Report on ICFA Asian Neutrino Community Meeting

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ICFA Asian panel members
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The Asian neutrino community meeting took place in the afternoon of November 13, 2013 on the last day of the NNN13 workshop at Kavli IPMU in Kashiwa city, Chiba, JAPAN. This meeting was organized by the Asian panel members (J. Cao, S.B. Kim, T. Kobayasi, N. Mondal, and M. Shiozawa) to collect input from the neutrino community in Asia and to receive reports from regional planning efforts. There were approximately 40 participants and the meeting program and presentation files have been made available on the web at:
http://indico.ipmu.jp/indico/getFile.py/access?contribId=8&resId=0&materialId=slides&confId=26
. The meeting consisted of an introductory talk, a theoretical presentation on neutrino physics, and a series of talks about the status and planning of neutrino experiments in China, India, Japan, and Korea with an emphasis on international accelerator-based neutrino oscillation experiments. Following these talks there was an open discussion among the meeting participants. Opinions were solicited through the web page in advance to collect broad inputs to the meeting and this discussion.

Presentation Summary

- **Introduction** by Takashi Kobayashi (KEK)
  An introduction to the ICFA neutrino panel, including its objectives, charges and procedures, was given and the goals of the town meeting were explained. It was noted that the panel would like to carry out a review of:
  (a) The present status of the neutrino oscillation program within Asia and the developments that can be expected on a 4-to-7-year timescale;
  (b) The discovery opportunities for which the accelerator-based neutrino oscillation program must be optimized over a 7-to-25-year timescale; and
  (c) The measurements and R&D (including software development) that are required for the near-term (4-to-7-year) and medium- to long-term (7-to-25-year) program in order to fulfill that potential.
- **Why Neutrinos?** by Hitoshi Murayama (Berkeley & Kavli IPMU)
  Although the theory of the strong, weak, and electromagnetic forces appears to be complete after the discovery of the Higgs boson, there are still many unanswered questions in particle physics. There are at least five missing pieces in the standard model: non-baryonic dark matter, the lightness of the neutrino masses, dark energy, acausal density fluctuations in the early universe, and a mechanism to generate the baryon asymmetry in the universe. In this context, neutrino and nucleon decay experiments are unique probes of high energy (up to $O(10^{16})$ GeV) physics beyond the standard model. In order to explain the observed baryon asymmetry of the universe, for instance, new sources of CP violation, like CP violation in neutrinos, are needed. Similarly, proton decay searches may shed light on the manner in which particles convert to anti-particles, another piece of information essential to understand how the baryon asymmetry evolved in the history of our universe.
- **Neutrino Program in China** by Jingyu Tang (Institute of High Energy Physics, CAS)
  The Daya Bay experiment is now running and aims to achieve a 3% measurement of $\sin^2\theta_{13}$ by accumulating data over the next four to five years. Its successor, JUNO, is a next-generation liquid scintillator detector whose primary physics target is the determination of the neutrino mass hierarchy using reactor antineutrinos over a $\sim$ 50 km baseline. It is also expected to measure Δm^2_{21}, Δm^2_{32}, and $\sin^2\theta_{12}$ at

the 1% level or better. High-precision measurements of supernova neutrinos, geo-neutrinos, and solar neutrinos are also anticipated. Additionally, the possibility of a CP measurement with a new neutrino beam facility based on muon decay, MOMENT, is under discussion.

- **Neutrino Program in India** by Sanjib Kumar Agarwalla (Bhubaneswar)
  Though the headline experiment of the India-Based Neutrino Observatory (INO) will be the ICAL neutrino detector, underground laboratories for double beta decay and direct dark matter detection experiments are available as well. ICAL will primarily study atmospheric neutrinos and is expected to have 2.5σ sensitivity to the mass hierarchy by itself and 3.4σ sensitivity in combination with T2K, NOνA, and reactor experiments. Further improvements in the ICAL event reconstruction lead to enhanced sensitivity of 3σ. It was also noted that many Indian institutions are involved in the FNAL neutrino program, including the MIPP, MINOS+, NOνA, and LBNE experiments.
- **Neutrino Program in Korea** by Kyung Kwang Joo (Chonnam National University)
  The short-baseline reactor neutrino experiment, RENO, is expected to improve its precision on its measurement of $\sin^2\theta_{13}$ to $\sim 5\%$ over the next five years. A longer baseline (~ 50 km) reactor experiment, RENO-50, is being pursued to perform high-precision measurements of Δm^2_{21}, Δm^2_{32}, and $\sin^2\theta_{12}$, and to determine the mass hierarchy. RENO-50 will also be capable of observing neutrinos from supernova, the Earth's interior, the sun, and J-PARC. Though a search for neutrinoless double beta decay is also within the scope of the detector, a dedicated double beta decay experiment, AMoRE, is being planned for a ten year run. Construction of a short-baseline neutrino oscillation experiment to study the reactor neutrino anomaly is also underway.
- **Neutrino Program in Japan** by Tsuyoshi Nakaya (Kyoto)
  With its approved 7.8×10^{21} POT, T2K by itself has a chance to exclude $\sin\delta = 0$ with an expected significance of $\sim 2\sigma$ if, as its latest data suggest, $\sin\delta = -1$. In that scenario the mass hierarchy could also be determined by the combination of measurements at T2K and NOνA. Additionally, the precision on its measurement of $\sin^2\theta_{23}$ will be 0.045 (2.6°) assuming $\sin^2\theta_{23} = 0.5$. High statistics studies of atmospheric neutrinos at Super-K will have $\sim 2\sigma$ mass hierarchy determination power and $\sim 2\sigma$ sensitivity to the θ_{23} octant if $\sin^2\theta_{23} = 0.6$. Sterile neutrino searches at KamLAND and the J-PARC/MLF (P56) are also in preparation.
  On a timescale of ~ 25 years the next-generation underground water Cherenkov detector, Hyper-Kamiokande (Hyper-K), is being proposed both to serve as the far detector for a long-baseline neutrino oscillation experiment using an upgraded J-PARC neutrino beam and as a detector capable of observing proton decay, atmospheric neutrinos, and astrophysical neutrinos. Hyper-K is expected to measure the CP phase with $10 - 20°$ precision and can establish CP violation with $> 3\sigma$ significance for 74% of the δ parameter space. The significance of the mass hierarchy determination is expected to reach 3σ or more using high statistics data from the J-PARC neutrino beam and atmospheric neutrinos. Additionally, if $\sin^2 2\theta_{23} < 0.995$, the θ_{23} octant can be resolved at $> 2\sigma$. Owing to its factor of 25 increase in fiducial volume, Hyper-K has sensitivity to nucleon decays exceeding what has been achieved at Super-K by an order of magnitude or more. Finally, discussions are underway within the community concerning ideas for new facilities to achieve a multi-MW neutrino beam, for the development of advanced neutrino detectors such as a large scale liquid Argon TPC, and for upgrades to KamLAND that will extend its sensitivity to $0\nu\beta\beta$ decay into the inverted hierarchy region and beyond.

