Main Ring Magnet system

Mika Masuzawa

Magnet design &
Field measurements
Installation
Survey & alignment

K. Egawa
H. Iinuma
M. Masuzawa
Y. Ohsawa

Power supply design
Testing
Tuning
Installation & Cabling

T. Adachi
T. Oki
T. Sueno→retiring next month

T. Kawamoto
2 more people will be retiring next year.

Retired but still active
R. Sugahara
K. Tsuchiya
N. Tokuda

Keep loosing people

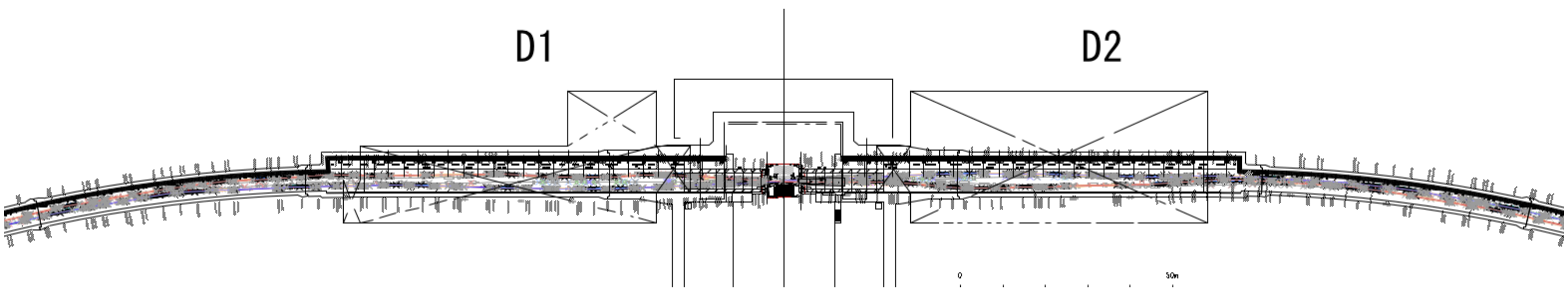
Contents

- Magnet installation
  - Mainly in the IR (Interaction Region)
- Field measurements
  - IR magnets (conventional ones)
- Power supplies
  - Preliminary test results
  - Cabling work
- Alignment
  - Effects of the excavation/construction
- Other
  - Cooling water system
- Summary

