EFFECT OF THE EARTHQUAKE ON THE J-PARC NEUTRINO FACILITY

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Abstract

The J-PARC neutrino facility was constructed for the T2K experiment based on the result of a long-baseline GPS survey between the J-PARC site and the Kamioka site. The position and the direction of the proton beam at the target was measured by beam monitors. Owing to the good accuracy of the beam monitors, we observed small periodical movement of the beam, which can be attributed to the tide effect. The neutrino beam had been delivered stably until it was interrupted by the earthquake on March 11, 2011. Some displacements of the beamline components were observed by the surveys done after the earthquake. The results of the surveys and the plan of realignment will be discussed.

INTRODUCTION

The neutrino facility was constructed at J-PARC for the T2K (Tokai to Kamioka) long-baseline experiment[1,2], which sends a high intensity neutrino beam produced at J-PARC to Super-Kamiokande. Since the beam direction is one of important points of the experiment, a long-baseline GPS survey between the J-PARC site and the Kamioka site was performed in 2001. The physics requirement for the beam direction is 1mradian. The facility was constructed based on the GPS survey of which accuracy is the order of μradian, which is good enough for the purpose.

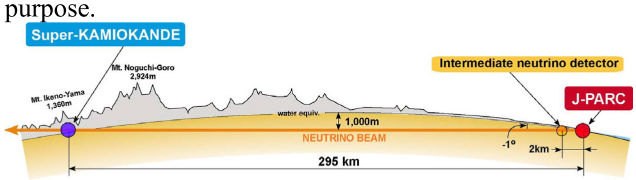

Figure 1: Overview of the T2K experiment.

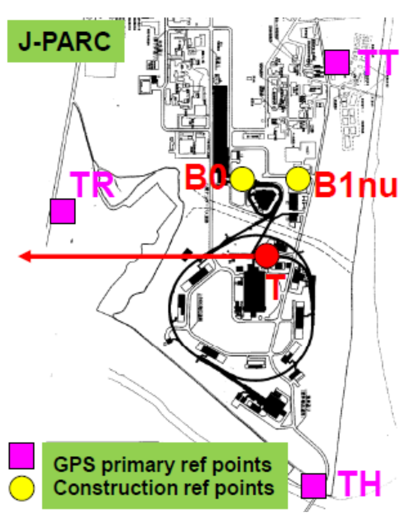

Figure 2: Survey reference points in J-PARC.

The neutrino facility consists of the primary beamline, secondary beamline which is further subdivided into the target station, decay volume, the beam dump and the muon pit, and the neutrino monitor building. The primary beamline is separated by two expansion joints, one in the arc section and the other in the final focusing section. The downstream part of the final focusing section and the secondary beamline from the target station through the muon pit is constructed as one structure. The neutrino monitor building is built separately.

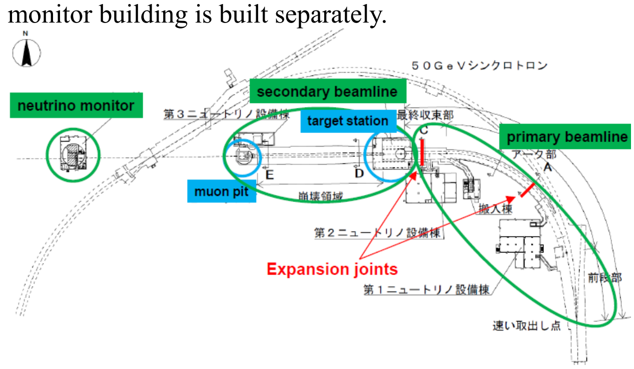

Figure 3: Neutrino facility at J-PARC.

Proton beam is transported through the primary beamline and hits the graphite target inserted into the 1st horn magnet which is located at the target station. Produced pions are focused into the forward direction by the three-horn system in the target station and decay into a pair of muon and neutrino during the fly in the decay volume.

NEUTRINO BEAM DELIVERY BEFORE THE EARTHQUAKE

Proton beam is monitored by various beam monitors including profile monitors (SSEM). The hit position of the proton beam at the target has been monitored to be well centered and stable within ~1mm.

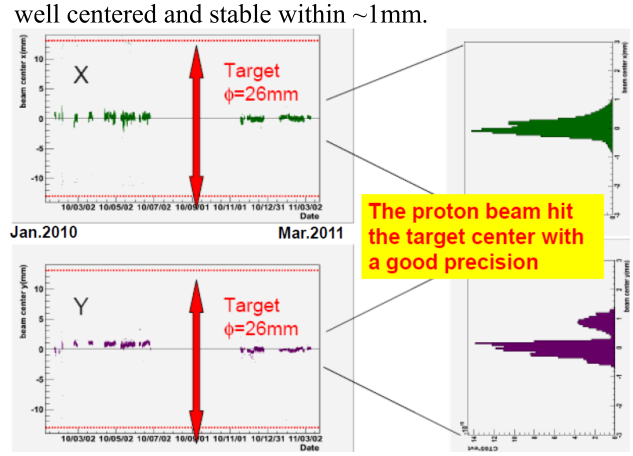

Figure 4: History of beam hit position at the target.