Discussion Summary

Figure 1 summarizes a conceptual timeline of both running and planned experiments with (optimistic) estimates of expected measurement sensitivities. T2K is now entering an era of CP violation studies, which will be significantly expanded at Hyper-K with the upgraded J-PARC neutrino beam. Indeed, Hyper-K's test of

CP violation in neutrinos represents a significant opportunity for discovery over the next 7-to-25-years. The effects of matter on neutrino oscillations mimicing CP violation are relatively small for ~ 600 MeV neutrinos from J-PARC over the 300 km Hyper-K baseline. Using well established water Cherenkov technology Hyper-K consequently offers an experimentally clean and promising way to approach the question of neutrino CP violation. Moreover, this technology is the only known realistic detector option that can probe proton lifetimes of the order of 10^{35} years. High statistics measurements of atmospheric neutrinos at Hyper-K and ICAL, as well as measurements of reactor neutrinos over moderate baselines at JUNO and RENO-50, each have the potential to determine the mass hierarchy with $> 3\sigma$ significance. These measurements, in conjunction with high precision measurements of the neutrino mixing and mass parameters by these projects, highlight the strength and versatility of the neutrino program in Asia.

In order to achieve these goals, several essential R&D studies were discussed at the meeting. Improvements on the neutrino detection technology are necessary in the following areas: the development of fast, high quantum efficiency photo-sensors and gadolinium loading technology for large water Cherenkov detectors, the development of advanced liquid scintillators for scintillator experiments, and the development of other advanced detector technologies such as the liquid argon TPC. To achieve a high intensity neutrino beam, upgrades to the J-PARC beamline to allow for 750 kW and multi-MW operation must be developed and as a part of that program research into high power targetry is needed. Additionally, both the development of a 15 MW proton driver and advances in muon transportation are essential for the success of the MOMENT concept. Central to all upcoming measurements is the reduction of systematic errors and accordingly, improved hadron production and cross section measurements are critical.

Finally, all participants agreed that the Asian program can be successful and strengthened by the mutual support and participation.

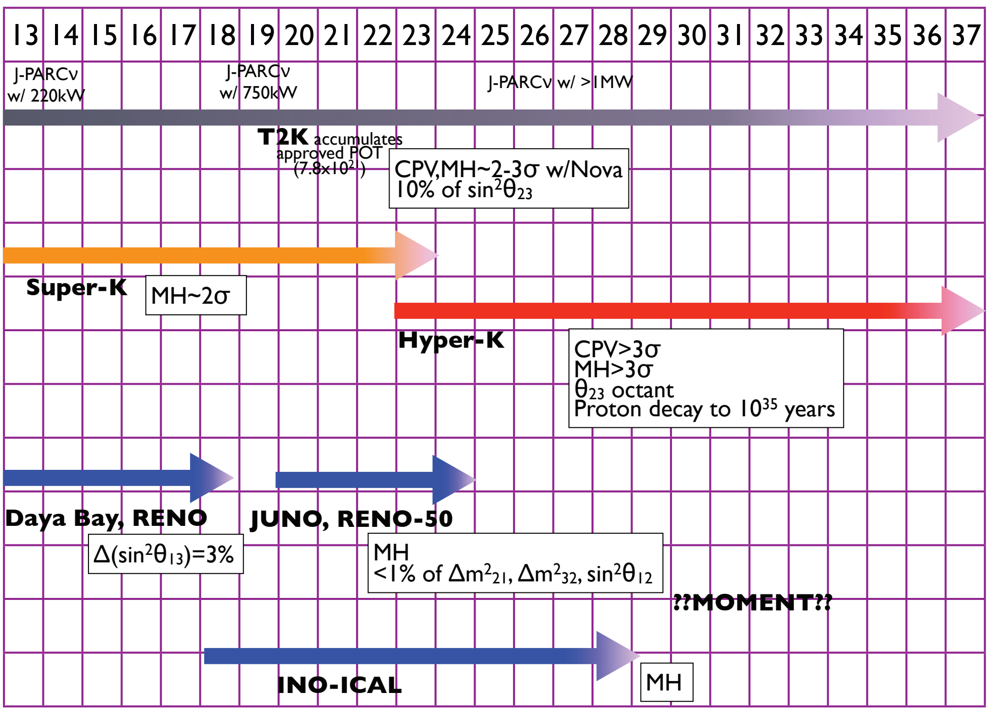

Figure 1: Working timeline of neutrino oscillation experiments in Asia and their expected sensitivities.