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V.V.Ammosov, I.A.Danilchenko, P.F.Ermolov, V.I.Koreshev,
E.P.Kuznetsov, V.V.Makeev, Y.G.Ryabov, V.I.Sirotenko,
E.A.Sloboduk, V.A.Yarba*)

PROPOSAL TO STUDY NEUTRINO AND ANTINEUTRINO INTERACTIONS IN BEBC

*)Contactman

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A B S T R A C T

It is proposed to study ν_μ N and $\bar{\nu}_\mu$ N interactions in BEBC associated with external muon identifier at highest possible proton beams available at CERN SPS. We are interested in two exposures, each about 500000 pictures, of BEBC complemented by a track-sensitive target using a wide band and narrow band beams. The main physical topics include the study of total cross sections, a detailed inclusive and exclusive investigation of charged and neutral current interactions, evaluations of rare reactions and searches for new phenomena.

I. I N T R O D U C T I O N

During the past years neutrino interactions have been investigated very intensively at high-energy accelerators. Some of the experiments have been already done[1], other are in preparation or performance stages. The study of neutrino collisions at Serpukhov accelerator, planned for SKAT[2] filled with heavy liquid in 1975-77 years, will help to investigate neutrino interactions in energy region up to 40 GeV.

The present proposal is an extention of the study of ν_μ N and $\tilde{\nu}_\mu$ N interactions which will allow to study in detail the properties of inelastic ν ($\tilde{\nu}$) events in energy region up to 200 GeV, using the Big European Bubble Chamber (BEBC). It is assumed that by the time the experiment begins there will be a possibility of getting ν ($\tilde{\nu}$) from the extracted proton beam with 400 GeV/c momentum. The BEBC is one of the best detectors for investigations of ν N and $\tilde{\nu}$ N inelastic interactions at high energies. The use of a deuterium track-sensitive target (TST) and neon, surrounding it in the chamber, gives us a possibility to study neutrino interactions on protons and neutrons and to increase considerably the detection of secondary neutral particles in ν($\tilde{\nu}$) events.

High energy and intensity of neutrino beam together with the aforementioned possibilities to detect neutrino events in the bubble chamber BEBC allows one not only to study inclusive processes but to make another step in neutrino investigations i.e., a detailed study of exclusive processes. It provides the required conditions for the search for new particles (heavy leptons, intermediate boson, particles with the quantum numbers of the „charm" type) whose life-time is $\tau < 10^{-12}$ sec, thus in the bubble chamber experiments the method to search for them is similar to that for resonances. On the other hand study of exclusive processes will give us important information on hadron dynamics in weak interactions (in particular the role of the diffraction mechanism in vector meson production is clarified.

The main statistical data in νD_2 interactions is planned to be obtained in a wide band neutrino beam with the view to follow the energy dependence of cross sections for different reactions in neutrino range 10-150 GeV/c. A part of pictures is thought to be obtained in quasimono chromatic ν and $\bar{\nu}$ beams so as to investigate deep inelastic neutrino scattering in the events with neutral currents.

We are interested in collaboration with other laboratories in order to be able to perform the proposed experiments in reasonably short time. Obviously many features of this proposal have been covered by the experiments proposed previously. The new experimental results that will be obtained at FNAL and

Serpukhov may, of course, change some aspects of the present proposal and the setting up these experiments.

II EVENT RATES

The high energy neutrino interactions in a bubble chamber are commonly accompanied with a high level of background. Therefore it is undesirable to have more than 2 events per picture. Preliminary scanning results, obtained in FNAL/1/, indicate that the mean prong number $\langle n_{ch} \rangle \sim 5-6$, the mean number of $\langle n_{\pi^0} \rangle \sim 2$ and a charge multiplicity may rise up to 15 particles.

Having 10^{13} ppp intensity for 400 GeV/c momentum proton beam and using 3 m^3 deuterium TST/3/ it is possible to have about 100000 of νN and 35000 of $\bar{\nu} N$ events for 250000 picture exposures. The detection efficiency for gamma-rays and neutrons in this case will be about 85% and 50%, respectively. The expected number of muonless events is about 20000 in neutrino and 12000 in antineutrino beams.

The expected number of the events from the same statistical data obtained in quasimonochromatic beam will be 20-40 times less, i.e., it will be some thousands of events. The ratio of the pictures in a wide band and monochromatic beams may be defined more accurately by the moment of the experiment start up.

III. SOME METHODICAL PROBLEMS

A detailed study of neutrino-nucleon interactions makes particularly important the investigation of a number of known problems concerning the experimental methods.

1. Neutron Background

According to the data obtained with the FNAL 15 feet bubble chamber/4/ the energy spectrum of neutron background sharply falls down with energy. In the energy range (2-10) GeV neutron background is considerable and comprises in average 100%. Above 10 GeV neutrons comprise only percent. As the neutron background arises mainly from the interaction of neutrino in the matter sorrounding operational volume of the bubble chamber, then its relative value in the BEBC chamber may turn out to be almost the same as in the 15 feet bubble chamber. It means that one will have a problem in indentifying the events caused by neutral currents at the energy below 10 GeV.

In this experiment we plan to use methods of selecting neutron events, that exploit a number of possibilities such as:

- Analysis of "evident" neutrino events, produced in the track sensitive target or neon and related to the initial interaction in the chamber walls or in the target volume.

- Kinematic analysis of neutron events and neutrino events caused by neutral currents.

- Statistical method of investigation in deep inelastic processes.

2. Neutrino Contamination in Antineutrino Beam

Contamination of $\bar{\nu}$ in ν beam will be of some percent. It is not a problem in investigating the most number of the reactions.

