Main Ring Magnet System Phase 2 & Phase 3

Magnet group
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- Introduction to the MR Magnet System
- Operation and work summary
  - Magnets
  - Power supplies (MR normal & QCS)
  - Survey and tunnel motion
- Summary

Introduction to the MR Magnet System

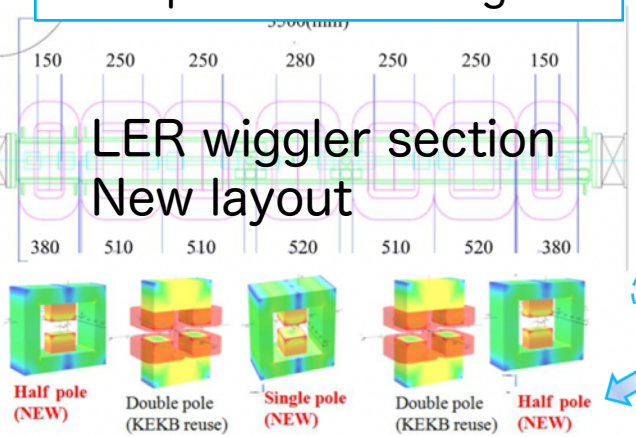
Ring	# of larger magnets Water-cooled/air cooled	Corrector magnets (air-cooled)
HER	740/6	~420
LER	986/12	~410

More than 1700 water-cooled magnets
More than 800 air-cooled corrector magnets

Integration of this large system went well, which contributed to a smooth start-up of the MR in Phase 1.

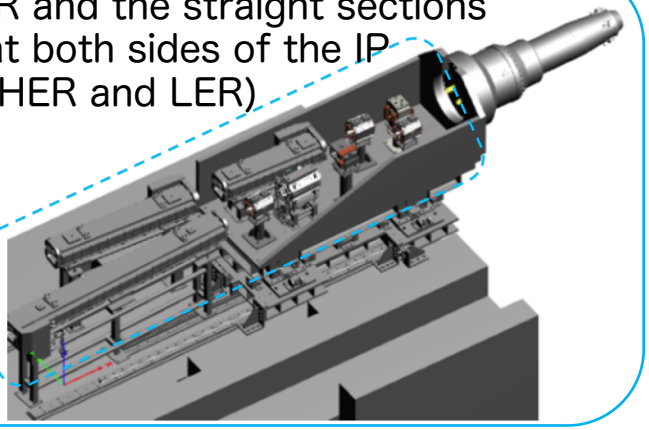
Breakdown
Recycled & Newly fabricated

Examples of new magnets



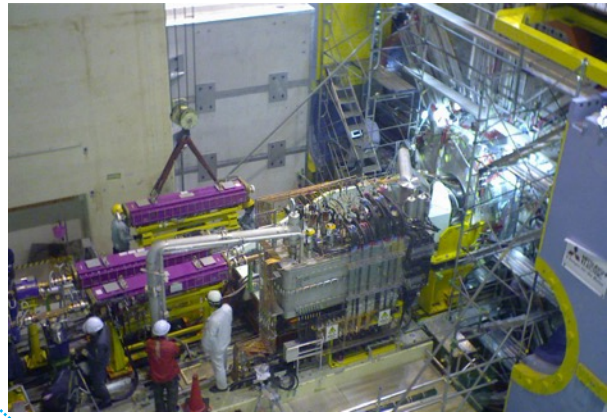
LER wiggler section
New layout

IR and the straight sections at both sides of the IP (HER and LER)



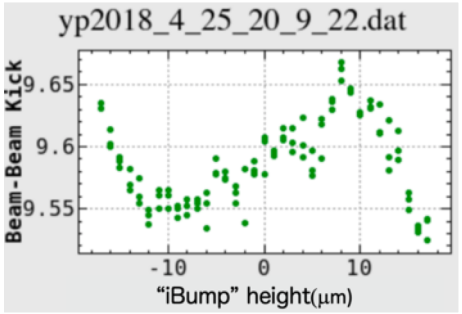
Magnets

Operation and work summary
Magnets



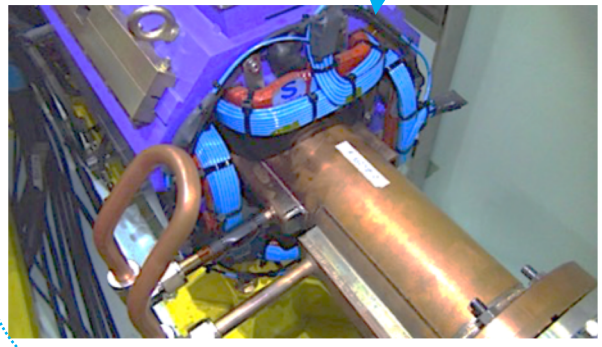
- IR construction (Phase 2) & Re-construction (Phase 3)

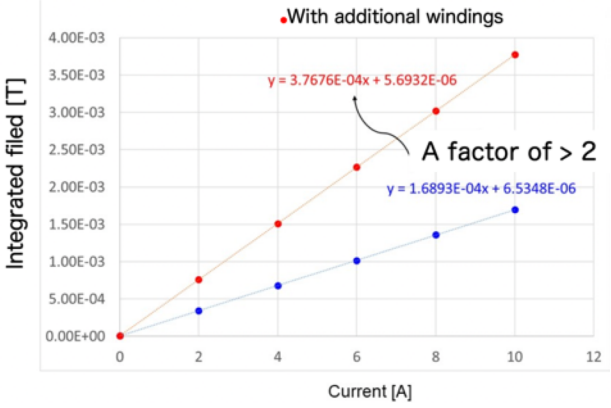
The 1st beam-beam deflection signal, obtained by shifting the electron beam (HER) by ~30 μm using a set of dipole corrector magnets in the HER.

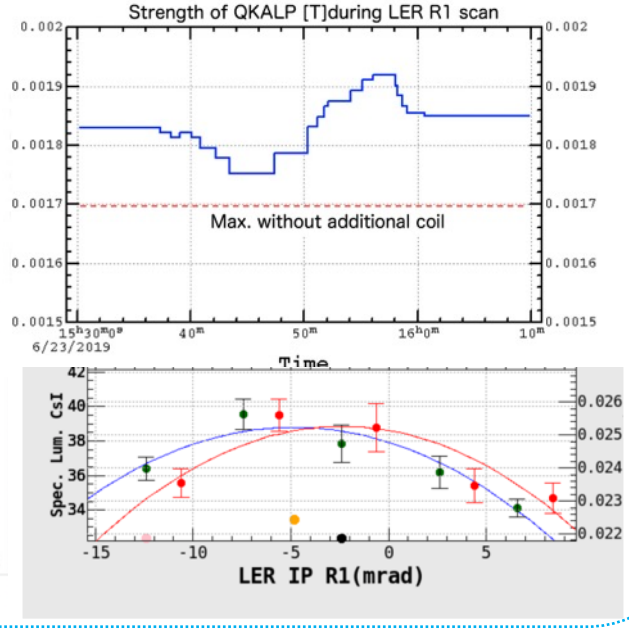


- From Phase 2 to Phase 3: IR skew quads

Skew quad strength increased from 0.0017 to 0.0038 [T] by adding more turns, for a larger knob tuning range (R. Ueki).