Since the muon and the neutrino beams come from the pions originated from the target, the profile measurement of the muon beam or the neutrino beam gives the direction of the neutrino beam. It has been enough stable within 1mrad till the beam stop by the earthquake.

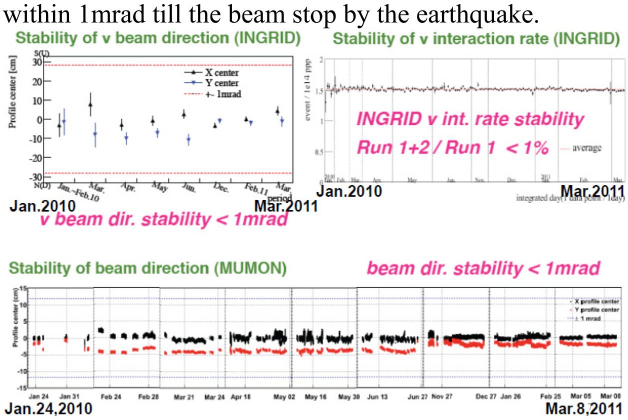

Figure 5: Beam stability measured by the neutrino monitor (top figure) and the muon monitor (bottom figure).

When we look at the beam position data in more detail, we found a periodical change, which is consistent with the tide effect. This is observed owing to the high accuracy beam monitors and this does not give any harm to the experiment.

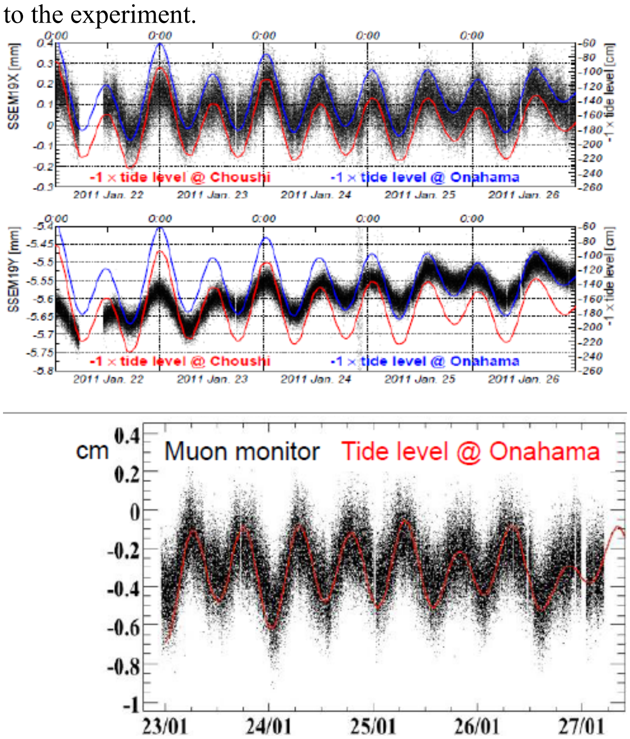

Figure 6: Beam position time dependence measured by SSEM (top figure) and by muon monitor (bottom figure). The tide data of Onahama and/or Choushi are overlaid.

SURVEY RESULTS AFTER THE EARTHQUAKE

Displacement and Rotation of the J-PARC Site

According to the GPS results of GSI (Kokudo Chiri-In), crustal movement of about 5.3m and 0.3m to east was observed at Ojika and Choushi, respectively. Since these points are apart by about 280km, there can be a rotation of about 0.02mrad at J-PARC.

We performed a GPS survey of the three primary GPS reference points of J-PARC after the earthquake. Since a GPS survey gives a vector between two points, the absolute rotation is obtained by only this survey. About (0.04±0.005)mrad clockwise rotation of the primary GPS reference points was observed. The neutrino beamline was also GPS surveyed and a rotation of (0.03±0.005)mrad was observed, which can be neglected for the T2K experiment.

