

How J-PARC recovered from the big earthquake

KEK / Fujio Naito

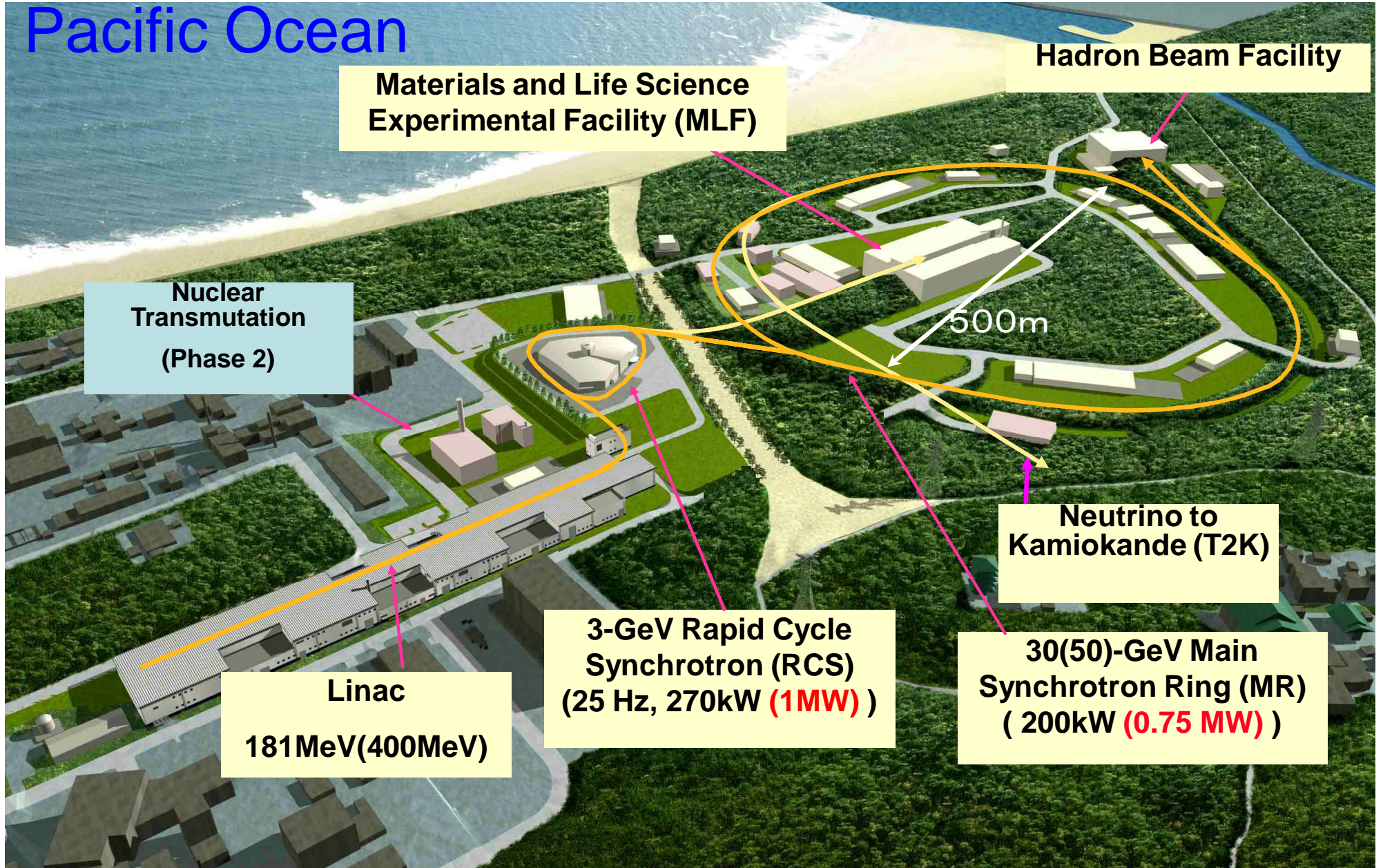
Outline

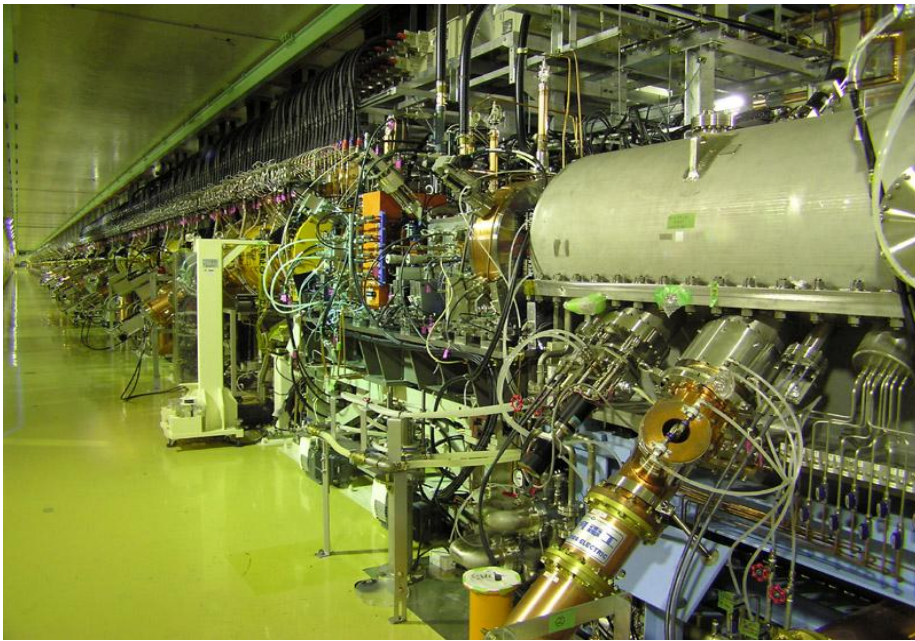
- About J-PARC
- The earthquake
- Damage on J-PARC
- Recovery plan
- Beam study results
- Summary

J-PARC

(Japan Proton Accelerator Research Complex)

Joint Project between KEK and JAEA





Linac (E:181MeV-> 400MeV (2013)
L:120m -> 250 m)



Rapid Cycle Synchrotron (RCS)
(3GeV, 25Hz, ϕ 100m)

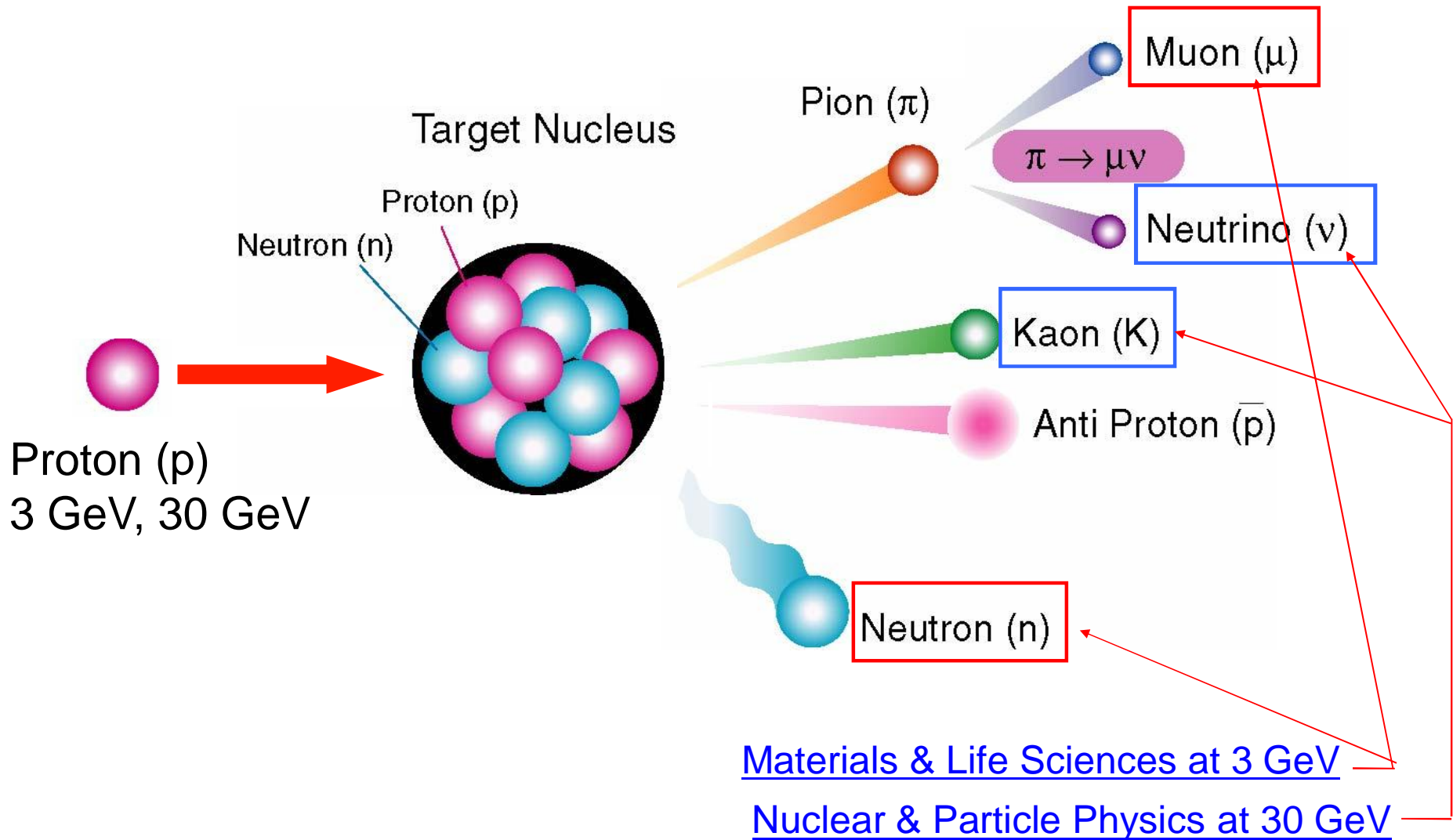


Main Synchrotron Ring (MR)
(30 (50) GeV, Period: 2.6~6.0sec, ϕ 500m) :



v-beam line (Super Conducting Mag.)

