J-PARC T59 experiment:

Plans and readiness for neutrino beam measurements

from October 2017 to May 2018

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October 6, 2017

Abstract

We had submitted a proposal of a test experiment to develop a new detector with a water target at the T2K near detector hall to J-PARC PAC on April 2014, and the proposal was approved as J-PARC T59. There are several updates on the project after three years from then. Fist, the start time of neutrino beam measurement is changed from December 2015 to October 2017, and the requested neutrino beam is changed from $1x10^{21}$ POT of ν beam to $0.8x10^{21}$ POT of anti-ν beam. Second, the detector configuration is changed. In the original proposal, central neutrino detector are expected to be surrounded by

newly developed muon-range detectors (MRDs), but we will use spare neutrino detectors of the T2K experiment instead of them during neutrino beam measurement from October to December 2017. Construction of the newly developed MRDs is in progress, and they will be installed to the both sides of the central neutrino detector from January to March 2018. Then, we will resume neutrino beam measurements from March 2018 and will take the neutrino beam data until May 2018.

1 Summary of J-PARC T59 experiment

In J-PARC T59, we are developing a new neutrino detector, WAGASCI (WAter Grid And SCIntillator detector) aiming to reduce systematic errors of neutrino cross sections in T2K oscillation analyses. A new idea, a 3D grid-like structure of scintillator bars, shown in Fig. 1, is adapted to detect tracks of charged particles with 4π angular acceptance and larger mass ratio of water to scintillator bars.

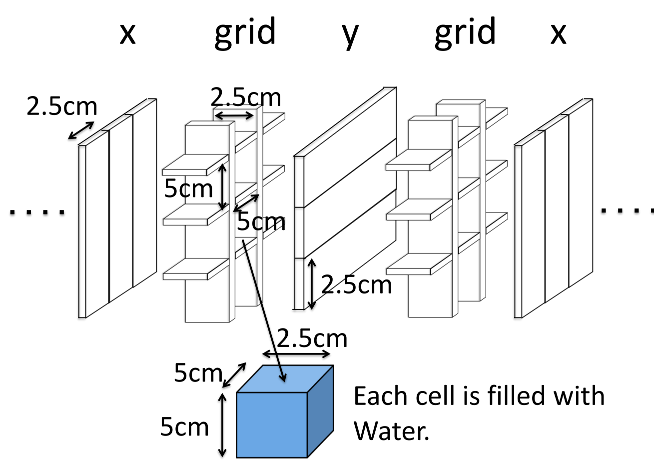

Figure 1: Schematic view of 3D grid-like structure of plastic scintillator bars inside the WAGASCI module.

The goals of the test experiment are to test basic performance of the detector, such as track reconstruction efficiency, track matching among sub-detectors and particle identification capability using neutrino beam data, and confirm capability of measuring neutrino cross sections. In order to achieve the above goals, we will perform neutrino beam measurements on the B2 floor of the T2K near detector hall from October 2017 to May 2018.

2 Neutrino beam measurements from October 2017 to May 2018

2.1 Plans

J-PARC MR will extract its proton beam to T2K neutrino beam-line from October to December 2017, and, from March to May 2018. T2K experiment will produce anti-neutrino beam and will accumulate $\sim 8 \times 10^{20}$ POT data during the above period.

J-PARC T59 will perform neutrino beam measurements on the B2 floor of the T2K near neutrino detector hall during the above period to test basic performances of the WAGASCI detector and new electronics. During the beam measurements from October to December 2017, one WAGASCI module will be placed between spare neutrino detectors of the T2K experiment, INGRID Proton module and INGRID standard module as shown in Fig. 2. Detector location on the B2 floor of T2K near detector hall is shown in Fig. 3. Here, the INGRID Proton module is used as a charged particle VETO detector and, the INGRID standard module is used as a downstream muon detector. We had submitted a proposal to use these spare neutrino detectors for the T59 neutrino beam measurements to the T2K collaboration, and we got an approval from T2K. During the beam measurements from March to May 2018, two side muon-range detector (Side-MRD) modules will be installed on the both sides of the WAGASCI detector, as shown in Fig. 4, to increase angular acceptance for secondary charged particles from neutrino interactions.

