A Reactor Working Group

authors: *Reactor Working Group*

A.1 Introduction

The worldwide program to understand neutrino oscillations and determine the mixing parameters, CP violating effects, and mass hierarchy will require a broad combination of measurements. Our group believes that a key element of this future neutrino program is a multi-detector neutrino experiment (with baselines of $\sim$ 200 m and $\sim$ 1.5 km) with a sensitivity of $\sin^2 2\theta_{13} = 0.01$. In addition to oscillation physics, the reactor experiment may provide interesting measurements of $\sin^2\theta_W$ at $Q^2 = 0$, neutrino couplings, magnetic moments, and mixing with sterile neutrino states.

θ_{13} is one of the twenty six parameters of the standard model, the best model of electroweak interactions for energies below 100 GeV and, as such, is worthy of a precision measurement independent of other considerations. A reactor experiment of the proposed sensitivity will allow a measurement of θ_{13} with no ambiguities and significantly better precision than any other proposed experiment, or will set limits indicating the scale of future experiments required to make progress. Figure 1 shows a comparison of the sensitivity of reactor experiments of different scales with accelerator experiments for setting limits on $\sin^2 2\theta_{13}$ if the mixing angle is very small, or for making a measurement of $\sin^2 2\theta_{13}$ if the angle is observable. A reactor experiment with a 1% precision may also resolve the degeneracy in the θ_{23} parameter when combined with long-baseline accelerator experiments (see Fig. 2).

In combination with long-baseline measurements, a reactor experiment may give early indications of CP violation and the mass hierarchy. The combination of the T2K and Nova long-baseline experiments will be able to make significant measurements of these effects if $\sin^2 2\theta_{13} > 0.05$ and with enhanced beam rates can improve their reach to the $\sin^2 2\theta_{13} > 0.02$ level. If θ_{13} turns out to be smaller than these values, one will need other strategies for getting to the physics. Thus, an unambiguous reactor measurement of θ_{13} is an important ingredient in planning the strategy for the future neutrino program.

A.2 Recommendations

Our group has one highest priority recommendation:

- We recommend the rapid construction of a multi-detector reactor experiment with a sensitivity of 0.01 for $\sin^2 2\theta_{13}$.

Our other recommendations are the following:

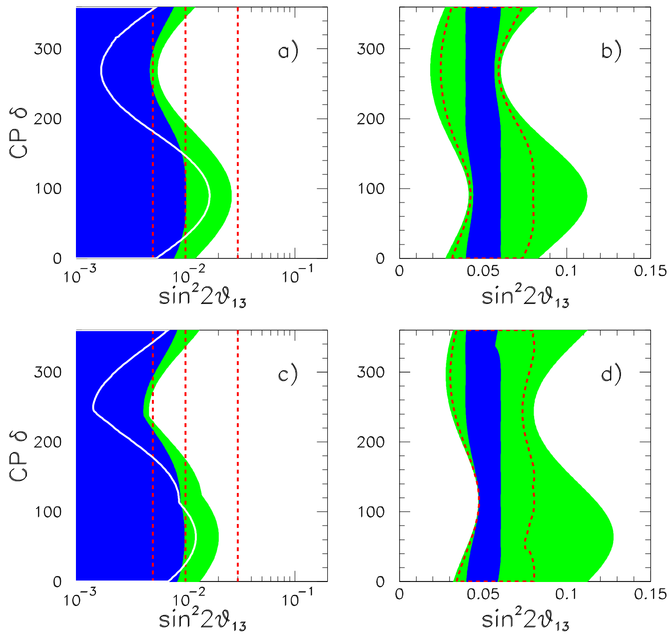

Figure 1: 90% C.L. regions and upper limits for various oscillation measurements for (a,c) $\sin^2 2\theta_{13} = 0$ and (b,d) $\sin^2 2\theta_{13} = 0.05$. The top (bottom) plots are for the T2K (Nova) long-baseline experiments. The three vertical dashed lines in (a) and (c) correspond to the 90% C.L. upper limits of 0.005, 0.01, and 0.03 possible with different scales of reactor experiments. The green region (white curve) is the 90% C.L. allowed region for the two long-baseline experiments for a five year neutrino-only run with nominal ($\times 5$) beam rate, and the blue region gives the combination of the five year long-baseline measurement with a reactor experiment with sensitivity of $\sin^2 2\theta_{13} = 0.01$; in (b) and (d), the dashed curves show how the combined measurement would be degraded with a reactor experiment with sensitivity of $\sin^2 2\theta_{13} = 0.03$.

- To help accomplish our highest priority recommendation, we recommend R&D support necessary to prepare a full proposal.
- We recommend continued support for the KAMLAND experiment. KAMLAND has made the best determination of Δm^2_{12} to date, and will provide the best measurement for the foreseeable future. As the deepest running reactor experiment, it also provides critical information about cosmic-ray related backgrounds for future experiments.
- We recommend the exploration of potential sites for a next-generation experiment at a distance of 70 km from an isolated reactor complex to make high precision measurements of θ_{12} and Δm^2_{12}.
- We recommend support for development of future large-scale reactor θ_{13} experiments that fully exploit energy spectrum information.

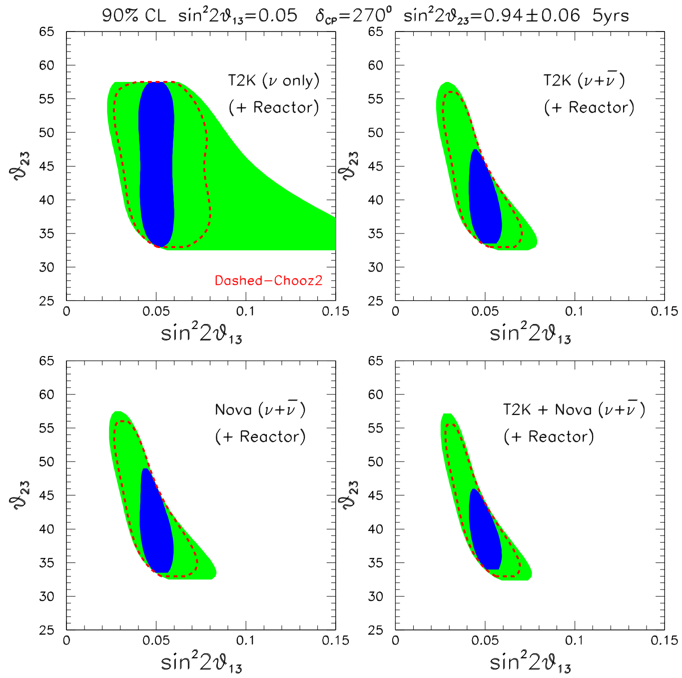

Figure 2: 90% C.L. allowed regions for simulated data with an underlying oscillation parameters of $\sin^2 2\theta_{13} = 0.05$, $\theta_{23} = 38^0$, $\Delta m^2 = 2.5 \times 10^{-3}$ eV^2 and $\delta_{CP} = 270$. The analysis includes the restriction that $\sin^2 2\theta_{23} = 0.94 \pm 0.06$. The green regions are for various combinations of the T2K and/or Nova experiments for five years of running periods. The blue regions are the 90% C.L. allowed regions for the combination of a reactor experiment with sensitivity of $\sin^2 2\theta_{13} = 0.01$ and a long-baseline experiment. The dashed red lines show how the combined measurement would degraded with a reactor experiment with 3 times worse sensitivity.