

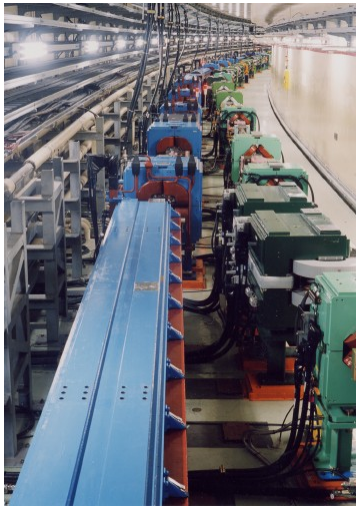


# Overview of Ring Construction Status and Schedule

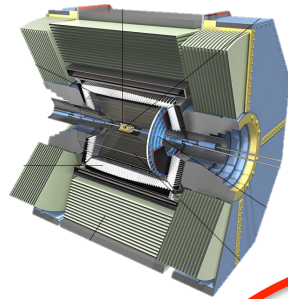
Contents:

- Ring construction status
- Budget, schedule and HR

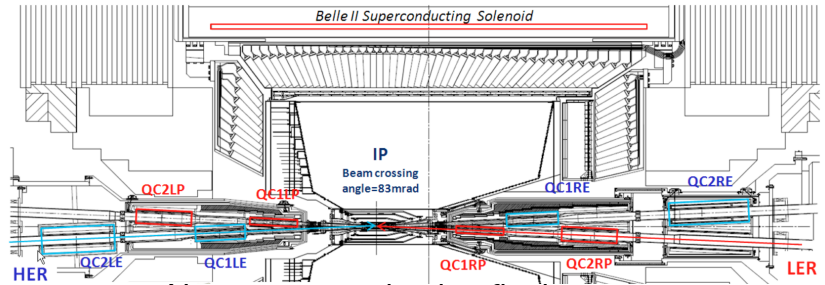
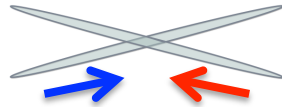
Kazunori AKAI  
KEK, Accelerator Laboratory  
Mar. 3, 2014, @19<sup>th</sup> KEKB Review



Upgrade to Belle II detector



Colliding bunches



New superconducting final focusing magnets near the IP

$e^+$  3.6A

$e^-$  2.6A

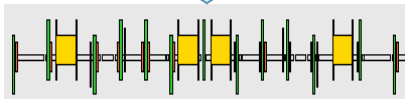
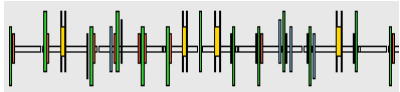
# KEKB to SuperKEKB

- ◆ Nano-Beam scheme  
extremely small  $\beta_y^*$   
low emittance
- ◆ Beam current double

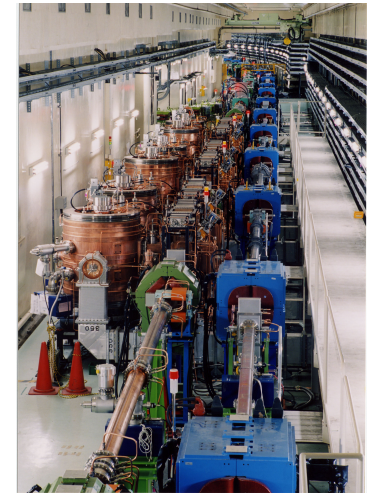
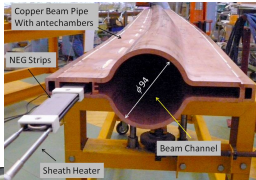
$$L = \frac{\gamma_{\pm}}{2e r_e} \left( 1 + \frac{\sigma_y^*}{\sigma_x^*} \left( \frac{I_{\pm} \xi_{\pm y}}{\beta_y^*} \right) \left( \frac{R_L}{R_y} \right) \right)$$

40 times higher luminosity  
 $2.1 \times 10^{34} \rightarrow 8 \times 10^{35} \text{ cm}^{-2} \text{ s}^{-1}$

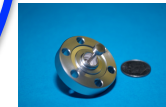
Redesign the lattice to squeeze the emittance (replace short dipoles with longer ones, increase wiggler cycles)



Replace beam pipes with TiN-coated beam pipes with antechambers



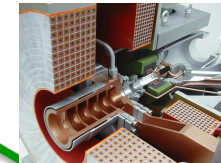
Reinforce RF systems for higher beam currents



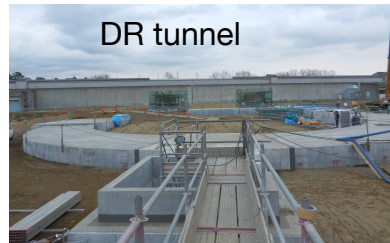
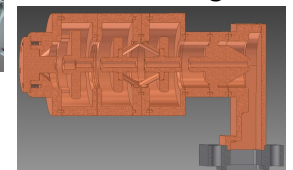
Improve monitors and control system

Injector Linac upgrade

Upgrade positron capture section



Low emittance RF electron gun



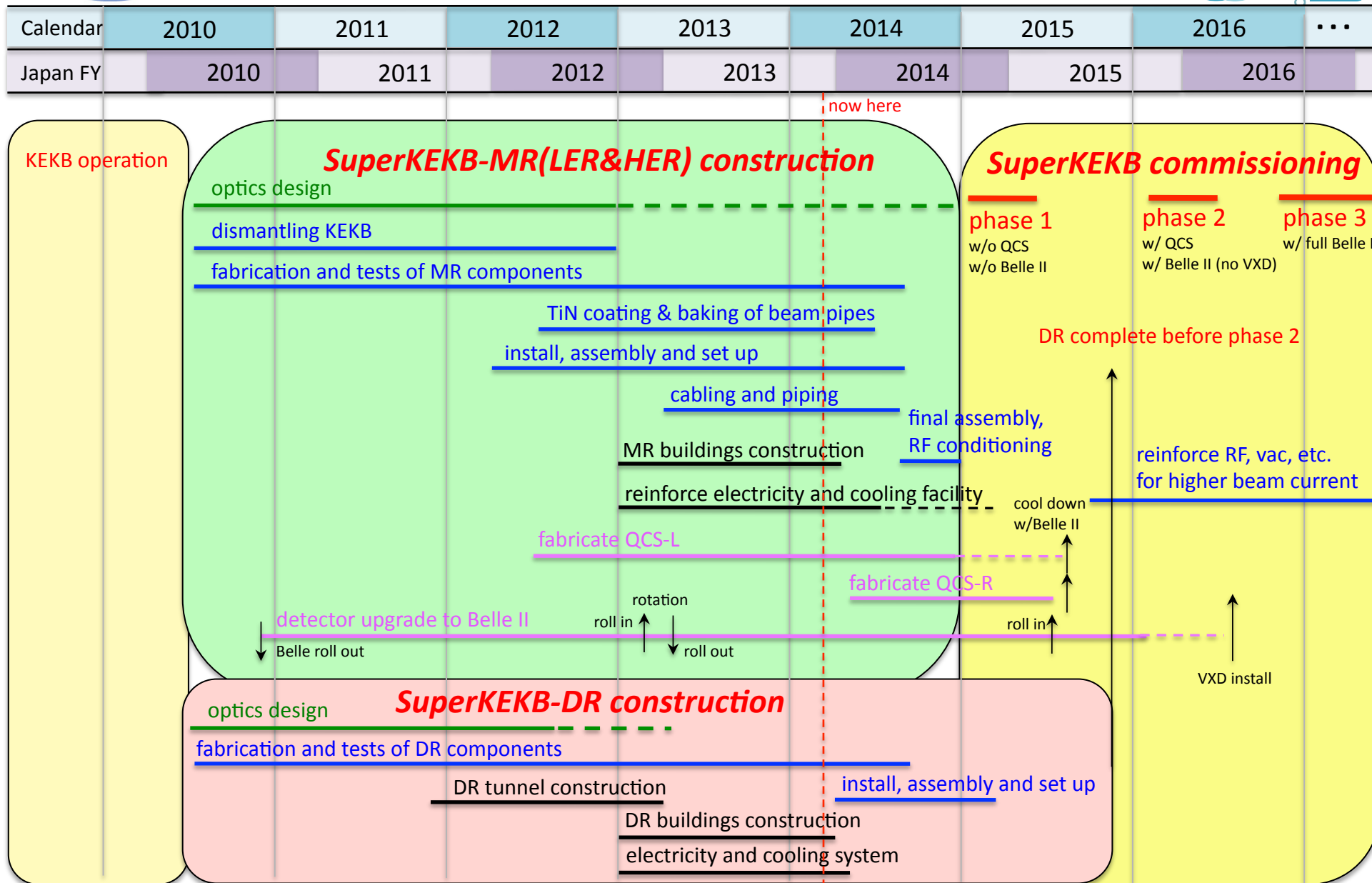
DR tunnel

New  $e^+$  Damping Ring



# SuperKEKB rings master schedule

Super  
KEKB





# Commissioning phases



- Phase 1
  - No QCS, No Belle II solenoid
  - Basic machine tuning
  - Low emittance tuning
  - Vacuum scrubbing
    - Belle II people request enough vacuum scrubbing in this stage (before Belle II roll in).
    - At least one month at beam currents of 0.5~1 A /ring.
  - DR is not needed in this phase.
- Phase 2
  - with QCS and Belle II (w/o VXD)
  - Low beta optics tuning
  - Small x-y coupling optics tuning
  - Beam collision tuning
  - Belle II background study
  - DR commissioning
  - Target luminosity at this stage is  $1 \times 10^{34} \text{ cm}^{-2}\text{s}^{-1}$
- Phase 3
  - Physics run



# Ring Construction Status



# MR Magnet & Vacuum Status



## Tsukuba straight section

- Most of magnets (except IR) installed.
- Beam pipes in fabrication this FY.
- Installation of beam pipes next FY.

