LONG DISTANCE NEUTRINO OSCILLATION EXPERIMENT NEAR FERMILAB*

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ABSTRACT

The possibility of carrying out an extremely sensitive neutrino oscillations experiment near Fermilab by placing a detector 15-30 Km from the neutrino beam is explored. By searching for the transition $\nu_\mu \to \nu_e$ or $\nu_\mu \to \nu_\tau \to e$ using a large water detector an experiment sensitive to a mass difference of 10^{-2}ev^2 and mixing angle of 0.1 can be carried out at small expense to the neutrino program.

Long baseline neutrino oscillation experiments have been discussed from time to time on the literature.[1] Such experiments could make use of the very intense neutrino flux from the high energy accelerators at Fermilab and CERN. The characteristics of the "available" neutrino beams and of the neutrino reactions that could signal neutrino oscillations are given in Table 1 and 2. Only neutrino beams with energy greater than ∿ 20 GeV are above threshold for all flavor changing reactions

$$\nu_e \to \nu_\mu \to \mu$$
$$\nu_\mu \to \nu_\tau \to \tau$$
$$\nu_e \to \nu_\tau \to \tau$$

Thus if there are appreciable oscillation effects in any of those channels high energy neutrinos are needed at some stage of the study to observe the transition to ν_τ.

In Figure 1 we attempt to summarize the present experimental evidence and theoretical dogma concerning neutrino mixing. Experiments in region II can be carried out by preparing neutrino beams and observing a deviation of the $1/r^2$ flux lower the detection of a rate of neutrino events that varies with distance. These experiments observe extinction of one form of neutrino and therefore require a good knowledge of the neutrino flux. It is precisely this problem that has caused the confusion in the reactor neutrino experiment.[2]

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Table 1
Neutrino Beams in Nature

Pure	$\bar{\nu}_e$	- Reactor
	ν_μ, $\bar{\nu}_\mu$	- Accelerators with tagged π beams
	ν_e	- sun or special radioactive sources
Mixed & Enriched	ν_μ, $\bar{\nu}_e$	- μ decays (μ storage rings) ∿ 50%
	$\nu_\mu, \nu_e, \bar{\nu}_\mu, \bar{\nu}_e$	- $K^\circ/\bar{K}^\circ$ decays ∿ 25% or charm decays
Normal	(ν_e/ν_μ) ∿ few percent	

Table 2
Characteristics of Flavor Changing ν Interactions

1.	Thresholds	$\nu_e \to \nu_\mu$, $\nu_\mu \to \mu$	$E_{threshold}$ ∿ 150 MeV
		ν_μ, $\nu_e \to \nu_\tau$, $\nu_\tau \to \tau$	∿ 20 GeV
2.	Neutrino Sources: Reactors	$\bar{\nu}_e$	below μ/τ threshold
	Meson Factories	ν_e, ν_μ	below μ/τ threshold
	Low Energy Accelerator	ν_e, ν_μ	above μ below τ
	High Energy Accelerator		above τ, μ...

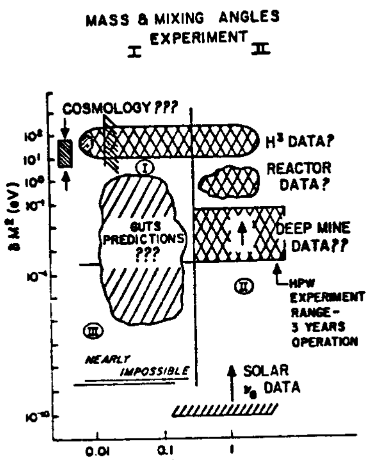
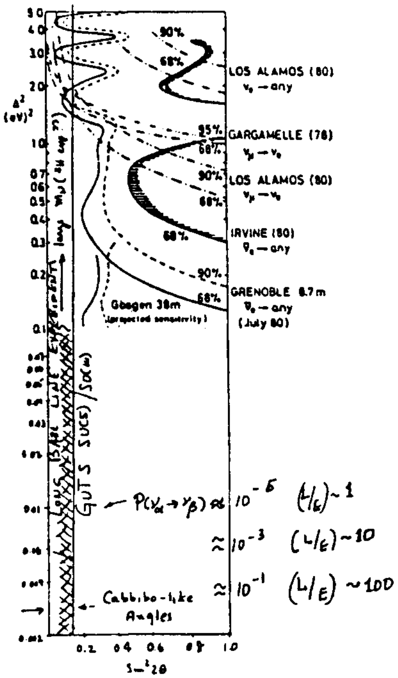