Goals at J-PARC



- Design beam power : 1MW for MLF & 750kW for T2K
(current beam power is 0.2 MW for both experiments)

Beam was provided to all users from April 2009.
Users run of JFY2010 was stopped as scheduled at 7:00 on March 11,
2011.

Just linac group continued the beam study in the daytime.....

Disaster we had in March 2011

1. **The biggest earthquake** (Mar., 11, 14:46)
2. Tsunami near J-PARC (Mar., 11, 16:52)
3. First hydrogen explosion of the nuclear power plant in Fukushima (Mar., 12, 15:36)

The Great East Japan Earthquake

March 11, 2011

1st 01:54

2nd 06:45

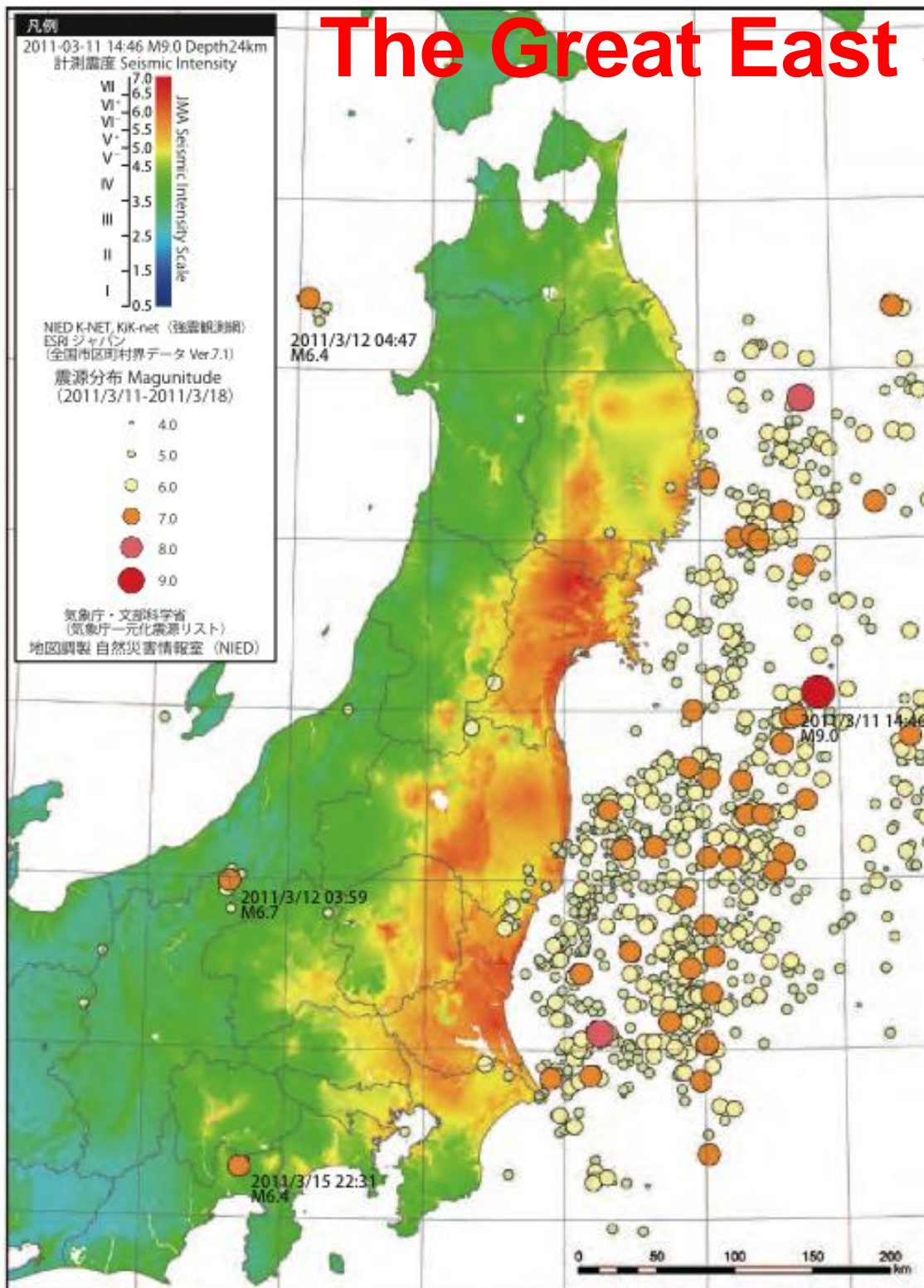
3rd 07:44

4th 14:46

.

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78th 23:56



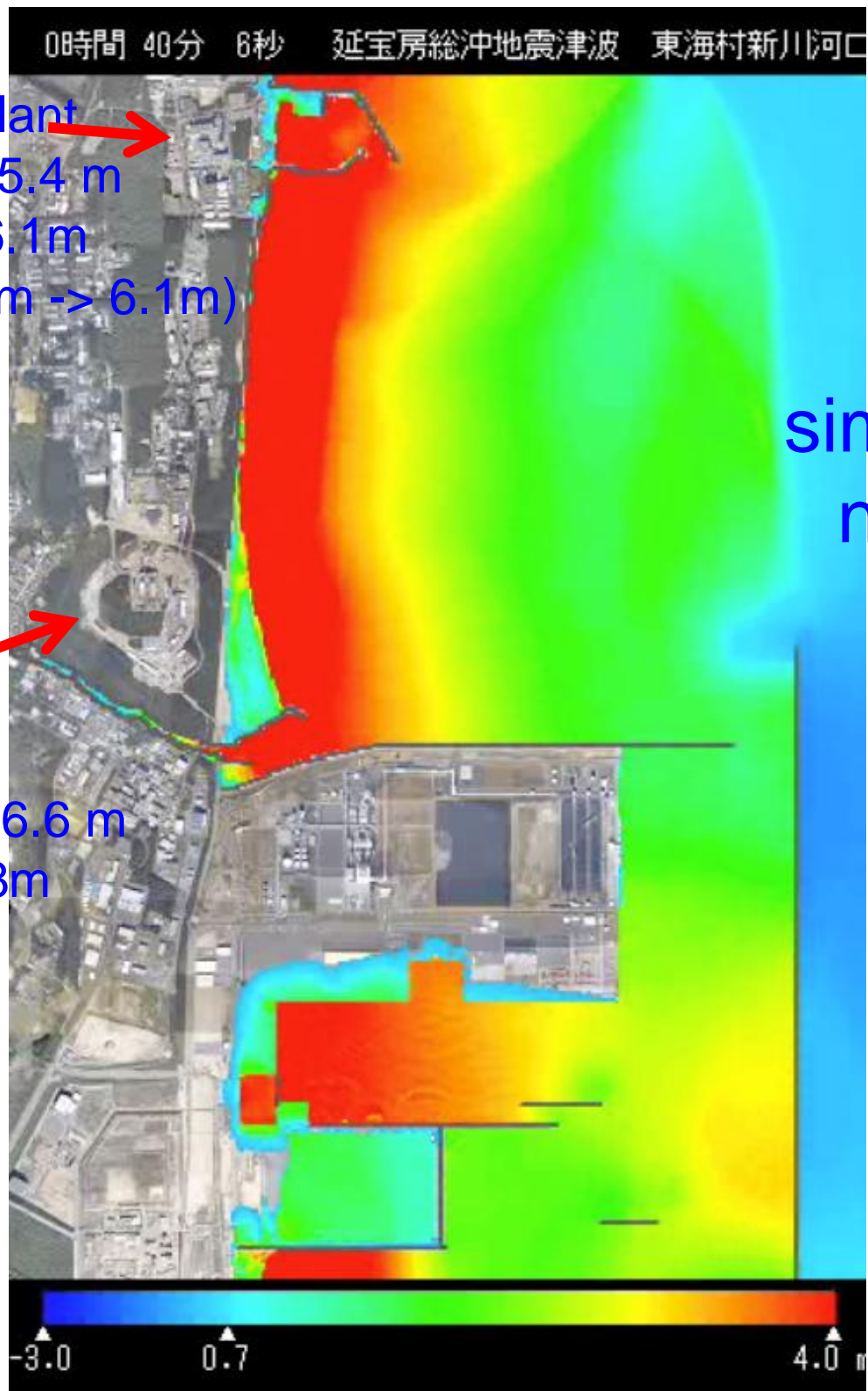
Seismic intensity map of the main shock on March 11, 2011, and epicenter distribution from March 11 to 18, 2011.

by National Research Institute for Earth Science and Disaster Prevention (NIED)