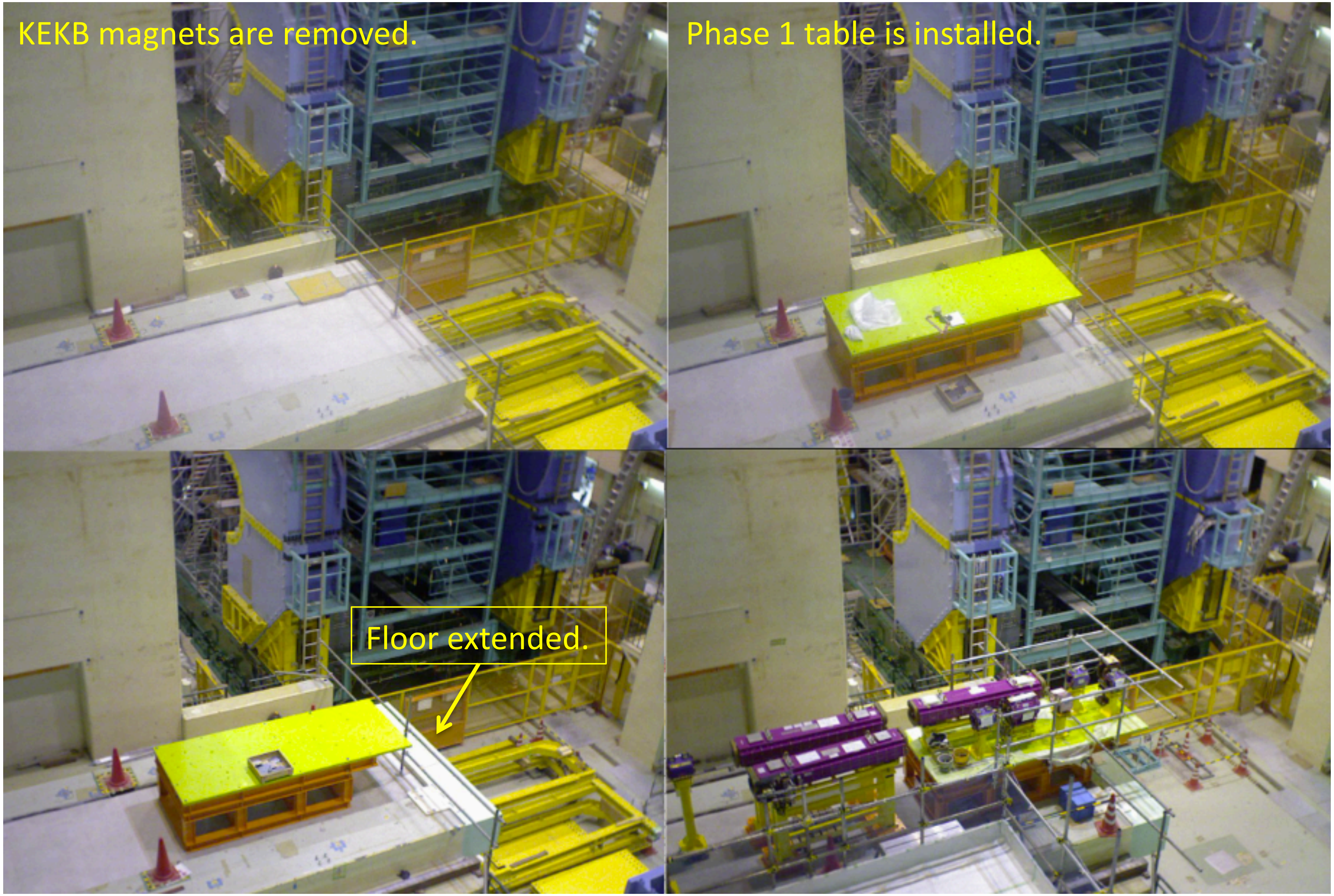
Magnet installation

In the IR (Interaction Region) & the straight sections

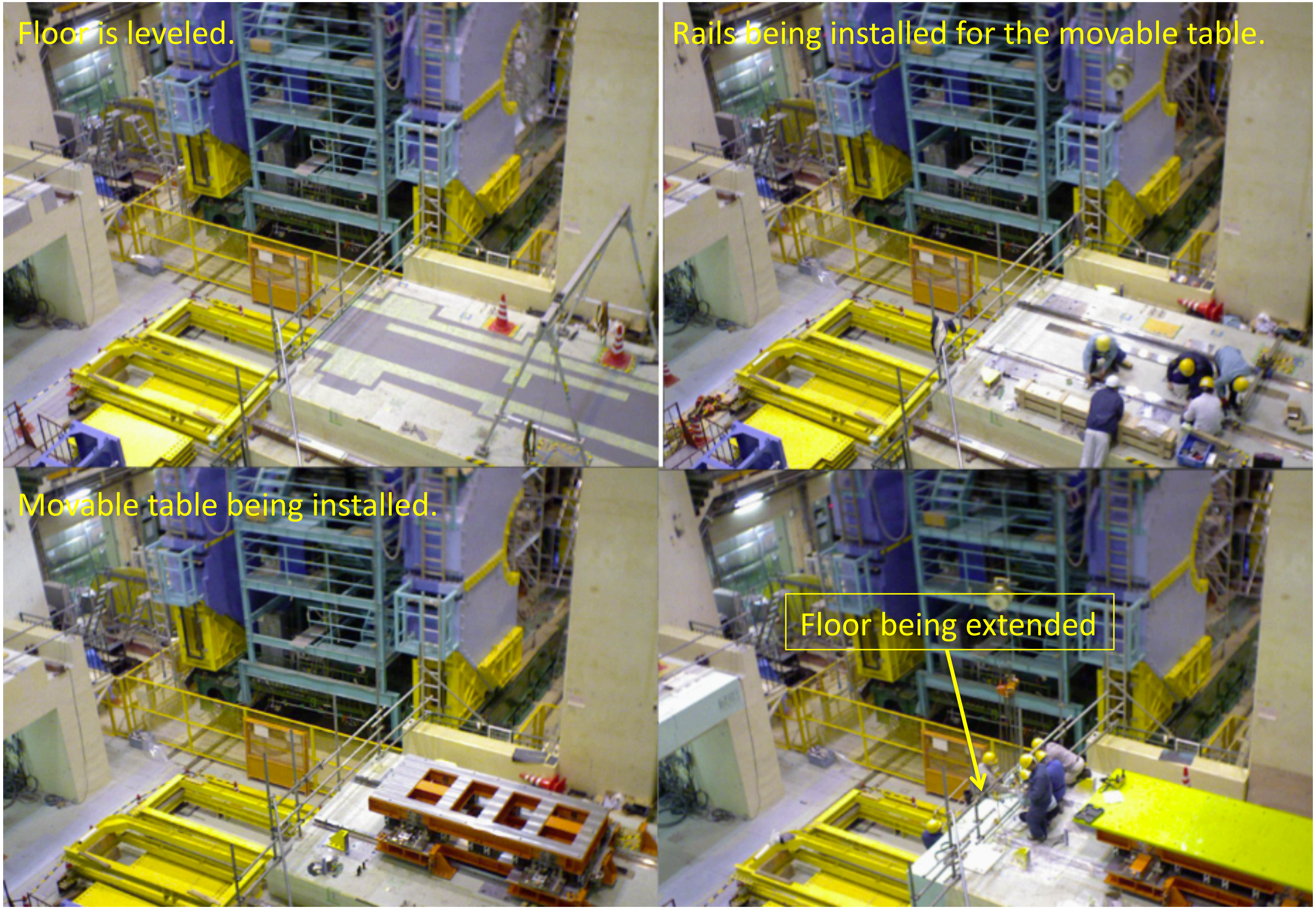
Tsukuba



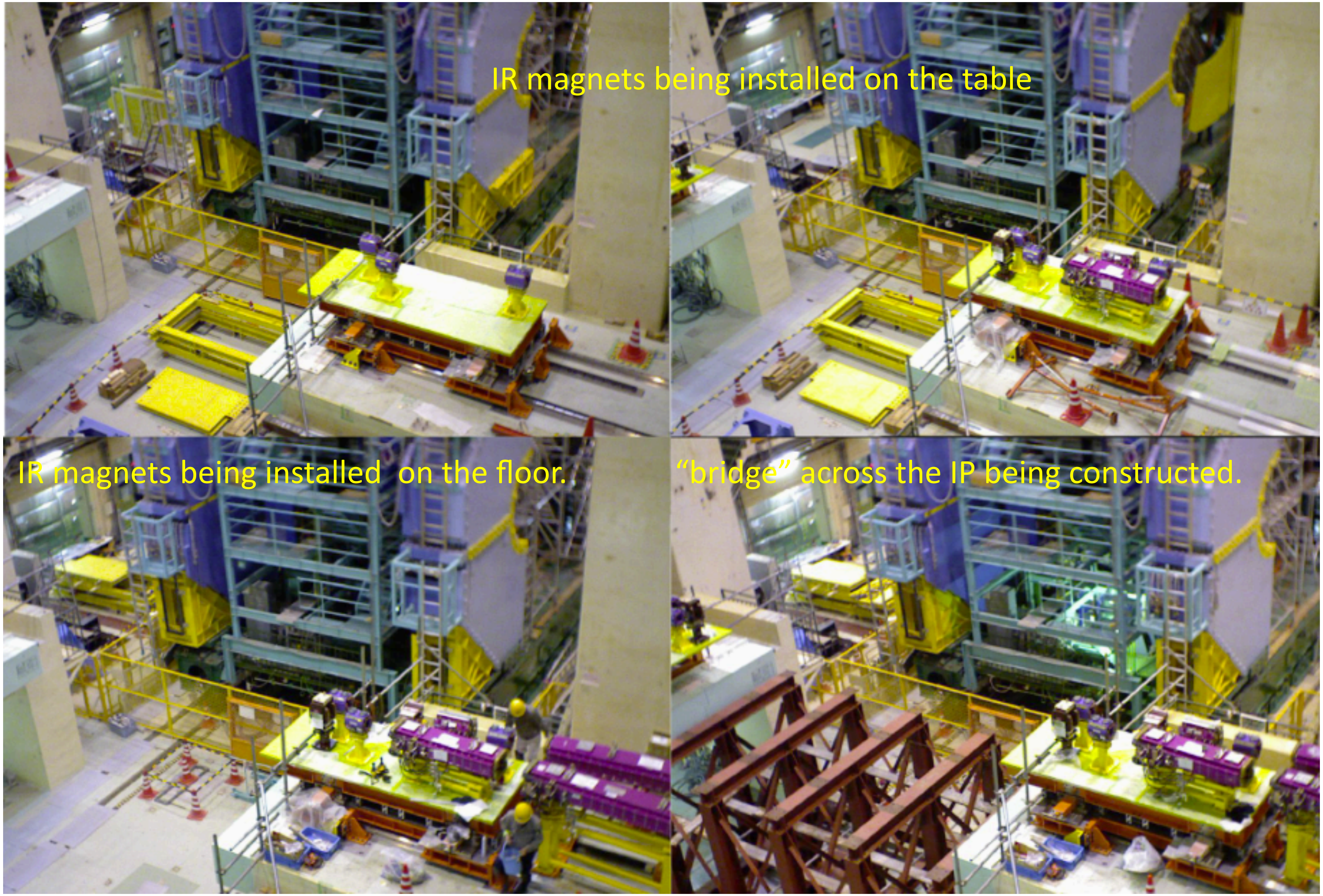
IR, Right-hand side



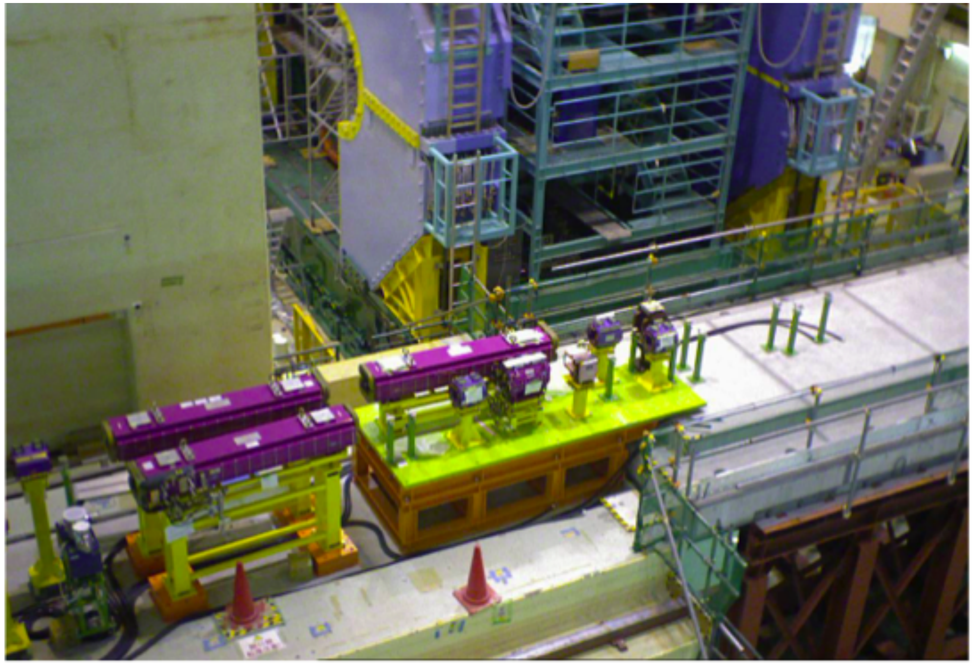
IR, Left-hand side

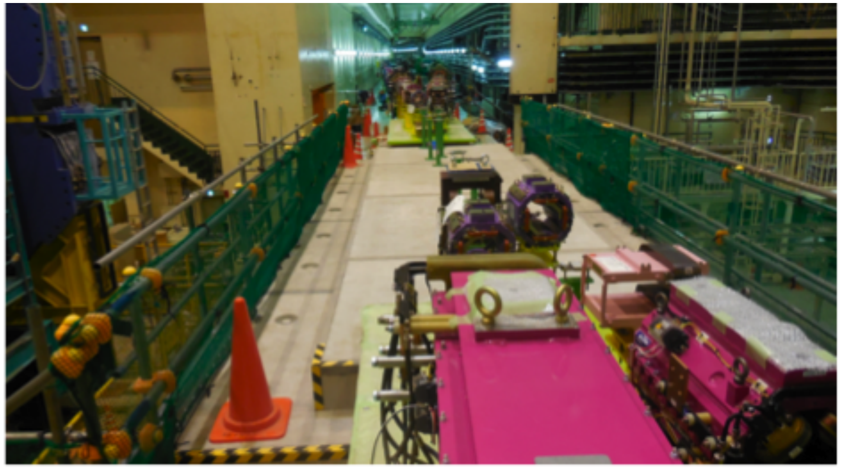


IR, Left-hand side

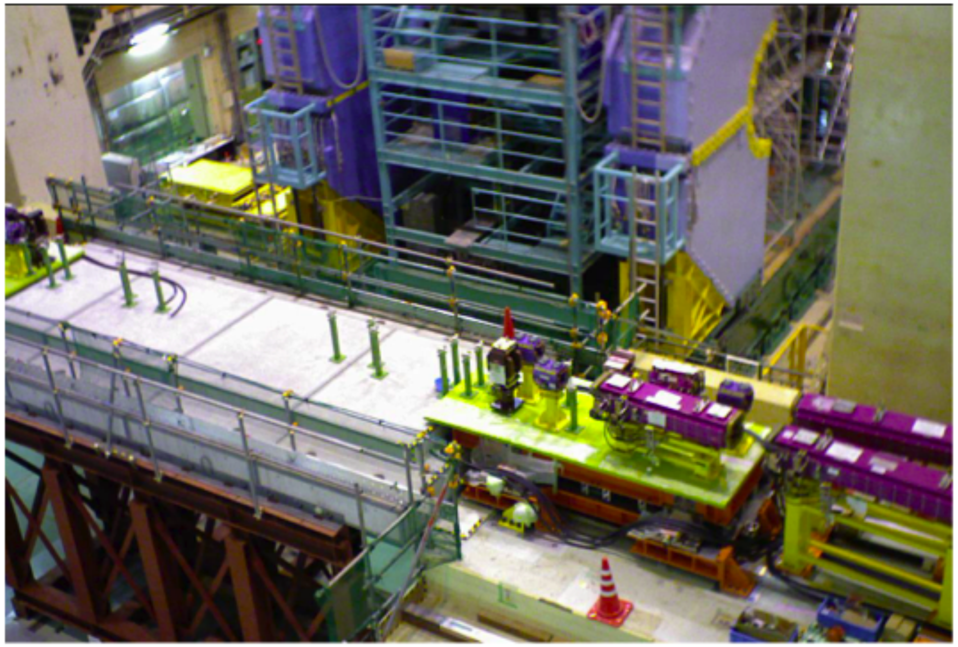


Around the IP



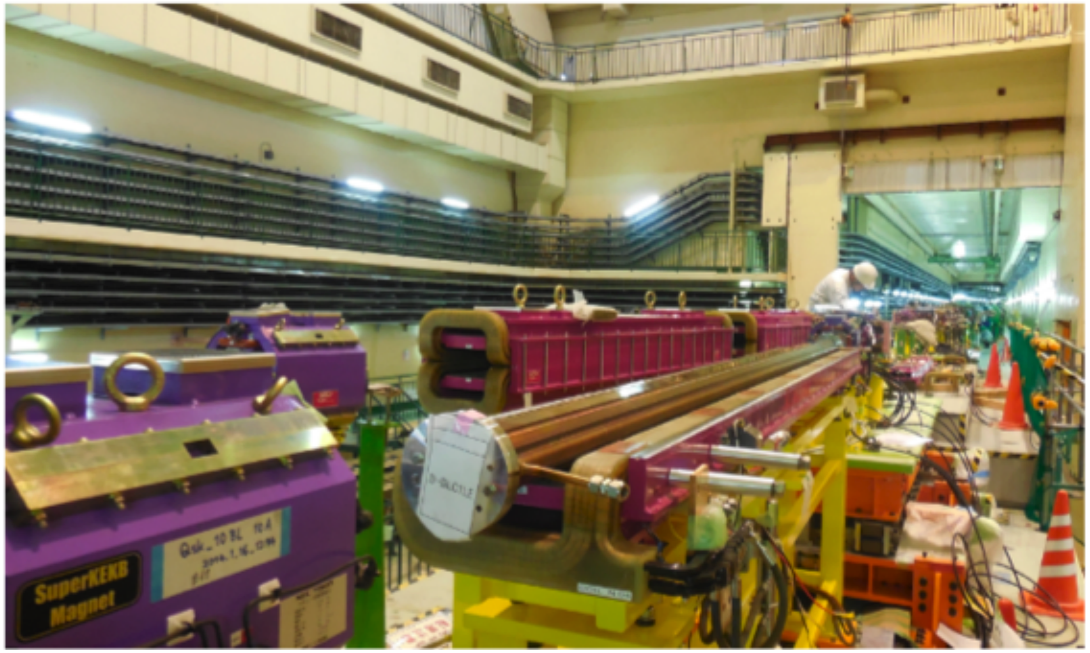


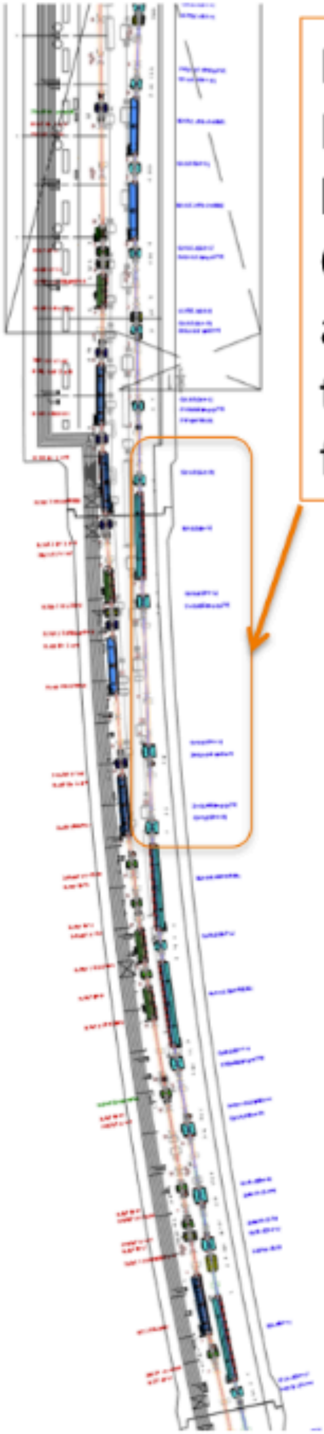
A safety fence was put around the newly built bridge across the IP.
One can now walk around on the bridge without fear.



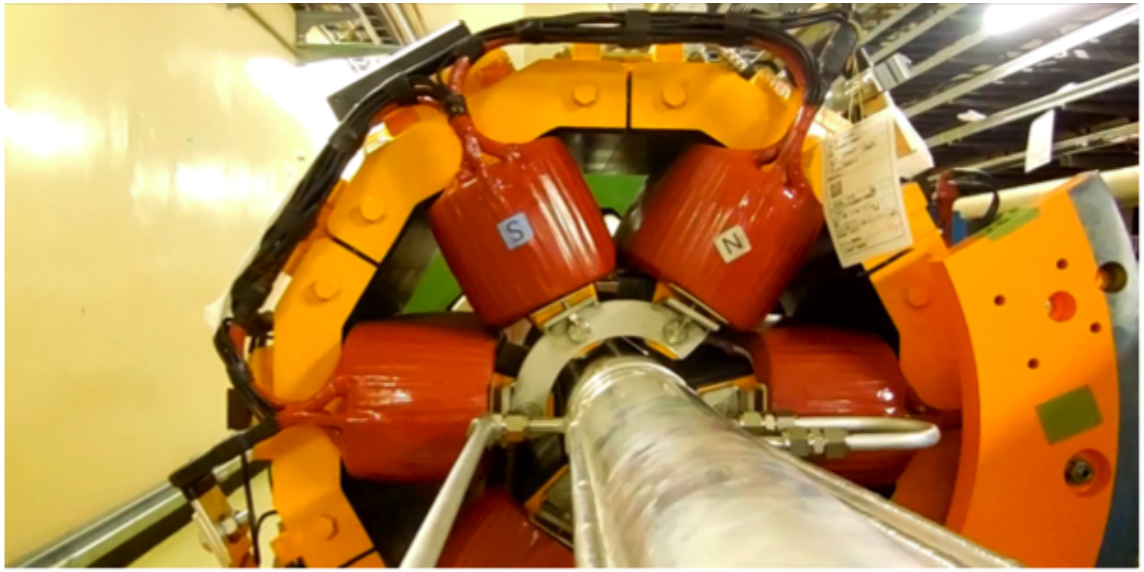
Magnet work for vacuum pipe installation

Removing the top part



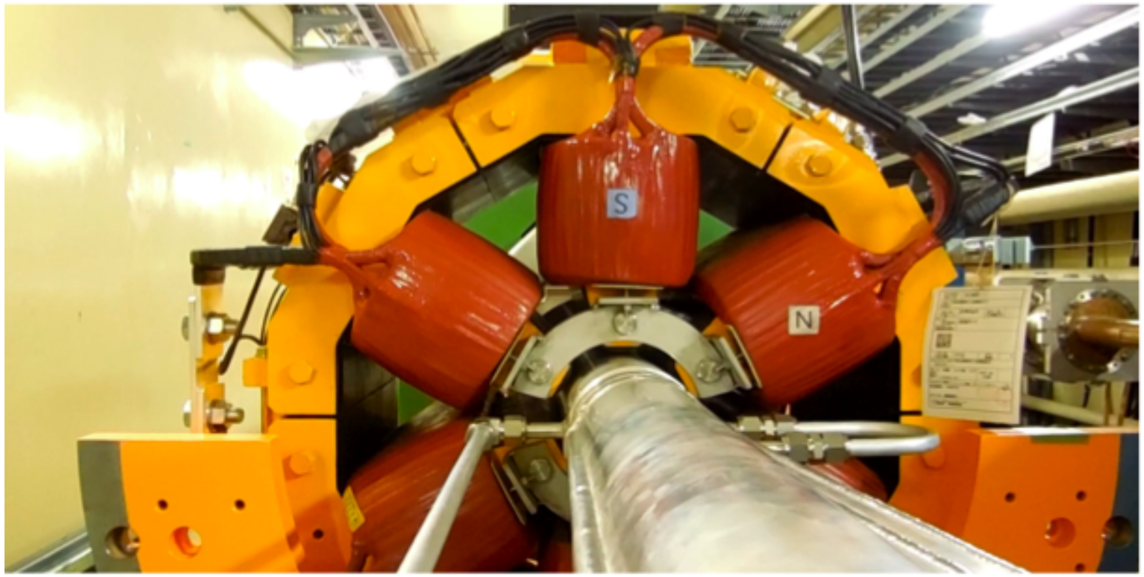


North tunnel:
HER magnet installation in this region will be done early next fiscal year.
Once the magnets are installed here, the air pallet can no longer be used to transport anything to the straight section from the access shaft in the arc section.

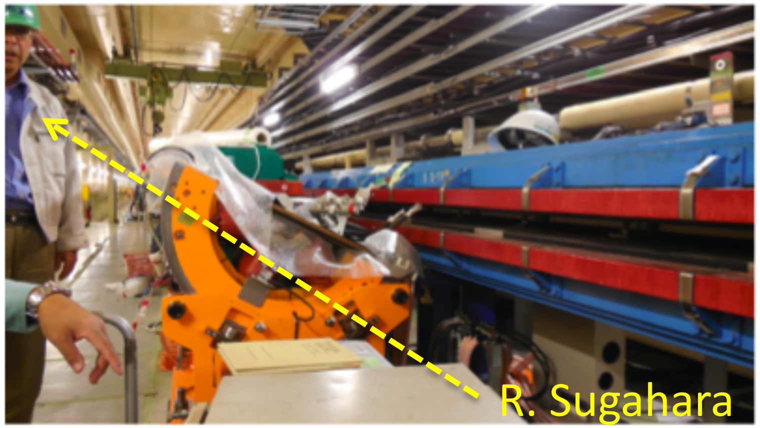


All 24 tilting sextupole magnets (from -30 degrees to + 30 degrees) were installed in the tunnel, and the vacuum pipes were also installed.

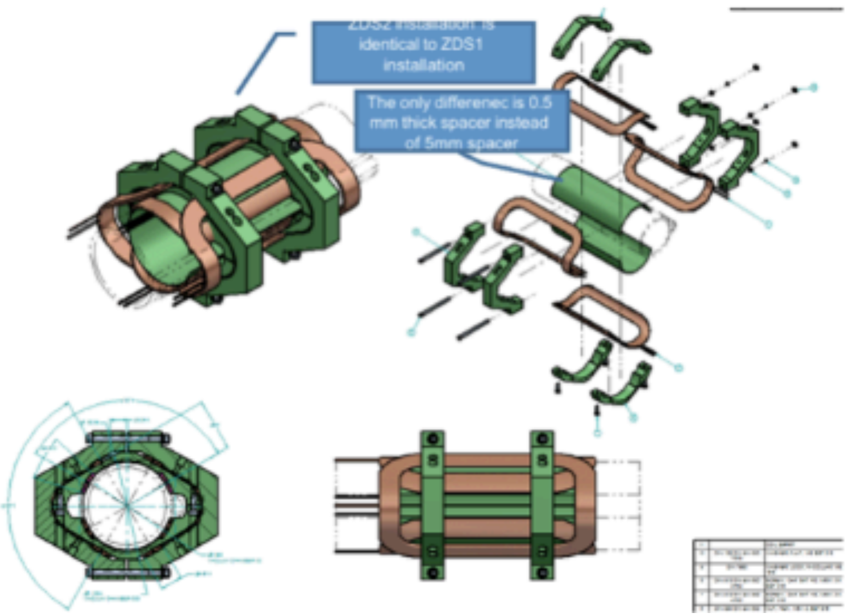
Magnet tilt by remote control was tested, without scraping the pipes inside.



Tilt control using EPICS needs to be developed.



Dithering coils (SLAC)



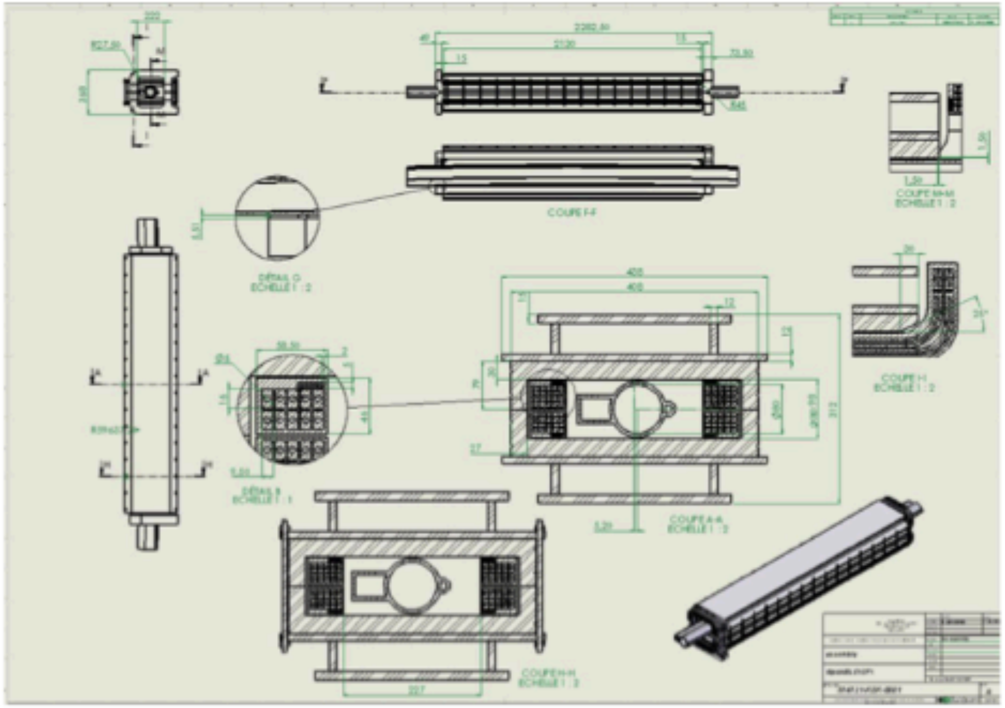
- The coils for dithering were designed, fabricated, field measured and shipped to KEK in April.
- We will install them in late May or June with Uli, following his instructions.

