Status Report of the Realignment for J-PARC 3GeV RCS

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Outline

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2. Misalignment caused by the earthquake
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Introduction

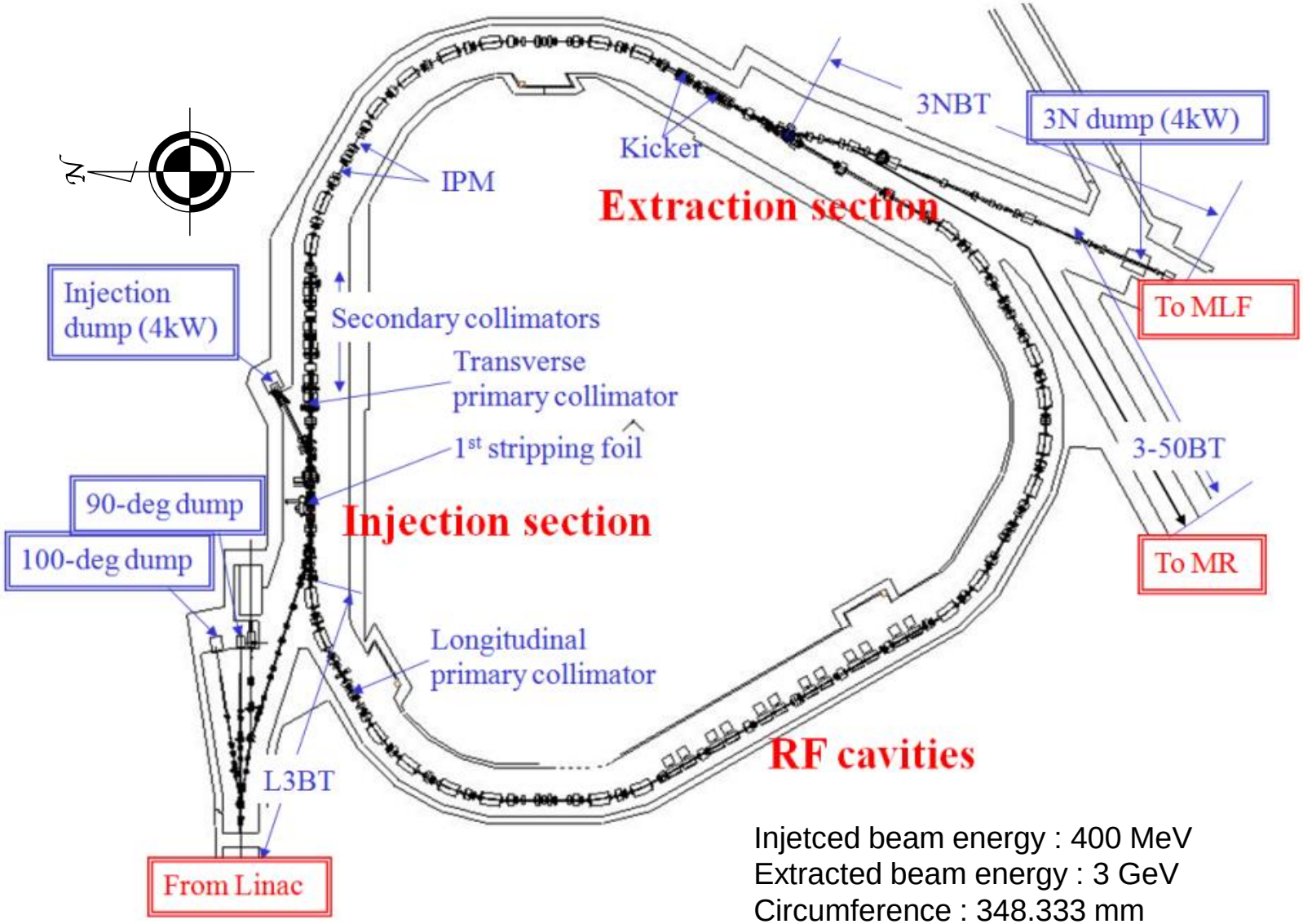
J-PARC 3GeV RCS magnets suffered from the misalignment from designed beamline caused by the earthquake in March, 2011.

As the result of the obit calculation showed that the beam loss was acceptable for beam operation at 300kW.
Therefore, beam operation with the current placement was implemented until May, 2013.
As beam loss increased at 1 MW operation, realignmnet of beamlines was necessary.

In addition to realignment of magnets, alignment for ducts of vacuum devices was implemented in order to secure the ring acceptance.

