec spill reduces the chances of accidents to a very low value.

B. Anomalies at small x in deep inelastic processes

Recently, anomalies have been observed for deep inelastic processes in the y-distribution for events in the small x region. Likewise, there seem to be deviations from the Adler and Gross-Llewellyn Smith sum rules at high energies. Such anomalies could be related to the production of hadrons with new quantum numbers.

These effects have to be confirmed in an independent experiment. For such studies the use of the quadrupole beam is of the greatest importance. The flux obtained from horn focussed neutrino beams, which falls rapidly with energy (three orders of magnitude for $10 < E < 160$ GeV) introduces systematic distortions of the y-distributions, which are difficult to be estimated. The spectrum obtained from the quad beam, with its almost flat energy distribution minimizes such distortion effects.

C. Muon Detection

The detection of muons is made possible in the 15 foot FNAL bubble chamber by use of a Ne-H_2 mixture. With the 20% by volume Ne-H_2 mixture of E28 we estimate that 50% of the hadrons in a high energy neutrino interaction can be identified visually because they will kink, scatter, interact or decay. The likely high multiplicity of the events with dileptons precludes a much larger mixture of Neon. The External Muon Identifier (EMI) can aid in the identification of those tracks which have not been visually identified. For dimuon events a combination of the two techniques will be used.

D. Electron Detection

The detection of electrons is possible with a $Ne-H_2$ mix. Electrons will bremstrahlung and lose energy. An abrupt change in curvature can be detected visually. The most unambiguous identification of a high energy electron occurs when the electron has a brem in which the electron loses greater than 30% of its energy so that the change in curvature is sufficient to be easily seen. If the brem converts and we can identify the gamma then the identification of the primary electron is clear. This requires at least two radiation lengths in the chamber plus some initial length for the primary interaction to take place and some visible length of the converted bremsstrahlung gamma ray. For a radiation length of 100cm as in the case for 20% by volume fraction of Ne two radiation lengths is half the chamber so we expect 25% detection efficiency for a primary electron. A slightly enriched $Ne-H_2$ mixture would moderately increase the detection efficiency depending on the mixture used. High energy electrons tend to develop an electromagnet shower. Electron neutrinos comprise 1-2% of the total neutrino flux. The detection of the electron will allow an investigation of electron neutrino interactions at the level of a few hundred events.

However with a heavily enriched $Ne-H_2$ mixture the event becomes difficult to analyze as can be seen (Fig. 2) from the attached events. The produced gammas will convert near the main vertex and secondary interactions will occur to the vertex. This causes many tracks to overlap so that is is very difficult to study the details of the primary interaction.

