The Tokai to Kamioka Experiment

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Abstract

The status of the T2K experiment, that started to take data in November 2009, is presented. T2K is a long baseline neutrino oscillation experiment that uses an intense neutrino beam, produced at J-PARC and whose properties are measured by a suit of near detectors, and detected 295 Km away at Super-Kamiokande. The main goal of T2K is to measure the mixing angle θ_{13} from the observation of the ν_e appearance.

1 Introduction

The T2K experiment consists of the world highest intensity muon neutrino beam produced at the 50 GeV Proton-Synchrotron at J-PARC (Tokai) being directed at a far detector, Super-Kamiokande [1] (SK), 295 Km away from J-PARC.

In the first phase of the experiment, which started data taking at the end of November 2009, a ν_μ beam of 0.1 MW, ramping up to 0.9 MW by 2011, is available. A total of about 5×10^{21} POT (protons on target) are foreseen to be collected during the first phase. The data will allow a determination of the mixing angle θ_{13} [2]. The second phase of the experiment, after about 5 years of data-taking, foresees an upgrade of the beam-line allowing the ν_μ beam intensity to reach 4 MW, which is required to study CP violation.

In the following, a description of the T2K experiment, its physics goals and its current status, are presented.

2 The T2K Experiment

The neutrino beam is produced by colliding 50 GeV protons from the J-PARC proton synchrotron onto a target. The initial proton energy is limited to 30 GeV and will then ramp up to 50 GeV. The proton beam is extracted into the neutrino primary beamline. The T2K neutrino beamline adopts an off-axis beam configuration. It exploits the kinematics of pion decay, where the neutrino energy is not strongly dependent on the pion energy at a fixed decay angle in the lab frame, to produce a narrow-band beam. The narrow-band beam is needed to maximize the neutrino flux at energies near the first oscillation maximum and to reduce the background. The off-axis angle is 2.5 degrees, corresponding to the peak beam energy of about 0.7 GeV. The schematic of the T2K neutrino beam is shown in Fig. 1.

Because of the off-axis beam configuration, the neutrino spectrum at Super-Kamiokande is sensitive to the neutrino beam direction. There are two detector systems designed specifically for online neutrino beam monitoring: a muon monitor and an on-axis neutrino detector. The muon monitor can measure the neutrino beam condition in real time by detecting the accompanying muons. The on-axis neutrino detector monitors the neutrino beam directly using neutrino interactions.

The near detector system N280 is located off-axis at 280 m from the target and consists of different sub-detectors (Fig 2). The main purpose of the near detector system is to measure the properties of the neutrino beam before oscillation:

- Measure the neutrino flux and spectrum
- Measure different interaction cross sections to estimate the backgrounds at Super-Kamiokande.
- Measure the ν_e beam contamination for ν_e appearance search.

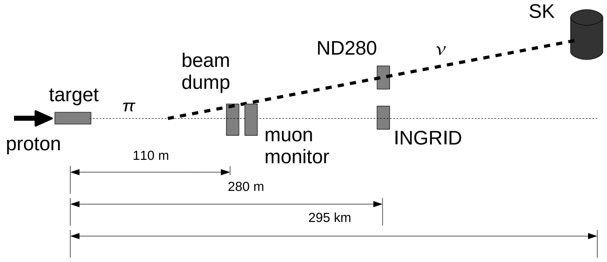

Fig. 1: Schematic of the T2K neutrino beam.

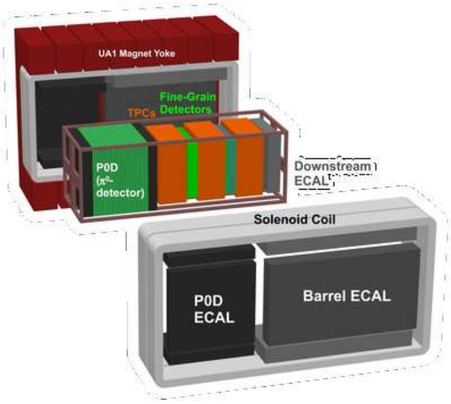

Fig. 2: ND280 detector schematic.

The ND280 sub-detectors are enclosed inside the UA1 dipole magnet operating at nominal 0.2 T for measuring the momentum of the charged particles.

The far detector Super-Kamiokande, located 295 km from the near detector at the Kamioka Observatory, is a 50 kton water Cherenkov detector. The detector is a cylindrical tank of 41.4 m in height and 39.3 m in diameter. The detector can distinguish electron from muon by the light distribution of the projected Cherenkov cone. Electrons scatter more than muons, and therefore make a fuzzy ring. However, SK can not distinguish between gamma and electron as they both produce e-like ring. Because of this, SK could mistake a π^0 for an electron when the two gamma's from the π^0 decay have a small open angle. So, it is important to determine the π^0 cross section at ND280.

