NEUTRINO PHYSICS AT LOW ENERGY MEDIUM BASELINE NEUTRINO BEAMS

P.F. LOVERRE
Universita' di Roma, "La Sapienza"
Roma I-00185 Italy
E-mail: Loverre@roma1.infn.it

ABSTRACT

Medium baseline ($L/E \sim 1Km/GeV$) experiments are proposed both in Europe and in the United States to test the LSND claim for oscillation. The BooNE project at FNAL and the I-216 project at CERN are discussed.

1. Introduction

The LSND experiment[1,2] at Los Alamos observes an excess of events ascribed to the reaction $\bar{\nu}_e p \to e^+ n$. Interpreted in terms of neutrino oscillation the excess corresponds to a $\bar{\nu}_\mu \to \bar{\nu}_e$ oscillation with probability of the order of 0.3%. Typical values of L/E for LSND are $30meters/30MeV$. This L/E would be perfectly matched by experiments using neutrino beams produced by the PS at CERN or by the Booster at FNAL. The neutrino energy of those beams is of the order of $1GeV$ and the intensity is high enough to provide the required statistics to an experiment located at about $1Km$ from the primary proton target, in the optimal condition to test the LSND result.

Has the LSND claim for oscillation to be tested? The LSND result was discussed at length by M.Mezzetto at this Conference. Here we only want to state that two collaborations believe that new experiments are needed to get a conclusive answer on this matter. Basic motivations for new experiments are

- the great statistical significance of the LSND signal (the probability that the excess is generated by a statistical fluctuation of the background is equivalent to $\sim 7\sigma$[1])
- the difficulty for the KARMEN[3]experiment at the ISIS facility to unambigously prove or disprove the LSND claim, given its limited sensitivity (few signal events expected in case the LSND signal is genuine, with comparable background)

The experiments proposed to test the LSND signal plan to search for interactions with an electron in the final state in an almost pure ν_μ beam ($E_\nu \sim 1GeV$). The experiments are BooNE[4] at FNAL and I-216[5] at CERN. They are described in the following sections.

2. BooNE at FNAL

MiniBooNE represents phase 1 of the BooNE[4] experiment (Booster Neutrino Experiment) and it has recently been approved to run at FNAL. The neutrino beam will be constructed using the $8GeV$ proton Booster at FNAL. The beam line will consist of a target within a two-horn focusing system, followed by a decay tunnel of variable length (25-50 meters). The average neutrino energy will be of the order of $800MeV$.
Figure 1 is a schematic view of the MiniBooNE detector.

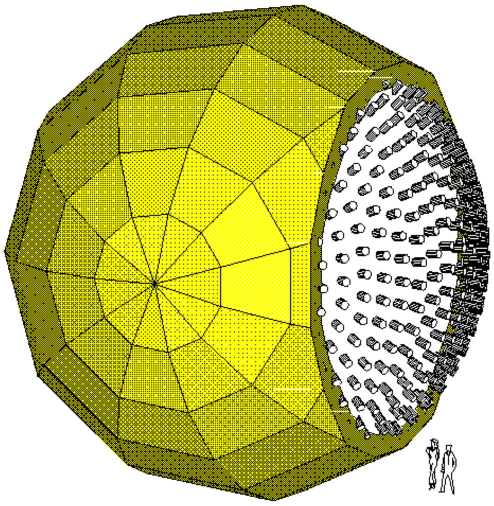

Figure 1: *Schematic view of the MiniBooNE detector*

The detector will be located at 500 meters from the target. It will consist of a tank filled with 770 tons of pure mineral oil (465 tons fiducial volume), surrounded by 1220 8-inch phototubes. For the construction, phototubes and electronics of the LSND experiment will be used. Note however that the experiment is far from being a repetition of LSND. Completely different are the neutrino energy domain ($800MeV$ instead of $30MeV$) and hence the detection techniques and the background sources. Also, the yield of Cerenkov light will be much enhanced with respect to scintillation light.
The aim of the experiment is to identify the reactions

$\nu_\mu C \rightarrow \mu^- N$ (normalisation)

$\nu_e C \rightarrow e^- N$ (signal)

rejecting the reaction $\nu_\mu C \rightarrow \nu_\mu \pi^0 X$ which constitutes the largest background to the electron signal.