Field measurements

IR magnets (conventional type)

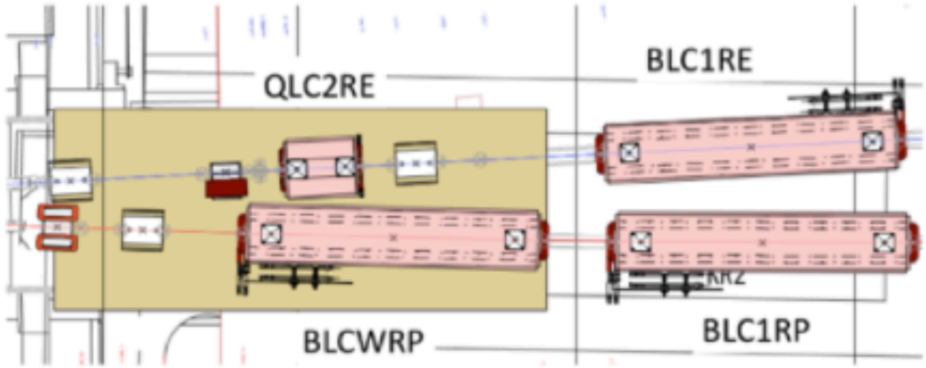
2 quads and 6 dipoles in the IR, where two beam lines converge.

IR Dipoles (1.5m, 2.2m and 3.6m)



Design concept (1)
Same cross section (using the same punching "die" for cost reduction)

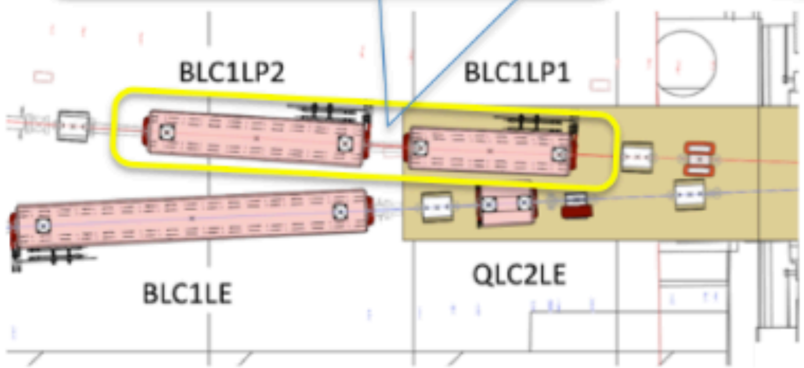
Challenges
Relatively (for the available space) large aperture needed ←→
Total width must be less than 440 mm



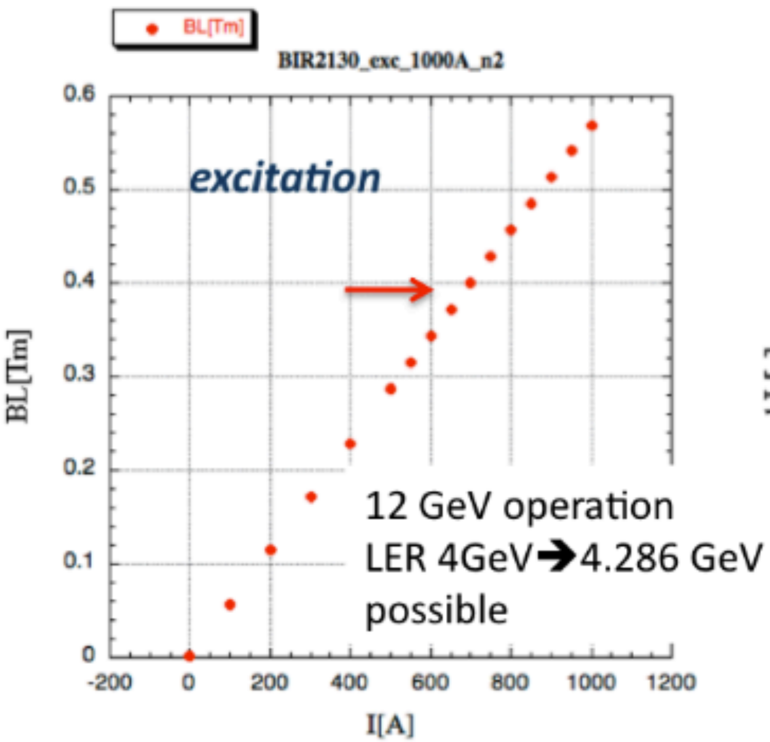
Design concept (2)
"H-type" was chosen
Pros:
Better field quality
More rigid
Less magnetic coupling to neighboring magnets
Cons:
More work needed to fit in the tight space.
Need to open and close for vacuum pipe installation.

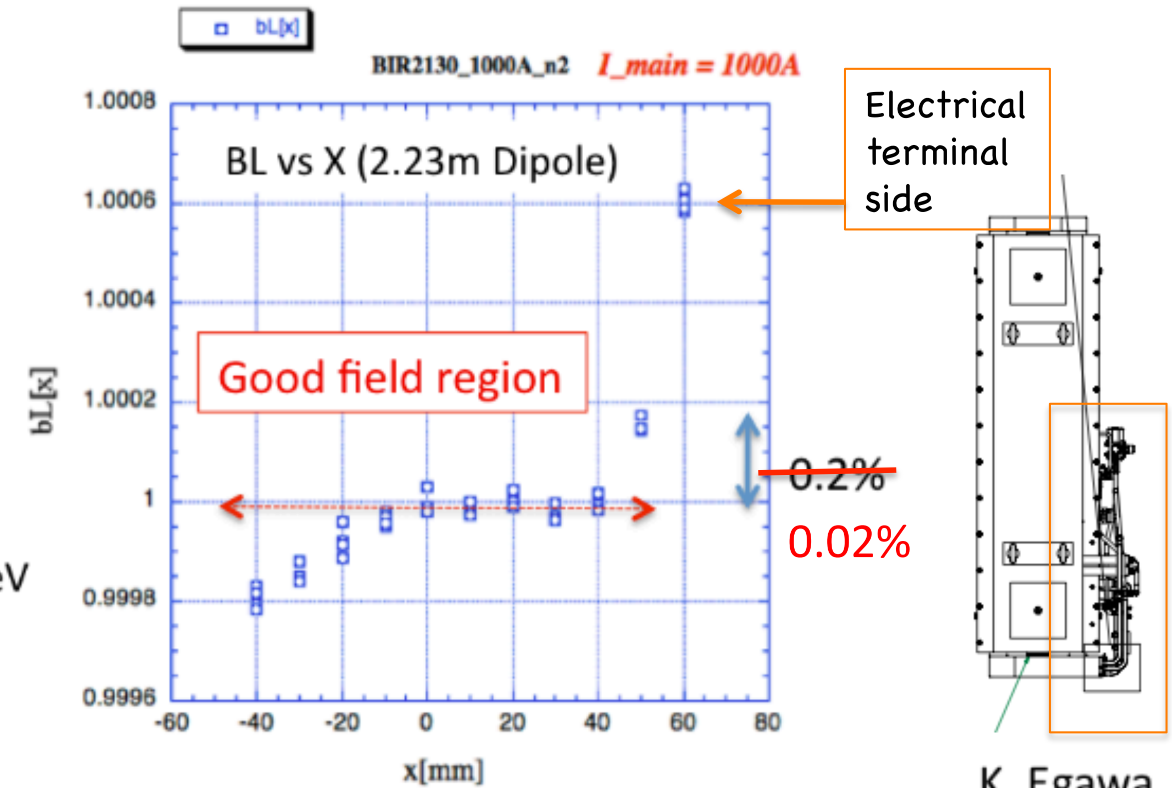
IR Dipoles specifications & 2.2 m results

Split into two to fit on the movable table.



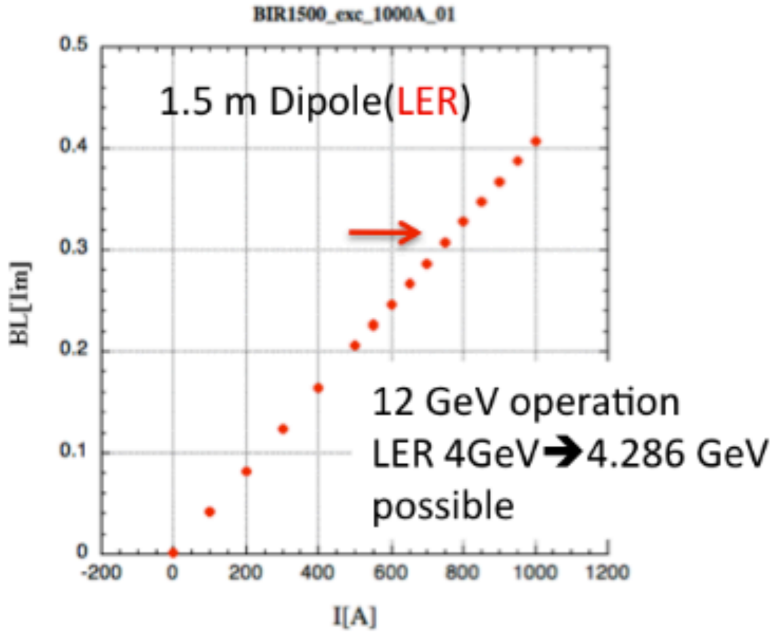
1670_2 / 5735b	L (m)	BL (Tm)	ΔBL/BL (%) r=50 mm (6極成分)
BLC1LP	3.99	0.493	±1.0
BLC1RP	2.23	0.385	±1.0
BLCWRP	2.23	0.199	±1.0
BLC1LE	3.6	0.138	±1.0
BLC2RE	2.23	0.138	±1.0

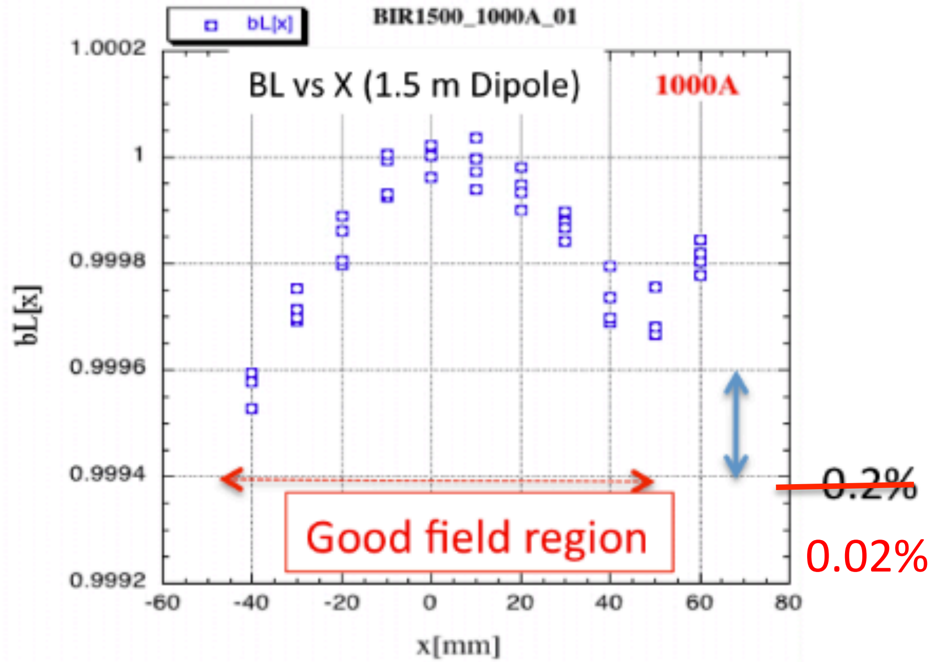


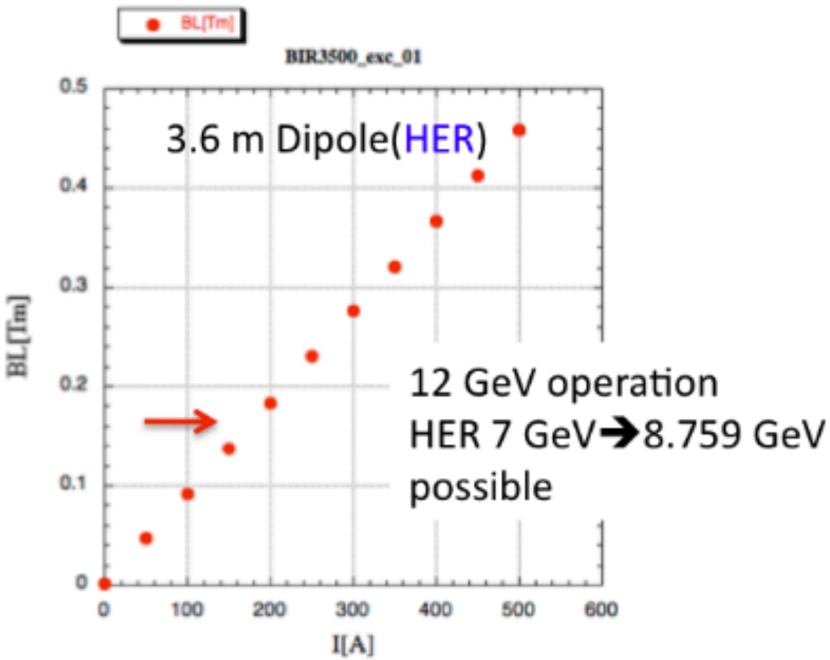


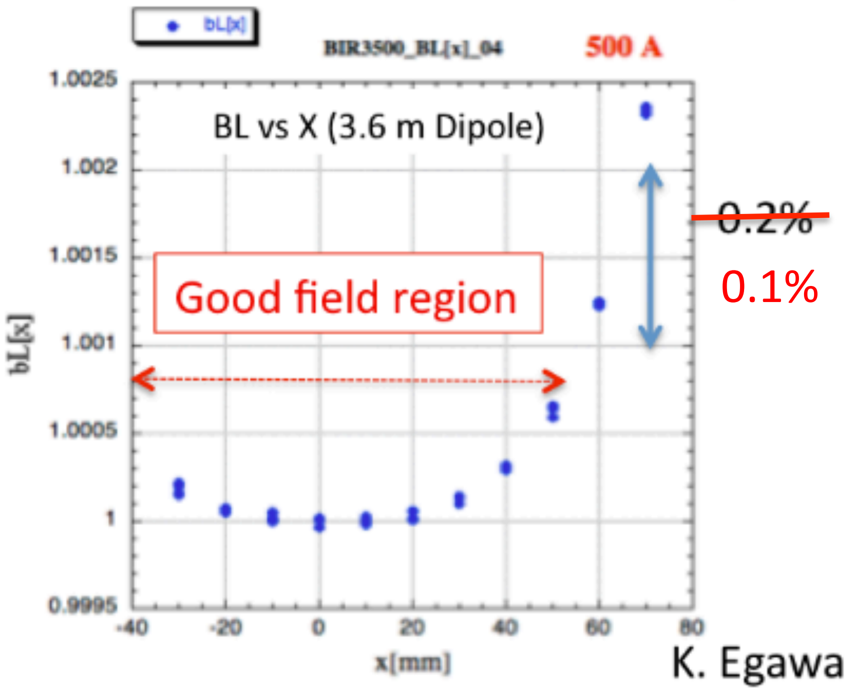
K. Egawa

IR Dipoles (1.5 m & 3.6 m results)



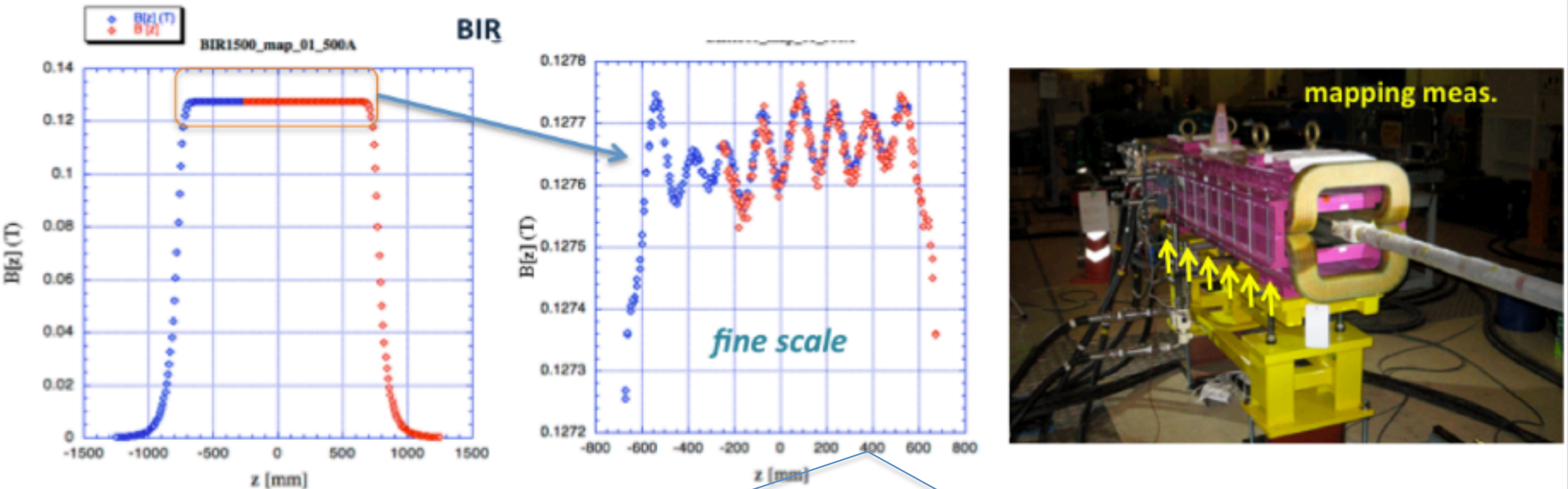






K. Egawa

IR Dipoles (mapping in the beam direction/effective length)