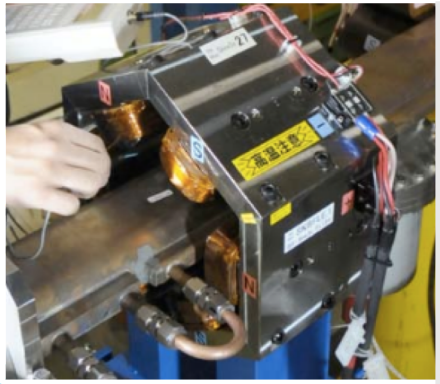


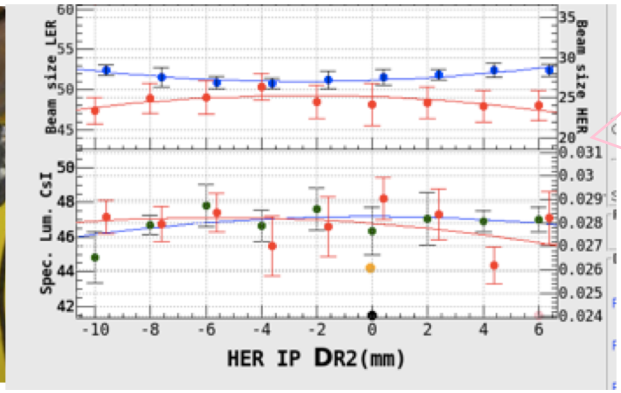


Operation and work summary
Magnets

- From Phase 2 to Phase 3: Skew sextupoles

The skew sextupole magnets used for KEKB luminosity tuning were hocked back up in HER.
This is done partially to determine the specifications for the SuperKEKB skew sextupoles



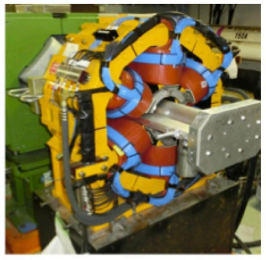


From Jun 22 swing shift report:
HER IP chromaticity scan
→Not sensitive, limited by hardware tolerances

- More study is probably needed to determine the specifications.
- We would also like to see the effects of the LER tilting sextupole magnets in Phase3-2.

- From Phase 2 to Phase 3:

# of skew quadrupole correctors in the arc sections was doubled by installing more power supplies the skew windings on the sextupole magnets.



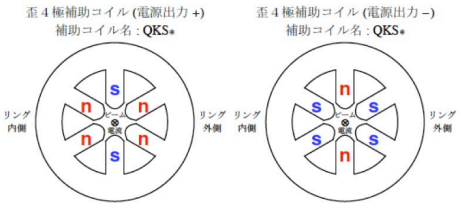
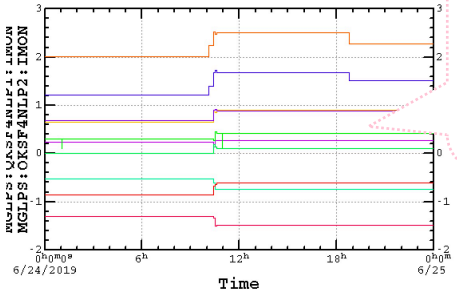


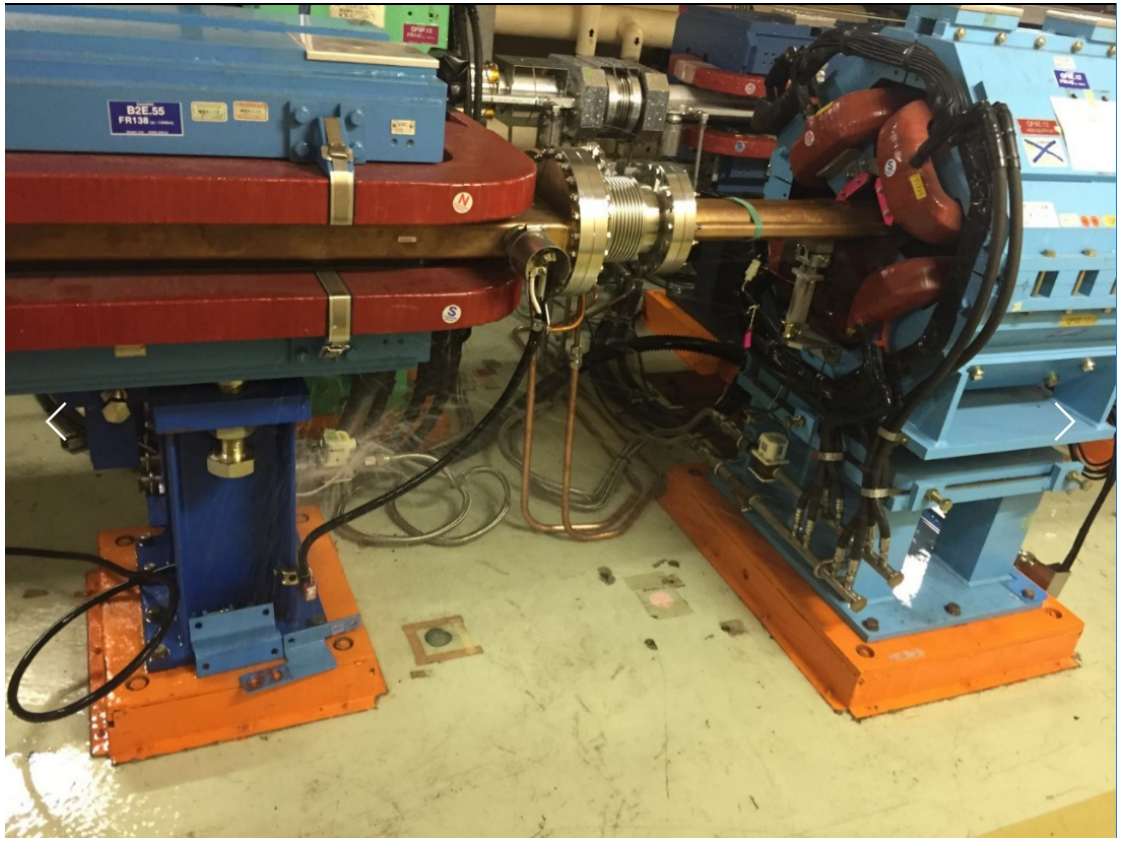
図 3.5. 歪４極補助コイルの極性．電源は両極性．



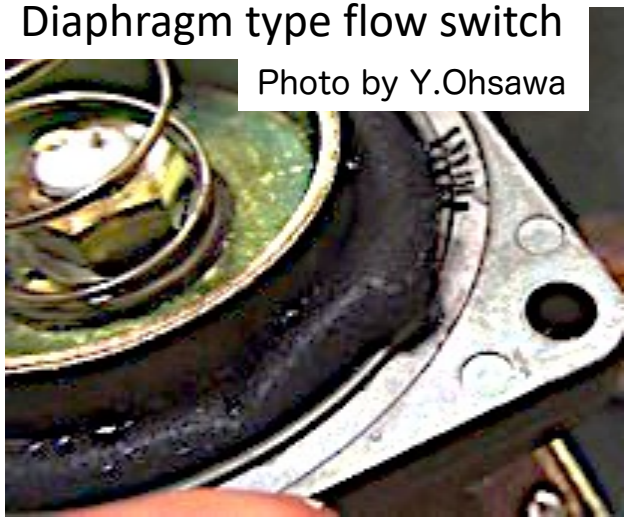
Example:
Skew quad coils on sextupoles used (LER optics correction)