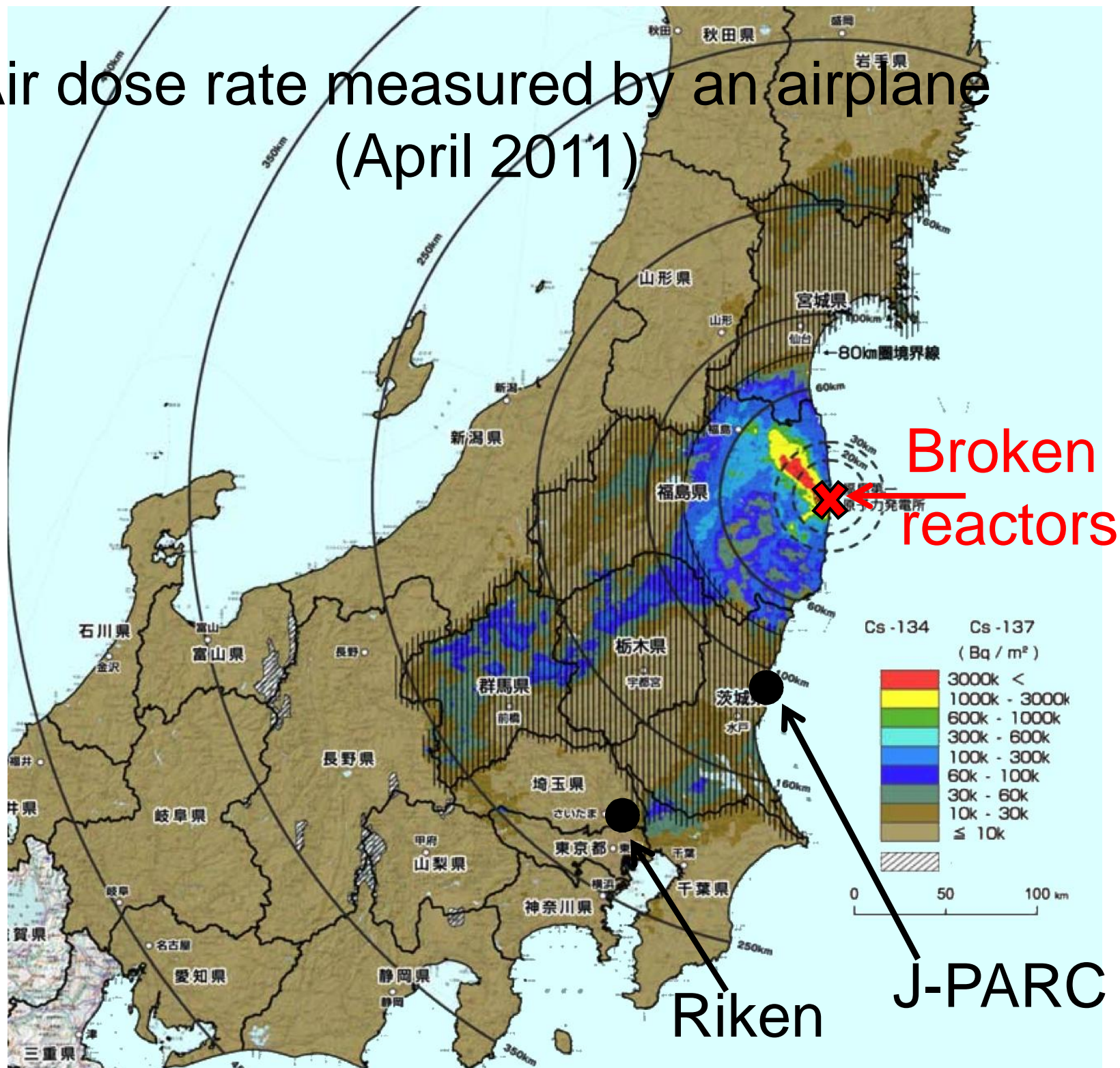
Tokai nuclear power plant
Tsunami max height : 5.4 m
Tsunami Protection : 6.1m
(On Mar. 09 2011, 3.3m -> 6.1m)

J-PARC
Tsunami max height : 6.6 m
Tsunami Protection : 8m

Tsunami simulation result near J-PARC



Air dose rate measured by an airplane (April 2011)

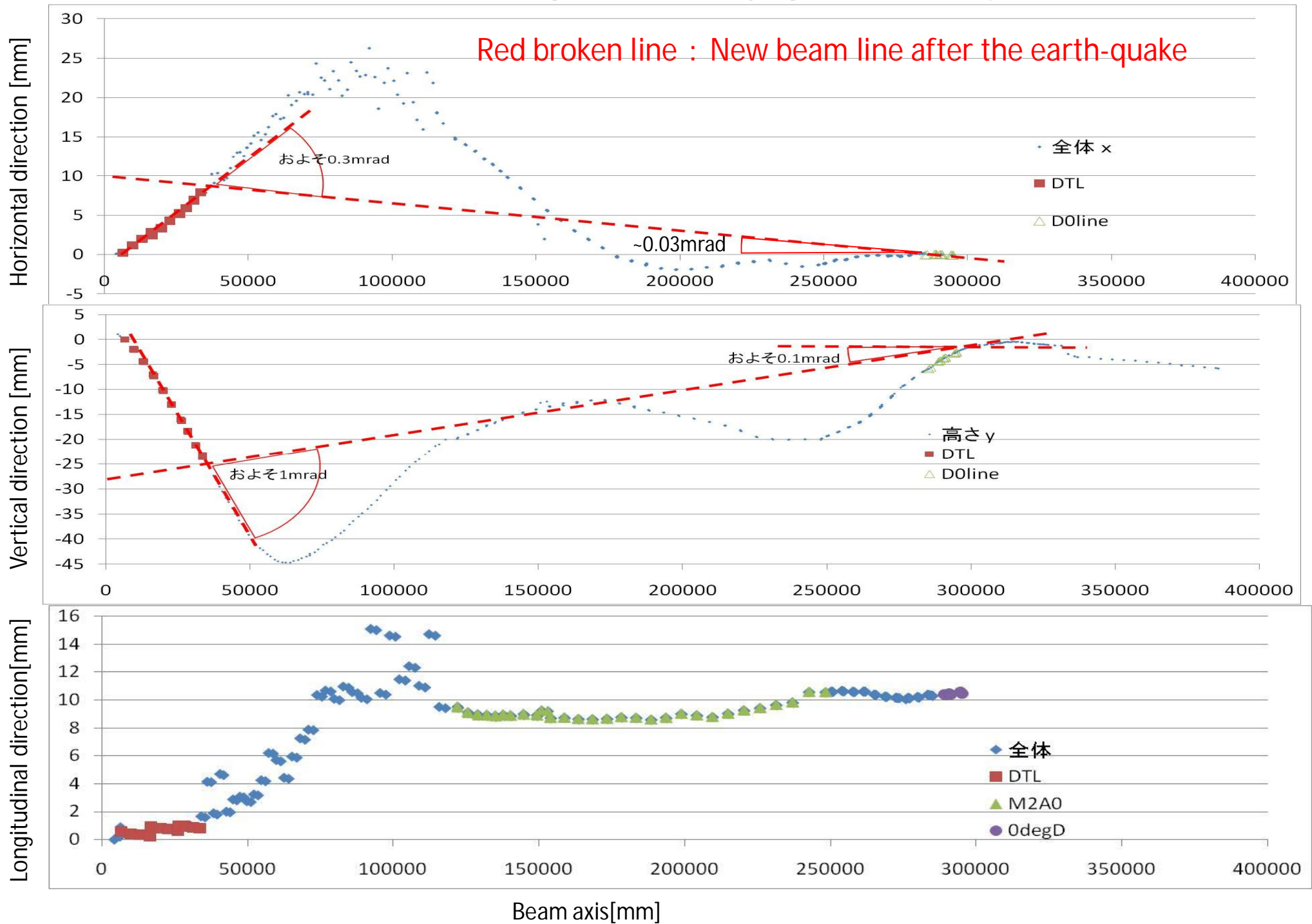


Linac Tunnel on March 24, 2011



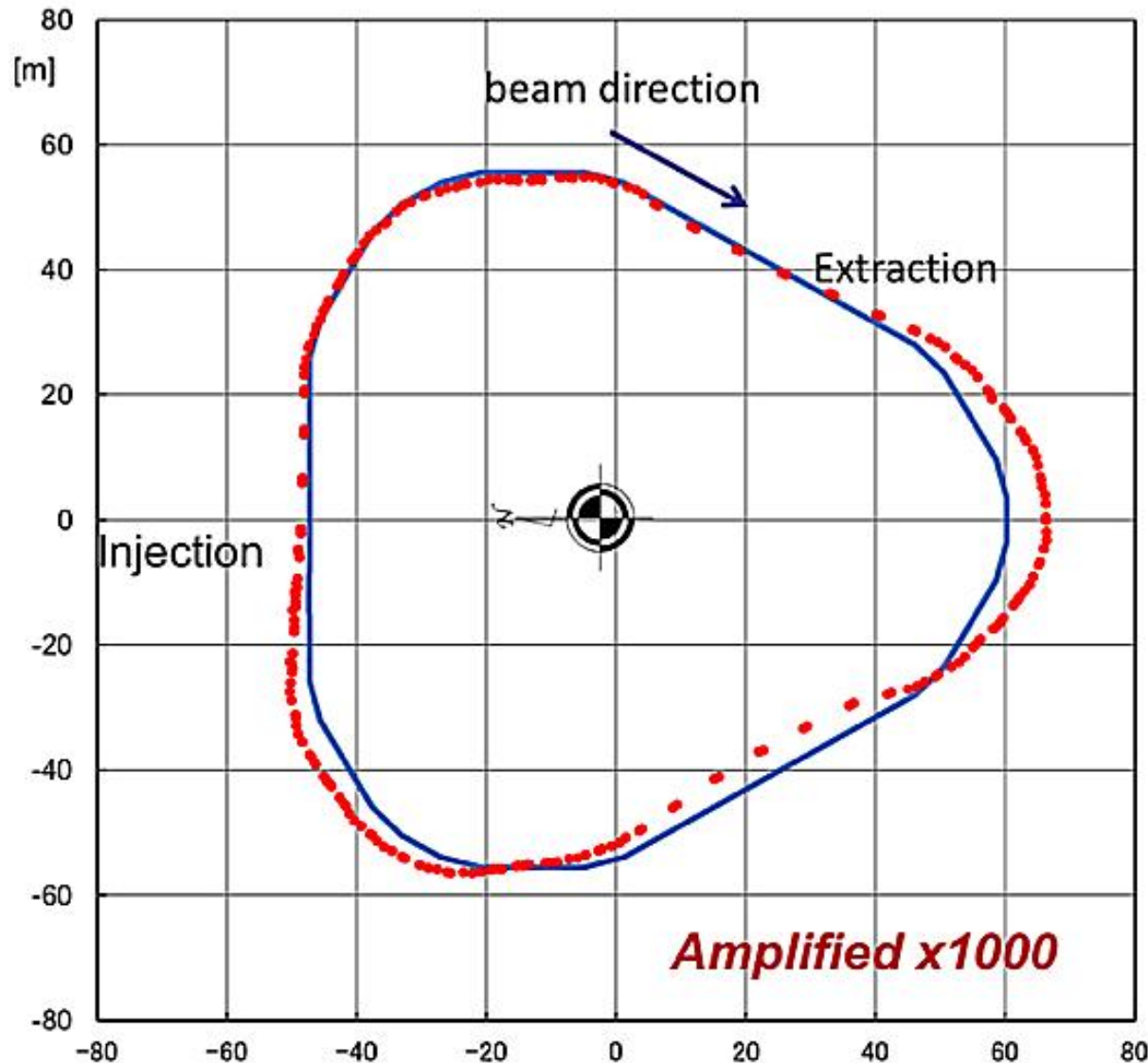
On March 17 the water level was only 1 cm, but it increased to 10 cm (100 tons) on March 24. The water was pumped out with a rented electric generator. PH=11 and tons of acid were necessary to neutralize water.

