4.3 K2K Experiment

The KEK-to-Kamioka long-baseline neutrino oscillation experiment (K2K) is the first accelerator-based experiment with a neutrino path length extending hundreds of kilometers. The intense, nearly pure neutrino beam (98.2% ν_μ, 1.3% ν_e, and 0.5% $\overline{\nu}_\mu$), having an average $L/E_\nu \sim 200$ ($L = 250$ km, $< E_\nu > \sim 1.3$ GeV), is directed toward the Super-Kamiokande detector at Kamioka. K2K focuses on the study of the existence of neutrino oscillation in ν_μ disappearance that is observed in atmospheric neutrinos, and on the search for $\nu_\mu \rightarrow \nu_e$ oscillation, with well-understood flux and neutrino composition in the $\Delta m^2 \geq 2 \times 10^{-3}$ eV^2 region.

The K2K experiment started data taking in June 1999. On November 12, 2001, however, the Super-Kamiokande detector suffered an accident. Over a period of one year, it was rebuilt with about half of the original photomultiplier density. The rebuilt detector is called Super-Kamiokande-II, as compared to Super-Kamiokande-I before the accident. Consequently, the K2K experiment is called K2K-I and K2K-II corresponding to Super-Kamiokande-I and -II, respectively. The K2K-I experiment was formally a Japan-U.S.-Korea collaboration, with a few people joining from Poland. In the K2K-II experiment, the collaboration expanded to include members from Canada, France, Italy, Spain, Switzerland, and Russia in addition to the original members from Japan, Korea, Poland and the U.S. (see Fig. 4-3-1).

In FY2003, K2K took data from April to June and October to February. The total number of protons delivered onto the pion production target (protons on target: POT) since the start of K2K in 1999 reached 1.01×10^{20} (see Fig. 4-3-2). The net POT, successfully

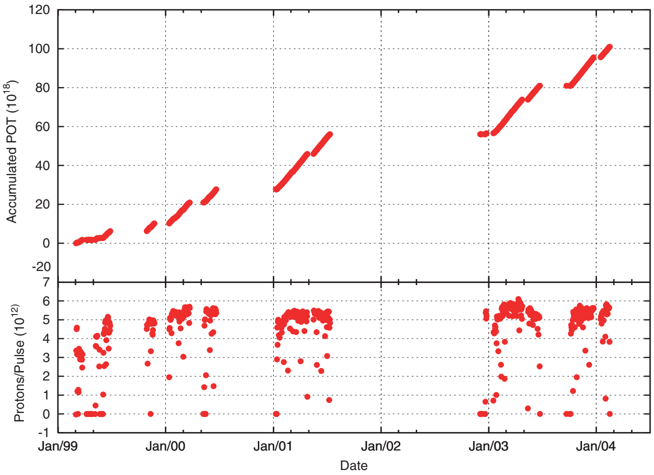

Fig. 4-3-2 History of the K2K experiment, showing accumulated POT and beam intensity per pulse.

Fig. 4-3-1 K2K-II collaboration.

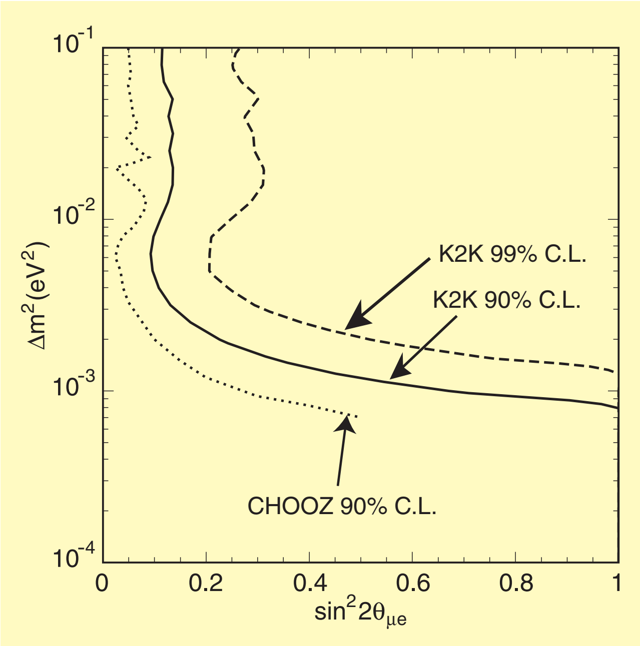

Fig. 4-3-3 Exclusion plots of $\nu_\mu \to \nu_e$ oscillations.

