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PROPOSAL TO STUDY DILEPTON NEUTRINO INTERACTIONS WITH THE TRIPLET QUADRUPOLE BEAM, THE PHASE I EMI, AND THE 15' BUBBLE CHAMBER FILLED WITH A H-Ne MIXTURE

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SUMMARY

We propose to study dilepton neutrino events in the 15' bubble chamber using the quadrupole beam. The chamber is filled with at least 80% neon (15 ton fiducial target), the EMI is rearranged into 2 planes to give at least 7 absorption lengths for muon identification and give time coincidence, and the beam has a 1 millisecond spill. This will give about 150 dimuon events and 150 muon electron events per 100,000 pictures. We request 200,000 pictures.

This proposal takes advantage of 3 unique situations that will happen in the spring of 1976:

1. The possibility of 400 GeV proton fluxes of greater than 10^{13} protons per pulse.

2. The fact that the triplet quadrupole beam reduces the low energy ($\lesssim 30$ GeV/c) neutrino flux (see Figures 1 and 2)[1] and thereby improves the identification by the EMI. The present 20 μsec horn beam floods the EMI with background from low energy neutrino interactions in the shield and magnet and makes it difficult to distinguish low energy muons and hadrons. The use of a long 1 millisecond beam spill also simplifies the fitting of EMI proportional chamber coordinates.
3. The 15' can operate with 80% neon.

Dilepton Production

Above 30 GeV $\sim$ 1% of all neutrino interactions have two muons associated with them.[2] With a H-Ne filled bubble chamber plus EMI one can detect muon pairs and muon-electron production to search for a hadron state that is decaying leptonically or semi-leptonically. We shall also examine the data carefully for evidence of heavy lepton production. There will also be some dilepton production ($\sim$ 2%) from antineutrinos.[2] We will assume then an event with a fast μ^- is produced by a neutrino and similarly a fast μ^+ by an antineutrino.

Table I summarizes the number of interactions one expects in a 15-ton target (80% Ne-hydrogen fill) per 10^{13} protons per pulse per 100,000 pictures. The quads have been set for 200 GeV/c with 400 GeV protons incident.[1] More than 2 x 150 = 300 dilepton ($\mu^+\mu^-$, $\mu^-\mu^+$) events are expected above 30 GeV.

The bubble chamber has the advantage over counter experiments of studying the particles associated with the dimuons, i.e., strange particles, multiplicities, etc. Since the events are on neon and there is most likely a missing neutrino one can not expect kinematic fits.

Experimental Apparatus

We assume that there is no problem operating the 15 foot bubble chamber with a high concentration of neon. Many of us have had much experience with heavy liquid bubble chambers and foresee no insurmountable problems with analysis of the events.

The muon identification is a serious problem. This is mainly a punch-through problem, since the quadrupole beam with 1 millisecond beam spill solves many of the other background problems associated with the horn. Since the dilepton production from neutrinos produced from the quadrupole beam is expected to be ~ 1% we need to reduce punch-through to less than 0.1%, corresponding to at least 7 absorption lengths of material. The present EMI has 3 to 5 absorption lengths (Figure 3), and the heavy neon adds at least 1 additional absorption length making the total 4-6 absorption lengths.

We propose to rearrange some of the EMI modules and add new absorber to take account of the fact that at higher energies the typical muon is produced at smaller angles (Figure 4). From existing data we know that 9-12 modules would intercept the majority of tracks greater than 5 GeV/c. We can do this by taking 9 modules from the sides and adding 6 feet of concrete.

This will also provide time coincidence between the two planes and further reduce background. The space behind the chamber is available. This will add 4 absorption lengths and give a total of 8-10 absorption lengths. We will need a small "dog house" to house the counters, which should be very inexpensive. The pit wall of the bubble chamber building is sufficiently strong to take the concrete load.

