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PROPOSAL FOR STUDYING NEUTRINO INTERACTIONS IN NEON WITH A NARROW BAND NEUTRINO BEAM IN THE 15' BUBBLE CHAMBER

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Summary

An experiment is proposed to study neutrino interactions in the 15' bubble chamber filled with a heavy neon-hydrogen mixture using a narrow band neutrino beam. The main purpose of the experiment is the detailed study of the weak neutral current interaction and the cross section measurement of specific reaction channels. With 2×10^{13} protons per pulse at 300 GeV we estimate 1 event every 10 pictures. We request 100,000 pictures (or 10,000 neutrino events). As a feasibility and rate study we would like to have an early run of 5,000 pictures with the existing narrow band beam and whatever neon-hydrogen bubble chamber filling is available.

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1. Introduction

The recent experiments in high energy neutrino physics have given a comprehensive picture of the main features of high energy neutrino interactions and led to the discovery of weak neutral currents. Future experiments may have to solve specific problems as well as look for new phenomena with greater sensitivity. It is in this context that more refined and more controlled experiments will play a dominant role. The use of dichromatic (or narrow-band) neutrino beams in conjunction with the 15' bubble chamber fits in this picture(1). One may think that the time has come to use neutrino beams in the same way as one used in the past beams of charged hadrons.

The main aim of this proposal is to make a detailed study of the weak neutral current and to measure the cross section of specific reaction channels. We believe that improvements in the circulating proton beam, in the narrow band beam and in the 15' operation will make it possible to obtain in the near future exposures in heavy neon-hydrogen mixtures containing one useful neutrino interaction every 10 pictures.

The 15' bubble chamber filled with a heavy neon-hydrogen mixture has a total fiducial mass of about 20 tons and is thus capable of yielding a large number of events. It furthermore has the advantages of 4π solid angle coverage, fine grain calorimetry for hadrons, good identification of electrons and muons (the external muon identifier will help considerably for this purpose), good detection of K^o, Λ^o and photons ($\varepsilon_\gamma \simeq 95\%$).

An exposure of 100,000 pictures will lead to 10,000 events (of which 2,000 will be neutral current events), which should be adequate to fulfill the aim of the present proposal.

2. Physics Topics of Interest

Some of the specific physics topics which will be attacked with the present experiment will be:

1. Study of the cross sections for many specific channels, in particular for neutral current channels. The comparison with measurements at other energies should allow us to see if the ratio of neutral to charged current events is constant or depends on energy.

2. Because one knows the incident energy, one can make inclusive (or deep inelastic) measurements in the real sense of the word. This is particularly important for neutral current events

$$\nu N \rightarrow \nu + \text{hadrons} \qquad (1)$$

   (i) The study of the y-distribution of events for reaction (1) is sensitive to the nature of the neutral current. A (V,A) interaction leads to a y-distribution which is either flat or decreases with increasing y, depending on the relative importance of the V and A terms. Instead an (S,P) interaction leads to a y-distribution which increases with y.

   (ii) The study of the combined x and y distributions will lead to estimates of the structure functions for neutral current events.

   (iii) One will be able to make a detailed comparison of (1) with inclusive charged current events

$$\nu N \rightarrow \mu^- + \text{hadrons} \qquad (2)$$

3. We shall be able to make detailed studies of some specific reactions, in particular one may be able to see if individual inelastic channels scale separately.

4. Search for new phenomena. The statistics in this experiment will not be as high as in other experiments performed with wide band beams, but some previous searches had more problems with background than with statistics. So the better controlled conditions of this experiment may be of considerable help.

3. Experimental Conditions

3.1 The beam

We shall briefly discuss three alternatives and refer for a more thorough discussion to the Fermilab Experiment E-21[2,3] and proposal P-380[4,5]. The three narrow band beam alternatives are:

i) The existing narrow band beam used by E-21[2,3]. It leads to a pion beam which has a momentum spread $\Delta p/p = \pm 20\%$, which is difficult to improve without sacrificing the ν-flux, because of the coupling between the momentum bite and the accepted solid angle.

ii) The proposed dipole-quadrupole narrow band beam designed by the Fermilab-Caltech group of E-21[3,6]. This beam would have good energy resolution and low background from wide-band ν and $\bar{\nu}$ components.

iii) The proposed two-horn narrow band beam using two pulsed magnetic horns as proposed by P-380[4,5].

As far as the fluxes are concerned the proposed dipole-quadrupole beam and the two-horn beam are essentially equivalent for the energy range considered in this proposal (see last figure of ref. 5).

The neutrino event rate for the two-horn and the dipole-quadrupole beams is optimized when the pion momentum is at about 100 GeV, which corresponds to $E_{\nu\pi} \simeq 35$ GeV and $E_{\nu K} \simeq 95$ GeV.for neutrinos coming from pion and kaon decays respectively. On the other hand the yield does not change appreciably from $80 < p_\pi < 140$ GeV/c (see Fig. 14 of Ref. 5 and Table 2 of Ref. 6).

Assuming p_p = 300 GeV/c, $p_\pi \simeq$ 100 GeV/c, both the new proposed neutrino beams would have $\Delta E_\nu/E_\nu \simeq \pm 30\%$. The knowledge of the radial position of each neutrino event allows the determination of the neutrino energy to $\Delta E_\nu/E_\nu \simeq \pm 10$- 15%.

We conclude that we could run using any of the three beams at pion momenta around 90-120 GeV/c, depending most on Fermilab policy and operation. The two new proposed beams are clearly superior to the present beam in flux-energy resolution.

The other possible running condition would be with the accelerator at 400 GeV, in which case the optimum beam conditions would be at somewhat higher energies and the dipole-quadrupole beam would gain flux over the two-horn beam.