Operation and work summary
Magnets

Troubles : Water leak from the flow switch of an HER dipole magnet
→ Interlock → Beam abort on April 15, 2018 (Phase 2)



Diaphragm type flow switch



Degraded over time (~20 years since KEKB startup) is the cause of this. All of the water-cooled magnets recycled from KEKB (more than 1000 !) face this aging issue

- We replaced all the flow switches of the HER dipoles in the fall of 2018, as a start.
- We will replace the flow switches of the HER quads in this summer.

Power Supplies

Operation and work summary
Power supplies

Main Ring power supplies

Output power	New	From KEKB (# overhauled)	Magnets
0.95 MW	2	0	Main dipoles
0.4-1 MW	9	0	Wigglers
0.1-0.5 MW	0	18#	Main quadrupoles
2-105 kW	92	335#	Bend./Quad./Sext.
0.3-2.4 kW	138	1681	Steering magnets/correction coils
Total	**359**	**2034**	2393 power supplies (as of June 2016)


Large class PS


Medium class PS


Small class PS

Operation and work summary
Power supplies

MR PS: # of Failures in Phase 1, 2 and 3 (by S. Nakamura)

Failures in Large class PS (BM / Wiggler)	# of event (P1→P2→P3)	comment
AC input over current	13 → 1 → 0	AC Line distortion
AC input Stop, CB Fault	6 → 0 → 0	Earthquake
Thermostat	1 → 2 → 0	High ambient temperature

Failures in Medium class PS (Quad. / Sext. / local Bend)	# of event (P1→P2→P3)	comment
IGBT module fault / Over current	6 → 1 → 0	Modules were replaced.
Cable GND fault	1 → 0 → 0	Cable fault.
AC over current	0 → 2 → 0	Most likely false alarm.
External I/L	3 → 1 → 6	Low magnet water flow.
Tracking error / Over voltage	3 → 0 → 2	Fault in the polarity inversion circuit(P1). Fault in the control board(P3).
Thermostat	7→ 13 → 1	High ambient temperature & Failure in the thermostat.

Magnet cooling water flow switch level set too high (human error) Workers not well trained…we will be careful next time.

Failures in small class PS	# of event (P1→P2→P3)	comment
DC-DC board failure Output over voltage etc.	10 → 2 → 0	Power supplies themselves were replaced.

Operation and work summary
Power supplies

MR PS: # of Failures in Phase 1, 2 and 3 (by S. Nakamura)

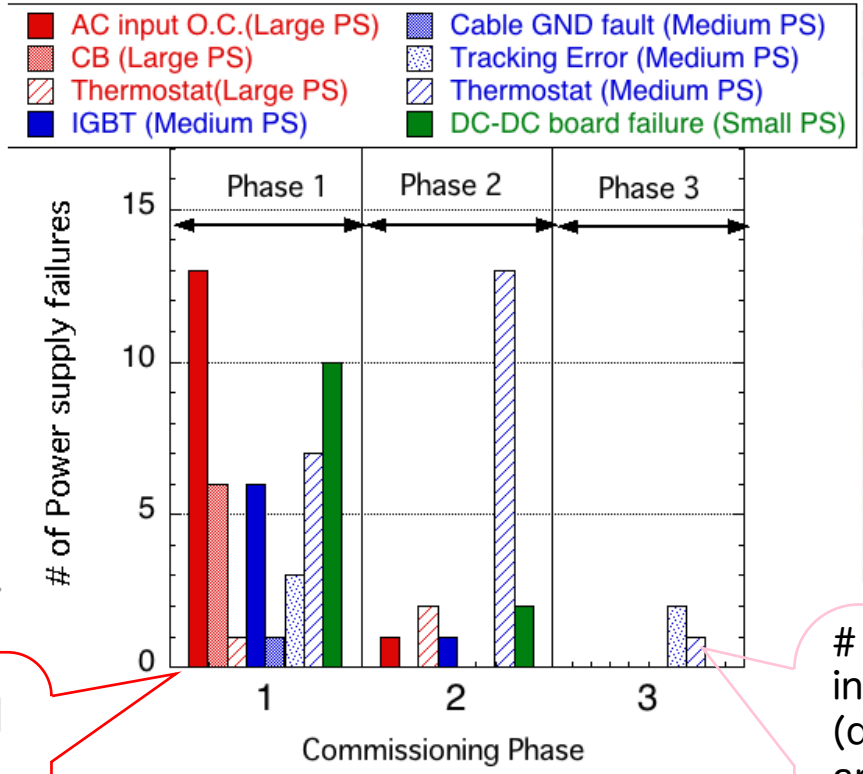
BM, Wiggler Power supplies

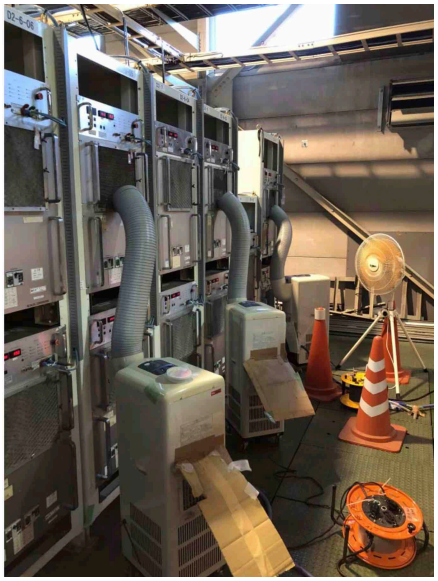
PS stop due to AC line distortion

Additional AC inductance

B2E@D2
B2P@D8
} installed before phase 2.

Wigglers@D11 … installed between phase 2 and 3.
Wigglers@D5 … will be installed after 2020.





No more “AC input O.C. ” ■ due to AC line distortion after we installed additional inductance

# of thermostat interlocks ▨ (due to overheating) are reduced after increasing the # of outside air intake fans to the utility buildings and spot coolers etc.

Operation and work summary
Power supplies

No more PS failure from “AC input O.C. ” caused by AC line distortion.

BM, Wiggler Power supplies

PS stop due to AC line distortion

Additional AC inductance

B2E@D2
B2P@D8
} installed before phase 2.

Wigglers@D11 … installed between phase 2 and 3.
Wigglers@D5 … will be installed after 2020.

B2E電源ACリアクトル追加作業

Adding reactance to the circuit

↓

The current surge due to a voltage drop becomes smaller.