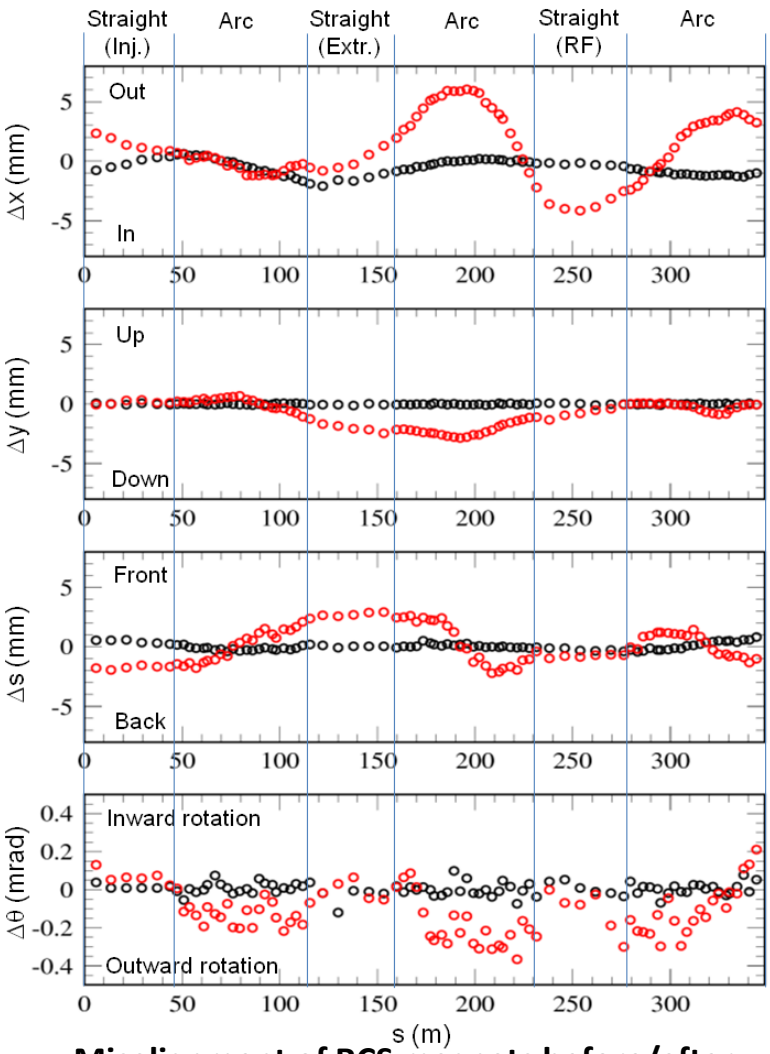
In this presentation the method and result of the realignment of RCS beamline implemented last year will be reported.

Placement of the beamline for RCS



Injetced beam energy : 400 MeV
Extracted beam energy : 3 GeV
Circumference : 348.333 mm

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.

Measurement of the magnets

The survey of the RCS magnets was carried out using a laser tracker and a digital level.

It was about 3 mm 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.

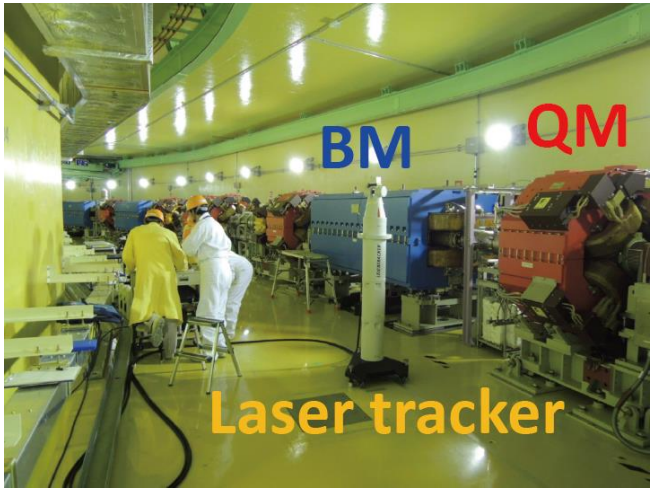
As the result, it was found out that the maximum displacement from design value of magnets

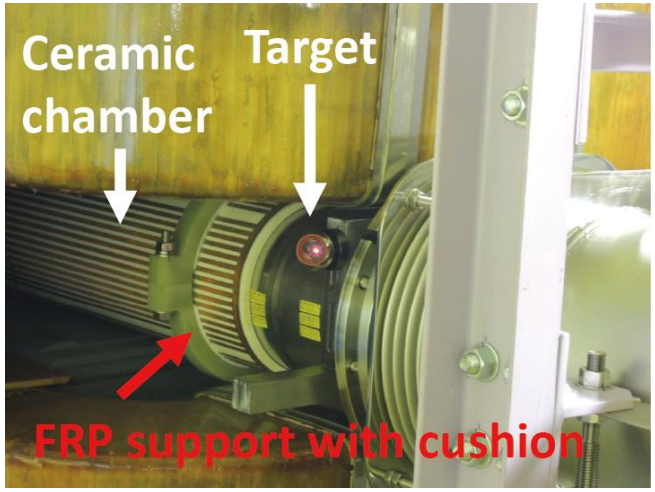
Δx ; about 6.0 mm in horizontal direction,
Δy ; about 2.8 mm in vertical direction
Δs ; and about 2.8 mm in longitudinal direction.

The circumference of RCS ring expanded by 10.4mm.

