SuperKEKB QCS R&D Magnet

KEK

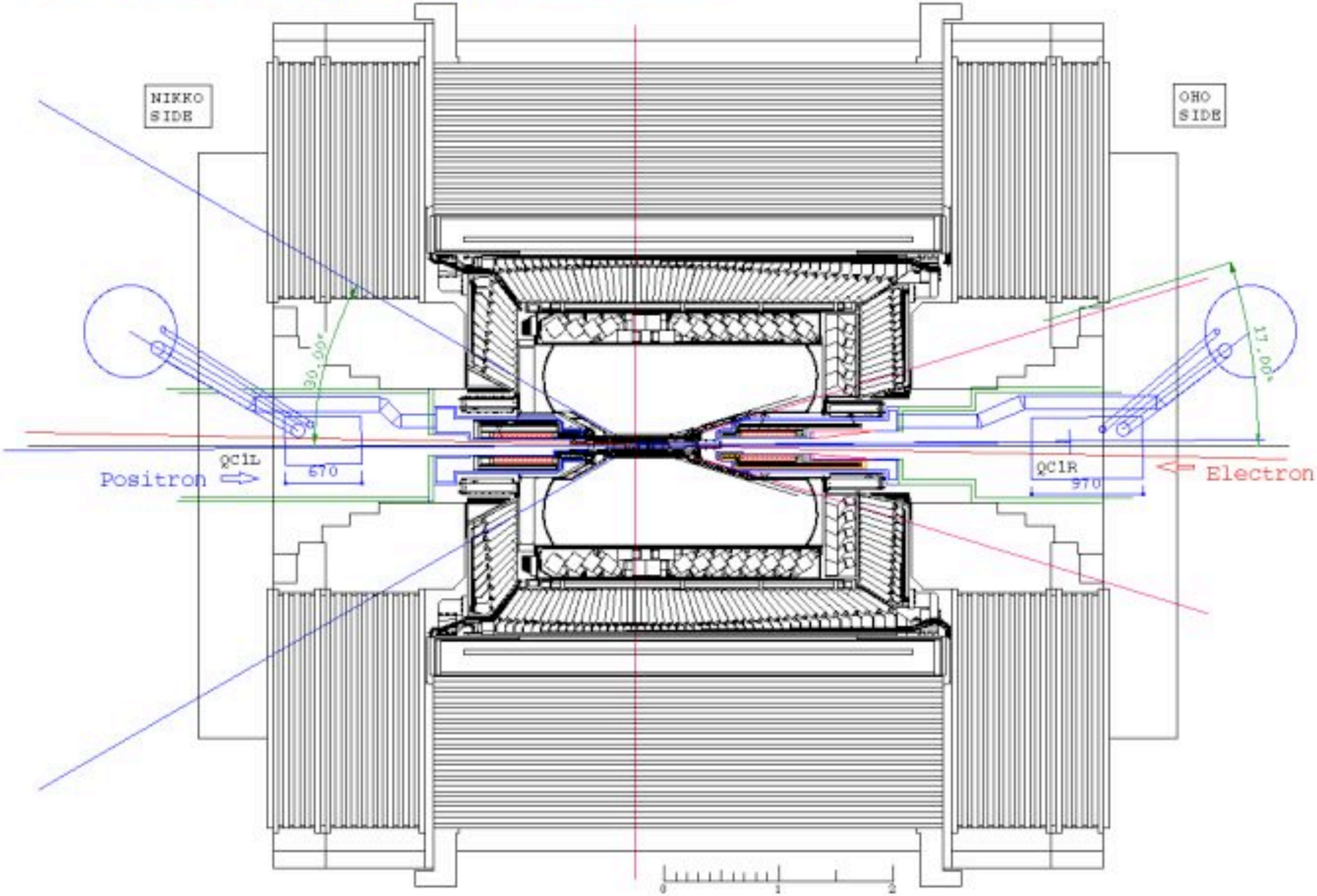
Norihito Ohuchi

1. SuperKEKB QCS Magnet Design
2. Construction of QCS R&D Magnet
3. Summary

SuperKEKB Magnet Design

(1-1) Schematic view of SuperKEKB-IR

- QCS and ES magnets with Belle detector



SuperKEKB Magnet Design

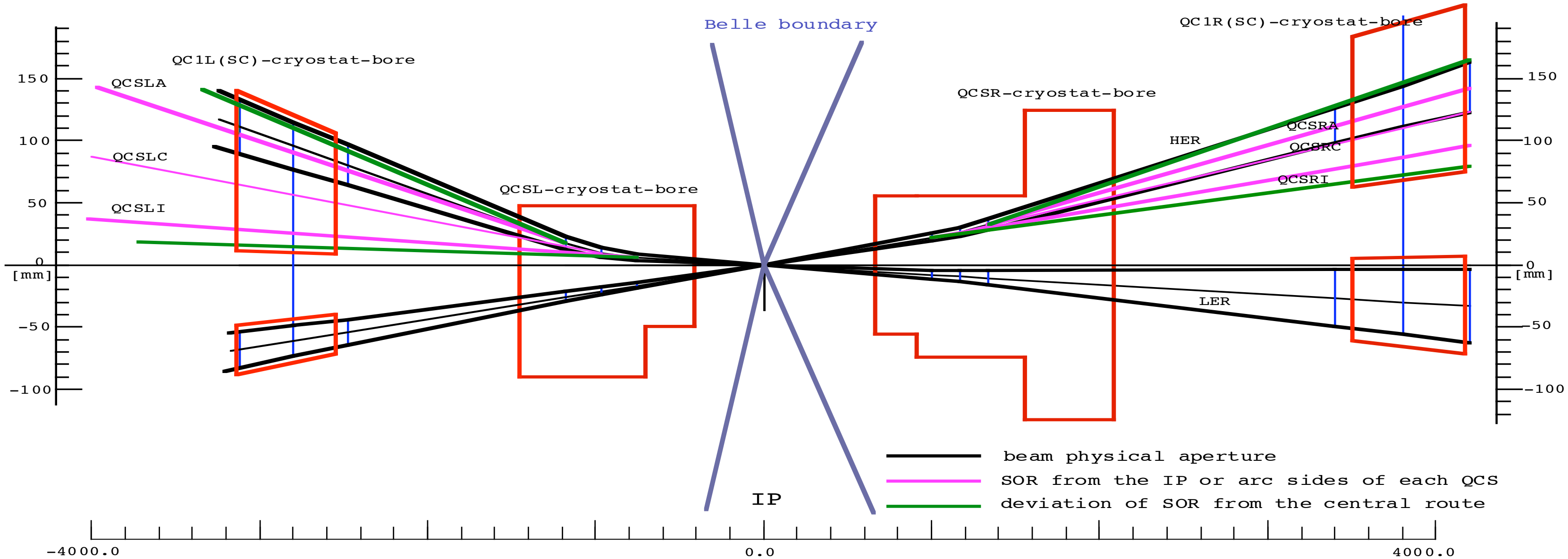
(1-2) Basic Backgroud Requirement for IR Magnet Design

- The crossing angle is 15mrad × 2.
- $\beta_x^* = 30$ cm, $\beta_y^* = 3$ mm
- Final focusing quadrupoles (QCS) locate at the position as close to the IP as possible.

Pos. from the IP	KEKB	Super-KEKB
QCS-R	1920 mm	1163.3 mm
QCS-L	1600 mm	969.4 mm

- Spatial constraints of the QCS cryostats against the Belle detector are the same as KEK-B.
- The compensation solenoids (ES) are installed outside of the QCS magnets. The axes of the QCSs and the ESs are parallel to the Belle detector axis.
- SR envelops from QCS magnets

The intensities of the SR power are 179 kW and 64.6 kW from QCSR and QCSL, respectively.