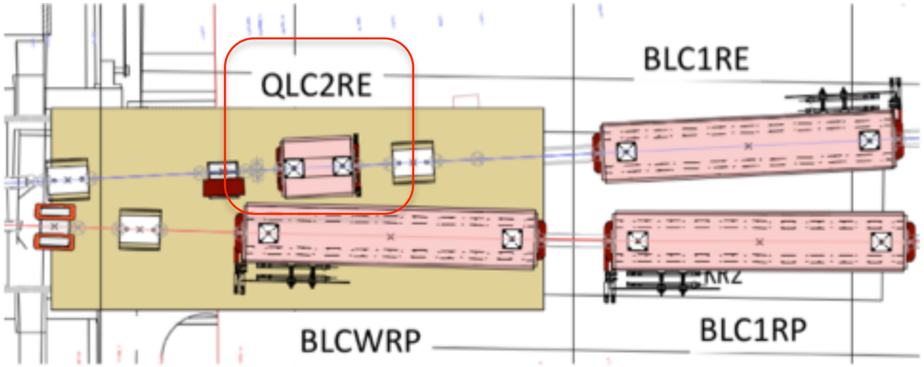


It does not exactly match the span of the bolts which connects the top half and the bottom half of the magnets.
This bumpy structure is NOT a problem as it is small and in the Z-(beam) direction.

Field measurement data, such as excitation curves and effective lengths are being transferred to the optics group.
Magnet database will be prepared for machine operation.

K. Egawa

IR Quadrupoles (QLC2LE, QLC2RE)



Challenges
Relatively (for the available space)
large aperture needed ←→
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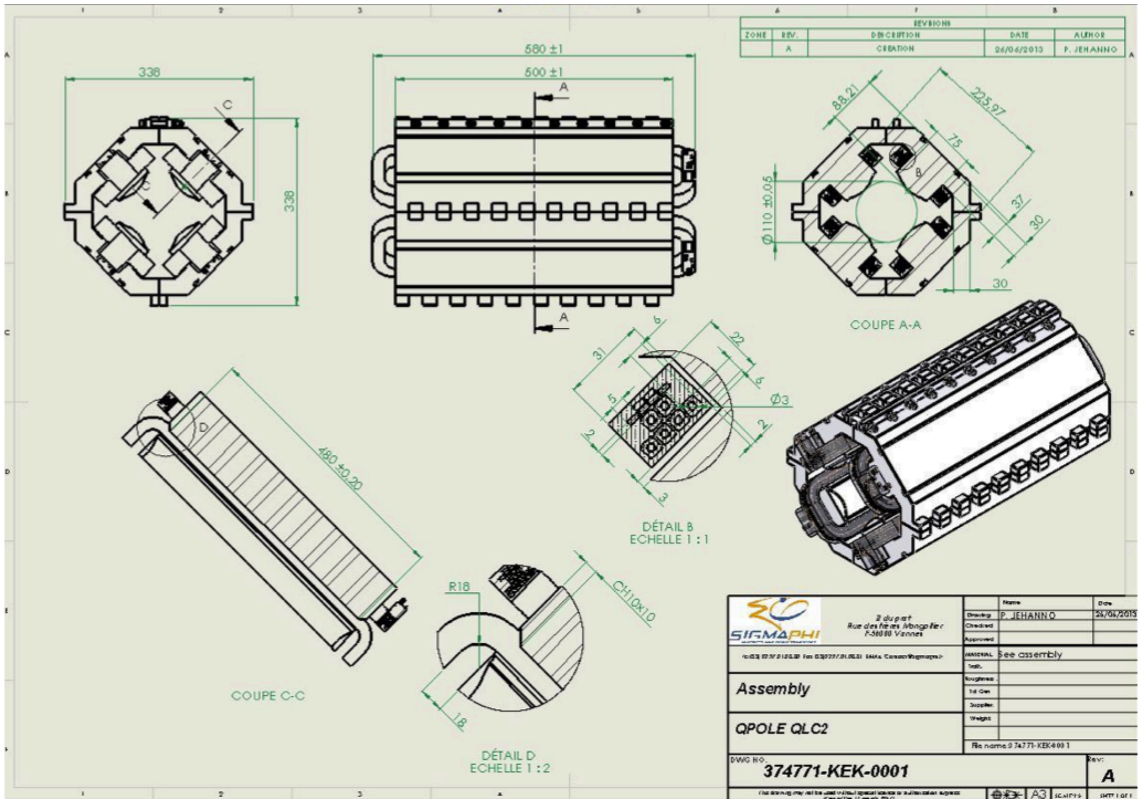
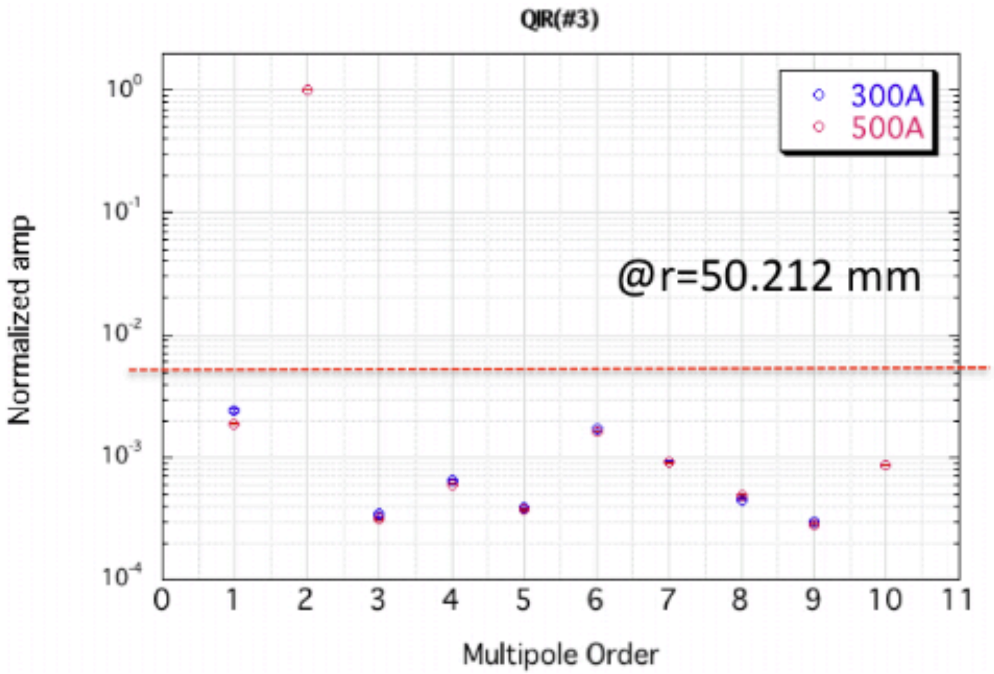
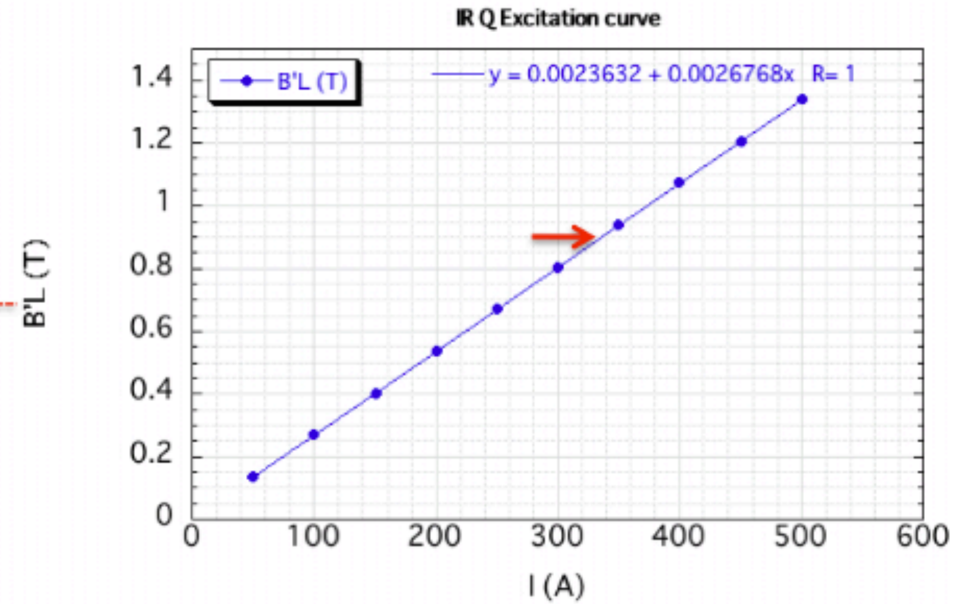


IR Quadrupoles (QLC2LE, QLC2RE)



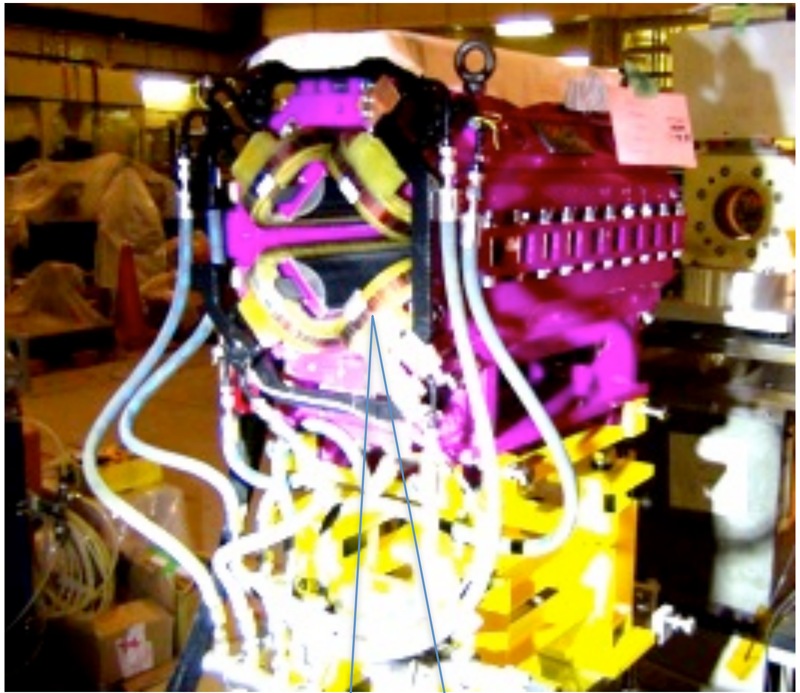


5735b	L (m)	B'L (T)	ΔBL/BL (%) r=50 mm (12極成分)
QLC2LE*	0.56	0.38	±0.5
QLC2RE*	0.56	0.89	±0.5

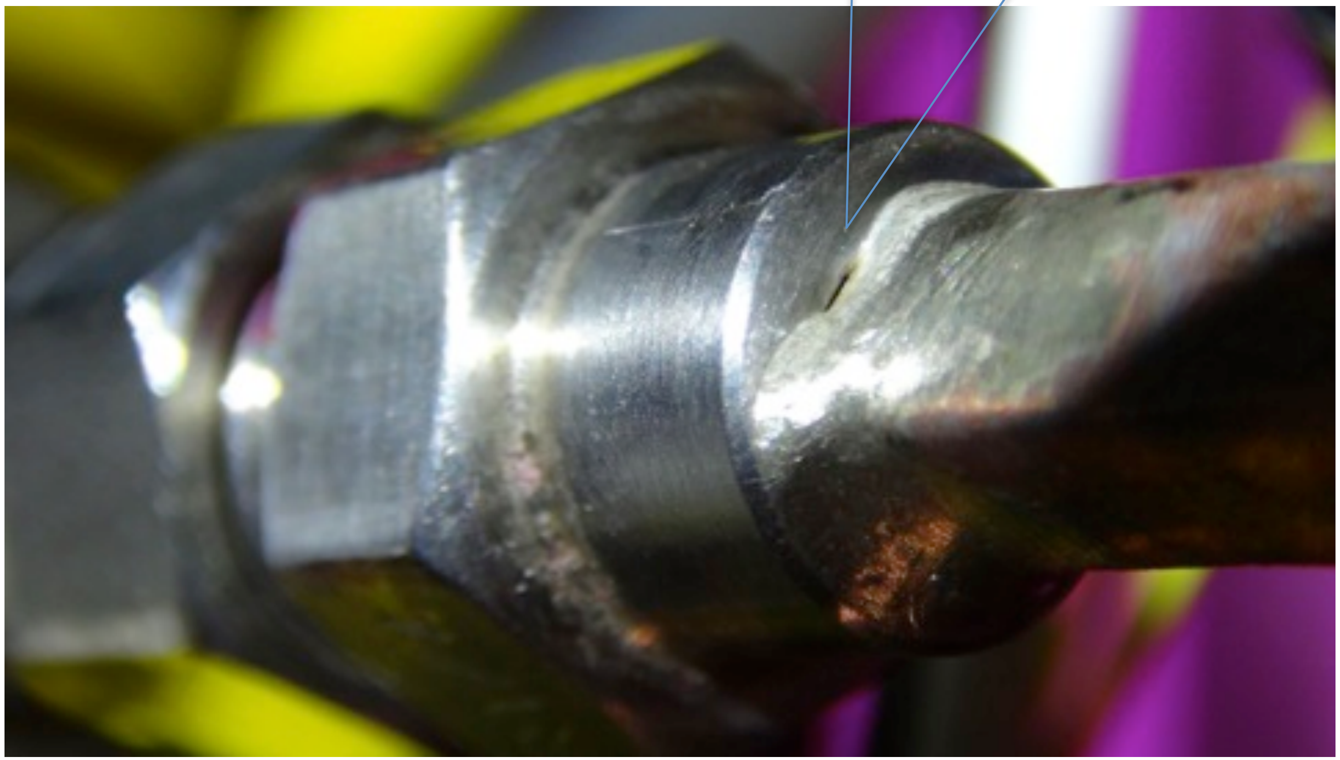
- IR conventional magnets (2 quads and 6 dipoles) satisfied the specifications.
- They showed no magnetic field problems, though did show some non-field-related problems.

An example of non-field-related problems

QLC2* water leak



Water leak found at the joint of the lower right coil during field measurement of No.2 quadrupole magnet on Apr. 15, 2014.



Bad silver alloy brazing. A hole (> 1 mm in length) can be seen.

