Eighth Int'l Workshop on Weak Interactions
and Neutrinos Sept. 5-11, 1982, Janea, Spain

BNL 32289
OG667

Neutrino-Electron Scattering - A Progress Report

Institutions:

Brookhaven National Laboratory, Brown University, K.E.K. (Japan), Osaka University, University of Pennsylvania, Stony Brook (S.U.N.Y.), Tokyo (I.N.S.)

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(Presented by D. H. White)

Research supported in part through the Japan-USA Cooperative Research Project on High Energy Physics under the Japan Ministry of Education, Science, and Culture.

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We present here a progress report on an experiment to measure the cross section for $\nu_\mu e$ scattering at the Brookhaven AGS. A wide band focusing horn is used with a neutrino beam energy centered at 1.5 GeV. We have in hand measurements with ν_μ and $\bar{\nu}_\mu$ beams but we present preliminary data on the ν_μ beam running only. We also measure the reactions.

$$\nu_\mu + \mu \to \mu^- + p$$

$$\nu_e + \mu \to e^- + p$$

which will be used in normalization and in background estimation. The principal kinematics signature is the forward going recoil electron, and to measure this particle with precision we have designed a detecter that is 85% active with fine segmentation. This permits good angular resolution, total energy measurement of hadrons and showers as well as particle identification.

The detector is constructed in a modular fashion. One module consists of one plane (Y) of liquid scintillator calorimeter and two planes (X and Y) of proportional drift tubes (PDT's). The details of one module are given in Table 1.

The main detector is followed by a "gamma catcher" consisting of 10 calorimeter modules each separated by one radiation length of lead. This allows energy determination of electron and photon events occurring in the down-stream portion of the detector. Following the "gamma catcher" is a magnetic spectrometer which aids in measuring $\nu_\mu(\bar{\nu}_\mu)$ contamination by $\nu_\mu(\bar{\nu}_\mu)$. The entire detector is under microprocessor control (Figure 1).

An important feature in limiting certain types of background is the time structure utilized in data taking. The primary beam from the Alternating Gradient Synchrotron of the Brookhaven National Laboratory is extracted in twelve, radio-frequency "buckets" each separated by 220 nanoseconds. Target associated background with $v \neq c$ then arrives out-of-time between the buckets. Figure 2 shows a portion of this bucket structure for triggers recorded in the detector; the out-of-time background is negligible.

The accelerator operates with an approximately 1.4 second repetition rate with an intensity approaching 1×10^{13} protons-on-target (POT) per pulse into a horn-focussed wide band beam.

To date approximately 1.5×10^{19} POT have been accumulated for ν_μ and about 1×10^{19} POT for $\bar{\nu}_\mu$. In an attempt to verify the existence of the rare $\nu_\mu + e \to \nu_\mu + e$ signal and to check upon its predicted rate, we have performed a preliminary analysis on the first 0.9×10^6 machine pluses with a ν_μ beam. These data are taken from the first half of the completed detector only; the last portion not yet having been brought into operation. In this preliminary analysis we have used very simple algorithms and further development of them is underway; however, as can be seen from what follows they adequately serve the present purpose.

As a guide to the magnitude of the quantities entering into the extraction of the $\nu_\mu e \to \nu_\mu e$ signal we quote the relevant, relative fluxes (Φ) and cross sections (σ):

$$\Phi(\nu_\mu) : \Phi(\nu_e) : \Phi(\bar{\nu}_\mu) : \Phi(\bar{\nu}_e) = 1 : 5 \times 10^{-3} : 1 \times 10^{-3} : 2 \times 10^{-4}$$

$$\sigma(\nu_\mu n \to \mu^- p) ; \sigma(\nu_\mu \mu \to \nu_\mu e) : \sigma(\nu_\mu n \to \nu n \pi^0) : \sigma(\nu_e n \to e^- p)$$

$$= 1 : 2 \times 10^{-4} : 0.1 : 1$$

The principal background to the $\nu_\mu e \to \nu_\mu e$ signal comes from $\nu_e n \to e^- p$ where the proton missed detection and from $\nu_\mu n \to \nu_\mu n \pi^0$ where the neutron and one of the photons from the π^0 were missed. Other reactions involving charged currents and/or charged hadrons are easily suppressed via energy deposition in the calorimeters. (See Figure 3).