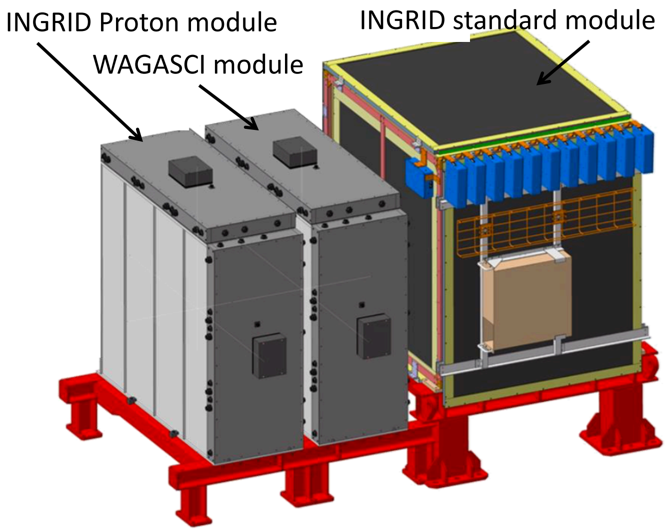

Figure 2: Detector configuration from Oct. to Dec. 2017.

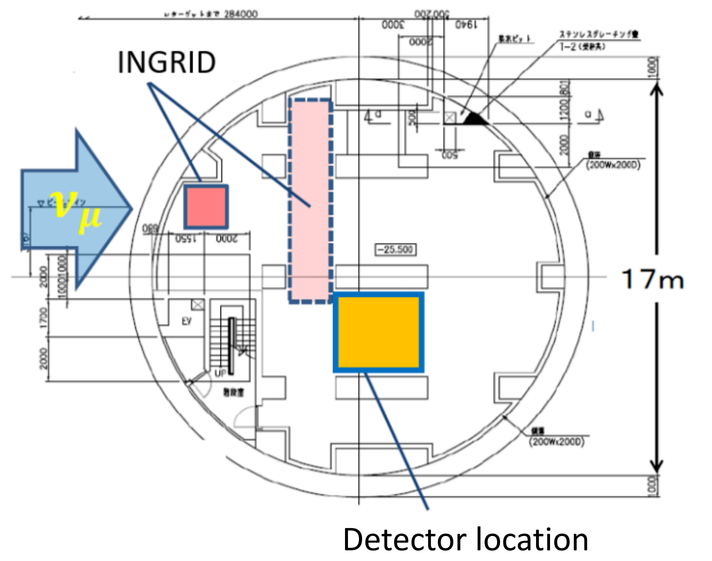

Figure 3: Detector location on the B2 floor of the T2K near detector hall.

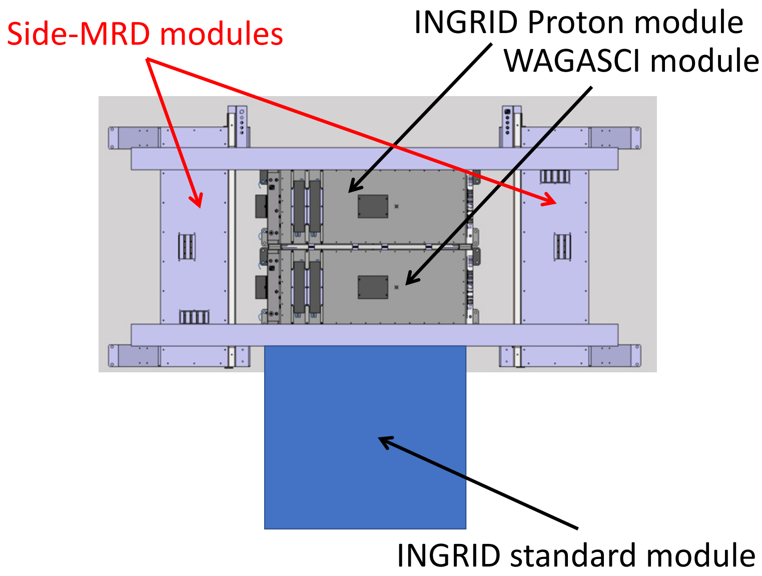

Figure 4: Detector configuration with two Side-MRD modules from Mar. to May 2018.

2.2 Expected number of neutrino candidate events

Expected number of neutrino events in the WAGASCI detector during the above beam period is evaluated with Monte Carlo simulations. Neutrino beam flux at the detector location is simulated by T2K neutrino flux generator, JNUBEAM, neutrino interactions with target materials are simulated by a neutrino interaction simulator, NEUT, detector responses are simulated using GEANT4-based simulation. The neutrino flux at the detector location, 1.5 degrees away from the J-PARC neutrino beam axis, is shown in Figure 5, and its mean neutrino energy is around 0.68 GeV. An event display of the GEANT4-based detector simulation is shown in Figure 6.