Figure 1

Figure 2



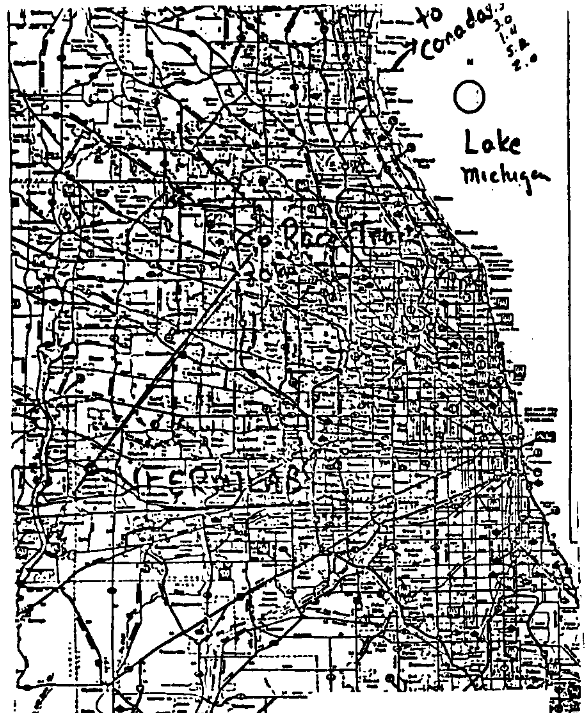


Figure 3

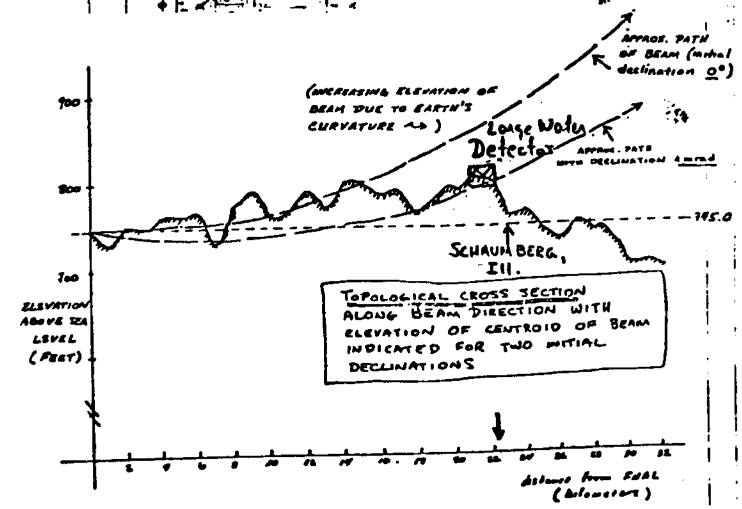


Figure 4

Experiments in Region I rely mainly on "flavor" changes in the neutrino beam and therefore require relatively pure beams and very intense beams over large L/E ranges. These exepriments could be sensitive to Cabbibo like mixing angles provided L/E is large enough Figure 2 shows the range of Δ^2 and $\sin^2 2\theta$ that will be obtained at new reactor experiments. The long baseline experiments discussed here would be designed to cover the cross hatched area. Note that L/E of 10 m/mev and a measured transition probability of 10^{-3} (i.e. $P(\nu_\mu \rightarrow \nu_\tau)$) give $\Delta^2 \sim 10^{-2} ev^2$ and $\sin^2 2\theta < 0.15$. Thus long range oscillation experiments will be necessary if the mass difference and mixing angles are both very small.

