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PROPOSAL TO MEASURE THE CROSS SECTIONS FOR

$$\bar{\nu}_\mu + e^- \rightarrow \bar{\nu}_\mu + e^-$$

AT FERMILAB

Submitted by

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I. Introduction

The purely leptonic processes

$$\nu_\mu + e^- \rightarrow \nu_\mu + e^- \quad (1)$$

$$\bar{\nu}_\mu + e^- \rightarrow \bar{\nu}_\mu + e^- \quad (2)$$

$$\nu_e + e^- \rightarrow \nu_e + e^- \quad (3)$$

$$\bar{\nu}_e + e^- \rightarrow \bar{\nu}_e + e^- \quad (4)$$

are, in principle, the best reactions to test the weak interaction theories. The theoretical estimates are precise in these cases because the complications due to hadronic effects are not involved.

The difficulties of measuring these reactions are mainly due to the smallness of their cross sections, which are of the order of $\sim 10^{-42} E_\nu$ cm^2, where E_ν is the neutrino energy in GeV. In a recent counter experiment at Fermilab, E-253, a significant measurement of reaction (1) was successfully performed. Based on a data sample of ~70% of the beam exposure, 34 $\nu_\mu e^-$ elastic scattering events were observed together with 12 events from background. This leads to the following results: $\sigma = (1.40 \pm 0.30) \times 10^{-42} E_\nu$ cm^2, and $\sin^2\theta_w = 0.25^{+0.07}_{-0.05}$, in agreement with the Weinberg-Salam theory and other measurements of $\sin^2\theta_w$ such as that in $\nu N/\bar{\nu} N$ interactions and polarized eD scattering. This result was reported at the 1979 Lepton-Photon Symposium at Fermilab and has been followed by a paper submitted to Physical Review Letters for publication. The analysis of the remaining ~30% of the data will be complete in the near future. It is anticipated that the experiment will yield ~50 $\nu_\mu e^-$ elastic scattering events, which is about twice the previous world total.

In this proposal, we propose the measurement of reaction (2) with comparable statistics. By combining the results of $\bar{\nu}_\mu e$ and $\nu_\mu e$ elastic scattering, the weak coupling constants, g_V and g_A, can be determined independent of any model. Furthermore, the specific condition of $g_A = -1/2$ in the Weinberg-Salam model can be tested critically. Alternatively, the parameter, ρ and $\sin^2\theta_w$, in the WS model

$$J^{NC} = \rho\ (I_3^{WI} - J^{EM}\sin^2\theta_w)$$

can be uniquely determined; where ρ measures the ratio of neutral to charged current.

It is interesting to notice that at $\sin^2\theta_w = 1/4$, the cross sections for $\bar{\nu}_\mu e^-$ and $\nu_\mu e^-$ elastic scattering are equal. Such a value of $\sin^2\theta_w$ is predicted by certain models; e.g., the integer charge quark model. At the present time, the most precise measurements of $\sin^2\theta_w$ are done in νN and polarized eD interactions. Their uncertainties are mainly from the complications of the QCD theory and the incomplete knowledge of quark distributions. In the forseeable future, the precision of measurement in the purely leptonic processes should be greatly improved. Interesting fine effects such as radiative corrections in νe scattering would become observable.

II. Beam and Apparatus

We propose using the single-horn focussed, wide-band $\bar{\nu}_\mu$ beam to run the experiment. The horn should be plugged to reduce the ν_μ contamination. The proton beam energy should be 350 GeV in order to reduce the muon background in the Wonder Building to a manageable level. Also, we request activating the muon spoilers to further reduce the muon background. Experience gained in the running of E-253 indicated that the spoiler magnets can reduce the muon rate to ~30 μ's/10^{13} protons at proton energy of 350 GeV.

Modular design of the apparatus is identical to that of E-253. Each module is made of 1 r.l. thick Aluminum radiator/target, one layer of plastic scintillator, and one MWPC with both x- and y-coordinate delay-line readout on the cathode planes. The performance of the detector is well understood. The angular resolution for measuring electromagnetic shower is $\pm$ 5 mr, with very little energy dependence. Since the intensity of $\bar{\nu}_\mu$ beam is only ~20% of the ν_μ beam, we propose adding another 30 new modules of detector to increase the event rate. These detectors will be housed in a suitable forward extension of the Wonder Building. Also, we will replace all the cathode plane amplifiers and TDC's with newly developed units. This change will almost entirely eliminate the equipment dead-time. For E-253, the dead-time was observed to be, on the average, ~33%. The new electronics have the capability of taking 10 triggers per 1 msec fast spill, far greater than the expected triggers of 1 trigger every 5 pulses.

Previously at the end of the detector assembly, there was only one iron shield and one hodoscope were used to identify the muons for E-253. Since there was no way to measure the muon energy, that experiment suffered from the lack of a measured neutrino spectrum. The knowledge of the neutrino spectrum was supplied by the measured visible hadron energy spectrum in charged current interactions, together with a Monte Carlo calculation. We propose removing the iron shield, and replacing it with a solid-iron dipole magnet. Behind the magnet, we will install a set of 2m x 2m drift chambers to measure the muon momentum. With this arrangement, we will be able to determine experimentally the neutrino spectrum from the charged current events without relying upon uncertain Monte Carlo calculations. The magnet has already been designed, and costed by W. Nestander of the Neutrino Section. The drift chambers have already been built.

III. Manpower and Schedule

In addition to the proponents listed on the cover page, we plan to add one graduate student from VPI. We have sent an invitation to the Erevan Institute, Armenian Academy of Sciences, U.S.S.R., to invite two physicists to join our $\bar{\nu}_\mu$ run. Also, we are in the process of inviting a few more physicists to join this collaboration. We feel that 12-15 physicists would adequately staff the needs of these experiments for the next year.

The new chamber construction will begin immediately as funds become available. Since the technology exists, there should be no problem. If fabrication begins soon, a majority of the new chambers can be installed before the commencement of the $\bar{\nu}_\mu$ run. The small remaining fraction can be installed during the run. All of the new electronics will be ready for the run. The schedule is tight, but we believe that it can be done.

IV. The Request

To adequately measure the cross section for $\bar{\nu}_\mu + e^- \rightarrow \nu_\mu + e^-$ we make the following requests:

(1) 1.2×10^{19} protons of 350 GeV on target during the $\bar{\nu}_\mu$ running period of January - April, 1980.

(2) 30 modules of new detectors, and extension of the Wonder Building to accommodate them.

(3) A solid iron dipole magnet for the muon measurement.

(4) PREP electronics for the added detectors.

With the improvements of ~1.75 X (given by 70/40) in detector size, ~1.33 X in equipment dead-time, and ~1.2 X in total number of protons, we anticipate ~35 $\bar{\nu}_\mu e^-$ elastic scattering events.

Also, we would like to be allowed to take more data on $\nu_\mu e^-$ elastic scattering during the wide-band $\bar{\nu}_\mu$ running period in 1980. For 1.0×10^{19}

protons at 350 GeV on target, we can detect 100 $\nu_\mu e^-$ elastic scattering events with the elimination of dead-time and the increased detector tonnage.