4.3 K2K Experiment

As reported in the KEK Annual Report 2001, Super-Kamiokande (SK), the far detector of the K2K experiment, suffered from an accident on November 12, 2001, in which about 60% of the 20-inch photomultiplier tubes (PMTs) for the inner detector and 8-inch PMTs for the outer detector were destroyed.

After extensive investigation of the cause of the accident and subsequent tests of protection measures against the shock waves produced by the PMT implosion, the Super-Kamiokande and K2K collaborations started rebuilding the SK detector in April 2002. The work took about half a year to complete. The inner detector was, however, only partially rebuilt. The 20-inch PMTs then available, most of which were those PMTs that fortunately survived the accident with the remainder from the stock at the Institute of Cosmic Ray Research (ICRR), were only 47% of the 11,146 PMTs necessary to cover the whole inner wall of the large water tank of the SK detector. In the restoration, all PMTs were encased in plastic covers as shown in Fig. 4-3-1. The front panel of the PMT case is made of 12 mm-thick UV-transparent acrylic so that, even if one PMT might implode due to water pressure, the shock waves should be safely confined in its plastic case. Although the inner detector still suffers from the accident, the outer detector has been completely restored thanks to the support of the U.S. Department of Energy.

Fig. 4-3-1 An encased 20-inch PMT for the Super-Kamiokande-II detector.

The Super-Kamiokande experiments before and after the accident are now called Super-Kamiokande-I (SK-I) and Super-Kamiokande-II (SK-II), respectively. Similarly, we refer to the K2K experiment with the SK-II detector as K2K-II and the one before the accident as K2K-I. While K2K-I was essentially a Japan-US-Korea collaboration with a few members from Poland, K2K-II enjoys a larger collaboration including members from France, Italy, Spain, Switzerland, Russia, and more recently from Canada.

Filling of the SK-II detector with water started at the beginning of October 2002, and K2K-II started data taking at the end of December 2002. After the New Year holidays in 2003, data taking resumed on January 18, 2003. Figure 4-3-2 shows the status of the K2K-II experiment around the end of April 2003. The total number of protons delivered onto the pion production target (protons on target: POT) for the K2K-II experiment has reached to 1.7×10^{19}. The corresponding SK-II live time was about 1.5×10^{19} POT.

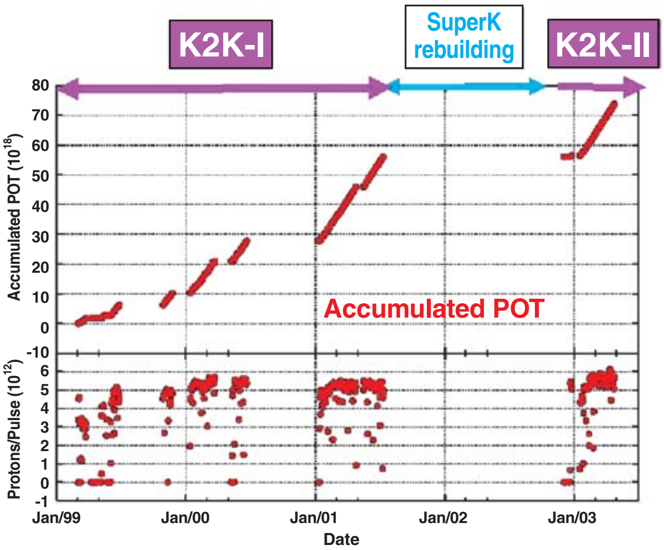

Fig. 4-3-2 Status of the K2K experiment. The integrated number of protons delivered onto the target (POT) and beam intensity per pulse are shown.

The K2K-I results for neutrino oscillations were published in January 2003. As already described in the 2001 Annual Report, 56 neutrinos from the KEK 12 GeV Proton Synchrotron (PS) were observed inside the SK-I fiducial volume of 22,500 tons of water. Assuming no oscillation, we expect $80.1^{+6.2}_{-5.4}$ events based on the neutrino intensity measured in the 1,000-ton water Cerenkov detector located at the KEK site.