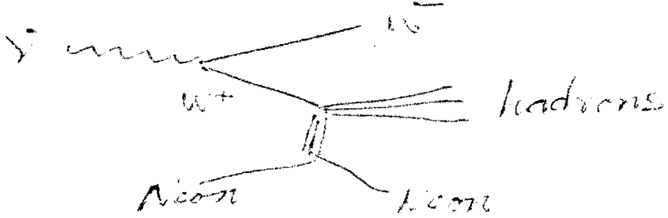
For the particles that traverse the 8-10 absorption lengths there is no problem of punch-through. Events of this type will comprise our dimuon sample. For lower energy particles that miss the second plane of counters, we will have to calculate the punch-through probability for each, since each will traverse a different amount of absorber due to the magnetic field and varying thicknesses of absorber. These less well identified muons (a few percent of the hadrons will punch through) can be used in conjunction with an identified positron (electron) to establish a sample of μ^-e^+ (μ^+e^-) events.

Identifying electrons in heavy liquid is very easy after about a radiation length (30 cm.).

Analysis of the Pictures

1. We expect from experience with other neon 15' bubble chamber film to be able to scan 15 frames per hour. Thus we can scan the film in a few months. The first events measured will be those which have a time coincidence dimuon signal or a muon-positron signal. We believe we can have preliminary results 5 months after the run.

2. There is other physics that can be done with this experimental arrangement. For example, from past experience, it is easy in heavy liquid bubble chamber experiments to identify diffraction. One "sees" a very clean event (no nuclear break up or protons) with only fast particles produced. We expect many events (theory[3] predicts thousands). These events can give indirect evidence of the intermediate vector boson quantum numbers and by comparing A_1^+ and ρ^+ production measure the V/A ratio.



This channel is not unique to this experiment; however it is easy to identify.

Conclusion

We believe this experiment is unique for the study of dileptons and can be done with small changes to existing equipment. The understanding of the dilepton production should produce fundamental answers for high energy physics.

References

1. A. Benvenuti, et al. "Simply Focused Neutrino Beams", Fermilab-Conf-75/30-EXP 7300.001. Attached.

2. A. Benvenuti, et al. Phys. Rev. Lett. <u>34</u>, 419 (1975)

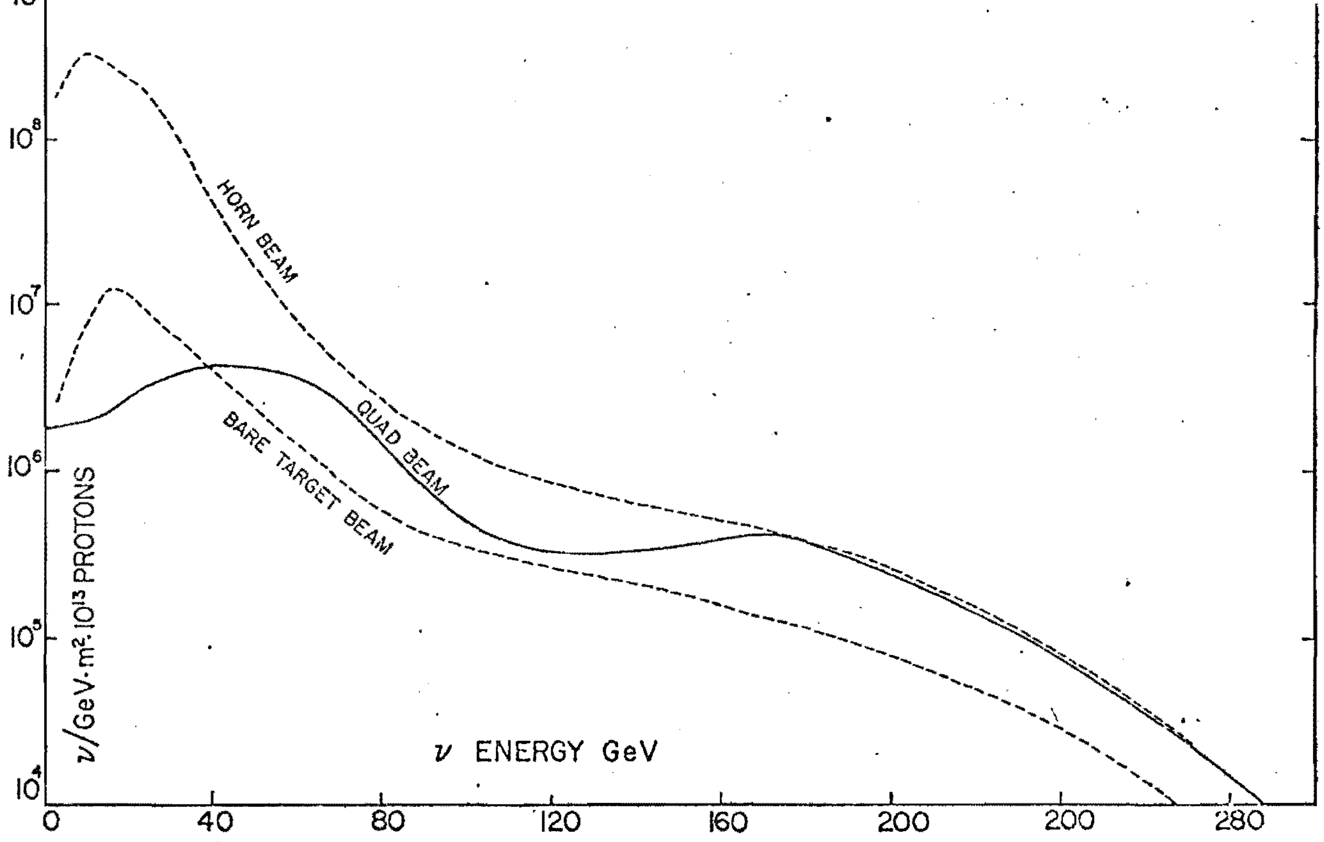
A. Benvenuti, et al. Phys. Rev. Lett. <u>35</u>, 1199 (1975)