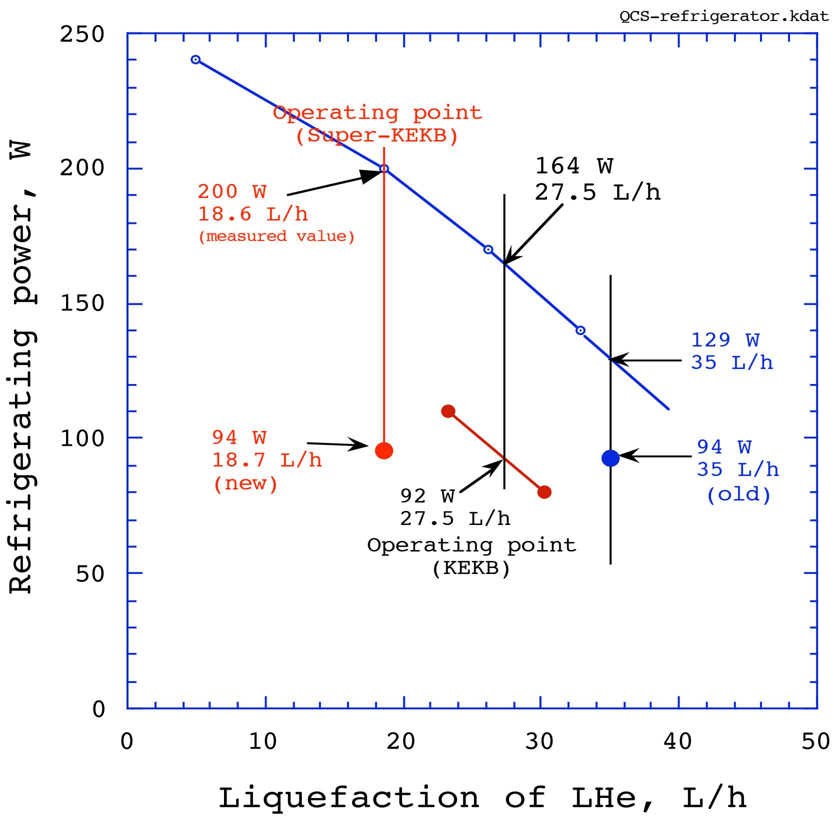


SuperKEKB Magnet Design

(1-3) Constraint from Cryogenic System

	KEKB	SuperKEKB
Current Leads QCS	15 L/h	5.7 L/h (22 L/h)
C. L. ES	8.5 L/h	8.5 L/h
C. L. Correctors	4 L/h	4 L/h
Cryostats	22 W	24 W
Transfer Lines	70 W	70 W
Total Heat Load	27.5 L/h + 92 W	18.7 L/h + 94 W (35 L/h + 94 W)
Refrigerator	27.5 L/h + 164 W	18.7 L/h + 200 W (35 L/h + 129 W)
Cooling Margin	72 W	106 W (35 W)

Cooling capacity of QCS refrigerator

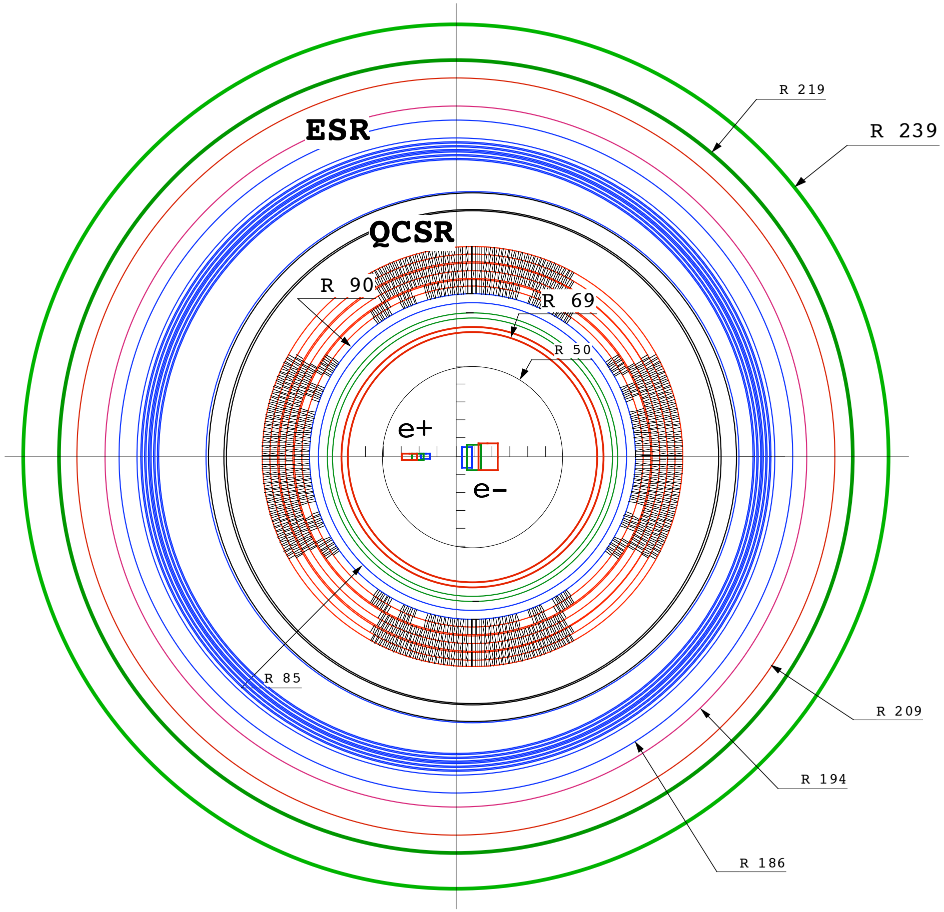


- Cooling time after quench
  - KEKB: 4 hours
  - SuperKEKB: 3.6 hours

    (KEKB type magnet: 4.3 hours)

SuperKEKB Magnet Design

(1-4) Cross Section of Magnet Cryostat



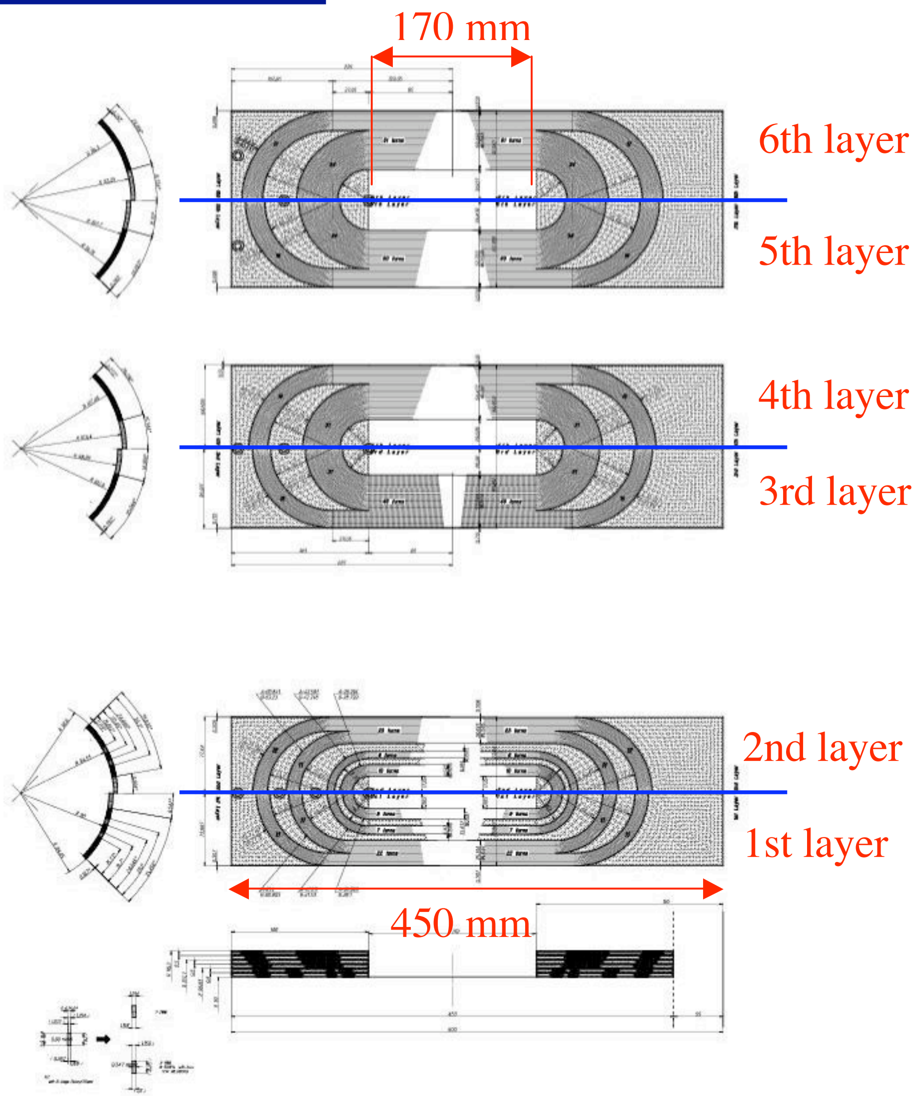
Magnet cryostat cross section in the right side

Design parameters of final focus quadrupole in the right side (QCS-R:R&D Magnet)

