Study on the Realignment Plan for J-PARC Linac after the Tohoku Earthquake in Japan

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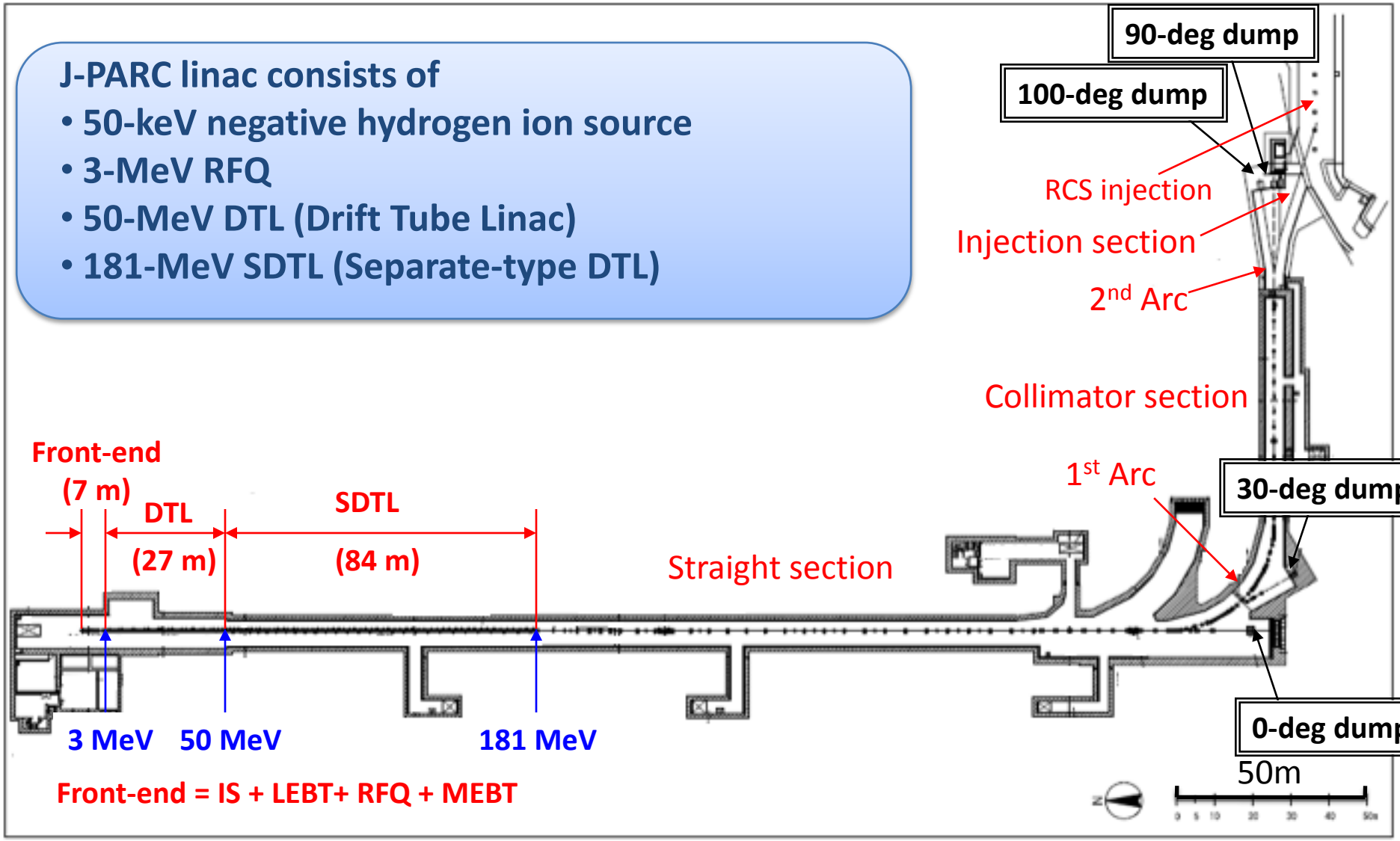
Outline

- Relevant specifications of J-PARC linac
- Misalignment due to the earthquake
  - Deformation of linac tunnel
  - Emergent survey of drift tubealingment
- Particle simulations with larger misalignment
- Realignment strategy
- Summary