Linac measured position (Apr. 2011)



Rapid Cycle Synchrotron (RCS, 3GeV)

- No serious damages on the equipment/instruments in RCS tunnel.
- Position of all equipment/instruments were measured.
The maximum displacement is 3.7mm vertically & 10mm



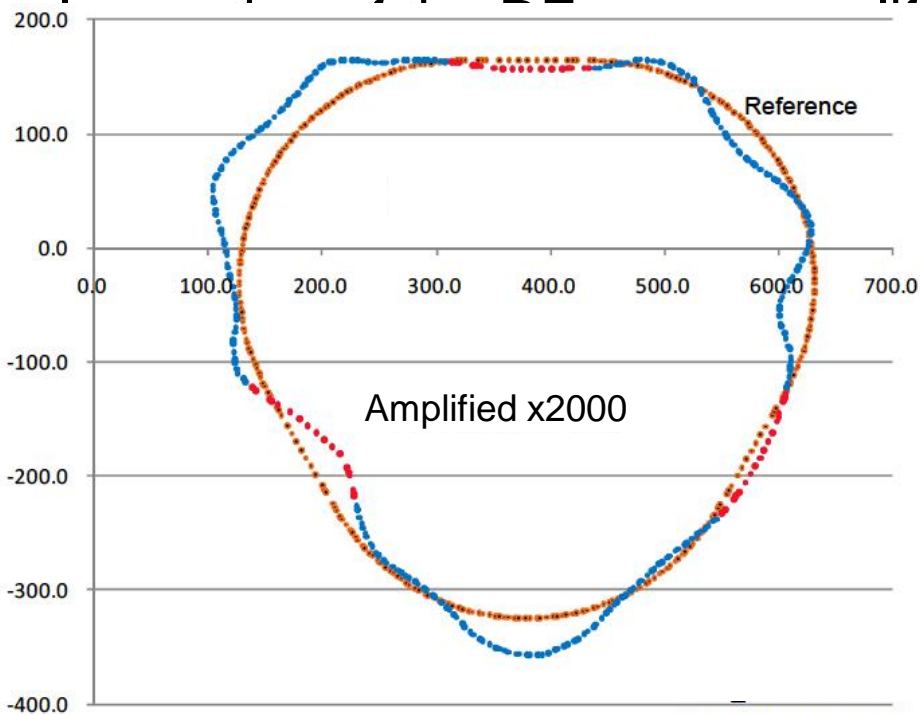
Blue : Reference positions of the magnet
Red: Measured positions after the earthquake
(Please note the magnitude of displacement is amplified x2000.)

Main Synchrotron Ring (MR, 30GeV)

- There were no serious damages on all MR equipment/instruments, such as magnets.

It, however, appeared they misaligned in both vertical and horizontal directions.

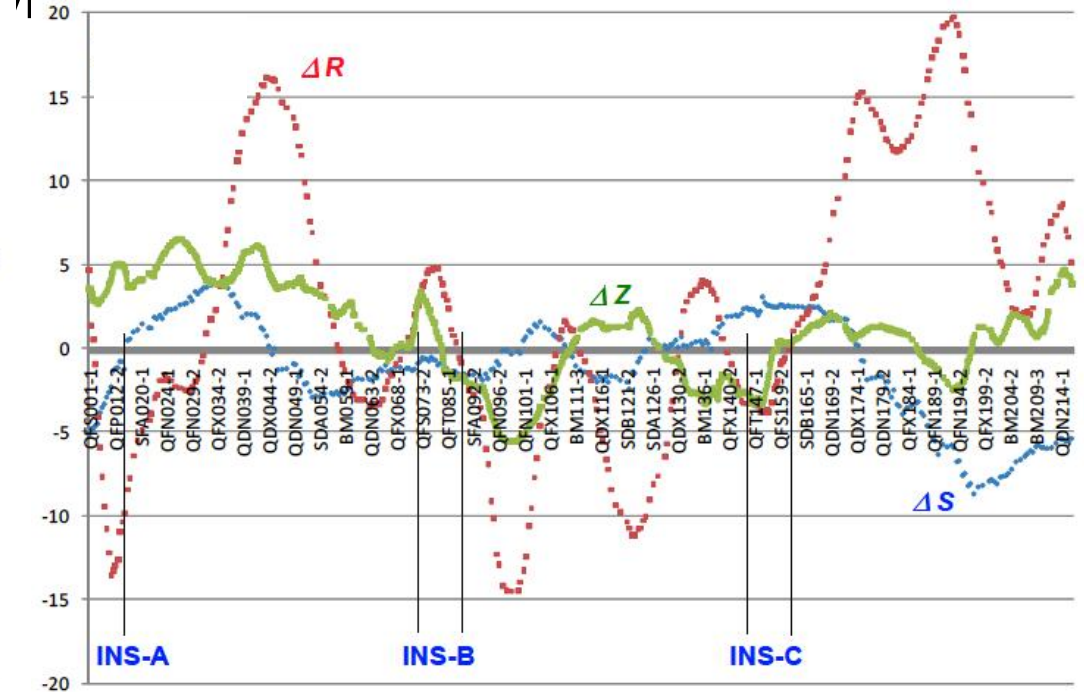
- Some magnets misaligned greatly are re-aligned with replacing a stage.



Orange : Reference positions of the magnet

Blue & Red: Measured positions after the earthquake (Please note the magnitude of displacement is amplified)

Alignment system has been completed



Magnet displacement from the reference line

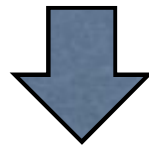
Green : vertical direction
 Red : horizontal direction
 Blue : beam deirection

Demand

from users (MLF, T2K) and the law fixed the MLF

budget:

Beam must be supplied to users during JFY2011 at least approximately two months.



Beam simulation

to keep the beam loss as same as before:

Results:

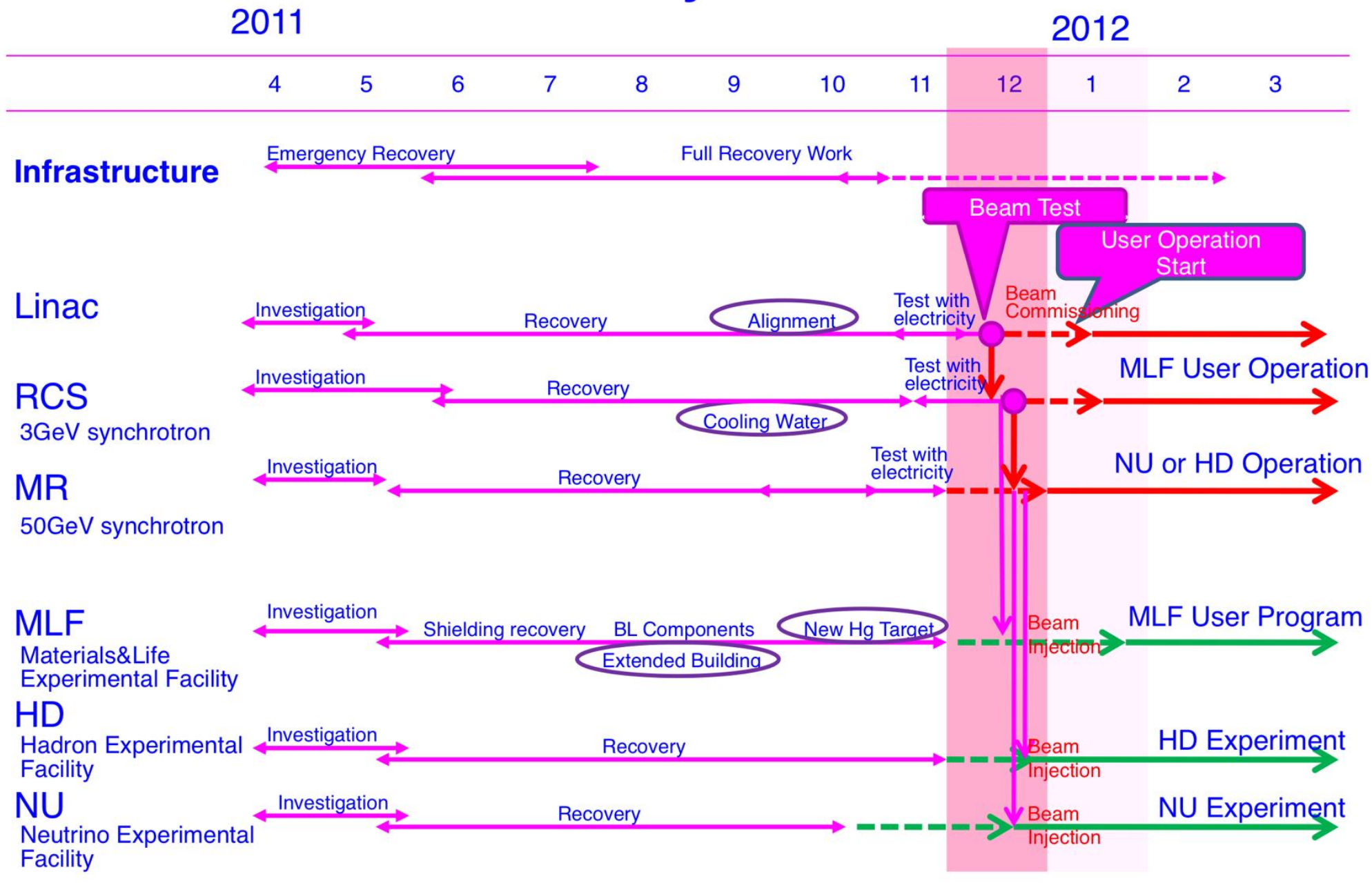
*Linac must be re-aligned but V-shape is approved.