Figure 4-3-3 shows the E_ν spectrum for 29 fully contained 1-ring μ-like events observed in the SK-I fiducial volume. In the event reconstruction, the kinematics of a two-body quasi-elastic (QE) reaction were assumed. The observed energy spectrum, therefore, mostly consists of that from real muon neutrinos or that of non-QE background. The non-QE background was estimated by a Monte Carlo simulation for the neutrino interactions with proper detector response. The box histogram is the expected spectrum without oscillations, where the height of boxes indicates the systematic error. The solid line is the best-fit to the data with $\sin^2 2\theta = 1.0$ and $\Delta m^2 = 2.8 \times 10^{-3}$ eV^2. The histograms are normalized to 29 observed events. The dashed line shows the expected spectrum with no oscillations, which is normalized to the expected number of events (44). The probability that the present observation is due to statistical fluctuation rather than neutrino oscillation is less than 1%.

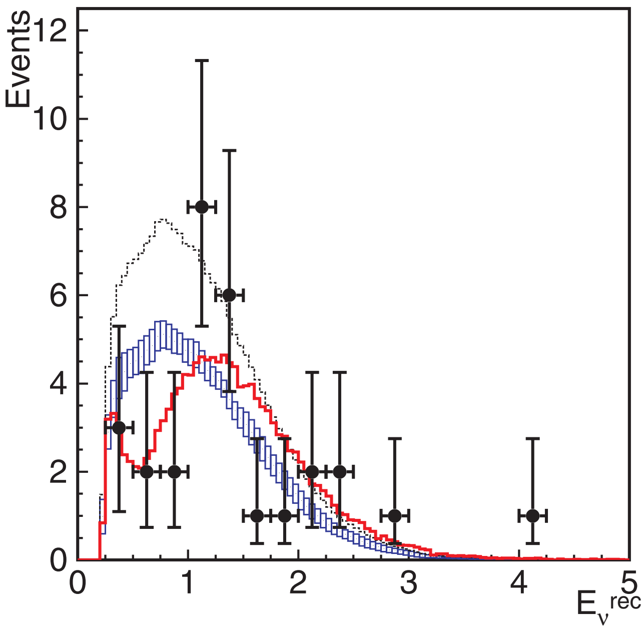

Fig. 4-3-3 The neutrino spectrum observed at the SK-1 detector compared with the spectrum expected for no oscillation and that for oscillation of best-fit.

Figure 4-3-4 shows the allowed regions of the oscillation parameters. The dashed, solid, and dot-dashed lines are the 68.4%, 90%, and 99% confidence level contours, respectively. The best-fit is marked by the star. The measured oscillation parameters are consistent with those suggested by the atmospheric neutrino observations in SK-I.

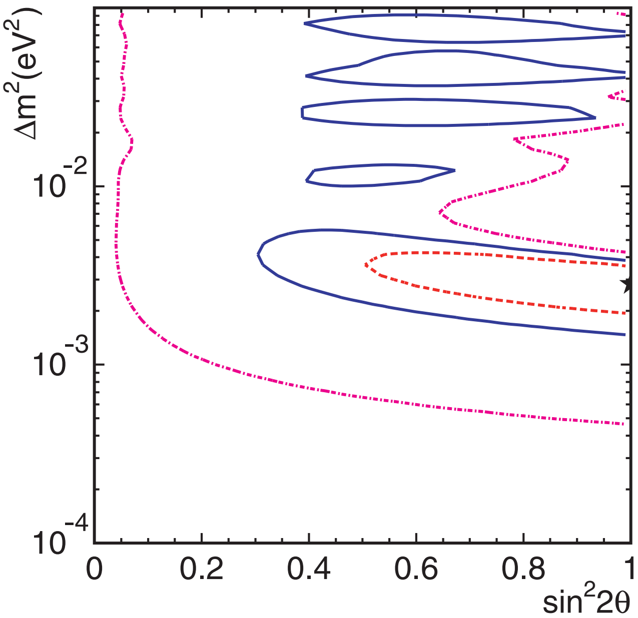

Fig. 4-3-4 Allowed regions of the oscillation parameters.