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NEUTRINO-OSCILLATION EXPERIMENTS AT BROOKHAVEN NATIONAL LABORATORY

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INTRODUCTION

Two groups have submitted major proposals(1,2) for neutrino oscillation searches at BNL. Both are two detector experiments with a close detector at $\approx$ 100m and a far detector at $\approx$ 900m. While the details of the experiments are quite different, both groups expect to obtain ν_μ disappearance limits of $\delta m^2 \sin 2\theta \approx 0.1 - 0.2$ for small mass difference and $\sin^2 2\theta$ at the few percent level for the most sensitive $\delta m^2 (\approx 25 eV^2)$. Since both detectors are designed to identify electrons as well as muons they expect to obtain significant limits on ν_e appearance ($\nu_\mu \to \nu_e$). Each has received approval for a single detector (Phase I) experiment with the two detector phase (Phase II) still pending. The remainder of this report details the present status of the single detector experiments.

Both single detector experiments are $\nu_\mu \to \nu_e$ appearance experiments and use narrow band horn focussed beams. This type of beam has many good features for $\nu_\mu \to \nu_e$ searches. The ν_μ beam is predominantly two peaks ($\approx$ 10% wide) from the two body decays $\pi \to \mu\nu$, $K \to \mu\nu$. The conventional sources of ν_e events are true ν_e events from 3-body decays ($K \to \pi e\nu$, $\mu \to e\nu\nu$) and apparent ν_e events from ν_μ events with a photon conversion near the vertex.(3) Neither of these sources produce spectra similar to that of the ν_μ beam. Consequently, with a narrow band beam the appearance of a peak in the distribution of ν_e events under the peak of ν_μ events is a positive indicator of oscillations. If no peak is observed the limit on $\nu_\mu \to \nu_e$ is determined by the apparent excess of ν_e events under the ν_μ peak.

EXP776

The EXP776 group(2) is building a 350 ton detector which will be located

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at ≈ 900m from the production target. The detector is modular in construction. There are ten sections each composed of ten modules of thin 5 1/2m x5 1/2m concrete slabs and x and y measuring proportional drift tubes followed by a plane of scintillation counters. Behind the primary detector is a magnetic spectrometer of iron toroids and proportional drift tubes. The group is also constructing a new narrow band horn beam which is optimized for E_ν ≈ 1 GeV. They expect to be taking data in the spring of 1984. With an expected e/μ rate of $< 10^{-3}$ they could attain $\nu_\mu \to \nu_e$ oscillation limits of $\delta m^2 \sin 2\theta = 0.03(\mathrm{eV})^2$ for small mass difference and $\sin^2 2\theta \approx 10^{-3}$ at large δm^2.

EXP775

The EXP775 group(1) have preliminary results on a $\nu_\mu \to \nu_e$ search using the existing BNL narrow band beam. The beam is optimized for π,K momenta of 10 GeV/c producing a ν_μ beam peaked at E_ν = 3 GeV, and a calculated ν_e/ν_μ event ratio of $\approx 9\times10^{-3}$. The detector used was the present E734 detector located 110m from the production target.(4,5) This is a 175mton, highly segmented, 90% active detector designed to measure $\nu e \to \nu e$ and $\nu p \to \nu p$ elastic scattering. It consists of 112 modules (4m x 4m x .17m) followed by a shower counter and magnetic spectrometer. Each module contains a 16 cell plane of liquid scintillator plus x and y measuring planes of proportional drift tubes. Times and pulse heights are recorded for every element to give excellent tracking capability and particle identification.

