NEUTRINO BEAM LINE AT J-PARC

M. Shibata, KEK, Tsukuba, Japan
for T2K collaboration

Abstract

A neutrino beam line for the long baseline neutrino oscillation experiment, T2K (Tokai to Kamioka), is under construction at J-PARC (Japan Proton Accelerator Research Complex) in Tokai. A neutrino beam is produced with a proton beam extracted from the MR (Main Ring) of J-PARC. Construction is proceeding on schedule and commissioning of the beam line will start in April of 2009.

INTRODUCTION

The first goals of T2K experiment are the direct observation of $\nu_\mu \rightarrow \nu_e$ oscillation for the first time and precise measurement of $\nu_\mu \rightarrow \nu_\tau$ oscillation. Now we are constructing the neutrino beam line (Fig. 1) for T2K experiment at J-PARC in Tokai. Proton beams injected from the MR are bent about 80 degrees toward the Super-Kamiokande detector located about 1000 m underground in the Kamioka mine that is 295 km away from Tokai. Pions produced at the target are focused by magnetic horns and muon neutrinos are produced through their decay.

PRIMARY BEAM LINE

Proton beams are injected from the MR in the fast extraction mode. The design intensity of the beam is 3.3×10^{14} protons/pulse, repetition rate is 3.3 s and beam power is 750 kW. One pulse consists of 8 bunches each with 58 ns full width and separated 598 ns. May 2008, 3 GeV proton beam was injected into the MR and captured by RF for 1 s. Acceleration to 30 GeV will start in the end of 2008.

The purpose of the primary beam line is to transport proton beams from the MR to the neutrino production target. It consists of the preparation, arc and final focusing section. In the preparation section, injected beams are tuned to match the acceptance of the arc section. In the arc section, the beams are bent toward Kamioka direction with superconducting magnets. In the final focusing section, the beams are shaped to be suitable for the neutrino target. Beam loss of 750 W, 1 W/m and 250 W are assumed in the preparation, arc and final focusing section, respectively. Beam line components and radiation shielding are designed based on the assumption.

Magnets in preparation section have been installed and aligned. Installation of magnets in arc and final focusing section is going. All system will be completed by the end of November 2008.

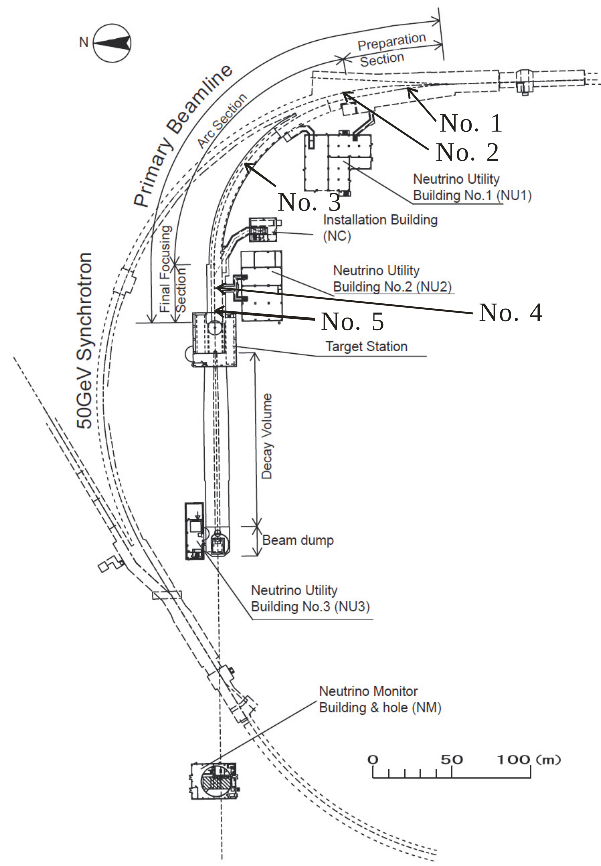

Figure 1: Layout of the neutrino beam line. Numbers (No. 1-5) correspond to the positions of ground sink measurement by the water tube tilt meter.

PROTON BEAM MONITORS

In the primary beam line, four types of proton beam monitors are installed for beam tuning, measurement of beam property and protection of beam line components; 1) beam intensity monitor, 2) beam position monitor, 3) beam profile monitor and 4) beam loss monitor. Installation in the beam line will be finished by the end of September 2008.

Beam Intensity Monitor

A CT (Current Transformer) made of a toroidal coil is employed to measure proton beam intensity by non-destructive way. Its core needs high saturation magnetic flux density since current of full power beam corresponds to 200 A and induces a large magnetic field. In addition, wide frequency response (10 kHz to 50 MHz) is required to measure each bunch shape and whole spill shape with 2% precision. To achieve these requirements, we employed Finemet 3M (Hitachi metal co.) as a core material.

A prototype CT was made to check performance. It was found that frequency response was unstable due to structural weakness of the core. The Finemet core is wound from a thin (18 μm) ribbon and the structure is kept by friction. We decided to make new cores impregnated with epoxy. This technique is widely used and effective to improve structural weakness.

New cores will be delivered by the end of July and CTs will be assembled in August 2008.

