Main Ring Magnet system

Mika Masuzawa

Magnets:
Magnet design &
Field measurements
Installation
Survey & alignment

Power supply design
Testing
Tuning
Installation
Cabling
Check

T. Oki's talk

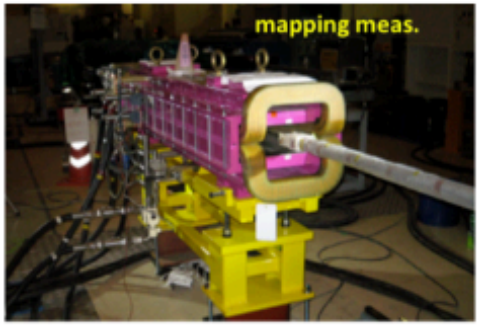
Contents

1. Introduction of the MR magnet upgrade
2. Things needed to be done for the MR start-up
   - Magnet installation
   - Survey & Alignment
   - Magnetic field measurements
3. For Phase II
4. Summary

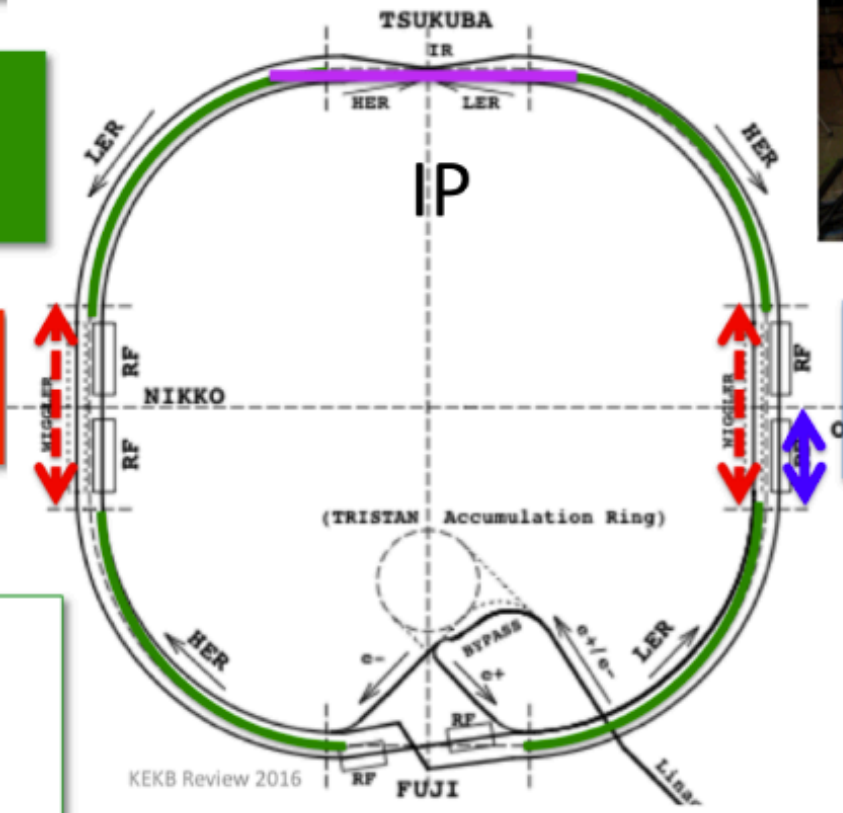
1. Introduction of the MR magnet upgrade

SuperKEKB Upgrade

Completely new beam lines around the IP “Tsukuba straight section”



New longer dipole magnets in the LER (~100)



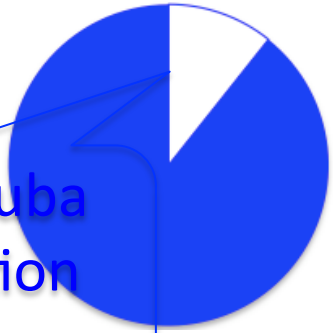
New: added 280 wigglers to the LER

36 wigglers added the HER.

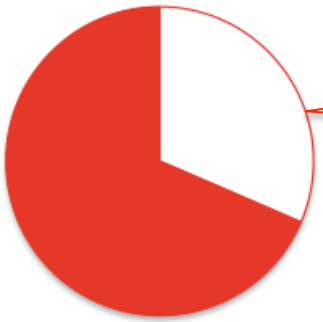
New vertical steering magnets (~220)。 Modification of horizontal steering magnets (~300)

Parameters of the newly fabricated MR main water-cooled magnets

Ring	Magnet (main locations)	g/2 (mm)	Leff (m)	Max. B, B', B'' (T),(T/m),(T/m^2)	I(A) × # turns/pole	# of magnets (Phase I)
HER	B (LC section)	55	3.96	0.3	1325×10	11
	B (IR)	55	3.60/2.23	0.112	500×10	1/1
	Q (LC sections, etc.)	50	1.12/0.57	18.0	700×26	2/33
	Q (Arc sections)	50	0.82	12.8	500×26	8
	Q (IR)	55	0.53	2.0	500×6	2
	Sx (LC sections)	56	0.608/0.509/0.335	472/465/447	600×22	4/4/2
LER	B (Arc sections, etc.)	55	4.19	0.19	840×10	114
	B (LC sections)	55	3.96	0.3	1325×10	5
	B (IR)	55	2.2/1.6	0.223	1000×10	2/1
	Wiggler	55	0.34/0.22	1.18/0.76	1400×36	56/112
	Q (LC sections, etc.)	83	0.58	6.3	500(600) ×35	12



Mainly Tsukuba straight section magnets



Arc dipoles, wigglers

+ ~250 steering magnets

2. Things needed to be done for the MR start-up

Things needed to be done for the MR start-up

Magnet installation

- In the north tunnel.

Survey and alignment

- 2nd round survey of the entire tunnel followed by final alignment of the magnets.

Magnetic field measurements (to evaluate the magnetic coupling between adjacent magnets)

Cooling water

- Water flow check and balancing among 2000 magnets

Power supply system (T. Oki's presentation)

- Full-scale start-up and tuning of the power supplies.
- Cabling checks, including polarity.

Completion of the database

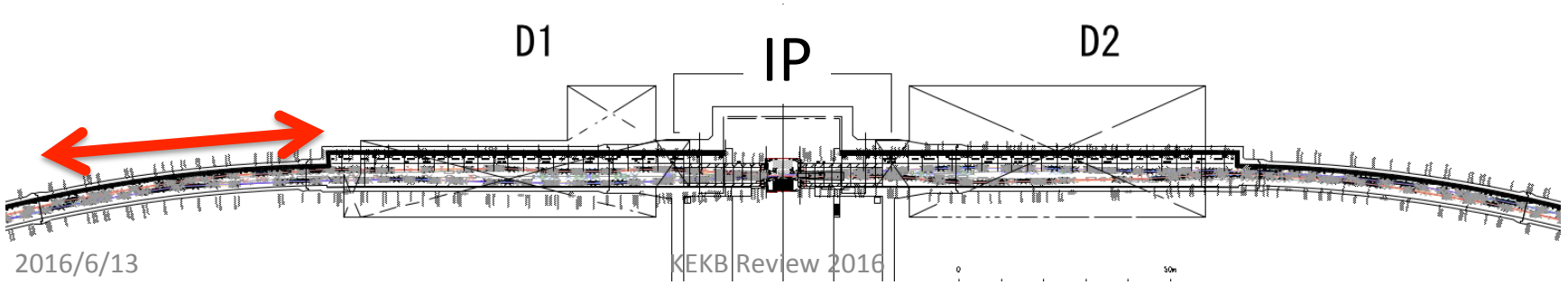
➔ Integration of all this in time was needed.

Magnet installation

NORTH TUNNEL
DITHER COILS (PHASE II)

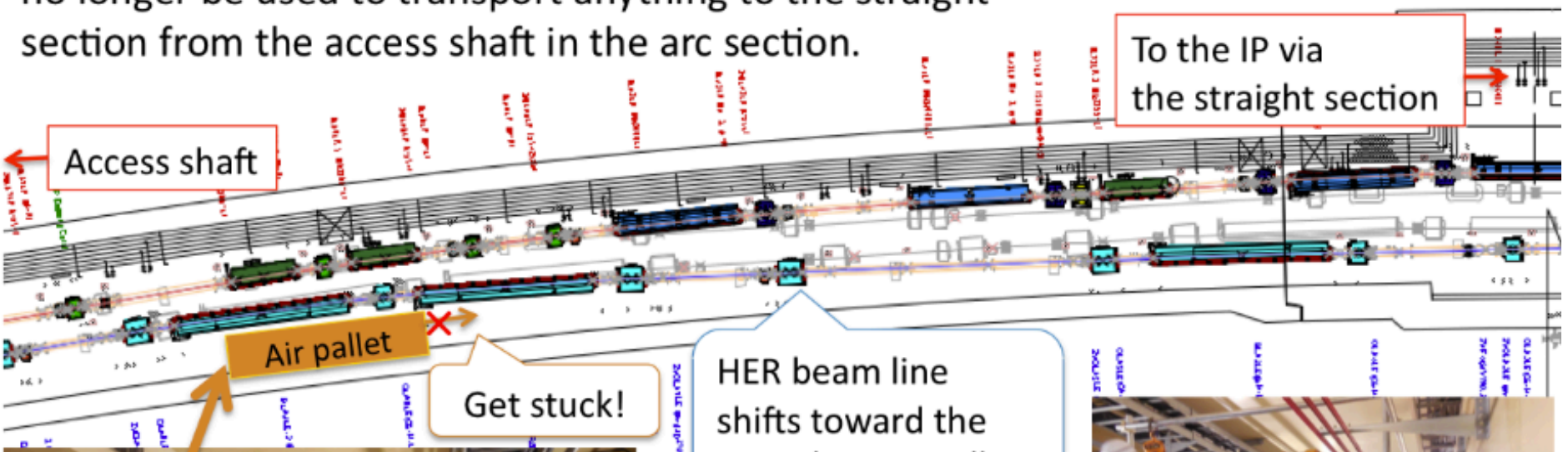
Magnet installation in the north tunnel

We needed to wait until the vacuum chambers were ready to be installed.