We have used a two step technique for background suppression in the present analysis. The first step is via an "anti-hadron and muon filter" algorithm based primarily on calorimeter information — this removes most of the charged current and charged hadron background while passing (according to Monte Carlo calculation) 96% of the electron signal. In the data sample under consideration here this filter passes 290 events with an energy > 200 MeV and in an angular interval with respect to the mean beam direction of approximately ±15°.

This sample of 290 events should then consist primarily of signal and electron and photon fragments of the reactions $\nu_e n \to e^- p$ and $\nu_\mu n \to \nu_\mu n \pi^0$ mentioned above. Thus the second step in our preliminary analysis is to try to suppress these fragments by passing them through a second algorithm which separates singly ionizing (favors $\nu_\mu e \to \nu_\mu e$) from doubly ionizing particles emerging from the vertex. This selection is guided by Monte Carlo studies (75% of single electrons but only 5-10% of photons should pass) and measurements with singly ionizing cosmic rays passing through the detector. The resulting algorithm is based upon use of the average energy deposited in the first two calorimeters after the vertex being less that 15 MeV and a similar cut using th PDT's. The PDT cut is made by selecting from the first six PDT's (X + Y) the average of the lowest two dE/dx measurements (to minimize Landau fluctuations). A value of < 9 keV is used as is illustrated in Figure 4. A distinct separation can be seen between singly and doubly ionizing particles. We are thus confident that a low background contamination can be achieved via this separation.

Evidence for the signal can be seen by selecting those events which pass the above cut (80 events) and plotting them so as to take advantage of the $\nu_\mu e \to \nu_\mu e$ kinematics. A scatter plot of E_e versus θ_e^2 (since $E_e\theta_e^2 < 2m_e$) would be most appropriate; however, until we have established our angular resolution and energy calibration in a tagged electron beam (this run is currently in progress at the A.G.S.) it is not useful to make such a plot. At this time a more appropriate variable is an $E_e^2\theta_e^2$ histogram and this is shown in Figure 5a. Also shown is the histogram of the same variable for those 210 events) which fail the cut. As can be seen from the two plots, there is a clean signal on a low background at small $E_e^2\theta_e^2$ and that the background at least as represented by Figure 5b has a very different shape.

Until we have completed out electron beam calibrations and extracted from the neutrino data samples of the background reactions, we are not in a position to make a reliable background subtraction. This work, as well as refinement of our algorithms, is already underway. If, however, we provisionally take the subtractions as normalized, then from this analysis we have a rate of $\nu_\mu e \to \nu_\mu e$ into the fiducial volume of the full detector of 2.5 ±1 event per day in agreement with our design expectations.

Using this number we would then expect to find in our presently accumulated data 65 $\nu_\mu e \to \nu_\mu e$ and 24 $\bar{\nu}_\mu e \to \bar{\nu}_\mu e$ events. Our future program includes the extraction and analysis of these events, additional approved running in 1983, identification and extraction of the $\overset{(-)}{\nu}_\mu p \to \overset{(-)}{\nu}_\mu p$ signals (several thousand of these should be in our present data), followed by a program in neutrino oscillation studies.

TABLE I

PROPERTIES OF A SINGLE MODULE

Calorimeter (liquid scintillator):

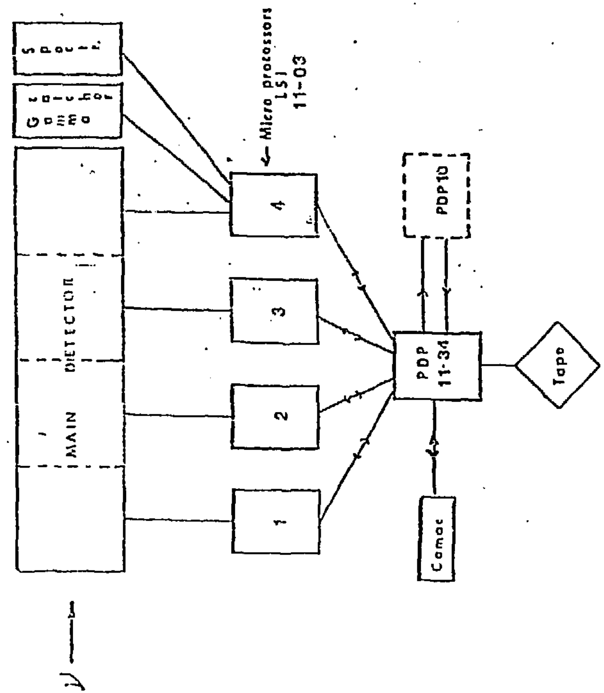
Active area	4.2 x 4.1 (meter)
Thickness per module	7.9 cm
No. of cells per module	16 (vertical segment)
Weight (liquid plus acrylic)	1.35 metric tons
Phototubes	two, Amperex 2212A/cell
1 pulse height per phototube	
> 2 timing hits per tube	