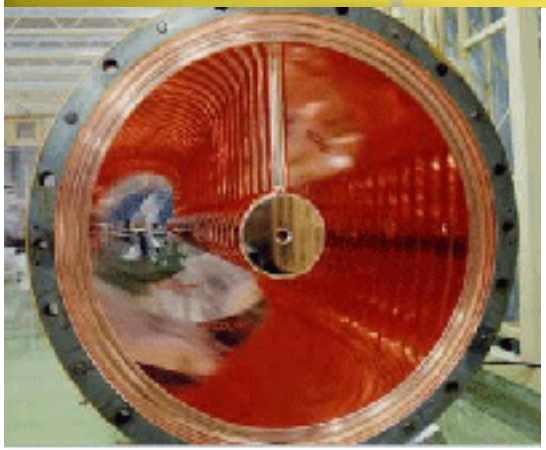
Layout of J-PARC linac

J-PARC linac consists of
- 50-keV negative hydrogen ion source
- 3-MeV RFQ
- 50-MeV DTL (Drift Tube Linac)
- 181-MeV SDTL (Separate-type DTL)



DTL

- 3 DTL tanks
- 27 m in total
- Each DTL tank consists of 3 unit tanks connected with flanges.
- 143 DT's (Drift Tubes) in total.
- Each DT is embedded with an electro-magnetic DTQ.
- Heavy cabling for DTQ.



Electro-magnetic DTQ

DTL (cont.)

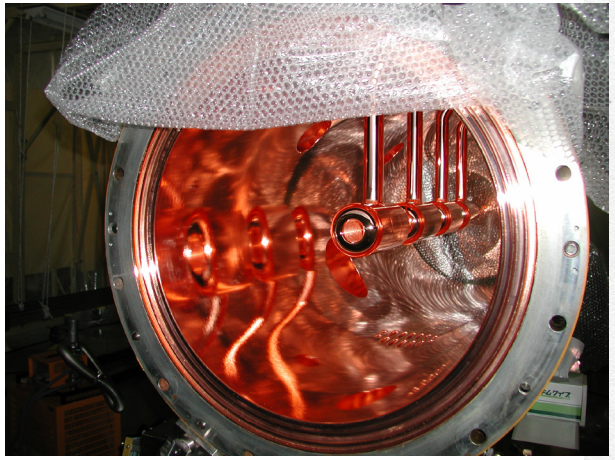
Alignment of DTL has two stages:

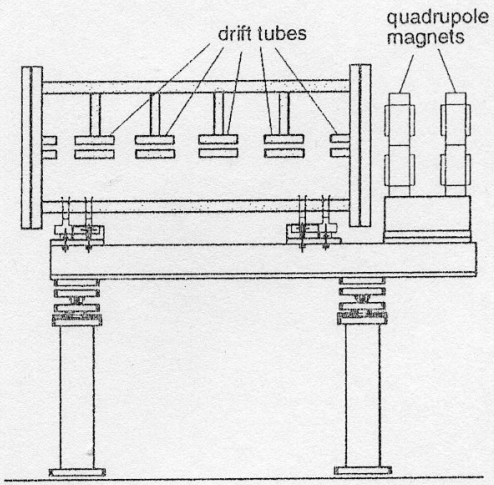
- Alignment of unit tanks
  - If the position adjustment is large, it requires to disconnect unit-tank flanges.
  - It involves disconnection of heavy cabling for DTQ's.
- Alignment of DT's in a unit tank
  - It requires to move the unit tank to an off-line working area.
  - Almost all DT's should be dismounted to conduct DT alignment over again.

Both procedures are very time-consuming and it takes months.

SDTL

- 30 SDTL tanks
- 84 m in total
- Each tank has the length of 1.5 to 2.6 m.
- 4 DT's for an SDTL tank
- No DTQ in DT.
- External quadrupoles at inter-tank spacing.





SDTL (cont.)