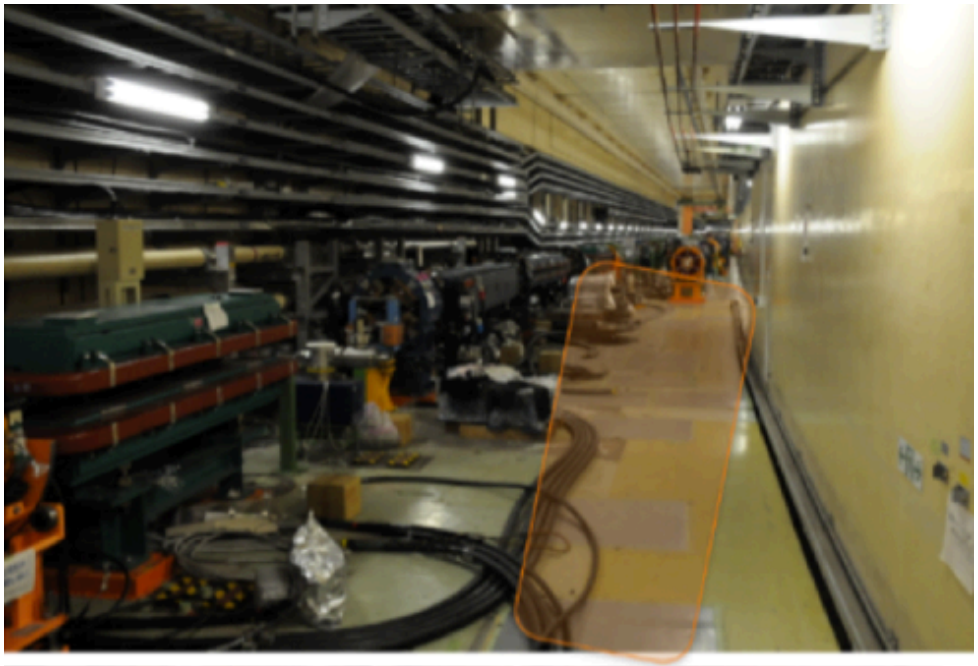
North tunnel

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.



Vacuum chamber installation

Magnet installation
with a chain-block
on a support frame.



North tunnel
Magnet installation completed
In May 2015.

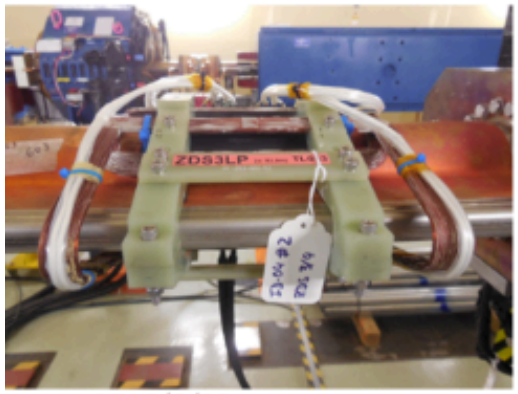
Replacement of a vacuum pipe in a quadrupole magnet would be a nightmare.
Because the air pallet can not go beyond this point and
We need to build a support frame from which to suspend the chain-block to open the quads.

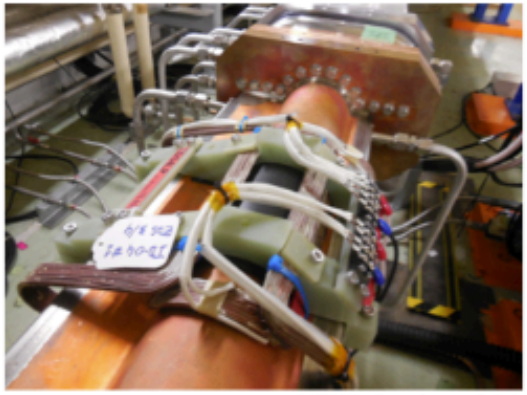
Installation of the dither coils

The dithering coils were designed, fabricated, and field measured by SLAC, and shipped to KEK in April, 2015

Installation

Installation and checks completed in June, 2015. Many many thanks to Uli and the SLAC team.





Power supplies, cabling done.

System not completed.

Survey and alignment

Survey Results,
Strategy for the final alignment
Tunnel motion monitoring

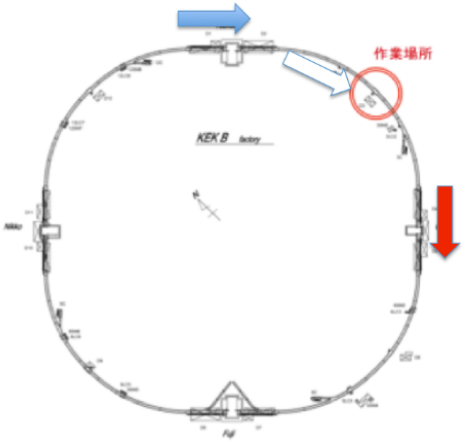
2nd round survey campaign

June and July 2015

Survey was carried out by 3 teams.
Calibration of the laser trackers was done carefully.

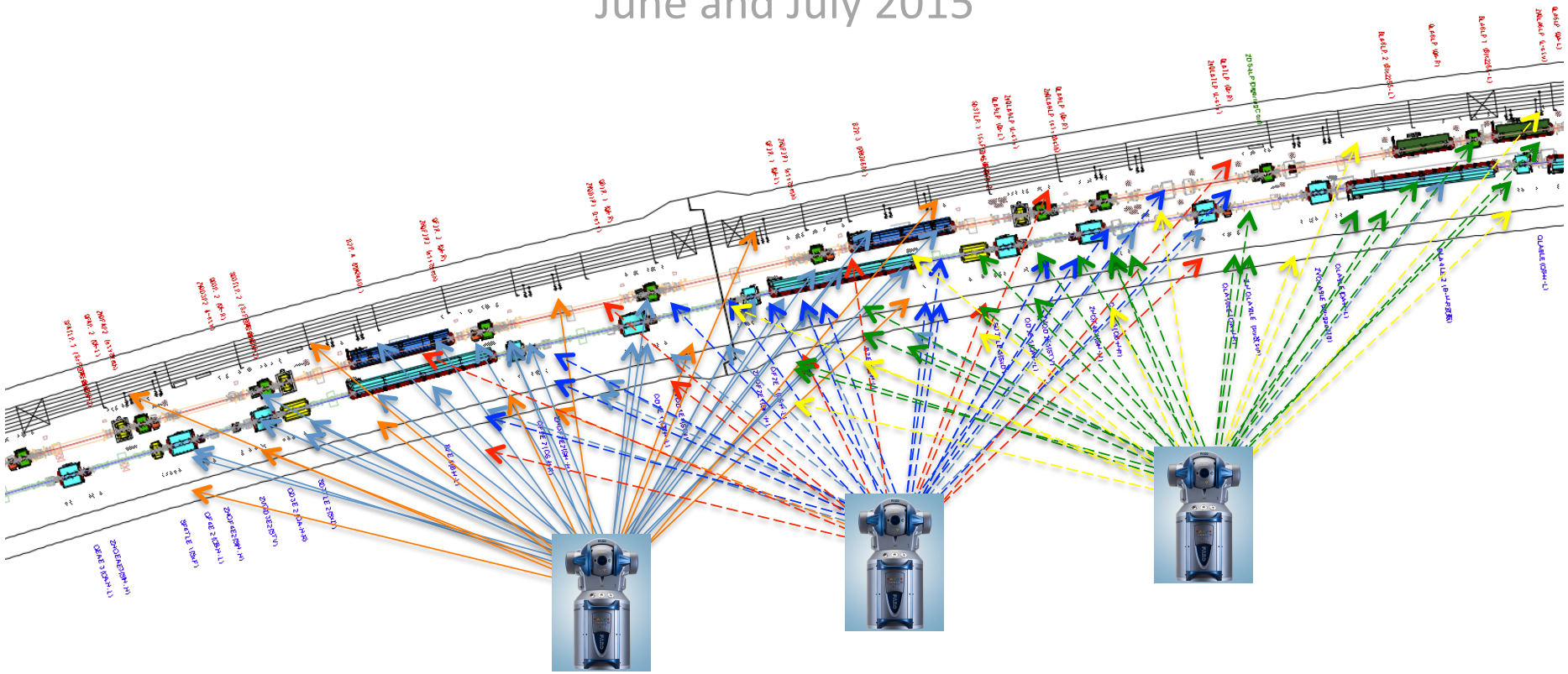
Special attention was paid to systematic errors, as even very small systematic errors can result in a large error at the end over hundreds of measurement sets.

(long) distance being compared with TS30



2nd round survey campaign

June and July 2015



Constraints on the working area/time

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…

More than 1200 network control points in the tunnel

More than 4000 reference points for the magnets

More than 5000 points to be surveyed and analyzed.