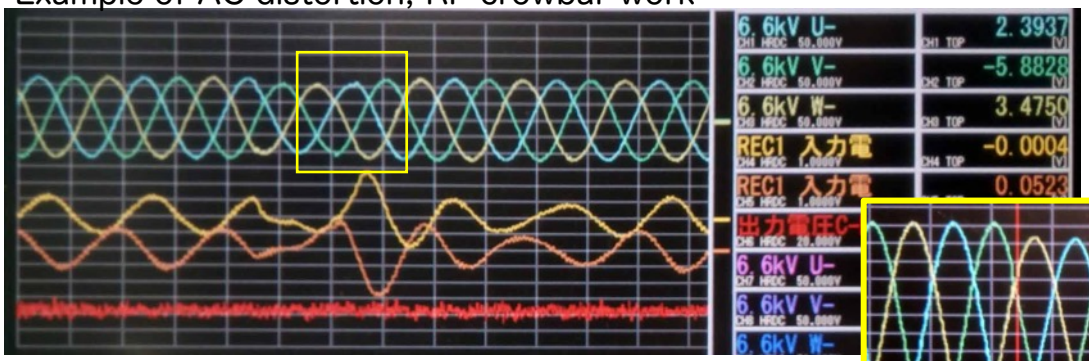
↓

PS failure from O.C. (over current) does not happen.

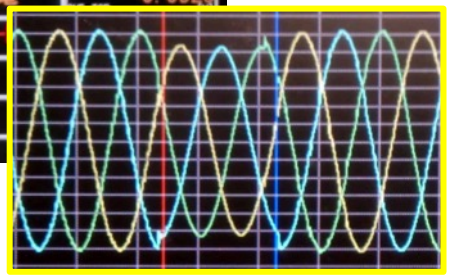
↓

Stable operation

Example of AC distortion, RF crowbar work

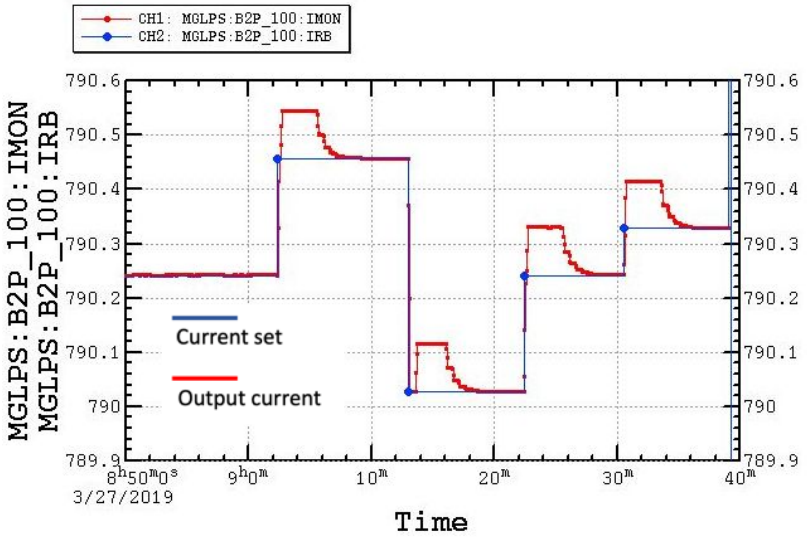


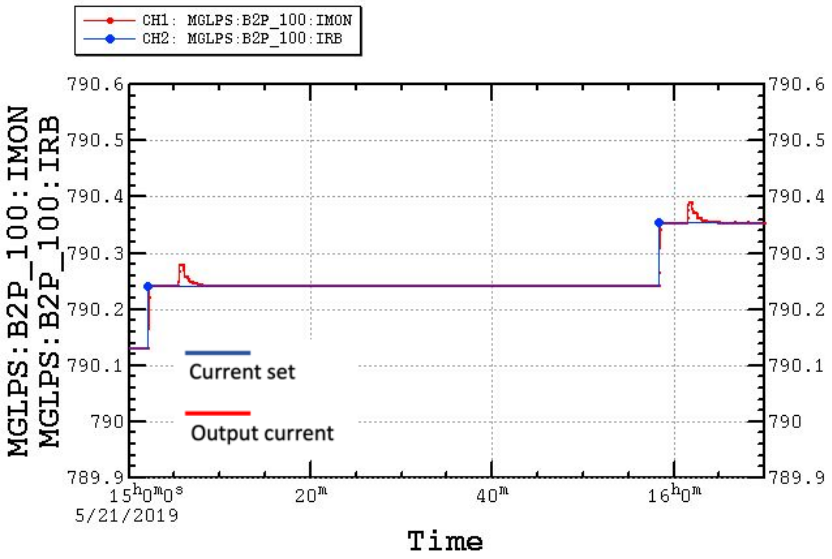
13% drop



Operation and work summary
Power supplies

Overshoot problem with Large Scale power supplies (Hitachi) and QCS power supplies (Nichikon)





Digital feedback program is modified.
(LER Dipole power supply case is shown as an example)
Still some overshoot is seen in the Hitachi power supplies.
The new program is being tested now.

There is no overshoot problem any more with the QCS power supplies (Nichikon).

QCS Power supplies

Operation and work summary
Power supplies

QCS power supplies

Magnet	Rated Output	# of PS's
Main Quads	2000A, 15V	8
Correctors	±70A, ±10V	43 + 2 (Spare)
ESL (Compensation solenoid)	410A, 30V	1
ESR1 (Compensation solenoid)	455A, 45V	1
ESR23 (Compensation solenoid)	155A,15V	1

Main quadrupole magnet:
Stability : 2 ppm/8 hours

Ripple: 1 ppm

Correction coils:
Stability : 5 ppm/8 hours with low cost

From T. Oki (KEKB Review 2018)

More work still needed to realize this stability

Operation and work summary
Power supplies

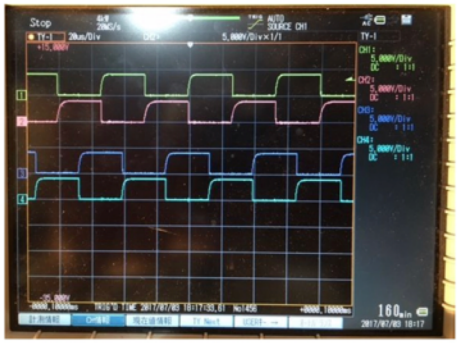
QCS power supplies

Down due to	# of event (P2→P3)	comment
Quench	27 → 3	e- or e+ beam hit the SC-coils.
Switching module fault	1 → 3	False alarm from the module, or false gate signal.
Over voltage	2 → 0	Due to a failure in the control board.