- 6 layer coils (3-double pane cake coils)
- Inner coil radius : 90.0 mm
- Outer coil radius : 116.8 mm
- Cable size : 1.1 mm × 4.1 mm
  - 1.1 mm × 7.0 mm (KEKB)
- Number of turns : 271 in one pole
  1st layer = 38, 2nd layer = 39
  3rd layer = 46, 4th layer = 47
  5th layer = 50, 6th layer = 51
- Field gradient : 40.124 T/m
- Magnet current : 1186.7 A
- Magnetic length : 0.299 m
- Inductance : 69.98 mH
- Stored energy : 49.3 kJ

SuperKEKB Magnet Design

(1-5) QCS-R (R&D Magnet) Design Field



Coil configurations of 6 layers

Design field of QCS-R (R&D Magnet)

- Multipole components in 2-D (magnet cross section) @ R_{ref} = 50 mm

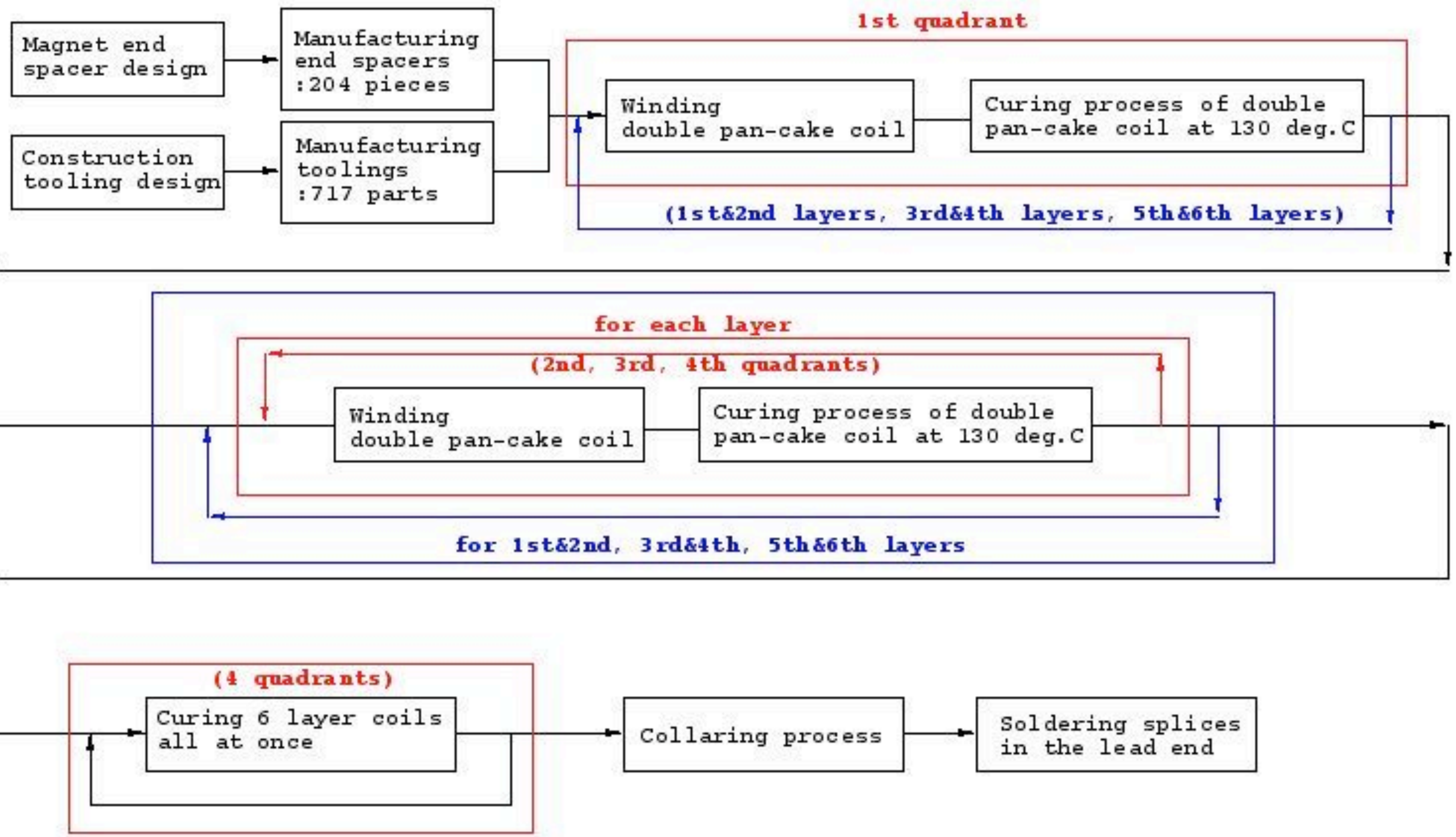
  b_2=10000, b_6=0.12, b_{10}=-0.04, b_{14}=0.12

- Integral multipole components (not including lead end geometry) @ R_{ref} = 50 mm

  $\int b_2 dl$=10000, $\int b_6 dl$=-0.04, $\int b_{10} dl$=0.46, $\int b_{14} dl$=0.02