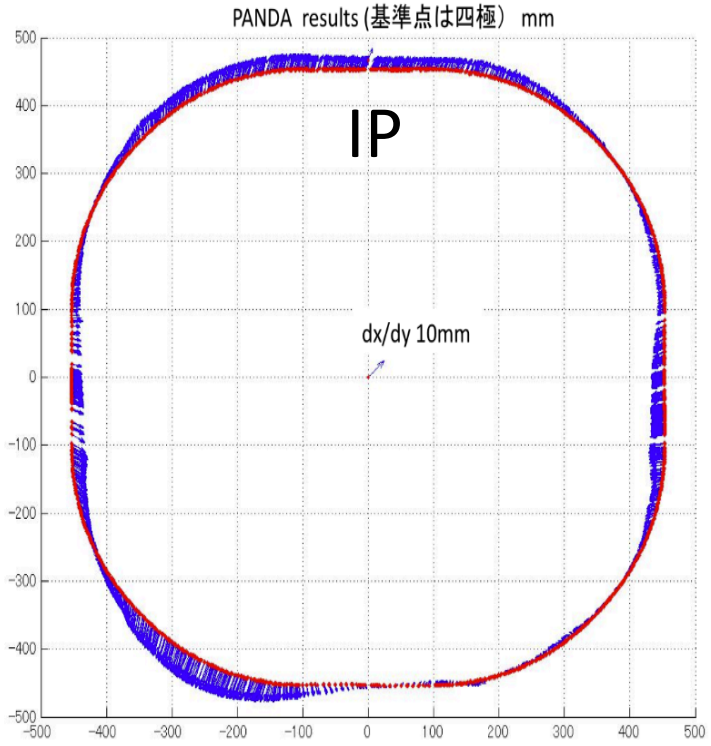
More than 400 LT settings, with overlaps

Survey Results

IN THE HORIZONTAL PLANE (X,Y)

We got hundreds of data points every day from 3 teams,
which were analyzed and cross-checked by T. Adachi, T. Kawamoto & M.Masuzawa independently everyday. If we found something funny, we requested the survey team to go back before they moved a long distance down the tunnel.

Survey Data and analysis results



The north and west parts expands to the outside as large as 10 mm. This probably happened when the TRISTAN monuments were first built.

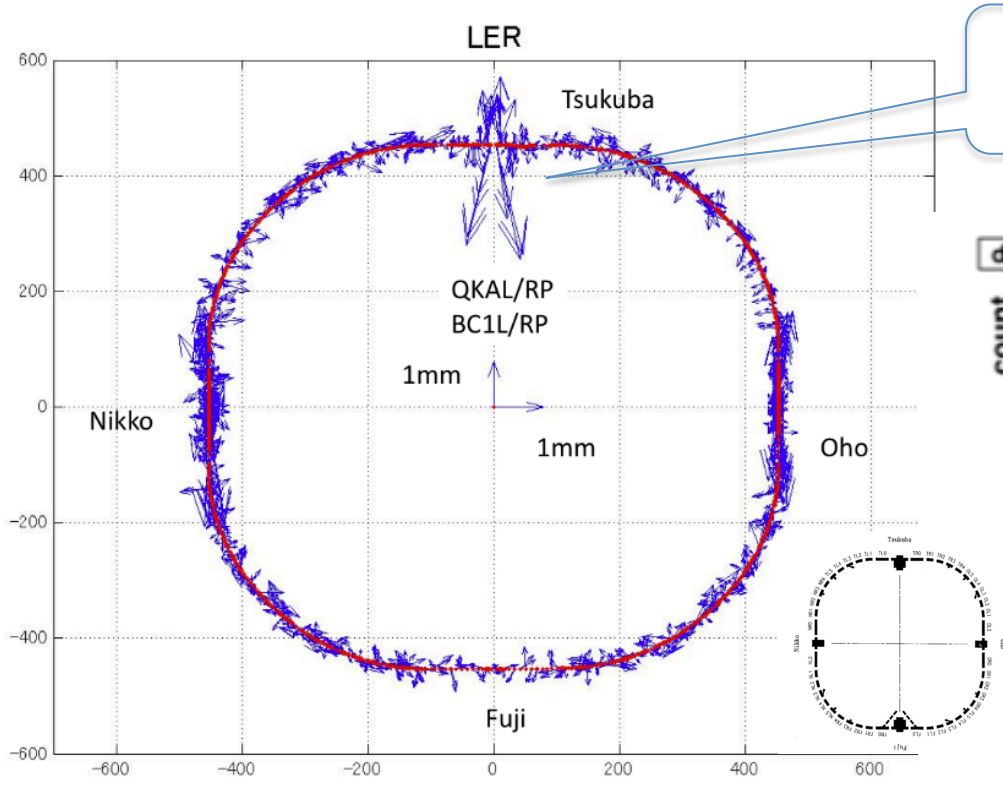
Does this matter?
➔No. Deformation of low order does not matter.

Constraints:
The rings have to close.
➔Smooth periodic curves will do.

Our choice was Fourier series (n=60). We tried FS with n=30 but the # of magnets to be adjusted increased, the amount of the adjustment became larger…
(of course we can do it but it would have affected other accelerator components such as vacuum chamber and rf…)

Survey Data and analysis results

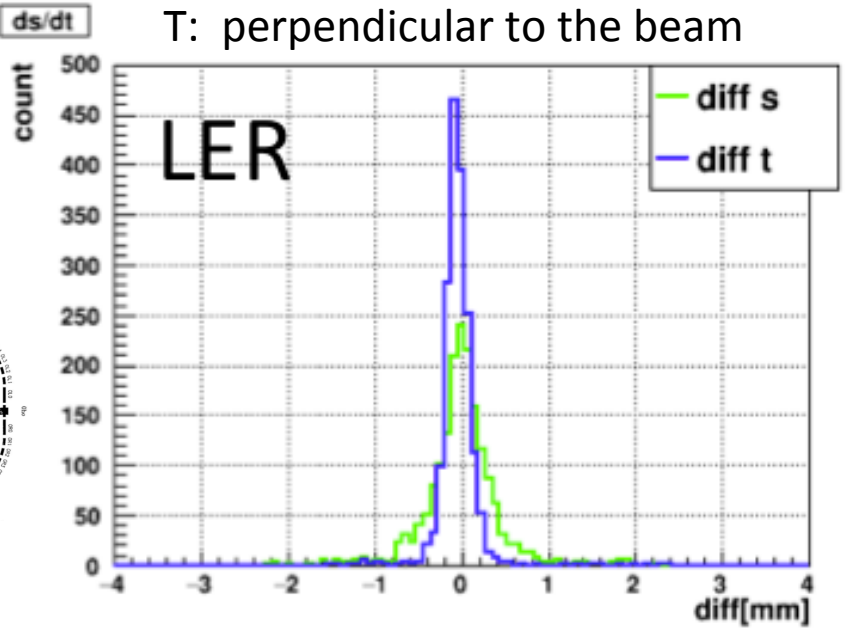
Deviation from smooth curves (we call it the “Adachi Curve”)



We used the old lattice (oops)

S: Beam direction

T: perpendicular to the beam



The spread in “s (beam direction)” is larger.

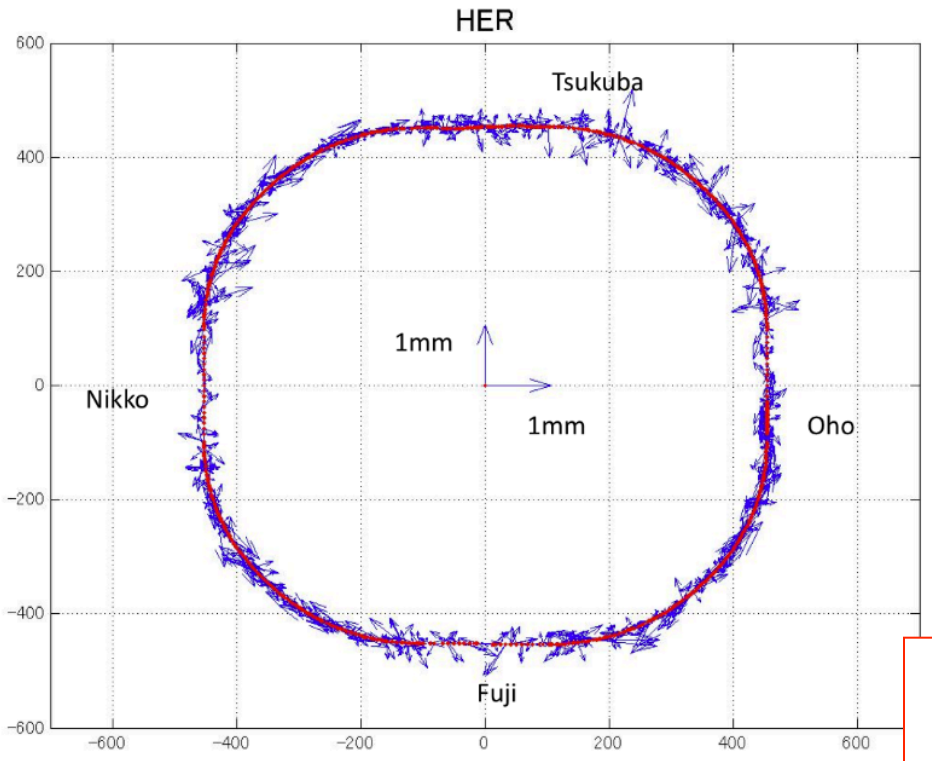
This is due to the expansion joints.

The temperature was NOT controlled during the SuperKEKB construction.

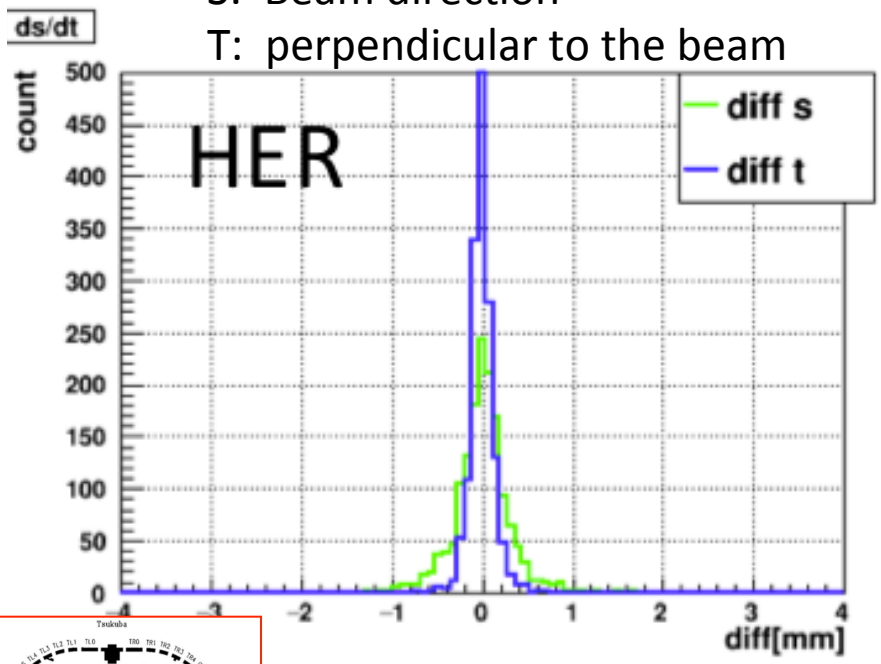
The temp. differ between when we did the 1st rough alignment and the 2nd survey.