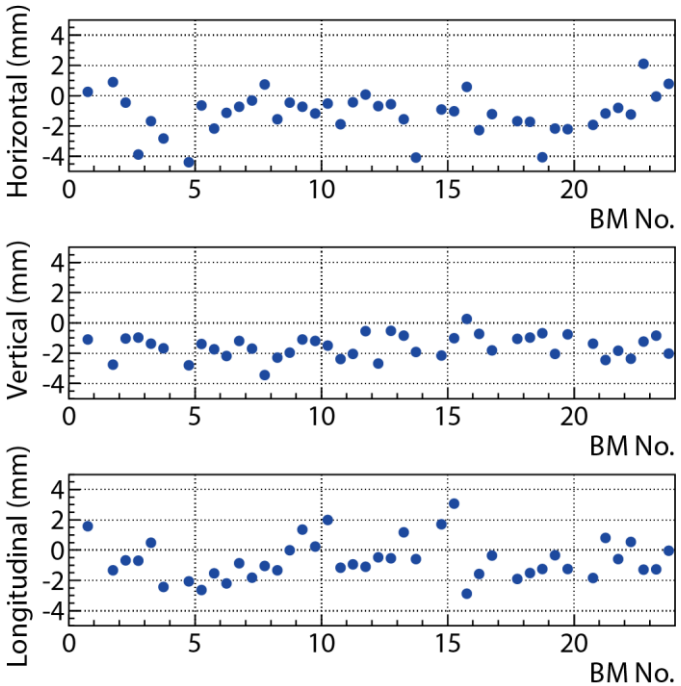
Measurement of the ceramic chambers

Ceramic chamber is used for a vacuum duct of RCS in order to reduce eddy current.
The measurement of displacement for the ceramic chambers of dipole and quadrupole magnets was also carried out using a laser tracker and a measurement device of target in 2012 summer.

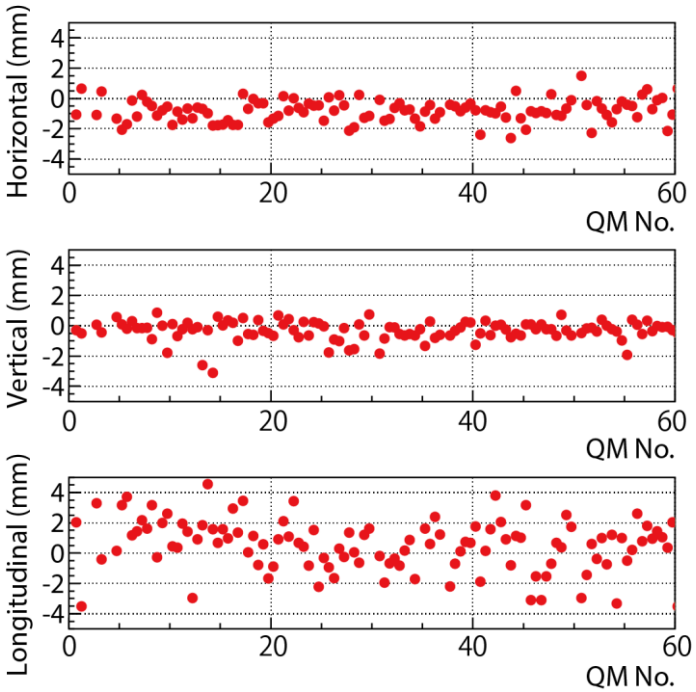




Measurement of up/down stream parts of each ceramic chamber was implemented by attaching a measurement device on a titanium sleeve connecting ceramic part and flange part of a ceramic chamber.



Ceramic chambers of dipole magnet



Ceramic chambers of quadrupole magnet

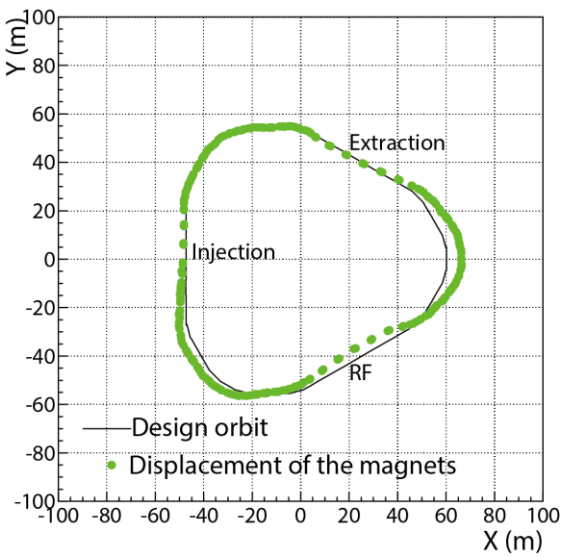
Alignment accuracy of ceramic chamber at the time of installation was within ±0.5 mm.
Ceramic chamber shifted from the ideal position.
It is considered this displacement was mainly caused by the earthquake.
⇒This measurement date was used to evaluate the acceptance of the ceramic chamber.

Accordingly, it was found out that for some ceramic chambers acceptance was not enough.
Therefore realignment was necessary also for ceramic chambers.

Strategy of the realignment

The most difficult part was adjustment of magnets near the injection collimator, because this area has high radiation dose and workability was very low.
Fortunately, relative displacement of all components at injection area was ***less than ±0.2mm***.
⇒Therefore, it was decided that ***magnets in the injection straight section*** would ***be fixed*** and the rest magnets would be adjusted. Height of the beam line was decided base on the magnets near the collimator (QDL4 and QFL5).