Bad silver alloy brazing also found in a newly fabricated wiggler magnet, casing water leak

日光BW3NLMP.1(NL007)

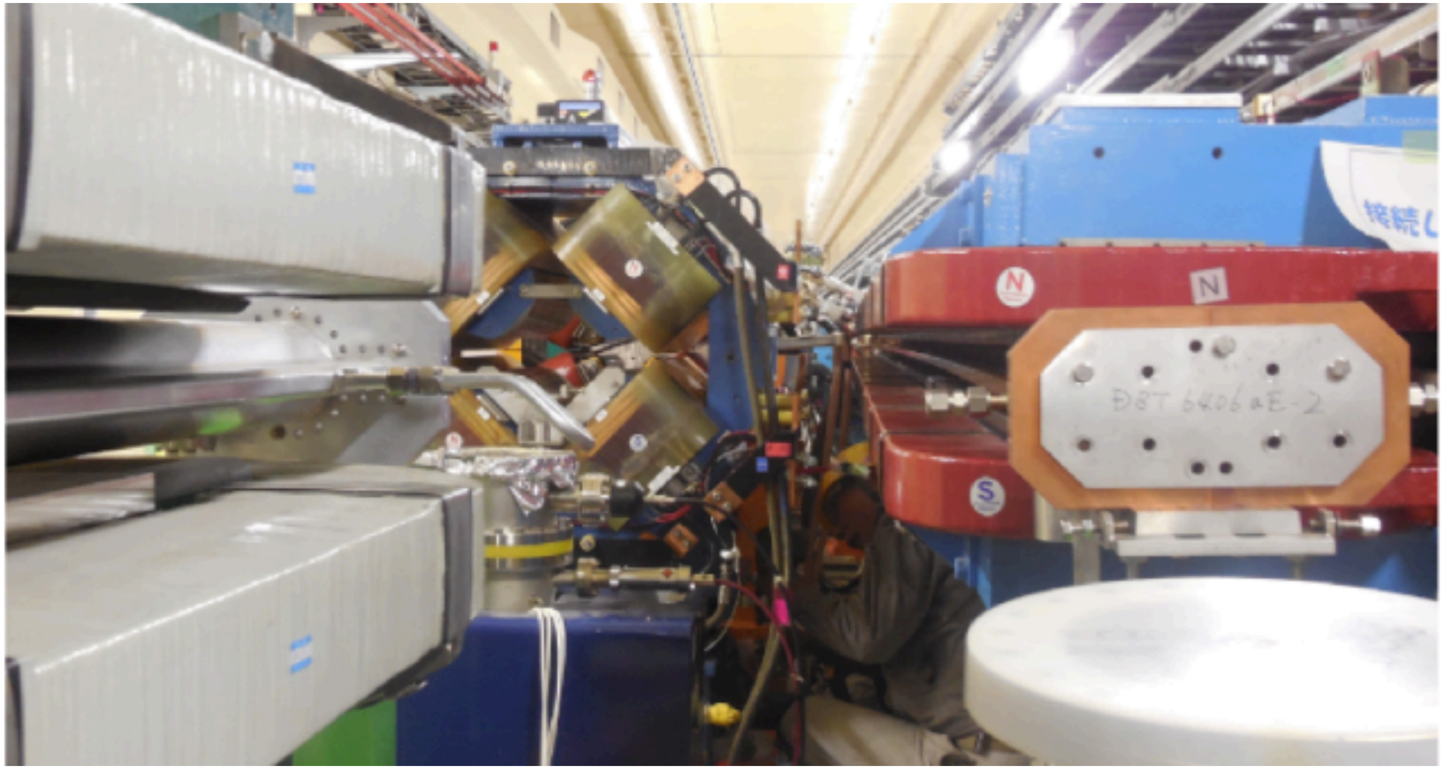
The hole was fixed in situ.

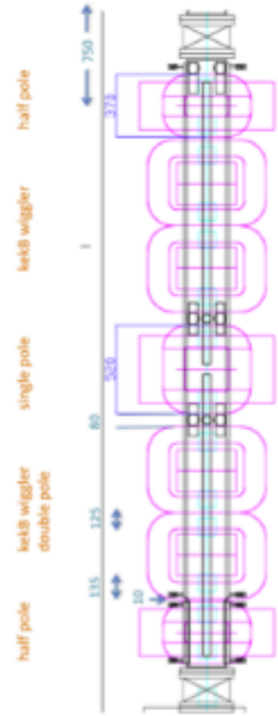
We hope that this is just an isolated case, as there are 168 newly fabricated wiggler magnets.

Magnetic coupling between neighboring magnets

Wigglers:
3D calculation results are being used by the Optics group.

Magnets close to each other:
We plan to carry out some measurements in 2015.





K. Egawa, H.Iinuma

Power supplies

Preliminary test results

Cabling work

N. Tokuda, T.Adachi, T.Sueno, T.Oki, T.Kawamoto

Power supplies newly fabricated or to be fabricated for Main Ring

Output power or current	FY 2011	FY 2012	FY 2013	FY 2014	Types of magnets
0.95 MW	2	–	–	–	LER/HER Main Dipoles
0.4 - 1 MW	8	1	–	–	LER/HER Wigglers
2.4 - 50 kW	–	–	102	–	Dipoles, Quadrupoles, Sextupoles
0.5 - 0.8 kW	–	29	100	~100	Steering magnets, Correction coils (~1900 small-class power supplies will be reused)
800 - 2000 A	–	–	2	6	Superconducting Quads
200 - 500 A	–	–	–	4	Superconducting Solenoids
± 60 A	–	–	4	~40	Superconducting Correction coils

■ Power supplies currently being tested

Power supply for the HER dipoles ("B2E") being tested while hooked up to the actual magnets

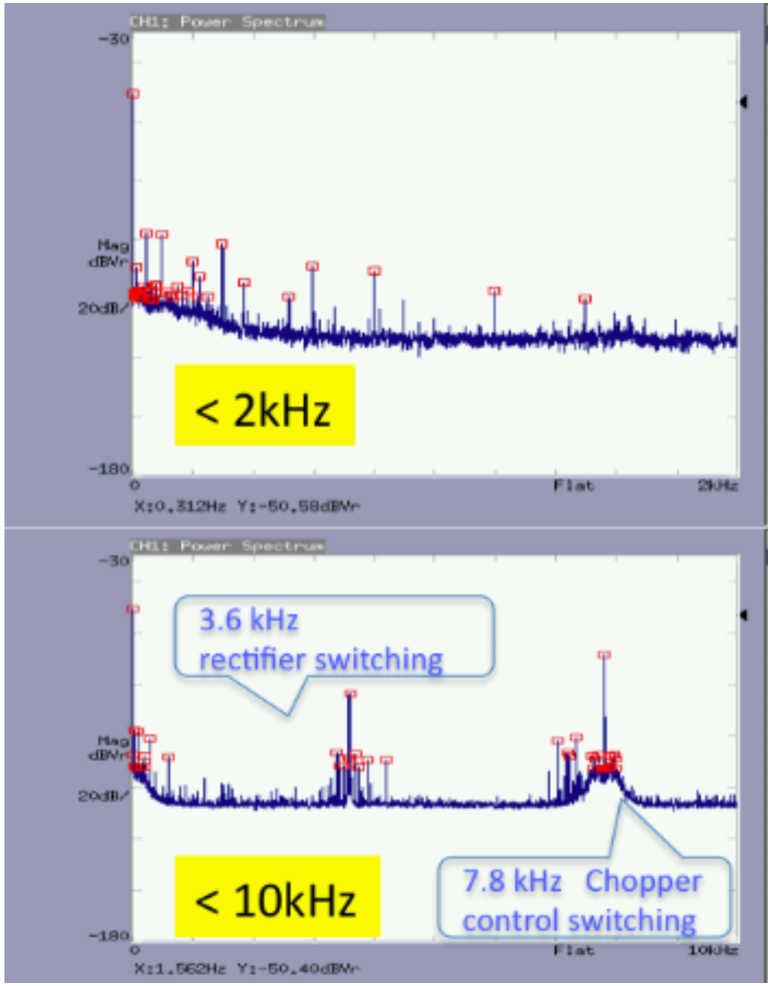
Feb.2, 2015

- B2E magnets were turned on for the first time with the new PS.
- Polarity of all 105 B2E magnets were checked at 50 A.
- The current was ramped up to 840 A (Max. current) successfully.
- No abnormal heating was observed at joints, connections between the electrical terminals of the magnet and power cables.
- Some problems with the interlock system, now being looked into.

Feb.6, 2015

- Ripple measurements at 840 A were carried out.
- Stability data were obtained.

Power supply for the HER dipoles ("B2E") being tested while hooked up to the actual magnets



No.	X(Hz)	Y(dBVr)
1	0.3125	-50.58
2	50.0000	-97.72
3	100.0000	-97.94
4	299.6875	-101.09
5	199.6875	-107.33
6	599.3750	-108.59
7	15.9375	-108.97
8	801.8750	-110.40
9	223.1250	-112.25
10	371.8750	-114.18
11	74.3750	-115.07
12	150.0000	-115.33
13	34.3750	-115.35
14	83.7500	-115.66
15	184.0625	-116.91
16	65.9375	-117.04
17	1199.0625	-117.05
18	27.1875	-117.16
19	25.3125	-117.16
20	115.9375	-117.42
21	11.8750	-117.56
22	76.2500	-118.03
23	10.0000	-118.04
24	21.8750	-118.21
25	18.1250	-118.25

No.	X(Hz)	Y(dBVr)
1	1.5625	-50.40
2	7812.5000	-68.38
3	3598.4375	-83.30
4	50.0000	-97.54
5	100.0000	-98.19
6	7346.8750	-100.42
7	300.0000	-100.70
8	7046.8750	-101.75
9	3398.4375	-106.42
10	7196.8750	-106.49
11	3698.4375	-106.95
12	15.6250	-107.17
13	7712.5000	-107.25
14	7962.5000	-107.26
15	7612.5000	-107.65
16	7912.5000	-107.69
17	7246.8750	-107.74
18	200.0000	-107.76
19	600.0000	-108.14
20	3582.8125	-108.35
21	3614.0625	-108.42
22	7662.5000	-108.71
23	8012.5000	-108.72
24	3898.4375	-109.01
25	4214.0625	-109.11

- Measurement of the output current ripple by DCCT :

Below 2 kHz ~ 2.1 ppm. From 2kHz to ~ <10 kHz Max. 50 ppm @~7kHz➔ Acceptable.

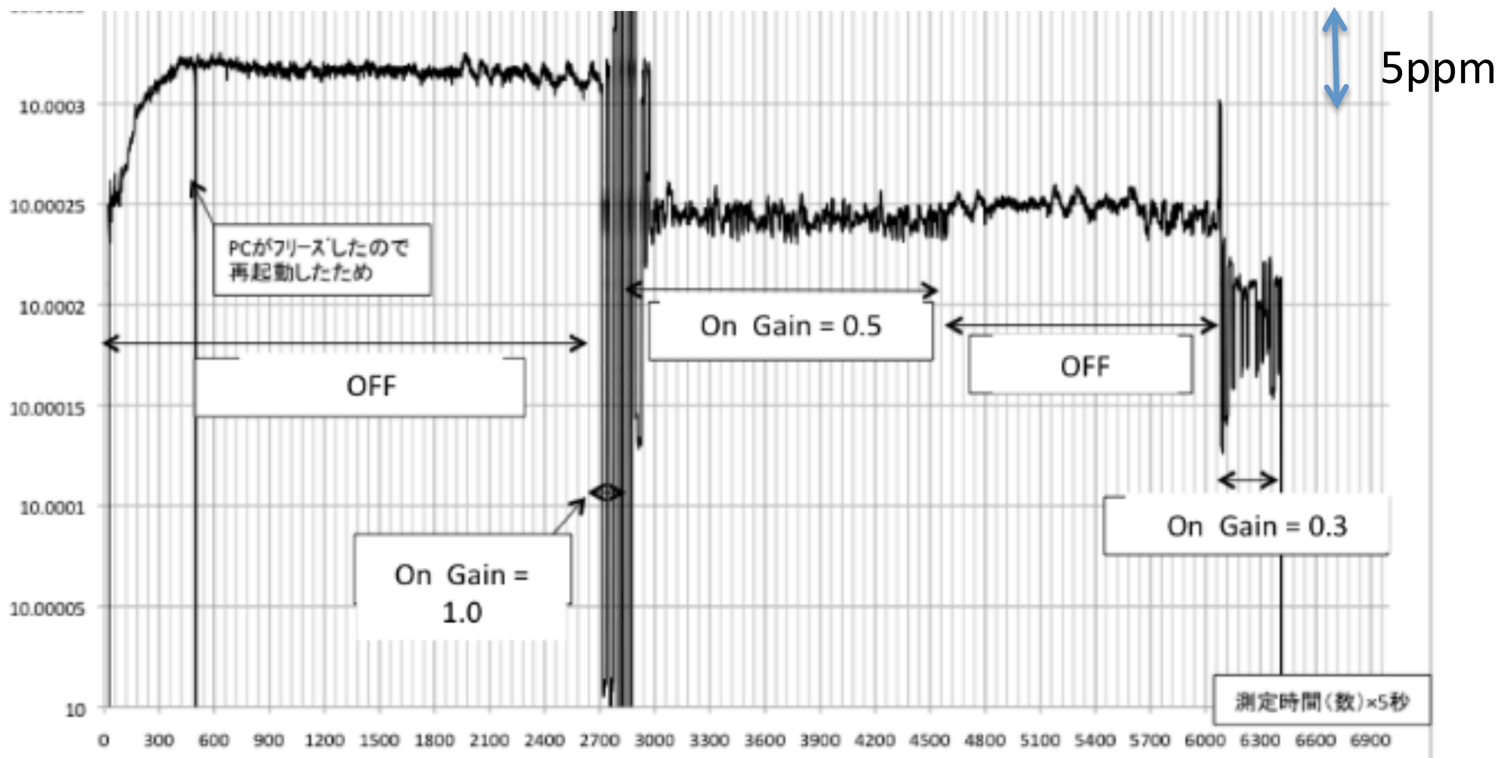
- Stability (~9 hour operation on Feb.6 2015) test:

FB parameters need to be adjusted but overall looks like we can achieve 2ppm/24 hours.
Some effects of RF Klystron power on/off in the same building are seen (a few ppm) though the propagation path needs to be investigated.

Power supply for the wigglers being tested while hooked up to the actual magnets

"Double pole" wiggler in the OHO section "BWDORP" data are shown as an example.
Ripple measurements carried out on Jan. 26, 2015

- Measurement of the output current ripple by voltage (translated into current ripple using inductance)
  - Frequency lower than 2 kHz: ~ 0.36 ppm
  - Frequency higher than 2 kHz: 0.32 ppm (0-p) at 70 kHz➔ No problem.
- Stability measurement on Jan. 29, 2015.
  - FB parameters need to be adjusted but looks promising.



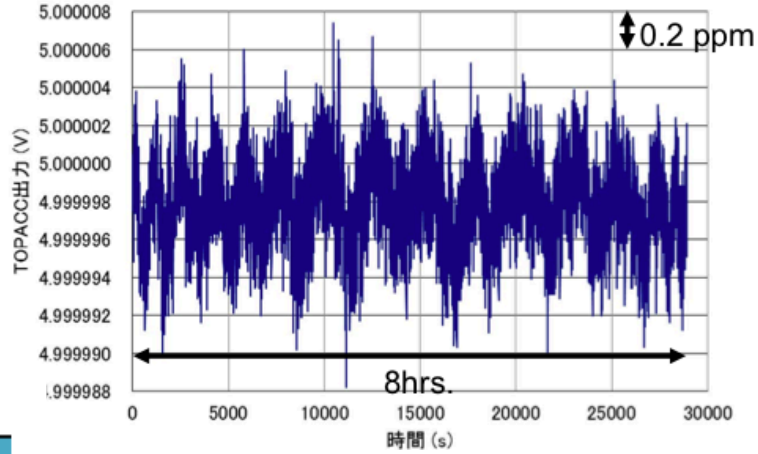
Power supply for superconducting magnet QSC-L
Test results with dummy load

Test result with dummy load – stability –

Output current
(1000A/5V)

1.9 ppm

OK



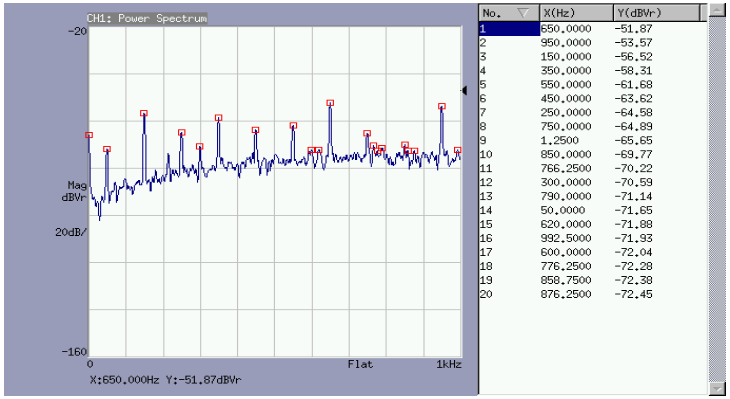
Test results with dummy load – ripples –

