Status Report on Survey and Alignment of J-PARC after the earthquake

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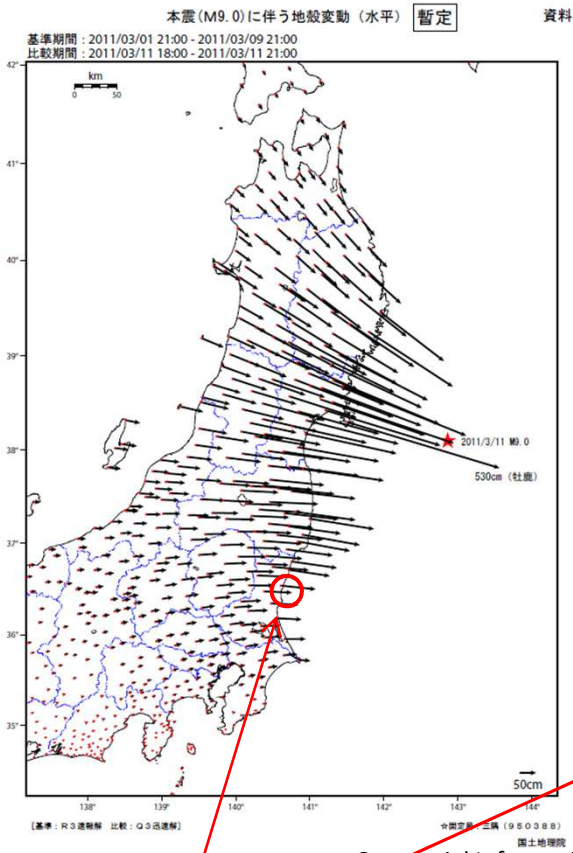
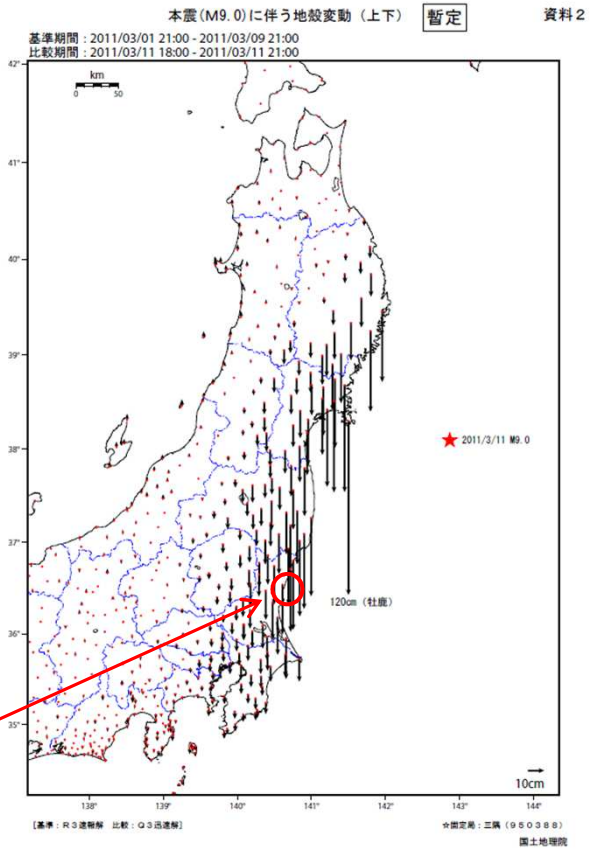
Crustal movement data by the earthquake

Horizontal direction



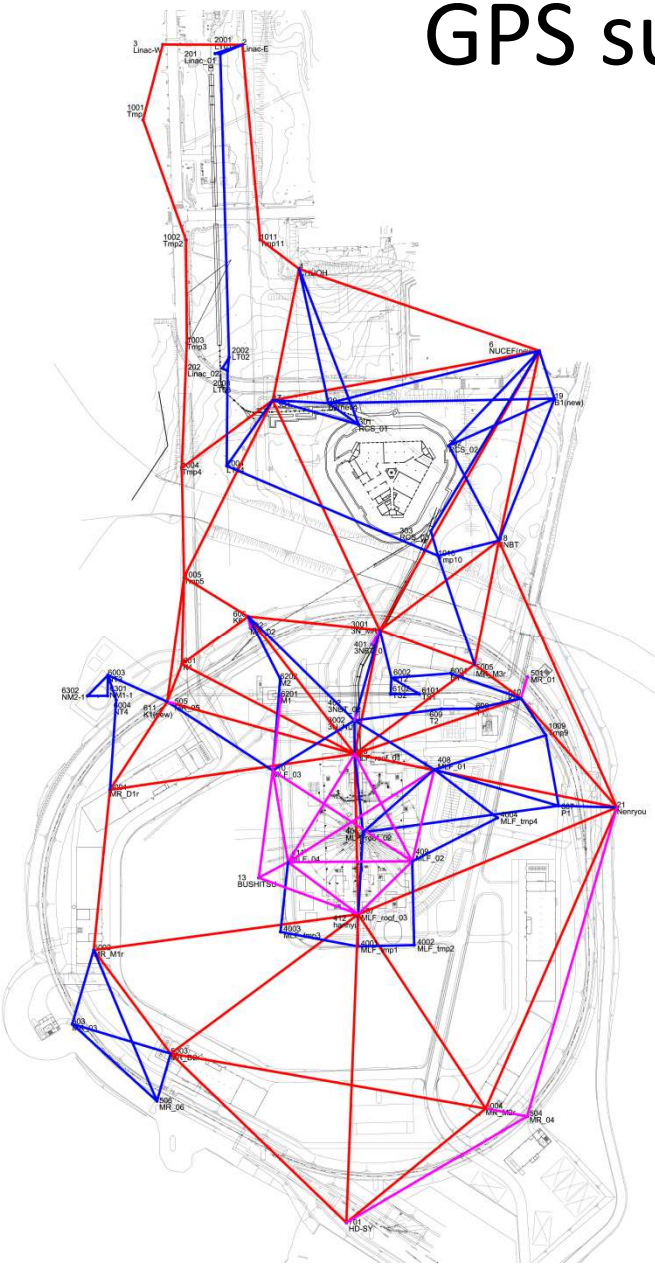
Vertical direction



Geospatial Information Authority of Japan (GSI)
Crustal movement by the Tohoku earthquake in 2011.
http://www.gsi.go.jp/chibankansi/chikakukansi_tohoku2.html

J-PARC area moved 91cm to east, 16cm to south and settled down by 36cm

GPS survey of J-PARC facility



At J-PARC facility precise traverse survey and leveling are being implemented every two years. The last survey before the earthquake was in August 2010. GPS observation network this time is the same as that of the precise traverse survey last year.

Observation time

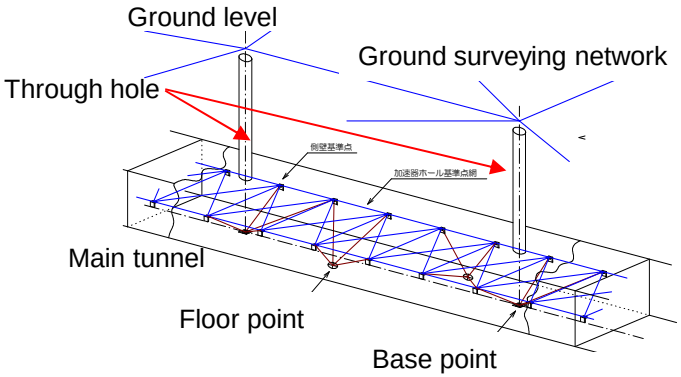
Primary reference point (red line): 4 hours