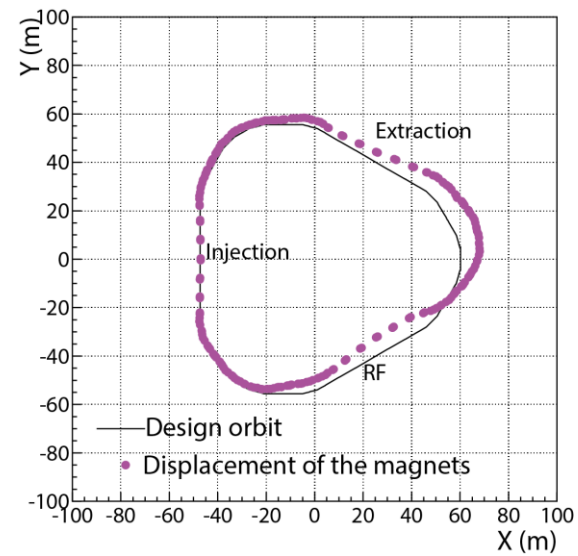
Decision of the RCS ring coordinate



Before coordinate adjustment

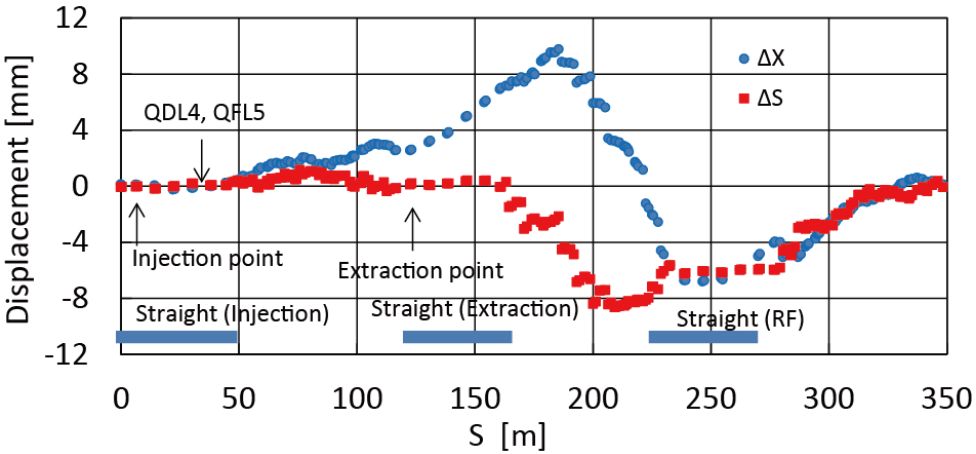
Ring coordinate adjustment to keep injection section.

The displacement is magnified by 1000 for convenience



After coordinate adjustment

Displacement of magnets when converted into new ring coordinate



Displacement of the horizontal and longitudinal direction

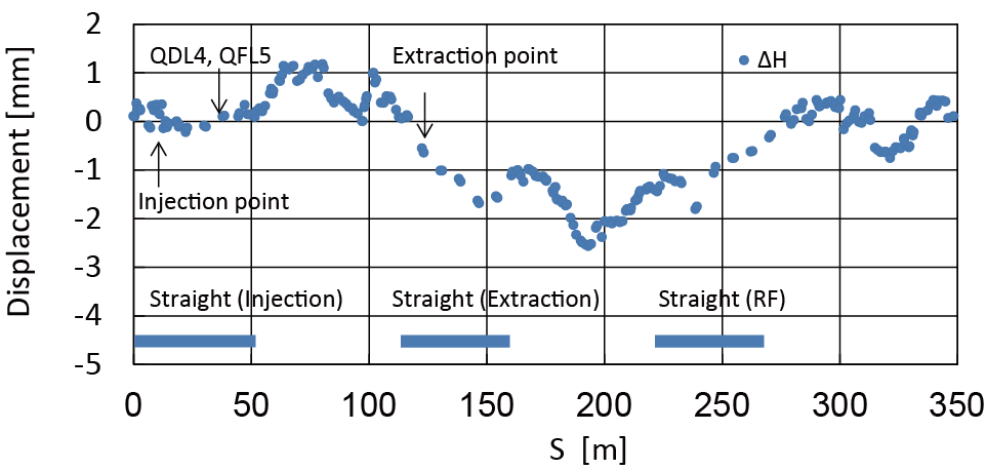
The maximum displacement from new design value of magnets

Δx ; about 10.9 mm in horizontal direction,

Δs; about 8.6 mm in longitudinal direction

ΔH ; and about 2.8 mm in vertical direction.

Displacement became bigger in the straight section between the extraction and RF due to the new coordinate.