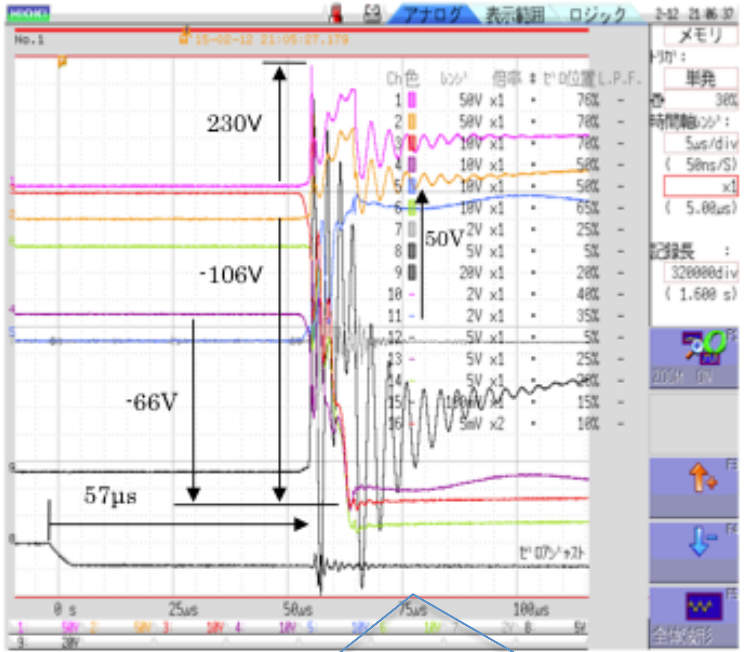
frequency (Hz)	Voltage ripple (dBVr)	Impedance of dummy load (Ω)	Current ripple (ppm(rms))	Impedance of QC1LP (Ω)	Expected current ripple for QC1LP (ppm(rms))	Rms value (<10 kHz)
60	-68.22	0.07	2.77	0.26	0.75	
180	-60.07	0.21	2.36	0.9	0.55	
300	-64.18	0.35	0.88	1.3	0.24	
420	-61.91	0.5	0.8	1.8	0.22	
540	-66.85	0.6	0.38	2.5	0.09	
660	-61.08	0.7	0.63	2.8	0.16	
780	-54.83	0.85	1.07	3.2	0.28	
900	-63.66	0.95	0.35	4	0.08	
1140	-50.54	1.1	1.35	5	0.3	1.27 ppm(rms)
1500	-45.28	1.5	1.82	6	0.45	
1860	-43.91	1.8	1.77	8	0.4	
2100	-51.14	2.2	0.63	9	0.15	
2220	-51.04	2.2	0.64	10	0.14	
2340	-57.03	2.3	0.31	10	0.07	
2460	-54.18	2.4	0.41	11	0.09	
2580	-59.08	2.5	0.22	11	0.05	
2700	-58.04	2.6	0.24	12	0.05	
19125	-40.8	10	0.46	50	0.09	-
38125	-38.55	15	0.39	100	0.06	-

Ripple specification
For frequencies lower than 10 kHz
1 ppm ➔ acceptable

Quench protection
✓Induced voltage OK
✓Time constant OK

Power supply for superconducting magnet QSC-L
Test results with QCS-L proto type





主要な成分について電流リップルを求めた結果を下表に示す。

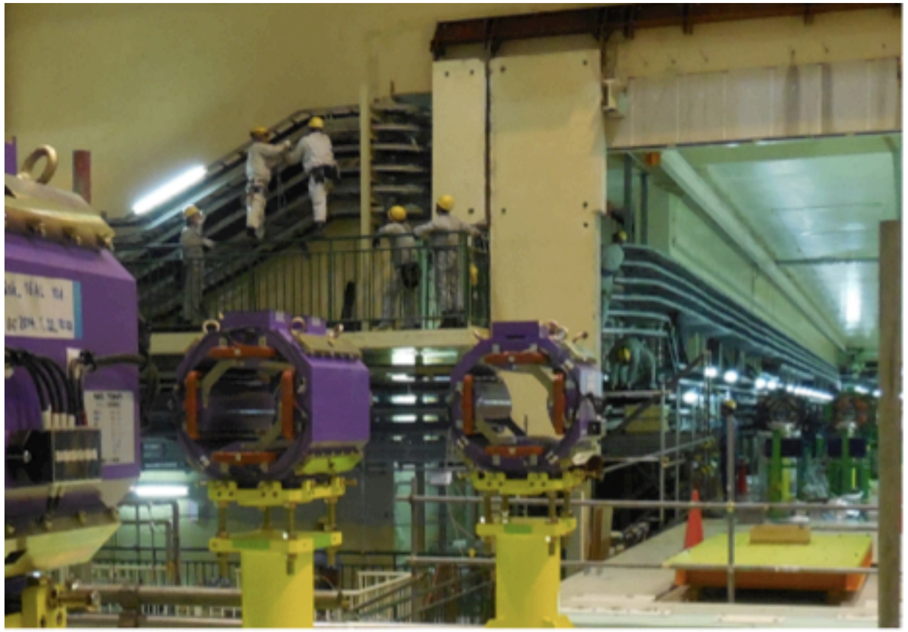
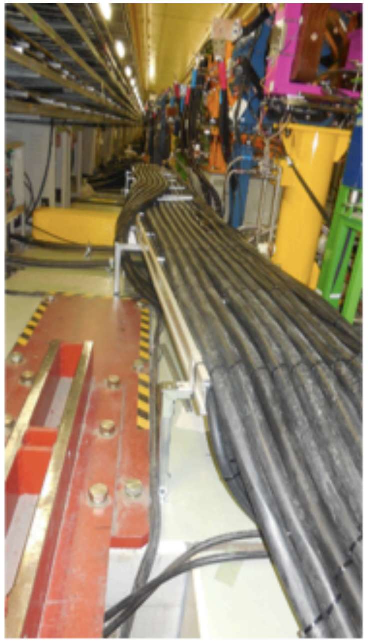
ノーマルモードリップル電流計算式: $10^{((電圧リップル)/20)}$/|Zpn|/2000A

主要な成分 [Hz]	電圧リップル [dBVrms]	|Zpn| [Ω]	電流リップル [ppm(rms)]	自乗和の平方根 [ppm(rms)]
50.00	-71.65	0.16	0.82	
150.00	-56.52	0.48	1.55	
250.00	-64.58	0.80	0.37	
300.00	-70.59	0.97	0.15	
350.00	-58.31	1.13	0.54	
450.00	-63.62	1.46	0.23	
550.00	-61.68	1.82	0.23	
600.00	-72.04	1.98	0.06	
620.00	-71.88	2.06	0.06	
650.00	-51.87	2.16	0.59	
750.00	-64.89	2.56	0.11	
766.25	-70.22	2.59	0.06	
776.25	-72.28	2.66	0.05	
790.00	-71.14	2.70	0.05	
850.00	-69.77	2.93	0.06	
858.75	-72.38	2.97	0.04	
876.25	-72.45	3.05	0.04	2.14
950.00	-53.57	3.38	0.31	
992.50	-71.93	3.59	0.04	
1150.00	-59.89	4.46	0.11	
1250.00	-54.92	5.11	0.18	
1450.00	-60.19	6.90	0.07	
1550.00	-55.88	7.87	0.10	
1750.00	-61.84	6.62	0.06	
1850.00	-56.24	4.53	0.17	
2000.00	-61.65	2.74	0.15	
2062.50	-60.15	2.57	0.19	
2150.00	-55.09	2.57	0.34	
2350.00	-57.62	3.18	0.21	
2450.00	-53.67	3.46	0.30	
2650.00	-57.27	4.13	0.17	
2750.00	-55.51	4.42	0.19	
2937.50	-61.71	4.98	0.08	

Quench detection in 57 micro seconds!
(much faster)
Induced voltage less than 200V

Acceptable
Since
L = 0.51mH (QCSL proto type) while 0.88 mH for the actual QCS-L.
Parameters were adjusted for the dummy load when these data were obtained. Parameter re-adjustment can improve the performance.

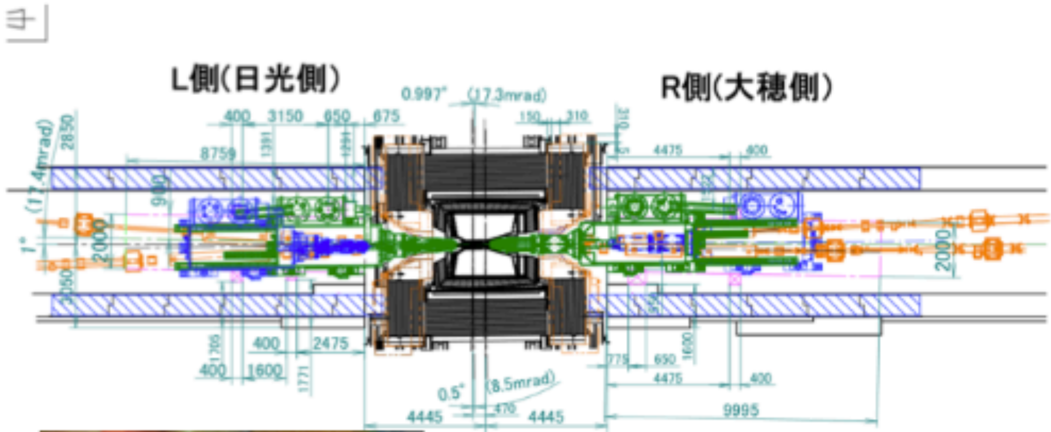
Cabling work
(Should not be taken too lightly; they are "heavy")



Cabling work
(Should not be taken too lightly; they are “heavy”)

- Most of the cables in the IR laid.
- Some are already connected to the magnets, some are to be connected.
- But the QCS power supply cable routing still remains to be finalized.



Cable type needed For QCS system	# of cables L-side	# of cables R-side
400 mm²	30	30
200 mm²	0	4
60 mm²	46	46
60 mm² (ground wire)	5	6

2182kg/560m
=3.89kg/m

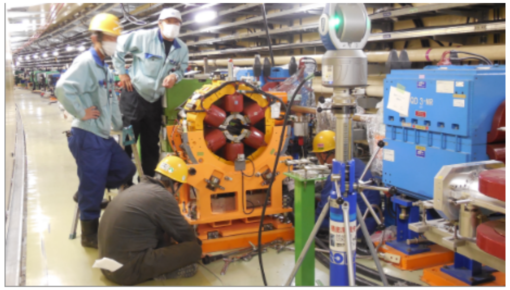
Routes:
Cables through (new) holes on the beam line floor?
Types:
Cables, bus bars or hollow conductors?
➔ Needs to be finalized VERY soon.

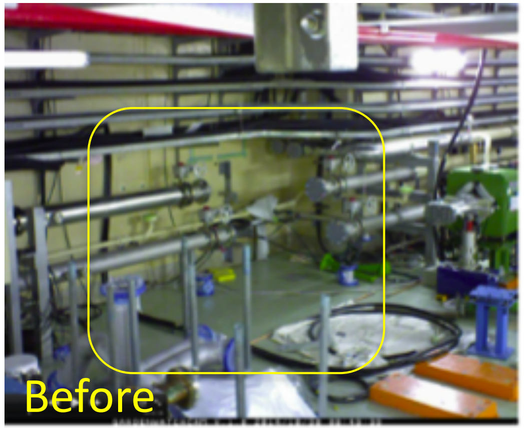
Alignment

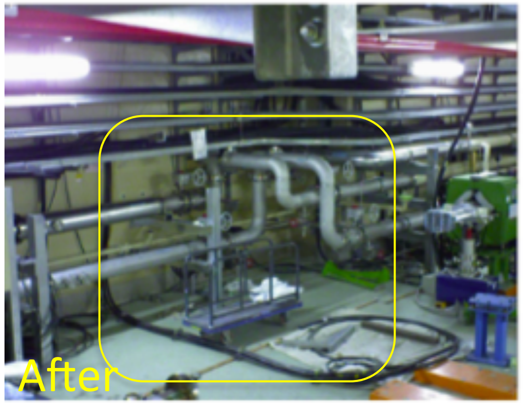
Effects of the excavation/construction

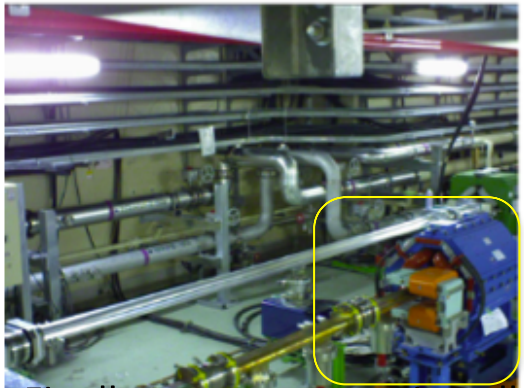
Work area needed for utility work in the mid-arc sections.

Magnet alignment

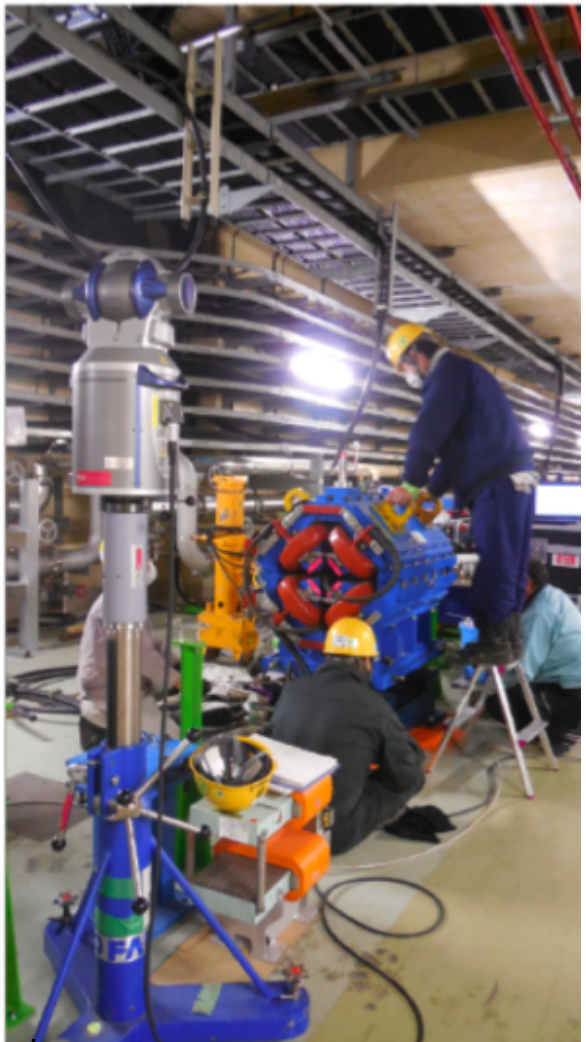








Finally magnets were installed



Magnets newly installed in the tunnel were aligned to the surrounding magnets using a laser tracker.

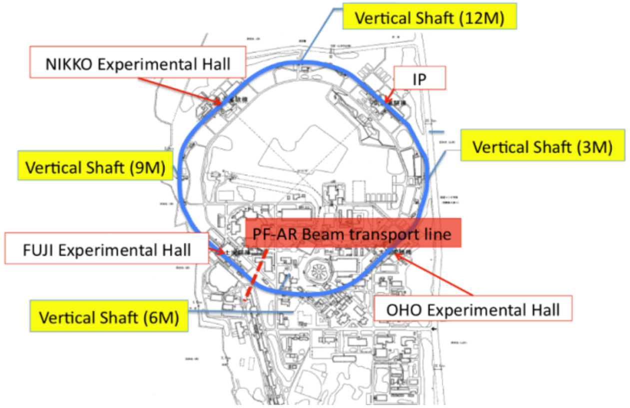
The newly installed magnets are:

- HER quadrupoles in the mid-arc sections
- IR magnets
- Tsukuba straight section
- Parts of the north and east tunnels.