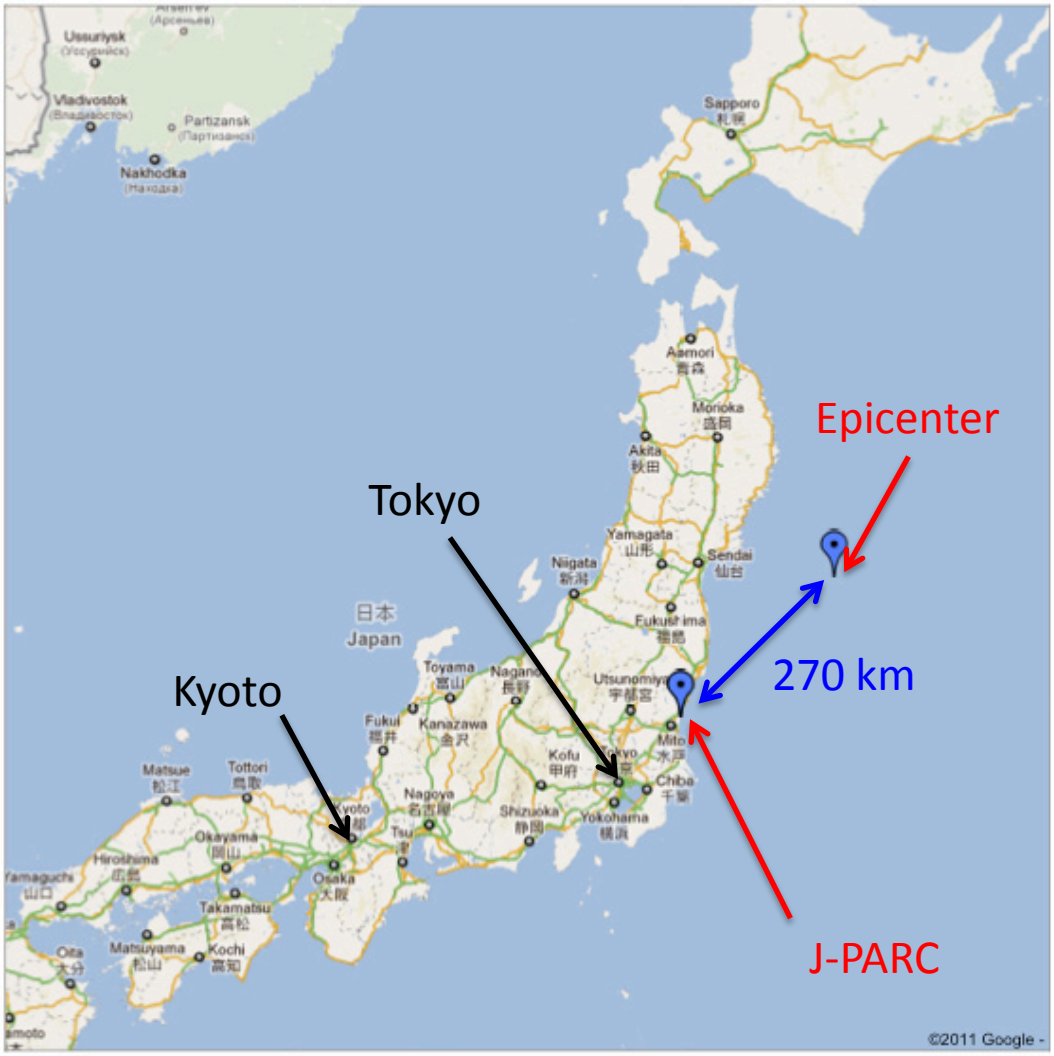
Alignment of SDTL also has two stages:

- Alignment of tanks and external quadrupoles
  - Conventional alignment with a laser tracker and a digital level.
- Alignment of DT's in a SDTL tank
  - It requires to move the SDTL tank to an off-line working area.
  - Number of DT's in a tank is much smaller, and the tolerance for the DT alignment is much larger because of the lack of DTQ.
  - No cabling for DTQ.

They are more straightforward than those for DTL.

The Tohoku Earthquake

- On March 11, 2011, we had a 9.0-magnitude earthquake off the Pacific coast of Tohoku region, Japan.
- J-PARC is 270 km away from the epicenter, but experienced a severe tremor with which it is difficult to remain standing*. The tremor lasted about 6 min.