Secondary reference point (blue line): 2 hours

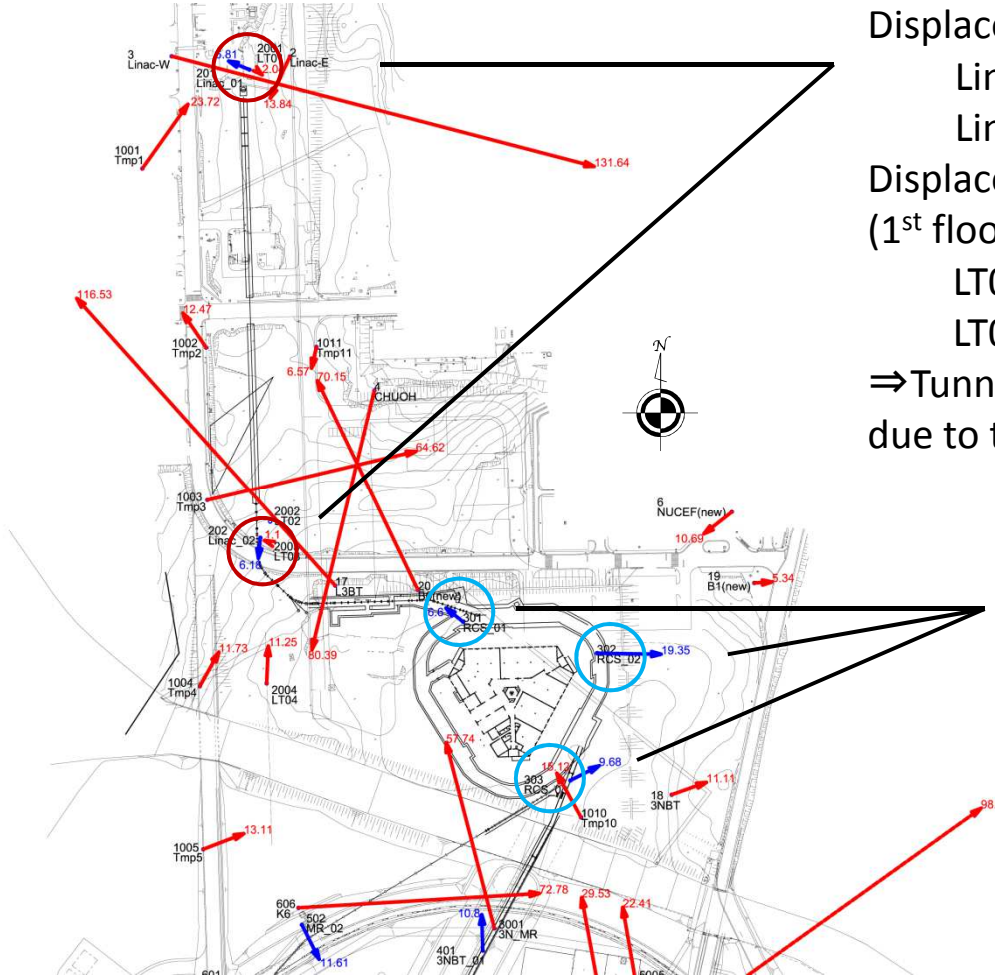
Equipment : Trimble 5700

However traverse survey was carried out to the secondary reference points set in the building using TDA5004 and evaluated referring to the reference point obtained by GPS survey.

Observation of through hole



Result of GPS survey（North area of J-PARC）



Displacement of reference points in Linac tunnel

Linac_01 : 6.81mm (west north-west)）

Linac_02 : 6.18mm (south)

Displacement of reference points in Linac building (1st floor)

LT01 : 2.04mm (east south-east)

LT03 : 1.10mm (west)

⇒Tunnel expanded to north and south direction due to the earthquake.

Survey accuracy:+-5 mm

Displacement of reference points in RCS tunnel

RCS_01 : 6.6mm（northwest）

RCS_02 : 19.35mm（east）

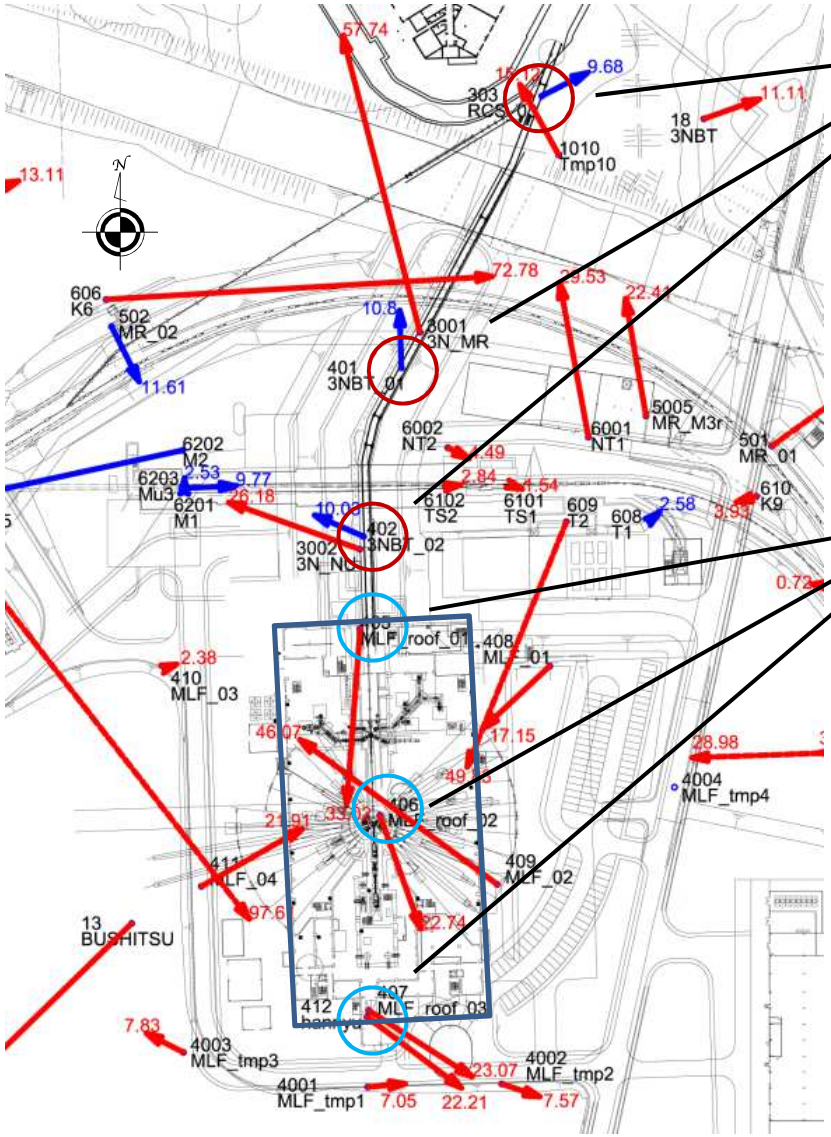
RCS_03 : 9.68mm（northeast）

⇒Tunnel expanded to east and west direction due to the earthquake.

Displacement vector (red): reference points on the ground and roof of the building

Displacement vector (blue):reference points in the tunnel

Result of GPS survey（Central area 1 of J-PARC）



Displacement of reference points in 3NBT tunnel

RCS_03 : 9.68mm（northeast）

3NBT_01 : 10.8mm（north）

3NBT_02 : 10.08mm（west-borthwest）

⇒Moved about 10mm toward RSC side due to the earthquake and rotated clockwise

Displacement of reference points in MLF building

MLF_roof_01 : 33.02mm（south）

MLF_roof_02 : 22.74mm（south-southeast）

MLF_roof_03 : 23.07mm（southeast）

hannyu : 22.21mm（southeast）

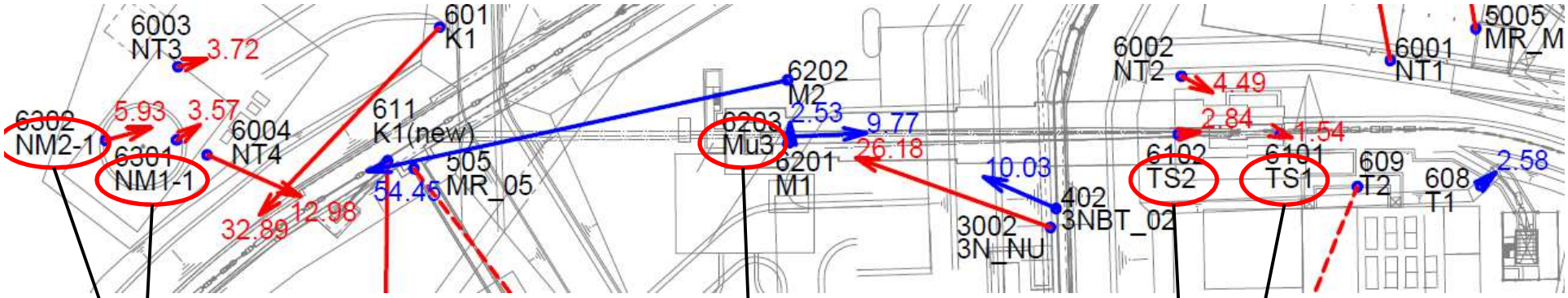
⇒Moved about 20mm to south due to the earthquake and rotated counterclockwise