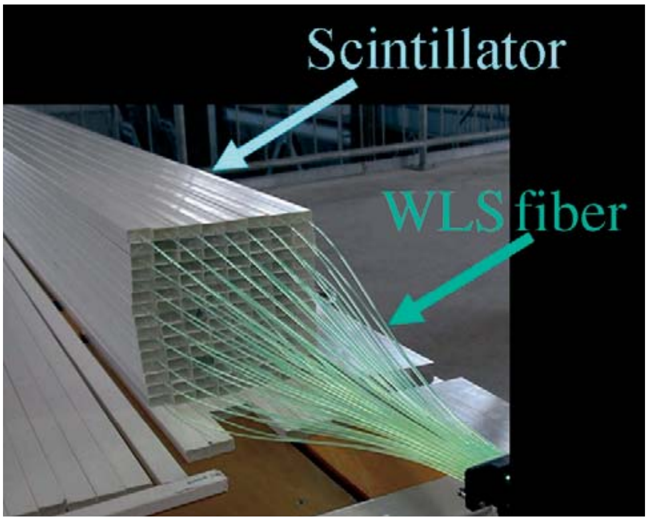

Fig. 4-3-4 Extruded scintillator strips and WLS fibers.

used for analysis of the Super-Kamiokande data, is 8.9 $\times 10^{19}$. The difference is attributable to various reasons: tuning of the beam channel, testing of the horns, Super-Kamiokande calibration, failure of Super-Kamiokande due to power failure, etc., and failure in the online data acquisition of the beam-monitoring data. As of February 2004, K2K was approaching the goal of 10^{20} net POT.

Although the main purpose of the K2K experiment is the study of ν_μ disappearance, $\nu_\mu \to \nu_e$ appearance can also be studied. Using the K2K-I data taken before the Super-Kamiokande accident, corresponding to 4.8 $\times 10^{19}$ POT, one candidate event was found. The expected background in the absence of neutrino oscillations is estimated to be 2.4 ± 0.6 events and is dominated by misidentification of events from neutral current π^0 production. The resulting confidence intervals for the $\nu_\mu \to \nu_e$ oscillations are shown in Fig. 4-3-3. This is the first accelerator long-baseline result for this oscillation mode. Assuming 3-flavor neutrino oscillations and CPT invariance, this result can be compared to the result from the CHOOZ reactor experiment. The limit on $\sin^2\theta_{13}$ by CHOOZ is converted by assuming $\sin^2\theta_{\mu e} = \frac{1}{2}\sin^2\theta_{13}$, and is also shown in Fig. 4-3-3.

A brand-new fine-grained near detector called the SciBar (Scintillator Bar) detector was installed during the summer shutdown in 2003. It is a fully active

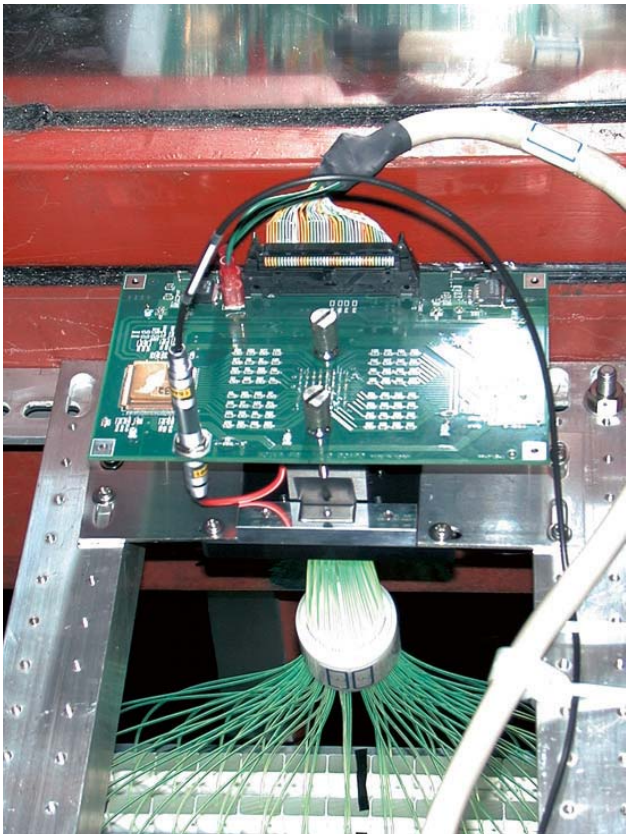

Fig. 4-3-5 This photograph shows how 64 WLS fibers are assembled in order to couple them with a 64-channel multianode PMT. A front-end electronics board is attached to the multi-anode PMT.