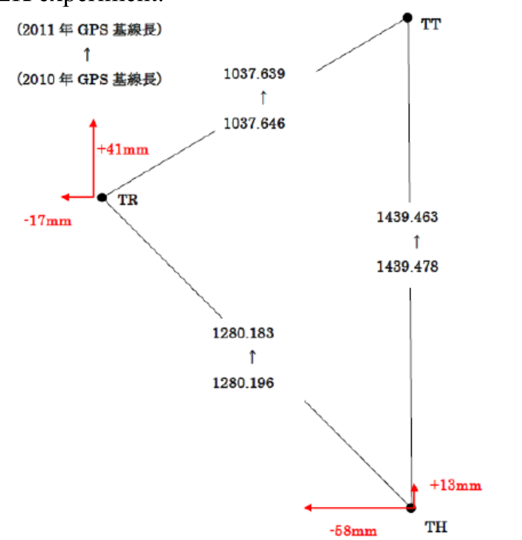

Figure 7: Movement of the primary GPS reference points with respect to TT.

2011長基線解析 2001年成果 震災前後比較 Koukyou zahyou in unit of m

	(B)	(A)	(B)-(A)
X	50779.644	50779.805	-0.161
Y	69322.500	69321.594	0.906
H	33.894	34.250	-0.356

TT moved south by 16cm,east by 91cm and down by 36cm by the quake (sys err~30cm)

Figure 8: Displacement of the J-PARC site relative to the Kamioka site.

Displacement of the J-PARC site relative to the Kamioka site was examined. By combining our J-PARC

GPS survey data with the GSI data of the GPS-based control stations around Kamioka, namely Toyama, Miyakawa and Kamitakara, it was shown that the J-PARC site moved east by ~91cm, south by ~16cm and down by ~36cm. We estimate the systematic error of this calculation to be about 30cm. This displacement is not a problem for the experiment.

Displacement of the neutrino facility

Secondary Beamline

Displacement of the reference points of the secondary beamline was measured by a GPS-based survey. As is shown in Fig.9, the displacement relative to the whole J-PARC site was less than 10mm. Vertical displacement was measured by a separate survey, which showed the displacement to be less than a few mm. These results are good enough for the experiment.

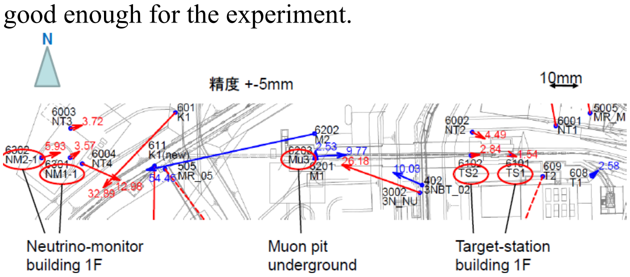

Figure 9: Displacement of the survey points downstream of the target station relative to the whole J-PARC site. Secondary beamline reference points are red circled.

Primary Beamline

Displacement of the magnets in the primary beamline was measured using a laser tracker. As is shown in Fig.10, about 10mm displacement was observed at maximum in the horizontal direction. Vertical displacement was measured by a separate survey, which showed displacement of about 4mm at maximum. Since these displacements are too large than the requirement of 0.3mm in the primary beamline, we will realign the beamline components.

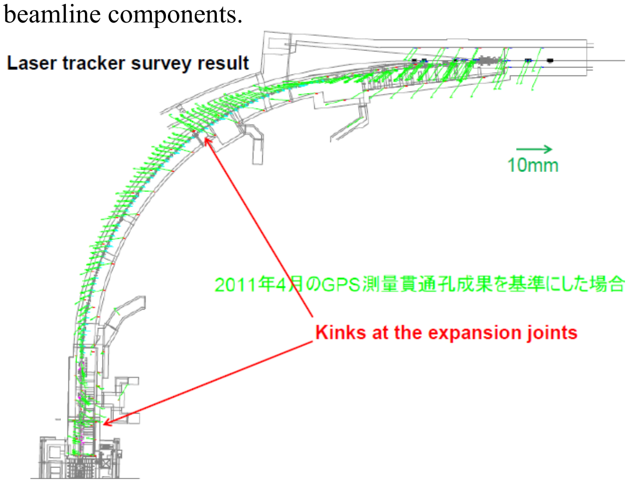

Figure 10: Displacement of the reference points and the magnets in the primary beamline by a laser tracker.

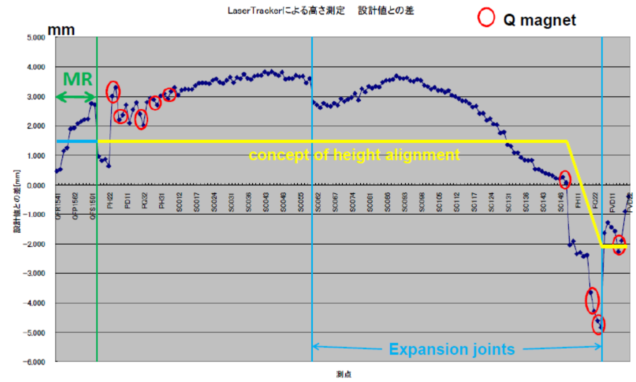

Figure 11: Vertical displacement of the magnets in the primary beamline. The magnets will be realigned to the yellow line, which smoothly connects the neutrino beam level to the realigned MR beam level.