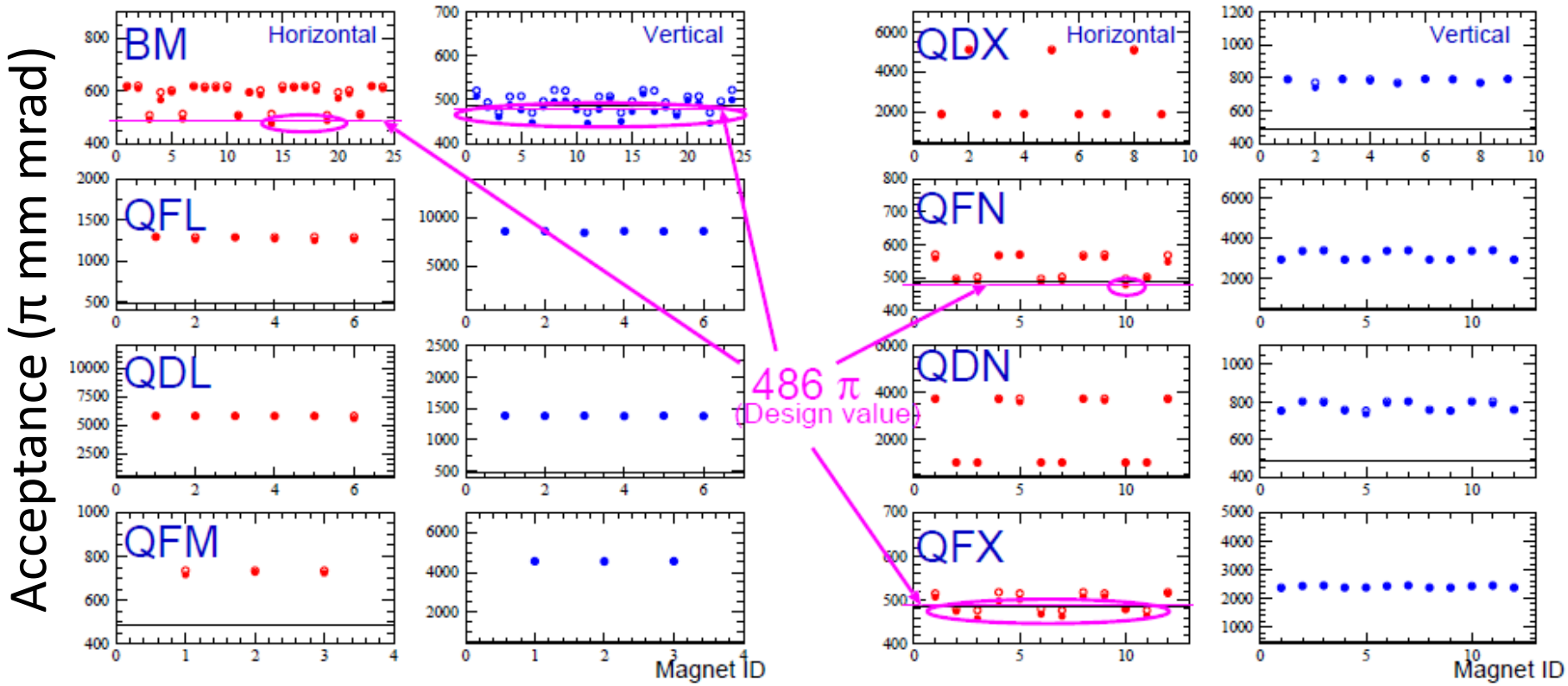


Displacement of the vertical direction

However this displacement can be adjusted sufficiently within the range of the magnets movement.

Realignment of the ceramic chambers

Ring acceptance must be secured to realize 1MW beam operation.
Acceptance calculation was implemented in consideration of misalignment and COD of 3mm for the ceramic chambers.



● ● Acceptance including COD of 3mm and misaligment

○ ○ Acceptance including COD of 3mm

Calculation conditions:

- Large β operation
- C.O.D. of 3 mm

⇒Acceptance can't be secured mainly for diapole and quadrupole magnets (QFN, QFX).

In addition, bellows will be installed up/down stream of the ceramic chamber.
Adjustment range of bellows is within 1mm.
When there is a displacement of more than 1mm between bellows and flanges, vacuum ducts can't be connected because of adjustment of bellows.
Therefore ceramic chambers there have to be aligned.

