2

CONF-870283--9

BNL 39668

OG 948

Received by OSTI

JUN 0 5 1987

Future Long Baseline $\nu_\mu \rightarrow \nu_e$ Oscillation Searches at Accelerators

BNL--39668

DE87 010068

Presented by Michael J. Murtagh
Department of Physics, Brookhaven National Laboratory *
Upton, New York 11973
USA

Invited talk given at
Neutrino Workshop, Brookhaven National Laboratory
Upton, New York, Feb. 5–7, 1987

---

*This work has been supported by the U.S. Department of Energy under contract DE-AC02-76CH00016.

MASTER

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

Future Long Baseline $\nu_\mu \rightarrow \nu_e$ Oscillation Searches at Accelerators

Presented by Michael J. Murtagh
Department of Physics, Brookhaven National Laboratory
Upton, New York 11973
USA

ABSTRACT

The additional neutrino flux available when the Booster at the AGS becomes operational will make possible $\nu_\mu \rightarrow \nu_e$ oscillation searches at Brookhaven which significantly extend beyond the present limits.

1. INTRODUCTION

Present $\nu_\mu \rightarrow \nu_e$ oscillation searches at accelerators are limited by their L/E_ν range (0.1–1) to $\Delta m^2 \geq 0.1\ eV^2$ and $\sin^2 2\alpha \geq 5 \times 10^{-3}$. It appears possible with the advent of the Booster$^{1)}$ to significantly improve the Δm^2 range to perhaps $\Delta m^2 \leq 0.01\ eV^2$ while maintaining reasonable $\sin^2 2\alpha$ coverage. However for a reasonable amount of Booster running ($\approx 10^{20}$ POT) with a modest detector (1 Kton fiducial volume), it will be difficult with distances greater than 10 Km to retain acceptable $\sin^2 2\alpha$ coverage.

2. NEUTRINO RATES

The analysis for most low energy $\nu_\mu \rightarrow \nu_e$ oscillation searches at accelerators focusses on quasi-elastic events. There are a number of reasons for this. They constitute a significant fraction of the total cross section at these energies ($(\nu n \rightarrow \ell^- p)/$ *all events* $\approx 0.6/E\nu(GeV)$). The topology is very simple, reducting to a single forward track at low Q^2, which simplifies the extraction of the signal and the rejection of π^0 backgrounds. In addition, if the lepton energy and angle with respect to the beam are known, the incident neutrino energy is calculable. Consequently, by restricting the analysis to single track muon and electron events, one can in principal measure the incident ν_μ and ν_e flux as a function of neutrino energy. An oscillation signal would show up as a distortion of the measured energy dependance of the ratio of ν_e/ν_μ fluxes compared to the calculated ratio which had the correct E_ν behavior.

The rates used for the estimates discussed below are based on the observed event rate in the E734 detector which has been taking data in the wide band neutrino beam at BNL for some time$^{2)}$. The conventional normalization in E734 comes from a measurement of low Q^2 ν_μ-quasi-elastic events which appear in the detector as events with a single forward track consistent with being a muon. Since most of these muons escape the detector it is not possible to reconstruct the incident spectrum from these events. The spectrum shape is determined either from the quasi-elastic events with muons which pass through the spectrometer ($E_\nu = F(P_\mu, \Theta_\mu)$) or high $Q^2 (Q^2 \geq 0.25 (GeV/c)^2)$ events in which both the muon and stopping proton are measured ($E_\nu = F(\Theta_\mu, E_p)$). The energy of quasi-elastic $\nu_e n \to e^- p$ events, on the other hand, can be reconstructed from the observed forward electromagnetic showers of low Q^2 events since the shower is, in this case, contained in the detector ($E_\nu = F(E_e, \Theta_e)$). While forward leptons constitute only $\approx 15\%$ of the total cross section at these energies they have many advantages as the basis for a good $\nu_\mu \to \nu_e$ oscillation search and provide a reasonable estimate of the number of usable events in the detector.

The rate of detected μ^- tracks with $\Theta_\mu < 30°$ and $P_\mu > 350 MeV/c$ from $\nu_\mu n \to \mu^- p$ quasi-elastic events in the E734 detector is $4 \times 10^{-2}\ \mu^-/10^{13}$ POT/30 mton. For distances > 1 Km this rate is given by

$$N \cong 20 \times M/L^2$$

where M is the detector fiducial mass in mton, L is the source to detector distance in Km and N is the observed number of quasi-elastic muons for 10^{19} POT. This rate assumes a $1/L^2$ beam dependence which is reasonable for $L > 0.5$ Km. The formula has been explicitly corrected for the measured E734 rate which is at 100m.