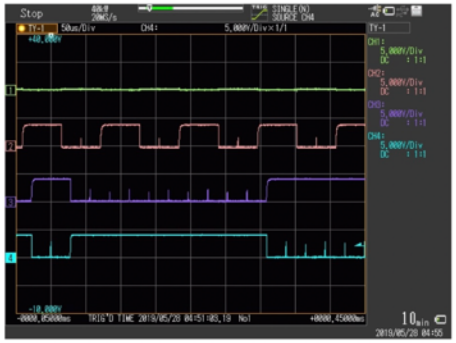
QC2LE PS

Gate pulse

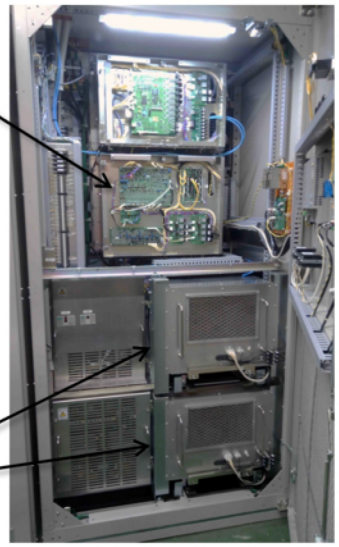
Good



Not Good



Control board
(making gate pulses)



Power modules
(SW modules are installed)

- We replaced these modules, but that did not cure the "gate signal going nuts suddenly" disease. The control board sent back to Nichikon has not shown any problems so far. Investigation continues.

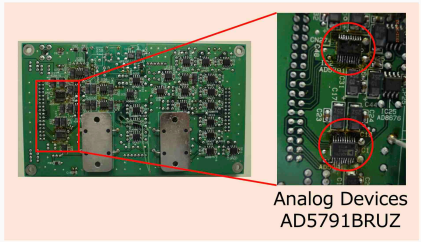
Trigger signal can be issued within (10 + a few) μs

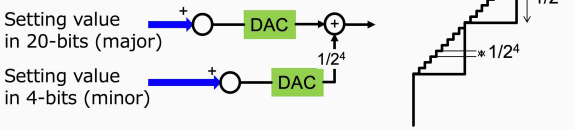
- For the fall run, we will prepare a fast abort signal (10 + a few μs and transmission time from the IP to the abort kicker) for the case where the QCS power supply self-diagnoses a problem.

QCS power supplies (in response to the 22nd KEKB Review)

R19.1: A significant test should be made on the monotonicity of the digital feedback path with the two 20-bit DACs, extending over the change-over between the 2 DAC systems (i.e with more than 16 counts, and including studies over a significant dynamic range of the output).

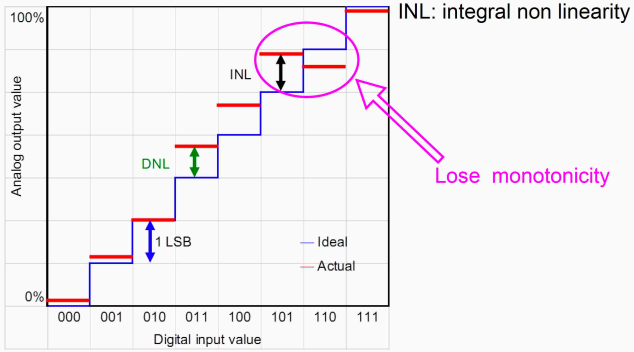
R&D item 1: Developed 24-bit board



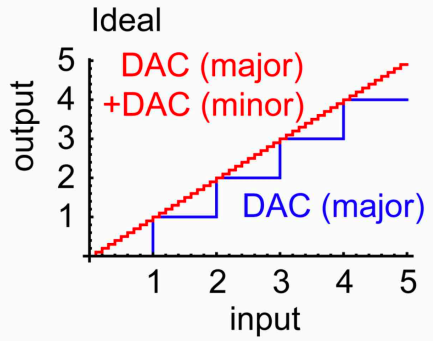


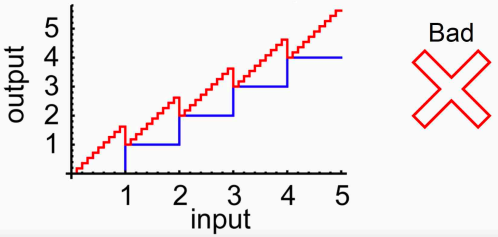
Non linearity and monotonicity

LSB: least significant bit
DNL: differential non linearity
INL: integral non linearity

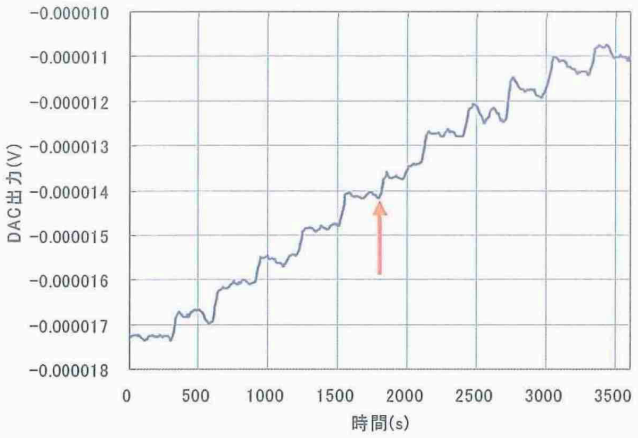


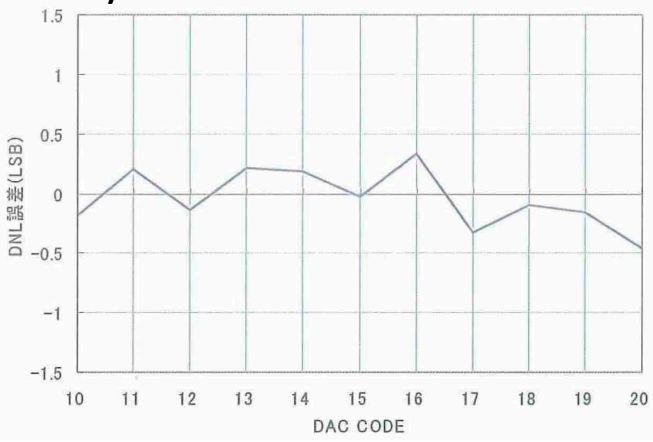
AD7846K (16-bit): DNL ±0.5 LSB max
INL ±2 LSB
AD5791B (20-bit): DNL ±0.75 LSB typ. (test result: <±0.1 LSB)
INL ±0.5 LSB typ. (test result: -0.2～+0.6 LSB)





