Results from solar, atmospheric and K2K experiments and future possibilities with T2K

TAKAAKI KAJITA
Research Center for Cosmic Neutrinos, Institute for Cosmic Ray Research, University of Tokyo, Kashiwa-no-ha 5-1-5, Kashiwa, Chiba 277-8582, Japan
E-mail: kajita@icrr.u-tokyo.ac.jp

Abstract. Recent results from solar, reactor, atmospheric and long baseline (K2K) experiments are discussed. With the improved data statistics and analyses, our knowledge on the neutrino masses and mixing angles are steadily improving. T2K is the next generation neutrino oscillation experiment between J-PARC in Tokai and Super-Kamiokande. This experiment will start in 2009. This experiment is expected to improve the current knowledge on the neutrino masses and mixings substantially.

Keywords. Neutrino; neutrino oscillation.

PACS No. 14.60.Pq

1. Introduction

Studies of the neutrinos have played an essential role in the understanding of elementary particle physics. Physics of the neutrino masses and mixing angles are believed to be related to physics in the very high-energy scale [1,2], probably physics at the grand unification scale [3,4]. Furthermore, measuring the CP-violation phase in the neutrino sector is considered to be an essential step towards understanding the baryon asymmetry in the Universe [5]. Because of these reasons, there are many experiments that study neutrino oscillations using various neutrino sources, and various possibilities are discussed for future neutrino oscillation experiments.

Since there are three neutrino flavors, there must be three mixing angles (which are called $\theta_{12}$, $\theta_{23}$ and $\theta_{13}$) and three neutrino mass squared differences (which are called $\Delta m^2_{12}$, $\Delta m^2_{23}$ and $\Delta m^2_{13}$). Among the three $\Delta m^2_{ij}$'s, only two are independent. Among the three mixing angles, $\theta_{13}$ is known to be small, while the other two angles are large. This fact, together with the hierarchy in $\Delta m^2$ ($\Delta m^2_{23} \gg \Delta m^2_{12}$), allows us to interpret the present data assuming 2-flavor oscillations to a good accuracy.

In this report, we discuss the present understanding of the neutrino masses and mixing angles based on results from solar, reactor, atmospheric and K2K neutrino experiments. We also discuss future possibilities with T2K. T2K is the next generation long baseline neutrino oscillation experiment between the J-PARC accelerator...
Takaaki Kajita

Figure 1. Constraints on $\nu_e$ and $\nu_\mu + \nu_\tau$ fluxes obtained by the SNO NC, CC and ES measurements, together with the high-statistics Super-K ES measurement.

and the Super-Kamiokande detector. We wrote this paper based on the presentations at the conference. However, the results on the detection of tau neutrino interactions are updated, since the results were finalized soon after the conference.

2. Solar neutrinos

The missing solar neutrino problem has been solved by neutrino oscillations. At present, one of the important goals is the precise determination of the solar neutrino oscillation parameters.

Recently, SNO published the final salt-phase data based on 391 days of exposure of the detector [6]. The salt phase of SNO has enhanced sensitivity to the neutral current (NC; $\nu_e + d \rightarrow \nu_e + p + n$, and $n$ is detected by $n + ^{35}\text{Cl} \rightarrow ^{36}\text{Cl} + \gamma (\Sigma E_{\gamma} = 8.6 \text{ MeV})$) interactions in addition to the measurements of the charged current (CC; $\nu + d \rightarrow e^- + p + p$) and elastic scattering (ES; $\nu_e + e^- \rightarrow \nu_e + e^-$) interactions. The measured CC/NC flux ratio was $0.340 \pm 0.023^{+0.029}_{-0.031}$, which is completely consistent with, but slightly higher than the previous central value ($0.306 \pm 0.026 \pm 0.024$) [7]. Figure 1 (taken from [6]) shows the constraint on the $\nu_e$ and $(\nu_\mu + \nu_\tau)$ fluxes from SNO and Super-Kamiokande (Super-K) [8]. All the data are consistently explained within the standard oscillation framework.

The day–night asymmetry was also measured in the salt phase. Defining the asymmetry as $A = 2(\phi_N - \phi_D)/(\phi_N + \phi_D)$ and assuming that the asymmetry is zero for NC events, the asymmetry in the salt-phase data [6] was $A_{\text{CC}} = -0.015 \pm 0.058(\text{stat.}) \pm 0.027(\text{syst.})$. If we combine the SNO pure D$_2$O data [9] with the SNO salt phase data, the asymmetry is $A_{\text{CC}} = +0.037 \pm 0.040$. Super-K measured the asymmetry in the ES events [8]. It was $A_{\text{ES}} = +0.021 \pm 0.020(\text{stat.})^{+0.013}_{-0.012}(\text{syst.})$. The asymmetry measured by ES is expected to be smaller than the asymmetry.