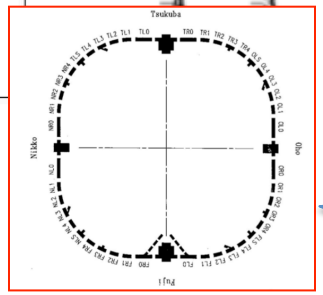
Survey Data and analysis results

Deviation from smooth curves (we call it the “Adachi Curve”)



S: Beam direction
T: perpendicular to the beam





Expansion joints to absorb the thermal expansion & contraction.

The spread in “s (beam direction)” is larger.
This is due to the expansion joints.
The temperature was NOT controlled during the SuperKEKB construction.
The temp. differs between when we did the 1st rough alignment and the 2nd survey.

Alignment strategy

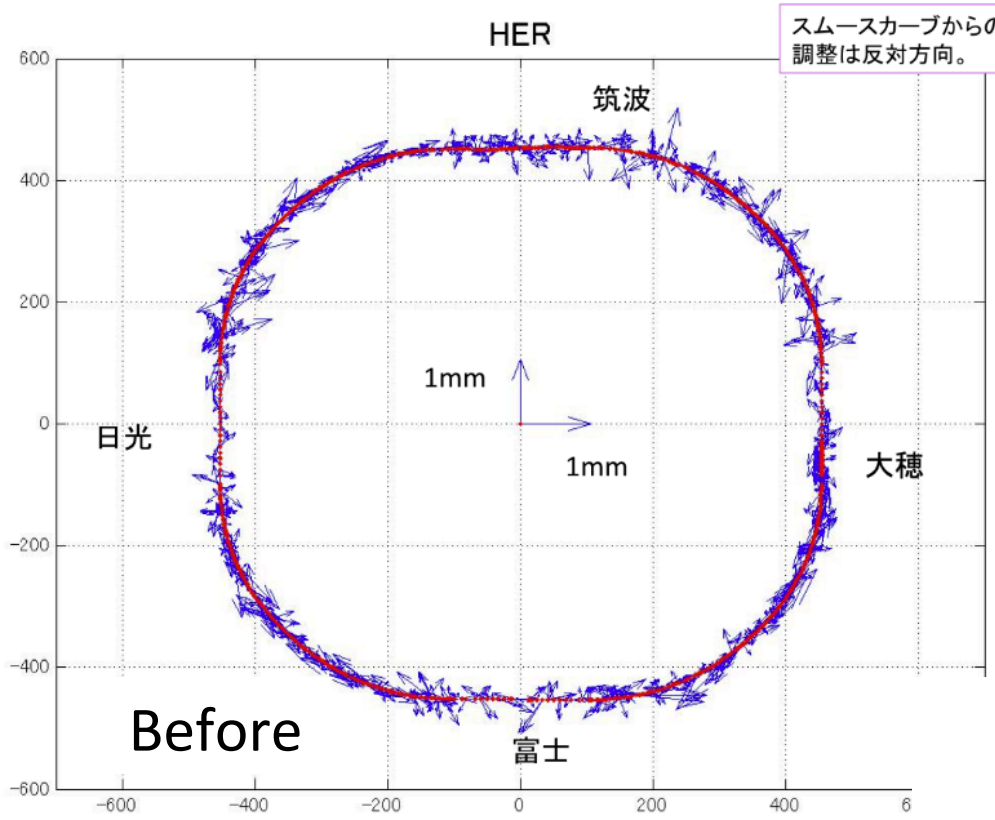
Discussion with the optics group

Time (schedule), man power (cost) ,impact to the other groups, against machine performance (good enough for Phase I) was discussed with the Optics G.

	Tolerance (Δt)	Tolerance (Δs)
Dipole	0.4mm	0.8mm
Wiggler	0.4mm	0.8mm
Quadrupole	0.2mm	0.4mm
Sextupole	0.2mm	0.4mm
LER Dipole(3 ref. pts)	0.4mm	0.8mm

Tough work in the tight space.

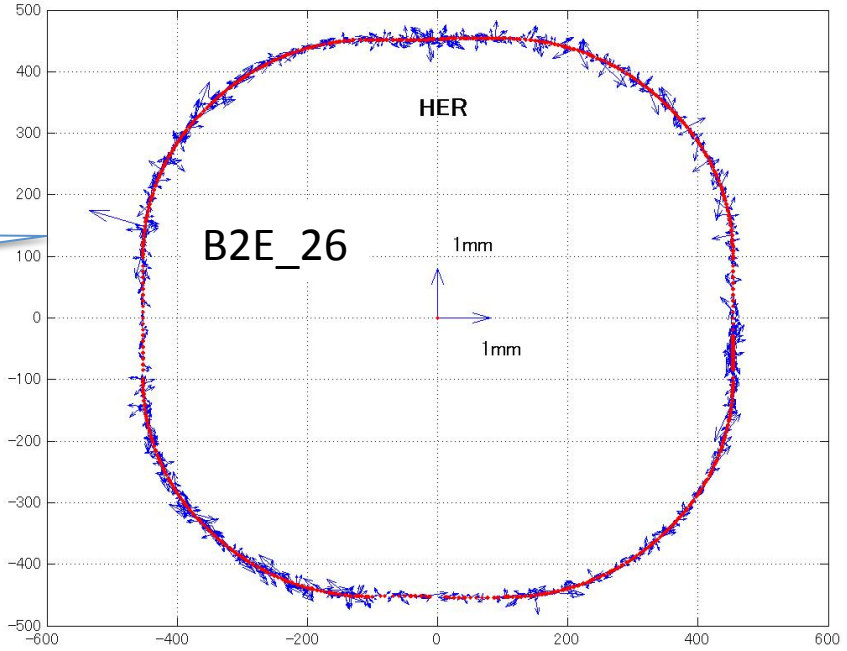
Obviously not here.



Alignment strategy

Alignment was carried out by two teams, followed by a survey team dedicated to checking the alignment.

Found a misalignment, which was fixed right away.



安心して下さい

Survey Results

VERTICAL (LEVEL)

Tunnel sinking continues

Utility building construction

1999 When KEKB started, it was leveled.

2011 earth quake

Utility building construction

2011 earth quake

AR-BT new tunnel construction

Utility building construction

2011 earth quake

Utility building construction

$34mm/16years$

$= 2.1mm/year$

Level (mm) wrt IP

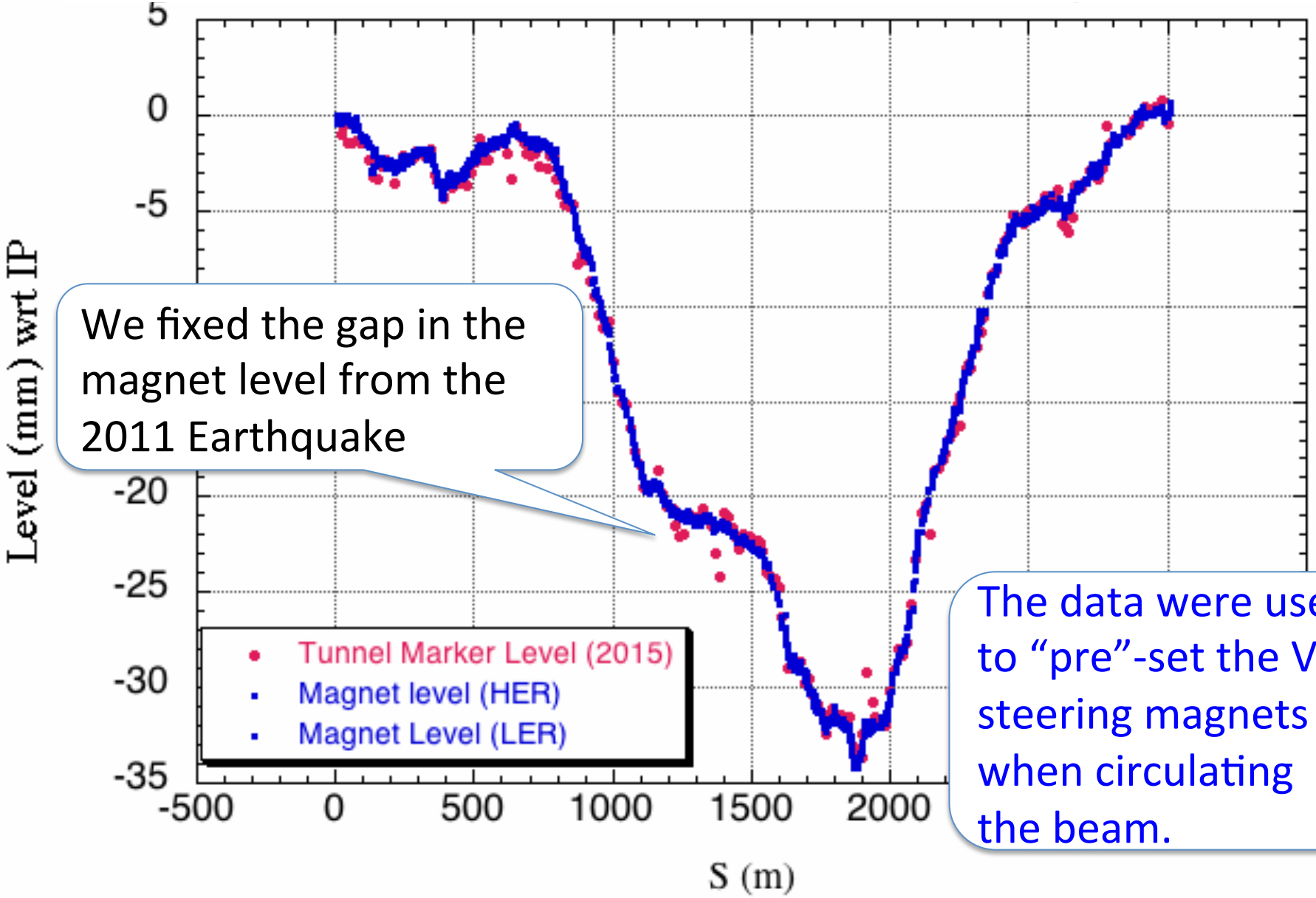
0
-5
-10
-15
-20
-25
-30
-35

2001
2003
2004
2005
2006
2007
2008
2009
2010
2011(After EQ)
2012
2013
2014
2015

0
500
1000
1500
2000
2500
3000

(S m)