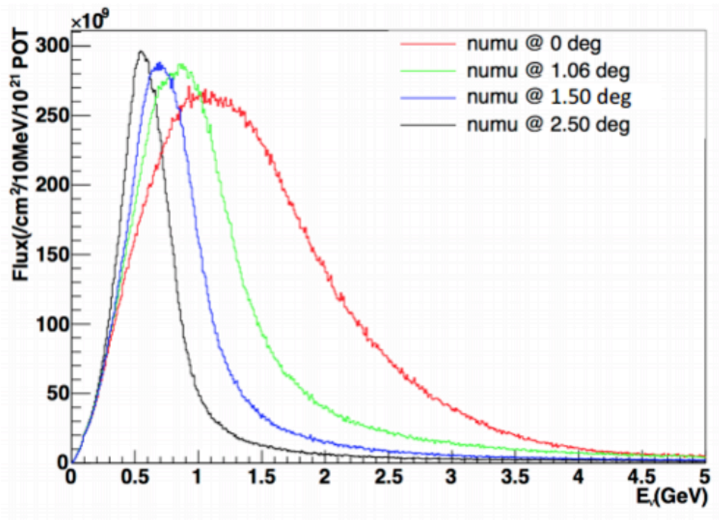

Figure 5: Neutrino beam flux on the beam axis and 1.06 degree, 1.50 degrees (T59 detector location) and 2.5 degrees (T2K off-axis detector location) away from the axis.

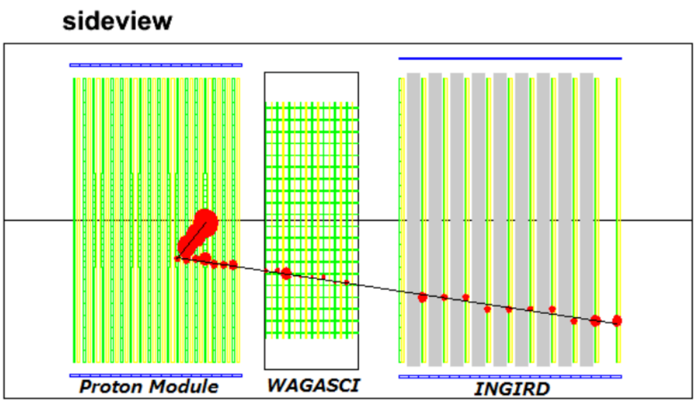

Figure 6: Event display of a neutrino event in the GEANT4-based detector simulation.

To perform the detector performance test, the following event selections are applied to the data. First, track reconstructions are performed in the WAGASCI detector, and the reconstructed vertex is required to be inside a defined fiducial volume, 80 x 80 x 32 cm^3 region at the center of the detector, to reduce contamination from external backgrounds. Second, at least one charged particle is required to reach to INGRID standard module or Side-MRD modules, and it makes more than two hits in these sub-detectors. With the event selection, expected numbers of the neutrino-candidate events during the beam period are summarized in Table 1. Using the data, we will test the detector performance with ~3% statistical uncertainties.

Table 1: Expected number of the neutrino-candidate events after the event selection with anti-neutrino-mode beam corresponding to 8×10^{20} POT.

	CCQE anti-nu	CC-other anti-nu	NC anti-nu	neutrino	Total
# of selected events	909	897	30	720	2556

3 Readiness for the beam

3.1.1 WAGASCI module (and INGRID modules)

The WAGASCI module is mainly composed of 1280 plastic scintillator bars and a surrounding water tank filled with 0.7 ton water. The water tank is constructed by welding stainless steel plates, is sized as 460x1250x1250 mm^3 as shown in Figure 7, and weights 0.5 ton. The plastic scintillator bars form a three-dimensional grid structure with 50x50x25 mm^3 cells. Each scintillator bar is sized as 1020x25x3 mm^3 including reflector part. The fraction of water mass in the fiducial volume is about 79%. Scintillation light is collected by wave length shifting fibers, Y-11 (non-S type) with a diameter of 1.0 mm produced by Kuraray. The fiber is glued by optical cement in a groove on the surface of the scintillator bar. 32 fibers are gathered together by a fiber bundle at edge of the module, and lead scintillation light to a 32-channel arrayed Multi-Pixel Photon

Counter (MPPC), S13660(ES1), produced at Hamamatsu Photonics. For each MPPC channel, 716 pixels of APD are aligned in a shape of circle of which diameter is 1.5 mm.

