Excerpt from April 2004 PAC Recommendations

P-929 NOνA (Cooper/Feldman) Proposal to Build an Off-Axis Detector to Study $\nu_\mu \rightarrow \nu_e$ Oscillations in the NuMI Beamline

Future goals of the neutrino oscillation program include measurement of θ_{13}, determination of the neutrino mass hierarchy, and study of CP violation in the lepton sector. These are among the most essential goals of particle physics. The program mounted to accomplish these goals will be challenging. In order to reach required sensitivities, this program will eventually require extremely large detectors and proton intensities higher than can be provided by the existing accelerator complex. NOνA proposes an off-axis detector to study $\nu_\mu \rightarrow \nu_e$ oscillations in the NuMI beamline as the next logical step in this program.

The NOνA experiment will extend the search for $\nu_\mu \rightarrow \nu_e$ by approximately an order of magnitude beyond the sensitivity of MINOS (which has a factor of two better sensitivity in $\sin^2 2\theta_{13}$ than the current best limit from CHOOZ). Depending upon the value of θ_{13}, NOνA will resolve or contribute to the determination of the mass hierarchy. It will start to gather information on CP violation, and it will improve on other MINOS measurements.

NOνA's expected sensitivity for θ_{13} ($\sin^2 2\theta_{13} \sim 0.01$) is approximately the same as that anticipated by T2K Phase I, and could be accomplished on roughly the same time scale. However, because NOνA will have a longer baseline, it will be more sensitive to matter effects that may help to resolve the mass hierarchy. NOνA should be able to resolve the mass hierarchy for a small range of parameters. To increase the range would require a proton driver and/or a second detector farther off axis. Possible future reactor neutrino experiments may measure $\sin^2 2\theta_{13}$ without the ambiguities arising from mass hierarchy and CP violation; however, the information from NOνA on the mass hierarchy and CP violation is complementary.

Organization of the NOνA collaboration and the design of the NOνA experiment are progressing well, and the design is being conducted with an appropriate emphasis on optimization of experimental sensitivity, including cost optimization. The experiment is optimized primarily for determination of θ_{13}. The proposal presents a good case for an experiment designed for this purpose. Given the very similar sensitivity of T2K Phase I for this parameter, as well as possible reactor neutrino θ_{13} measurements, the Committee is concerned that the experiment as proposed may lack sufficient unique physics reach in the absence of a proton driver and may not be optimized for the era of a proton driver. At its June meeting, the Committee would appreciate the Laboratory providing an overview of planned and prospective neutrino oscillation programs at other laboratories. The Committee also looks forward to a revised proposal by the time of its June meeting covering (1) how NOνA extends the understanding of phenomena in the neutrino sector in the context of other planned experiments, and (2) how the initial experimental setup can smoothly evolve in conjunction with a proton driver for future measurements of mass hierarchy and CP violation.

In conjunction with a revised proposal, the Committee would appreciate a detailed written evaluation of the optimization and physics reach of NOνA for a range of assumptions regarding oscillation parameters, e.g. Δm_{23}^2 , ambiguity in $\sin^2 \theta_{23}$, θ_{13}, and δ; considering statistical and systematic experimental uncertainties; and quantifying the extent to which NOνA is complementary with results from other planned or proposed experiments. The following questions illustrate issues that such an evaluation should address:

1. Show how experimental uncertainties (statistical and systematic) will smear the ellipses in the $\sin^2 2\theta_{13}$ vs P(anti-ν_e) plane (as in Fig. 5.1 of the proposal). Also show the smearing due to the expected uncertainty on other oscillation parameters, e.g. Δm_{23}^2 , at the time that NOνA will run.

2. For $\sin^2 2\theta_{13} = 0.1$ and $= 0.01$ and for P(anti-ν_e) corresponding to $\delta = \pi$, plot $\Delta\chi^2$ vs $\sin^2 2\theta_{13}$ to give an idea of how cleanly the ambiguities are resolved, taking into account known sources of experimental and theoretical uncertainty.

3. While NOνA aims to improve the upper limit on θ_{13}, or make the first measurement of this parameter, there is still a fairly wide range of possible values of other oscillation parameters, e.g. Δm_{23}^2. What is the worst case combination of parameters (other than θ_{13}), and under this worst case assumption what is NOνA's sensitivity, as proposed, to $\sin^2 2\theta_{13}$?

4. What information on oscillation parameters will become available prior to final site selection for NOνA that might influence the location? How would the availability of this information improve the optimization or strategy of the experiment for measuring θ_{13} and for resolving the mass hierarchy?

5. Show the sensitivity to the ν_e /anti-ν_e asymmetry vs off-axis angle.

6. By giving up some sensitivity for $\sin^2 2\theta_{13}$, for instance because data on θ_{13} will be available from other experiments, is it possible to significantly improve sensitivity to the mass hierarchy, for instance by running with two (smaller) far-detectors at different angles?

7. How does the effect of backgrounds on the figure of merit (including non-neutrino backgrounds, e.g. for neutrons) depend upon off-axis angle? Does the baseline detector have adequate background rejection at off-axis angles greater than 14 mrad (energies less than 2 GeV)?

NOνA is investigating a totally active detector as an alternative to the baseline sampling calorimeter. The Committee will be interested to hear the outcome of this investigation and would appreciate an update for its June meeting.