III. Event rates

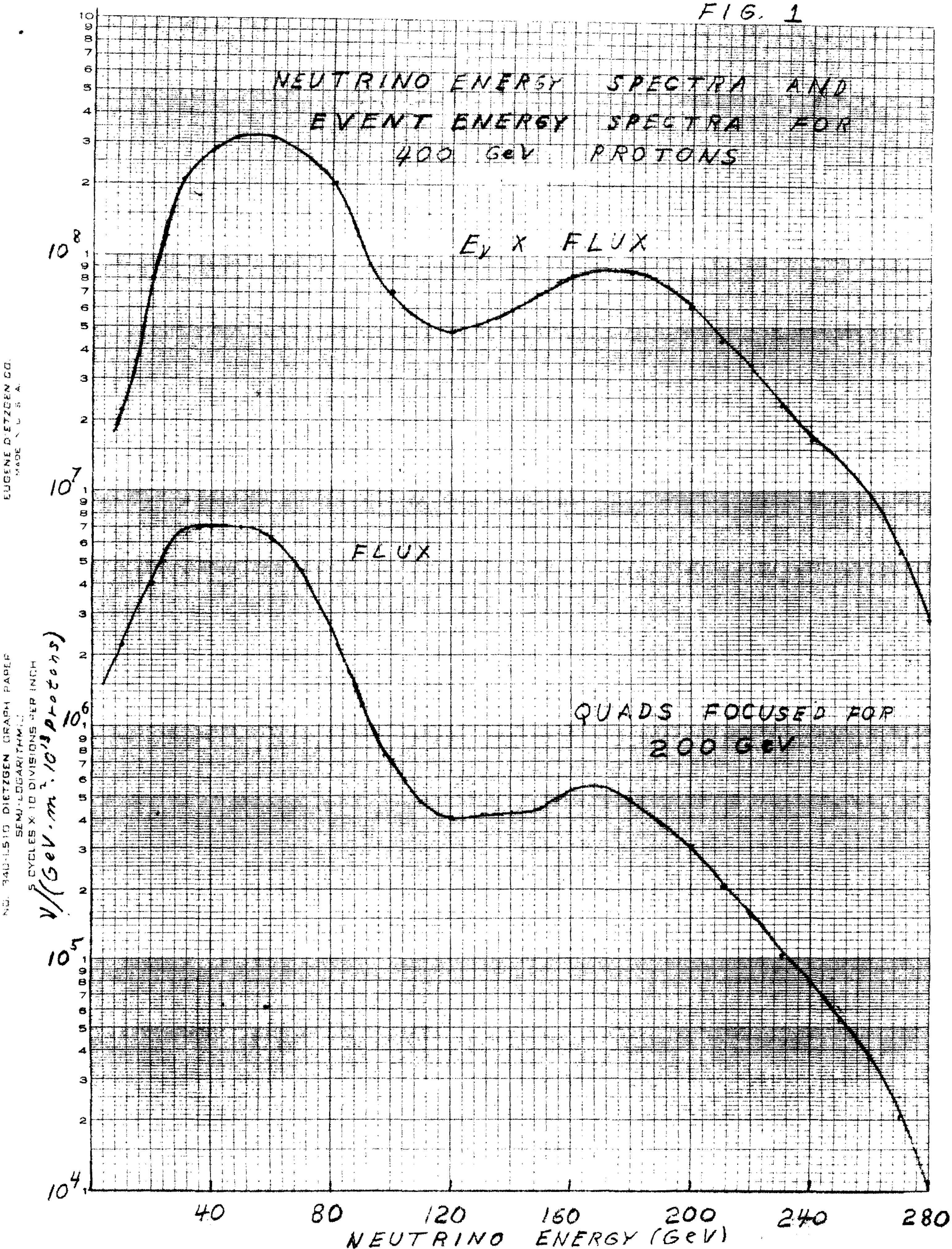
E28A has found that with 6×10^{12} protons on target, a primary energy of 300 GeV and a Ne mixture of 20% by volume there is a neutrino interaction every 8 frames. The raw rate of the quad triplet beam decreases by a factor of 6 compared to the horn focused beam. The flux is essentially the same above 100 GeV and substantially reduced for lower energies. For the present quad triplet beam with 10^{13} protons on target and 400 GeV primary proton energy a 20% Ne-H_2 will yield an event in every 20 frames. There will be an event over 30 GeV every 40 frames. For an exposure of 1,000,000 pictures we would have 25,000 events. The dimuon event rate is about 1% so 250 dimuon events would be produced. Assuming a 20% electron detection efficiency we would expect 50 $\mu^- e^+$ events uniquely identified. We estimate that at least 70% of the $\mu^+\mu^-$ events will be detected for a total of 200 events. A few tens of $\mu^- e^-$ and $\mu^-\mu^-$ events should also be detected.

IV. Summary, Conclusions and Detailed Proposal

In summary, we propose to run this coming spring, 1976, during the quad triplet run for E310, with the enriched Ne-H_2 mix available from the immediately preceeding bubble chamber neutrino runs. Since the neutrino beam will be on and the bubble chamber and neon there, it seems good sense to use this unique opportunity to best advantage and run the two experiments concurrently.

The relatively flat neutrino spectrum reduces the background of conventional neutrino interactions without suppressing the high energy neutrino interactions of interest. Because all events are interesting high energy neutrino events even though the total number of events compared to broad band are reduced, the analysis is greatly simplified. Depending on the neon mix available we would expect 1 interaction in about 10 pictures. We request 1 million pictures with 400 GeV proton and 10^{13} proton on target. The beam structure, spill time, is compatible with running the bubble chamber and E310 at the same time. Of course the EMI will be used to enhance muon identification and aid in neutral current determination as well as for the dimuon search.

FIG. 1



NEUTRINO ENERGY SPECTRA AND
EVENT ENERGY SPECTRA FOR
400 GeV PROTONS
E_ν X FLUX
FLUX
QUADS FOCUSED FOR
200 GeV
$\nu/(GeV \cdot m^2 \cdot 10^{13} protons)$
10^8
10^7
10^6
10^5
10^4
40
80
120
160
200
240
280
NEUTRINO ENERGY (GeV)
EUGENE DIETZGEN CO.
MADE IN U.S.A.
NO. 340-L510 DIETZGEN GRAPH PAPER
SEMI-LOGARITHMIC
5 CYCLES X 10 DIVISIONS PER INCH


fig. 2

6/17/76

Addendum to Proposal P459

A Study of Electron-Muon Events ($e^-\mu^+$) in a Sign Selected Antineutrino Beam

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I. Introduction

The discovery of the high multiplicity of k° associated with $(e^+\mu^-)$ events from the 15 foot chamber at FNAL, has created a great interest in trying to determine the properties of this particle. The light mixture in the 15 foot chamber seemed to be ideal for the initial proof for this particles existence. However, for studying in greater detail the complicated phenomena associated with these events, the increased statistics gained by the heavy mixture of Neon would appear at this time to be more productive.