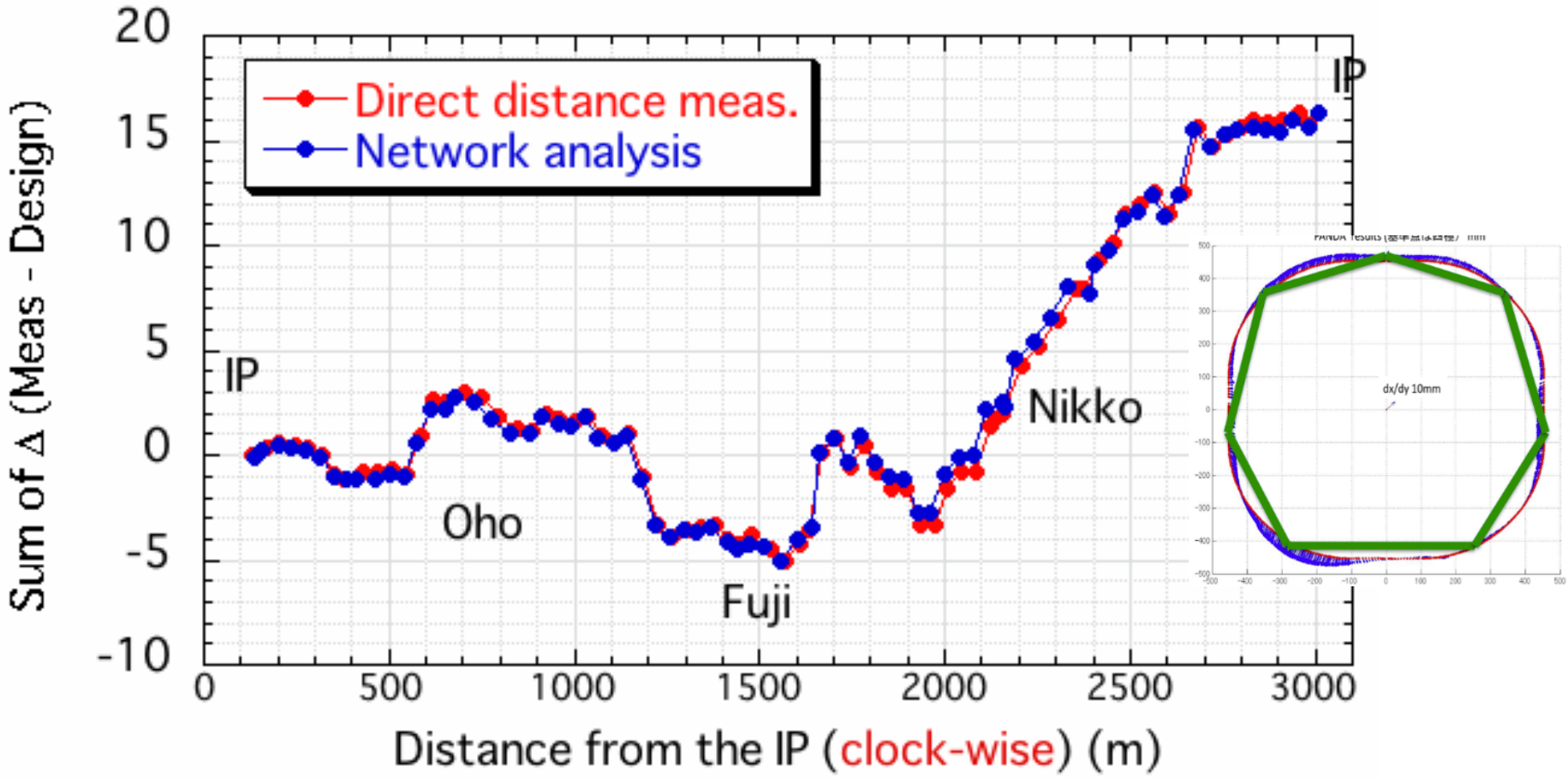
Survey Data and analysis results



Survey Results

CIRCUMFERENCE PREDICTION FOR A SMOOTH START UP OF THE BEAM CIRCULATION

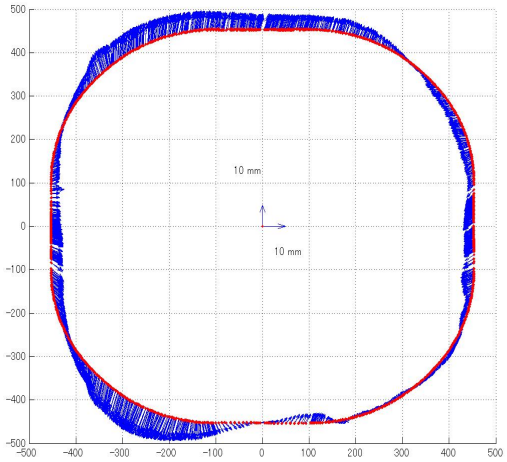
Circumference estimate



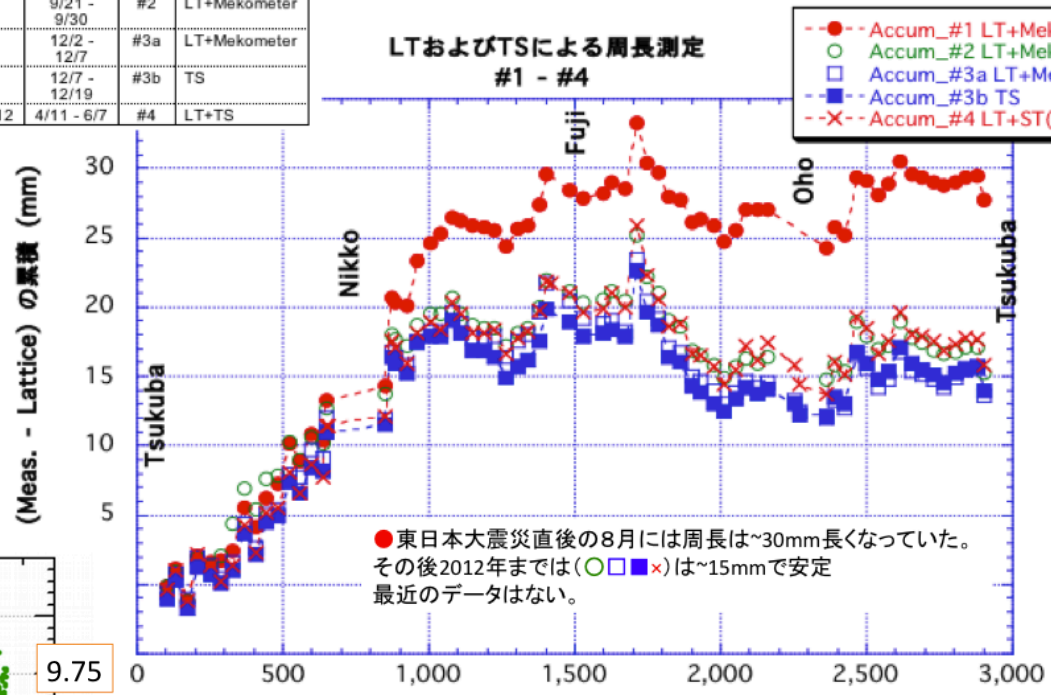
Our best guess from the survey and analysis was that the circumference is about 16.4 mm longer than the SuperKEKB design. This information was used when injecting the LER beam to the ring on Feb.9, 2016 and the beam said Yes!

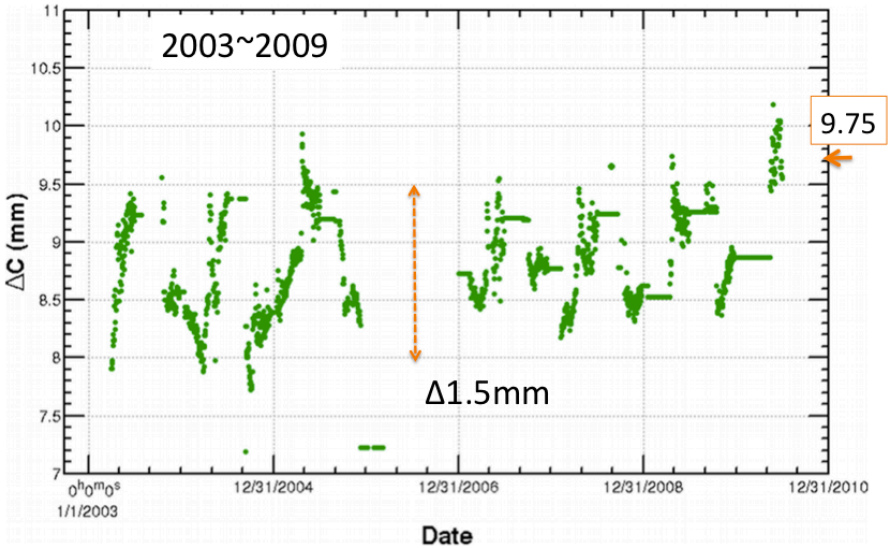
Our rings look like this

(Our rings have been always larger than the design)



2011	7/28 - 8/24	#1	LT+Mekometer
	9/21 - 9/30	#2	LT+Mekometer
	12/2 - 12/7	#3a	LT+Mekometer
	12/7 - 12/19	#3b	TS
2012	4/11 - 6/7	#4	LT+TS





Our rings were the largest right after the Great East Japan Earthquake in 2011. They started shrinking but not back to the level of KEKB.