Proportional Drift Tubes:

Active area	4.1 x 4.1 (meter)
Thickness per module	7.9 cm
No. of cells per module	54(X) and 54 (Y)
Cell size	4.1 m x 7.7 cm x 3.8 cm
1 pulse height per cell	
2 timing hits per cell	

Total Assembly:

1. 118 modules (172 tons)
2. Gamma catcher (30 tons)
3. Magnetic spectrometer
4. Phototubes (total of 4096)
5. PDT (total of 13,824 cells)
6. Volume (4 meters x 4 meters x 24 meters)
7. Control (Logic in four parts under microprocessor (LSI-11/03) and PDP-11/34 control).



E-734 DATA COLLECTION

FIG. 1

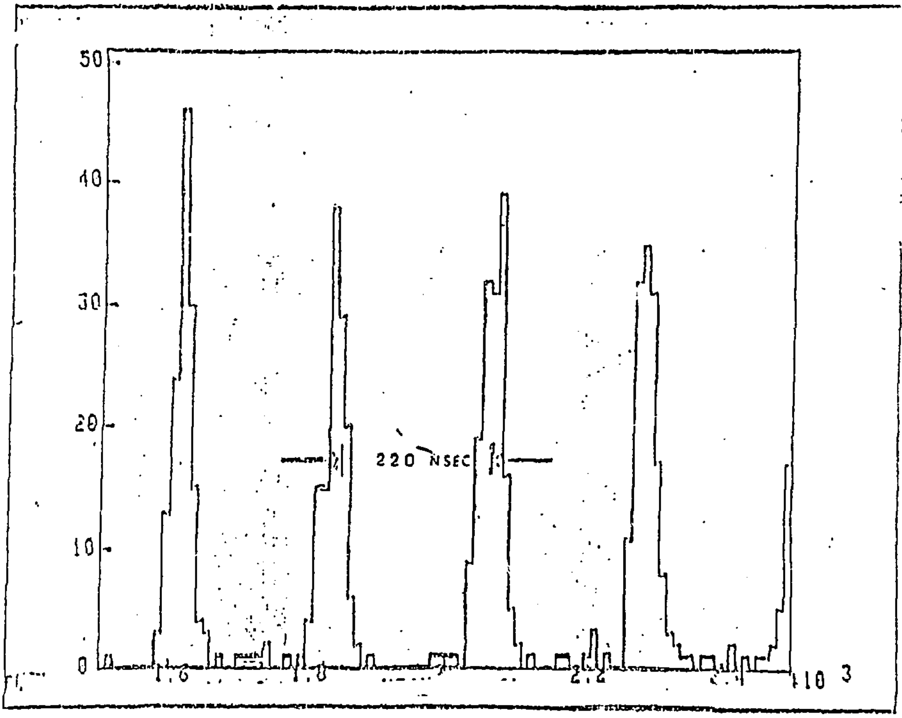


FIG 2

ENERGY DEPOSIT
IN
CALORIMETERS

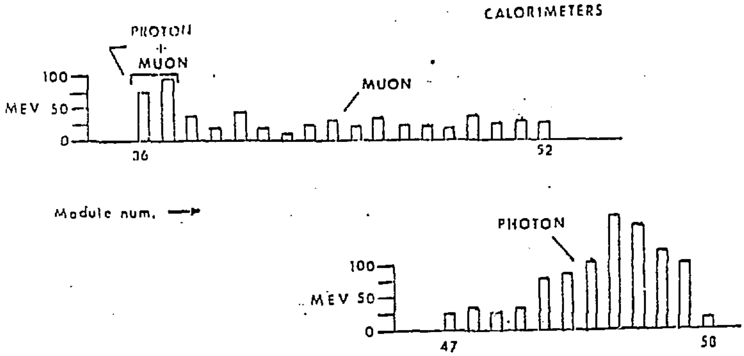


FIG. 3

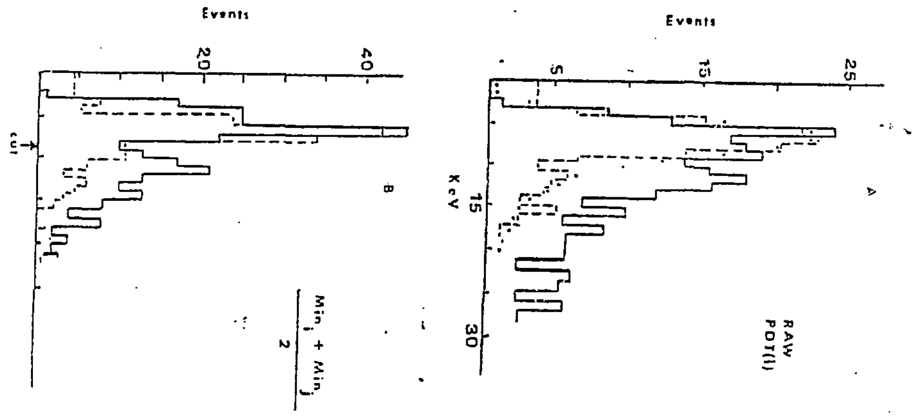


FIG 4

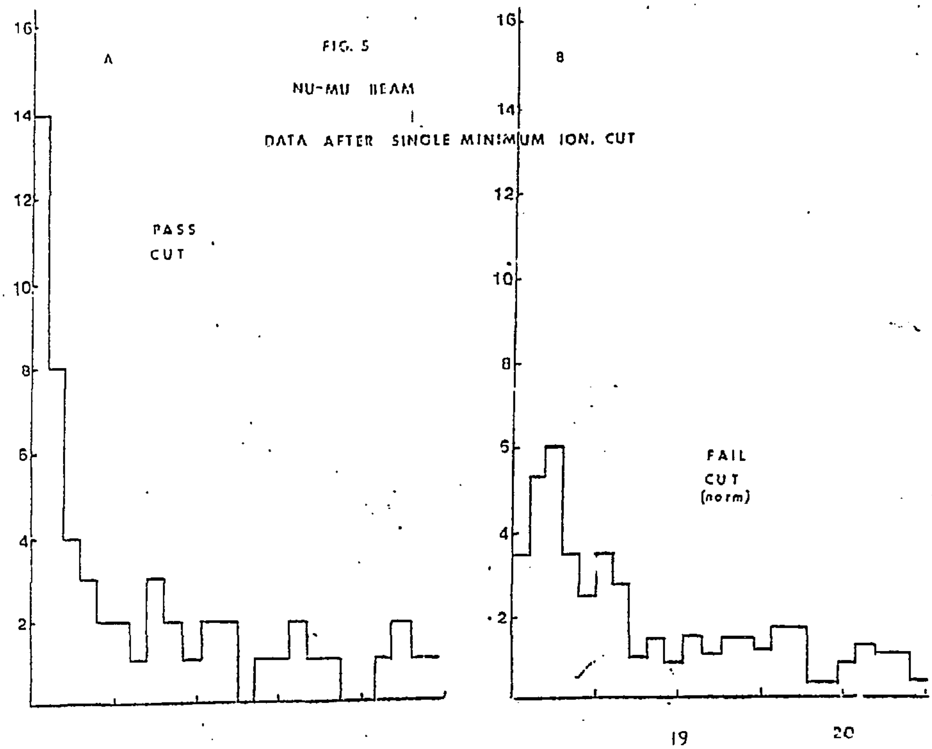


FIG. 5

NU-MU BEAM

DATA AFTER SINGLE MINIMUM ION. CUT