## Interaction Region

- Magnets close to the IP in fabrication this FY.
- Beam pipes for the IR (Phase 1) next FY
- Installation of IR magnets and beam pipes next FY.
- Superconducting magnets under construction for Phase 2.

## Arc sections

- LER new bending magnets installed.
- Installation of most of other new magnets to be done in this FY.
- Beam pipes and bellows connection to be completed in this FY.
- 24 sextupole magnets with tilting table to be installed next FY.

## Oho and Nikko straight sections

- Wiggler magnets installed.
- Beam pipes installed.

## Around the ring

- Power cables, control cables ongoing.
  - Piping for cooling water ongoing.
  - Alignment on going.
- (these works continue in FY2014)

## Cooling facility reinforcement

- Replacing cooling pipes in tunnel completed.
- New buildings construction (2012-13).
- Pumps and other equipments under construction: to be completed in Sep. 2014.

## Power supply buildings

- Power supplies fabrication ongoing.
  - Cabling and piping.
  - Starting up power supplies.
- (these works continue in FY2014)

## Fuji straight section

- Most of KEKB magnets and beam pipes are reused.
- Beam pipes for injection, abort, crossing etc. are in fabrication this FY. (some will be later)
- Installation of these new beam pipes next FY.



# Beam pipes preparation



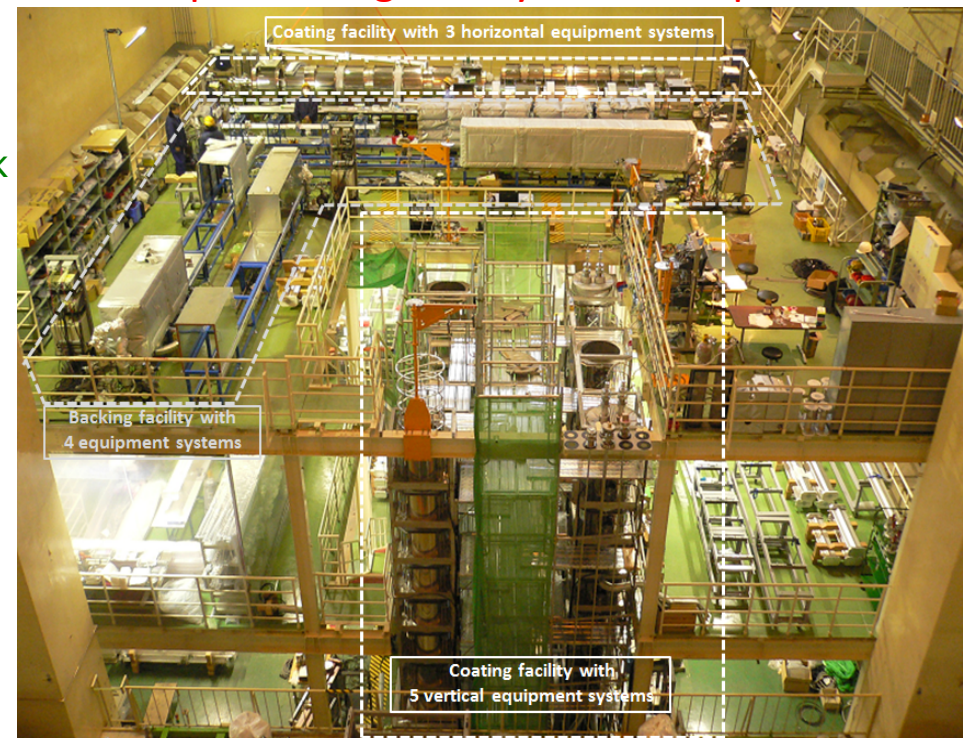
- Fabrication

- Most of MR vacuum components, such as beam pipes, pumps, bellows etc., required for Phase 1 were already ordered, and will be delivered in this fiscal year.
  - Tsukuba straight section, beam injection/abort sections, SR monitor sections, etc. were finally ordered last year (in JFY2013).
  - Only beam collimator system is still remained. (to be ordered in April 2014)

- Baking and TiN coating

- About 930 beam pipes already done using a facility in KEK site.
  - Output: 10 ~ 15 beam pipes per week
- Preprocessing work for the rest of the beam pipes will start from this spring.
  - About 330 beam pipes should be processed, including the TiN coating for ~140 beam pipes.
  - Mainly for Tsukuba and Fuji straight section.

Preprocessing facility at Oho exp. hall



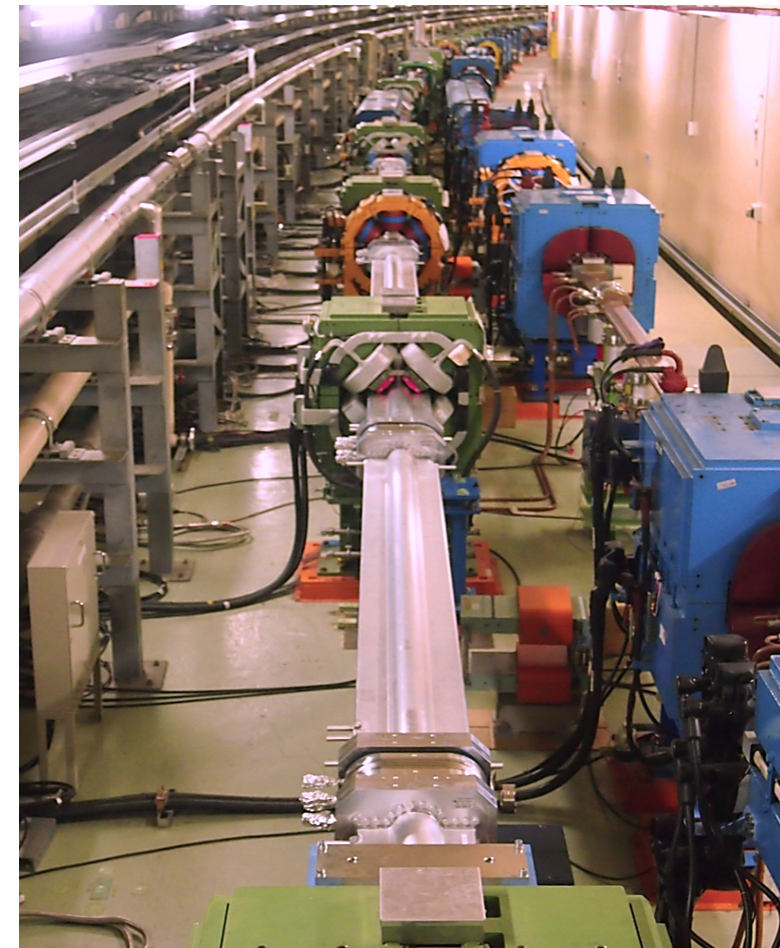


# Beam pipes installation



- Installation of beam pipes and bellows has started in 2013.
  - About 830 beam pipes were already installed for arc sections and wiggler sections, followed by the connection of bellows.
  - Some sections were already evacuated, and the control system was checked.
  - Installation of the remained beam pipes (Tsukuba straight section, injection/abort, SRM), and the following evacuation of the whole ring will start from this summer, and the MR vacuum system will be ready in this year.
- Upgrade of monitoring and control system are in progress.
  - Cabling and piping of cooling water have started.