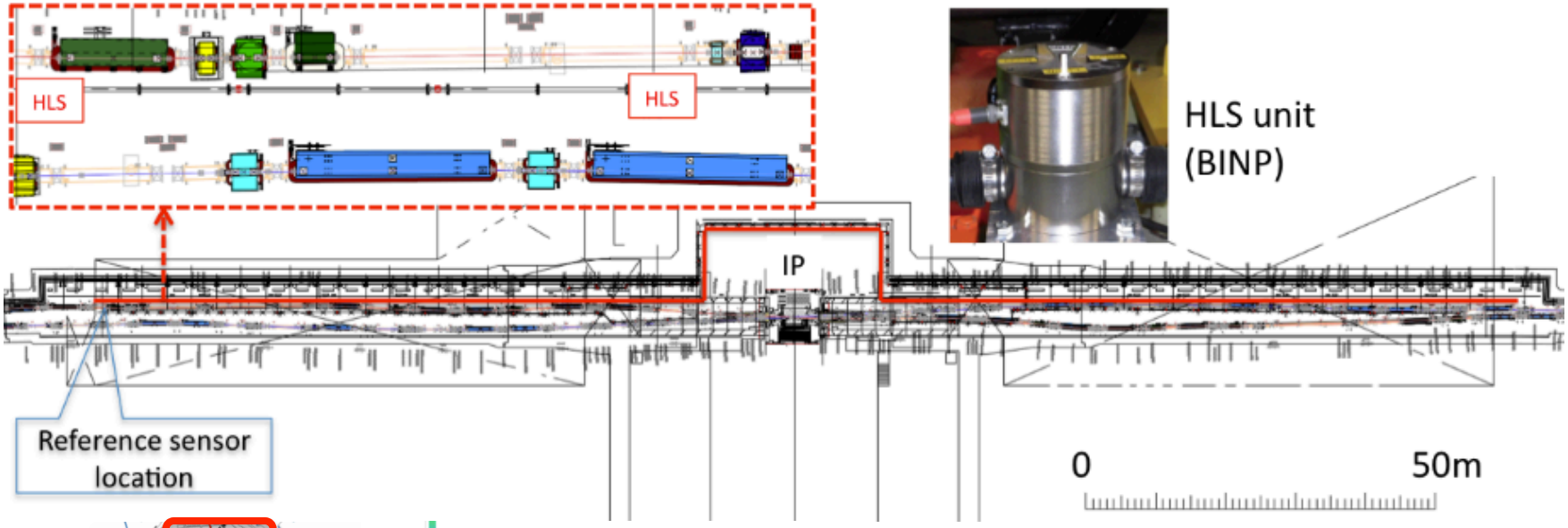



SuperKEKB (Phase-1)
アライメント終了
2015.10.14
御用

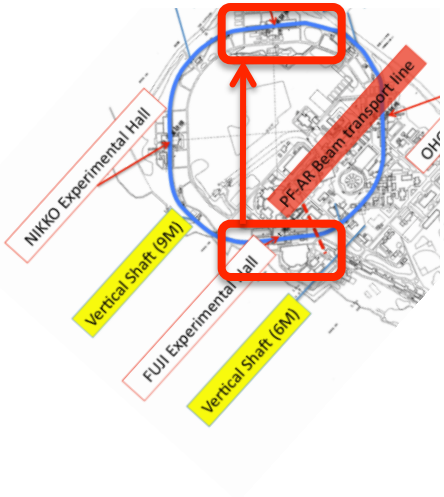
Tunnel Motion Monitoring

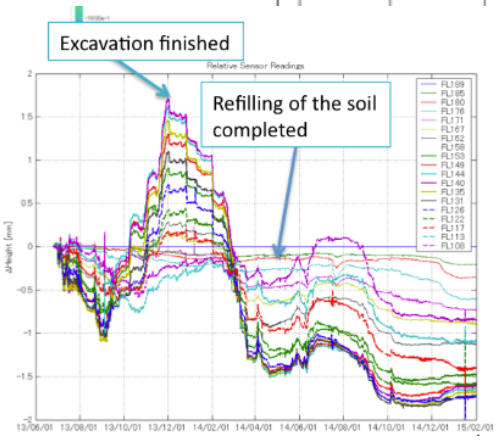
HLS (HYDROSTATIC LEVELING SENSORS)

Tunnel motion monitoring



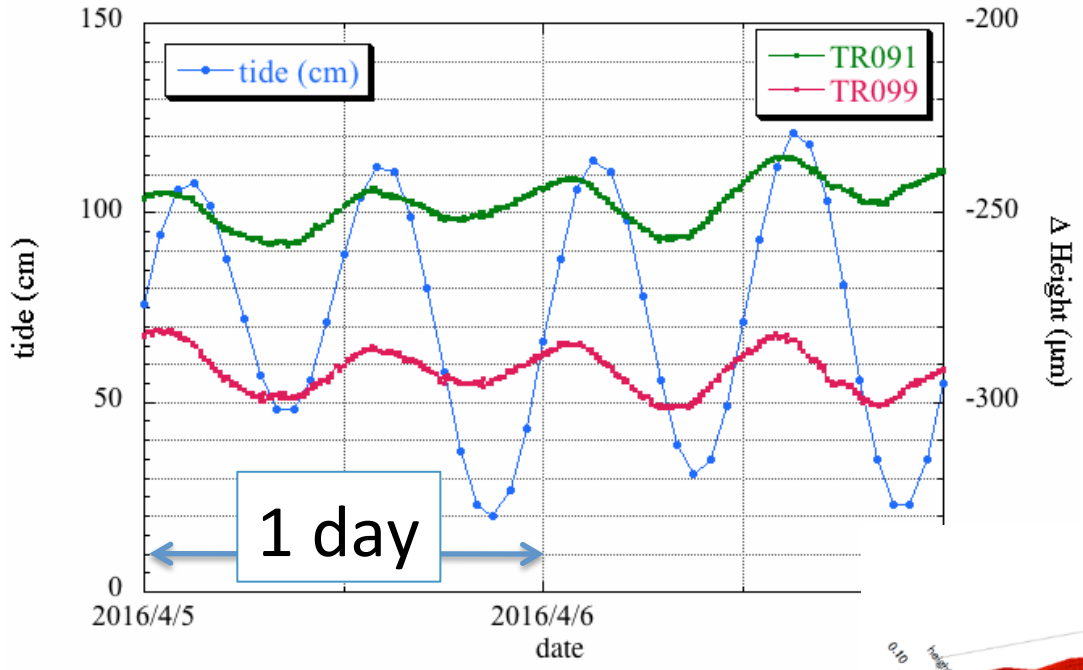
HLS unit (BINP)





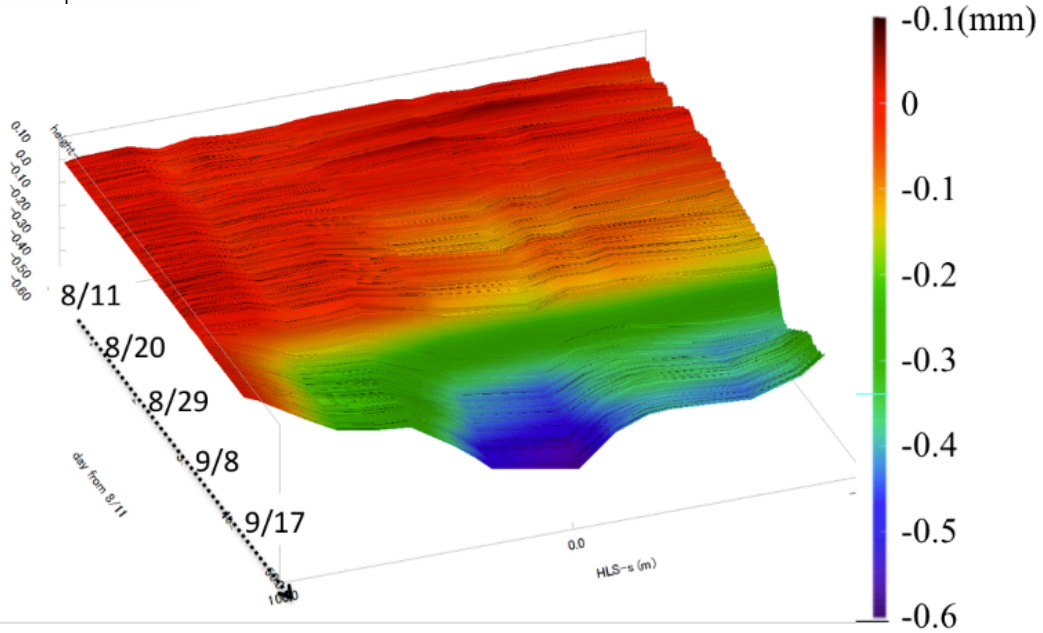
The HLS system was used to monitor the tunnel motion during the PF-AR BT tunnel construction (presented at 2015 review). It was relocated to the straight sections on ether side of the IP in Aug.2015.