*RCS is usable without re-alignment if power $\leq 300\text{kW}$

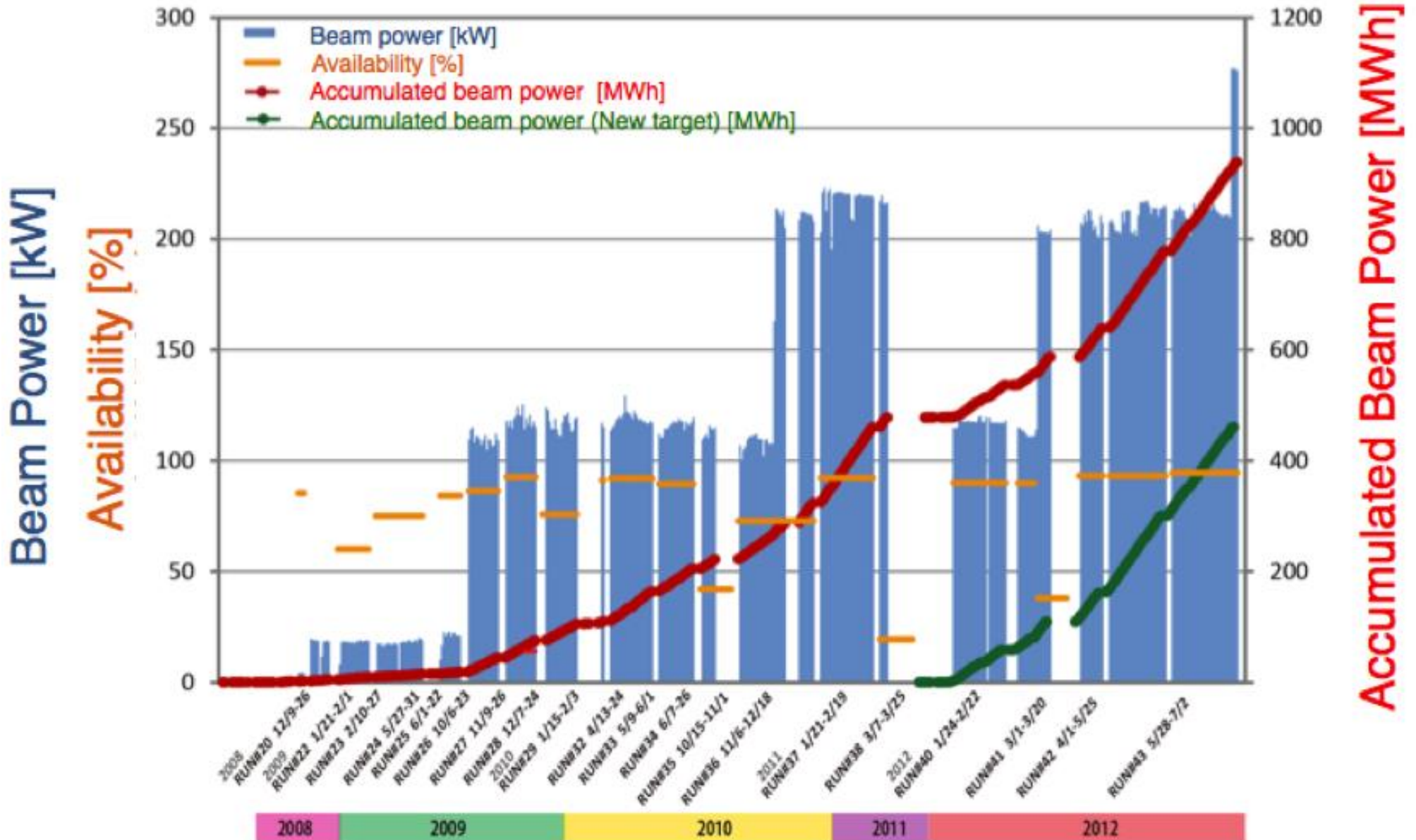
*MR must be re-aligned.

>> Minimum repair of the broken building has been done to resume the beam acceleration as soon as possible.

J-PARC Recovery Schedule (@2011.5.20)



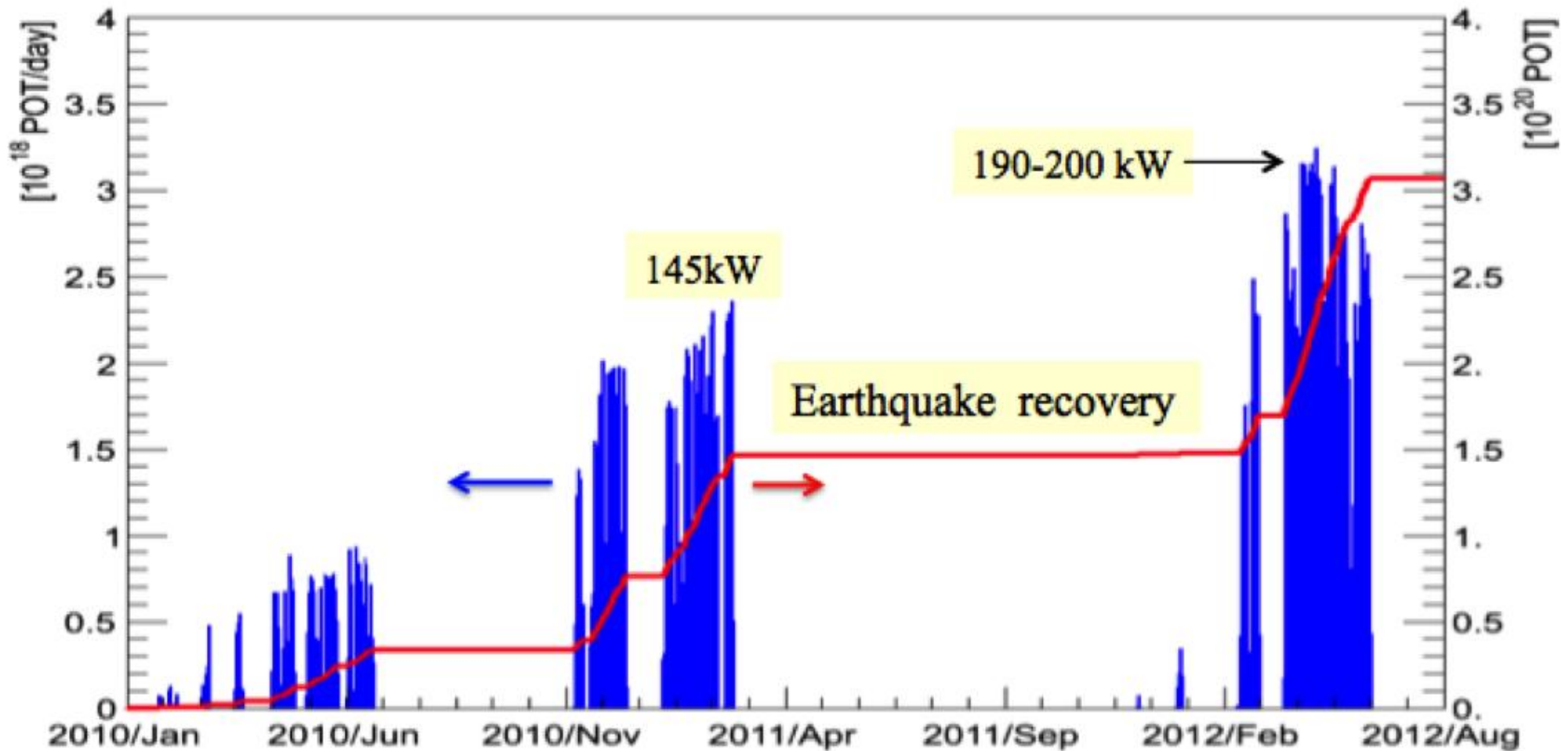
History of beam delivery from RCS to MLF



In the last three days, 275 kW beam was delivered to MLF. Stable operation of 275 kW was successfully demonstrated.

History of beam delivery from MR to the T2K experiment

Delivered POT to Neutrino Beam line (MR-FX)



Operation for beam delivery to the T2K before summer 2012 was finished on June
T2K accumulated the beam of $\sim 3 \times 10^{20}$ POT.

Summary

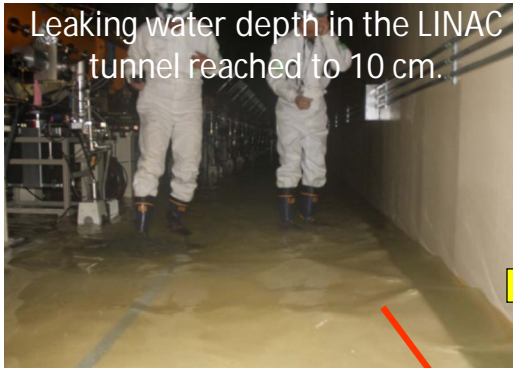
- Although J-PARC had the big damage by the earthquake, it has been fixed in minimum to accelerate the beam.
- J-PARC resumed to accelerate beam from Dec., 2011.
- Experiments by user restarted in Jan., 2012.
- However a lot of troubles of the earthquake origin(?) still happen in the accelerators.
- Damage on the accelerator buildings of linac (wall, doors, cranes, floor) and MR (expansion joints, ground-water leakage) is not fixed yet.

Thank you very much!

Recovery Status of J-PARC from Damages by the 3.11 Earthquake

- Fortunately no victims at J-PARC, but severe damages on the facilities, such as piping systems, power devices, and instruments. We also had land subsidence at many places around buildings, water leaks, and misalignment of electromagnets and shielding blocks.