Test carried out on the monotonicity with the actual PS





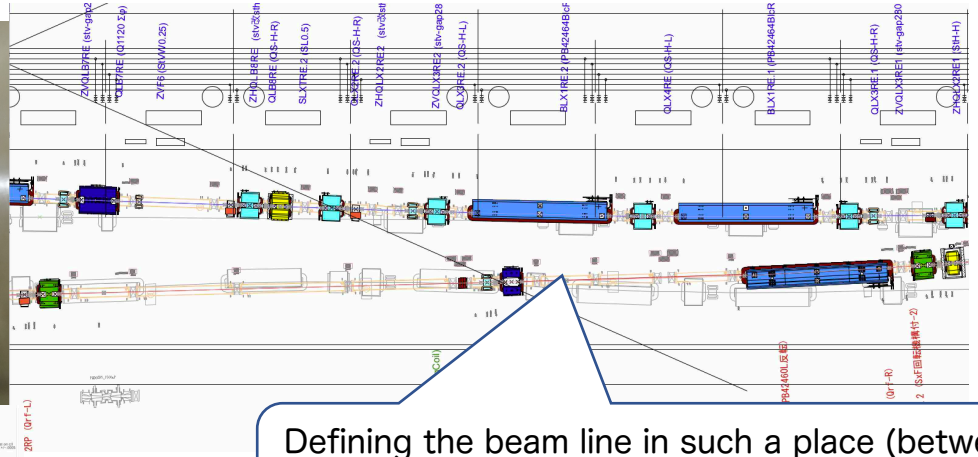
Monotonicity confirmed

Survey and tunnel motion

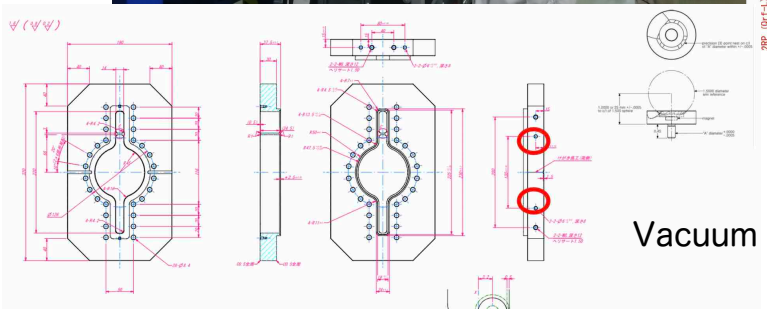
Operation and work summary
Survey & tunnel motion

Requested to survey and help re-aligning the collimators by the vacuum group after Phase 2.

We did a survey using a laser tracker and found out that
- D2V1 collimator was off by a few millimeters.
- D1V1 collimator was off by about 1mm.



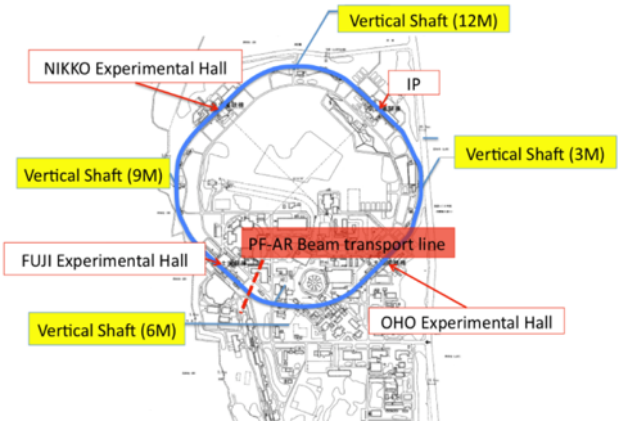
Defining the beam line in such a place (between a dipole and quadrupole) is not really possible without a laser tracker.

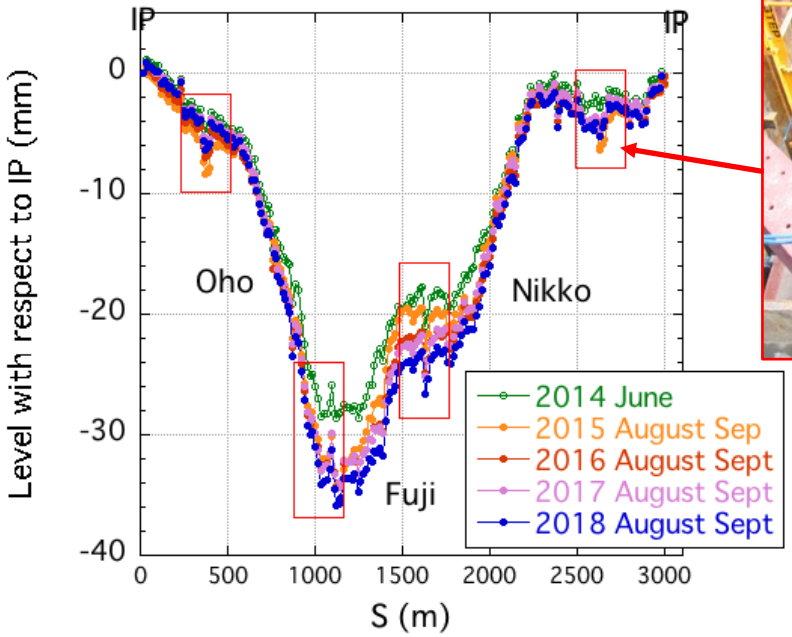


Vacuum group will prepare holes for holding a LT target.

Photo by S. Terui

Operation and work summary
Survey & tunnel motion

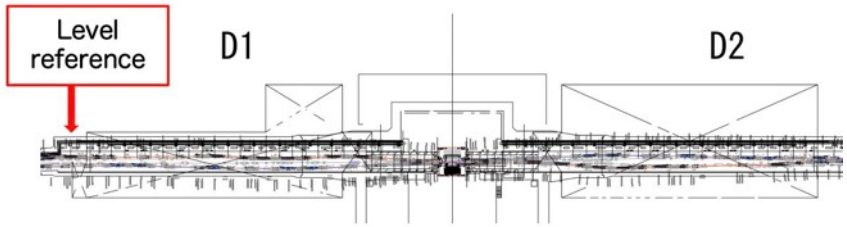


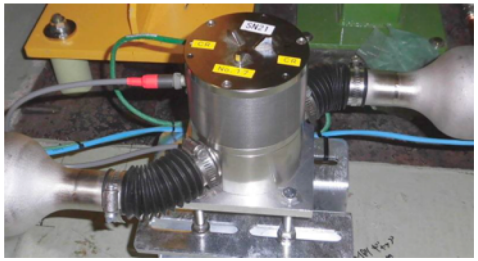


- Effects of the construction of the new facility buildings are still seen by tunnel level survey.
- Average rate of sinking is ~ 1.9 mm/year.

Photo by Y.Ohsawa

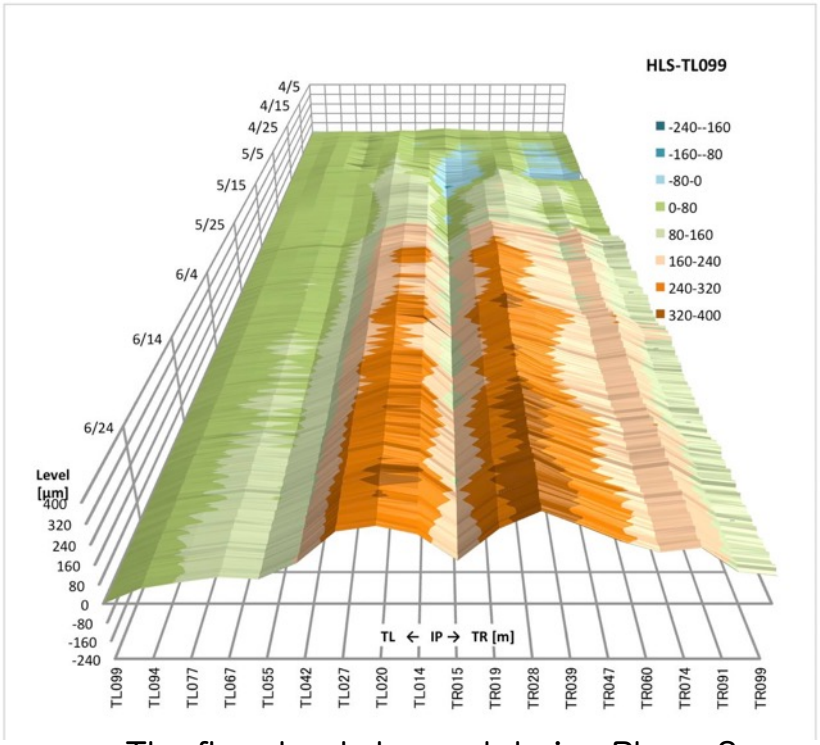
Operation and work summary
Survey & tunnel motion