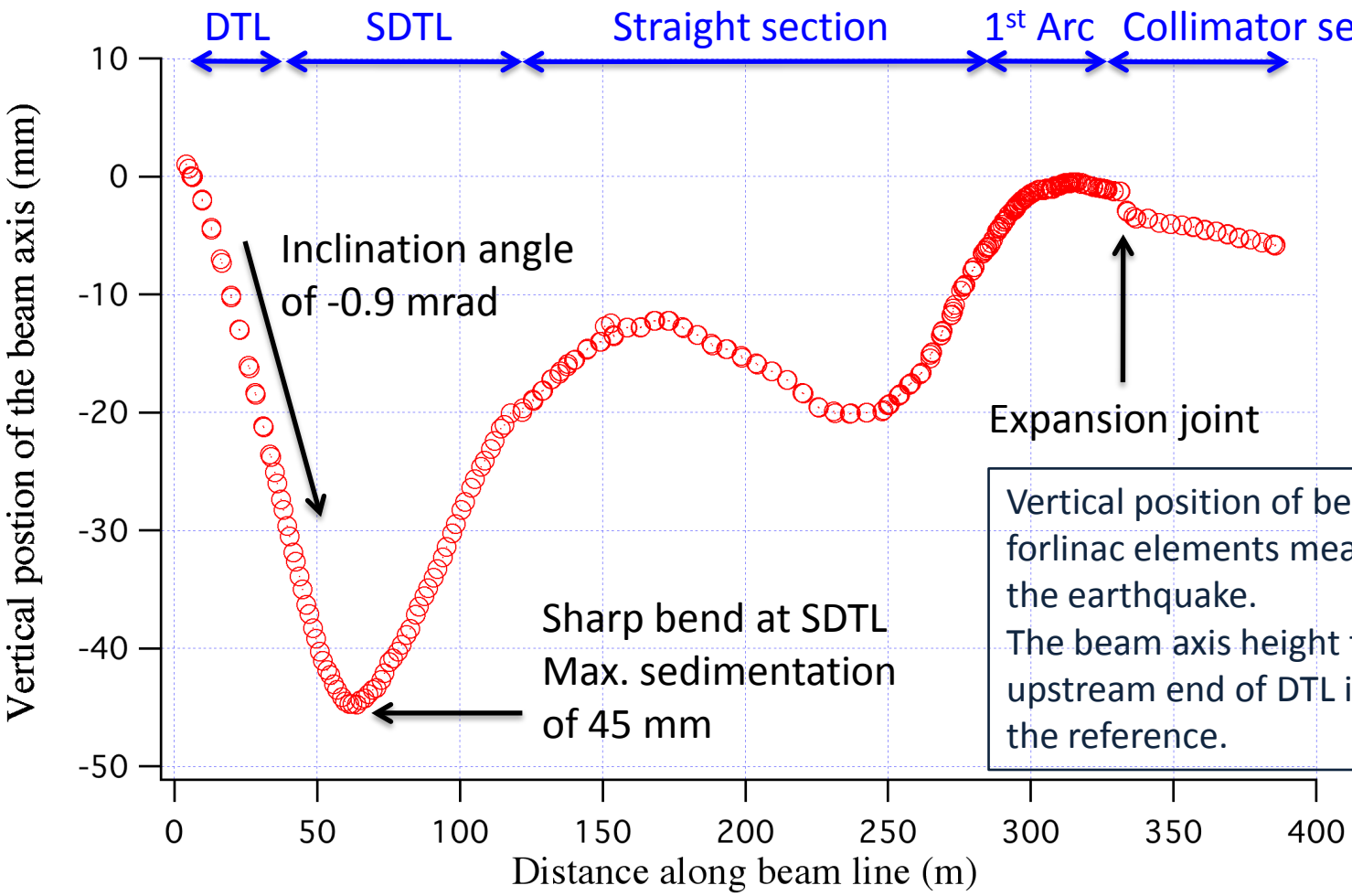


* Measured acceleration at Nakaminato (10 km south from J-PARC site) was 5.5 m/s^2 horizontally and 4.1 m/s^2 vertically .