A. Benvenuti, et al. Phys. Rev. Lett. <u>35</u>, 1249 (1975).

3. M. K. Gaillard, et al. "Diffractive Elastic Neutrino-Production of Vector Mesons," TH. 2049-CERN.

Table I. Neutrino and antineutrino production/10^{13} protons per pulse x 100,000 pictures.

Energy (GeV)	ν interactions	$\bar{\nu}$ interactions
20 - 40	1520	210
40 - 60	3310	415
60 - 80	2350	415
80 - 100	1300	140
100 - 120	860	65
120 - 140	800	40
140 - 160	1100	40
160 - 180	1210	30
180 - 200	1120	20
200 - 220	830	10
220 - 240	440	5
	14840	1385



[redacted] Neutrino spectrum for horn, quadrupole and bare target beams. The quadrupole triplet is set to focus point to parallel at 200 GeV. The calculation is based on measured hadron production spectra.

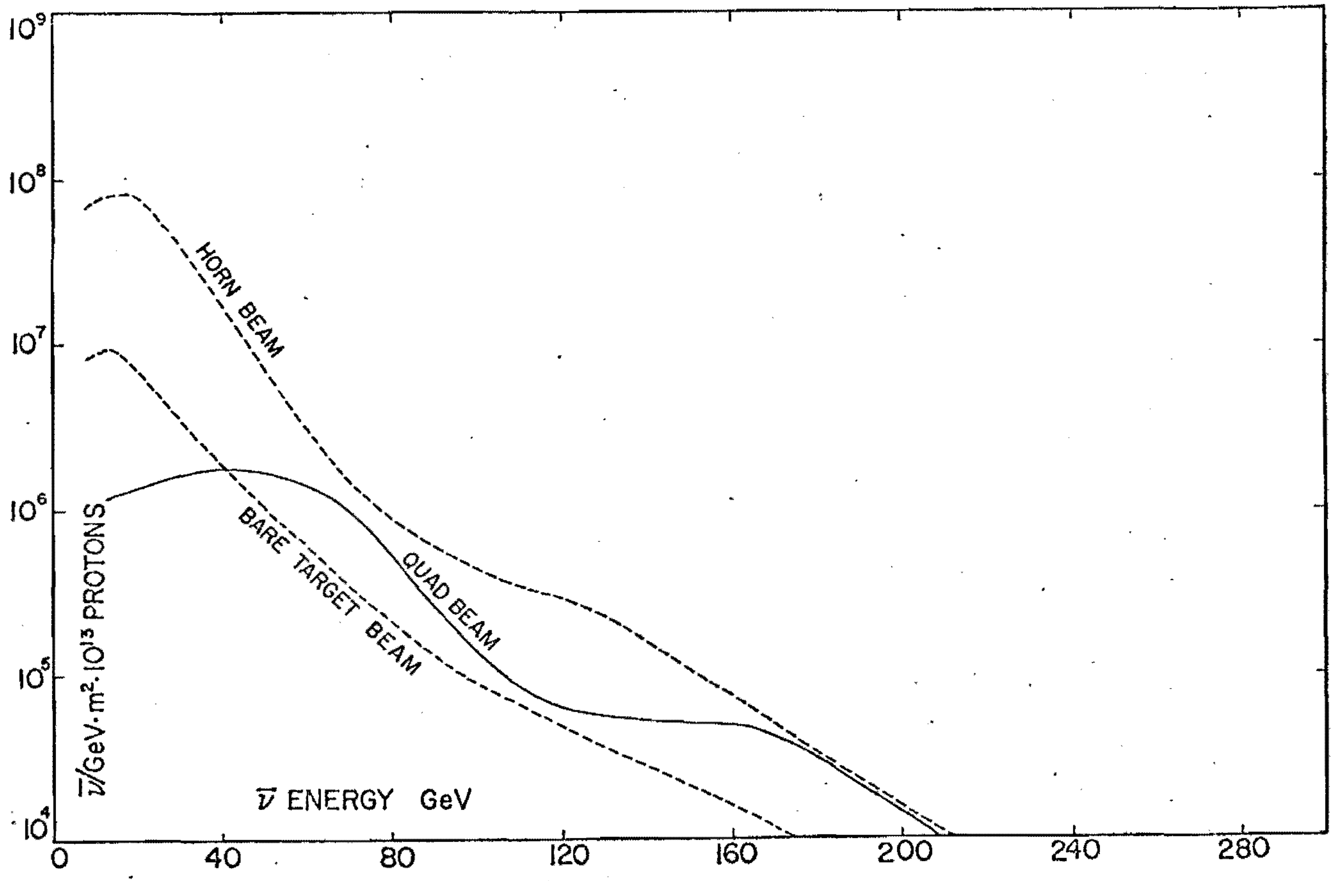


Figure 1. [redacted] Same as above [redacted] for antineutrinos.