Result of GPS survey（Central area 2 of J-PARC）

Points of through-holes cannot be used due to the earthquake
⇒P1, T2 an d M2

Accuracy: +-5mm

10mm



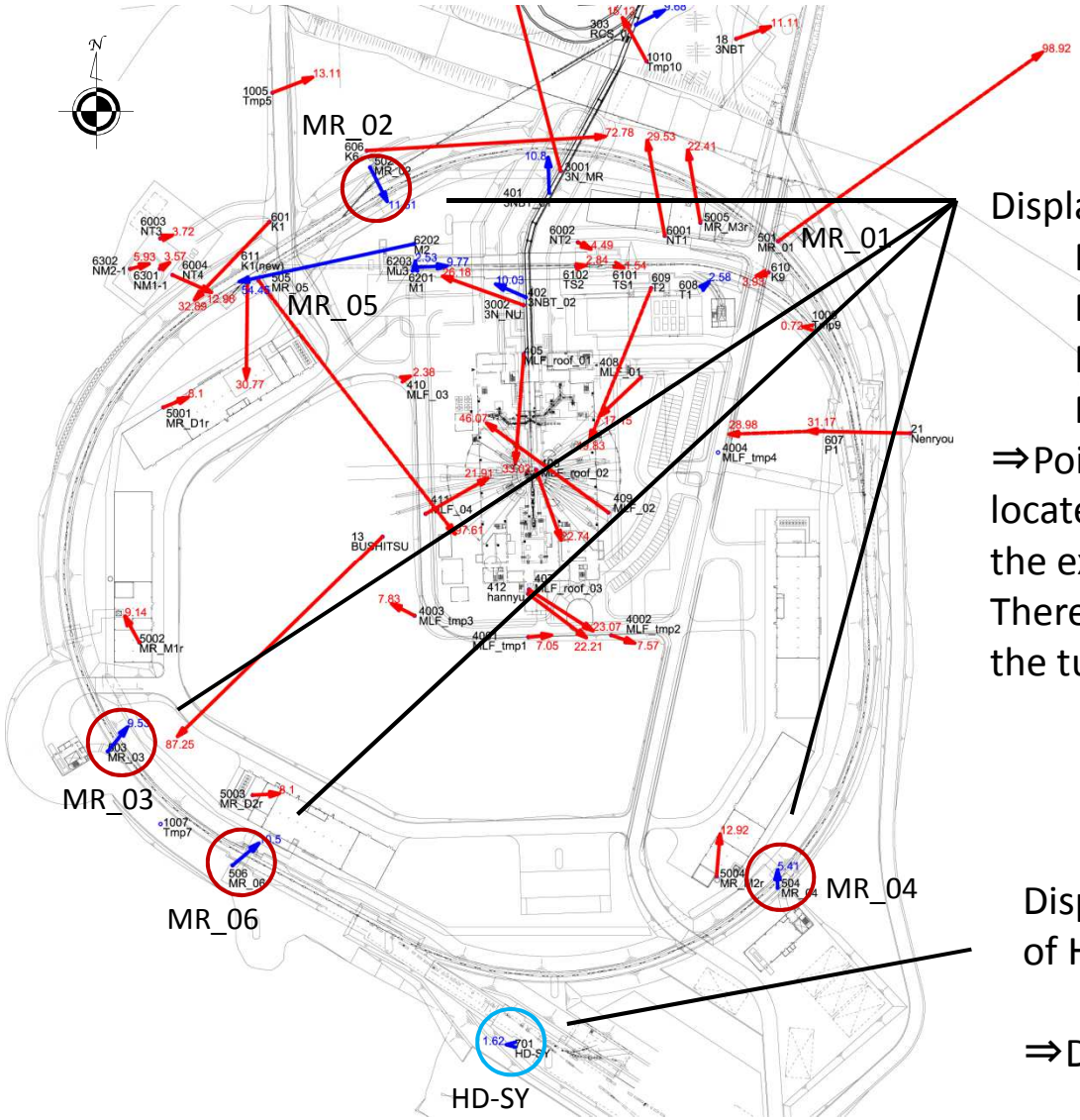
Neutrino-monitor building 1F

Muon pit underground

Target-station building 1F

These points are reference points of Neutrino beam line.
It was confirmed that these points did not move enough to affect the experiment.
(Accuracy of a few mm is acceptable at the lower section of Target station.)

Result of GPS survey（South area of J-PARC）

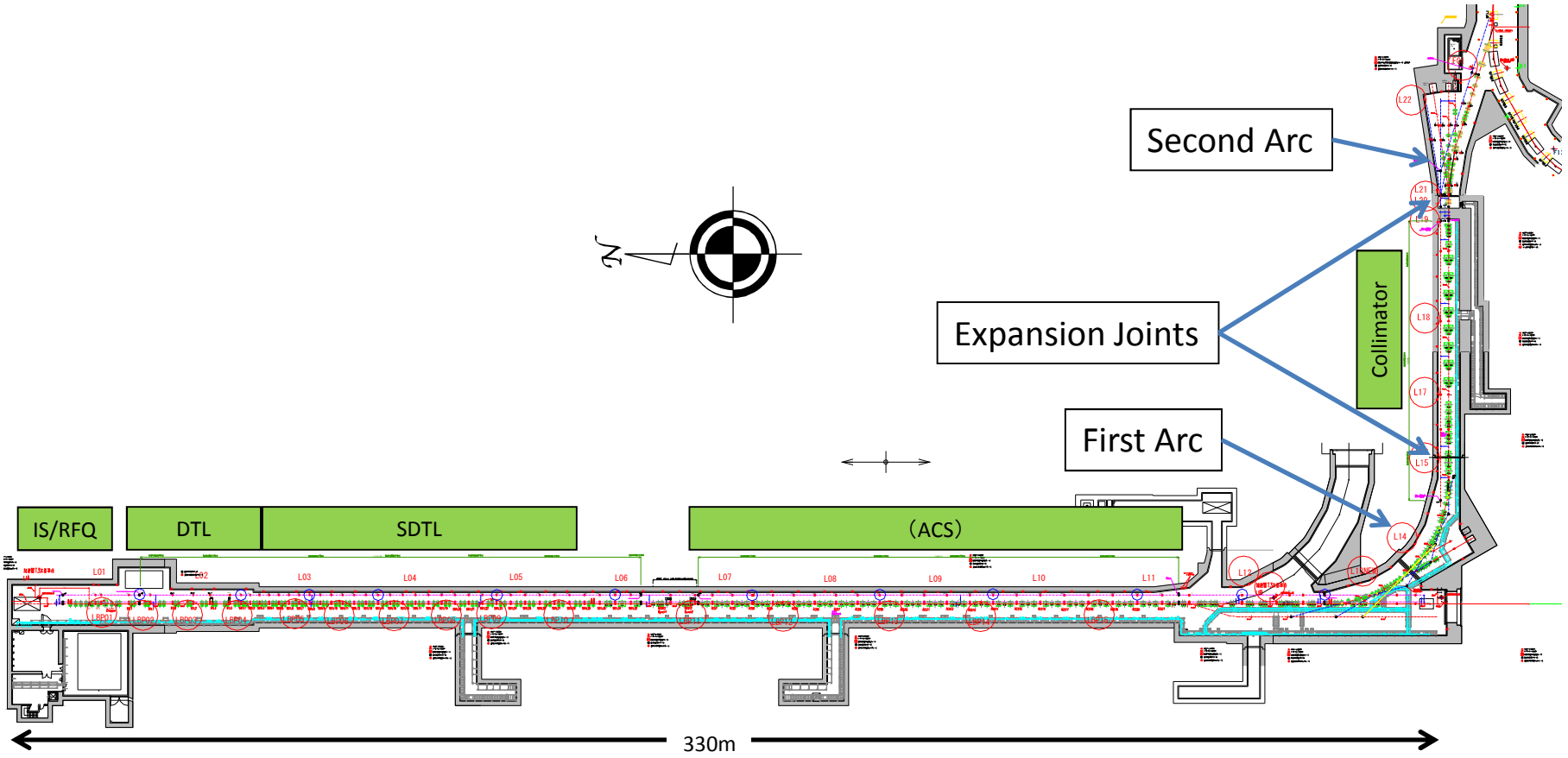


Points of through-holes cannot be used due to the earthquake
⇒MR_01 and MR_05

Displacement of reference points in MR tunnel
MR_02 : 11.61mm（south-southeast）
MR_03 : 9.53mm（north-northwest）
MR_04 : 5.41mm（north）
MR_06 : 10.6mm（northwest）
⇒Points except for MR_03 and MR_04 are located outside of the main tunnel separated by the expansion joints.
Therefore we cannot directly check the status in the tunnel, but it seems it is deformed.

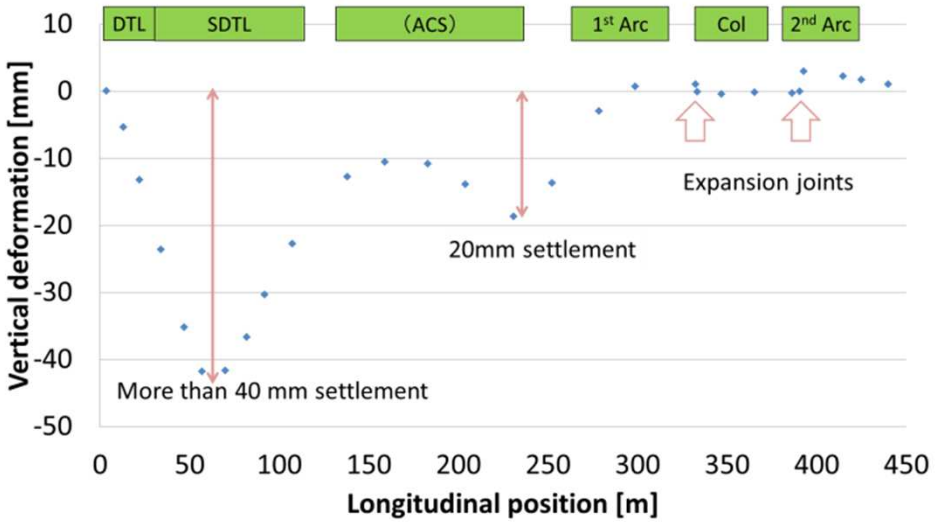
Displacement of reference points in tunnel of Hadron beam line
HD-SY : 1.62mm（west）
⇒Did not move largely due to the earthquake