Beam pipes installed into arc section







North tunnel



LER Gate valve in West tunnel



LER Oho wigger downstream



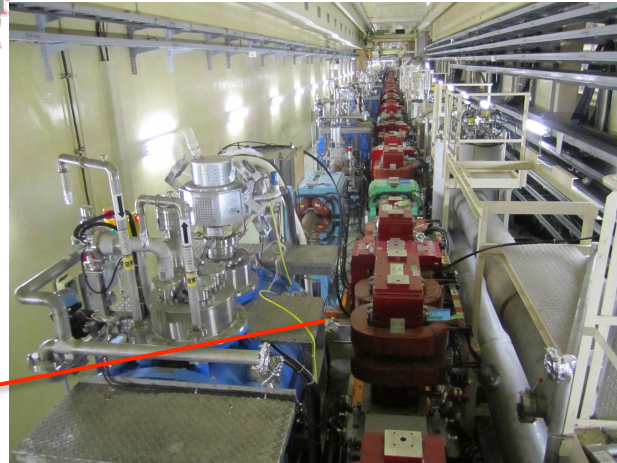
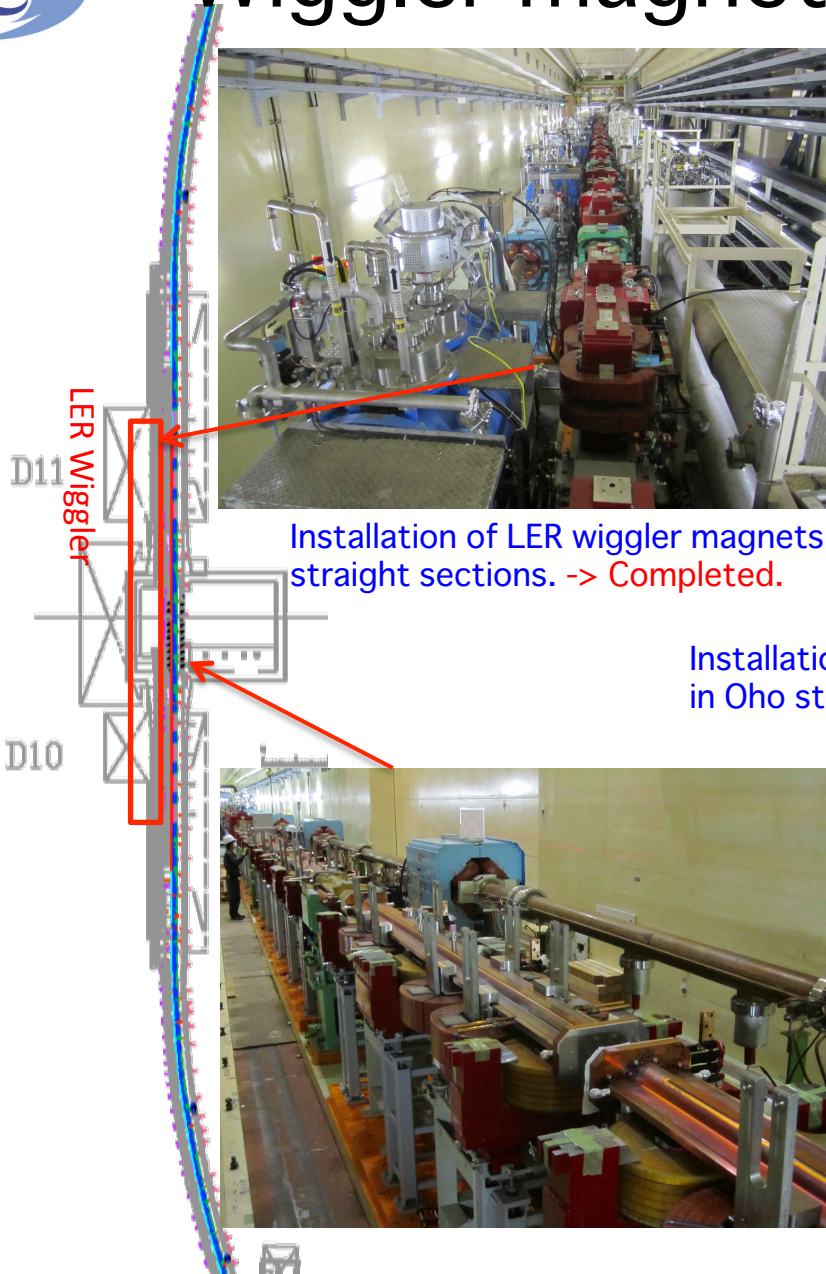
LER Nikko wigger downstream



# Wiggler magnets and chambers



Nikko



Installation of LER wiggler magnets and chambers in Nikko and Oho straight sections. -> Completed.



Installation of HER wiggler magnets and chambers in Oho straight section. -> Completed.

LER Wiggler

Oho





# Tilting table for sextupole magnets

## Magnet modification and table production ongoing

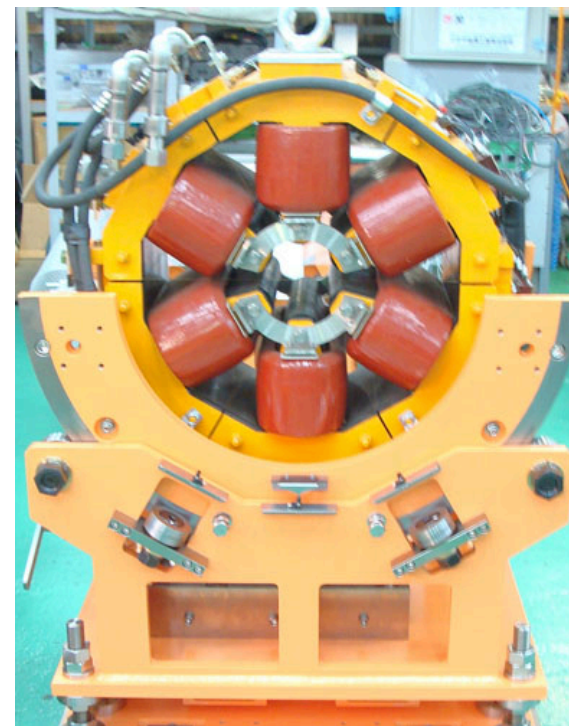


16 tables (of 24) arrived at KEK.



16 magnets (of 24) been modified and arrived at KEK.

M. Masuzawa,  
R. Sugahawa



Assembled magnet: Proto type

Assembly work using survey instruments to adjust the tilting center will start sometime in February. Installation to the beam line will take place in JFY2014.

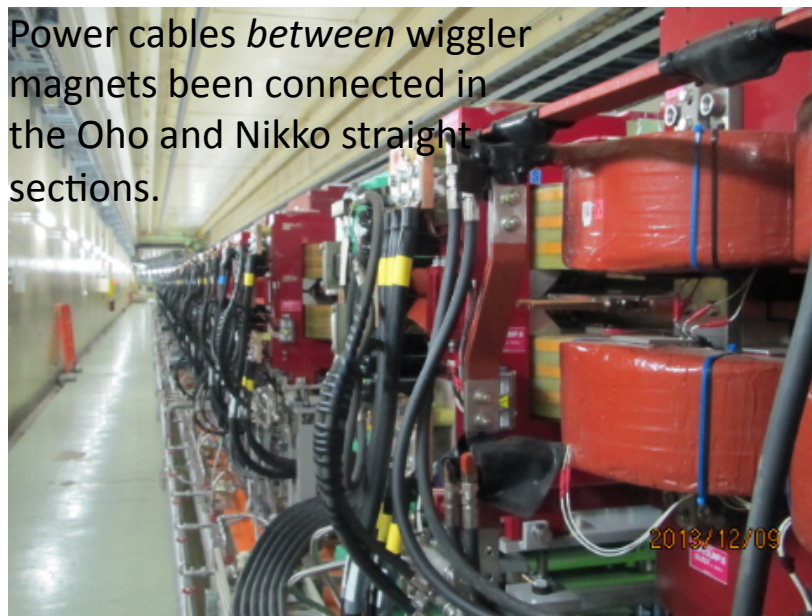
# Piping, Cabling and Alignment



These works are also laborious, takes time and money.



Cooling water pipes.



Power cables *between* wiggler magnets been connected in the Oho and Nikko straight sections.



SSC in HER

He pipe

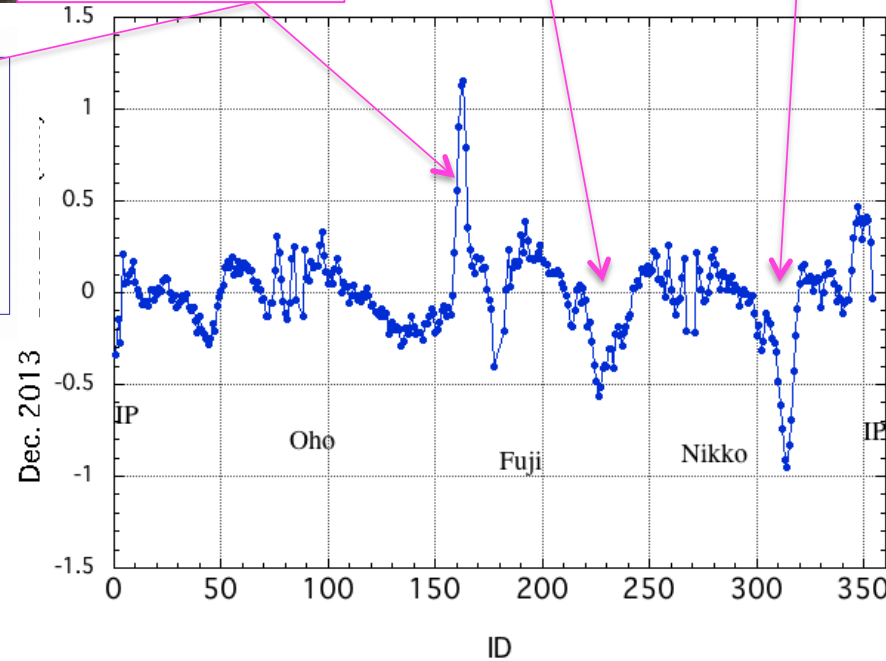
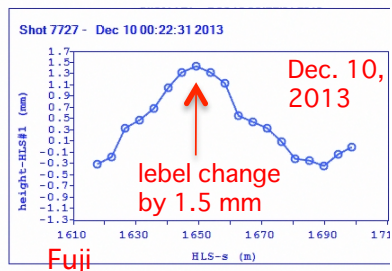
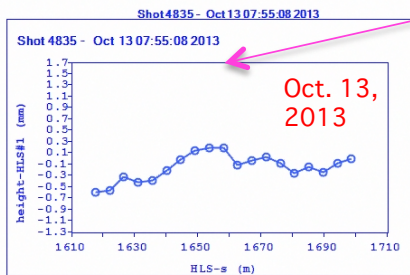
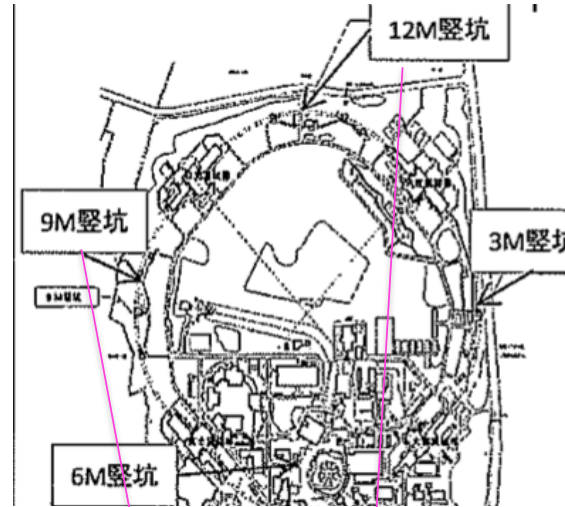
Workers adjusting the bolts, in between the magnet and the pipe, not easily seen.