3.2. The 15' bubble chamber

We assume that it will be possible to operate the 15' chamber with a heavy neon-hydrogen mixture containing from 80% to 95% of neon[(1)]. The corresponding density will be between 1 and 1.2 g cm^{-3}. It should be possible to utilize a fiducial volume containing 20 tons of material[(1)]. The radiation length will be about 25 cm and the effective interaction length about 80 cm.

We furthermore assume that the full magnetic field of 30 Kgauss will be available.

3.3. Event yield

Assuming

2×10^{13}, 300 GeV protons per pulse on the ν-target

20 tons of fiducial mass of heavy neon-hydrogen

$p_\pi \simeq$ 100 GeV/c ($E_{\nu\pi} \simeq$ 35 GeV, $E_{\nu K} \simeq$ 95 GeV)

$\Delta p_\pi/p_\pi \simeq \pm 10\%$

dipole-quadrupole or special-horn narrow band beam we estimate 1 event every 8-10 pictures[3,4]. Thus the 100,000 pictures requested should correspond to about 10,000 events, of which 2,000 are expected to be neutral current events.

3.4 External muon identifier (EMI)

We would like to use the information from the external muon identifier built by the Hawaii-LBL group.

4. Data Analysis

All the groups involved in this collaboration have many conventional scanning and (pre)measuring image plane projectors and have direct access to automatic measuring devices of the HPD type[7].

The CERN chain of computer programs HYDRA will be used at the CDC 6400, 6600 and 7600 of Amsterdam, Bologna and Saclay.

Measurement errors should be adequate for the physics program under study; for instance for an inelastic interaction with $q^2 = 1$ $(GeV/c)^2$ we estimate a typical error in the transverse momentum of about 20 MeV/c.

5. Experimental Effort

The participating groups will be part of a larger collaboration, which has requested bubble chamber pictures in BEBC filled with deuterium and exposed to neutrino beams at the CERN-SPS[7]. At the time of writing it is anticipated that these pictures cannot be available before the end of 1977.

Four of the institutions of the collaboration will participate in the proposed experiment. From each institution there will be at least 6 physicists with a total of 15 scanning projectors and 3 HPD's available (see addendum).

6. Summary of Requests

We request 100,000 pictures, containing 10,000 events, of the 15' bubble chamber filled with a heavy neon-hydrogen mixture exposed to a narrow band neutrino beam with parent pion momentum around 100 GeV/c. This proposal is quite similar to proposal P-380. On the other hand the two can be run at different neutrino energies and thus become complementary. We could operate with any of the three neutrino beams discussed in section 3.1 and with the accelerator at 300 or 400 GeV/c. Use of the EMI is envisaged. Because of the considerable uncertainties in the absolute ν-fluxes at the 15' location, we think that it would be important to have as soon as possible a test run of one day, or 5000 pictures, of the 15' chamber filled with the neon percentage now available. This exposure would constitute a feasibility study and would be performed with the present narrow band beam used by E-21.

References

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6. H.W. A therton, Some characteristics of the WANF narrow-band neutrino beam, CERN/Lab II/EA/74-6 (1974)
7. Amsterdam-Bologna-Padova-Pisa-Saclay-Torino collaboration. Proposal for studying neutrino and antineutrino interactions in deuterium, CERN/SPSC/74-72/p 16, (1974).

ADDENDUM

EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

CERN/SPSC/74-105/P 16/Add.1
October 25, 1974

ADDENDUM TO PROPOSAL CERN/SPSC/74-72/P 16

Amsterdam-Bologna-Padova-Pisa-Saclay-Torino Collaboration

October 20, 1974

After we submitted our proposal for the study of neutrino and anti-neutrino interactions in deuterium, a letter has been circulated by the chairman of the SPS committee (D.Ph.II/PL/tr, 05/07/74). The information requested in this letter is covered by our proposal. In order to answer some specific questions mentioned in the letter, we like to make the following addendum:

a. Scanning and measuring capacity

From the added table it can be seen that by the end of 1976 the collaboration will be equipped with 27 scanning and measuring tables. All groups will have access to an automatic measuring device and will have computing facilities both for bringing their scanning and measuring equipment on-line, and for carrying out the subsequent geometrical and kinematical calculations. It is anticipated that 20 events can be fully processed per scanning table per normal working day.

b. Type of neutrino/anti-neutrino beams

The first exposures should be carried out with a wide-band beam and subsequently with the narrow-band beam as mentioned in the proposal. The requested beams should be optimized for the total number of events.

c. Number of pictures

For the first two years we request a million pictures devided over neutrinos and anti-neutrinos. For a SPS intensity of 10^{13} protons per pulse and a realistic choice of proportions of the various experimental conditions, this can result in 200,000 events. The collaboration is able to handle these pictures and analyse the events within two years.

A.G. Tenner
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PICTURE HANDLING CAPACITY BY 1976

AMBCPAPISATO

GROUP	SCANNING AND (PRE)MEASURING TABLES			ON-LINE TO	MEASURING DEVICE	GENERAL COMPUTER
	image plane digitizers	film plane digitizers	total			
Amsterdam	2	4	6	CDC 6400	HPD with CDC 6400	CDC 6400
Bologna	4		4	Siemens	HPD with CDC 6600	CDC 6600 or CYBER 67
Padova	4		4	HP 2100	Bologna HPD	Bologna computer
Pisa		3	3	IBP 1800	Bologna HPD	IBM 370/151, 360/67
Saclay	5	3	8	PDP 15	CRT with CII 10070 or HPD with PDP 10	CDC 7600
Torino	2		2	IBM 1130 or PDP 11/10	Bologna HPD	IBM 360/67
		total	27			