Status of Linac



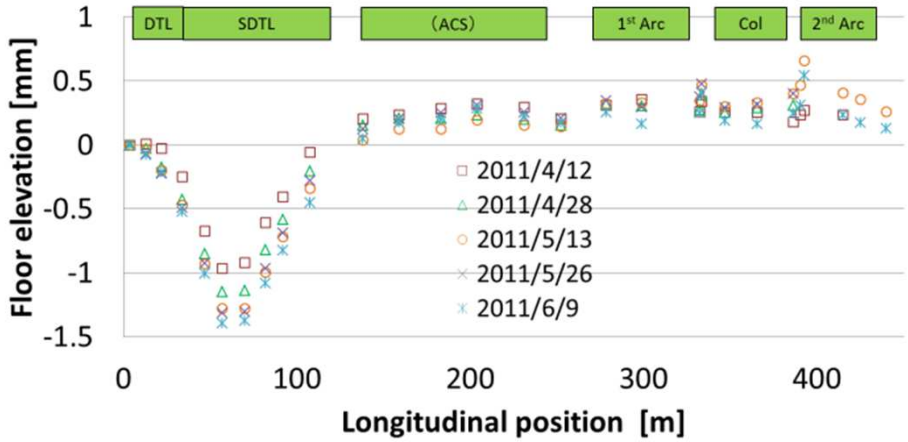
Floor settlement after the earthquake

Floor settlement by the earthquake



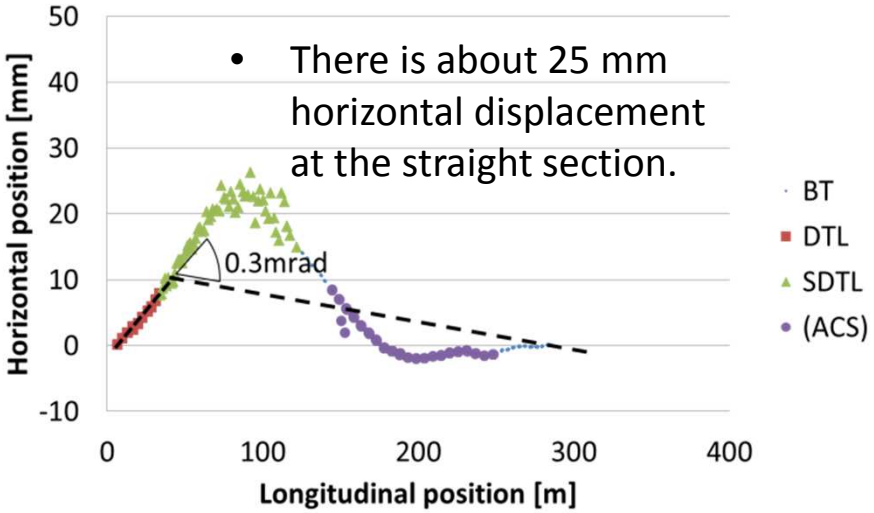
- There are local settlements at the DTL/SDTL sections (more than 40 mm) and at the end of the ACS section (about 20 mm).
- The step-like level difference occurred at the expansion joints.

Floor elevation change until June

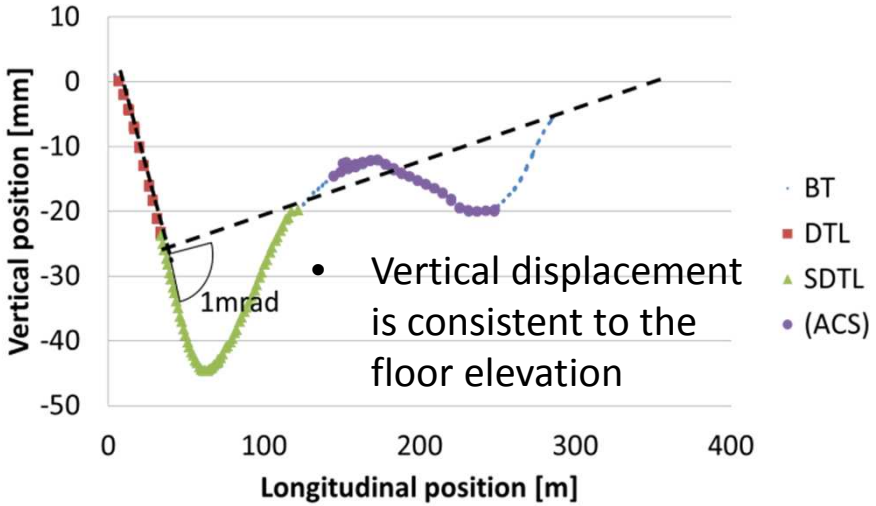


- There were frequent aftershocks after the earthquake. Then we continued the level survey every two weeks.
- The local settlement continued at the upstream side of the straight section. Most of the elevation change to this direction ceased two months later.

Displacements of the Linac and re-alignment plan in the straight section



- There is about 25 mm horizontal displacement at the straight section.

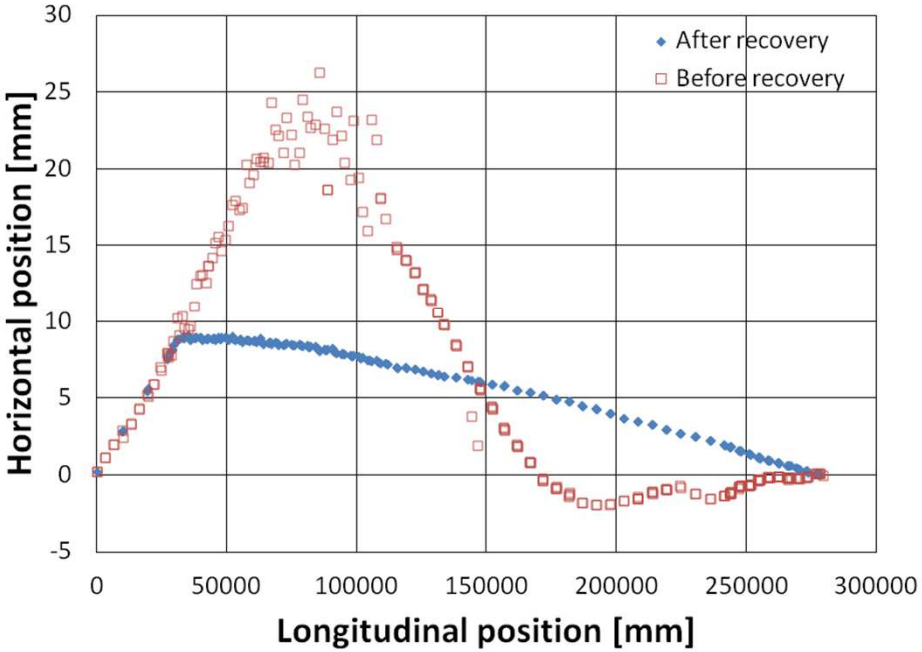


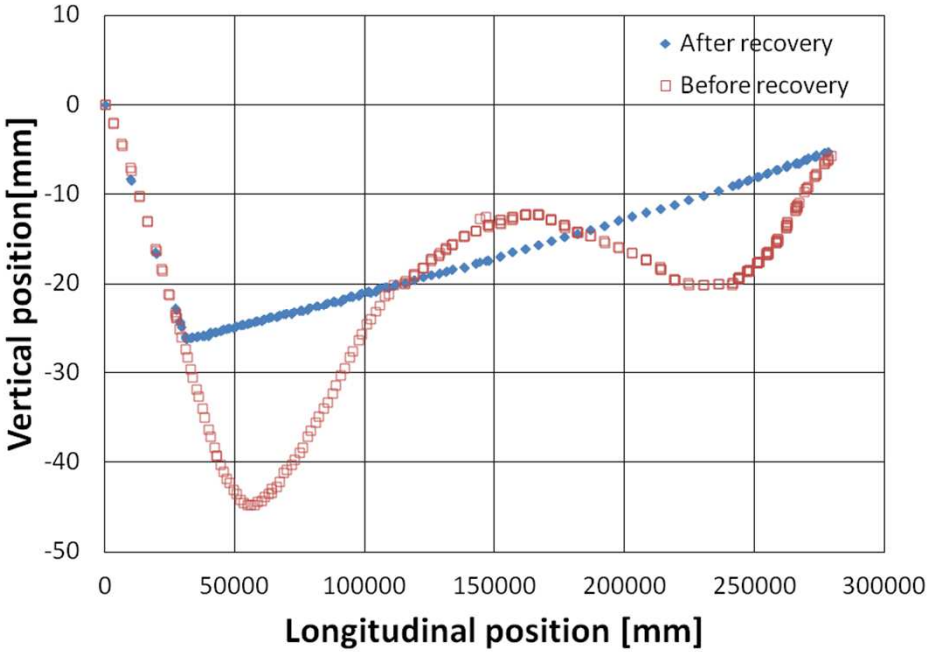
- Vertical displacement is consistent to the floor elevation

- The dotted line shows the target re-alignment line in the straight section.
  - The range of the DTL movement is a few millimetres without re-wiring for DTQs. Therefore, aiming at an early restart of the beam operation, we decided to steer the beam at the steering magnets located downstream of the DTL section horizontally and vertically.

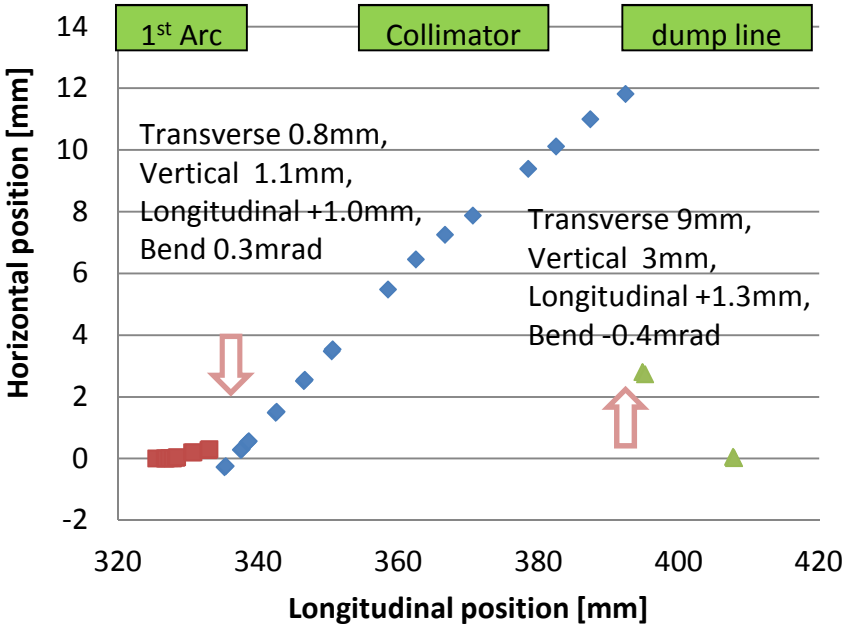
- Longitudinally, the accelerator tunnel was extended about 9 mm at the upstream part of the SDTL section.
  - This extension was absorbed smoothly by adjusting the magnets interval at the matching section (about 15m) between SDTL and ACS.