Recently the AGS has averaged 1.5×10^{13} POT/pulse with a 1.4sec rep. rate during fast extracted beam running. This corresponds to 10^{19} POT in less than 3 weeks of running if one assumes 80% operating efficiency. E734 has actually averaged 10^{19} POT per 3 calendar weeks for significant parts of its last two major runs. If the Booster increases the rate by a factor of 4, then a run of 10^{20} POT appears quite reasonable. The observed forward μ^- quasi-elastic rates for a 1 Kton fiducial volume detector with a 10^{20} POT run are given in Table 1. the expected e^- quasi-elastic rates for an e/μ ratio of 1% are also listed.

TABLE 1

Observed Rates for 10^{20} POT with 1 Kton Fiducial Volume Detector

L(Km)	$\#\mu^-(\mu^-p)$	$\#e^-(e^-p)$
1	2×10^5	2×10^3
10	2×10^3	20
100	20	.2
1000	.2	.002

The rate beyond 10 Km is discouraging. This is unfortunate because one might hope that with sufficient distance matter oscillation effects might become significant. However, even at 1000 Km (Fig. 1) the matter effect is insignificant$^{3)}$ and at this distance the rate is negligible. Significant enhancements for specific $E/\Delta m^2$ ranges do occur but only for distances in the earth of $\approx$ 8000Km.

3. RESULTS AND CONCLUSIONS

If one assumes that the large detector used in this search has approximately the electron identification and photon rejection capabilities of the E734 detector$^{4)}$, then it is straightforward to calculate the expected oscillation limits (Fig. 2). As is clear from these limits, the lack of statistics beyond 10 Km severely restricts the $\sin^2 2\alpha$ limit and the increased distance does not substantially aid the Δm^2 limit. Consequently, even with the added flux of the booster it is unlikely that searches much beyond 10 Km will be effective. On the other hand, there is every possibility of significantly extending the present $\nu_\mu \rightarrow \nu_e$ oscillation searches. Clearly any experiment which improves $\nu_\mu \rightarrow \nu_e$ searches should be able to improve on ν_μ disappearance searches but it is more difficult to estimate the expected limits in this case.

REFERENCES

1) Booster Design Manual, Accelerator Development Dept., Brookhaven National Laboratory, 10/29/86.

2) Elastic Scattering of Muon Neutrinos at BNL, Presented at this workshop by S.L. Durkin.

3) A.J. Baltz, Presented at this workshop.

4) A Search for $\nu_\mu \rightarrow \nu_e$ Oscillations Using the E734 Detector, Presented at this workshop by M.J. Murtagh.

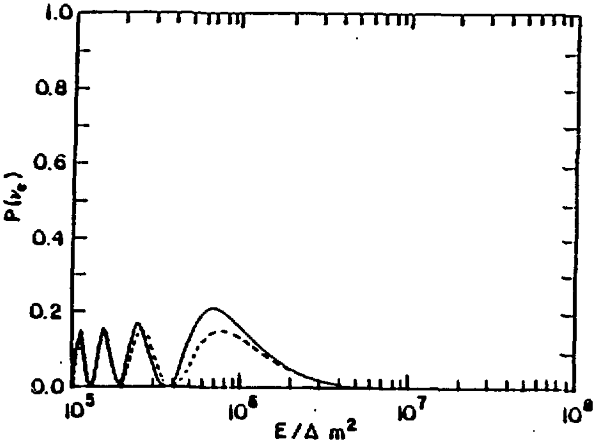

Fig. 1. Probability for ν_e events due to oscillations as a function of $E(MeV)/\Delta m^2(eV)^2$ at 1000 Km taken from a calculation by A. Baltz, J. Weneser (Ref. 3). Dashed curved is for vacuum oscillations only while the solid curve includes matter enhancement from passage through the earth.

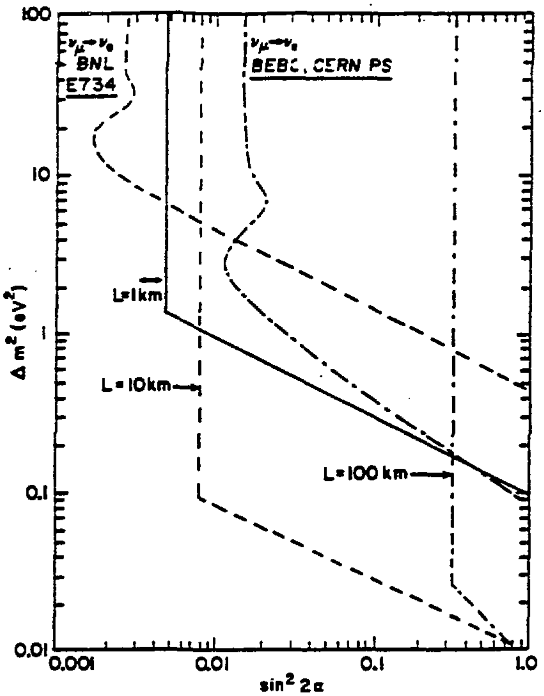

Fig. 2. Estimated $\nu_\mu \to \nu_e$ oscillation limits for various source to detector distances (L) for a 1 Kton fid. vol. detector and 10^{20} protons on target.