Damages and Recovery Status of Accelerator Facilities

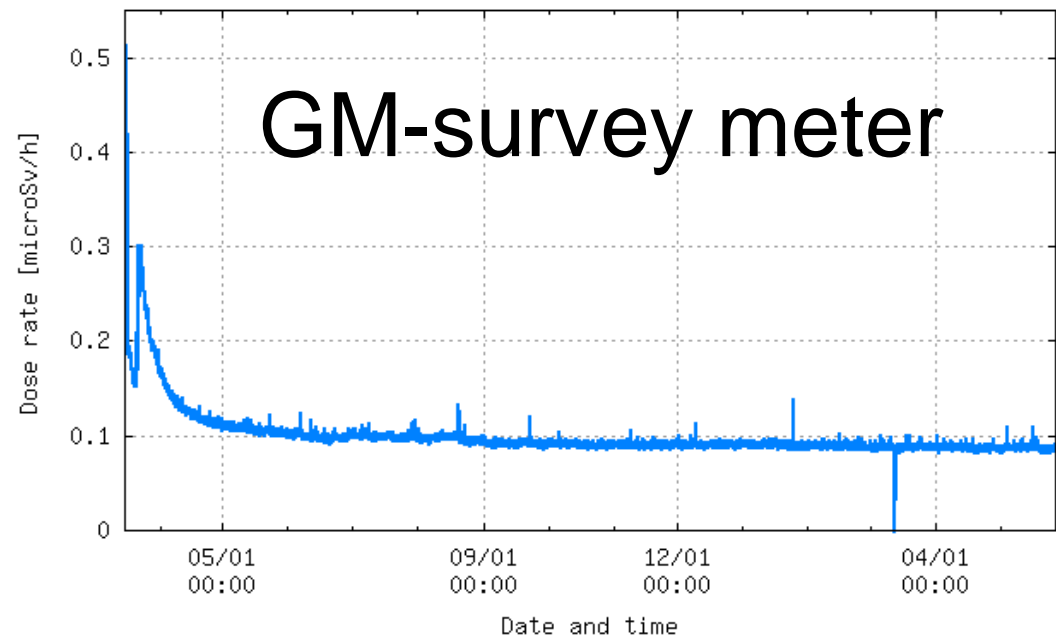
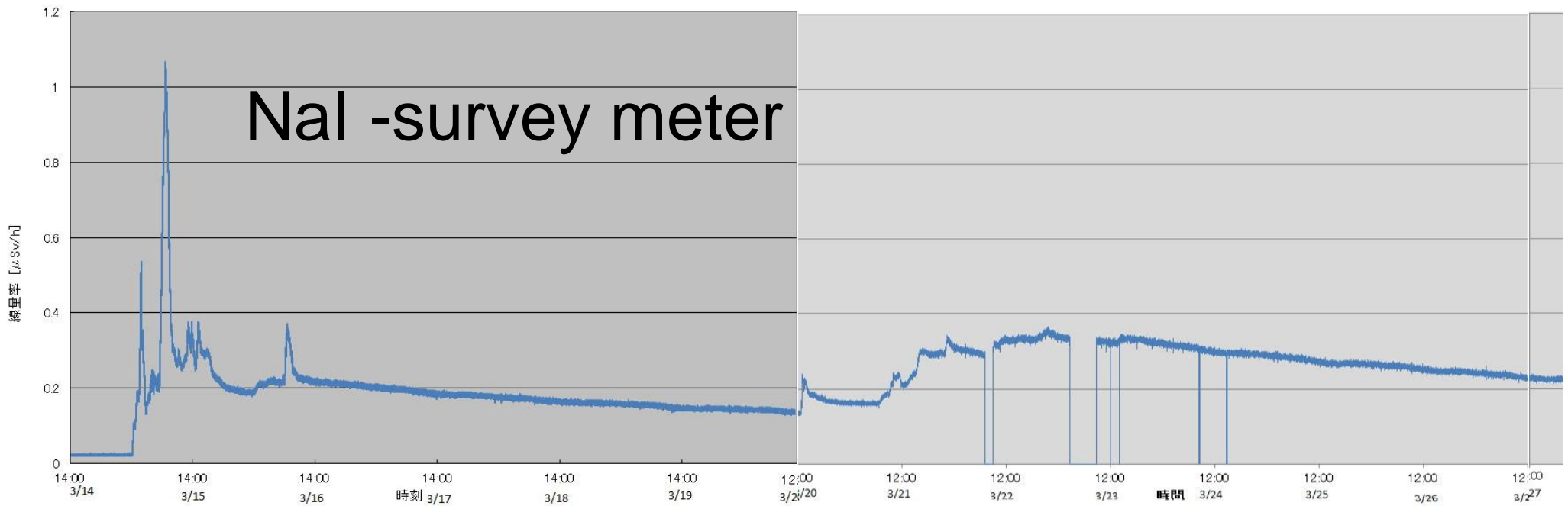


The approach to the LINAC entrance subsided more than 1 m. In contrast, the front road raised a few 10s cm.

Still under the construction

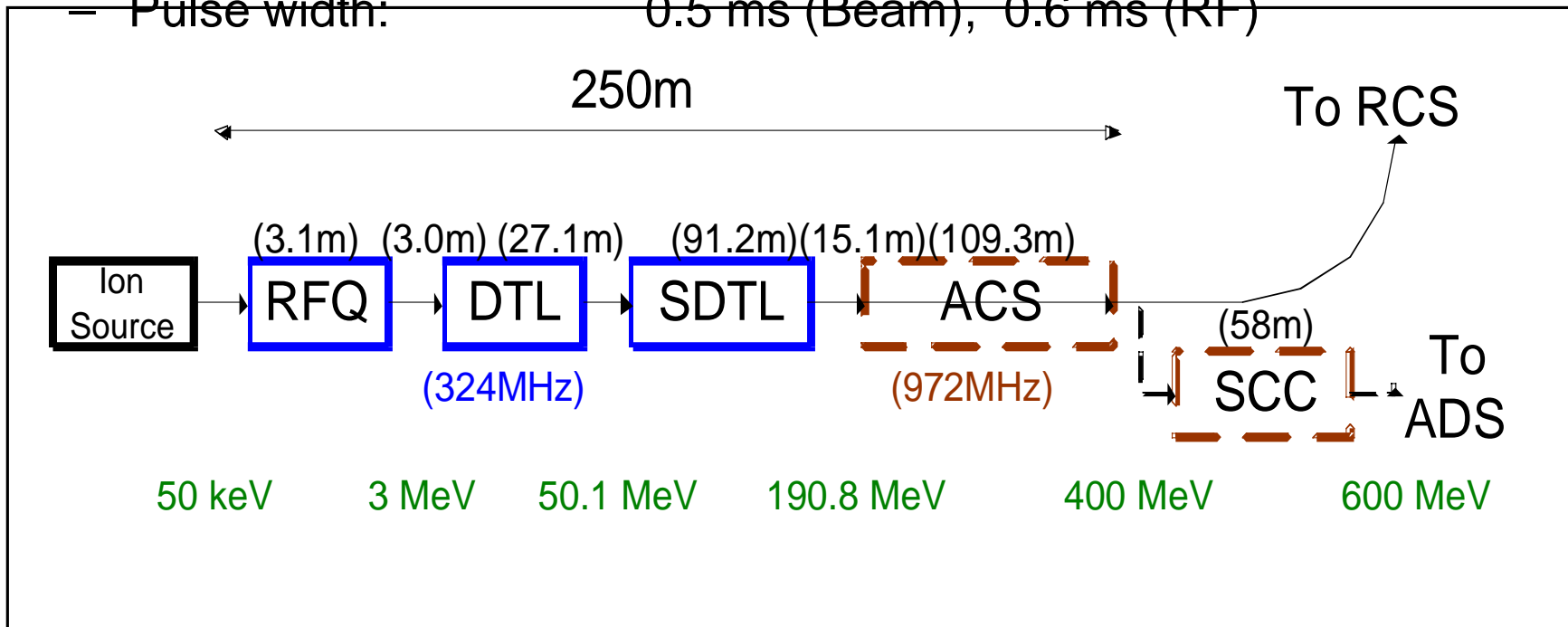
Re-leveled the basis

Dose rate in KEK Tsukuba campus



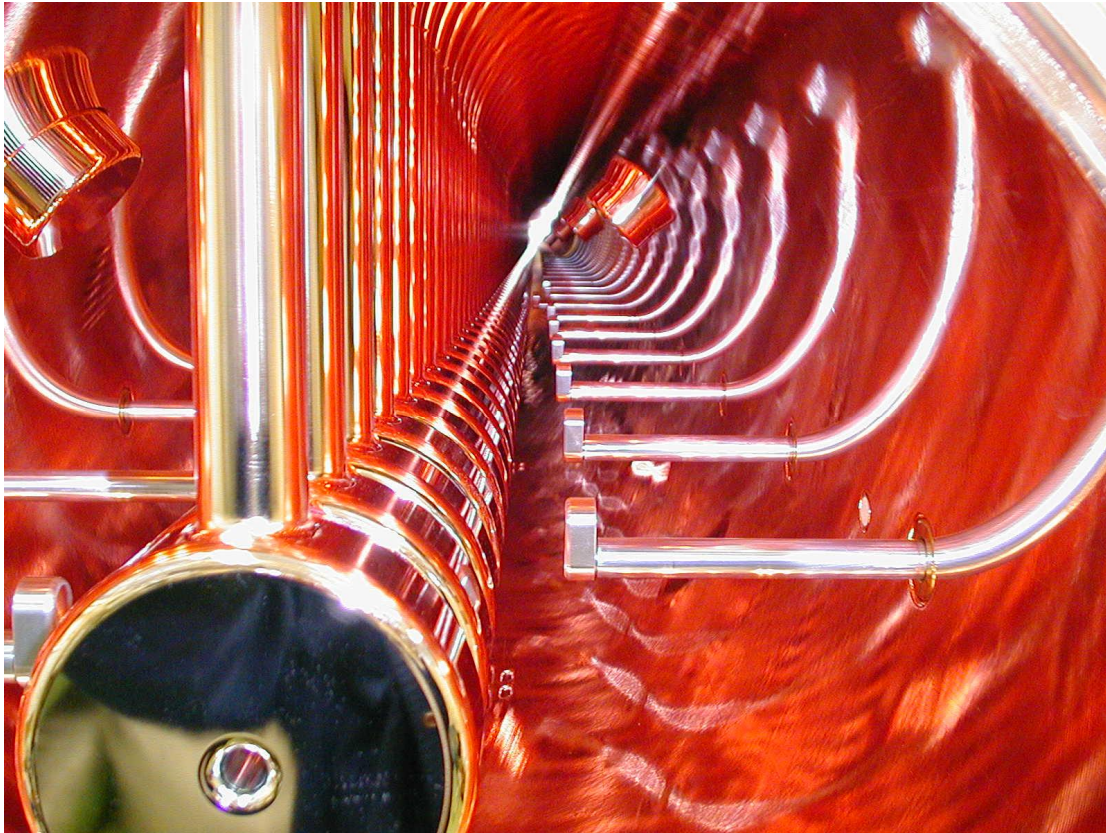
Linac major parameters

- Accelerated particles: H^- (negative hydrogen)
- Energy: 181 MeV, The last two SDTLs are debunchers
(400 MeV for ACS, 600 MeV for SCL)
- Peak current: 30 mA (50 mA for 1MW at 3GeV)
- Repetition: 25 Hz (additional 25 Hz for ADS application)
- Pulse width: 0.5 ms (Beam), 0.6 ms (RF)