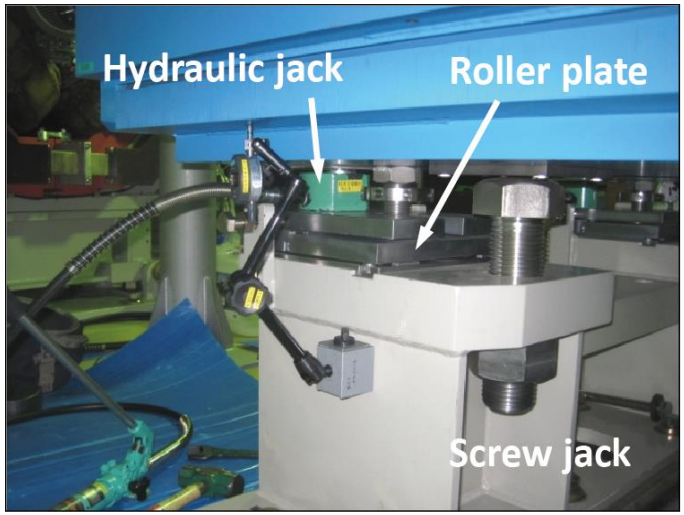
Realignment ceramics chambers

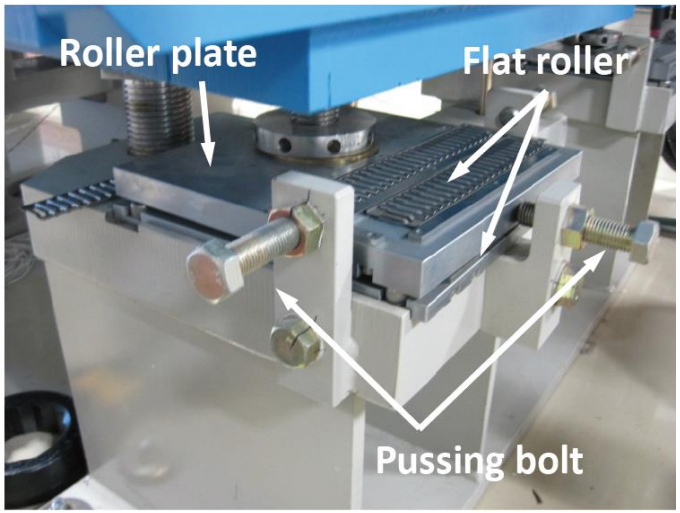
Ceramics chambers	Realignment	Total
BM	20	24
QM	23	60
SM	6	18

The amount of the realignment components

Component	Realignment	Total
BM	24	24
QM	53	60
SM	18	18
Ext. Sept.	2	3
Ext. kicker	2 (8 kicker-mag. installed in 2 vacuum chambers)	2
RF Cavity	11 and new 1 cavity installed	12
Monitors, vacuum pumps, exciters, ….		
Connected flanges : 336		

Method of the realignment for the dipole magnet





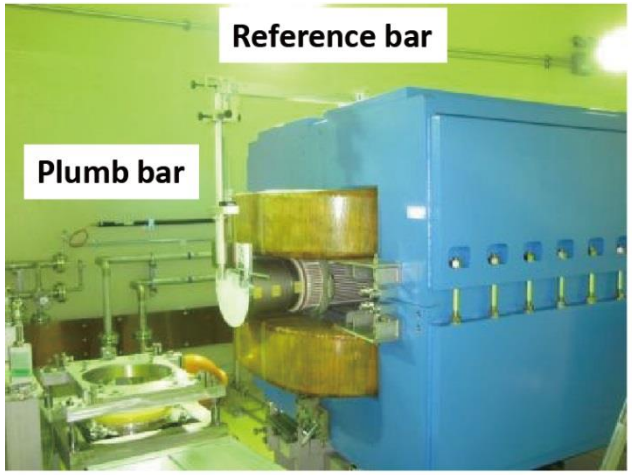
- Alignment of magnets was carried out using a laser tracker and a digital clinometer.
- Generally magnets are adjusted first in the vertical direction and then in the horizontal direction.
- Magnets were adjusted within ±0.2 mm after repetition of adjustment in vertical and horizontal directions.
- Dipole magnets of RCS weigh 38 ton. ⇒ Normal adjustment can't move them.
- To reduce weight and friction at the time of adjustment, 4 sets of hydraulic jack and roller plate were installed between the magnets and the girder.

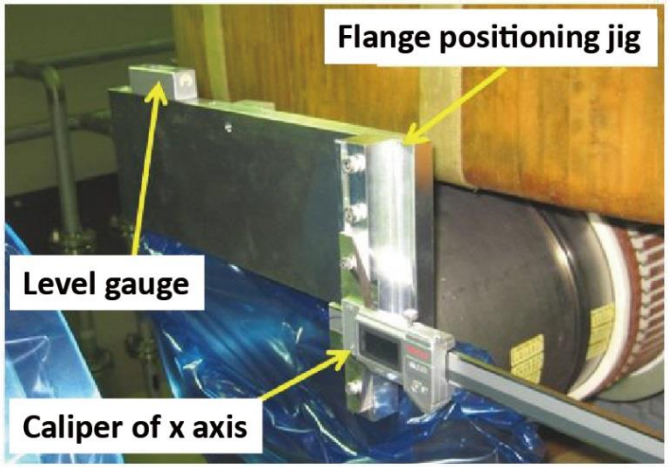
  Hydraulic jack was used for adjustment in vertical direction.

  In order to adjust both in horizontal and longitudinal directions 2 roller plates were set.

  ⇒ These jigs made the very smooth adjustment of dipole magnets possible.