Particle identification will be based on many different parameters. Here I only recall the different characteristics expected for the Cerenkov rings. A "fuzzy" ring for the electron (due to the showering process), two "fuzzy" rings for a π^0, a sharp outer ring with "fuzzy" inner region for a muon.

One of the highlight of MiniBooNE is the very large statistics that it will be able to collect in a short time because of the high intensity of the Booster. Data taking is planned to start early in 2002 and in one year 5×10^{20} protons will be sent on target. This will give in the detector the following numbers of events

590000 $\nu_\mu C \rightarrow \mu^- N$ (normalisation)

1800 ν_e interactions from beam contamination

600 misidentified π^0 events

600 misidentified muons

The total background of 3000 events has to be compared with a signal of 1200 electron events expected from LSND (for $sin^2 2\theta = 0.02$ and $\Delta m^2 = 0.4 eV^2$). Already after 1 year of data taking the statistical error will be very small ($\sim \sqrt{3000} = 55$ events) compared to the expected signal.

There are many sources of possible systematic error related to the background subtraction. Also in this case the large statistics is of great help, allowing many different checks (e.g. the expected number of misidentified π^0's can be precisely predicted from the large number of π^0's well identified through the detection of two gammas at large angle). The Collaboration expects that the total systematic error will be of the order of 5% of the 3000 background events, and therefore small compared to the expected signal (~ 1200 events).

The sensitivity of the MiniBooNE experiment is displayed in figure 2 (90% exclusion plot). The plot shows that if no signal will be detected it will be possible to exclude the favoured region of LSND with very large confidence.

3. I-216 at CERN

I-216[5)] is the code of a Letter of Intent submitted to the CERN Scientific Committee SPSC. The proponents intend to check the LSND signal with a neutrino beam similar to the one used by MiniBooNE, but with a different experimental approach. The neutrino beam is produced by the CERN Proton Synchrotron (PS). The beam set-up is the one adopted by the BEBC-PS180 experiment[6]. The energy of the PS proton beam would be 19.2 GeV and the existing magnetic horn and 50m long decay tunnel would be used. The ν_μ beam has an average energy of 1.5 GeV and the ν_e contamination is 0.4%.

Main characteristics of the experiment are:

1) - the high statistics: the experiment would collect data for two years with a total of 2.5×10^{20} protons on target, corresponding to an integrated flux surpassing by more than a factor 10 all previous neutrino experiments at the PS

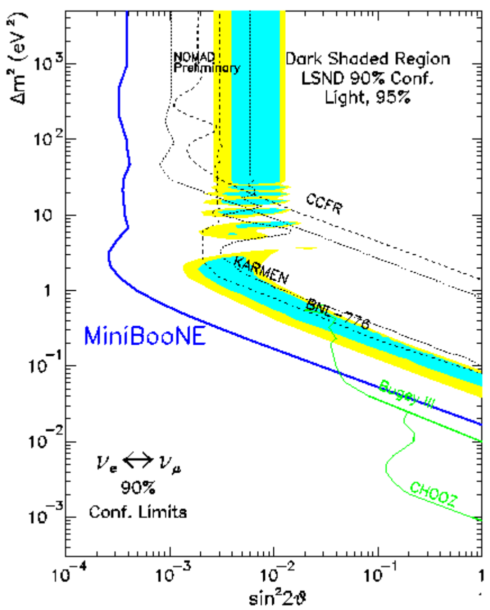

Figure 2: *Sensitivity of the MiniBooNE experiment*

2) - the use of the two-detector technique. The full apparatus would consist of 3 identical modules. One of them would be located at 130 m from the proton target and act as "close" detector. Two more modules would be placed in a hall at 880 m from the proton target and act as "far" detector. The quantity to measure is the ratio of electron-like to muon-like events in the close and far detector. An excess of electron events in the far detector would unambigously tag $\nu_\mu - \nu_e$ oscillations. The power of the two-detector method is clear: errors in particle identification will have the same effect in the close and in the far detector. Therefore systematic errors in the background subtraction largely cancel.