It appears to us that there are three other basic explorative experiments related to $(\mu^{\mp}e^{\pm})$ events which have yet to be done; namely (1) the production of $e^{\pm}$ in neutral current interactions both in neutrino and (2) in antineutrino beams and (3) the production of μ^+e^- in charged current antineutrino interactions. It is the study of processes (2) and (3) that we would like to pursue. Results from process (1) will probably come from horn ν runs with a heavy mix which have already occurred.

We wish to emphasize that the study of this phenomena in antineutrino beams is considerably more difficult than in neutrino beams because of the background of electron phenomena associated with γ rays as well as possibly a reduced flux and reduced cross section. Because of the considerations it is important to reduce the ν_μ and $\bar{\nu}_e$ flux to as low a level as possible.

For (μ^+e^-) $\bar{\nu}_\mu$ neutrino events, backgrounds can come from

1) compton electrons plus hadron punch-through
2) very asymmetrical Dalitz pairs plus hadron punch-through
3) $\bar{\nu}_e$ interactions plus hadron punch-through.

For the study of (μ^+e^-) production in neutral current interactions the backgrounds are even more serious. They are the following

1) neutron interactions with any electromagnetic phenomena giving an electron

2) ν_μ interactions in the N.C. (they must be separated from $\bar{\nu}_\mu$ N.C. interactions)

3) $\bar{\nu}_e$ charged current interactions. These, aside from their kinematic variables, automatically fit the category of N.C. interactions.

This long list of backgrounds makes it imperative that the $\bar{\nu}_e$, ν_μ flux contamination be lower than the $\bar{\nu}_\mu$ flux by at least two orders of magnitude. To our knowledge this can only be accomplished by a sign selected bare target beam. This beam has a flux considerably higher than the dichromatic beam; has similar spectial shape as a horn beam and has a background of ν_μ and $\bar{\nu}_e$ down by more than two orders of magnitude.

As a matter of fact, one event which looks like a antineutrino production of this category of events has been observed in E-28. It has an electron of 3.1 GeV, a muon of 7 GeV which has a good hit in the EMI, along with other hadrons. A sketch of this event is enclosed. If the event is real, then the antineutrino partial cross section is probably not very small. A sketch of this event is included.

II. <u>Beams and Flux</u>

A new sign selected broad band beam has been designed by Ray Stefanski. The beam uses a bare target followed by dipoles and a beam dump to achieve a clean separation between oppositely charged particles in the secondary beam from the target. With a proton energy of 400 GeV on target the resulting antineutrino beam is very clean while the yield is greater than the proposed DC dichromatic beam. Figure 1 shows the relative $\bar{\nu}$ flux ratios for the double horn with plug, sign selected bare target and dichromatic beams (with the largest momentum bite). Also shown is the background neutrino flux. It can be seen from this figure that the sign selected bare target beam gives the largest yield of high energy antineutrino flux while maintaining a good sign selection at high energy. Note that the $\bar{\nu}_\mu$ high energy horn flux is strongly contaminated by neutrinos.

III. Event Rates

We assume 17 ton fiducial volume for the heavy Neon-H_2 mix in the 15' bubble chamber. We also assume a 100,000 picture run with 10^{13} protons on target/pulse giving 10^{18} protons on target. The total yield of antineutrino events in this run will be 4000-5000 depending on the actual $\bar{\nu}$ cross section at high energy (present measurements of $\sigma^{\bar{\nu}}/\sigma^{\nu}$ from E1A indicates a rising $\sigma^{\bar{\nu}}/\sigma^{\nu}$ cross section ratio with energy exceeding 0.5 somewhere above 50 GeV). The average $\bar{\nu}$ energy will be $\sim$100 GeV. We estimate the dilepton yield from the data of E1A which give

$$\mathrm{Rate}(\bar{\nu}_\mu + N \to \mu^+\mu^-\nu X) = 2 \pm 1\%$$

for $E_{vis} > 40$ GeV and $E_{\mu^-} > 3$ GeV. The rate estimates could be in error by a factor of 2. The resulting μ^+e^- number of events is 44 ± 22 events. Since the data from E28 indicate more events with e^+ momentum below 3 GeV than above, we estimate the actual number of μ^+e^- events will be greater than twice or > 88 ± 44. This yield appears adequate to uniquely identify the μ^+e^- signal and to study the possible association with strange particles as well as the x_{vis} and y_{vis} distribution to compare with the dimuon events. We also expect to be able to select dimuon events thus increasing the rate by another factor of $\sim$1/3.