Result after re-alignment of linac straight section



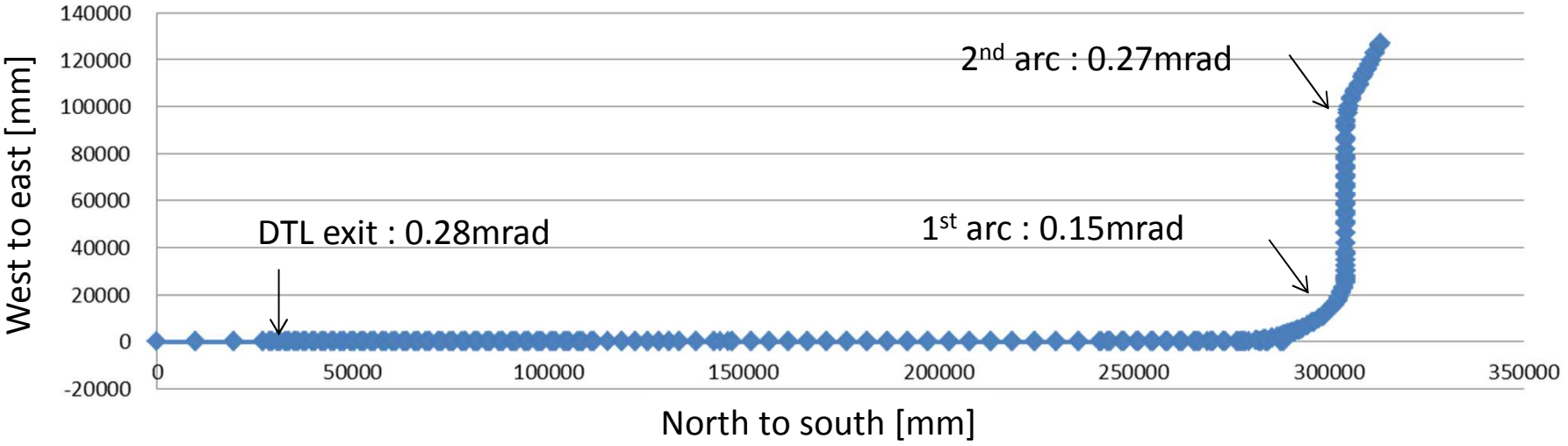


Beam transport line (expansion joints)

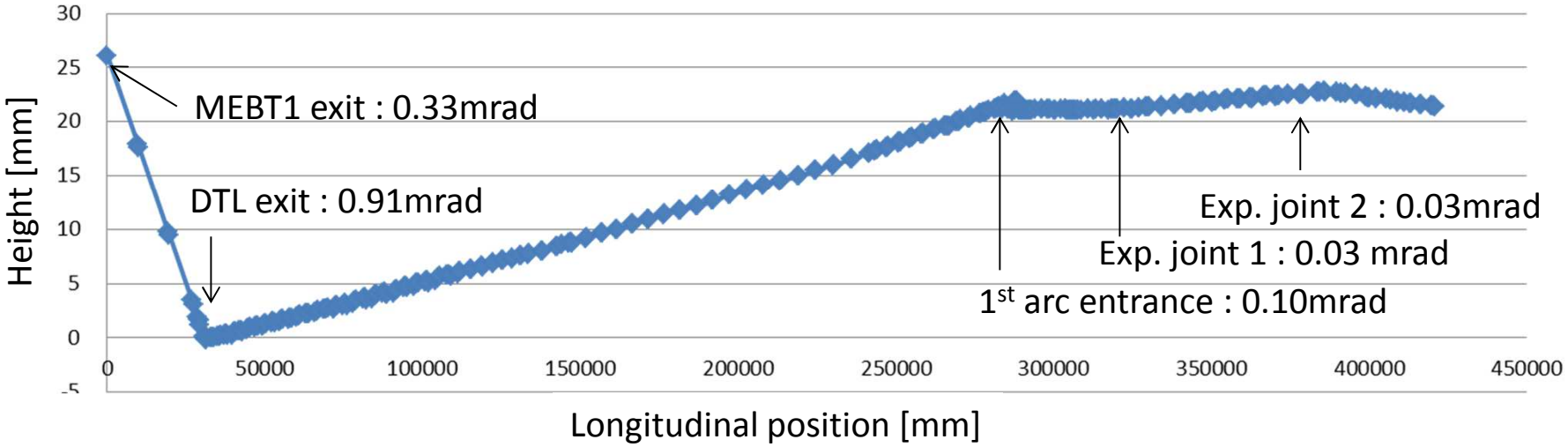


- Relative position after the first arc to the 90 degree dump.
- The beam transport section (from the first arc to the injection line to RCS) was adjusted to maintain the proper injection angle and position to RCS.

Steered angles of the beam line

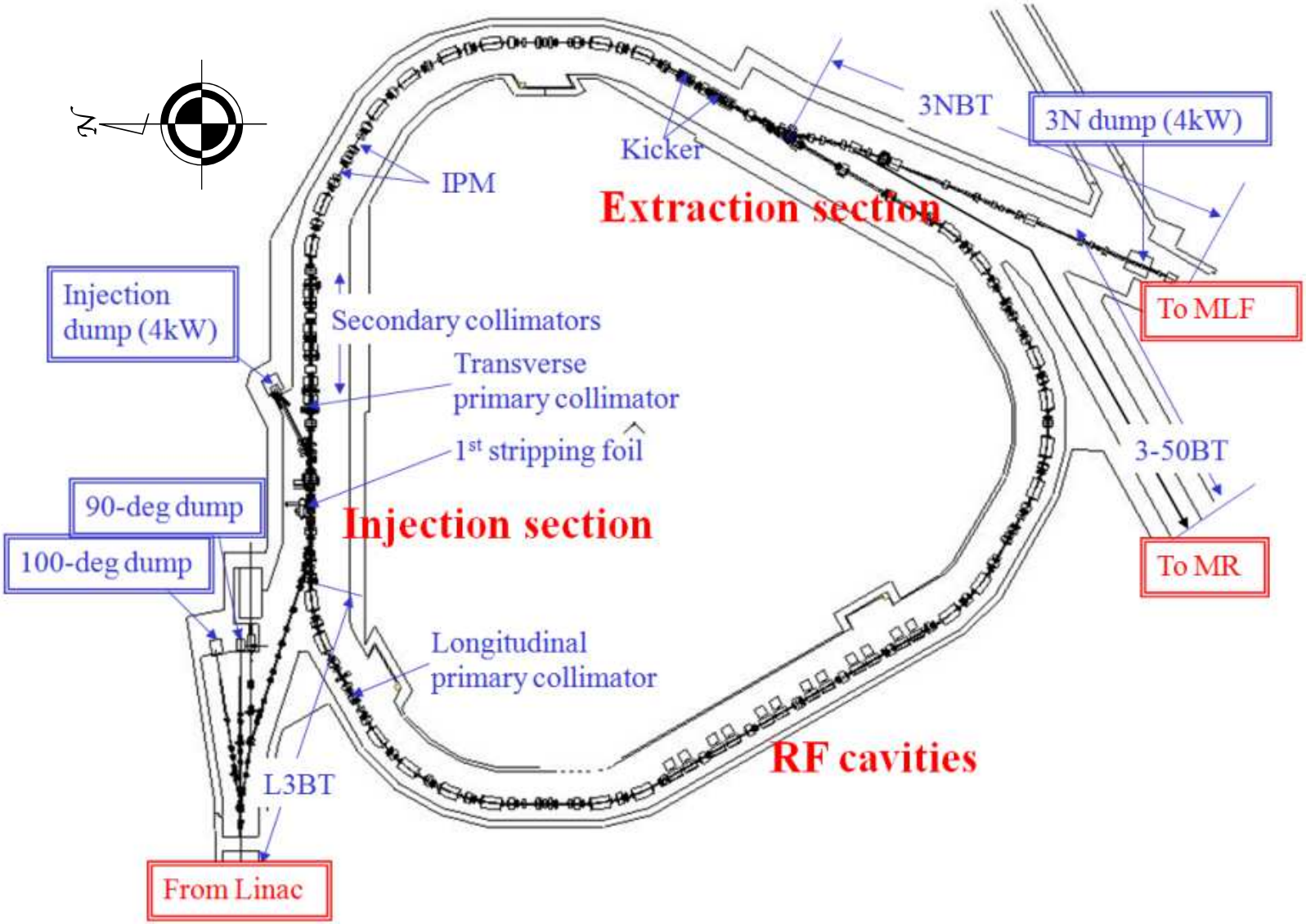


Bending magnets are re-aligned and those angles are slightly changed for the connection to RCS.

