Future of short baseline neutrino experiments in Europe - I216

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Experiments are proposed both in Europe and in the United States to test the LSND claim for oscillation. The I-216 project at CERN is discussed.

1. Introduction

The LSND experiment[1,2] at Los Alamos observes an excess of events ascribed to the reaction $\bar{\nu}_e p \rightarrow e^+ n$. Interpreted in terms of neutrino oscillation the excess corresponds to a $\bar{\nu}_\mu \rightarrow \bar{\nu}_e$ oscillation with probability of the order of 0.3%. Typical values of L/E for LSND are 30 m/30 MeV. 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.

Basic motivations for new experiments designed to test the LSND claim for oscillation 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. The latter will be described in the next section.

2. I-216 at CERN

2.1. Principles of the experiment and detector layout

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 (phase 1 of the BooNE experiment), 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 $50m$ long decay tunnel would be used. The ν_μ beam has an average energy of 1.2 GeV and the ν_e contamination is 0.6%.
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

2) - the use of the two-detector technique. The full apparatus would consist of 3 modules of identical structure, but for the length. One module (140 planes) would be located at 130 m from the proton target and act as *near* detector. Two more modules (320 planes each) 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 near and far detector. An excess of electron events in one 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 near and in the far detector. Therefore systematic errors in the background subtraction largely cancel.

3) - the use of quasi-elastic reactions only

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

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

4) - the use of a fine grained detector to distinguish electrons from π^0's. All three detector modules (two far, one near) have the same simple structure, made of a fine grained *tracking calorimeter* that constitutes the neutrino target. The tracking calorimeter consists of a succession of layers of plastic scintillator followed by 2 mm thick iron foils. The module at the close location has 140 planes for a total mass of 104 t. The detector at the 885 m site (two modules of 320 planes each) will have a total mass of 476 t. Each scintillator plane consists of 128 bars of 3×3 cm^2 section, 3.84 m long, individually read-out by wave-length shifting (WLS) fibers. Given the fine granularity, the system combines tracking capabilities with good energy measurement. In the calorimeter, particle trajectories and energy loss are both sampled every $0.19 X_\circ$.

The detector represents a rather innovative application of the technique of scintillators read by WLS fibers, while at the same time satisfying the requirement of a relatively short time scale for construction.

The construction of the detector will take two years. Final results will be obtained with two years of data taking.

2.2. Sensitivity to oscillations

A comparison between the samples of charged-current ν_e events collected at the two detector locations will be made to search for neutrino oscillations. The quasi-elastic interactions from ν_μ neutrinos will be used as a normalization. The ratio of identified ν_μ interactions and ν_e interactions will be measured at the close and the far locations. The difference between the ratios measured at the two locations provides a test of neutrino oscillations:

$$\Delta_{\rm e} = \left(\frac{N_{\rm e}}{N_\mu}\right)^{\rm far} - \left(\frac{N_{\rm e}}{N_\mu}\right)^{\rm close} \qquad (1)$$

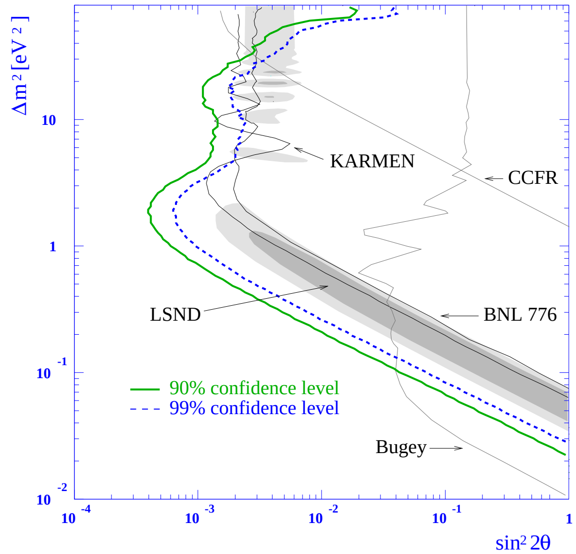

Figure 1. Sensitivity of the I-216 experiment

where N_μ is the number of events identified as ν_μ interactions and $N_{\rm e}$ is the number of events identified as ν_e interactions, including backgrounds. The comparison of the two locations practically eliminates systematic errors due to uncertainties in the estimate of the background processes, since the processes will be the same in the close and the far detectors.

In the absence of oscillations, the experiment would measure a value of $\Delta_{\rm e}$ consistent with $\Delta_{\rm e} = 0$. A measurement of a value of $\Delta_{\rm e}$ significantly different from zero would be a sign for oscillations.

Table 1 shows the expected number of events in the different samples for two years of data taking and two sets of oscillation parameters.

In these two cases, that are representative of the region of parameter space favoured by LSND, the experiment would measure a value of $\Delta_{\rm e}$ significantly different from zero. The result would be clearly inconsistent with the no-oscillation hypothesis at the level of 7.4 and 7.8 σ respectively. When the energy distribution of the signal is taken into account, the significance of the effect corresponds to 10.7 and 11.3 σ respectively.

Table 1
Expected events for two years of data taking. The errors on Δ_e are both statistical (first error) and systematic (second error).

ν_e candidates	close	far
$\Delta m^2 = 0.8$ eV^2; $\sin^2 2\theta = 0.007$	79	456
$\Delta m^2 = 0.4$ eV^2; $\sin^2 2\theta = 0.025$	71	487
Total background	12140	1200
ν_μ normalization	8.8×10^5	8.7×10^4
Δ_e ($\Delta m^2 = 0.8$ eV^2; $\sin^2 2\theta = 0.007$)	$(5.20 \pm 0.50 \pm 0.50) \times 10^{-3}$	
Δ_e ($\Delta m^2 = 0.4$ eV^2; $\sin^2 2\theta = 0.025$)	$(5.50 \pm 0.50 \pm 0.50) \times 10^{-3}$	

The region in the parameter space excluded by I-216 in the absence of an oscillation signal is shown in figure 1. The statistics corresponds to two years of data taking.

3. Conclusions

The I-216 experiment could allow to carry on at CERN a highly sensitive search for $\nu_\mu - \nu_e$ oscillation in the *appearance* mode, and a decisive test of the LSND claim, as shown by the sensitivity plot of figure 1.

The MiniBooNE experiment, which has similar goals, is now in preparation at Fermilab. MiniBooNE should be able to collect in one year (year 2002) twice the statistics of I-216 (2 years of data taking). The proponents of I-216 believe that their experiment, when compared to MiniBooNE, benefits from the following important advantages:

- very good control of systematic errors due to the use of the two-detector technique;
- extremely fine granularity of the detector allowing very good identification of electron and muon events;
- high sensitivity to the ν_μ disappearance search, again making use of the two-detector technique.

At the time of writing this note (September 1999), a Collaboration of 24 Institutions has submitted a *Proposal*[7] to the CERN Scientific Committee SPSC. The SPSC has decided not to approve the experiment. The motivation of this decision is not yet known.

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