IV. Request

We request a run of 100,000 pictures with the 15 foot chamber filled with the conventional "heavy neon" mixture exposed to the bare target sign selected antineutrino beam, along with the EMI behind the chamber.

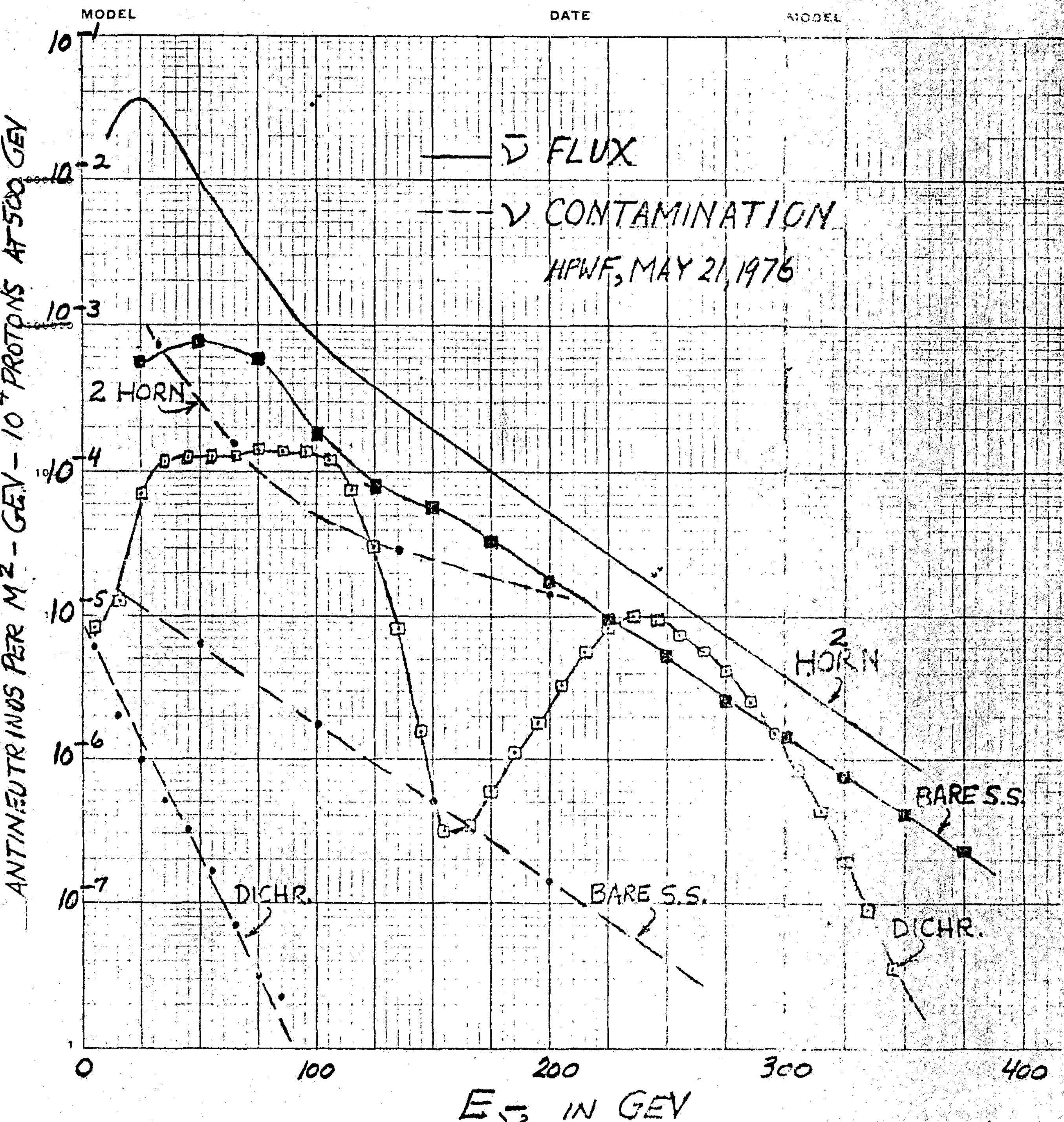
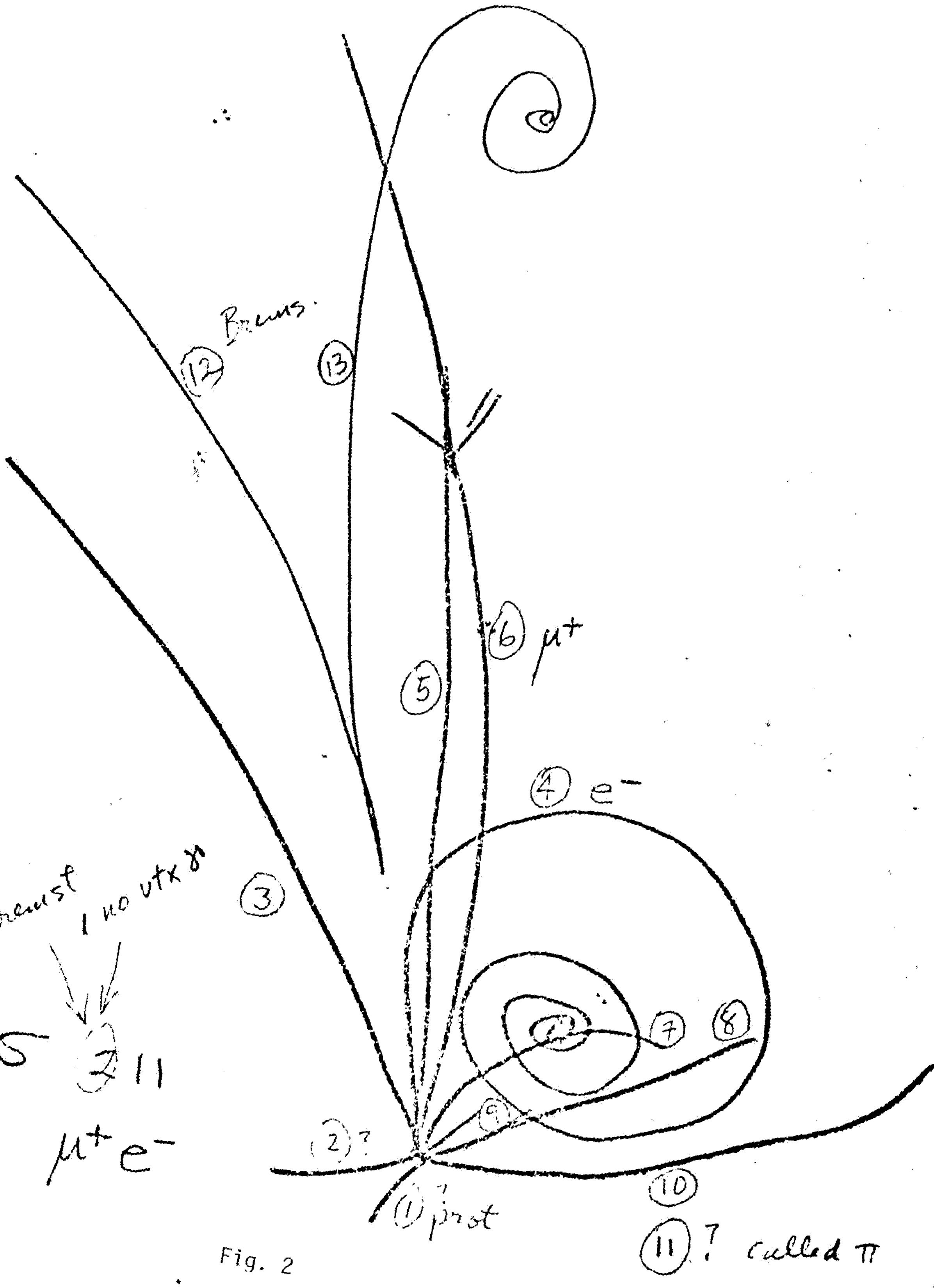

MODEL
DATE
MODEL
$\bar{\nu}$ FLUX
ν CONTAMINATION
HPWF, MAY 21, 1976
2 HORN
2 HORN
BARE S.S.
BARE S.S.
DICHR.
DICHR.
ANTINEUTRINOS PER M^2 - GEV - 10^4 PROTONS AT 500 GEV
$E_{\bar{\nu}}$ IN GEV
0
100
200
300
400
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}

Fig. 1



1 Bremst
1 no vtx γ

78 445 211

B - 3 $\mu^+ e^-$

Fig. 2