Nikko wiggler alignment in a very tight space

# Alignment work ongoing

Difficult to coexist with the heavy duty construction work above ground.

Effects of the new utility buildings and new tunnel are clearly seen.





# Tsukuba straight section



Before 2013

(2)KEKB電磁石撤去済  
新ビームライン用測量・寫描き 済  
ベースプレート設置進行中



電磁石搬入・据え付けは来年度から  
一部の電磁石は新規製作予定

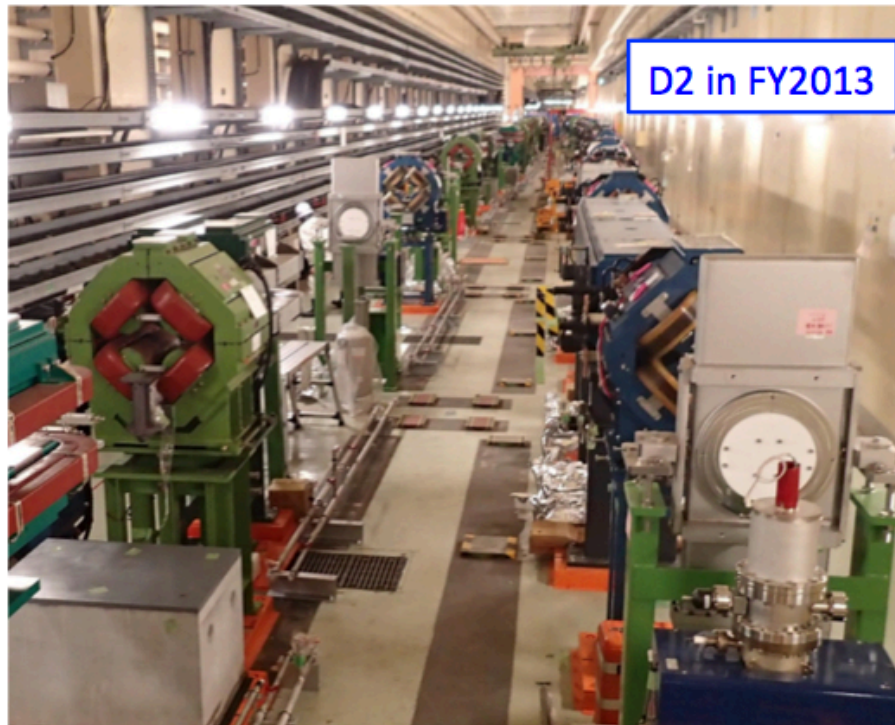
Done

- Dismantling all magnets, beam pipes, cables, etc.
- Belle rotation, roll-out
- Installation of magnets (except close to IP)

On going 2013-14

- Beam pipes fabrication
- magnets close to the IP fabrication
- Cabling and piping
- Floor modification and Moving stage
- Radiation investigation and shielding

Tsukuba section waiting for beam pipes



D2 in FY2013



D1 in FY2013



# IR Magnet production status (QK\* and BC\* and etc.)



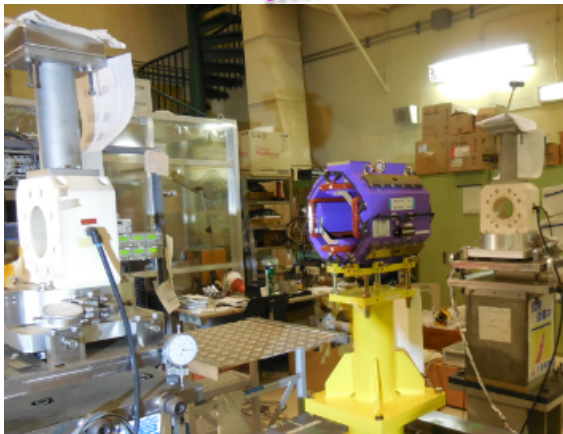
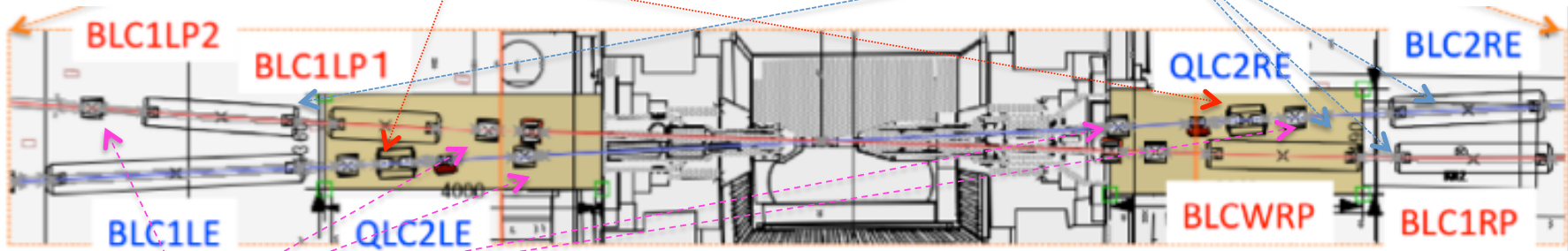
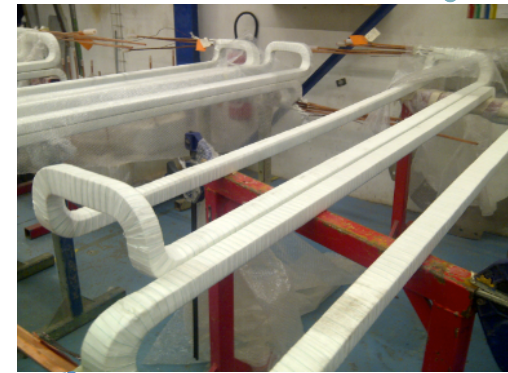
Two quadrupoles (QLC2LE/QLC2RE)

M. Masuzawa et al.

Coils have been wound & impregnation is ongoing

~2.2m Dipoles  
All coils have been wound

Yoke stacking and assembly will start in mid-February.



All 16 (+1spare) Skew Quads (QK\*) arrived at KEK and the magnetic measurements ongoing at KEK.

