T2K Beam Operation Summary
(earthquake recovery and beamline survey)

NBI 2012
T. Ishii (KEK)
for the T2K beam group
J-PARC Neutrino Beam Facility
Data accumulation

Delivered POT to Neutrino Beam line (MR-FX)

- Apr. 2009  First beam
- Jan. 2010  Physics run (Run1) started including the near detectors
- July-Oct.2010  Summer maintenance period
- Nov.2010  Run2 started
- Mar.2011  Stop due to the earthquake, $1.43 \times 10^{20}$ POT for physics accumulated by then
- Apr.-Dec.2011  Recovery from the earthquake
- Dec.2011  Horn power supply broken
- Mar.2012  Run3 started using old PS (with lower horn current in March)
- Apr.-Jun.2012  Run3 with nominal horn current, $3.01 \times 10^{20}$ POT for physics accumulated so far ($8 \times 10^{21}$ POT approved)
- Oct.2012  Run4 started and 200kW continuous operation achieved

- $6 \nu_e$ events (indication)
- $11 \nu_e$ events (evidence)

- Run1
- Run2
- Run3
- Maintenance
- Horn power supplies broken
- EQ recovery
- Earthquake

190kW
145kW
200kA
Beam-line Problems & Main Works

• 2010
  – Radiation in exhaust at NU3/TS restricted the beam power. → Ishida’s talk
  – Relocation of underground control panels of air ventilation / water circulation at TS to avoid attack of fast neutrons to PLCs

• 2011
  – Earthquake (Mar.11, 2011)
  – Realignment of the primary-beamline magnets → This talk
  – Repair of submerged components of the primary beamline
  – The first operation of remote maintenance of irradiated Horn-3 → Sekiguchi’s talk
  – Realignment of horns in the vessel → Sekiguchi’s talk
  – New horn power supply damaged during test operation (Dec.22, 2011) → Sekiguchi’s talk

• 2012
  – Rapid re-installation of old horn PS → Sekiguchi’s talk
  – Upgrade of TS air ventilation to reduce radiation in the exhaust. → Ishida’s talk
Summary of beam operation in Spring 2012

- Allocated beam to MR user: 1853hrs ~80% of total time 97days
- Running efficiency: ~70% = physics run (1310h)/allocated (1853h)
- Acc. trouble ~20%: LINAC klystron PS down, MR injection kicker down, MR BM down, FX kicker down, high radiation in MR machine room limited the beam power
- Nu trouble ~4.2%: horn PS down, cryo. of magnet stopped due to a thunder storm, horn cooling water’s quality deteriorated due to air contamination and intense beam → performed ion exchange of the cooling water
Earthquake damage and recovery

- The earthquake occurred on Mar. 11, 2011
- Large displacement everywhere in J-PARC
  - Beam-line components were displaced
- Ground collapse at some places
- Cracks in buildings and tunnels
  - Cracks in the MR tunnel resulted in a water leak and some of cables and monitors were submerged
- Electricity, network, cranes, air conditioning, ventilation, cooling water and drainage stopped or got damaged
- Everything necessary for beam operation were recovered before the scheduled beam on Dec. 24, 2011
Recovery around Target Station
Displacement data due to the earthquake by GSI (geospatial information authority of Japan)

Most concern was the direction and baseline change. We performed a long-baseline GPS survey.
  Direction change $< 0.001$ mrad
  Distance change $= +0.9$ m
Effect of these changes on the oscillation analysis is negligible.

More concern is the rotation of the J-PARC area. (next page)
Movement of the J-PARC GPS Primary Reference Points

GPS gives a vector between two points. Hence it gives the direction angle. Here, we assume TT has not moved.

Survey result
The GPS primary reference points seem to have rotated clockwise by 0.04mrad (accuracy ~0.005mrad). This is still negligible for T2K.
GPS-based survey result in April, 2011
Movement from Summer, 2010
Movement from Summer, 2010 around the neutrino beam line

GPS-survey result (accuracy is +5mm)

NU3 building moved a lot

Neutrino-monitor building 1F

Muon pit underground

Target-station building 1F

Level-survey result (accuracy is +1mm)

Relative alignment is OK for the experiment
NU3 and Muon pit

Joint was repaired in Summer 2012

Deformed Old rubber

New rubber
Displacement of the primary beamline magnets

Magnets were surveyed by a laser tracker.

Kinks at the expansion joints

The tunnel moved differently at upstream and downstream of each expansion joint. We need magnet realignment.
Primary-beamline magnets were realigned.

Realignment was done based on the May 2011 survey results. The beam orbit was also redesigned.

--- $\Delta R$ : horizontal direction
--- $\Delta H$ : height

TS is 3mm lower than FF.
Horns and target

- Horns were realigned at the markers on the support module.
- The alignment was confirmed remotely by using a laser and cameras.

On Dec. 22, during final operation test, horn power supply was broken

- Several IGBTs to switch charging capacitors were burst
- We changed to the old power supply, which had been used for K2K and at beginning of T2K

→ Sekiguchi-san’s talk for detail
Summary

• The T2K neutrino beam line suffered serious damage from the earthquake in March 2011
• Long-baseline and local surveys were done to confirm the beam direction and alignment of the beam line components
• Everything necessary for beam operation were recovered before the beam resumed in Dec. 2011
• The new horn PS was broken and we ran with the old PS in Spring 2012
• We achieved the beam power of 190kW and ~70% running efficiency in Spring 2012
• 200kW continuous operation was achieved in this month and we are trying to increase the power and efficiency