Damages to J-PARC linac

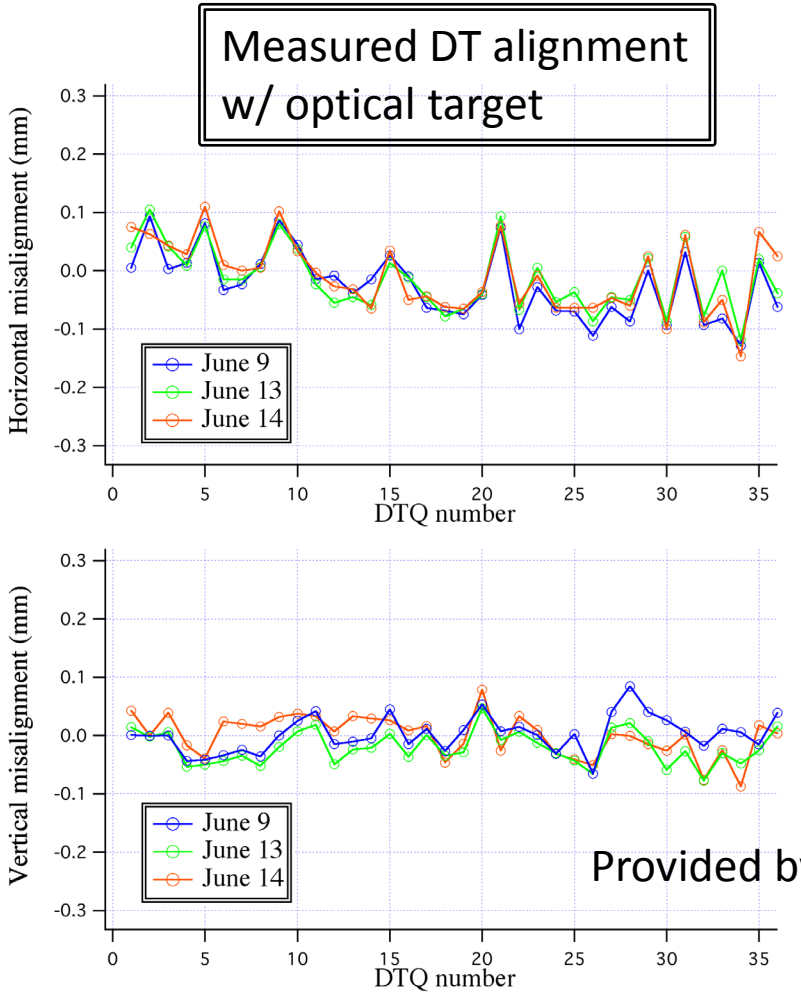
- Significant subside is seen in wide area. It reaches 1.5 m beside the entrance.
- No toppling is seen for elements in linac tunnel.
- Ground water leaks from cracks in the linac tunnel.
- Numerous damages to inner walls of the building, utilities, cranes, etc.

Floor deformation

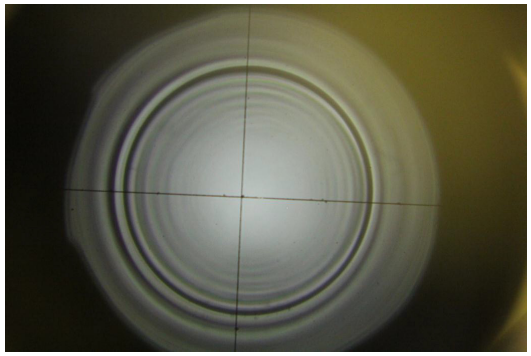


Significant deformation of the linac tunnel necessitated us to conduct urgent realignment.

