Mission Need Statement
for the MINERνA project

Office of High Energy Physics
Office of Science

Perhaps the most significant development in particle physics 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, a quantum mechanical phenomenon in which neutrinos of one type turn into neutrinos of another type.

A variety of experiments are currently being conducted including the Mini-Booster Neutrino Experiment (MiniBooNE), the Main Injector Neutrino Oscillation Search (MINOS), and from KEK to Kamioka (K2K). In addition, two experiments are being planned, the Electron neutrino Appearance experiment (EνA) and from Tokai to Kamioka (T2K) to study neutrino oscillations around the world. All of these experiments will use neutrinos with energies from about 0.5 GeV to around 3 GeV, since neutrinos with these energies provide the largest oscillation effects.

The probability that a particle interacts in a particular material is called a cross section. The cross section for a particle varies as a function of beam energy and has been measured and published. However, the cross sections for low energy neutrinos (below 10 GeV) are difficult to measure and have not been studied with any reasonable accuracy.

Improved knowledge of the cross sections will provide smaller systematic uncertainties on the oscillation measurements. Measurement of these cross-sections provide better understanding of how to determine the neutrino energy in observed neutrino events and how to reject background processes that can mimic oscillations signals.

The Main INjector ExpeRiment ν-A (MINERνA) project is the fabrication a high resolution neutrino detector capable of distinguishing explicit final states in the energy range of 0.5 to 3.0 GeV and measuring their neutrino cross-sections. It supports 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….*

B. Analysis to Support Mission Need

Neutrinos very rarely react with matter as they pass through it. For example, a neutrino with energy of about 1 GeV would go through a stack of steel that measured the distance from here to the moon before it interacted. The interaction probability increases for higher energy neutrinos, and the best data on neutrino cross sections so far has been measured for the neutrinos with the beam energies of 100 GeV or higher.

The joint study on neutrinos by the American Physical Society discussed the importance of improved cross section measurements:

> *"The precise determination of neutrino cross sections is an essential ingredient in the interpretation of neutrino experiments and is, in addition, capable of revealing exotic and unexpected phenomena, such as the existence of a neutrino magnetic dipole moment. Interpretation of atmospheric and long-baseline accelerator-based neutrino experiments, understanding the role of neutrinos in supernova explosions, and predicting the abundances of the elements produced in those explosions all require knowledge of neutrino cross sections. New facilities, such as the Spallation Neutron Source, and existing neutrino beams can be used to meet this essential need."*[1]

Alternative 1

The NuMI (Neutrinos at Main Injector) facility at Fermilab delivers the most intense neutrino beam in the world to the MINOS experiment which currently is in operation to study neutrino oscillation. To maximize the observation probability of neutrino oscillation in the MINOS Far Detector, located in northern Minnesota, the NuMI facility produces the low energy neutrinos in the 1 to 5 GeV range. However, the MINOS detector can not measure the neutrino cross sections because it can not identify the complete set of particles produced in a neutrino interaction.

This NuMI beam can be enhanced with a relatively small and inexpensive detector that has higher detection sensitivities to the particles produced in a neutrino interaction. It will provide high quality cross section data.

Alternative 2

There are no other existing neutrino beams which produce neutrinos at the same energy. A neutrino beam could be constructed at another high intensity proton accelerator, such as the Spallation Neutron Source. This would incur additional costs (~$200M) for the

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[1] http://www.aps.org/neutrino/

construction of the neutrino beam and perhaps a detector hall. It would also disrupt operation of that facility.

C. Importance of Mission Need and Impact If Not Approved

The MINERνA project is part of a program to understand neutrino oscillations and to study the lack of symmetry (CP violation) in the universe. The Department of Energy (DOE) strategic goal to advance scientific understanding includes a strategy to study the lack of symmetry in the universe. The study of CP violation falls under this strategy. Since the discovery of CP violation in 1964, it has been an important component of the DOE HEP program with the Stanford Linear Accelerator Center (SLAC) B-Factory being the most recent large scale facility to address it.

The only alternatives to the MINERνA project are basically to rely on near detectors to provide an appropriate normalization for neutrino oscillation measurements. The calculation of oscillation parameters from near and far detectors does cause many systematic effects to cancel. However, there are limits to this technique and MINERνA is designed to address those limits. The impact if MINERνA is not approved will be a lack of our knowledge in neutrino cross sections which will limit the obtainable precision from the current and future high priority neutrino oscillation measurements.