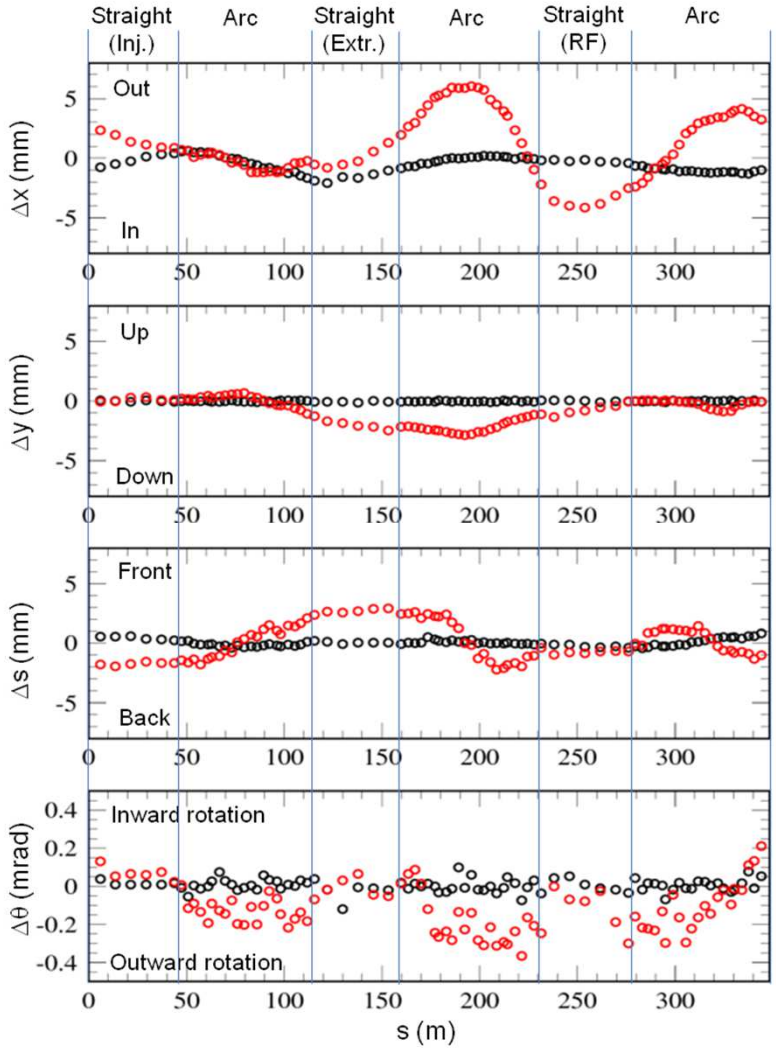


Vertically steered at the entrance of the 1st arc and expansion joints.

Status of RCS



Misalignment caused by the earthquake



Misalignment of RCS magnets before/after the earthquake

Black dots are values taken before and red dots are values taken after the earthquake.

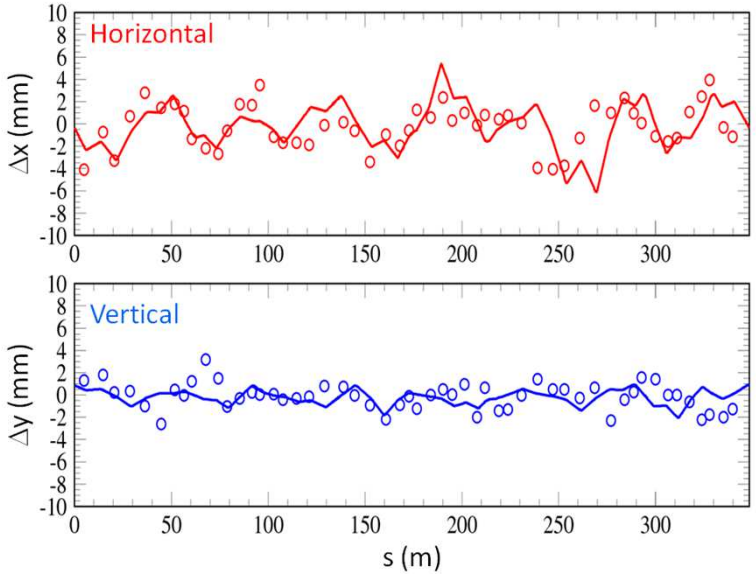
It was about 3mm displacement to horizontal direction before the earthquake. Expect for that, displacement was small.

Horizontal direction moved largely from the extraction straight section to the injection straight section after the earthquake.

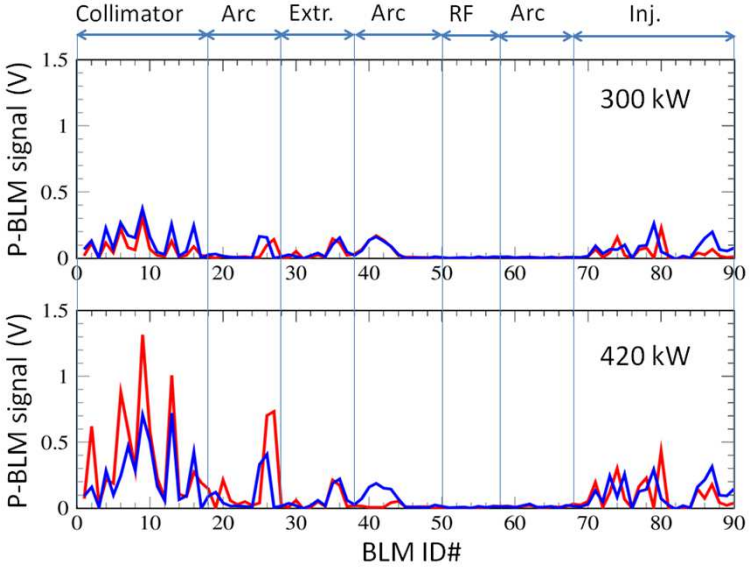
The amount of displacement was 10mm in a horizontal direction, 3.7mm in a vertical direction and 5mm in a longitudinal direction.

Orbit analysis using these results was shown next.

Influence on Beam operation by misalignment



Solid line shows calculated value and dots shows measured value.



Blue line shows beam loss before and red line shows beam loss after the earthquake.

The result of COD survey with 30kW beam after the earthquake using the parameter of the steering magnets before the earthquake.

Calculated value and measured value are nearly the same and it shows COD correction is possible.

The effect of misalignment on the beam was surveyed with the operation condition (300kW and 420kW) before the earthquake.

At 300kW operation, there was not a big difference in beam loss before and after the earthquake
but at 420 kW beam loss near the injection collimator almost doubled, obviously showing the effect of misalignment.

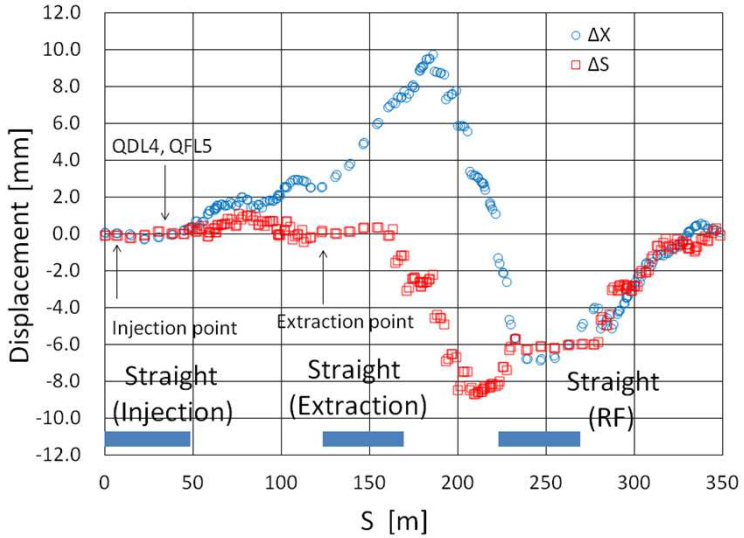
Realignment plane of RCS

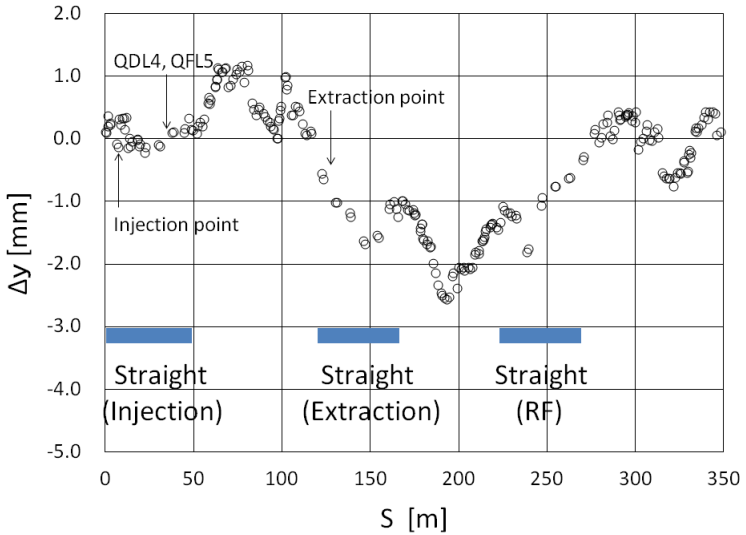
The most difficult part is adjustment of magnets near the injection collimator.

