New Results From K2K

(KEK to Kamioka Long Baseline Neutrino Oscillation Experiment)

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The K2K Experiment recently reported updated results, which provide increased confidence in the existence of a phenomenon known as neutrino oscillations, indicating that neutrino particles have mass. The new results represent all data accumulated by K2K from April, 1999, to June, 2001.

K2K is a particle physics experiment in which a beam of neutrinos is directed through the earth a distance of 250 km, to the Super-Kamiokande underground neutrino detector located near Kamioka, Gifu, Japan. K2K (KEK to Kamioka), a Japan-Korea-US collaboration, uses a neutrino beam generated by the proton accelerator at KEK, the Japanese National High Energy Research Laboratory, in Tsukuba Science City, Ibaraki, Japan, about 40 km north of Tokyo. K2K is the world's first operating long-baseline neutrino experiment.

Neutrinos are subatomic particles associated with radioactive decay processes, and other phenomena related to the "weak interaction", one of the four fundamental forces of nature. Neutrinos have no electrical charge, and come in three distinct varieties, or "flavors", called electron-, muon- and tau-neutrinos. Until 1998, all neutrinos were assumed to be massless.

At that time, the Super-Kamiokande Experiment, a collaboration of physicists in Japan and the USA, presented the first compelling results clearly demonstrating the observation of "neutrino oscillations", a phenomenon predicted by quantum theory *only* if neutrinos have non-zero mass. In that case, neutrinos apparently change from one flavor to another in flight. The existence of such "oscillations" indicates that at least one neutrino flavor must have mass, while the Standard Model of particle physics assumes massless neutrinos. Thus neutrino oscillations are the first evidence for the existence of phenomena beyond the Standard Model, an exciting prospect for physicists.

Super-Kamiokande results were obtained from observations of neutrinos produced in the earth's atmosphere by cosmic ray particles. K2K provides an independent test, using a laboratory neutrino beam whose characteristics are calibrated by independent detectors at the KEK accelerator

The proton synchrotron at KEK generates a high-purity beam of muon-neutrinos, with only about 1% contamination by other flavors. Neutrino beam pulses, only a few millionths of a second in duration, were sent from KEK to Super-Kamiokande every 2.2 sec. The pulsed time structure of the beam made it possible to distinguish the interactions of beam neutrinos from those of cosmic ray (atmospheric) neutrinos, which arrive randomly in time.

K2K has observed 56 beam-induced neutrino interactions in the Super-Kamiokande detector. In the absence of neutrino oscillations, the expected number of such events would be 80.1 (+6.2, -5.4). Taking into account measurements of the beam energy spectrum obtained from "near" detectors on the KEK site, the probability that neutrino oscillations do not exist, and the observed deficit comes solely from statistical fluctuations, is less than 1%. However, the data *are* consistent with the hypothesis that neutrino oscillations exist with the parameter values reported by Super-Kamiokande using atmospheric neutrino data. K2K also has begun to see the energy dependence of the number of observed events which is expected from the oscillation phenomenon.

After K2K data taking concluded in July, 2001, the Super-Kamiokande detector was shut down for maintenance. Unfortunately, an accident in November, 2001, destroyed about half of the detector's photomultiplier tubes (PMTs). We expect that the experiment will resume operations at the end of this year, after an intensive effort by physicists and technicians to restore the Super-K detector to operation with about half of its original complement of PMTs mounted. Although the number of PMTs in Super-K will be reduced by about 50%, only the lowest energy neutrino data will be affected, and K2K data will be negligibly impacted due to the high energy of the KEK neutrino beam.

By July, 2001, the K2K experiment had used about 50% of the amount of beam exposure originally allocated by KEK. We will continue to run the experiment and use the remaining beam allocation to double the number of neutrino interactions observed in

Super-Kamiokande. This will allow K2K to observe oscillatory spectrum distortion and determine more precisely the neutrino oscillation parameters.

Neutrino research continues to explore fundamental questions in particle physics and astrophysics. However there are still many unresolved challenges in these fields, for example further exploration of “CP violation”, which is closely related to the origin of the apparent disproportionate abundances of matter and anti-matter in the universe. We will continue to pursue these challenges.

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