Electron Neutrino Appearance (EνA) Detector

Status: CD-0 Approved in November 2005

Mission Need

Recent developments are beginning to unravel the mystery of the neutrinos. Perhaps the most significant development in the last several years is the discovery that the three known types of neutrinos mix with one another. The results of a number of experiments together provide convincing evidence for neutrino oscillations. Neutrino oscillations can only occur if neutrinos have masses, since the rate of oscillation depends on the difference between the neutrino masses. This is indirect but compelling evidence that at least two of the neutrinos have masses. What makes this particularly striking is that the masses of the neutrinos appear to involve a different physical mechanism than the Higgs mechanism believed to be responsible for the masses of the other known particles, the quarks and charged leptons. The only way the Higgs mechanism can be responsible for neutrino mass is if there is a new fundamental symmetry of nature. In either case the fact that neutrinos have masses has revealed new facets of nature that we do not yet understand.

The experimental study of neutrino oscillations also can offer the possibility of observing CP violation, In the early universe equal quantities of matter and antimatter were created, but the present universe is filled with matter and not antimatter. A slight difference in the behavior of matter and antimatter has been observed in some decays of particles containing heavy quarks, but these effects are too small to explain the observed dominance of matter in the universe. There are interesting models for explaining the observed matter-antimatter asymmetry that involve new sources of CP violation in the neutrino interactions. Thus it is important to look for CP violation in the neutrinos as well as continuing studies of CP violation with quarks.

The disappearance of ν_μ has been observed by seeing fewer muon neutrinos at a distance hundreds of kilometers from the source than would be expected if neutrinos do not oscillate. It is assumed that most of ν_μ from the original neutrino source (neutrino beam) oscillated to $\nu_{\tau,}$ since the detectors were sensitive enough to detect ν_e for such a rate of oscillation but not ν_τ. The oscillation of ν_μ into ν_e over those distances may occur, but the rate of such oscillation is smaller than is detectable in current experiments.

An experiment that is highly optimized to detect ν_e together with high intensity neutrino source will be needed. In addition, such an experiment with a neutrino beam that travels a long enough distance will provide necessary information to determine the neutrino mass spectrum by measuring the “mass hierarchy”.

A joint study on the future of neutrino physics was published in November 2004 by four divisions of the American Physical Society: Division of Nuclear Physics, Division of Particles and Fields, Division of Astrophysics, Division of Physics of Beams. They recommended *“a comprehensive U.S. program to complete our understanding of neutrino mixing, to determine the* *character of the neutrino mass spectrum and to search for CP violation among neutrinos."* The report describes one required component of the program as, *"A timely accelerator experiment with comparable* $\sin^2 2\theta_{13}$ *sensitivity and sensitivity to the mass hierarchy through matter effects."*

HEP is proposing an experiment based on a detector capable of addressing ν_μ to ν_e oscillations and the "mass hierarchy". This experiment and detector will support the Department of Energy's Science Strategic Goal within the Department's Strategic Plan dated September 30, 2003: *To protect our National and economic security by providing world-class scientific research capacity and advancing scientific knowledge*. Specifically, it will support the two Science strategies: *1. Advance the fields of high-energy and nuclear physics, including the understanding of … the lack of symmetry in the universe, the basic constituents of matter, …* and *7. Provide the Nation's science community access to world-class research facilities….*

Options

Two of the questions discussed above: the observation of ν_μ to ν_e oscillations and the determination of the mass hierarchy can be answered by a single experiment. The observation of ν_μ to ν_e oscillations requires a large detector that is optimized to detect the interactions of electron neutrinos.

Various project scopes will be evaluated, including the risk of doing nothing, and presented to the Acquisition Executive at Critical Decision (CD) 1:

Option 1: Fabrication of new detectors (a large far detector and a small near detector) with better sensitivity for ν_e using existing neutrino beam facility. The Neutrinos at the Main Injector (NuMI) facility at Fermilab produces the world highest intensity neutrino beam and is being used for the MINOS experiment which has the far detector located in Soudan Mine in northern Minnesota. However, MINOS is not sensitive enough to ν_e. The planned intensity of the existing NuMI facility is sufficiently high that there will be no need for modification of the NuMI facility.

Option 2: Participate in a future experiment in Japan. A neutrino beam comparable to NuMI is under construction at the Japan Proton Accelerator Research Complex in Tokai, Japan. The neutrino beam will be aimed at an existing far detector in Kamioka, Japan, but one or two small detectors will need to be built near the neutrino source. The distance between neutrino source and far detector will be only 1/3 of that in Option 1.

Option 3: Do nothing. Some progress in this area may be made in Japan but the long distances needed for the mass hierarchy measurements and the expandability toward future program (higher beam intensity needed to study CP violation and origin of neutrino mass) will only be available for the option in the U.S site.