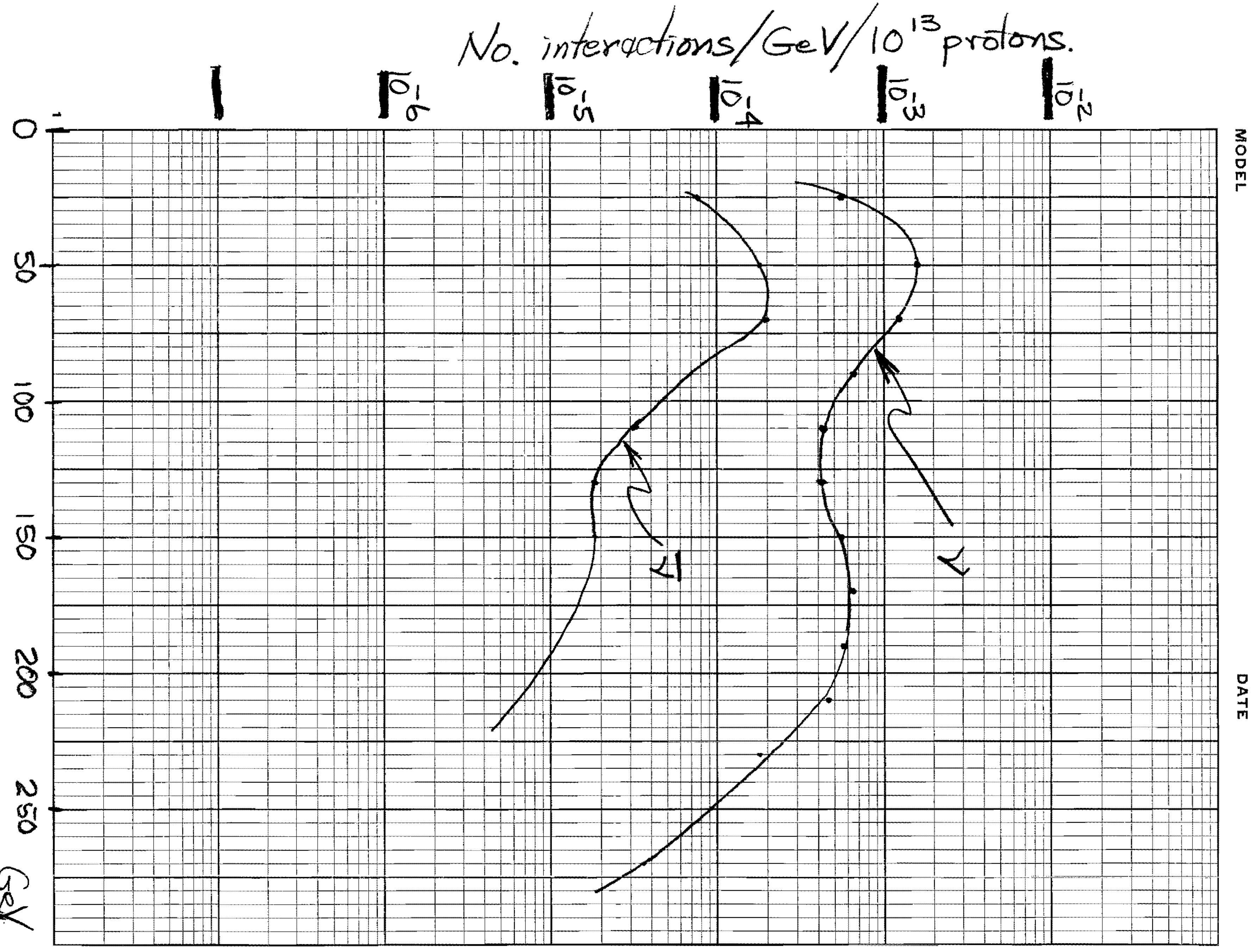