Emergent survey for DT alignment

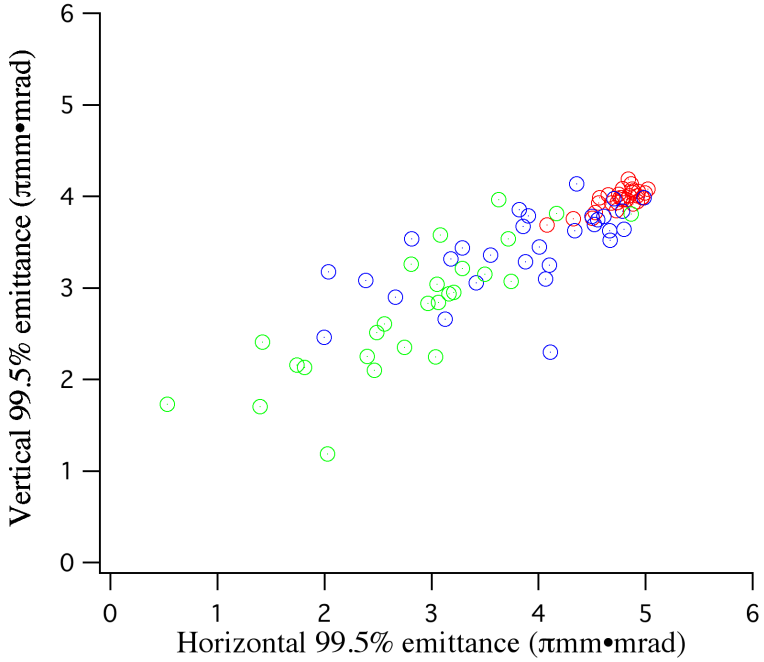


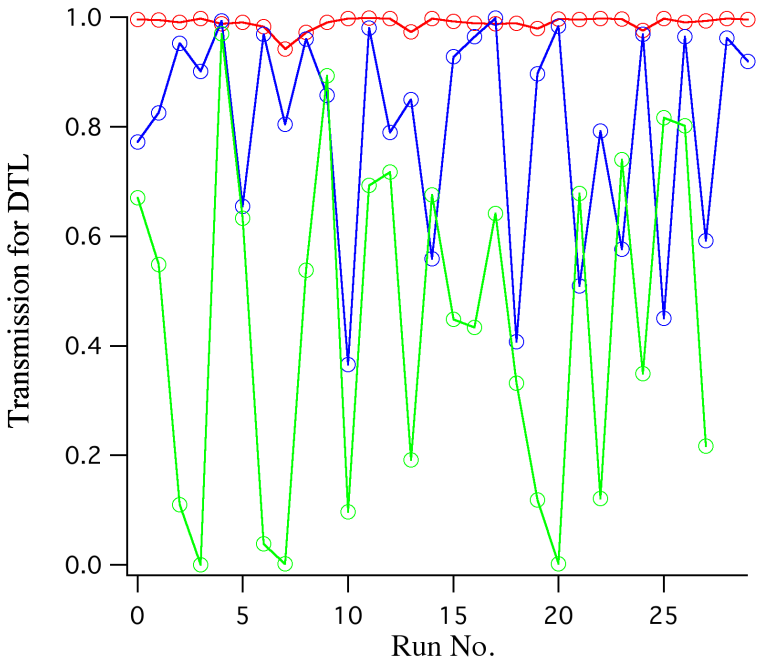
Provided by T. Ito



- Emergent survey of DT alignment has been conducted, and we have not found visible misalignment except for DTL1.
- The DT misalignment in DTL1 is estimated to be around 0.1 mm.