Beam Position Monitor

The beam center position is required to be measured within 0.5 mm accuracy to control the neutrino beam direction within 1 mrad. ESMs (Electro-Static Monitor) with four pick up electrodes are employed. ESMs for the preparation and arc section were manufactured. Current calibration shows position resolution of better than 0.3 mm. ESMs for final focusing section are under production and will be delivered by the end of August 2008.

Beam Profile Monitor

The beam profile monitor is required to measure beam center position with 0.5mm precision and width with 0.35 mm precision to control the beam size on the target and to protect the target. SSEMs (Segmented Secondary Emission Monitor) are employed. Each SSEM has 2 planes of segmented titanium foils (5 μm thick) for the vertical and horizontal direction measurement and a HV anode foil to collect electrons. The SSEM also has moving structure to be retracted away from the beam line when not in use to minimize the beam loss and the deterioration of the foils. In the beam test with prototype SSEM, position resolution and beam width precision were measured to be 0.2 mm and 0.3 mm, respectively. SSEMs for preparation and arc section were manufactured. SSEMs for final focusing section are under manufacturing and will be delivered by the end of August 2008.

Beam Loss Monitor

50 beam loss monitors will be installed along the beam line to protect beam line components and reduce radio activation. We employed ion-chambers of Ar + CO_2 (1%) filled E6876-400 (Toshiba). 20 loss monitors have been delivered and rest 30 are under manufacturing and will be delivered in September 2008.

TARGET

The pion production target is made of graphite since high-Z materials are melted within a few spills because of high beam intensity. The size of the target is 26 mm in diameter and 900 mm in length. The total energy deposit by proton beam and secondary particles in the target is estimated to be 60 kJ/spill and the maximum temperature rise reaches 200 K/spill. Therefore the target is cooled by helium gas circulation.

The target was assembled and then helium gas circulation test of 500 hours was performed without any problems. The target will be installed in the beam line by the end of November 2008. Helium gas circulation tuning in the actual condition is planed in January and February 2009.

HORN

An electromagnetic horn system is employed to focus pions generated at the target. It consists of three horns and will be operated with 320 kA peak current generating 2.1 Tesla maximum field. The target is installed inside the first horn inner conductor.

First, second and third horn is completed, under assembling and under final modification, respectively. For first and third horn, 1.3×10^6 and 4.3×10^5 pulse operation tests were successfully finished. Installation in the beam line will be done from July 2008 to January 2009.

TARGET STATION

The target station is a building and facility where the target and horns are placed. In order to avoid activation of the air, the target and horns are in an iron container filled with helium gas. Vicinity of the target and horns will be highly activated and contaminated by radiation hence will never be accessible by hands once beam commissioning starts. Thus a remote controlled maintenance system is equipped.

Construction of the structure was finished in April 2008. The interior and exterior will be completed by the end of June 2008. Installation work will start from July 2008.

DECAY VOLUME

The decay volume is a free space down stream of the horn where pions decay in flight into neutrinos. The length of the decay volume is 94 m. The decay volume is made of iron plates with water cooling pipes to form a rectangular box, is filled with helium gas to reduce pion absorption and is surrounded by concrete shields of 6 m thick. The construction will finish by the end of August 2008.

BEAM DUMP

The beam dump is placed at the end of the decay volume and stops hadrons such as remaining protons and secondary mesons. The dump consists of 14 modules, composed of 7 graphite blocks with cross section of 670 mm × 450 mm and about 1 m with water cooling unit made of aluminium alloy.

All 14 modules have been assembled and overall assembly will be done in September 2008. Installation in the beam line is planed in October 2008.

GROUND SINK

Ground sink was found around the final focusing section of the primary beam line and the target station December 2007. At that time the floor level sunk 10-20 mm from completion. We think it is due to weight of 30000 ton soil added on the beam line during this period. To check further ground sink, a water tube tilt meter was installed in the primary beam line and the floor level is continuously measured. Apparent relation between weight on the beam line and floor level is observed (Fig. 2). Further ground sink will probably happen, because 7000 ton soil will be added by March 2009. However, we decide to align the beam line components based on a survey performed in April 2008, because the expected sink is smaller than acceptable value of 10 mm from the view point of beam optics.

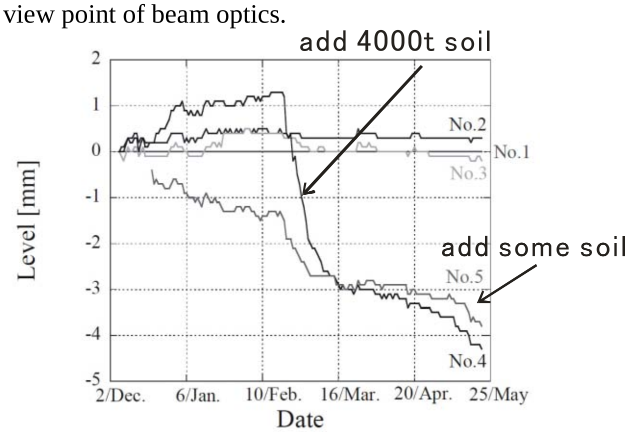

Figure 2: Ground sink measured by the water tube tilt meter. Measured positions are shown in Fig. 1.

SUMMARY

Construction of the neutrino beam line is going on schedule. It will be completed by the end of March of 2009. The first proton beam will be injected at 1st of April 2009. Then the first physics result will be published in summer of 2010.