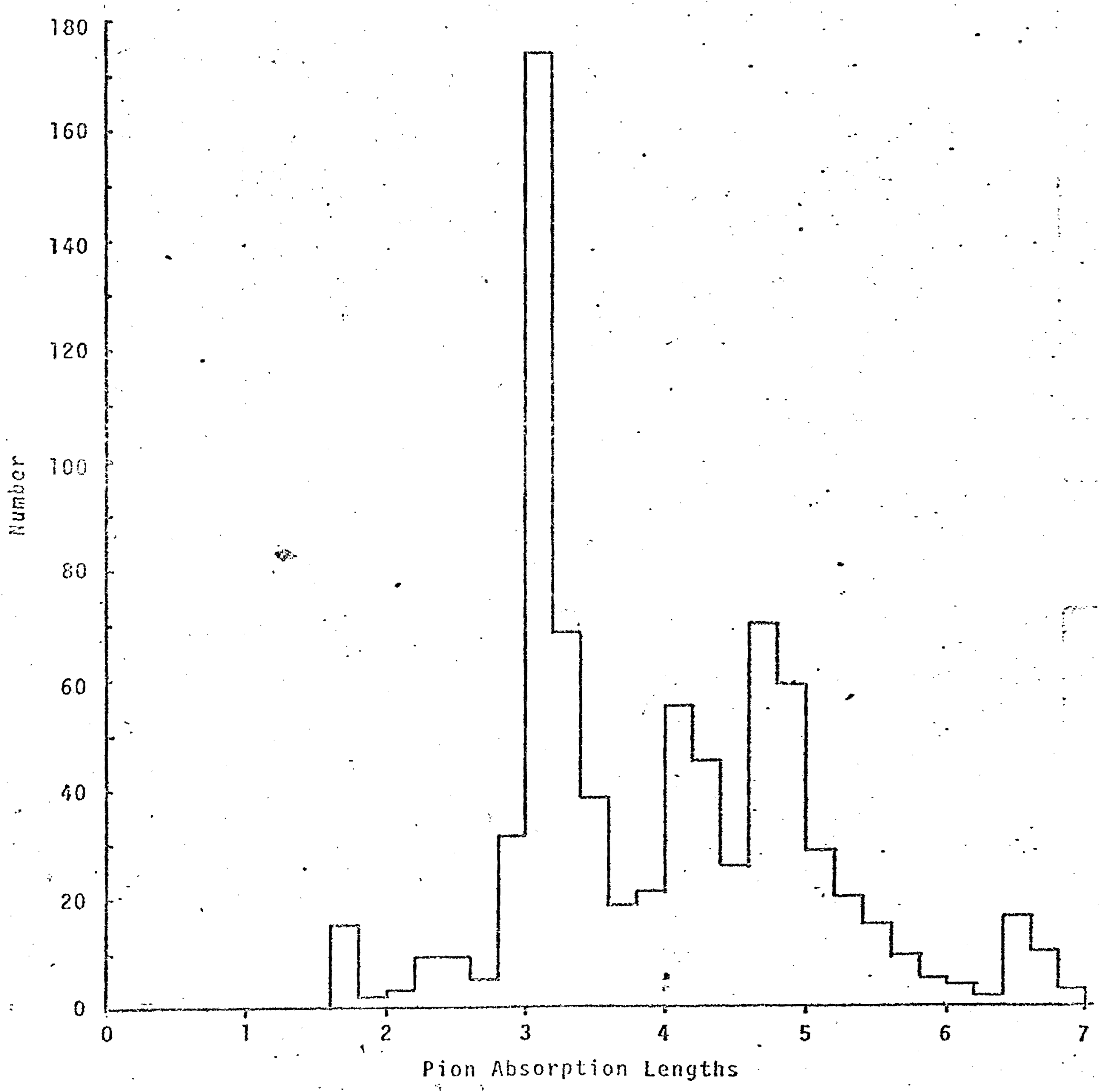