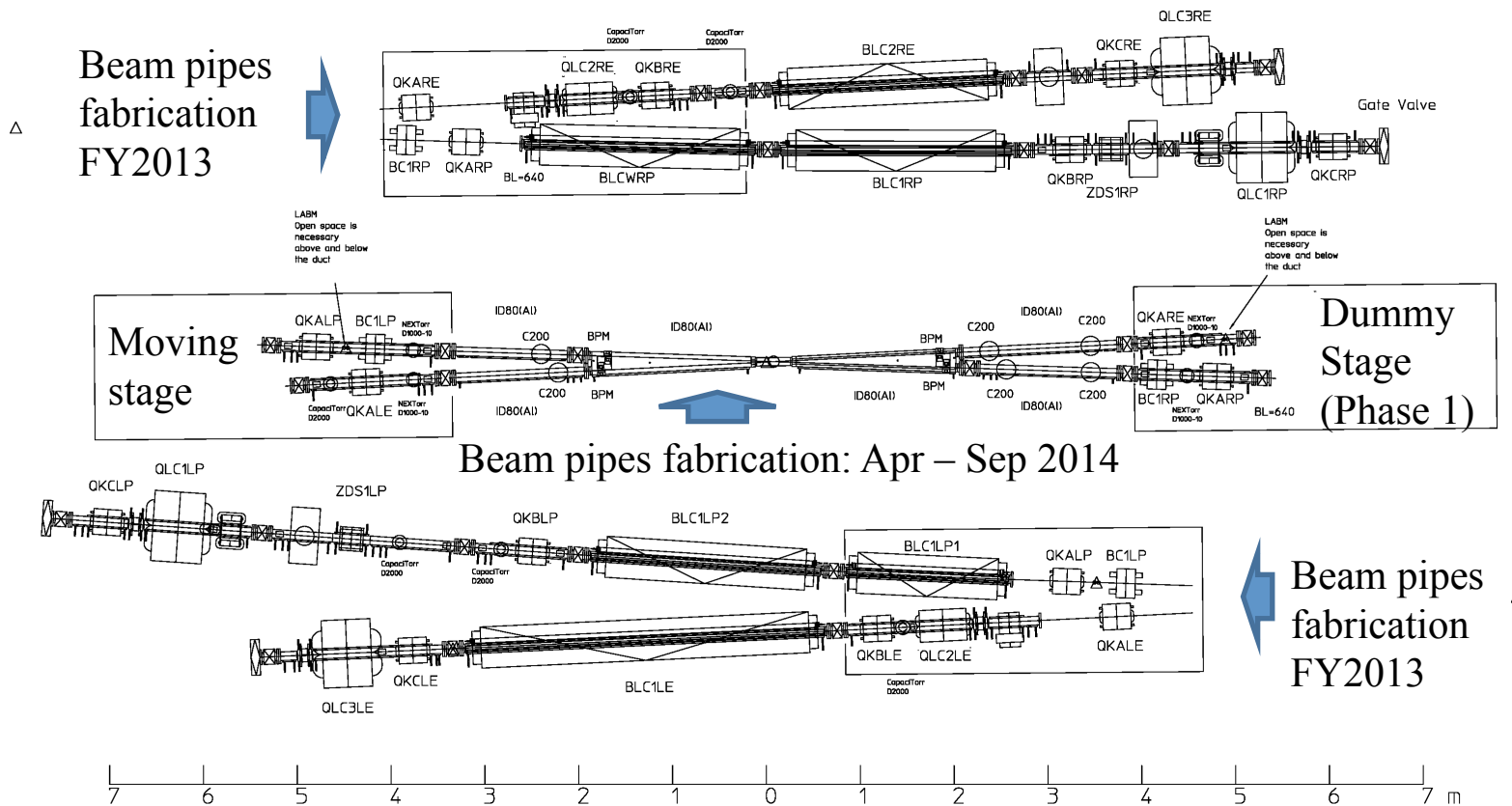


Small dipole magnets near the QCS (BC1LP,BC1RP) & other dipole magnets (BC\*E) and etc. Yoke stacking ongoing

# IR status – magnets and beam pipes

K. Kanazawa

New IR magnets are fabricated in FY2013.  
 Installation of the new IR magnets will start June 2014.

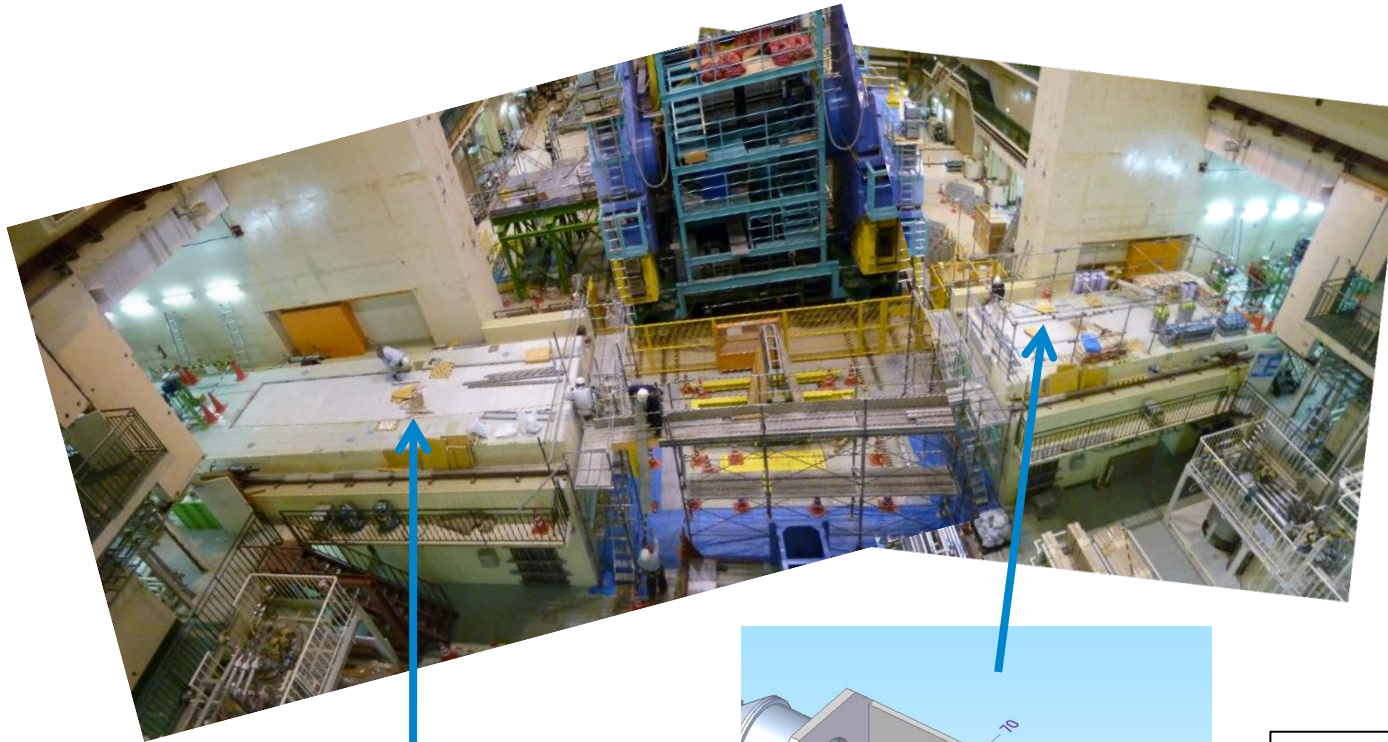


Installation of beam pipes will start around August 2014.



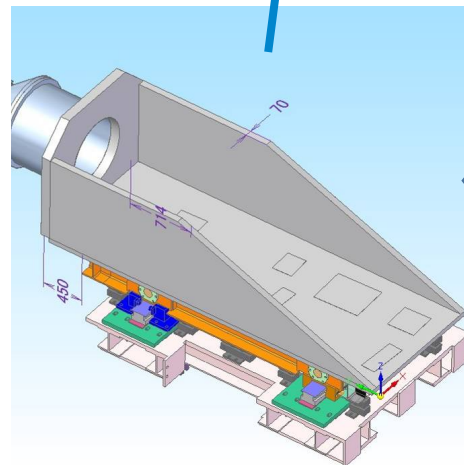


# IR status – Accelerator floor



The accelerator floor has been modified for the new QCS moving stages.  
The QCSL moving stage will be set on the floor in FY2013.

QCSR  
moving stage to be fabricated  
(dummy stage at Phase 1)