Method of the realignment for the dipole magnet ducts

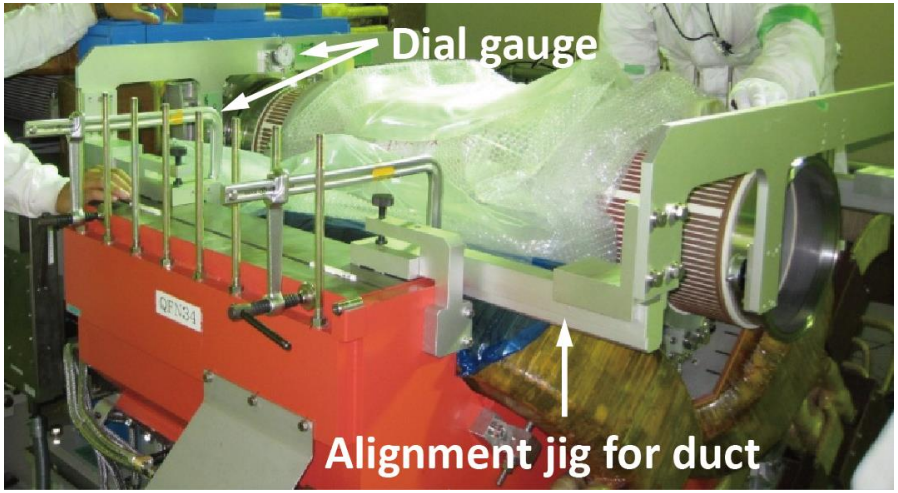




- At the beginning of installation, duct alignment was carried out by separating diapole magnets into upper and lower part. This time magnets were not separated to save working time and space and a jig exclusively for alignment was made.
- First, a flange positioning jig was set on the side of duct sleeve in order to adjust a duct tilt.
- Then a reference bar was fixed on the fiducial point located on the upper part of a magnet.
- Alignment in the beam axis direction was implemented by hanging a plumb bob from the end the reference bar.
- Finally alignment in height and in horizontal direction was carried out with a caliper, hanging a plumb bar from the reference bar.

⇒ Therefore for ceramic chambers of dipole magnets, duct adjustment became possible with an accuracy of less than ±0.1mm.

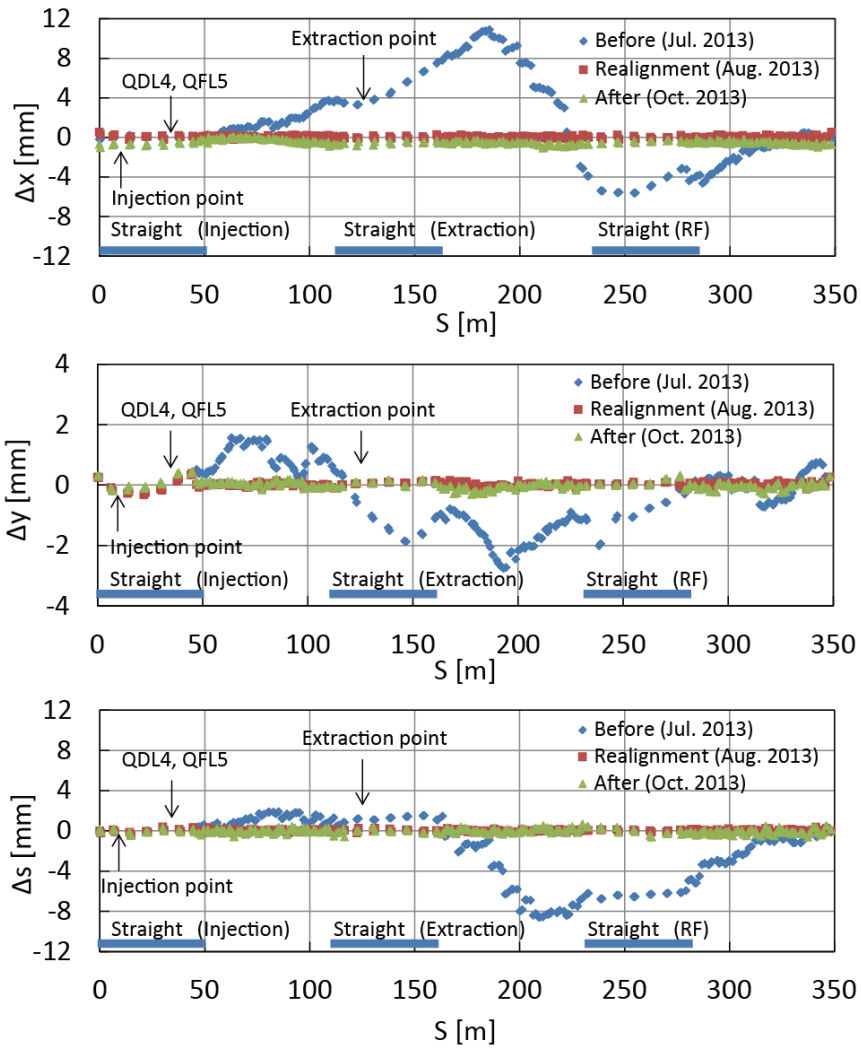
Method of the realignment for the quadrupole magnet ducts



- As with the case of diapole magnets, a method not to separate magnets was considered for realignment of quadrupole and sextupole magnets.
  But with that method a working space would narrow and adjustment would become complicated. Therefore the magnets were separated into upper and lower parts.
- An alignment jig for ducts was set on the divided face of a lower iron core.
  A dial gauge of each axis set on a alignment jig was used for alignment in height and horizontal direction.
- However as the jig mounting surface inside the magnets was rough because of the adhesive seeped from a steel sheet, the installation accuracy of the alignment jig was not good.
- Therefore this ceramic chamber was relatively moved using the measured data of Laser Tracker.
  Measurement accuracy of this method was within ±0.5mm.