No. interactions/GeV/10^{13} protons.
1
10^{-6}
10^{-5}
10^{-4}
10^{-3}
10^{-2}
0
50
100
150
200
250
GeV
E_{ν} interaction
$\bar{\nu}$
ν

Figure 2.



Pion Absorption Lengths of Absorber Traversed by Hadrons

Fig. 3

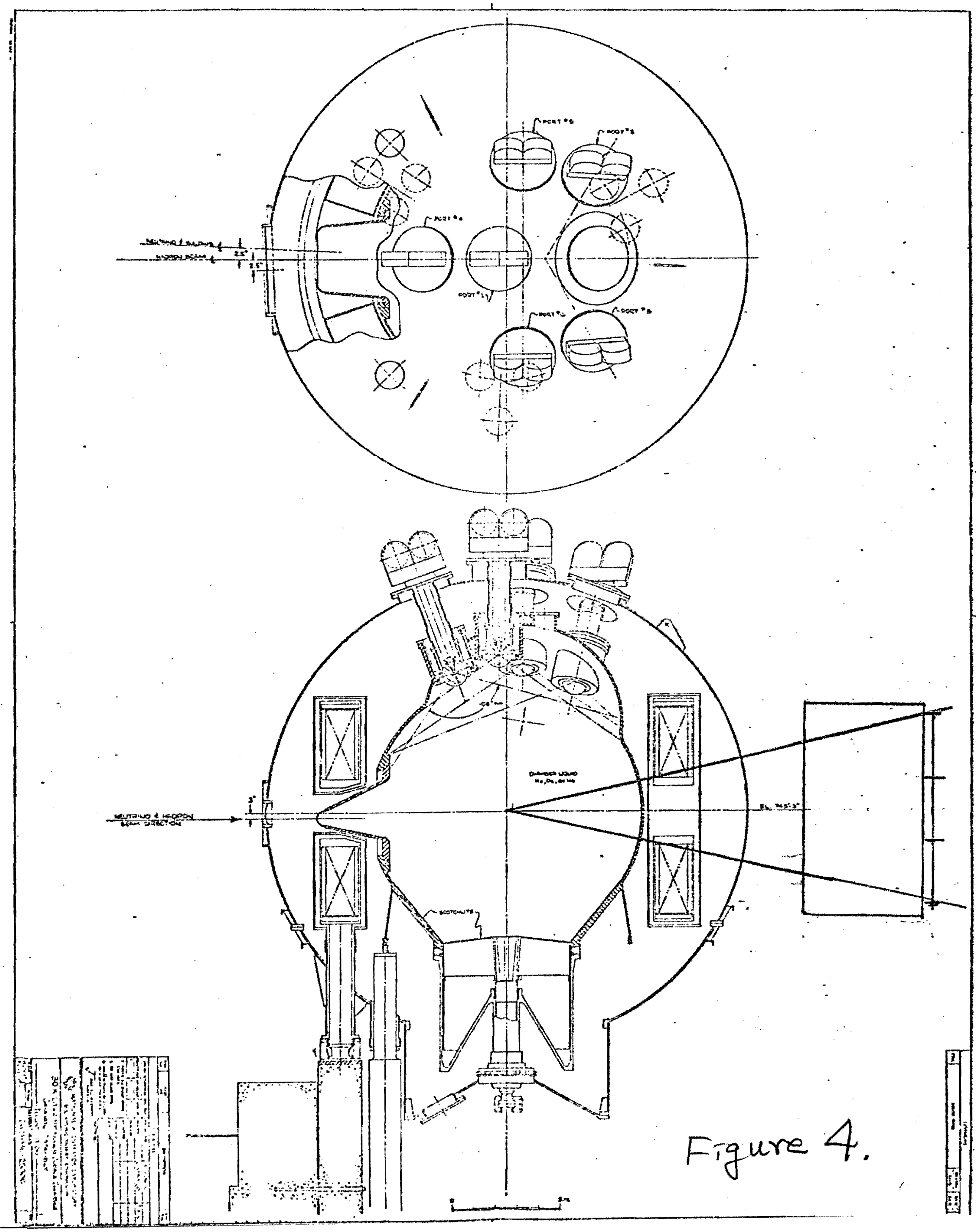

PORT #5
PORT #3
PORT #4
PORT #1
PORT #6
PORT #2
NEUTRINO ℄ BUILDING
HADRON BEAM ℄
2.5°
2.5°
CHAMBER LIQUID
H2, D2, or Ne
NEUTRINO & HADRON
BEAM DIRECTION
3°
EL. 745'3"
SCOTCHLITE

Figure 4.

Fermi National Accelerator Laboratory

FERMILAB-Conf-75/30-EXP
7300.001

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SIMPLY FOCUSED NEUTRINO BEAMS

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Abstract

This paper gives a description of a neutrino beam designed specifically to provide neutrino spectra that can easily be calculated from a hadron production spectrum. The beam uses quadrupole·focusing with a limited angular acceptance (2 mrad) so that only forward yields are important in determining the neutrino flux spectra. A facility to measure the forward production of pions and kaons is an explicit part of the design.

The Beam Design

A schematic diagram of some of the elements in the Fermilab muon beam is shown in Fig. 1. Only that part of the muon beam that is pertinent to neutrino experiments is shown in the figure. As a neutrino facility the beam is divided into two parts: (1) The quadrupole triplet located just downstream of the target is used as the focusing element for the neutrino beam. This is the only element that is actually required for a neutrino run; (2) The beam elements and Cerenkov counters downstream of the decay pipe are used as a double-bend spectrometer to measure the forward production of pions and kaons from the neutrino target. A target located in the so called bypass beam provides for yield measurements at alternate angles. From the yield measurements, the ν, $\bar{\nu}$ flux can be calculated by tracing the π, K rays through the quadrupoles and allowing for their decay. The shape of the neutrino spectrum is adjusted by varying the quadrupole tune.

A distinct advantage of the beam lies in its ability to suppress low energy flux and enhance the high energy region. Thus high energy interactions can be studied under conditions of a suppressed low energy background. The high energy flux that can be obtained is comparable to that of a horn focused beam.

Another distinct advantage of the beam lies in its ability to flatten the energy dependence of the neutrino flux. This is perhaps particularly important for total cross section measurements to minimize the systematic bias inherent in a steeply falling neutrino spectrum.

Some pertinent properties of the beam can be summarized: (1) The beam is not particularly sensitive to the angle at which the proton beam hits the target since production spectra tend to be relatively flat in the forward direction. An accuracy of 0.5 mrad in the targetting angle is quite sufficient; (2) The magnification of the triplet is about fifty in each plane. Thus, a displacement of the beam of 1 cm at the target will displace the beam by 0.5 m at the detector.