Tunnel motion monitoring

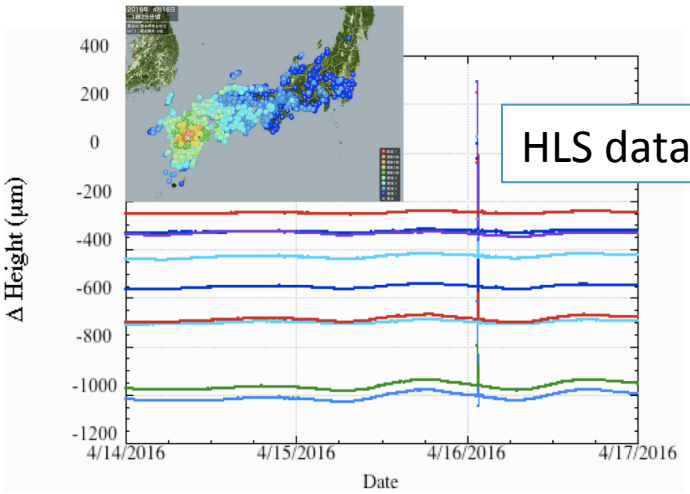


A clear tidal (vertical) motion is seen around the IP.
The amplitude is ~20μm (P-P) during this period.

IP sank with respect to the ends of the straight sections by ~0.6mm due to heavy rainfall in the area.



Tunnel motion monitoring

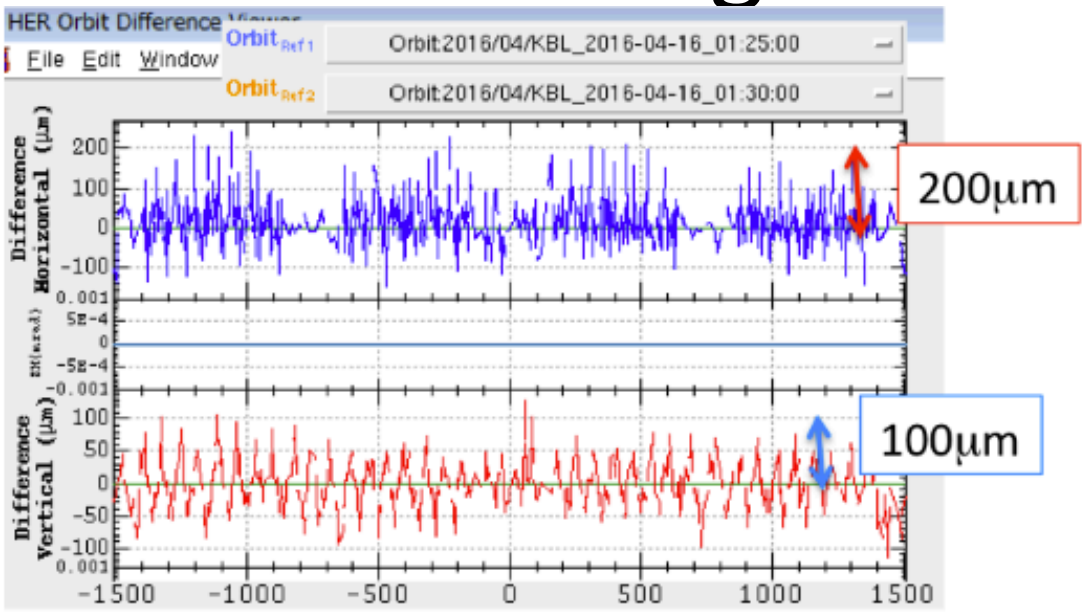


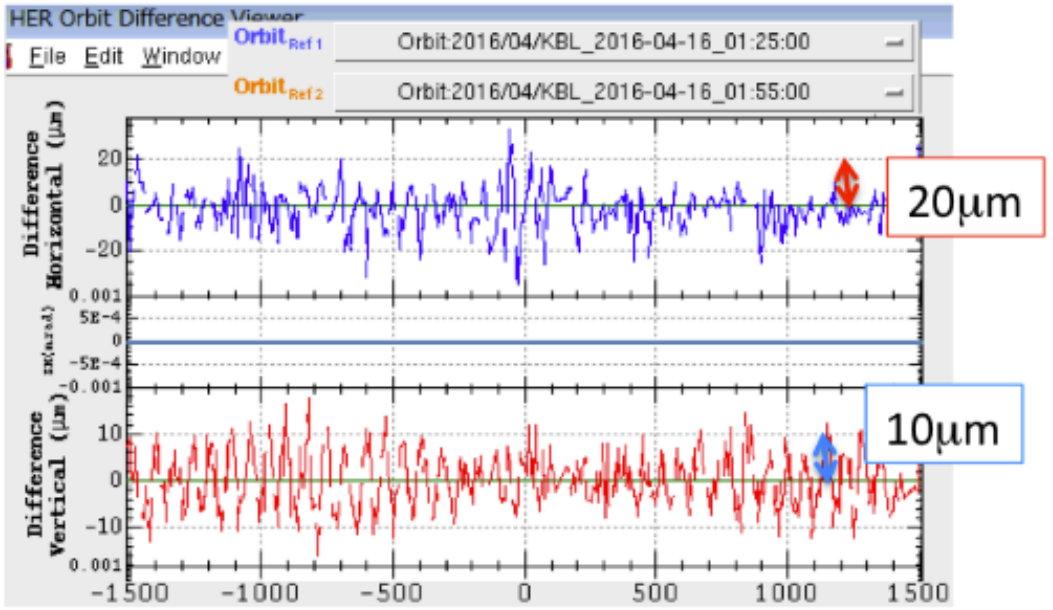
The 2016 Kumamoto earthquake (magnitude 7.3) hit Kumamoto.

It took ~ 4 minutes for the seismic wave to arrive at the SuperKEKB ring.

It disturbed the accelerator components but the abort system for the circulating beams was not triggered.

Orbit difference
During the EQ – before EQ (top)
After the EQ – before EQ (bottom)