QCSL  
moving stage

Pictures by  
H. Yamaoka

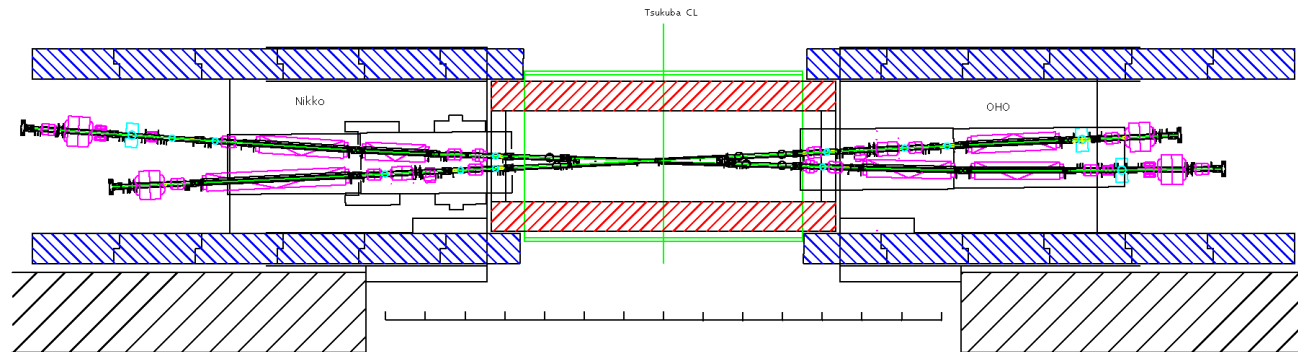


# IR status – Radiation shield

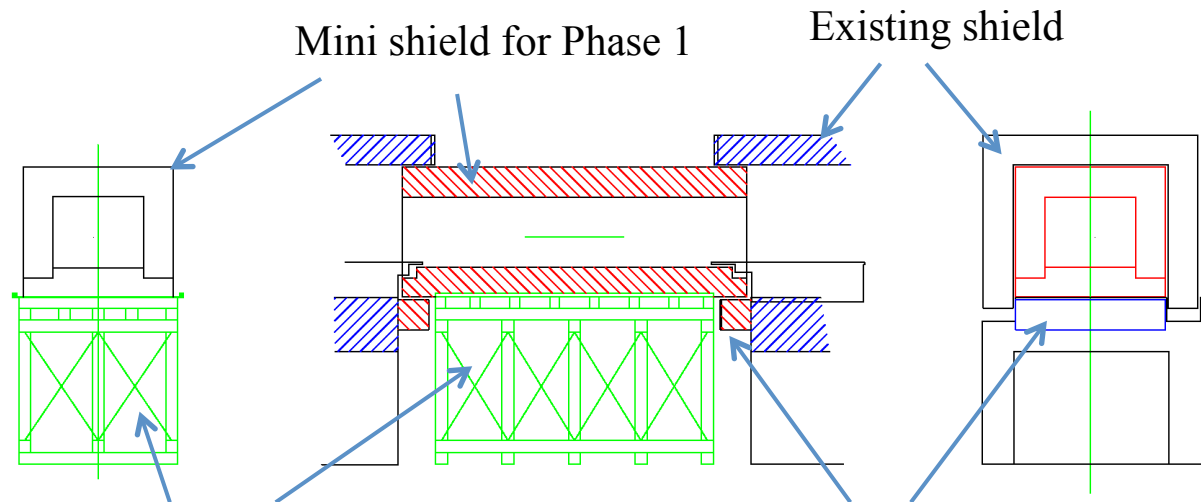


K. Kanazawa

A mini-shield for Phase 1 is going to be fabricated in Feb - Jun 2014.  
Installation of the mini shield and the shield support stage: ~Aug 2014



Phase 1  
IR



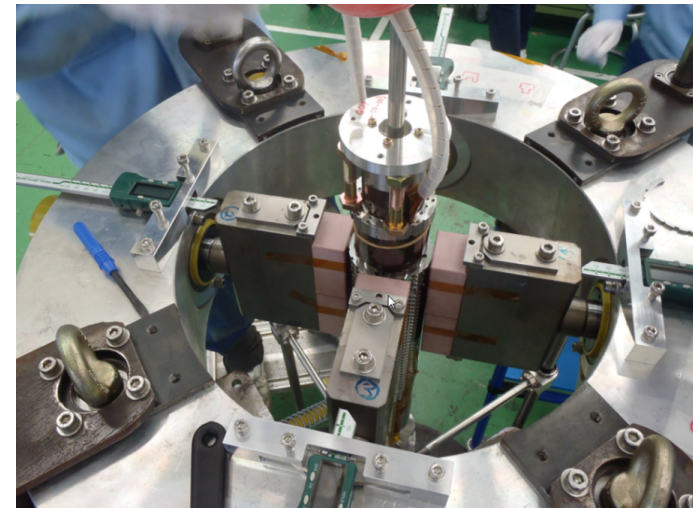
Shield support stage (re-use)    Additional shield to fill a floor gap (FY2013)



# IR Superconducting Magnet

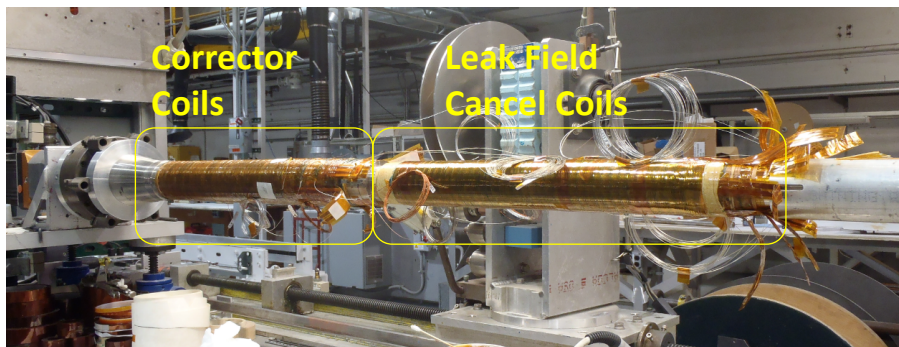


- **Left side magnets and cryostats**
  - will be completed by Dec. 2014. (original schedule was Dec. 2013.)
  - to be cold-tested in KEK before installation in beam line.
- **Right side magnets and cryostats**
  - main magnets will be completed in March.
  - collector coils windings at BNL started.
  - cryostats will be completed in Jul. 2015.
  - No time for cold-test before installation in beam line.

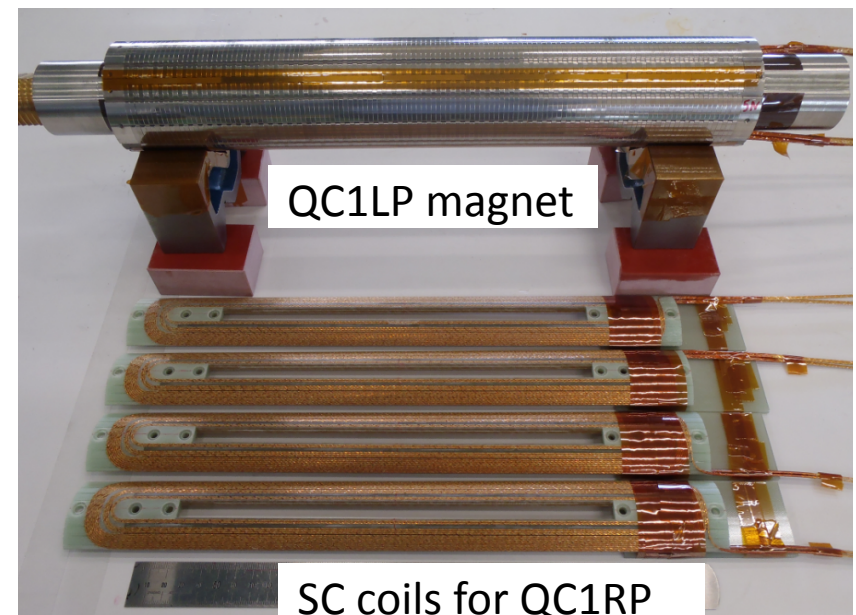


QC1LP collaring work at Mitsubishi Company

Details will be reported by Ohuchi-san.