Flux Distributions

Pion and Kaon yields were measured from a neutrino production target using the muon beam as a spectrometer. (See paper presented at this conference.) From these measurements neutrino distributions have been calculated for various beams and are presented in Fig. 2. In the notation used in the figure, the triplet is said to be tuned to 200 GeV if it is set to focus point to parallel at that energy.

The distributions presented in the figure are for ideal conditions. That is, no account has been made for scattering or production sources in the beam other than at the target. Measurements made with the target removed in the broad-band beams at Fermilab indicate that 25% of the neutrino flux comes from these sources. All two-thirds of this flux is presently understood, but these corrections have not yet been applied to the neutrino distributions.

A feature of the triplet beam is its ability to shape the neutrino spectrum to meet the requirements of the experiments. Thus, for example, the 200 GeV beam has a neutrino spectrum that is nearly independent of energy for momenta between 100 and 200 GeV/c. The overall distribution is also considerably less energy dependent than for other beams. This is a good spectrum for a total cross section measurement.

Bare Target Beams

Also given in the flux distributions are spectra for so called bare target beams - Neutrino beams that are completely unfocused. An advantage to running an experiment with such a beam is that biases are minimized in the flux calculation: Only the production spectrum and decay kinematics are required to calculate the neutrino energy distributions. The flux from such a beam is, of course, much lower than for other beams. However, for a 200 ton detector and 10^{13} protons on target, the event rate is about one per pulse, which is a useable event rate. Operation with a bare target beam is pertinent to total cross section measurements and measurements of the ratio of $\sigma_{\bar{\nu}}/\sigma_{\nu}$.

Conclusions

Because the quadrupole triplet beam does not distort the ν and $\bar{\nu}$ spectra relative to each other, it will be particularly useful in determining the ratio of $\sigma_{\bar{\nu}}/\sigma_{\nu}$. Because it can produce a relatively flat energy spectrum it will be valuable in measurements of the total cross sections. At the Fermilab facility, it also has provision for its own flux measuring spectrometer. Combined with bare target beams, sign-selected beams, and horn focused beams, neutrino spectra with a variety of individual properties are available at Fermilab for a comprehensive program of neutrino physics.

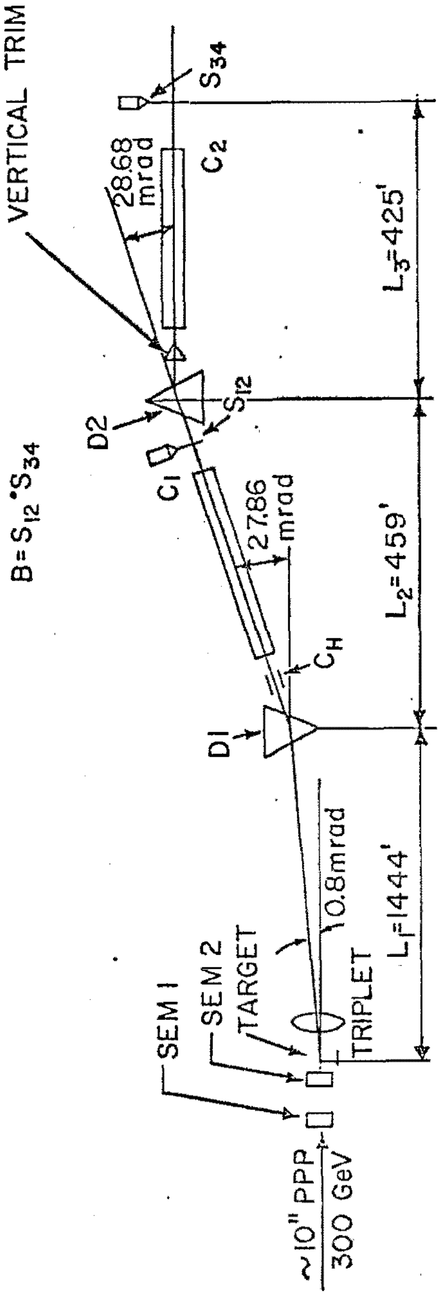

Figure 1: The Fermilab muon beam as it is adapted for neutrino physics. The quadrupole triplet focuses and shapes the neutrino spectrum; The rest of the beam is used as a double-bend spectrometer to analyze the hadron production spectrum.