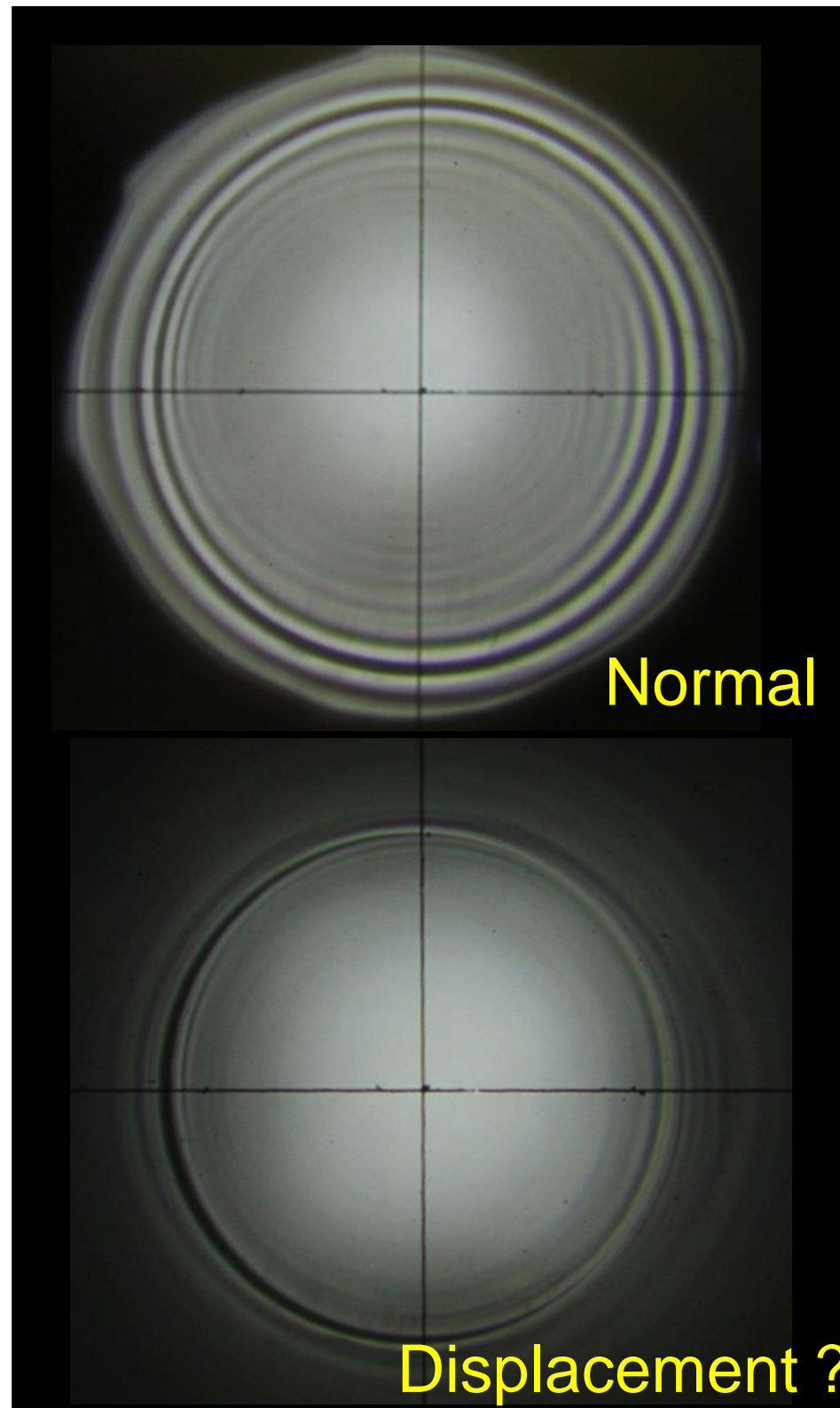


Drift Tubes in DTL

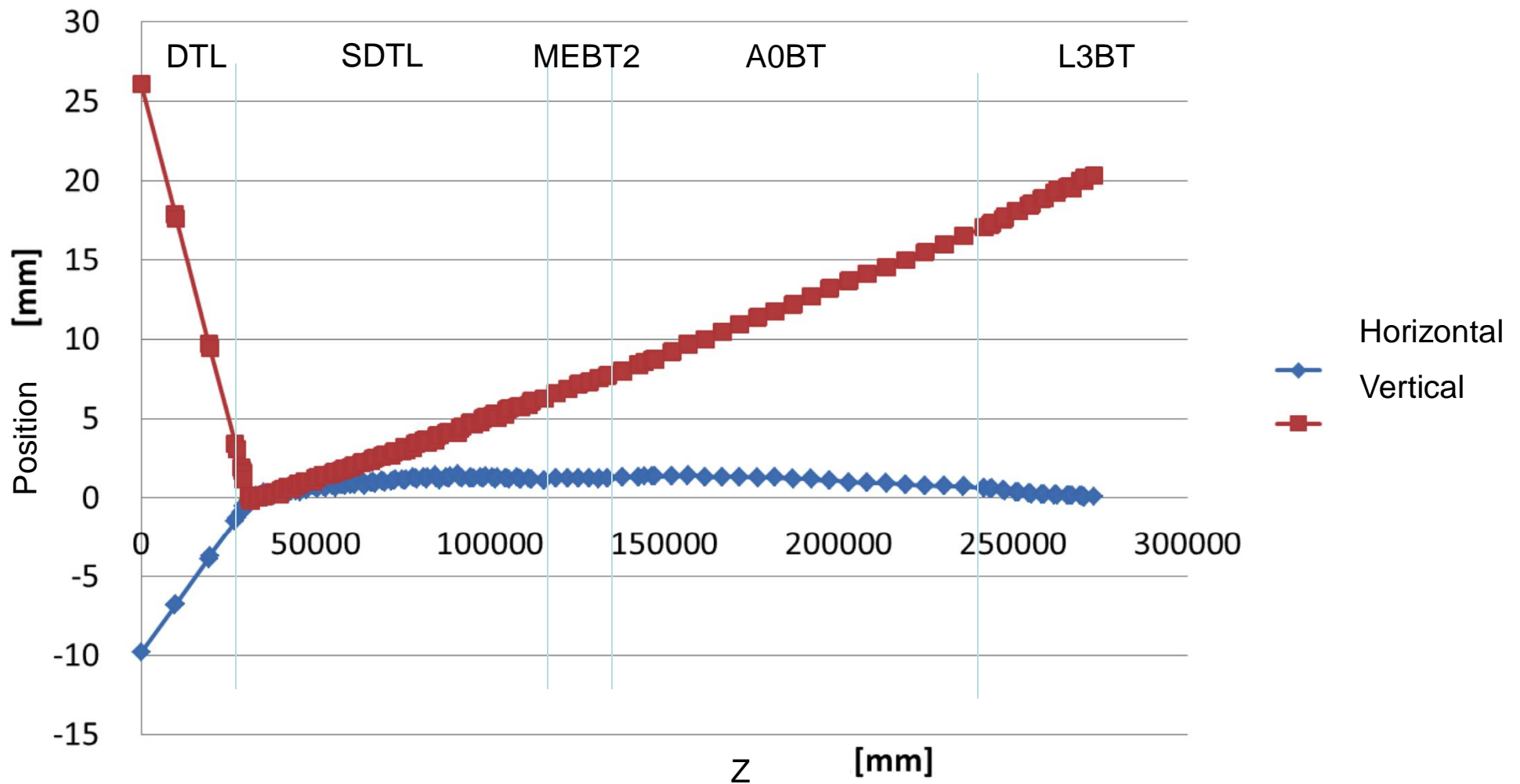
Observation of the shadow of the DT by an alignment telescope



Inside view of the DTL
before installation



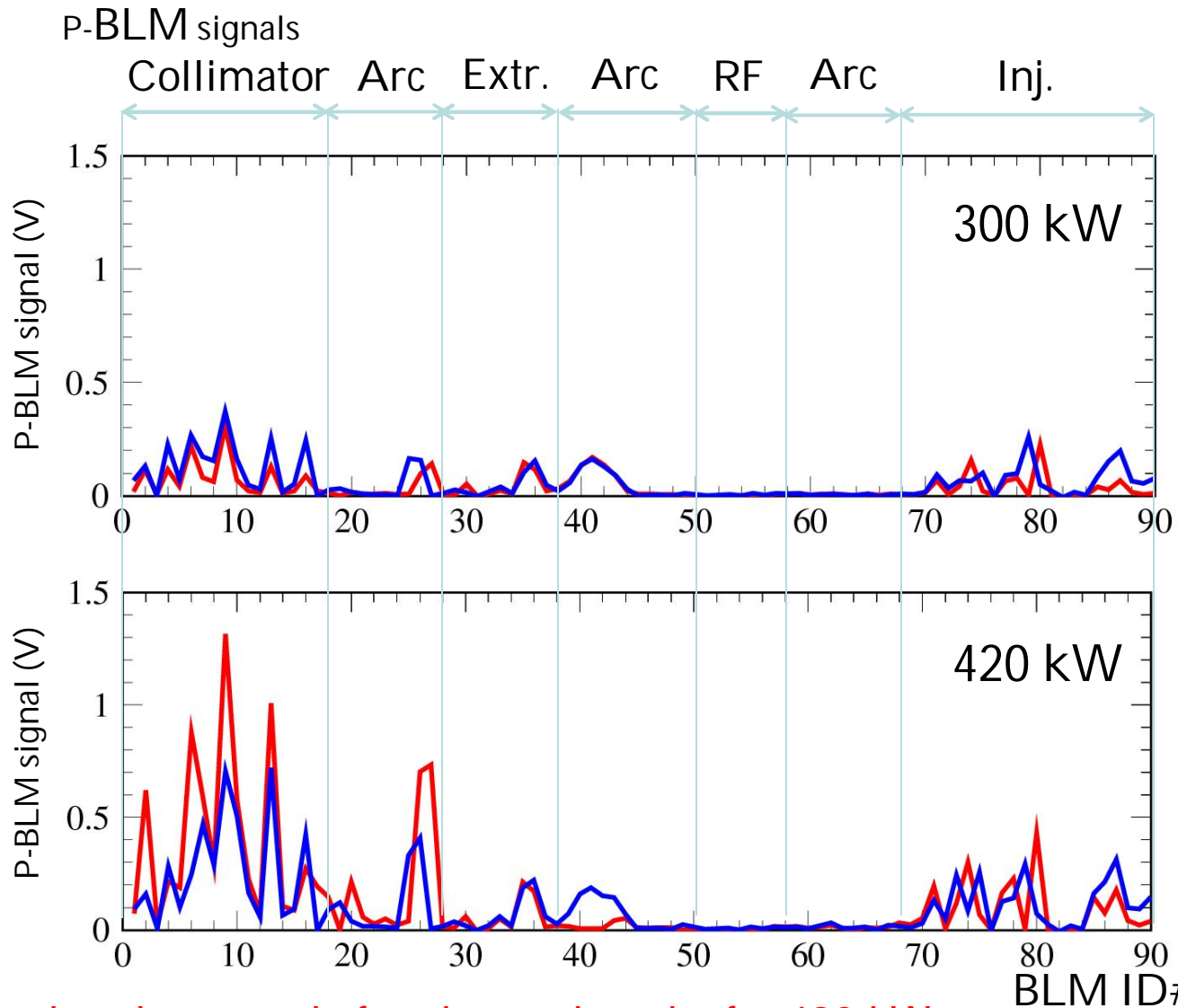
Alignment result of the linac



Bending angle at DTL end : 0.91-mrad horizontally, 0.28-mrad vertically.