⇒ This area has high radiation dose and workability is very low.

Therefore for realignment it will be adjusted so that adjustment of magnets at the injection straight section becomes as small as possible.

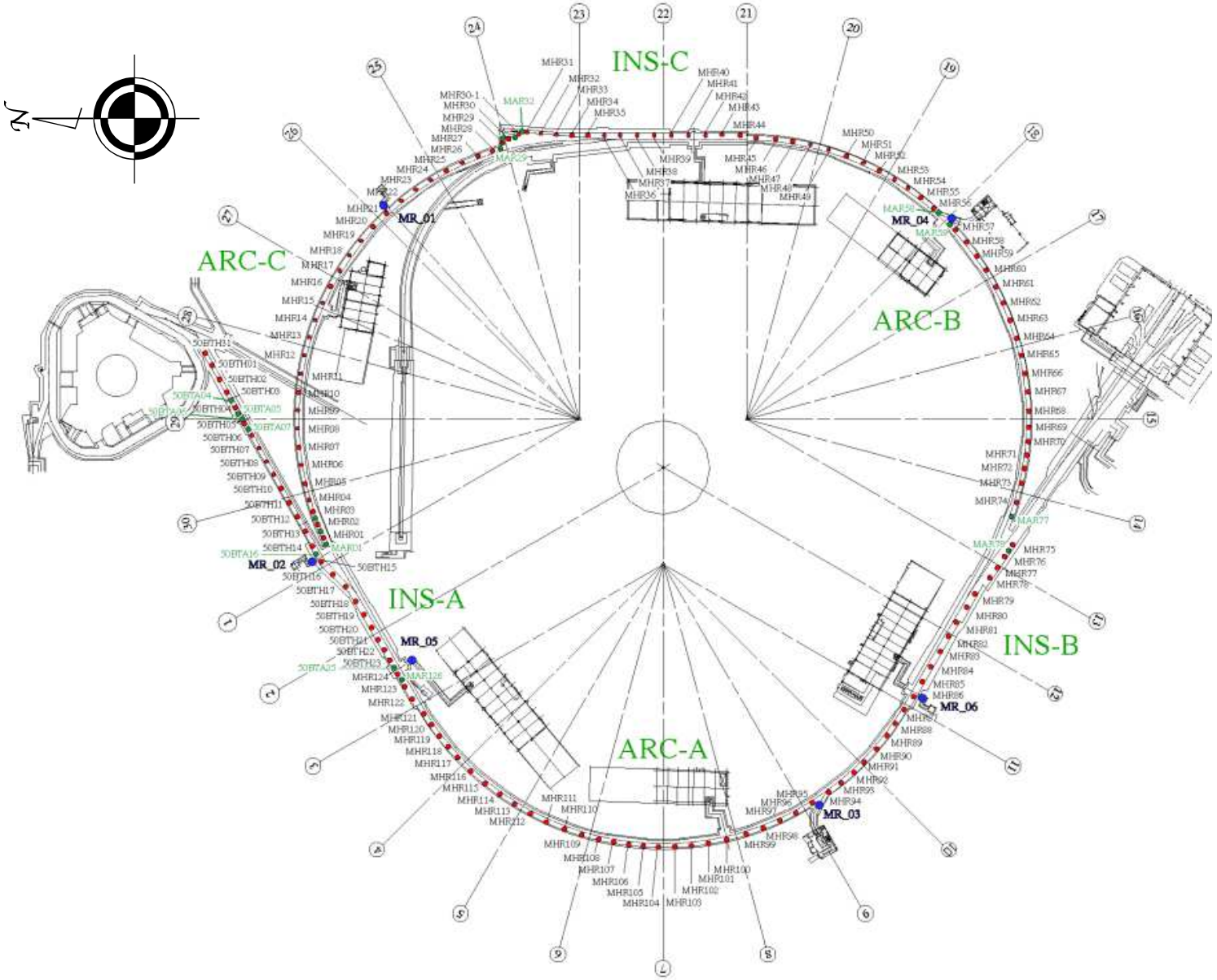
Displacement expected at this realignment is shown in the figure below.



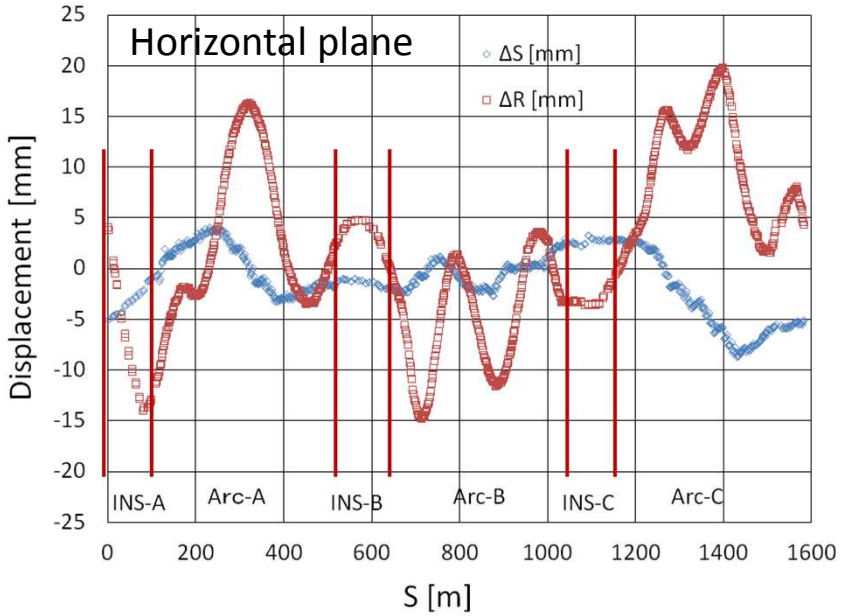


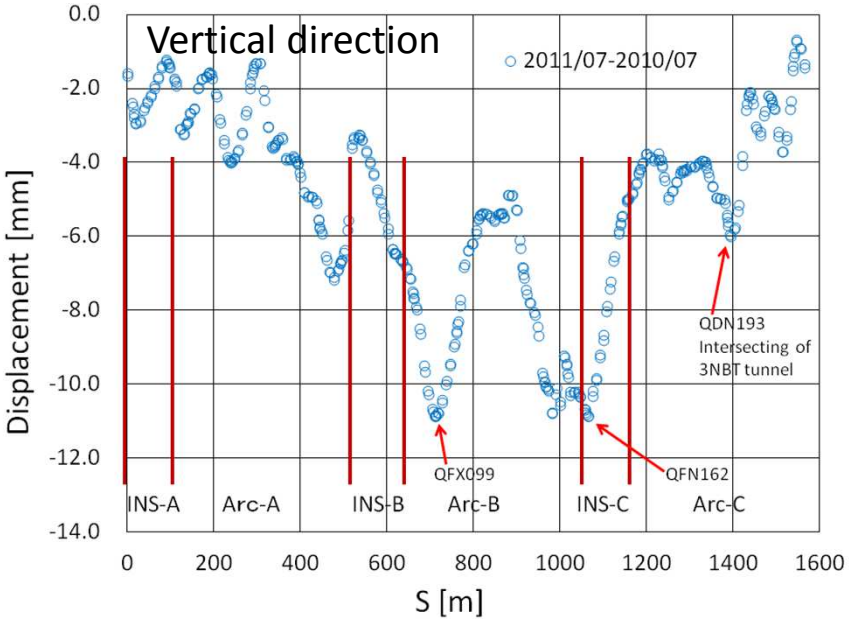
It was necessary to adjust the magnets about nearly 10 mm in horizontal direction.
However this displacement can be adjusted sufficiently within the range of the magnets movement.
The realignment of RCS magnets is planned from summer through fall in 2013.

Status of Main Ring(MR)



Misalignment caused by the earthquake





The displacement range was 35 mm horizontal, 13 mm longitudinal and 10 mm vertical direction.