Construction of the WAGASCI detector has been completed at the neutrino assembly building in J-PARC, and it was installed to the B2 floor of the T2K near detector hall in August, 2017 with the INGRID Proton module and the INGRID standard module as shown in Figure 8.

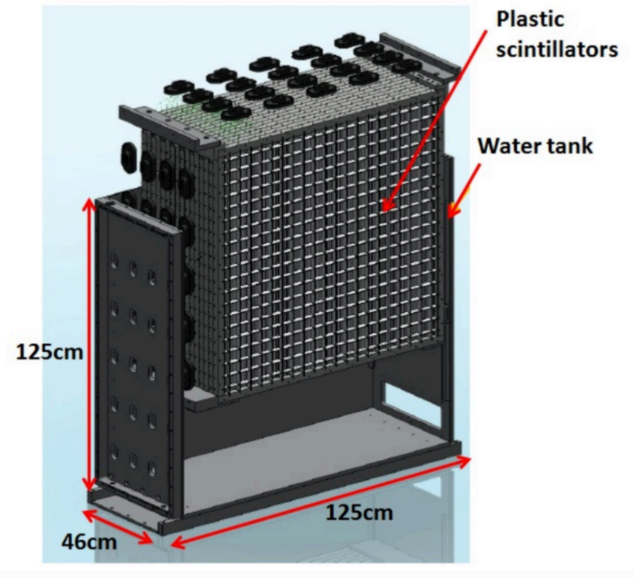

Figure 7: Inner structure of the WAGASCI module.

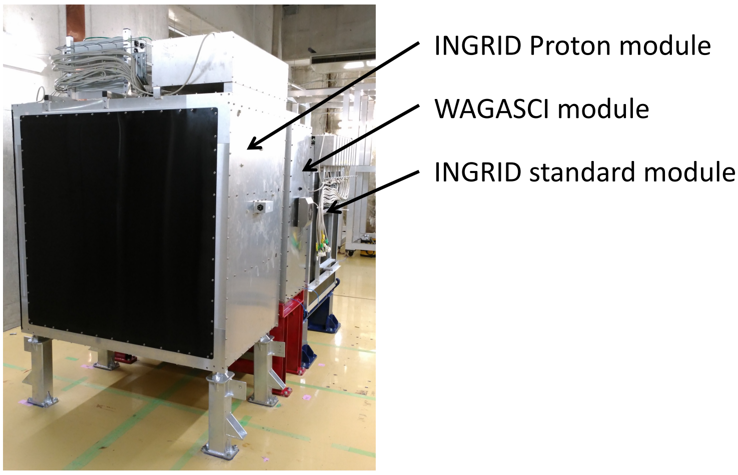

Figure 8: T59 sub-detectors after the installation to the B2 floor of the T2K near detector hall in August 2017.

3.1.2 INGRID standard module and INGRID Proton module

The INGRID standard module and the INGRID Proton module are neutrino detectors of the T2K experiment.

The INGRID standard module is composed of iron plates and of scintillator bars for tracking secondary particles from neutrino interactions. T2K experiment has 14 of the INGRID standard modules on the beam axis, and two extra INGRID standard modules which are not used for neutrino beam monitoring now.

INGRID Proton module is composed only with scintillator bars in its tracking region. It was installed at the neutrino beam axis on the SS floor of the T2K near detector hall in 2010, and have been used for neutrino cross section measurements.

After getting the approval from T2K to use them, we moved one of the extra INGRID standard modules and the INGRID Proton module to the B2 floor of the T2K near detector hall in August 2017.

3.1.3 Electronics and DAQ

As front-end electronics of the WAGASCI module and the Side-

MRD modules, a Silicon PM Integrated Read-Out Chip (SPIROC) is adopted. SPIROC is a 36-channel auto-triggered front-end ASIC, and is produced by OMEGA/IN2P3. A Front-end electronics board, Active Sensor Unit (ASU), has been developed with the SPIROC2D chip, which is the latest version of SPIROC. Each readout board is designed to read 32 MPPCs. Our data acquisition system, including back-end boards, is independent of T2K near detector DAQ system, and has originally been developed for ultra-granular calorimeters for the International Linear Collider (ILC) [I]. To synchronize the DAQ system to J-PARC neutrino beam, pre-beam triggers, beam triggers and spill numbers are processed at the back-end boards. The events of the WAGASCI module and the Side-MRD modules will be off-line matched with those of the INGRID Proton module and the INGRID standard module by using the spill number information.