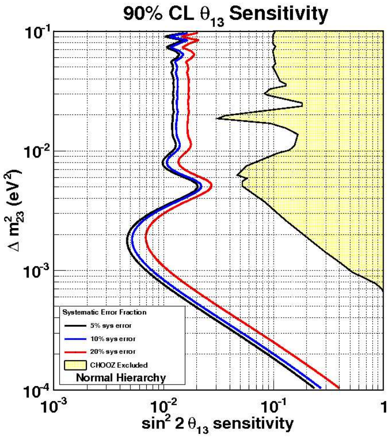

Fig. 3: Diagram of a straight line. T2K sensitivity to θ_{13} at the 90% confidence level as a function of Δm^2_{23}. Beam is assumed to be running at 750kW for 5 years (or equivalently, 5×10^{21} POT), using the 22.5 kton fiducial volume SK detector. 5%, 10% and 20% systematic error fractions are plotted. The yellow region has already been excluded to 90% confidence level by the CHOOZ reactor experiment. The following oscillation parameters are assumed: $\sin^2 2\theta_{12} = 0.8704$, $\sin^2 2\theta_{23} = 1.0$, $\Delta m^2_{12} = 7.6 \times 10^{-5}\text{eV}^2$, $\delta_{CP} = 0$, normal hierarchy.

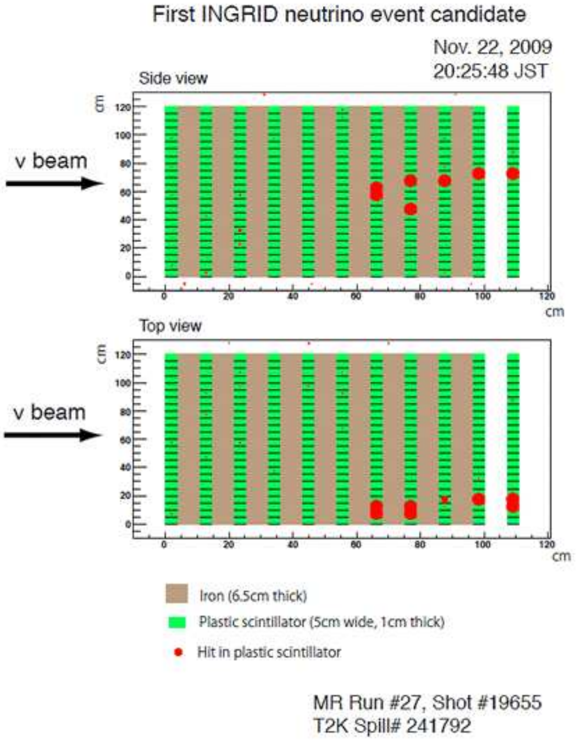

Fig. 4: The first neutrino interaction event detected by the on–axis neutrino detector.

3 T2K Physics Goals

The T2K experiment aims to measure the mixing angle θ_{13} through the ν_e appearance. It is noted that the appearance probability also depends on the atmospheric oscillation parameters $(\Delta m^2_{23}, \sin^2 2\theta_{23})$. For this reason, the T2K experiment will measure both these oscillation parameters and the mixing angle θ_{13}.

The oscillation parameters $(\Delta m^2_{23}, \sin^2 2\theta_{23})$ will be determined from the survival probability of ν_μ after traveling 295 km. This probability can be measured by comparing the neutrino spectra at the near and far site.

The mixing angle θ_{13} is determined from the measurement of the ν_e appearance signal. The ν_e signal comes from $\nu_\mu \to \nu_e$ oscillation if the mixing angle θ_{13} is nonzero. Electrons from ν_e quasi-elastic charged-current interactions are detected by the presence of an electron-like ring. Backgrounds from ν_μ interactions are further reduced by requiring that there is no electrons coming from the decay of the muon. After this, there are two main backgrounds to the ν_e search at Super-Kamiokande: the background from single π^0 from neutral current interactions and ν_e intrinsic to the beam. These backgrounds are measured by the near detector system before oscillation and extrapolated to Super-Kamiokande. The estimated π^0 and intrinsic ν_e backgrounds are subtracted from the selected ν_e events, both measured at ND280.

The final appearance signal is fitted to the appearance probability to find $\sin^2 2\theta_{13}$. Fig. 4 shows T2K sensitivity to θ_{13} at 90% confidence level as a function of Δm^2_{23}, assuming no CP violation (δ_{CP} = 0) and normal mass hierarchy.

4 Status of T2K

The first neutrino events detected at the T2K near detectors were observed at the end of November 2009, detected by the on-axis neutrino detector monitor. The event is shown in Fig. 4. Currently data also from the other detectors are being observed.

5 Conclusions

The T2K experiment is a long baseline neutrino oscillation experiment to measure the last mixing angle θ_{13} using the $\nu_\mu \to \nu_e$ appearance channel. The experiment uses the neutrino beam produced at J-PARC which has full power of 0.75 MW and Super-Kamioakande as the far detector 295 km away. The experiment has started to take data in November 2009.

Acknowledgements

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References

[1] Y. Fukuda et al., Nucl. Instrum. Meth. A501, 418 (2003).
[2] C. Amsler et al. (Particle Data Group), Physics Letters B667, 1 (2008) .