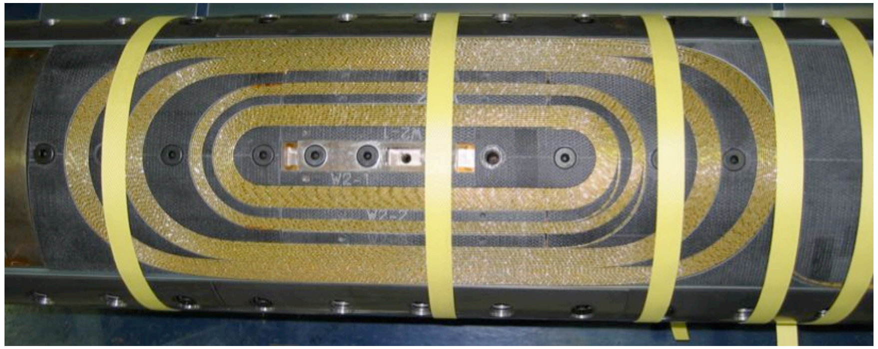
Construction of QCS R&D Magnet

(2-1) Magnet Construction Process

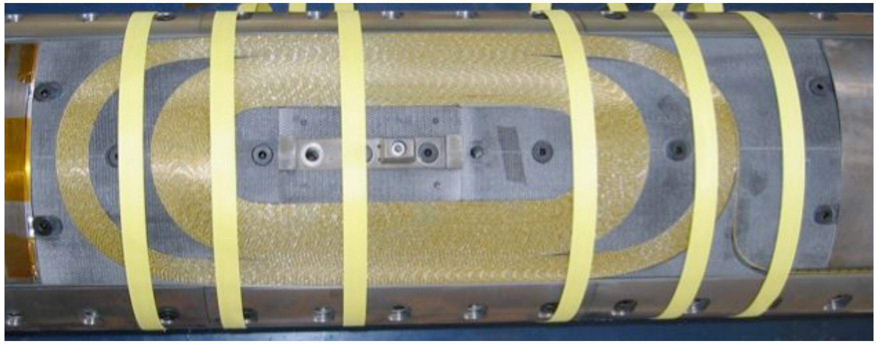


Construction of QCS R&D Magnet

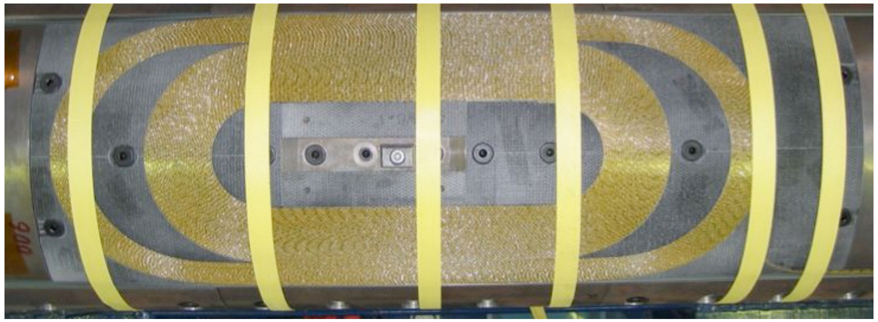
(2-2) Winding Coils



2nd layer coil after winding 1st layer coil



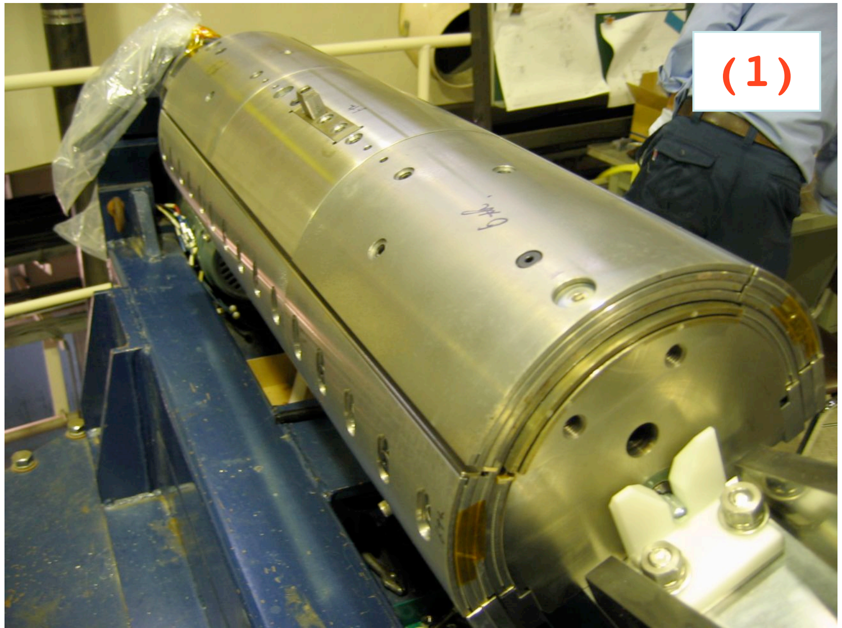
4th layer coil after winding 3rd layer coil

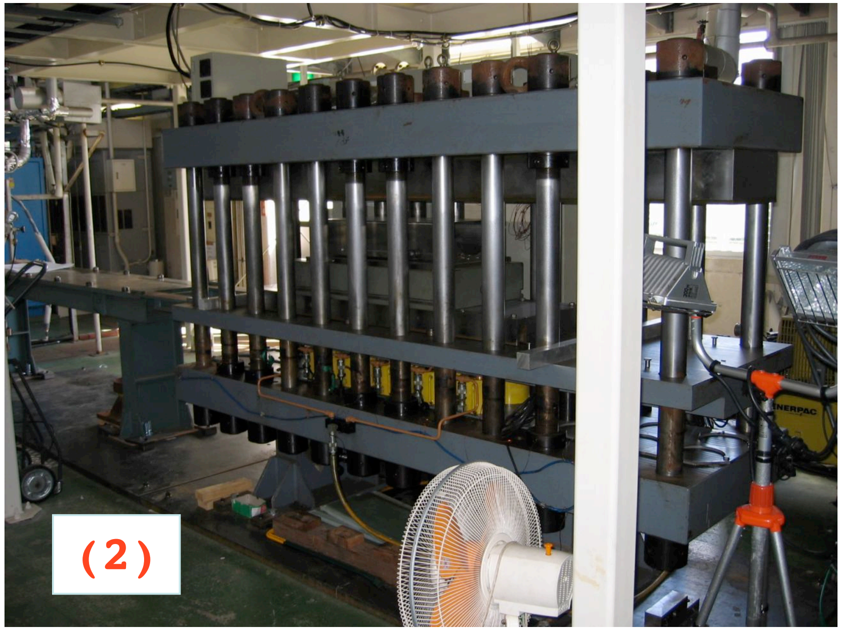


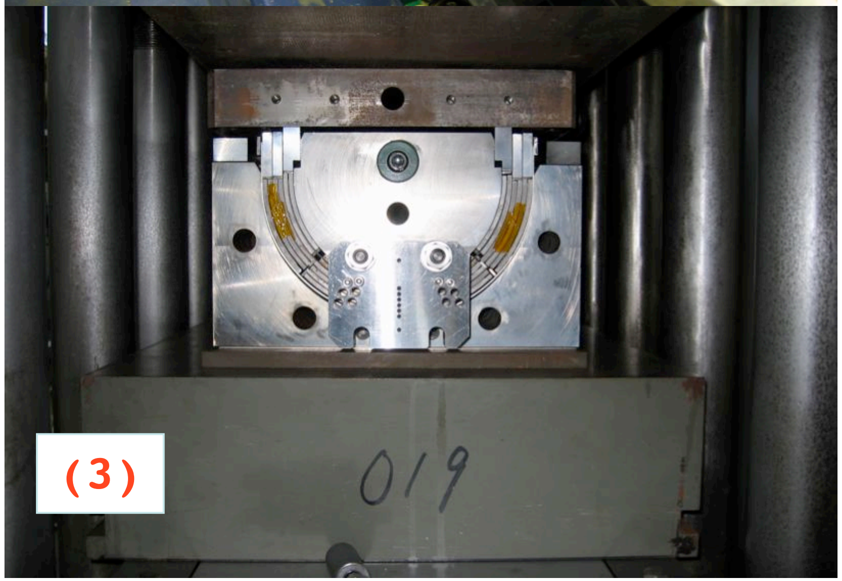
6th layer coil after winding 5th layer coil

Construction of QCS R&D Magnet

(2-3) Curing Coils



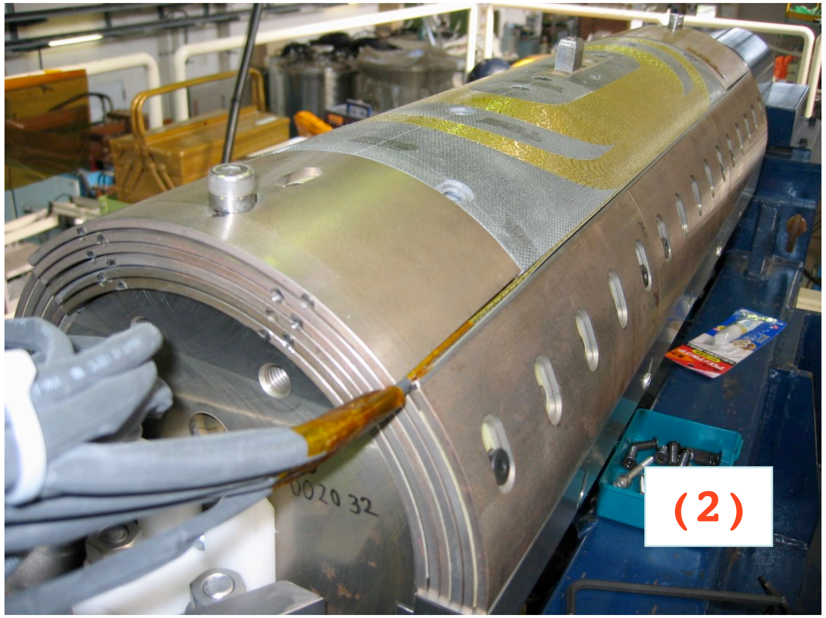


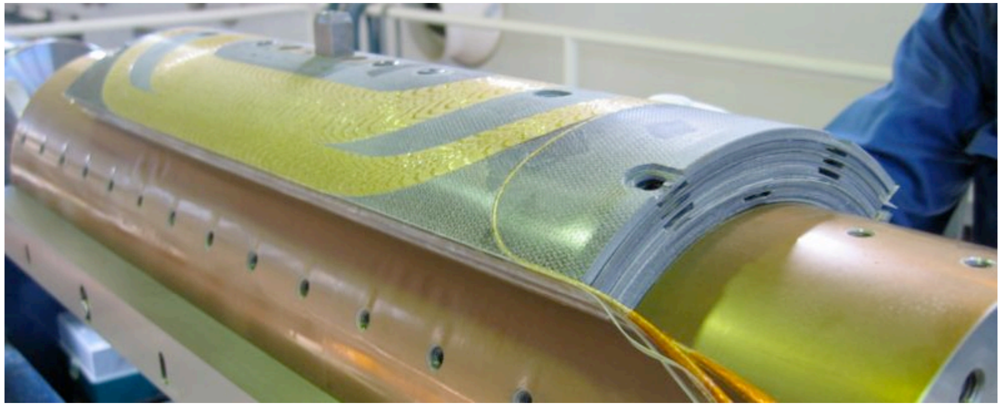


(1) The 1st and 2nd layer coils are assembled on the mandrel. On the these coils, dummy coil blocks are assembled for curing process.
(2) 5000 tons curing press. The coils are heated up to 130 degree C, and pressed by this press machine.
(3) Coils and dummy coil blocks in the form block inside the press.