The present results come from the analysis of 1.26×10^6 AGS pulses or 9×10^{18} protons on target. The objective is to determine the number of quasi-elastic ν_e ($\nu_e n \to e^-p$) and ν_μ ($\nu_\mu n \to \mu^-p$) events. From the observed ν_μ events the expected number of ν_e events can be calculated. The comparison of expected and observed ν_e quasi-elastic events yields information on $\nu_\mu \to \nu_e$ oscillations. The present analysis compares the number of events with $E_\nu > 2$ GeV. For the expected ν_e spectrum approximately 85% of events with $E_\nu > 2$ GeV have $\theta_e < 15°$. With this cut one can use all the E734 analysis(4) designed to select forward electromagnetic showers and descriminate between e's and γ's. Approximately 3000 of the original 1.26×10^6 beam pulses yield a shower candidate passing the electron filter.(6) This filter, based only on scintillator information, rejects single hadron and multiprong events. It requires 70% of the event energy to be within a 20° forward cone and the event not look like a single hadron track. An eyescan of events (≈ 1800) in a restricted fiducial volume produced a final sample of 72 e or γ candidates. This eyescan rejected additional multiprongs, showers pointing to upstream energy deposits and required the proton candidate to have a kinetic energy consistent with a $\nu_e n \to e^-p$ scatter. A simple cut based on the energy in the first scintillator plane after the vertex and the energy in the first two modules of PDT's identified 22 of the 72 candidates as γ's. This cut was selected to reject < 5° of electrons while identifying 50% of the photons. The true number of e^-p candidates is therefore 28±8. The equivalent number for events with $E_\nu > 2$ GeV are 35 ep candidates, 13 γ candidates or 22±7 true ep candidates. Correcting for acceptance the number of ep candidates is 25±7. As can be seen in Fig. 1 the observed energy spectrum of these events is in good agreement with that expected from the calculated ν_e spectrum. The number of ν_μ events is determined from the number of events with only a single long (> 20 modules) muon candidate with $\theta_\mu < 15°$ and no additional tracks. This sample of 3037 events contains not only low Q^2 quasi-elastics but contributions from single pion channels as well. Correcting for undetected π^+ decays and removing events with clear π° conversion, the corrected number of ν_μ quasi-elastics is 2186. The actual shape of the ν_μ spectrum is determined from kinematically fitting higher Q^2 quasi-elastics where both muon and proton are measured. Correcting the observed 2186 single track events for the fraction below 2 GeV (34%) and the acceptance above 2 GeV (65%), as well as the tracking efficiency (90%) yields a final ν_μ sample of 2466 quasi-elastics.

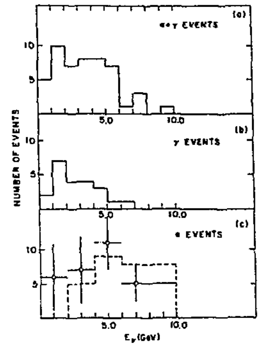

Fig. 1. Energy distribution of selected shower candidates a) all candidates, b) identified photons, c) electron events; dashed line is expected events with E_ν > 2 GeV from Monte Carlo calculation.

Since the calculated ν_e/ν_μ ratio above 2 GeV is 9×10^{-3} the expected number of ν_e quasi-elastics in the beam is 22. The observed number is 25±7 so there is no evidence for $\nu_\mu \to \nu_e$ oscillations. Since only ν_e events under the ν_μ spectrum peak (≈ 1/2 ν_e events) could be due to oscillations, these numbers correspond to a preliminary limit for $\nu_\mu \to \nu_e$ of $\sin^2 2\theta \leq 2\, n_e/n_\mu \approx 8 \times 10^{-3}$ at 90% CL. This result is preliminary as final checks and corrections have yet to be made.

REFERENCES

1. AGS EXP 775, M.J. Murtagh ,Spokesman; Brookhaven National Laboratory, Brown University, University of California, Irvine, KEK, Osaka University, SUNY, Stony Brook, University of Pennsylvania.

2. AGS EXP 776, W.Y. Lee, Spokesman; Brookhaven National Laboratory, Columbia University, University of Illinois, Johns Hopkins Unversity.

3. This latter background is very low if one searches for low multiplicity final states such as $\nu_e n \to e^-p$. For $\nu p \to \nu p\pi^\circ$ to simulate this only a gamma and the p are observed and the rejection is ≈ 10^3.

4. L.A. Ahrens et al., Submitted to Phys. Rev. Lett. 7/27/83. See also the contribution of S. Durkin to this conference (Session C1.1).

5. The E734 group is presently analyzing their wide band ν_μ data to search for $\nu_\mu \to \nu_x$ by studying $\nu_\mu n \to \mu^-p$ as a function of position in the detector and energy. Early indications are that results similar to those presented by the CDHS and CFRR groups in this session, but sensitive near $\delta m^2 \approx 25$ eV^2, will be obtained in the near future.

6. Only 1 in 10 pulses has a possible event of any kind and ≈ 1 in 40 has a potential neutrino event.