QC1LE correctors coils in BNL at November 2013

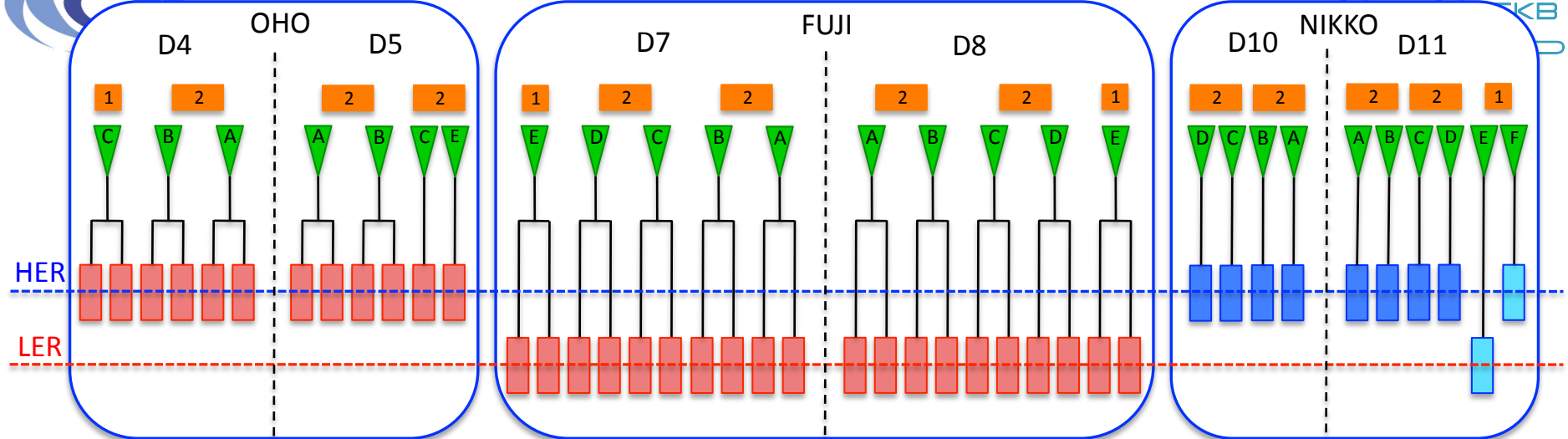


QC1LP magnet

SC coils for QC1RP

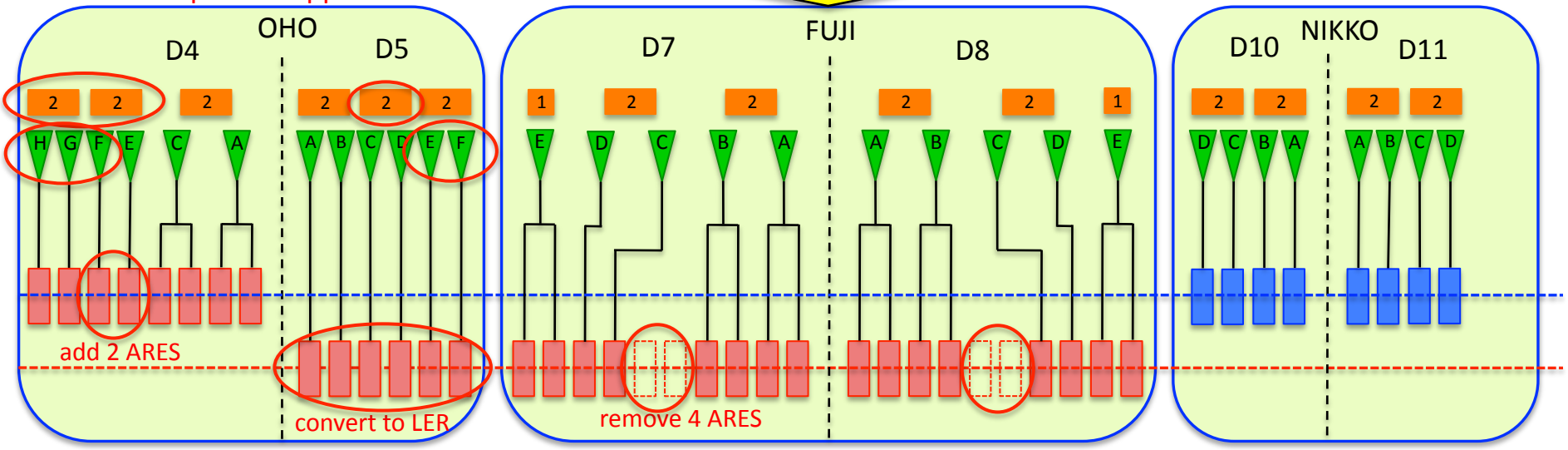


# KEKB-RF



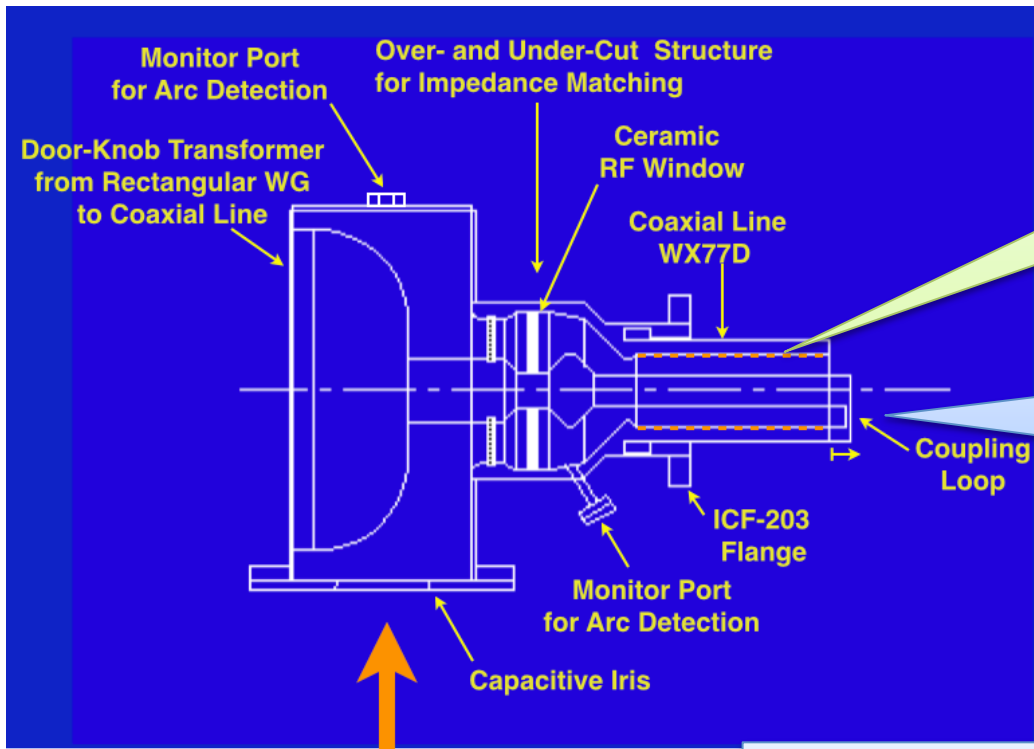
## SuperKEKB-RF (phase 1)

add 5 klystrons, HP&LL  
add 3 power supplies



- Klystron, HP&LLRF system
- 2 Type "A" power supply (for two klystrons)
- ARES cavity
- SC cavity
- SC crab
- 1 Type "B" power supply (for one klystron)

# ARES Cavity System / Input Coupler / Performance Upgrade



Fine grooving inside the outer conductor of the coaxial line to suppress multipactoring discharge.

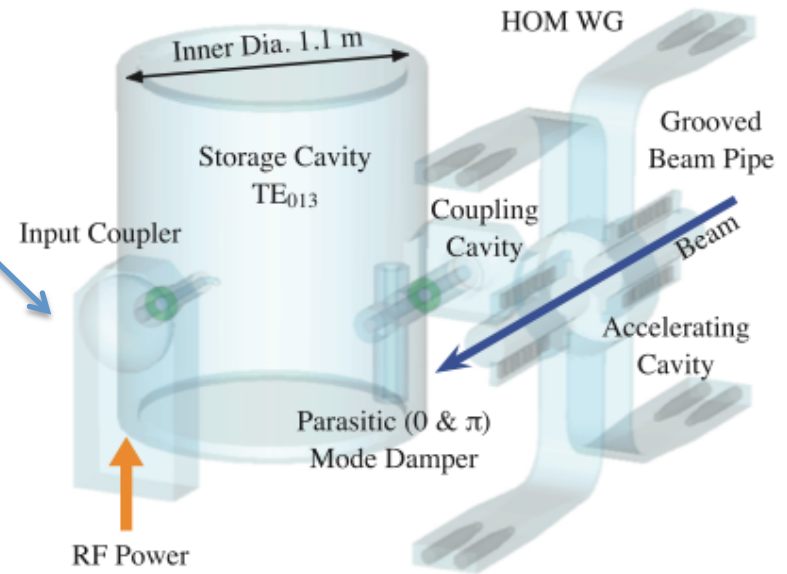
The coupling loop is extended to increase the input coupling factor.

The optimum input coupling factor  $\beta_{opt}$  is given by  $\beta_{opt} = 1 + P_{beam}/P_c$ .