All the back-end boards and 40 (plus a few spares) of the ASU boards for the WAGASCI module were produced, and commissioning of them is in progress on the B2 floor of the T2K near detector hall. 22 (plus a few spares) of the ASU boards for the Side-MRD modules are in production and will be completed by the end of 2017.

3.1.4 Side-MRD modules

Two Side-MRD modules will be constructed by the end of January 2018. Each Side-MRD module is composed of iron plates and scintillator bars for tracking secondary particles from neutrino interactions. Support structure of the Side-MRD module mainly consists of 11 steel plates of which dimensions are 1800x1610x30 mm^3, is sized as 2236x1630x975 mm^3 as shown in Figure 9, and weights ~8 ton. 80 scintillator bars are install in one Side-MRD module, and each scintillator bar is sized as 1800x200x7 mm^3 including reflector part. Scintillation light is collected by wave length shifting fibers, Y-11 (S type) with a diameter of 1.0 mm produced by Kuraray. The fiber is glued by optical cement in a S-shape groove on the surface of the scintillator bar as shown in Figure 10. Two optical connectors are attached to either end of the fiber, and scintillation light is lead to two MPPCs, S13081-050CS(X1), produced at Hamamatsu Photonics. For each MPPC, 667 pixels of APD are aligned in a shape of square 1.3 mm on a side.

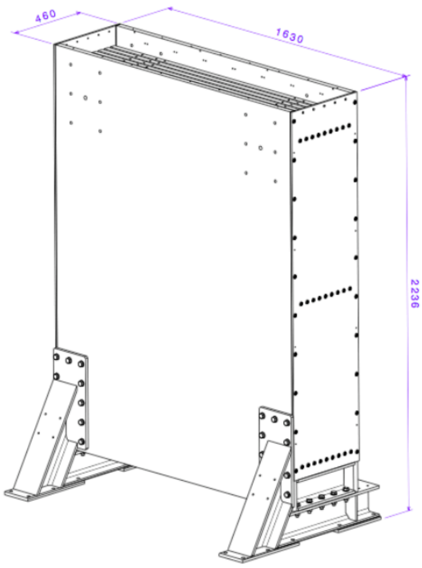

Figure 9: Support structure of the Side-MRD module

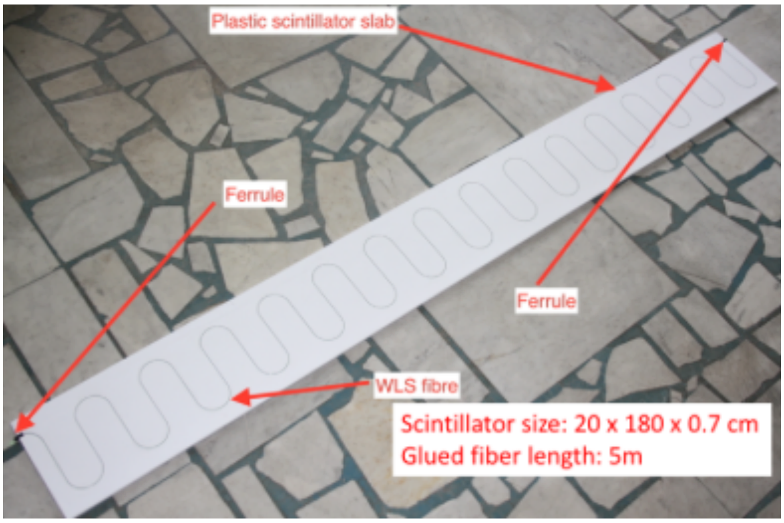

Figure 10: Scintillator bar of the Side-MRD modules

Construction of scintillator bars of the Side-MRD modules had been completed in Russia, and they were transported to Yokohama National University in July 2017. Construction of Side-MRD modules will be done from November 2017 to January 2018 at Yokohama National University, then they will be transported to J-PARC and will be installed to the B2 floor of the T2K near detector hall before staring the T2K beam in March 2018.

4 Summary

J-PARC T59 will perform neutrino beam measurements using the WAGASCI detector, the INGRID Proton module and the INGRID standard module from October to December 2017. Then, two Side-MRD modules will be installed on the both sides of the WAGASCI detector to increase angular acceptance for secondary charged particles from neutrino interactions. We will resume neutrino beam measurements from March 2018 and will take the neutrino beam data until May 2018. Using the data, we will test the detector performance with ~3% statistical uncertainties.

References

I. F. Gastaldi, R. Cornat, F. Magniette and V. Boudray, A scalable gigabit data acquisition system for calorimeters for linear collier, in proceedings of TIPP2014, PoS 193, (2014).