$\bar{\nu}$ contamination in antineutrino beam may be 20-30 % for high energy parts of neutrino spectrum, that will be a great obstacle. It seems to us that the basic method to select neutrino events in $\bar{\nu}$ exposures is to compare the data by the characteristics of neutrino events (such as hadron and muon transverse momenta, energy fraction carried away by each particle, etc) obtained from ν exposure.

3. Muon Identification and Determination of Neutrino Energy

In the present experiment we propose, that the methods of muon identification should be based on application of the following:

- External muonic identifier.
- Detection of the secondary hadronic interactions in neon.
- Common statistic analysis of the events on the basis of study of the secondary features for positive and negative particles.

The ways to identify muons and to determine neutrino energy in bubble chambers /5/ proposed now are based on the physical assumptions. Therefore they cannot be applied in detailed study of neutrino interaction with nucleons.

When investigating the characteristics of deep inelastic processes such as x, y, q^2, $p_\perp$ etc. distributions it is necessary to reconstuct neutrino energy in each event. We suppose that in the given experiment we can use statistical methods in order to obtain deep inelastic characteristics in charged current events as about 80% of the hadronic energy is detected. It means that instead of P_ν we may use $(P_\nu)_{vis}$ is for all the distributions we are interested in, and then having the experimentally obtained characteristics for neutral component go over to real distributions.

The same goal is achieved in the case with neutral currents when narrow band neutrino beam is used.

IV PHYSICS PROBLEMS

1. Study of Inelastic Inclusive Interactions

Investigation of inelastic neutrino interactions and energy dependence of total cross sections are very important problems in high energy neutrino physics. The problems include also the determination of $R = \sigma(\bar{\nu} N)/\sigma(\nu N)$. The comparison of this ratio with other experimental data will allow us to check some theoretical models[6]. The recent Gargamelle experiment in the neutrino energy range 1-10 GeV for the isoscalar target has shown that values of $R_{cc} = 0.38 \pm 0.02$, $R_{NC} = 0.53 \pm 0.15$[1] and differential cross sections in x, y, variables are in a good agreement with theoretical predictions. Preliminary data have been obtained for higher energies as well[1].

The determination of this ratio for muon and muonless events in wide energy range for proton and neutron targets will make it possible to check the existence of charms which must change this ratio above the charm threshold.

It is natural to suppose that most events at high energies inelastic events should allow to perform a detailed analysis of the structure functions F_{1-3} in deep inelastic region on different targets and to compare the results with the prediction of naive quark model. The study of structural functions for $\nu(\tilde{\nu})N \to \nu(\tilde{\nu})X$ processes is of special interest because the present data on this problem are very poor.

The hadronic part of neutrino inelastic interactions is not well investigated yet. It will be interesting to study in detail some inclusive distributions depending on the hadronic par of the events (charge multiplicity, multiplicity and kinematical characteristics for some sort of particles $\pi^{\pm}$, π^{0} , K^{0} etc).

2. Study of Rare Processes and Search for New Phenomena

The analysis of purely leptonic events is the best way for investigation of weak interactions. But the cross sections of these processes are three orders less than those with nucleus. There may be expected ~40 events of $\nu_{\mu} e \to \mu^{-}\nu_{e}$ and a few events of $\nu_{\mu}(\tilde{\nu}_{\mu})e \to \nu_{\mu}(\tilde{\nu}_{\mu})e$. The detection of purely leptonic events in neon, surrounding TST may give an extra information for the study of rare processes in neutrino physics. The high density of electrons in neon will allow to increase considerably (10 times as much) the detection probability of leptonic interactions.

One may hope that the proposed experiments will reveal some new and unexpected phenomena. For example, it is interesting to search for charged heavy leptons with helicities opposite to those of the known leptons in $\nu(\tilde{\nu})N \to L^{+}(L^{-})X$ reactions, where heavy leptons should decay in muon and two neutrino and also heavy leptons (μ') with decay $\mu' \to \mu\gamma$. The investigation of $\mu\mu$ and μ e pair production in inelastic interactions will make it possible to estimate $W^{\pm}$-production probability with mass up to 9-10 GeV. The analysis of leptonic pairs and strange particle production along with the energy dependence of cross sections should help to estimate the upper limits of charm production.

3. Exclusive Reactions

The study of exclusive muonless interactions is of the most interest in this experiment. For example, we may analyse elastic scattering $\nu_\mu(\tilde{\nu}_\mu)p \to \nu_\mu(\tilde{\nu}_\mu)p$, reactions with a single pion production $\nu p \to \nu n\pi^+$, $\nu p \to \nu p\pi^0$ ect. There may be expected a few thousands of such events.

We note also that it is very interesting to continue the investigations of some classical questions in the theory of weak interactions - the study of quasi-elastic scattering, the analysis of some reactions in which isobars, ρ mesons and strange particles are produced. The study of traditional reactions should allow to verify the correctness of the selection rules $\Delta S = 0$, $\Delta T = 1$, $\Delta S = 1$, $\Delta T = 1/2$, $\Delta S = \Delta Q$ in neutrino interactions at high energies.

V. EQUIPMENT AND PERSONNEL

Our equipment available for scanning and measurement of neutrino events from BEBC will include 3-4 tables meant for with varying magnification (15^x and 60^x) and CRT device. The total measured power of this equipment for the first period of time will be 20000 events per year. At the beginning of 1978 about 8-10 physicists of our laboratories may take part in these experiments. As is seen from our man and equipment power it is desirable to share our efforts with those of other laboratories for performance of νN and $\tilde{\nu} N$ experiments.

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