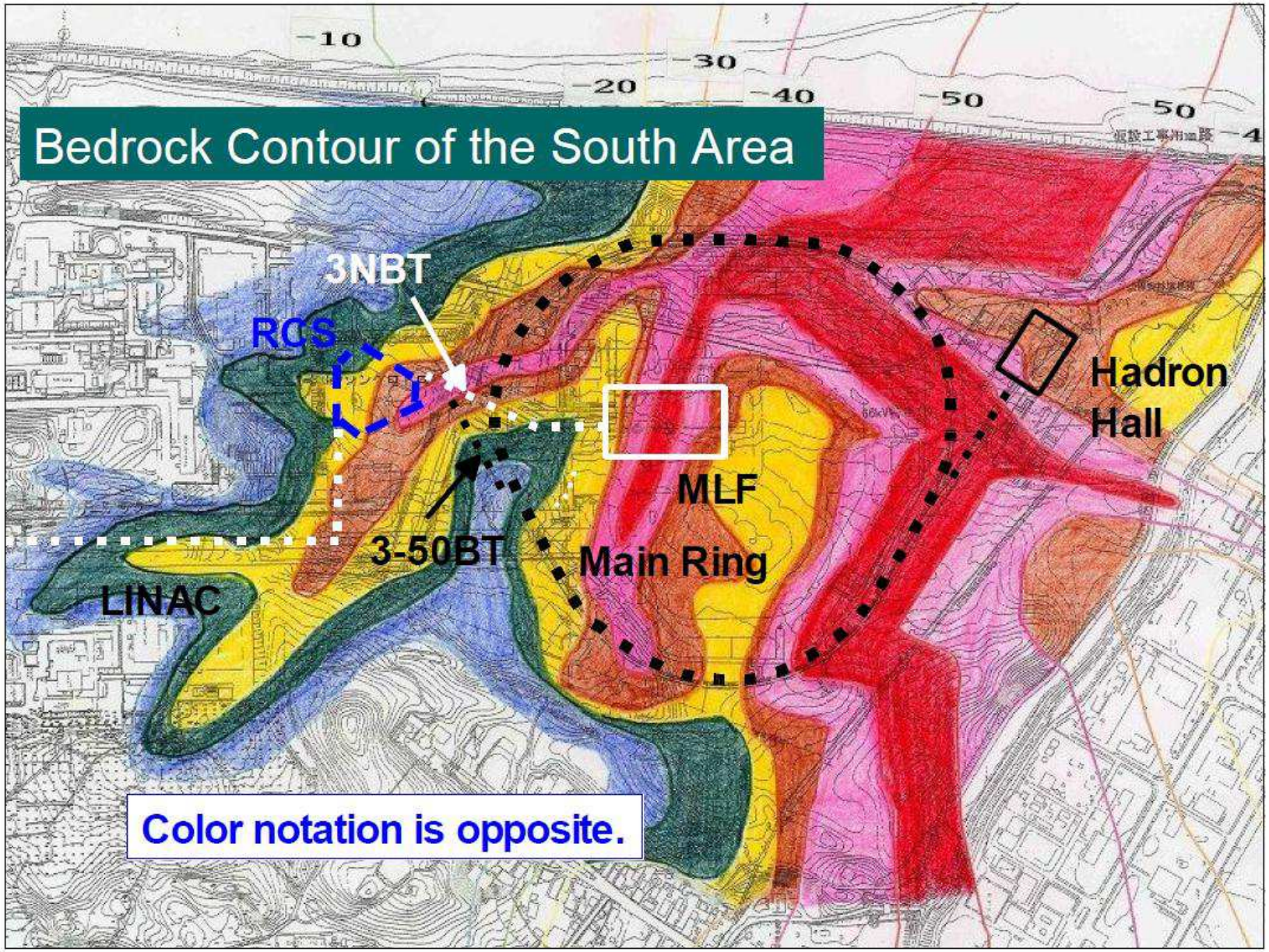
It is seen that the whole beam line showed settlement of about 2mm.

In addition, magnets from INS-B to INS-C settled down largely.

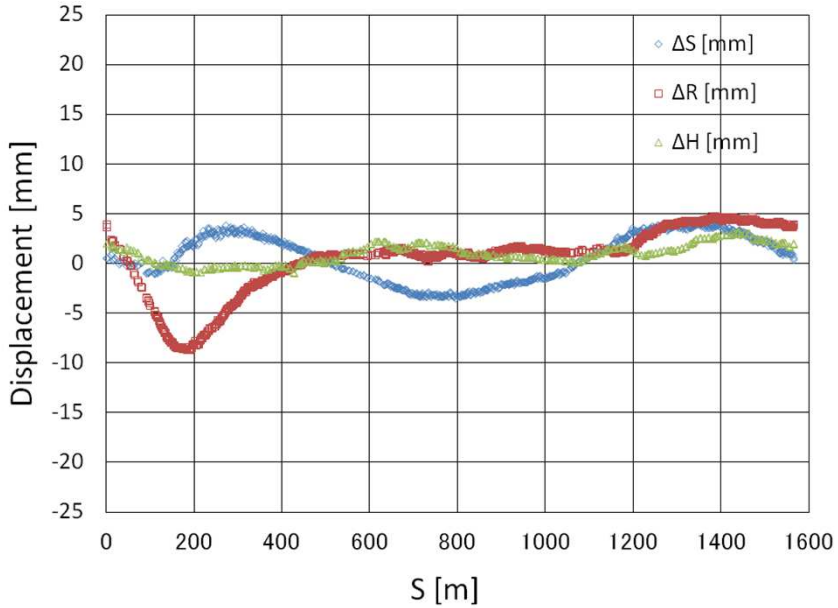
Compared to bedrock contour, it is found out that change of height from QFX099 and QFN162 corresponds to the relief of basement layer.

As there was a large displacement throughout MR, alignment of the all magnets was implemented from August through November 2011.

Bedrock contour around J-PARC facility



Survey result after alignment of MR magnets



For horizontal direction, displacement of about 8mm occurred regardless of the alignment.

When survey data is analyzed, usually through-hole data (6 points) measured by traverse survey is included.

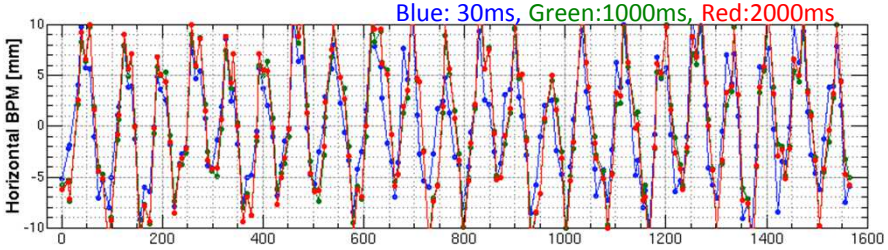
However this time through-hole data measured by GPS survey was used and among the 2 points could not be used due to the earthquake. Therefore it was considered that sufficient data accuracy could not be obtained.

Effect of aftershock was also considered but the levelling data of the floor reference points implemented before/after the alignment (July and November 2011) showed displacement range of the tunnel of 0.7mm so it was difficult to think of displacement of several mm in a horizontal direction.

COD measurement without correction before the earthquake

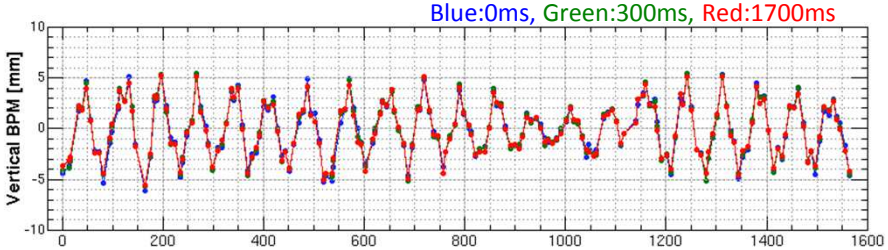
Run27 Shot#19294 (20 Nov 2009) rms: 6.4mm

Blue: 30ms, Green:1000ms, Red:2000ms



Run26 Shot#398 (16 Oct 2009) rms: 2.6mm

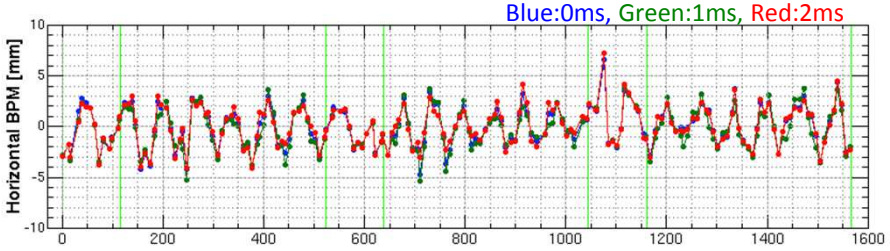
Blue:0ms, Green:300ms, Red:1700ms



COD measurement without correction after the earthquake

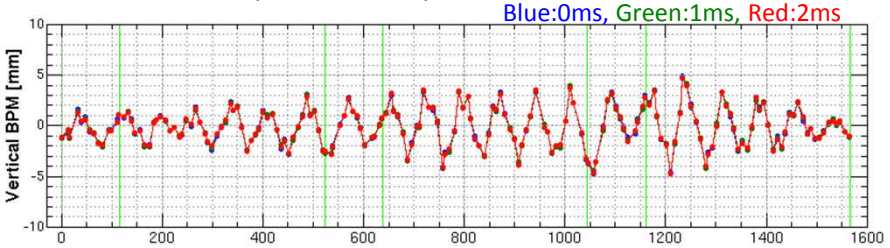
Run39 Shot#97 (22 Dec 2011) rms: 2.0mm

Blue:0ms, Green:1ms, Red:2ms



Run39 Shot#97 (22 Dec 2011) rms: 1.8mm

Blue:0ms, Green:1ms, Red:2ms



Luckily the result of COD measurement without correction after restart of beam operation was better than that of before the earthquake so it was considered that the alignment status was good enough.

The final conclusion of MR alignment will be made based on the result of the survey in summer 2012 carried out after through-holes are recovered.

Summary

- As the main tunnel of the accelerator facility is held by driving piles into the basement layer (gravel mudstone layer), GPS survey found smaller displacement in a horizontal direction than that of reference points on the ground. However deformation in the tunnel and displacement between facilities were well identified.

- Displacement of the beam line was identified by the survey after earthquake.
  Displacement of RCS and MR in a vertical direction corresponded to the relief of basement layer.

- At Beam transport line displacement at expansion joints in a tunnel was large.

- Based on these results, alignment was carried out for all the facilities except for RCS and the beam operation restarted in December 2011.

- Precise traverse survey of reference points on the ground is being implemented at this moment and more detailed data is expected to be obtained.