Construction of QCS R&D Magnet

(2-4) 12 Cured Coils and curing 6 layer coils all at once



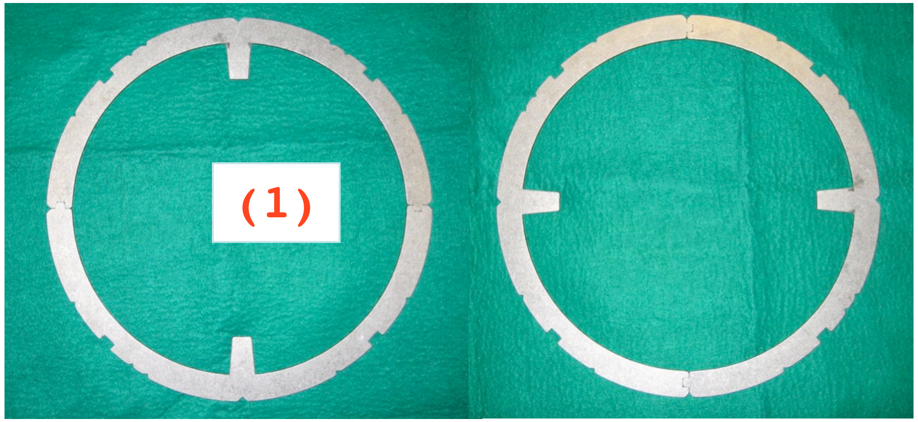


(1) 12 cured double pan-cake coils.

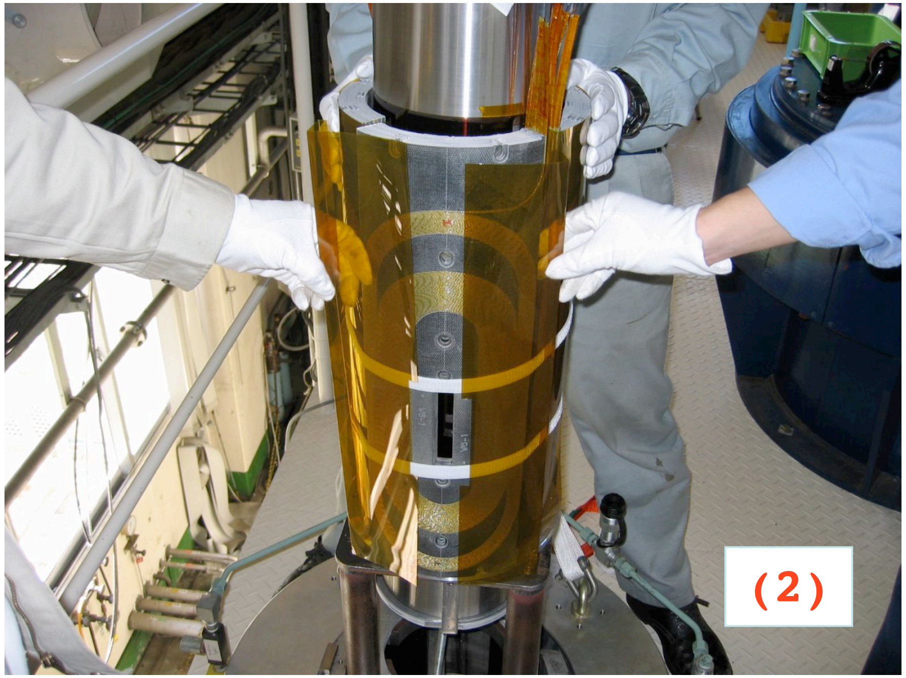
(2) Curing process of 6 layer coils. This process is necessary for improving the field quality in the magnet straight section (magnet body).

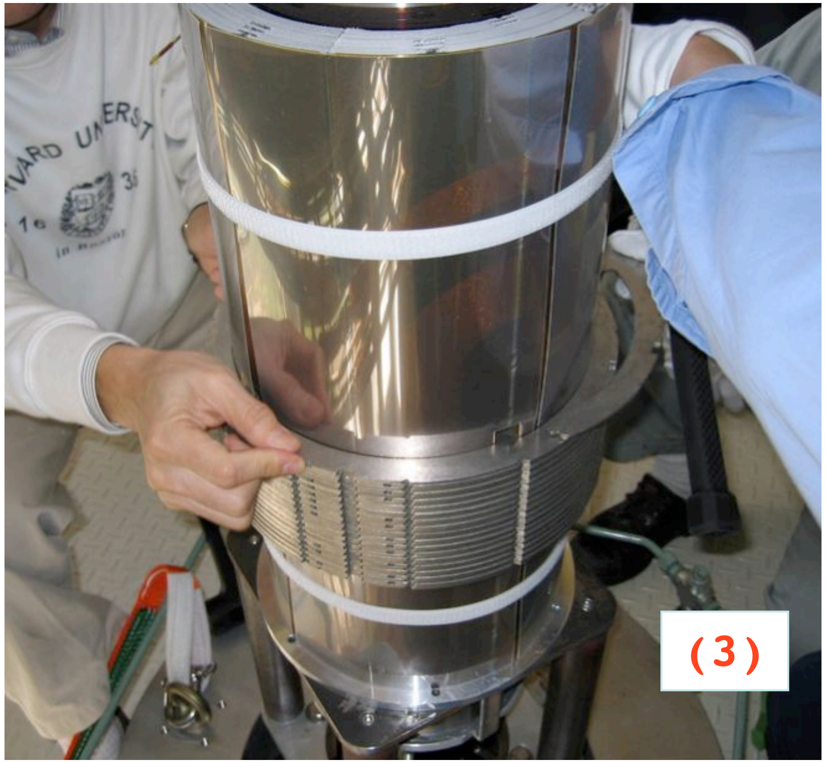
Construction of QCS R&D Magnet

(2-5) Collaring coils



SUS collars (High Mn Material)





(1) SUS collars. The material is High Mn steel. This material has a tensile strength of 1.25 times higher than SUS-316, and non-magnetic.

(2) Four 6 layer coils are assembled on the support cylinder.

(3) Collars are mounted on the coils.

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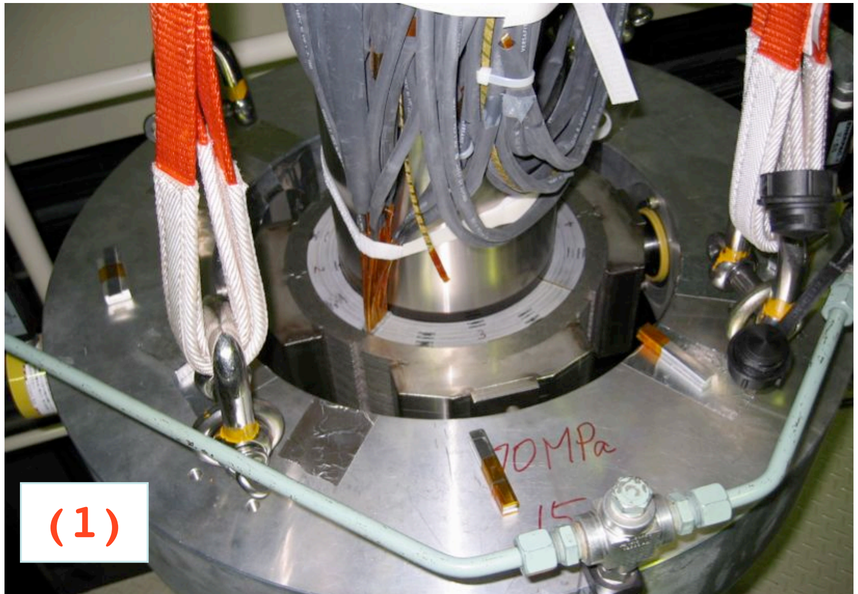
Construction of QCS R&D Magnet

(2-6) Collaring coils-2



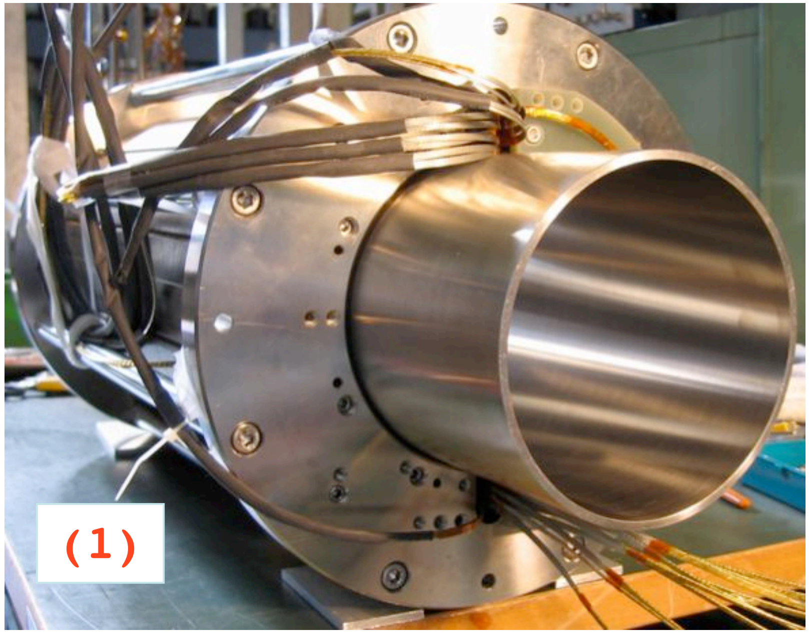
(1) Pushing SUS collars with a hydraulic collaring press in order to give an azimuthal pressure of 32 MPa on the coils.