tracking detector consisting of 14,848 extruded scintillator strips, each 1.3 cm thick, 2.5 cm wide, and 300 cm long. A group of 116 strips are glued together to form a plane, and a combination of two planes, one horizontally and the other vertically segmented, forms a unit layer. Altogether there are 64 layers and the total scintillator volume weighs 15 tons. Each strip of scintillator is read out by a wavelength shifting (WLS) fiber, and 64 WLS fibers are coupled to a 64-channel multianode photomultiplier tube (PMT) (see Figs. 4-3-4 and 4-3-5). Figure 4-3-6 schematically illustrates the SciBar detector and the near detector complex. Figure 4-3-7 shows a sample of an interesting event observed in SciBar.

SciBar is a powerful detector to improve measurements of the neutrino energy spectrum and to study neutrino interactions around 1 GeV. As a result, SciBar will significantly contribute to improved oscillation analysis by reducing systematic errors due to uncertainties in the neutrino energy spectrum and neutrino interactions.

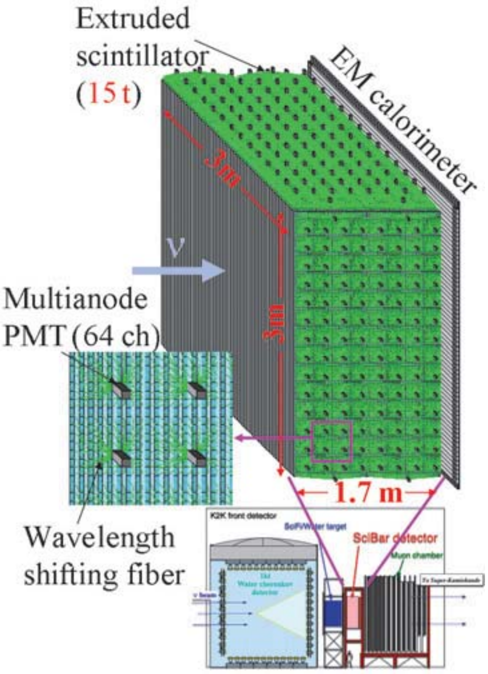

Fig. 4-3-6 Schematic illustration of the SciBar detector. Its location in the K2K-II near detector complex is also shown. The detector behind SciBar is a spaghetti calorimeter recycled from the CHORUS experiment at CERN.

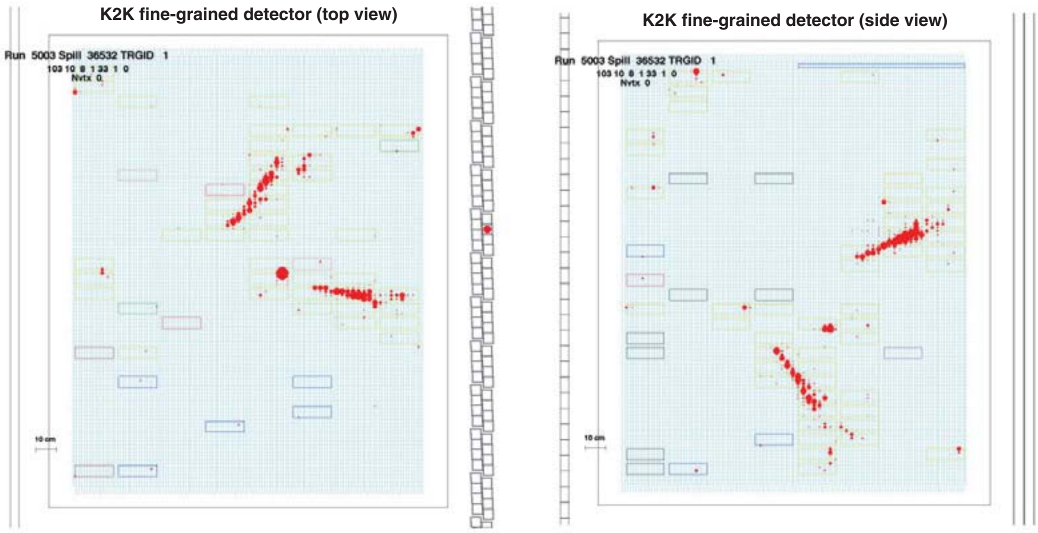

Fig. 4-3-7 A neutral-current single π^0 production event observed in the SciBar detector. The left panel shows a top view and the right panel shows a side view.