Particle simulation

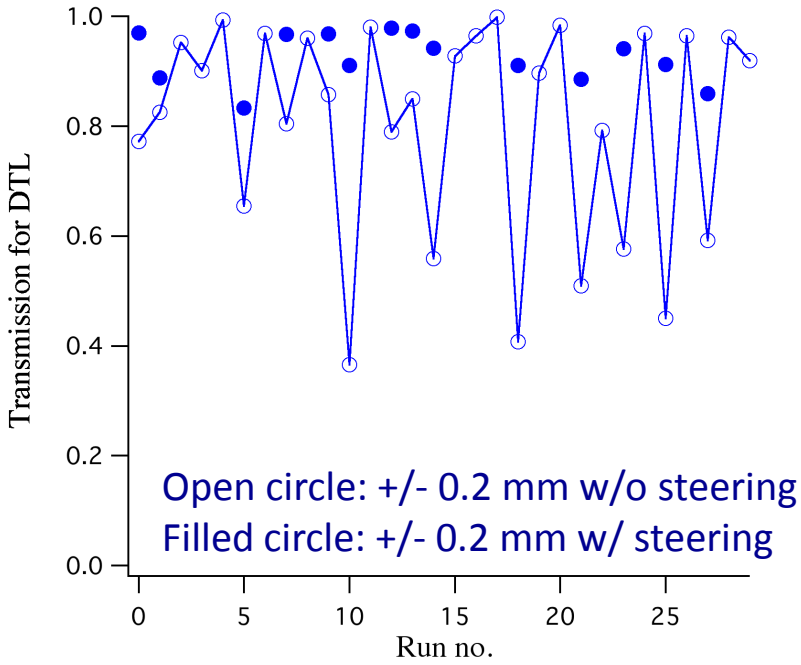




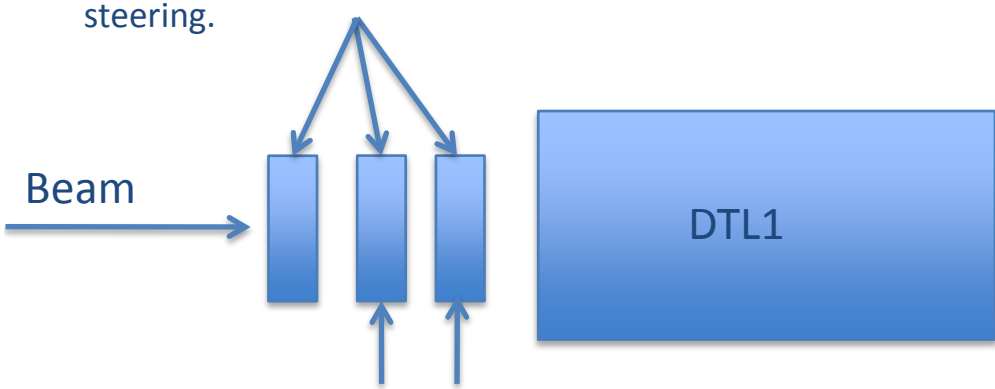
DTQ misalignment: Red: +/- 0.1 mm, Blue: +/- 0.2 mm, Green: +/- 0.3 mm

- We have conducted particle simulations with IMPACT assuming lager DTQ misalignment than usual.
- DTL has the small aperture radius of 6.5 mm in the upstream portion of DTL1, and we don't have a steering magnet in the DTL section.
- Larger DTQ misalignment causes substantial beam loss at the narrow section rather than emittance growth.

Particle simulation (cont)



Each quad in MEBT has additional windings for H&V steering.



The strengths of the last two steerings have been adjusted to maximize the transmission efficiency for the entire DTL.

- The transmission efficiency can be restored to above 80% by beam steering with 0.2 mm misalignment.
- We need to increase the capacity of steering to cope with 0.2 mm misalignment.
- We have concluded that the tolerable limit for the DTQ misalignment is around 0.2 mm assuming increase of steering capacity as a temporary expedient.
- This limit is set considering the present peculiar situation where the soonest recovery of the beam operation is strongly requested after the earthquake.

Realignment strategy

- Laying down the realignment plan, we put emphasis on the soonest recovery of the beam operation basing on the observed misalignment and particle simulation results.
- We have concluded that the observed DT misalignment is not critical to resume beam operation.

  We omit realignment of DT's in DTL and SDTL.