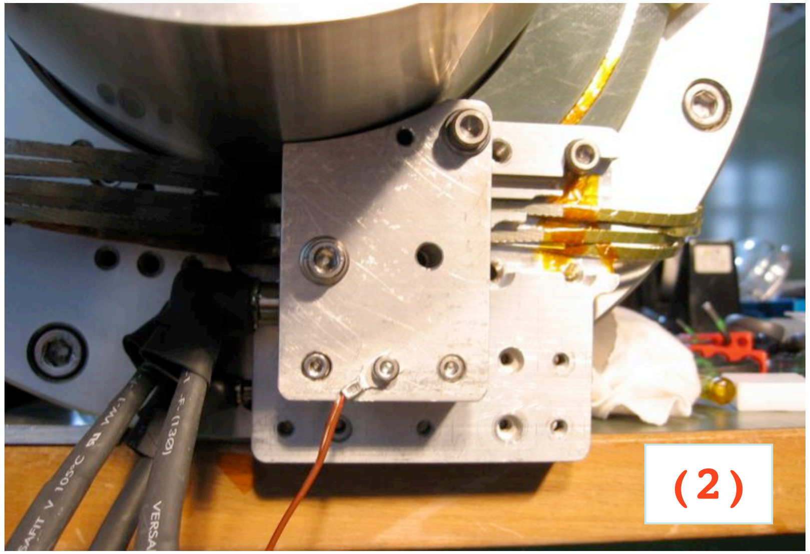
(2) Keying collars with High-Mn SUS bars.

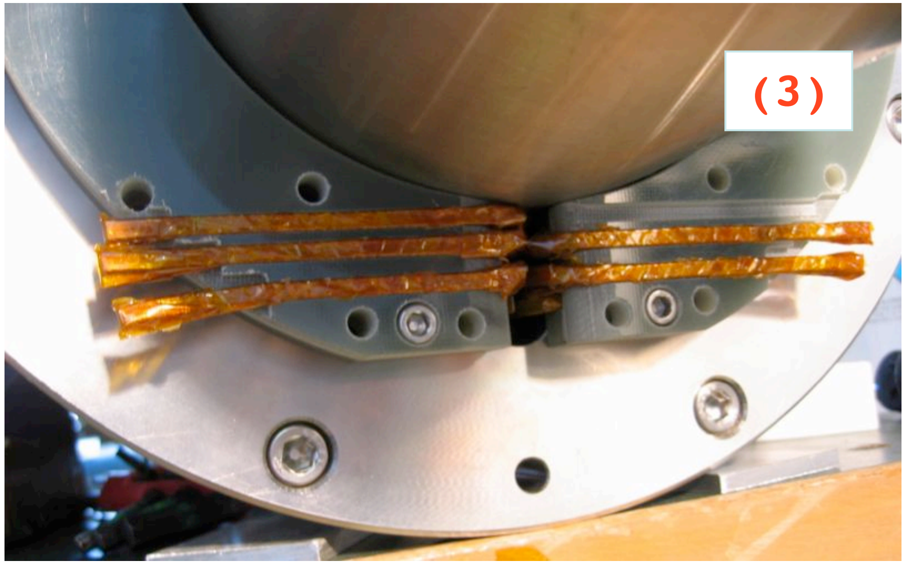
(3) Completed collared coils.

Construction of QCS R&D Magnet

(2-7) Soldering leads from coils







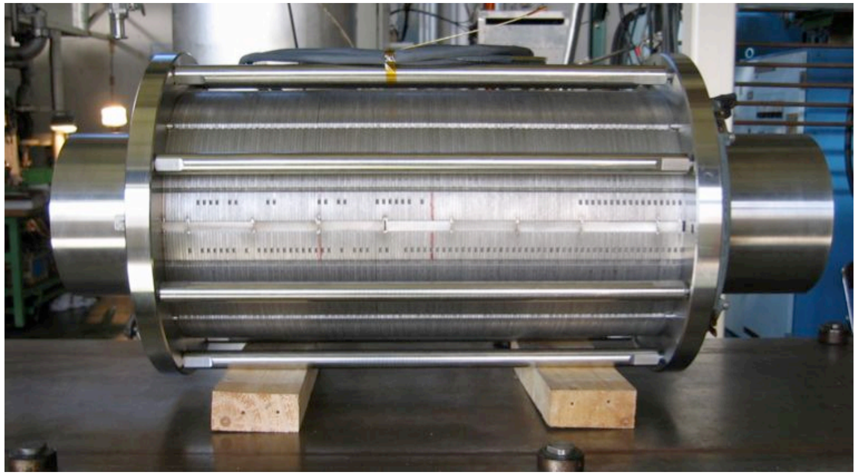
(1) In total, 24 leads come from the non-return end of the coil.

(2) These leads are connected with solder. Special temperature-controlled tools are used for soldering.

(3) Soldered leads with an electrical insulation.