We came a long way

The last days of KEKB

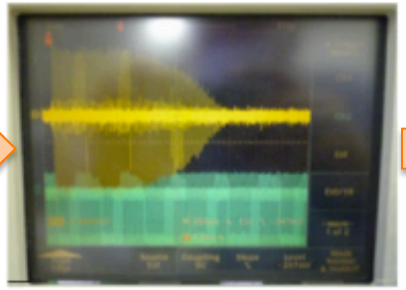
Dismantling of the KEKB magnet

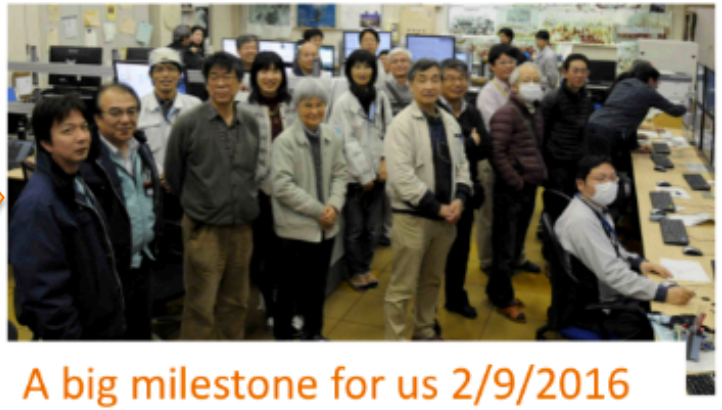
Magnets cables removed

SuperKEKB Beam line

Magnets being installed

SuperKEKB layout





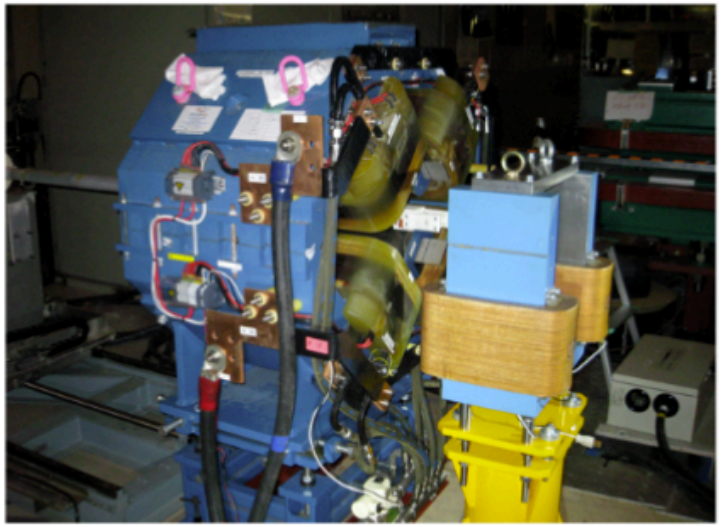
KEKB Review 2016

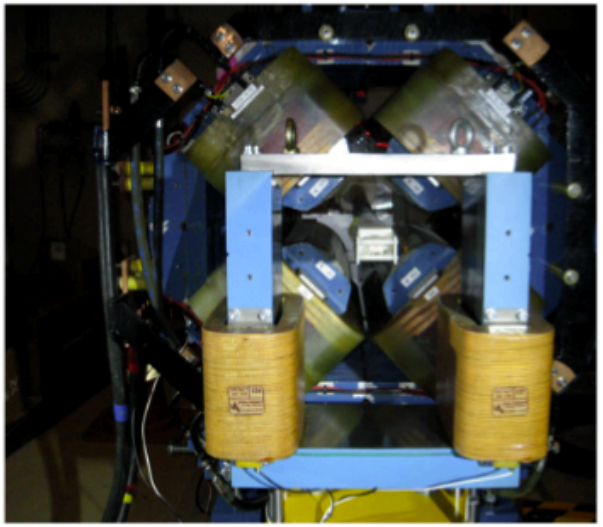
A big milestone for us 2/9/2016

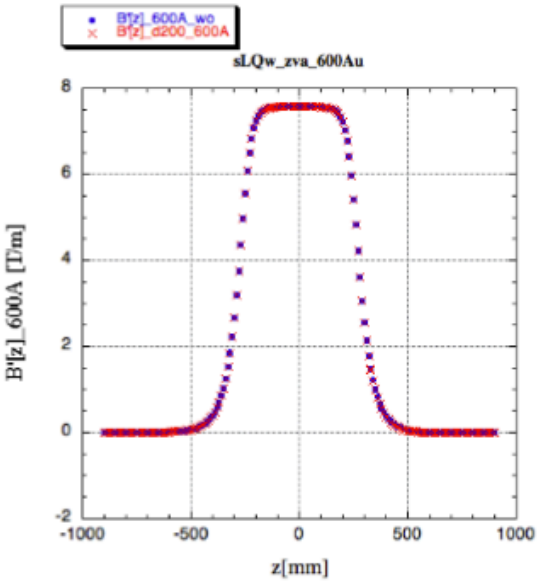
Magnetic field measurements

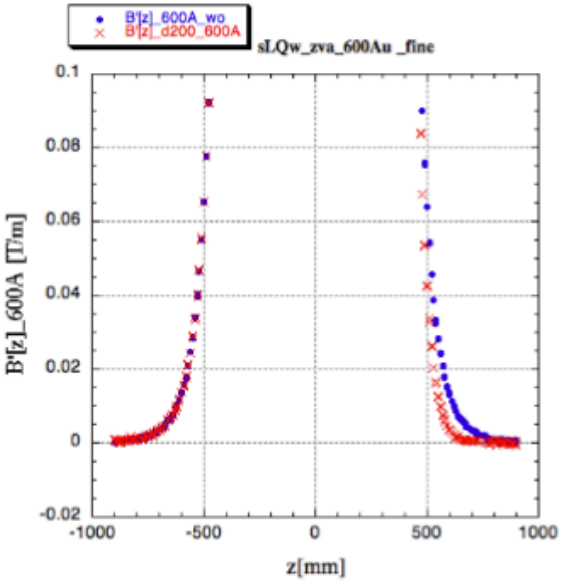
coupling between adjacent magnets

Magnetic coupling between adjacent steering magnet and Quadrupole magnet was evaluated & measured by K. Egawa

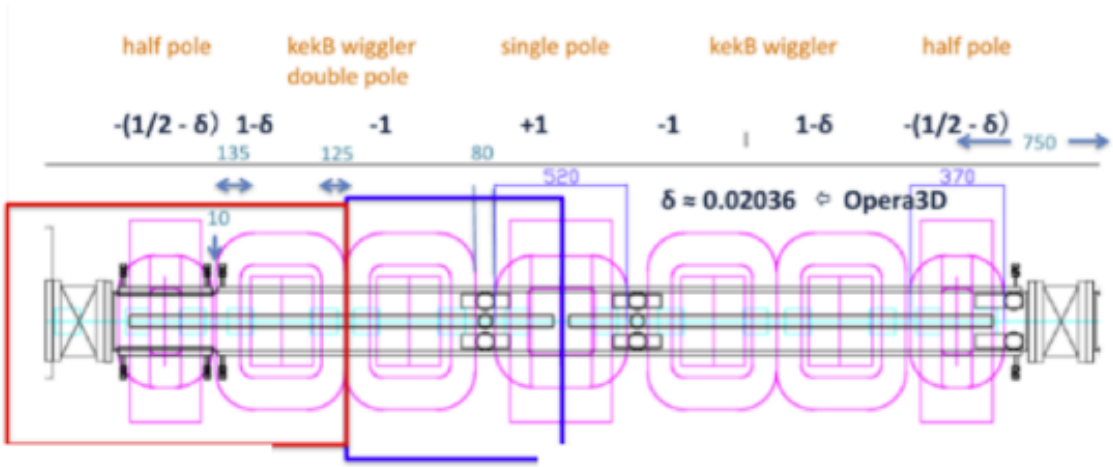




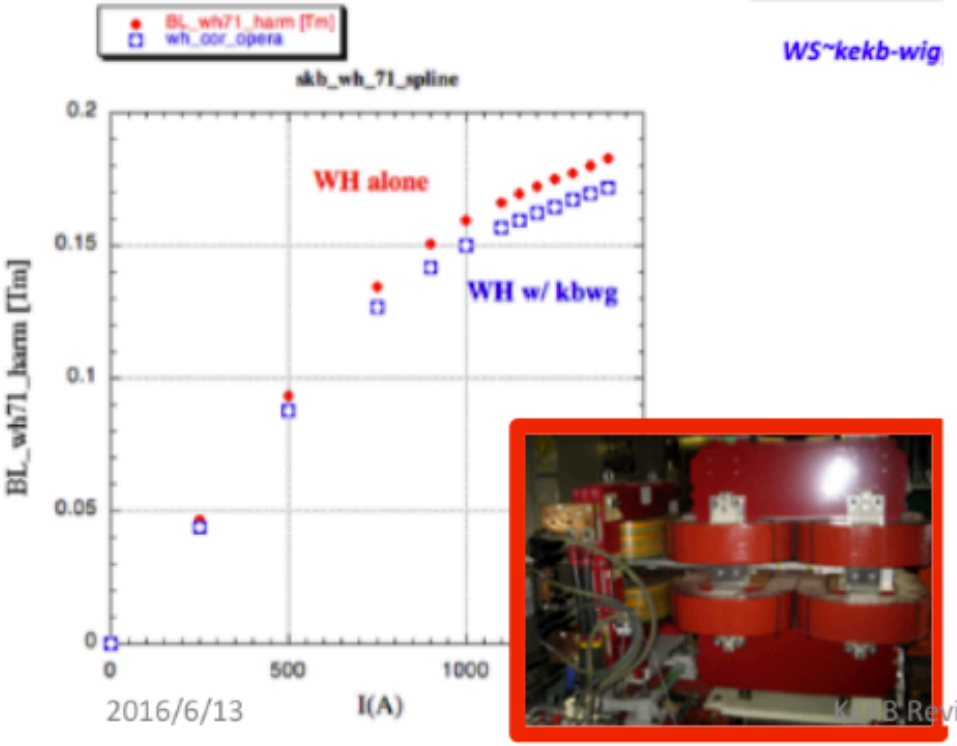


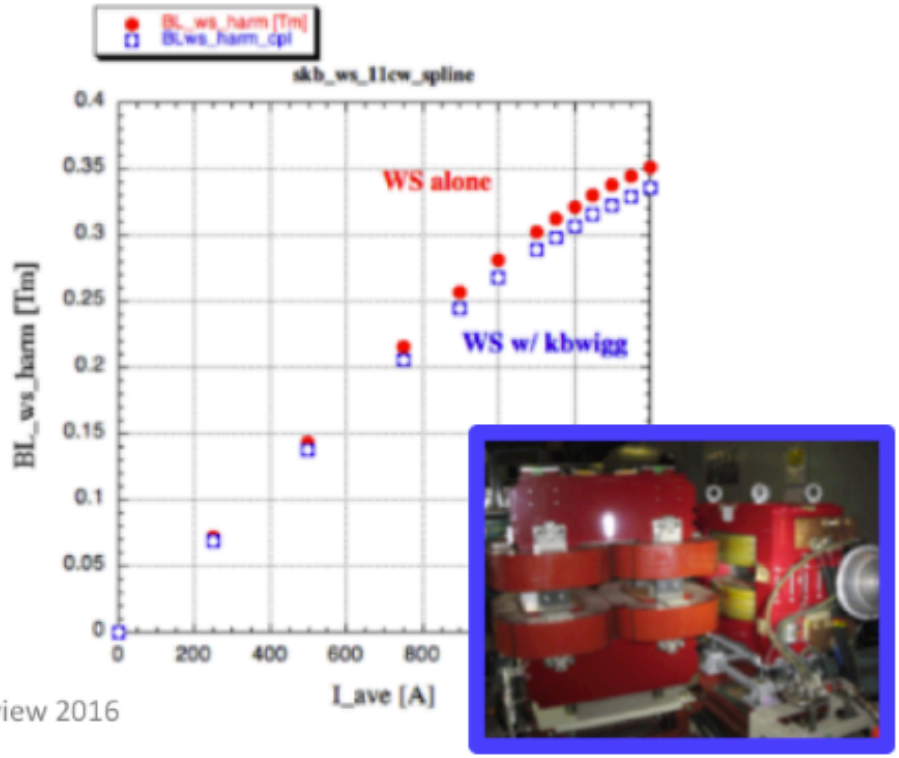


Magnetic coupling between adjacent wigglers was evaluated & measured by K. Egawa



WS~kekb-wig





3. For Phase II

Preparation for New IR,
Installation & alignment of the QCS magnet system,
design and fabrication of the collision FB (“iBump”)
magnets, building the dithering system, and so on.

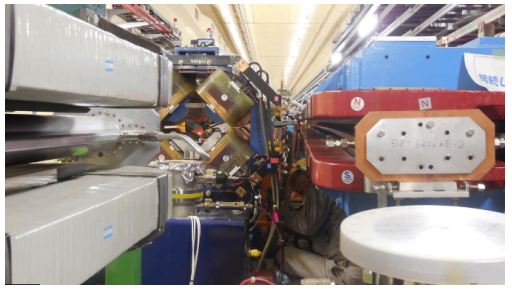
Survey of the rings after a long shut-down and
before Phase II.
Alignment of the ring magnets, if needed.

Summary

- The SuperKEKB MR magnet system was completed in time for Phase I commissioning.
- The prediction for the circumference agreed with the actual circumference within 1 ppm accuracy and the difference in the circumference in both rings was found to be a couple of hundred microns, which contributed to a smooth start-up of the MR.
- We would like to add more (BINP) HLS sensors to monitor the tunnel level change, especially at the IP & LCC sections.

- The power supply system is up and running smoothly with very high stability➔T. Oki's talk.

Summary



- We will investigate any problems found by beam commissioning:
  - Misalignment if any,
  - Improvement in the magnet data
    - Magnetic coupling of wigglers, near-by magnets, for example.
- We are preparing for the installation of the QCS system, which will take place in the summer, 2016.
  - We have started to work closely with the QCS group on the alignment of the Single Stretched Wire (SSW) system, which affects the cryostat alignment to the beam line.