We have another vertical-displacement data using a set of water-tube tiltmeters. The location of the water-tube tiltmeters are indicated in Fig.12. The data is available since December 2007, when the primary beamline was almost completed. At the beginning, sink of up to about 10mm was observed at the latter half of the primary beamline. They had been stable since summer of 2009. Sink of about 3.5mm at maximum was observed at the earthquake, in agreement with the vertical survey mentioned above.

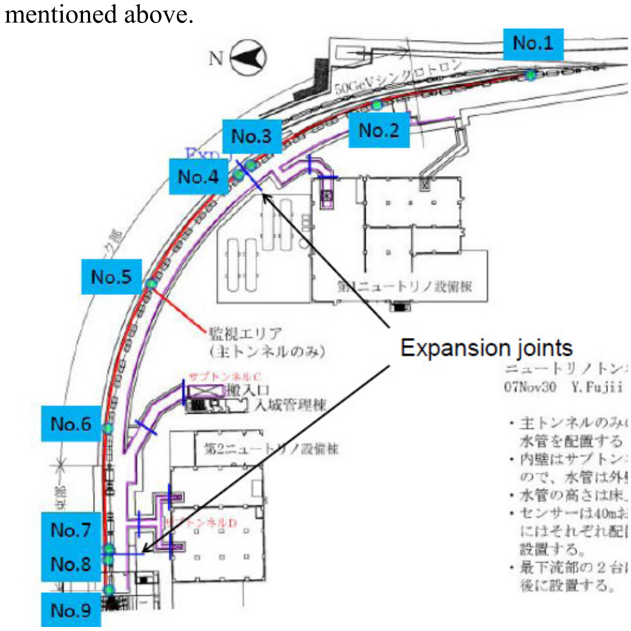

Figure 12: Layout of the water-tube tiltmeters.

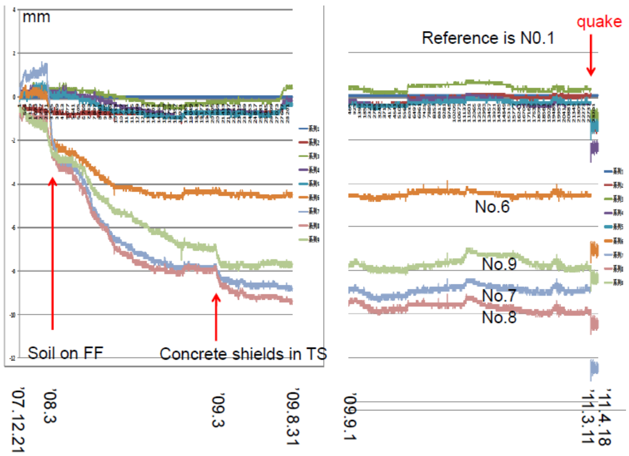

Figure 13: Data of the water-tube tiltmeters.

RECOVERY SCHEDULE

In the primary beamline, we will realign 15 normal conducting magnets out of 21 and all 14 doublets of the superconducting magnets starting this August. It will be finished at the middle of October. After that or in parallel, works on the beam monitors and vacuum will be done.

In the secondary beamline, the 1st horn is currently being examined and tested for damage by the earthquake, and may be replaced by a spare one. The 2nd and the 3rd horns will be checked and be realigned.

The neutrino beamline will be ready by the end of November 2011.

SUMMARY

The J-PARC neutrino facility was constructed based on the long-baseline GPS survey between Tokai and Kamioka, which was performed in 2001. The neutrino beamline had been working well and a stable beam had been delivered until it was interrupted by the earthquake on March 11, 2011. A tide effect was observed in the beam position data, which confirmed the good accuracy of the beam monitors.

By the earthquake, the neutrino beamline rotated about 0.03mrad and moved about 1m relative to the Kamioka site. This movement can be neglected for the experiment. At the target station and downstream, no displacement larger than 10mm was observed. This is good enough for the experiment. In the primary beamline, displacement of about 10mm at maximum was observed. Especially, large displacements were observed at the expansion joints. These displacements will affect the experiment. Therefore we will realign the beamline components.

The neutrino beamline will get ready by the end of November to accept proton beam in December.

REFERENCES

[1] K. Abe et al. (T2K Collaboration), (2011), accepted for publication in Nucl. Instrum. Methods, article in press, doi: 10.1016/j.nima.2011.06.067, arXiv:1106.1238 [physics.ins-det].

[2] K. Abe et al. (T2K Collaboration), (2011), Phys. Rev.Lett. 107, 041801 (2011), arXiv:1106.2822 [hep-ex].