We have explored a possible long base line experiment near Fermilab on the normal neutrino beamline.[3] Figure 3 shows the beamline extended into the area adjacent to Fermilab. Figure 4 shows a topological cross section of the area along the beam line. There appears to be locations where the experiment could be carried out approximately 30 Km from the beam origin.

Large water detector similar to that being used in the HPW proton decay detector at Park City Utah could be used to detect the neutrino interactions. Figure 5 shows a schematic view of such a detector.

SEQUENTIAL WATER POOL DETECTOR

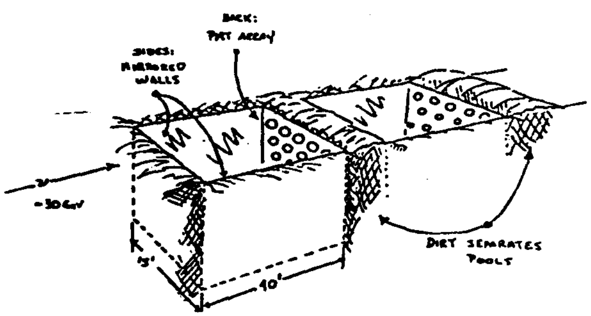


Figure 5

We have carried out a calculation of the neutrino flux event rate at 25 Km and find that the rate is 3.5 events/day for a 200 ton detector. A similar calculation made for CERN gives 1000 events/day for a 100 ton detector.[4] We are investigating the source of the discrepancy between these two calculations. In terms of the beam divergence and the assumed number of protons on target and focussing device.

It appears that the rate for long range oscillation experiments is adequate we are now studying the possibility of separating ν_μ, ν_e and ν_τ events in the large water detector.

I wish to thank J. Matthews for his help in these calculations.

REFERENCES

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A MOVABLE DETECTOR TO SEARCH FOR NEUTRINO OSCILLATIONS IN THE BNL NEUTRINO BEAM

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ABSTRACT

A simple, straight-forward, and economic experiment utilizing a set of water Cherenkov counters is proposed to search for neutrino oscillations in the AGS neutrino beam. The detector will be movable and will be able to provide reasonable counting rates up to 2 km. downstream of the pion decay tunnel. Whereas previous accelerator experiments have sought to increase the ratio ℓ/p (with ℓ the neutrino path length and p its momentum) by decreasing p,[1] we suggest increasing ℓ instead. Further, by making measurements at several different values of ℓ with the same apparatus, many sources of systematic error are eliminated. The experiment will measure beam-associated muon- and electron- type events at each position. A change in the ratio of muon-to electron-type events as a function of position would be evidence for $\nu_\mu \to \nu_e$ oscillations. Sensitivity in terms of $(\Delta m)^2$ (the square of the mass difference in the mass eigenstates) can be as low as 0.1 eV^2, for full mixing, which is below the most probable value found by Reines et al.[2] for Δm^2 in their electron neutrino reactor experiment. This experiment would be parasitic, running behind the usual neutrino beam experiments, assuming the nominal beam energy (peaked at 1 GeV), and would thus make a minimal demand on AGS support. It is suggested that the first two measurements be made inside the Isabelle tunnel at the points of intersection with the AGS neutrino beam. No further excavations would be required, and the data could be taken before ISA equipment is installed.

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INTRODUCTION

Interest in neutrino oscillations has quickened recently, following a short lull, due to the recent well-known results of two experiments. Reines, et al.[2], in early 1980, presented evidence for a depletion of $\bar{\nu}_e$ over distances of several meters. This could be explained by the oscillation of $\bar{\nu}_e$ into other neutrino states. At about the same time, Lyubimov et al.[3] reported evidence for a non-zero mass of the electron neutrino, deduced from observations of the Beta-spectrum (Kurie plot) from tritium decay. This Soviet experiment finds $14 < m_{\nu_e} < 46$ eV to

†List of participants at end of proposal.