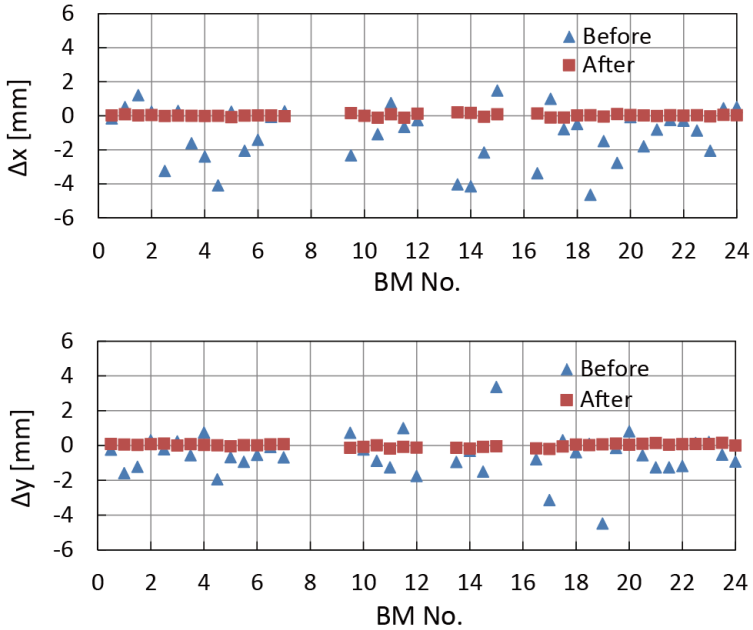
Results of the realignment

Displacement of magnets before/after realignment

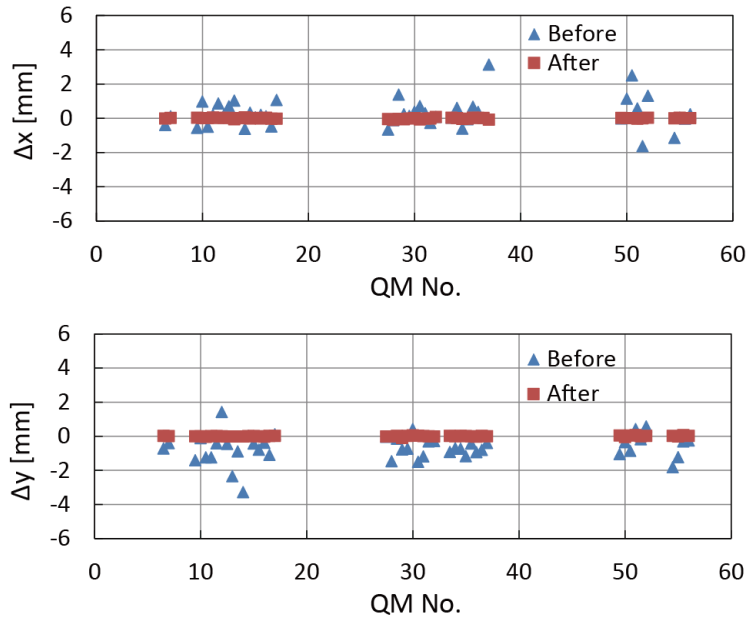


- Magents and fiducial points on the wall were measured before the realignment.
- Using the fiducial points at that time, the realignment of magnets was carried out from August to September, 2013.
- The realigned magnets were adjusted ***within ±0.2mm*** compared with the design value.
- The measurement after the realignment found that the fiducial points on the wall and the magnets were contracted inward.
- As a result, the beam line of RCS was displaced inward by 0.5mm and its circumference shortened by 3.1mm.

Displacement of ceramic chambers before/after realignment



Ceramic chambers of dipole magnet



Ceramic chambers of quadrupole magnet

- The realignment of ceramic chambers was carried out from August to October, 2013.
- The ceramic chambers of BM were adjusted ***within ±0.2mm***.
- The ceramic chambers of QM were adjusted ***within ±0.1mm***.

  Alignment accuracy of the ceramic chambers is deemed to be about ±0.6mm at a maximum when installation accuracy of the mesurement device for a laser tracker measurement (±0.5mm) is considered.

➢ Although alignment accuracy of the ceramic chambers exceeded the targeted value (±0.5mm), the value is well accepted.

Summary

- The alignment of the RCS has been successfully completed within long shutdown period. Working period was 5 months from 22 June to 27 November 2013.

- The alignment procedure for RCS beamline equipment was confirmed for the first time by the realignment and it was carried out.

- The magnets of the beamline were adjusted to within ±0.2mm.
  The ceramic chambers were aimed to be adjusted within ±0.5mm.
  As a result, a sufficient ring acceptance to achieve the 1MW operation was secured.

- Beam commissioning started on January 30, 2014. RCS succeeded in injection of 400MeV beam from the upgraded Linac, and extraction of 3GeV beam to MLF.

Thank you for your attention!!