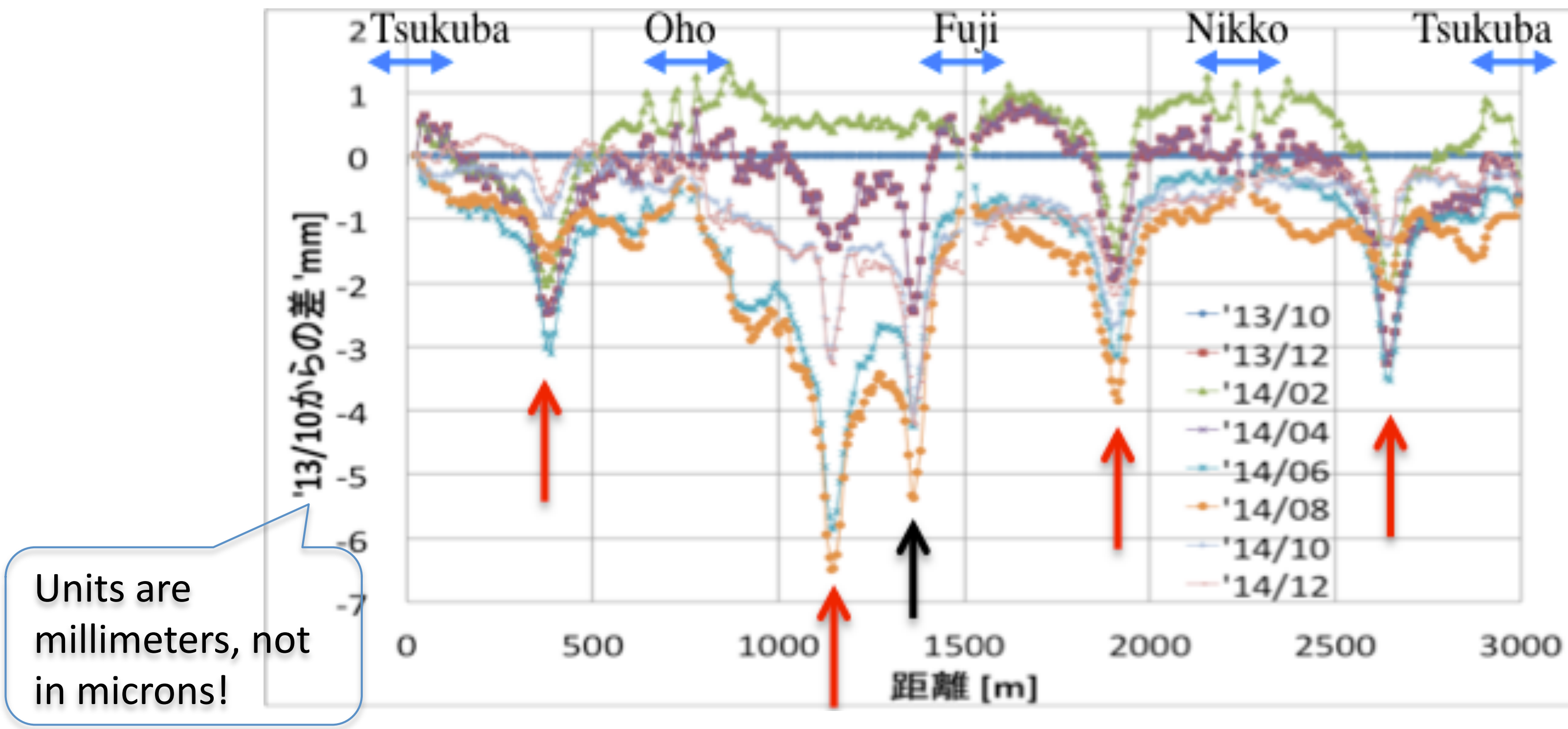
The entire ring survey and alignment was not carried out (see next slide).

Magnet alignment

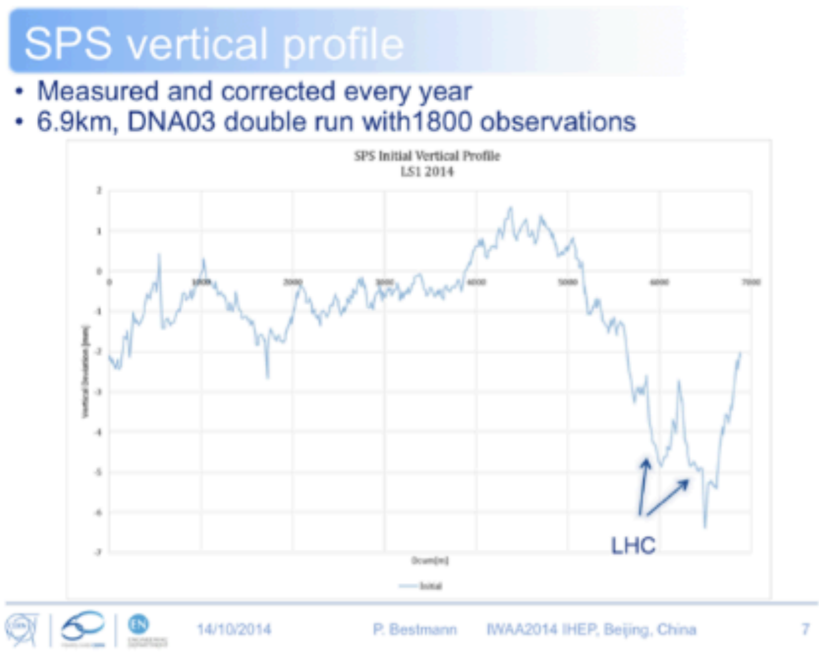
- 1st round alignment of the newly installed magnets has been done
- We could not carry out 2nd round alignment last year because
  - Effect of the construction of new facility buildings along the tunnel was large.
  - Tunnel temperature was not stable at all (varied more than 10 degrees)

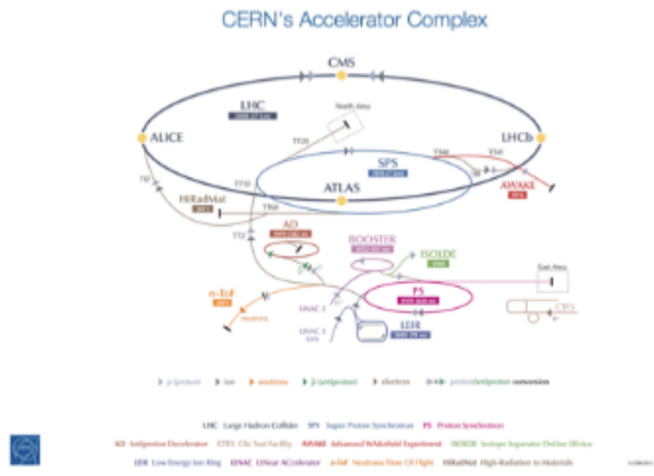


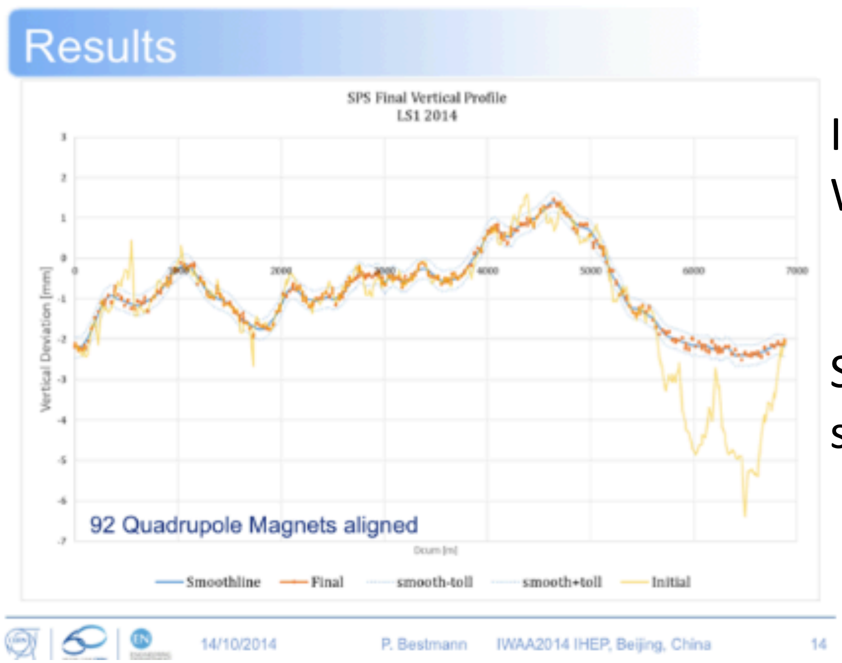
Tunnel monument height variation since October 2013 surveyed with Digital level



Y. Ohsawa





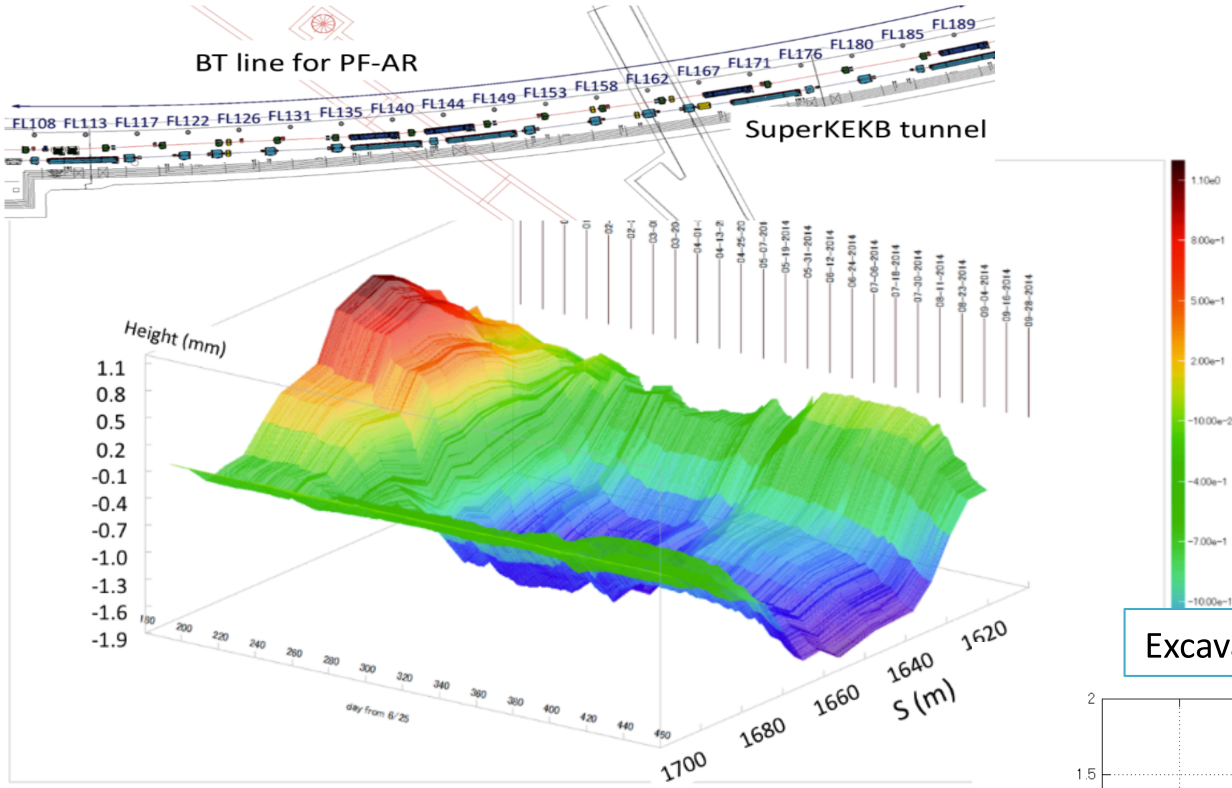


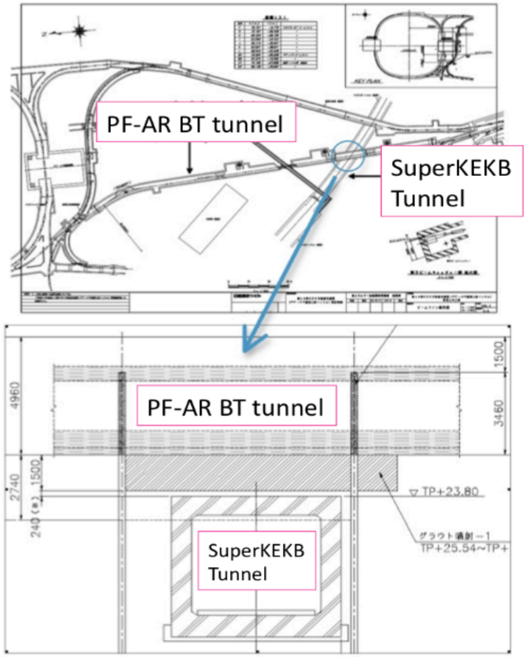
It happens.

We will smooth out the bumps, too.

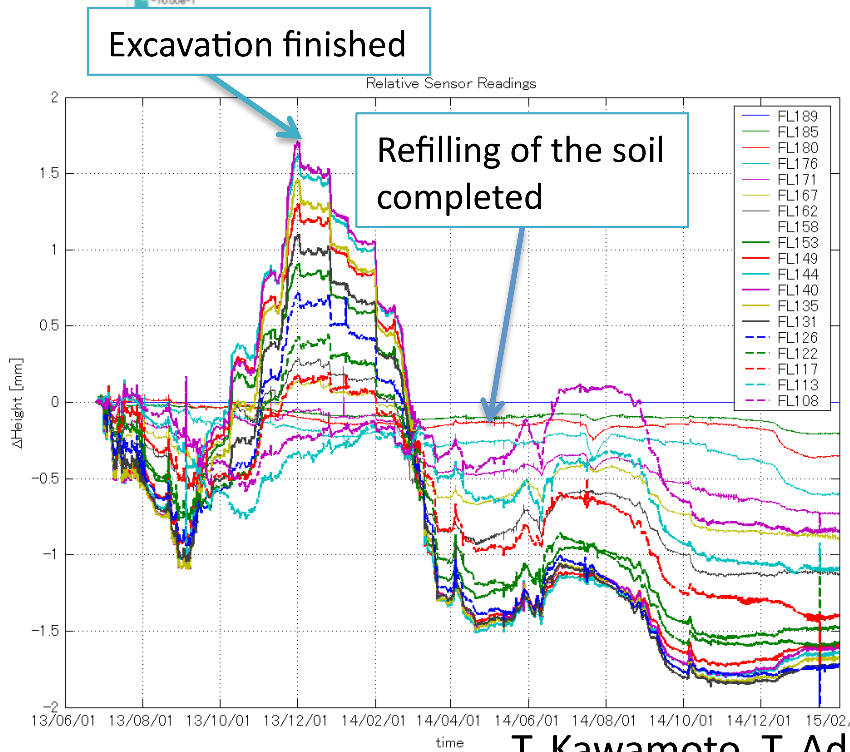
Smoothing works as long as the tunnel is stable.

Effect of the new BT line to PF-AR monitored by HLS





The tunnel level does not seem to go back to where it was before the construction.



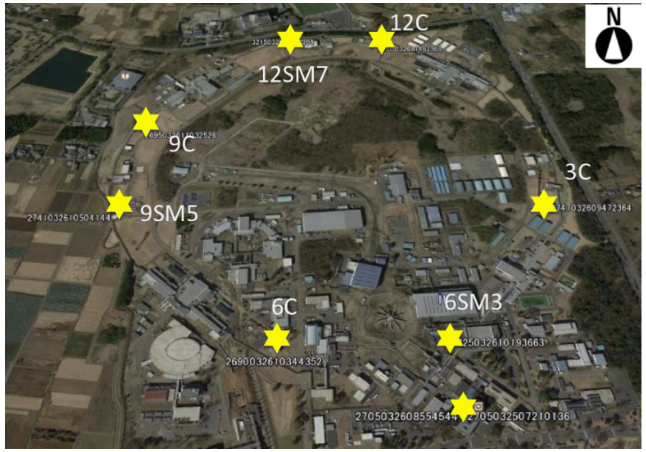
T. Kawamoto, T. Adachi

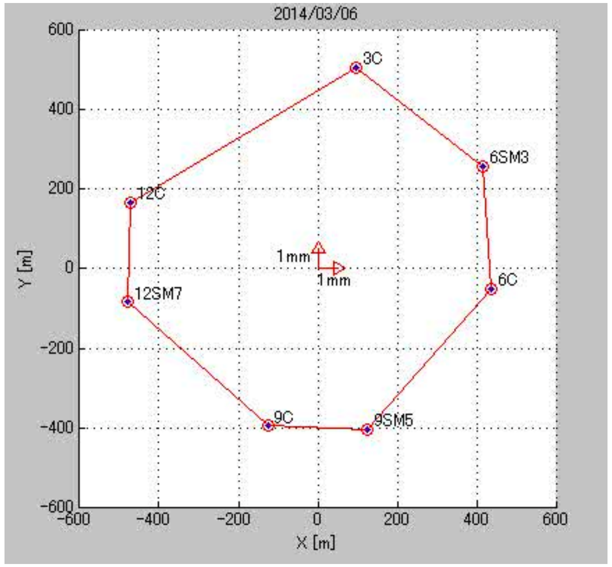
GPS system

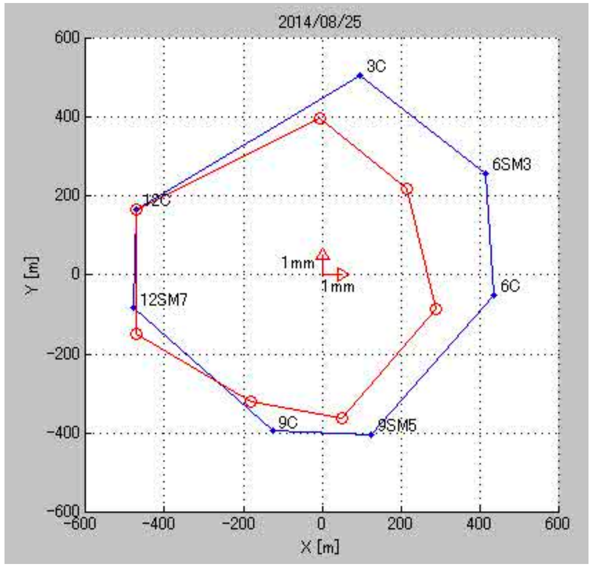
A GPS network system was installed in 2012, after the Great East Japan Earthquake struck Japan, in order to:

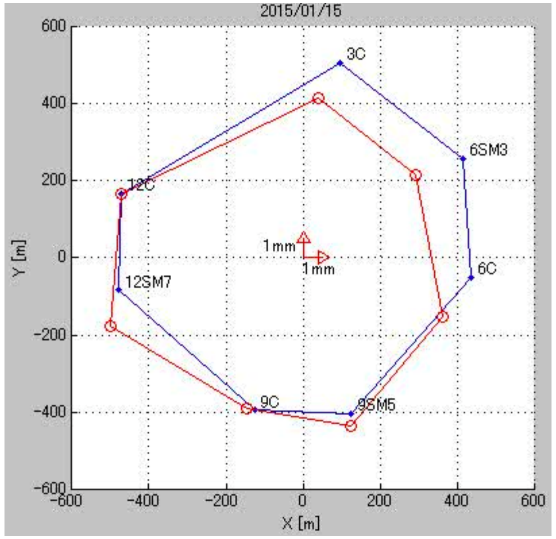
(1) connect the tunnel survey network to the surface network ;and,

(2) monitor long-term ground and building motion.