Construction of QCS R&D Magnet

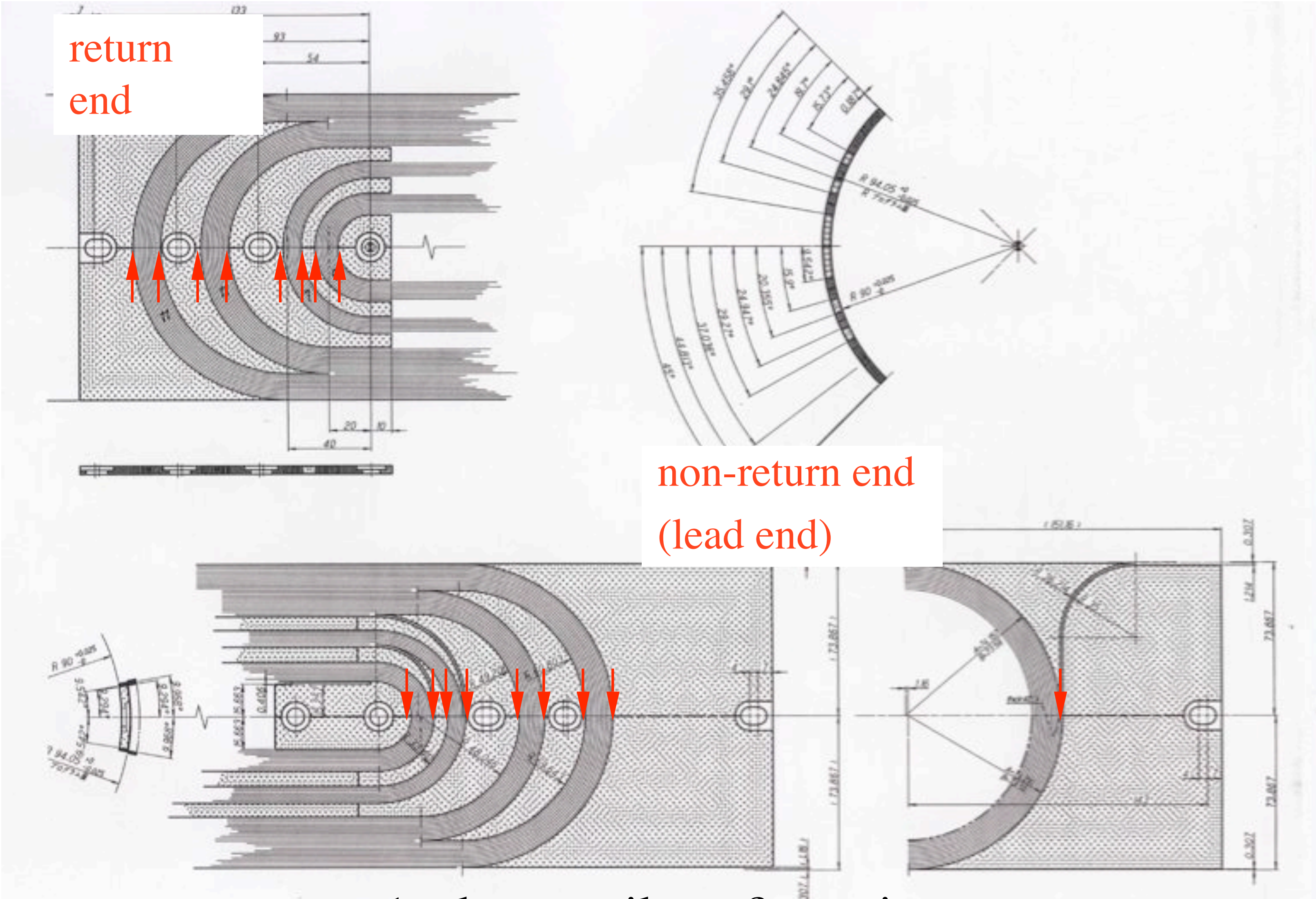
(2-8) Completed R&D Magnet



Preparation of the vertical test

Construction of QCS R&D Magnet

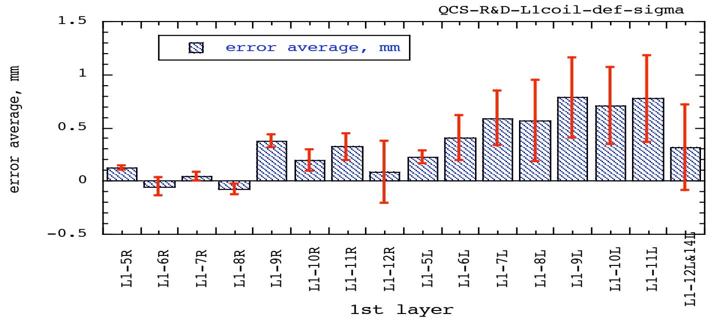
(2-9) Measurement of Coil Size

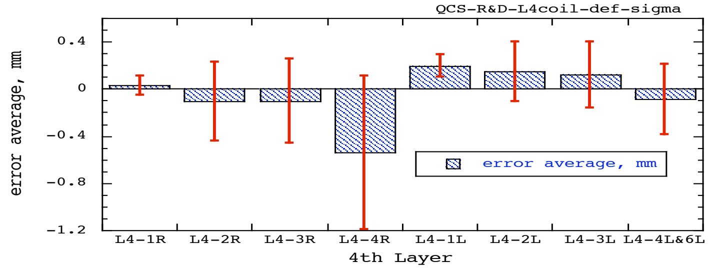


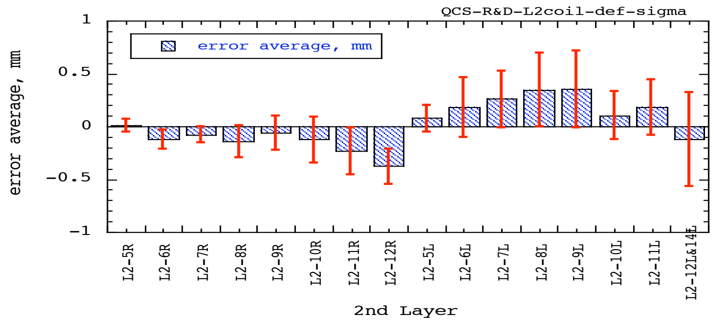
1st layer coil configuration

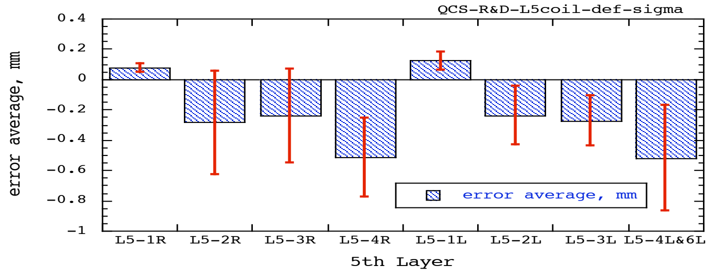
Construction of QCS R&D Magnet

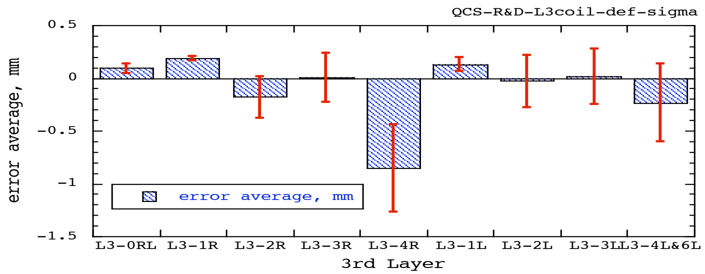
(2-10) Measurement of Coil Size-2

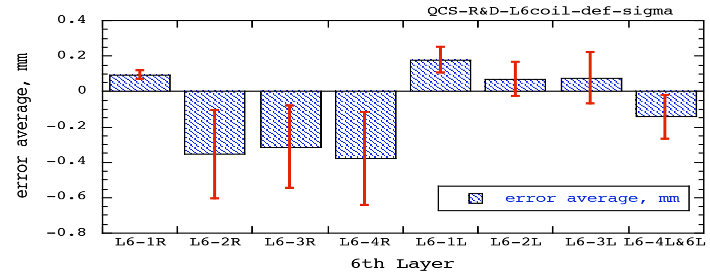












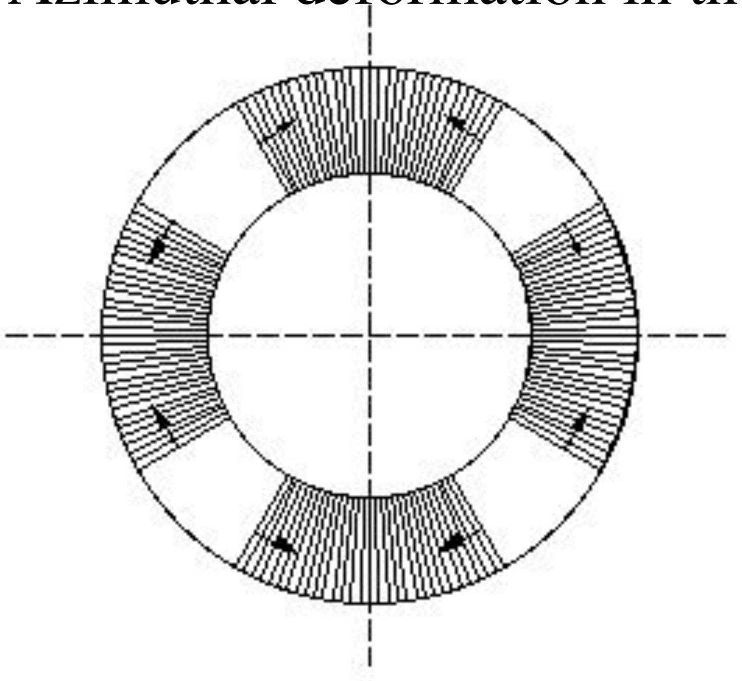
Average geometry error (maximum value)