In the SDTL & A0BT section, the displacement is 1.5-mm in maximum for horizontal direction.

Beam loss in RCS with the beam > 400 kW



— Before the earthquake
— After the earthquake

No large difference
in beam loss

Significant difference
in beam loss

Beam loss increased after the earthquake for 420 kW

Particle loss before the earthquake: $\sim 0.4\%$

Particle loss after the earthquake: $\sim 0.8\%$

In the summer of 2013, the entire
adjustment of the RCS will be done

Problems after the beam resumption

Linac:

- * HV terminals of Ion pump have the discharge problem.
- * Almost temperature sensors were corroded.
- * A HV rectifier in the oil tank for the Klystron was broken.
- * Humidity in the tunnel is still high by the leakage of ground water.
- * Cranes are still not usable.
- * Floor is broken and tilted.

RCS:

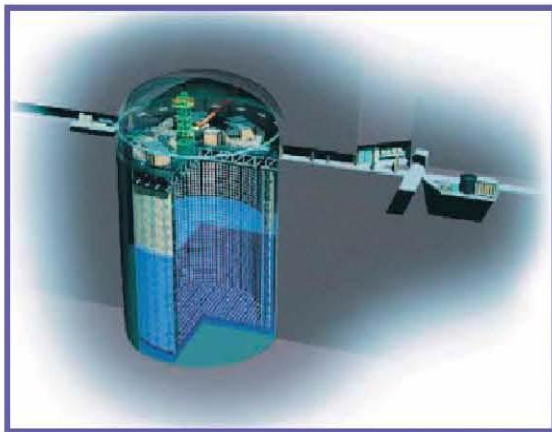
MR:

- * New leakage of the ground water found in the tunnel.
- * Twisted expansion joints of the tunnel are not fixed.

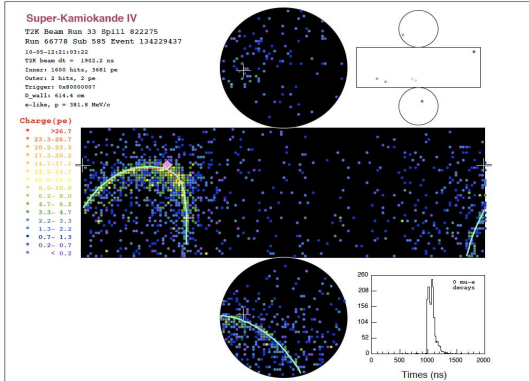
Exp:

- * Power supply of the magnetic horn for T2K was broken.

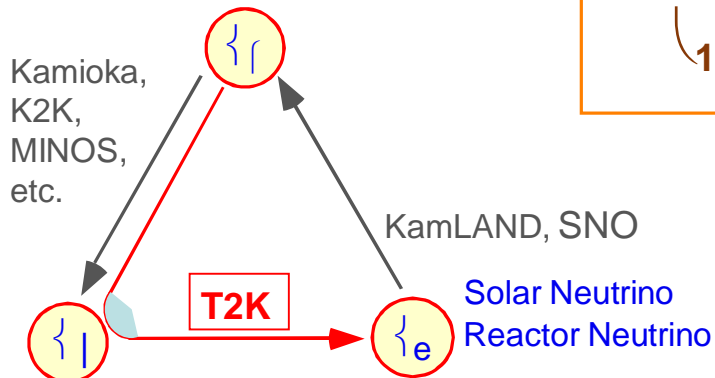
Neutrino Oscillation (T2K) Experiment



Super-Kamiokande



Atmospheric Neutrino
 Accelerator Neutrino



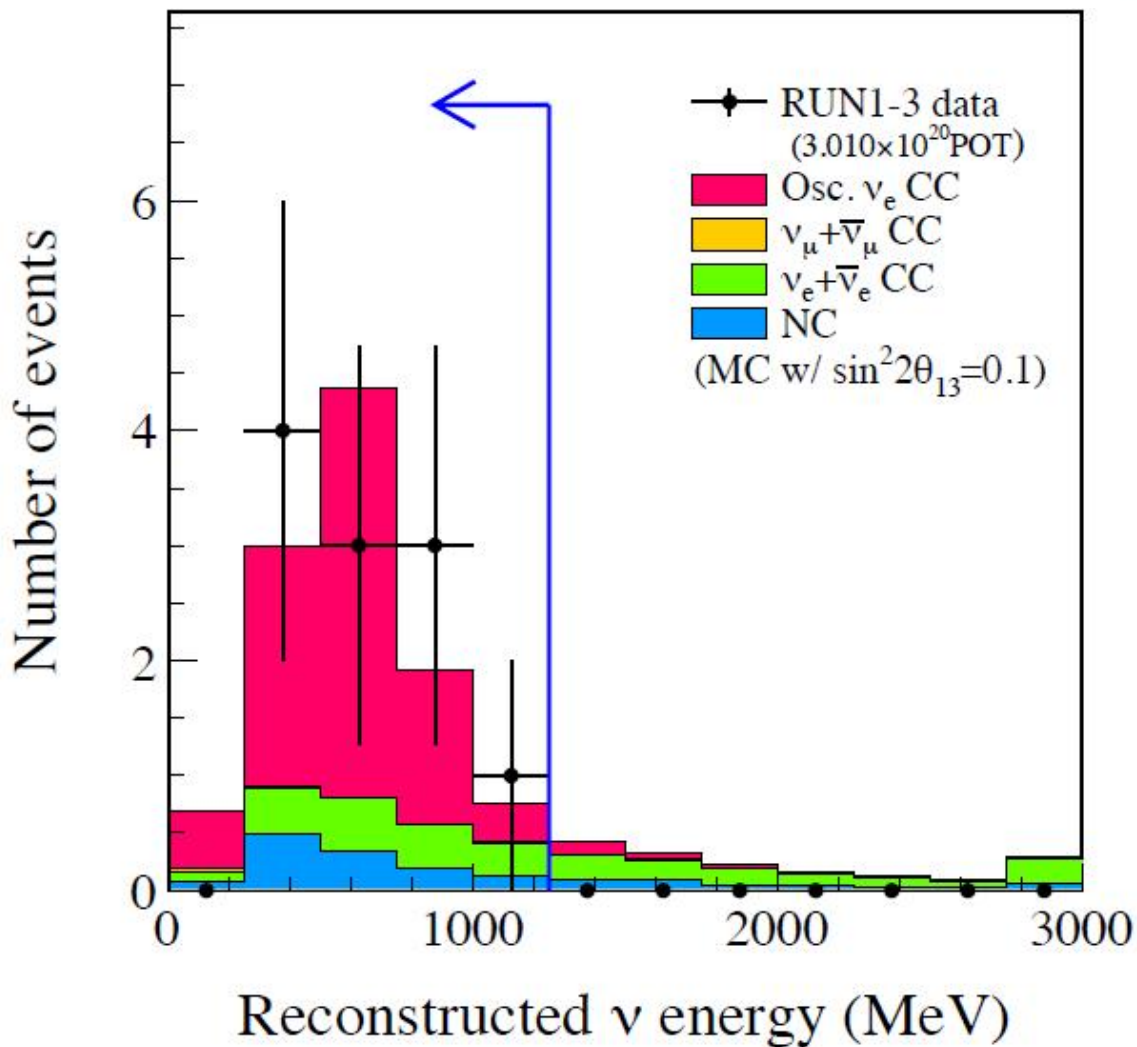
Electron neutrinos ← Mu neutrinos

ν_{13} ↔ Mixing between the 1st and 3rd generation

Goal is to measure $\sin^2 2\nu_{13}$ down to 0.01

Competition with Double Chooz, Daya Bay, FNAL, etc.

T2K electron neutrino candidates



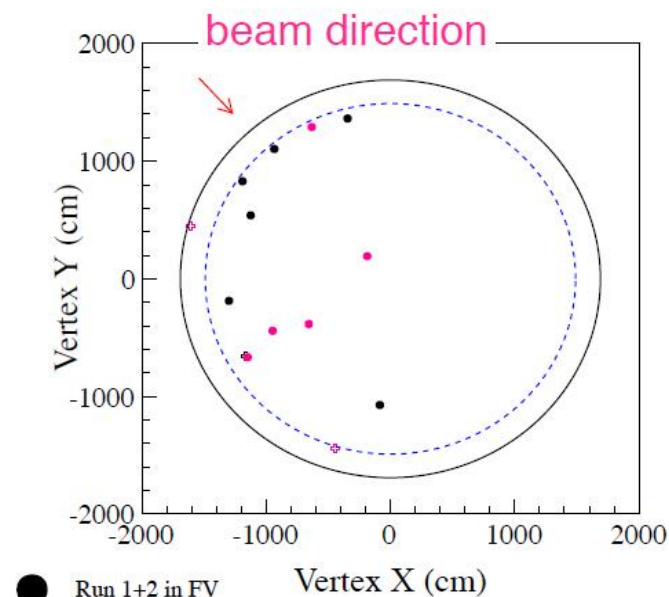
11 candidate events are observed

$$N_{\text{exp}} = 3.22 \pm 0.43 \text{ for } \sin^2 2\theta_{13} = 0$$

The probability (p-value) to observe 11 or more events with $\theta_{13} = 0$ is 0.08% (3.2σ)

Evidence of ν_e appearance

Vertex distribution



p values of several distribu