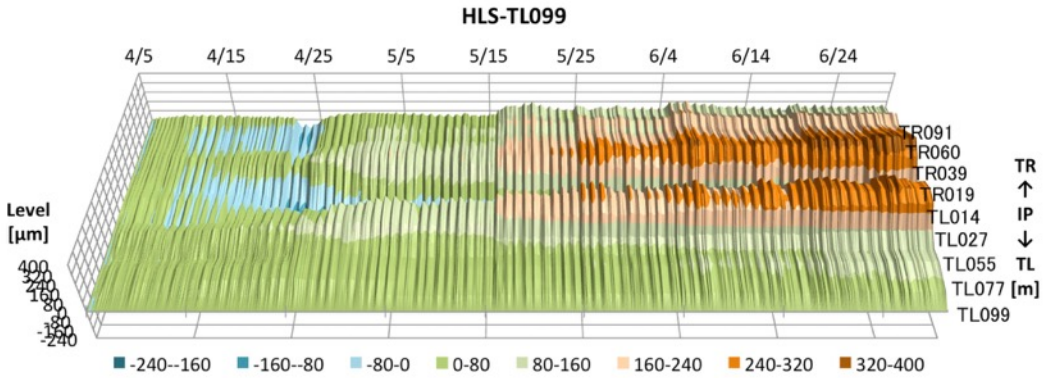


HLS sensor by BINP
(**H**ydrostatic water **L**eveling **S**ystem)

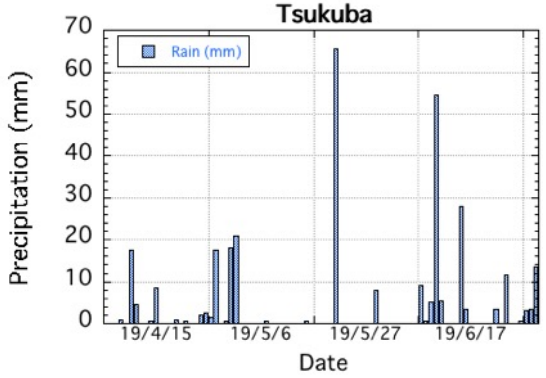
There are 18 HLS sensors at the Tsukuba straight section.



The floor level changed during Phase 3.
IP has become a local minimum.

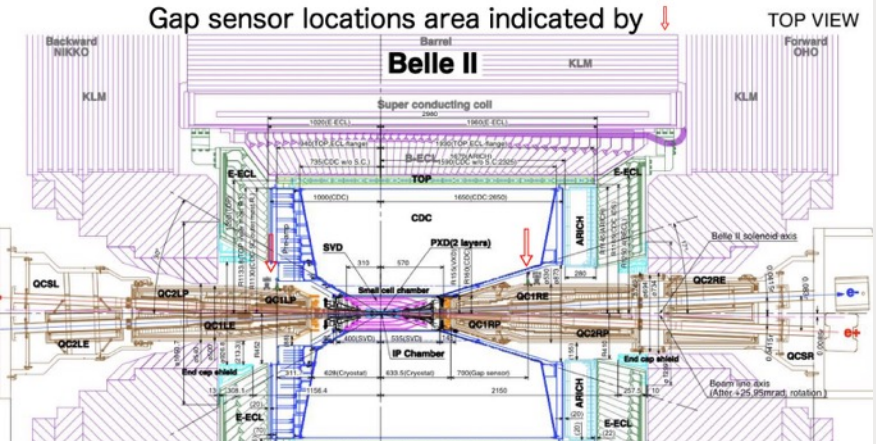


Some seasonal effects are seen.
We suspect that the level change has something to do with the ground water (rain, pumping for rice planting…).