3) - the use of quasi-elastic reactions only

$\nu_\mu n \to \mu^- p$ (normalisation)

$\nu_e n \to e^- p$ (signal)

4) - the use of a fine grained detector to distinguish electrons from π^0's. The detector design is not finalised. A possible scheme foresees 3 modules each consisting of 300 planes of scintillator for a total mass of about 150 tons per module. The scintillator acts as target and sensitive medium. Each plane would have a thickness of few centimeter ($\sim 0.1\ X_0$) allowing to evidentiate the different development of the electron and π_0 showers.

After two years of data taking I-216 would collect in the far detector 309 background "electron" events (248 ν_e interactions from the ν_e contamination in the beam, 61 wrongly identified π^0's). The oscillation signal would consist in 295 more electron events if the oscillation parameters are those indicated by LSND ($sin^2 2\theta = 0.006$ and $\Delta m^2 = 2eV^2$ in our example). In this case the difference Δ between the ratio of electron-like to muon-like events in the far detector and in the close detector would be

$$\Delta = (3.10 \pm 0.29 \pm 0.10) \times 10^{-3}$$

ten standard deviations away from zero.

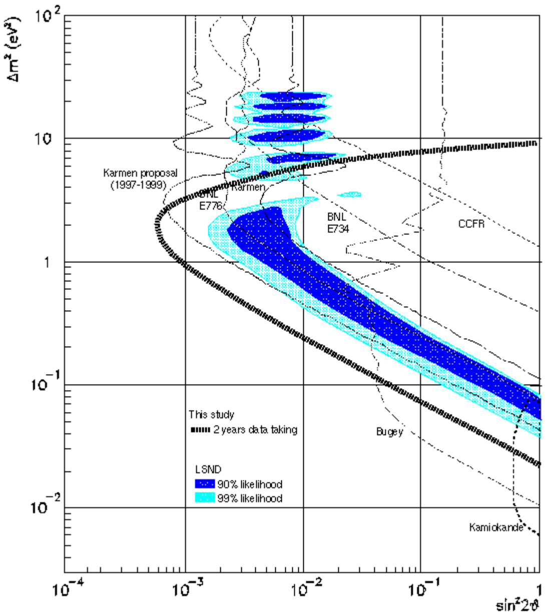

Figure 3: *Sensitivity of the I-216 experiment (the I-216 curve is flagged "This study")*

The region in the parameter space excluded by I-216 in the absence of an oscillation signal is shown in figure 3 (90% exclusion plot).

4. Conclusions

Two experiments are planned to study with great sensitivity $\nu_\mu - \nu_e$ oscillation in the $\Delta m^2 = 1eV^2$ region where the LSND measurements suggest the presence of a signal. The MiniBooNE experiment at FNAL is approved and data taking should start in year 2002. I-216, if approved by CERN in the current year, would have a similar time schedule. The experiments use a similar beam, but the experimental techniques are different and in some way complementary. The larger statistics of MininBooNE is balanced in I-216 by a more direct control on the background. Most likely, very clean and interesting results will be available already in 2003.

5. References

1) C.Athanasopoulos et al., *Phys. Rev. Lett.* **77** (1996) 3082.
2) C.Athanasopoulos et al., *Phys. Rev. Lett.* **81** (1998) 1774.
3) K.Eitel (KARMEN Collaboration *Proceedings of Lake Louis Winter Institute* (1999) 14-20 Feb. 1999, Lake Louise.
4) E.Church et al., LA-UR-97-2120, June 1997.
5) N.Armenise et al., CERN-SPSC/97-21, SPSC/I 216, October 10, 1997.
6) C.Angelini et al., *Phys.Lett.* **B179** (1986) 307.