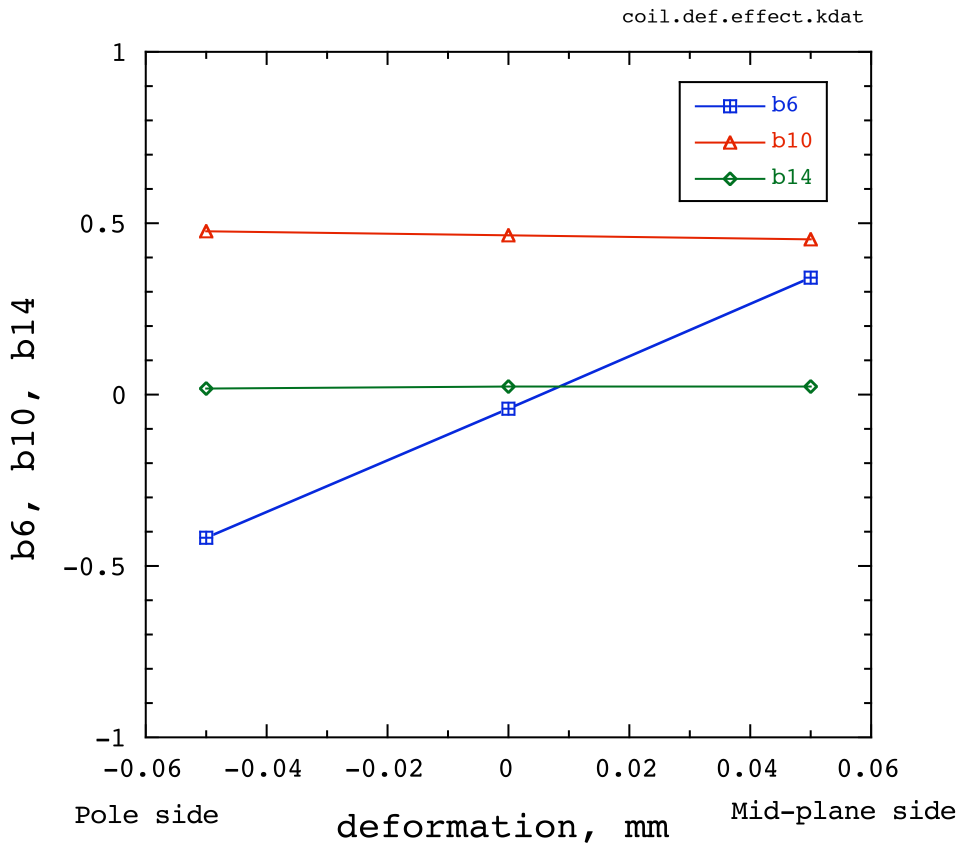
- 1st layer : 0.78 +/-0.38 mm (non-return end),
- 2nd layer : 0.35 +/-0.37 mm (non-return end),
- 3rd layer : -0.85 +/-0.41 mm (return end),
- 4th layer : -0.54 +/-0.65 mm (return end)
- 5th layer : -0.52 +/-0.35 mm (non-return end)
- 6th layer : -0.38 +/-0.26 mm (return end)

Construction of QCS R&D Magnet

(2-11) Error Estimation-1

Azimuthal deformation in the coil size





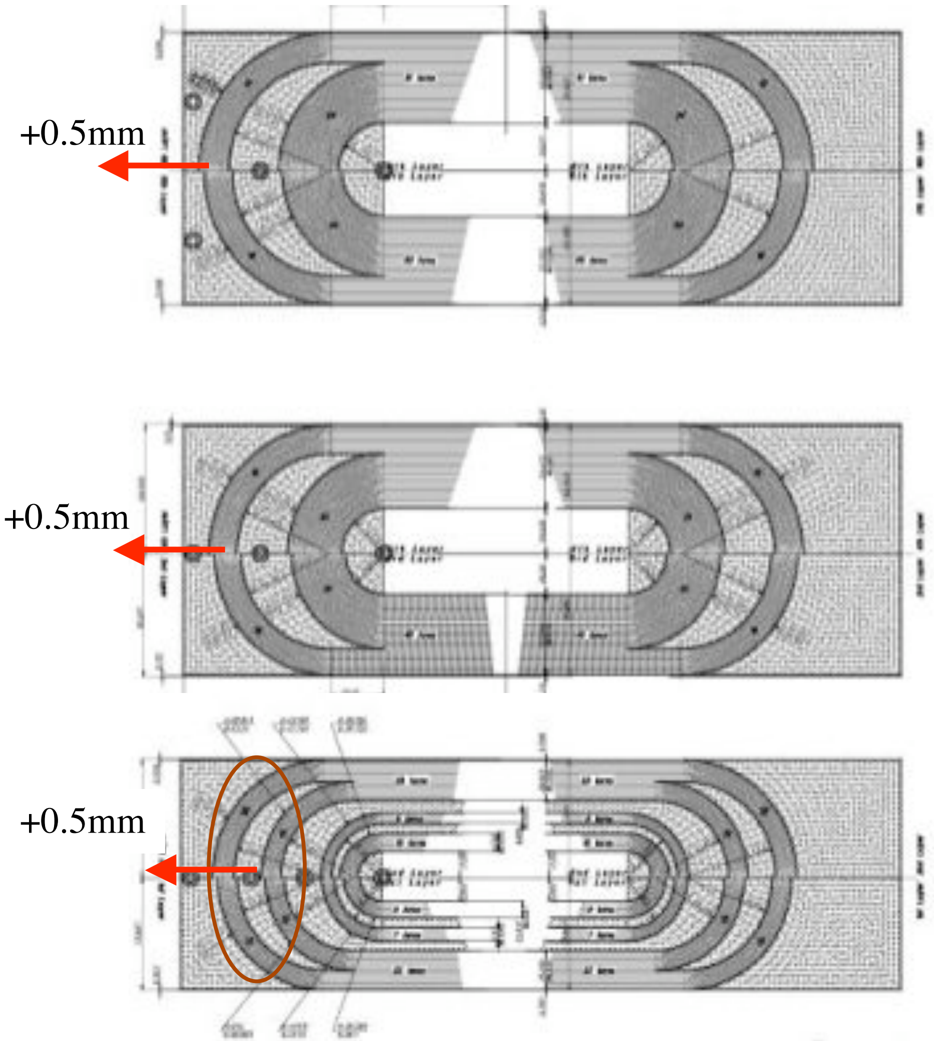
Design multipole components @ R_{ref} = 50 mm

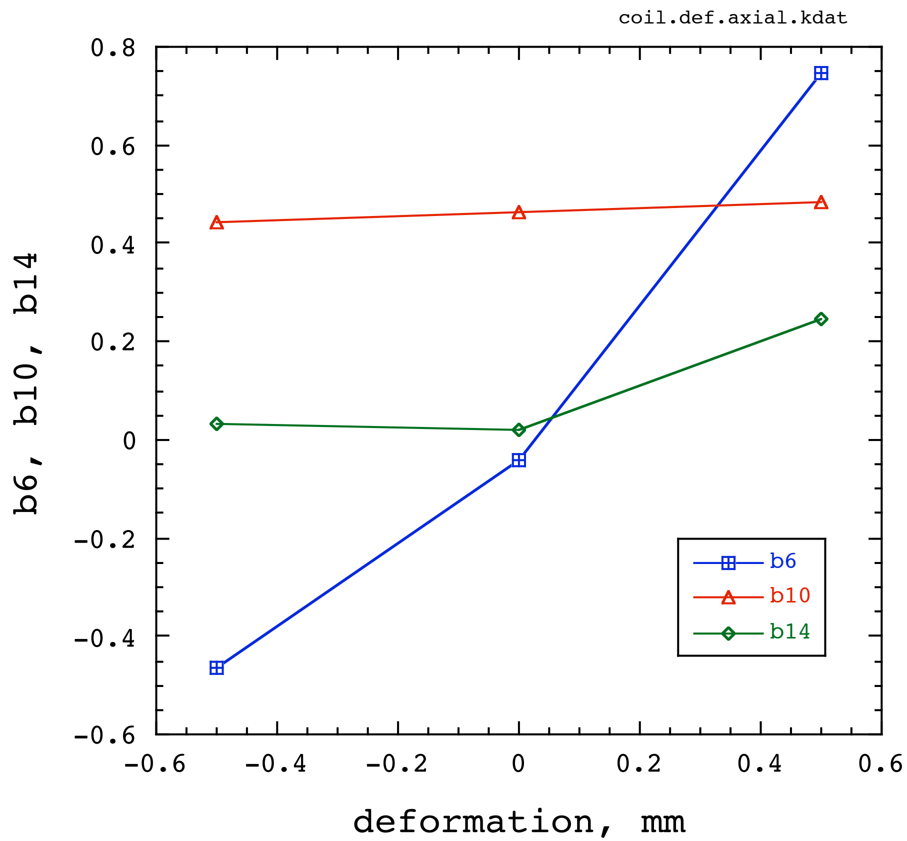
$\int b_2 dl$=10000, $\int b_6 dl$=-0.04, $\int b_{10} dl$=0.46, $\int b_{14} dl$=0.02

Construction of QCS R&D Magnet

(2-12) Error Estimation-2

Axial deformation in the coil size





Summary

- The R & D magnet of the final focus quadrupole for SuperKEKB has been completed.
- Some of the tools should be improved.
  - Dummy coil blocks for curing coils.
  - Tools for tuning axial coil length.
- Measurements of the coil size were preformed.
  - The averages of the coil deformation in the axial length were less than 1 mm.
  - The coils for the first pole have larger errors than the other coils.
  - We plan to make another coils for the one pole, and re-assemble the magnet with the new pole.
- Effect of coil deformation on the multipole was calculated.
  - Azimuthal coil size error of 0.05mm : $\Delta b_6 = 0.4$
  - Axial coil size error of 0.5mm : $\Delta b_6 = 0.8$
- The 1st R&D magnet will be tested in June.