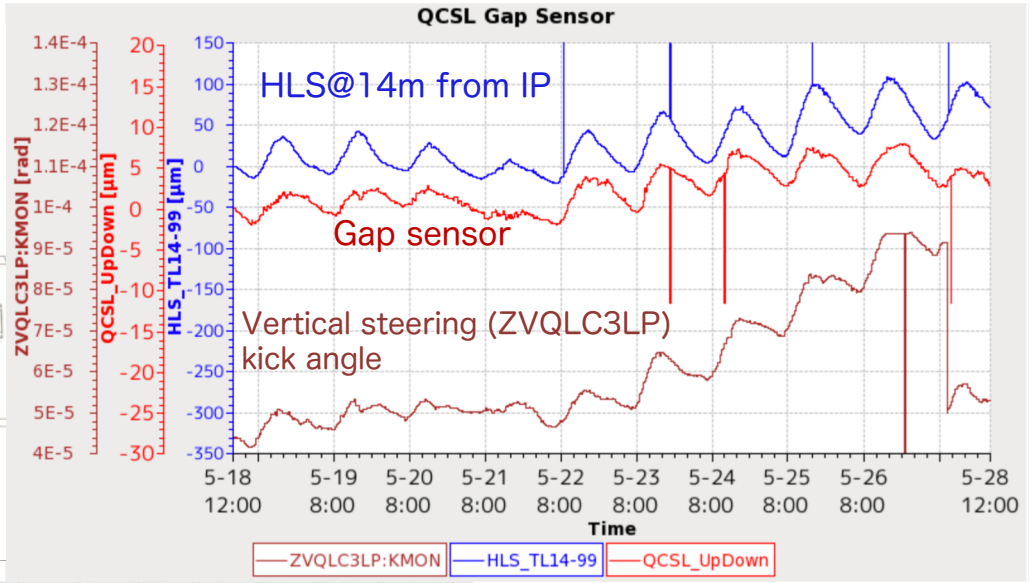


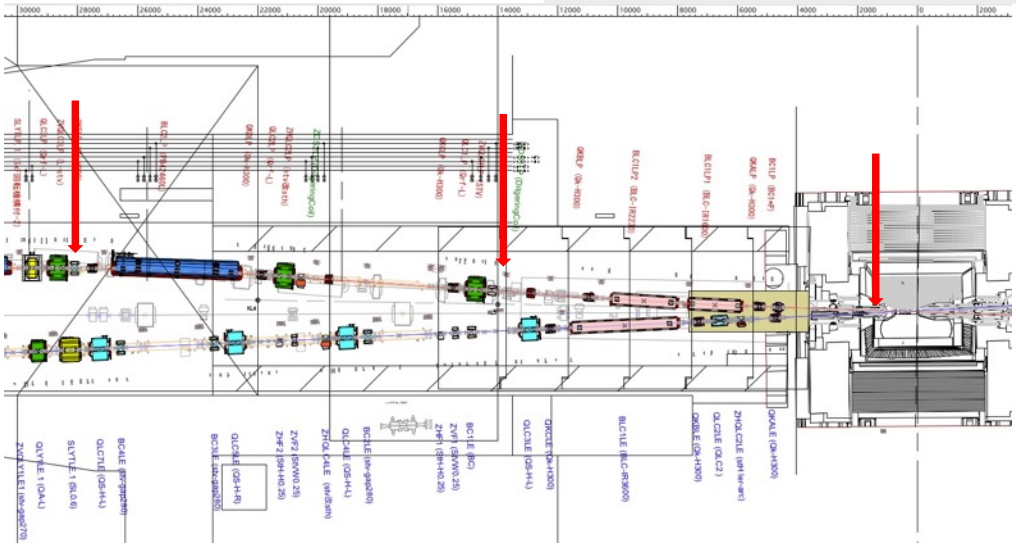
by T. Kawamoto

Operation and work summary
Survey & tunnel motion



Gap sensors measure the distance between QCS cryostat and CDC



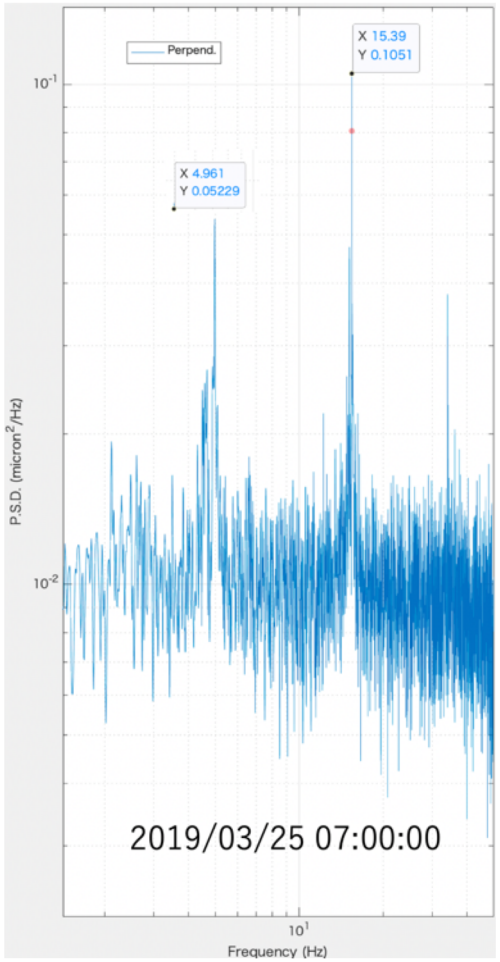


by T. Kawamoto

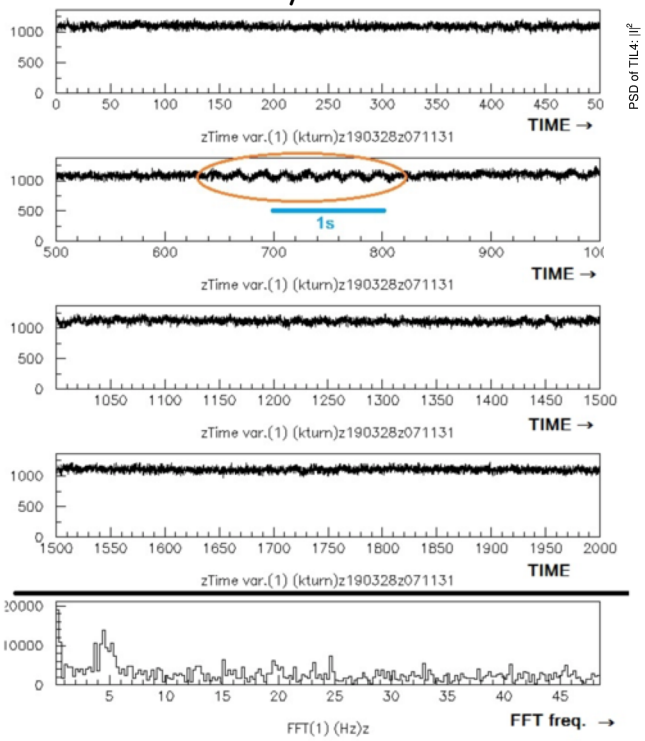
Operation and work summary
Survey & tunnel motion

Luminosity variation and floor/cryostat vibration are seen and they are sometimes correlated.

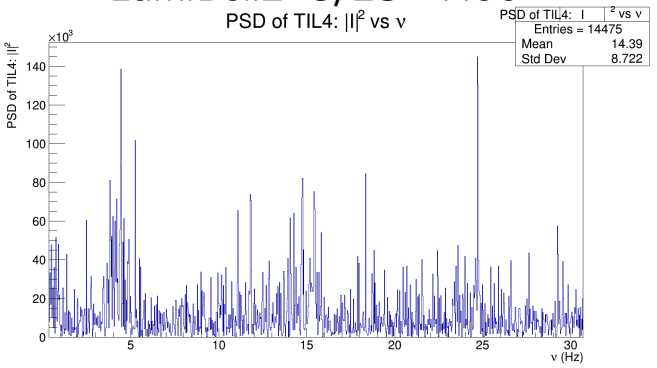
Gap sensor (R-side)



ZDLM 3/28 7:11



LumiBell2 3/28 ~7:00



~5Hz vibration, as an example.

There are also vibration at ~1.7 Hz and 15 Hz and...

Luminosity : S. Uehara(ZDLM), S. Di Carlo, et al. (LAL)
Floor motion : L. Brunetti and G. Balik (LAAP), under the framework of FJPPL & KEK

MR Magnet System Summary

- The IR construction went well, which lead to a smooth 1st collision in Phase 2.
- The IR re-construction for Phase 3 also went well, with good reproducibility of the IR orbit.
- Additional coils in the IR skew quads made it possible to scan a wider range in the IR coupling knob scans.
- A water leak from a ~20-year-old flow switch led us to start replacing the flow switches used in the KEKB magnets.
  - This could be a very costly operation so we will do it over time.
  - Flow switch is just one of the magnet subsidiary components.
  - What about rubber hoses? Will they last for the next ~10 years? Everybody ages.

- The # of power supply failures decreased from Phase 1 to Phase 3.
- Investigation of the QCS (QC2LE) power supply failure due to distorted gate signals is on-going. This is one of our highest priority items for the summer shutdown.
- Adding a fast abort signal from the QCS power supplies looks feasible, and we will try to implement a fast abort signal from the QCS PS for the fall run.

- The south arc of the MR continues to sink, at an average rate of 1.9 mm/year.
- A correlation is seen between the HLS, the cryostat motion and the steering currents.
- Some correlation is seen between the fast luminosity signal and vibration data. We will keep looking into the vibration issues.