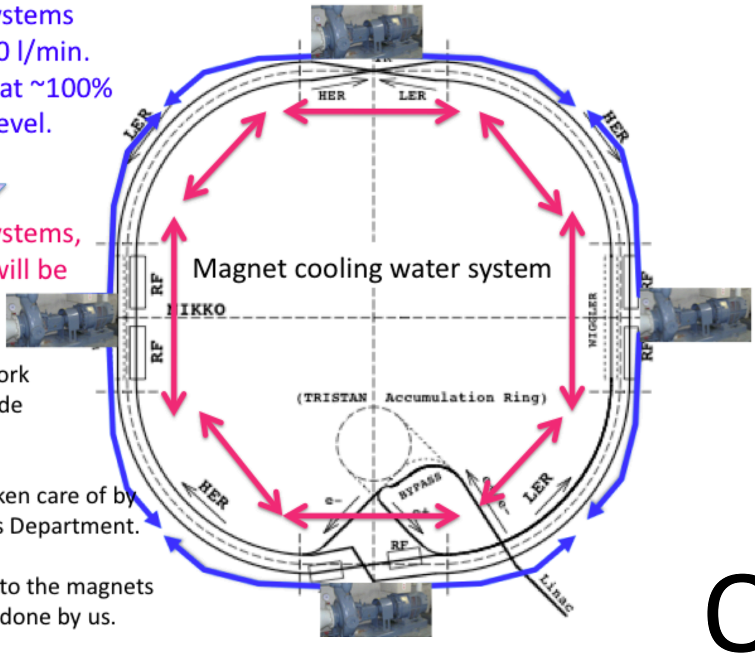


- Whether the GPS results indicate SuperKEKB tunnel deformation is not clear at this point.
- More thorough examination of GPS data and tunnel survey needed.
- GPS data were very stable if daily averages were taken.
- A few-millimeter change in distance can be detected with our local GPS network.

H. Iinuma, T. Adachi, T. Kawamoto

4 pump systems
Each~3600 l/min.
Operated at ~100%
Capacity level.

8 pump systems,
Capacity will be
doubled.



Plumbing work
outside/inside
the tunnel
is needed.
⇒will be taken care of by
the Facilities Department.

Connection to the magnets
will have to done by us.

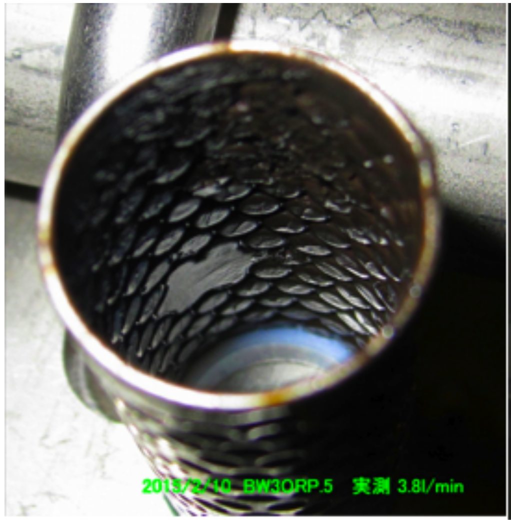
Other

Cooling water system

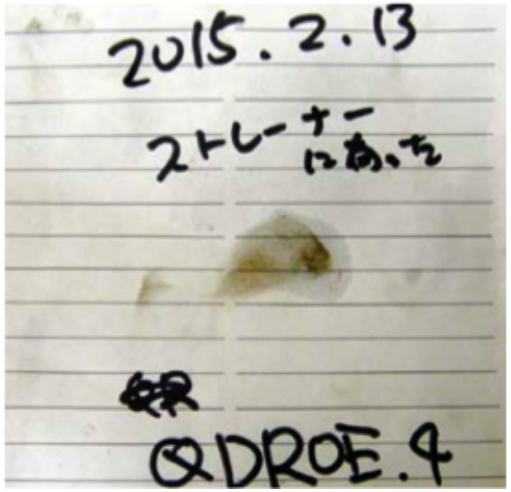
Cooling water problem

Feb. 10, 2015

A few wiggler magnet strainers got clogged and caused a water flow interlock while the wiggler PS was being tested.



copper oxide



Silicon oil

Thanks to Adachi-san's work on interlock

Y. Ohsawa, T. Sueno

Summary

- Magnet installation is completed, except for several tens of meters' worth in the north tunnel.
- We have been working closely with the vacuum group on vacuum pipe installation.
- Tilting sextupole magnets were tested in the tunnel and calibration data are being taken.

- Field measurements of the newly fabricated magnets delivered in FY 2013 were carried out. They satisfy the specifications.
- The field measurement data are now being summarized and shared with the optics group. The data will be installed in the database for the machine operation.

- Bad silver alloy brazing was found in several magnets fabricated by the same company. They caused water leaks and a delay in the power supply test. The holes were fixed in situ, though we worry that there may be more.

- Power supplies delivered before FY2014 are being tested with the actual magnets hooked up. Preliminary test results indicate that they (will) meet the tight specifications.

Summary

- Interlock system is also being tested and some modification seems to be needed.
- Noise issues will be looked into more when turning on multiple power supplies.
- We are aware that attention should be paid to the noise from/to the AC "environment".
- Most of the cabling work is completed though connection work of the power cable to the electrical terminals of the some magnets remain. Polarity checks of all the magnets need to be done, along with many other things.
- Cable route of the QCS system still remains to be finalized.

- The effects of the construction of the new facility buildings along the ring and the new BT line to PF-AR are clearly seen in the tunnel. They caused misalignment of the magnets along the tunnel. Re-alignment (final one before Phase 1) will take place from June. HLS system is a powerful tool for monitoring the vertical tunnel motion.
- We will install them in the Tsukuba LC section and near the IP, where alignment tolerance is tight.
- We would like to install inexpensive HLS sensors (under R&D) all around the ring in the future to monitor a long-term tunnel sinking.

Summary

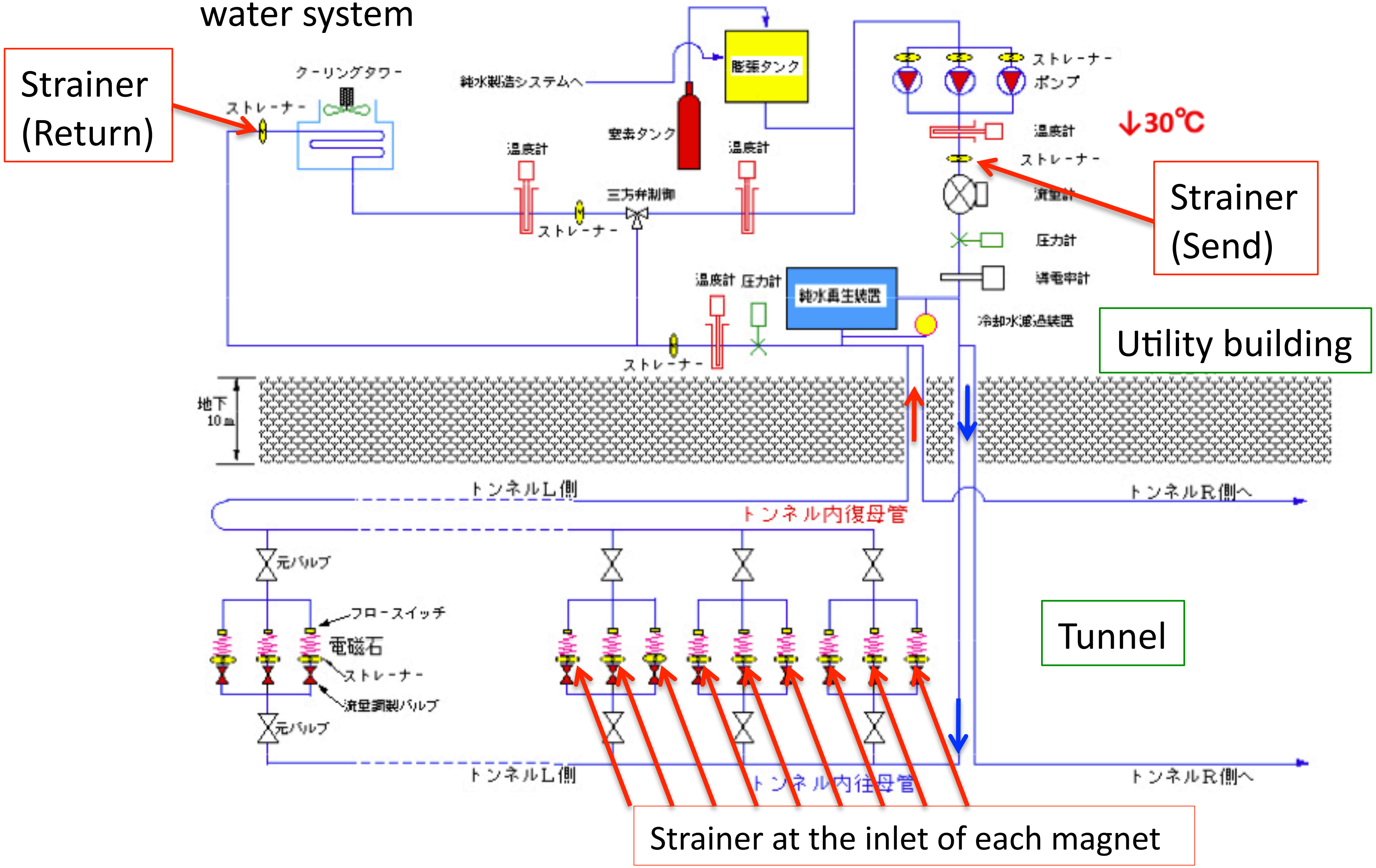
- A few wiggler magnet strainers got clogged and caused a water flow interlock while the wiggler PS was tested. We are currently investigating this problem. Hope it is not too serious…

FY2015

- Magnet installation in the north tunnel.
- 2nd round survey of the entire tunnel (2000 magnets and several hundreds of monuments) followed by final alignment of the magnets.
- Full-scale start-up and tuning of the power supplies.
- Cabling checks, including polarity.
- Completion of the database.
- Water flow check and balancing among 2000 magnets.
- …
- To make a long story short, we need to integrate all this and complete the main ring magnet system in time.
- "Traffic control" (scheduling of the work in the tunnel) is very important.
  - Alignment can not coexist with PS test, PS test can not coexist with water flow check, none can coexist with RF high power test (if in the same area)…,civil engineering can not coexist with survey/alignment…

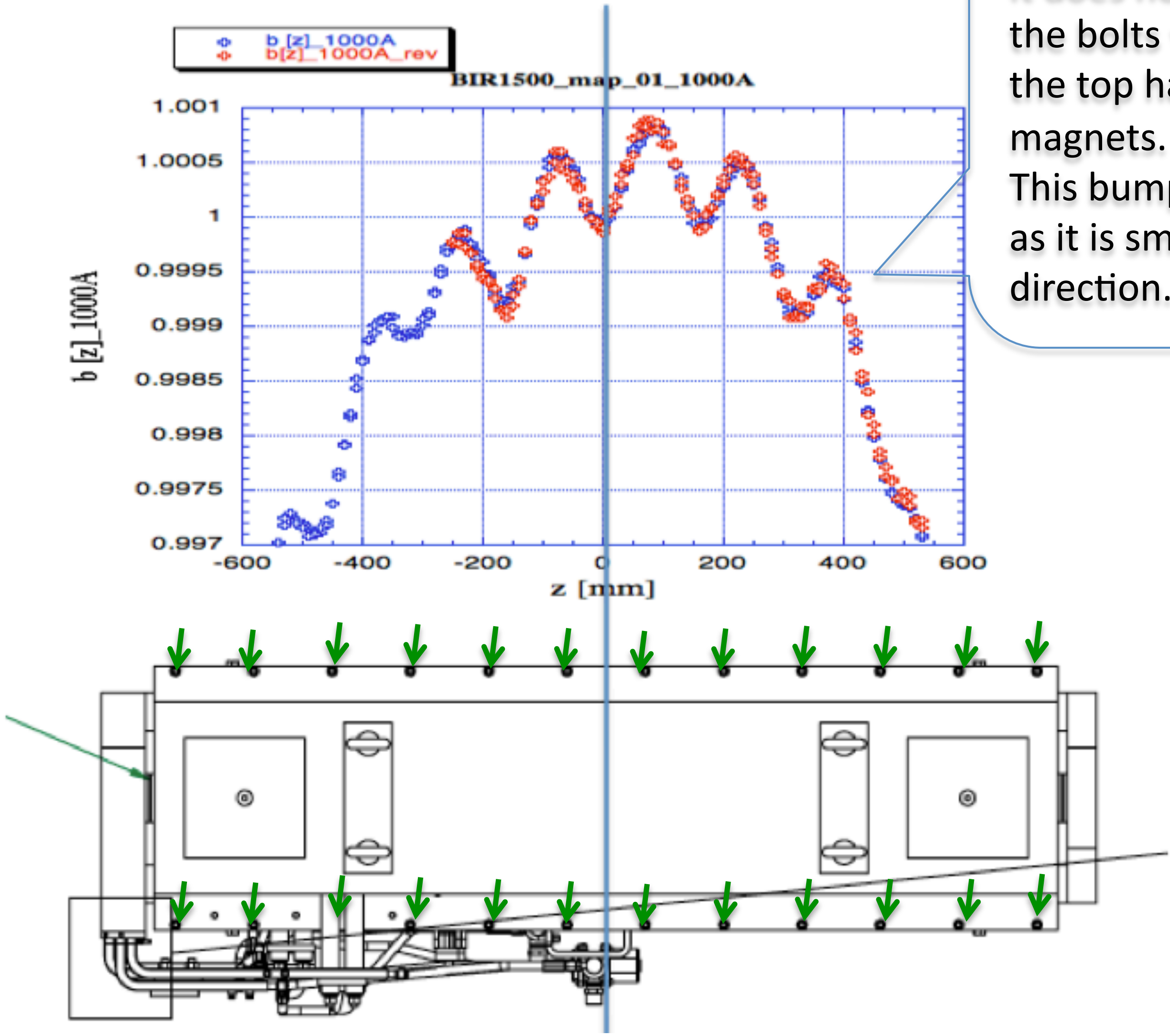
Spare

KEKB/SuperKEK cooling water system



Spare

It does not exactly match the span of the bolts which connects the top half and the bottom half of the magnets.
This bumpy structure is NOT a problem as it is small and in the Z-(beam) direction.



bolts

K.Egawa