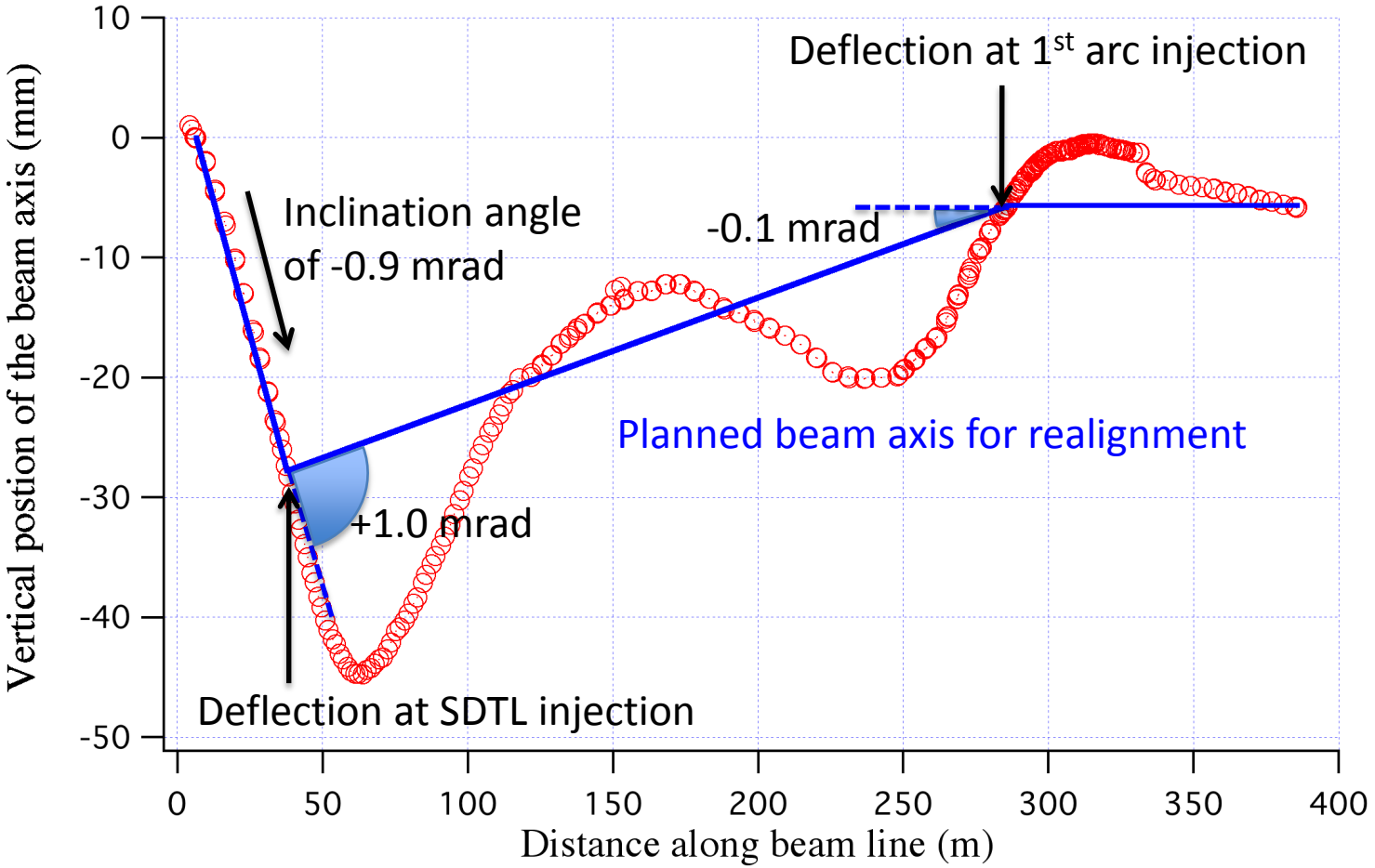
Realignment strategy (cont.)

- We have concluded that the DTL realignment with disconnection of unit tanks is too time-consuming.

  We realign DTL with inclination angle of -0.9 mrad.
- Inclined DTL alignment requires deflection of beam axis somewhere downstream.

  We deflect the beam axis at SDTL injection by +1.0 mrad, and at 1st arc entrance by -0.1 mrad.
- We introduce similar but smaller deflections in the horizontal direction at the same deflection points.

Planned beam axis



- The beam axis is deflected by steering magnets.
- Adopting this beam axis, we can avoid the modification of stands for accelerator components.

Summary

- A 9.0-magnitude earthquake in March 2011 forced us to conduct urgent realignment of J-PARC linac.
- A realignment plan is laid down putting emphasis on the soonest recovery of beam operation.
- Based on the observed misalignment and particle simulation, we decided to omit DT realignment for DTL and SDTL.
- We also decided to align DTL with the inclination angle of -0.9 mrad to avoid time-consuming disconnection of unit tanks.
- It necessitated us to introduce deflections in the beam axis with the deflection angle of around 1.0 mrad.
- The actual realignment is now underway with this strategy, aiming at the resumption of beam operation in December 2011.

Thank you

Please visit related posters also:

- K. Hasegawa et. al., “Status of J-PARC Accelerator Facilities after the Great East Japan Earthquake”, **WEPS095**.
- T. Morishita et. al., “Floor Deformation of J-PARC Linac after the Tohoku Earthquake in Japan”, **WEPS049**.
- A. Miura et. al., “Beam Monitor Deformation by Tohoku Earthquake and its Recovery Project”, **WEPC144**.
- M. Shirakata et. al., “Displacement of J-PARC Caused by Megaquake”, **TUPS057**.