**Power Handling Capability (Spec.)**

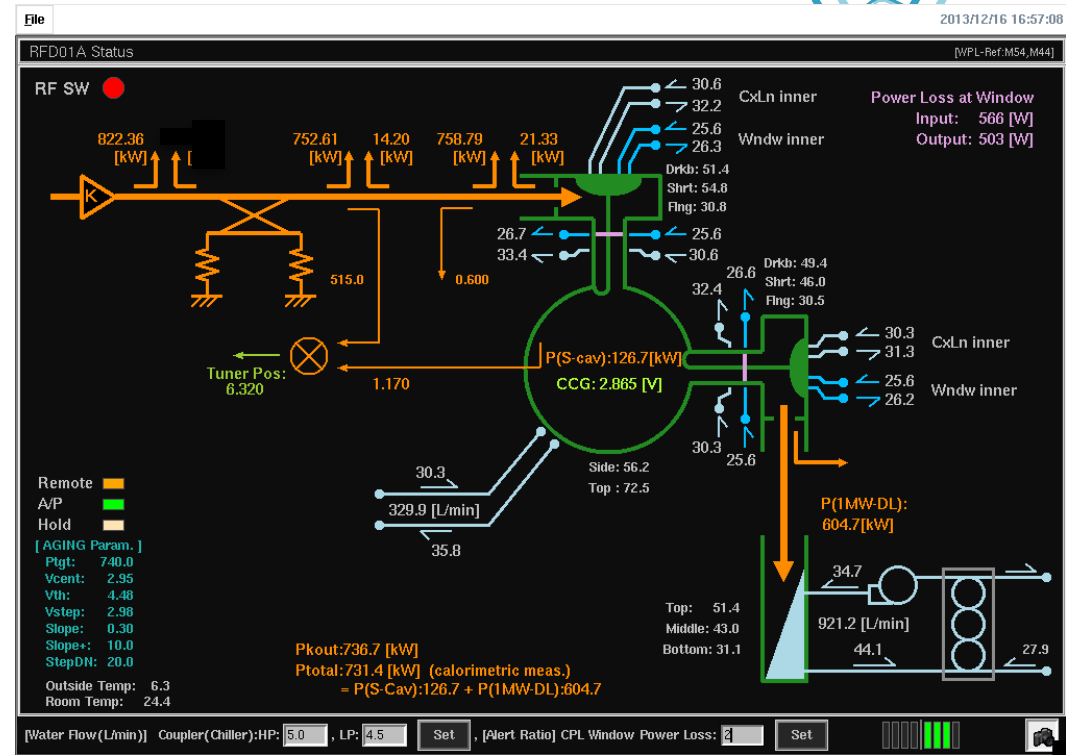
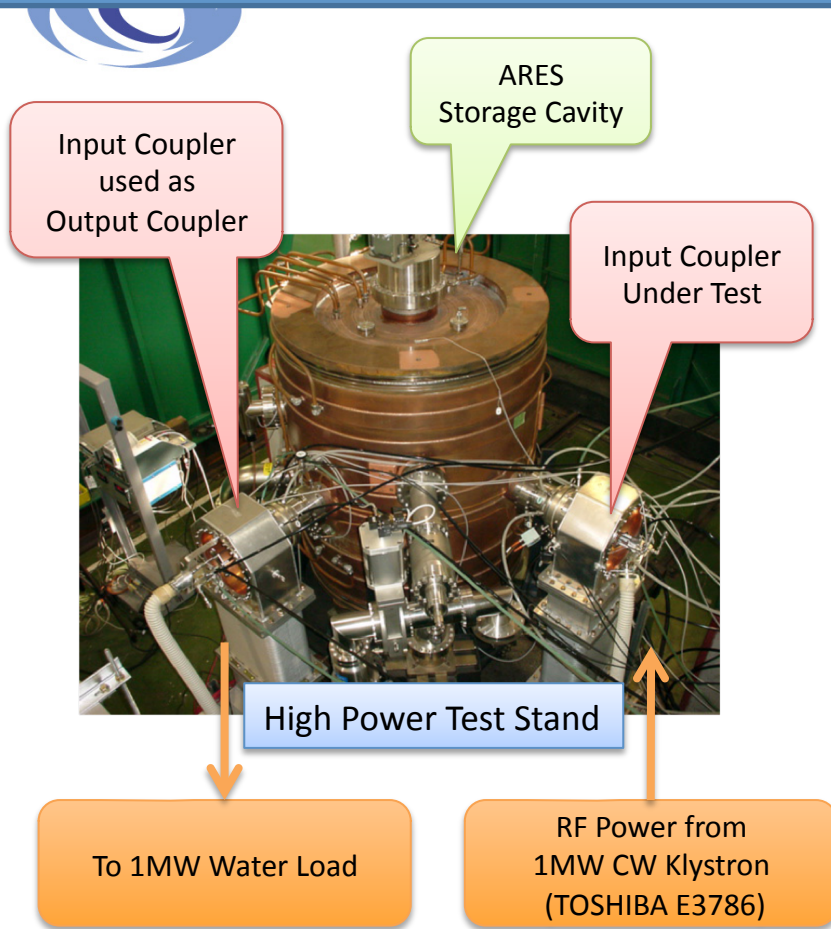
	$P_{input}$	$P_c$	$P_{beam}$
SuperKEKB	: 750 kW	= 150 kW +	600 kW
KEKB	: 350 kW	= 150 kW +	200 kW

$P_c = 150$  kW generating  $V_c = 0.5$  MV per ARES cavity.



3D Transparent View of ARES Cavity System

# ARES Cavity System / Input Coupler / Production & Processing



Snapshot of Status Monitor for RF Processing

T. Kageyama et al.

## Status & Plans

- So far, 10 couplers have been processed up to 750-800 kW.
- By the end of this April, 4 more couplers are going to be processed.
- In 2014, 10-14 out of 30 couplers existing in the MR tunnel will be replaced with new ones, and the ARES cavities will be all set for "T = 0".

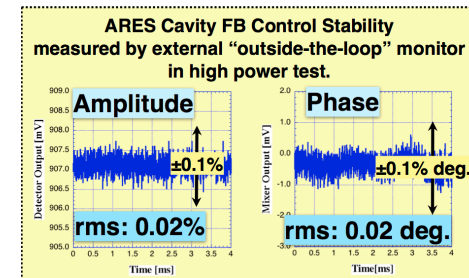
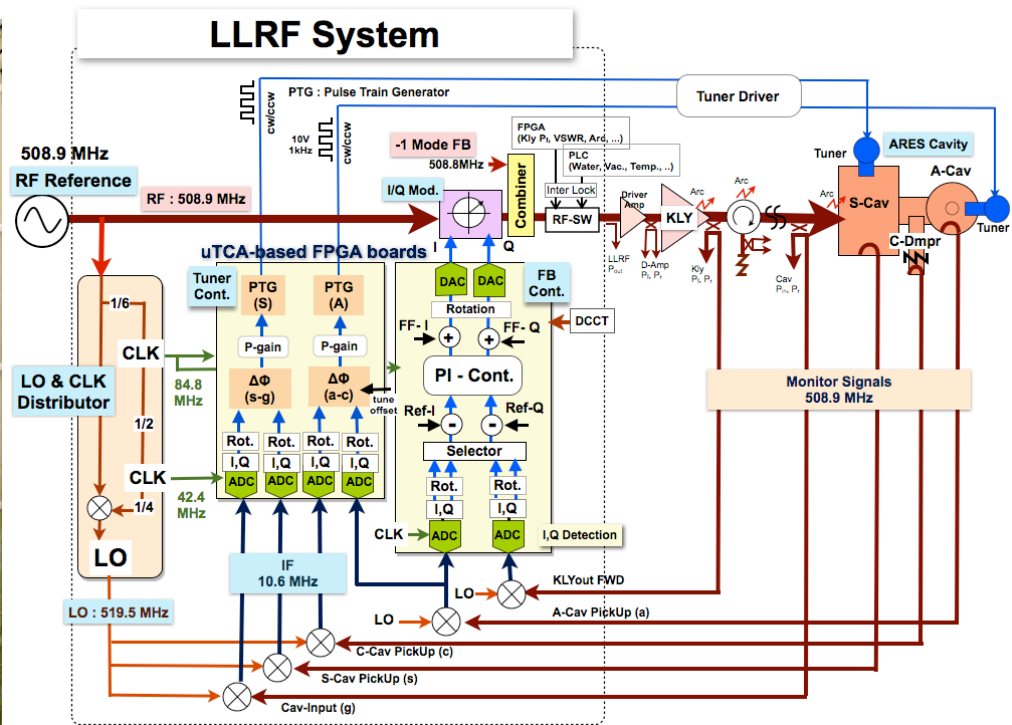
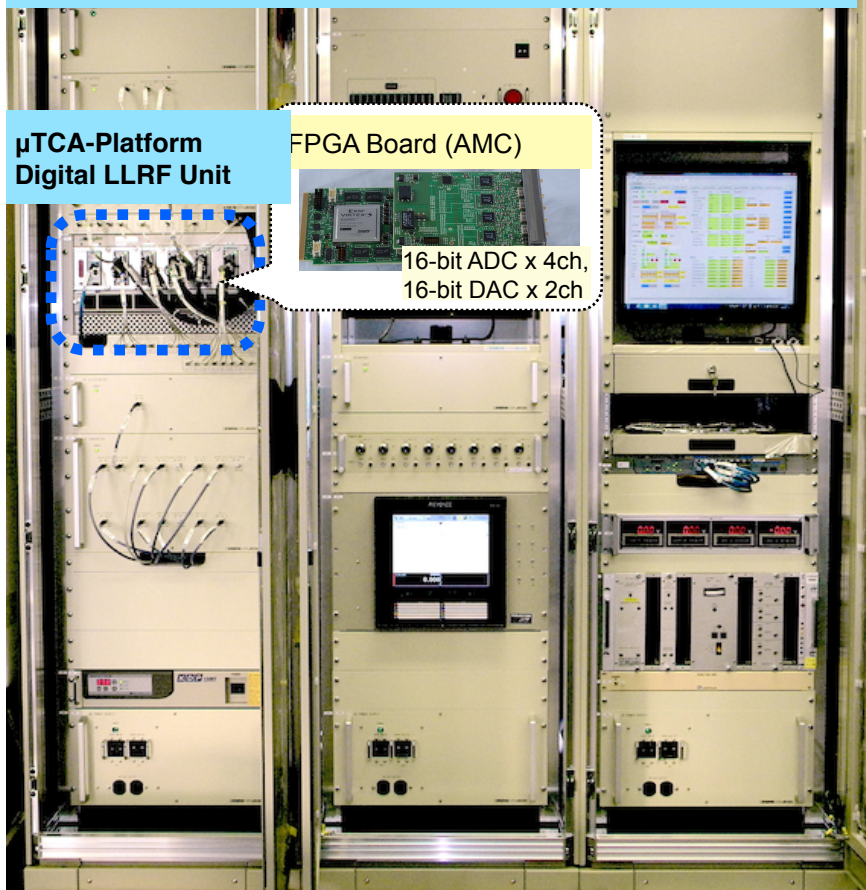


# New LLRF control system



- A digital LLRF control system, which is dominated by  $\mu$ TCA-platformed FPGA boards, has been developed for higher accuracy and flexibility, and many improvements were applied for SuperKEKB.
- Now the quantity production of 8 systems is in progress. Six of them will be installed in D5 in March and two in D4 in June.

## LLRF Control System for SuperKEKB





# New LLRF reference distribution

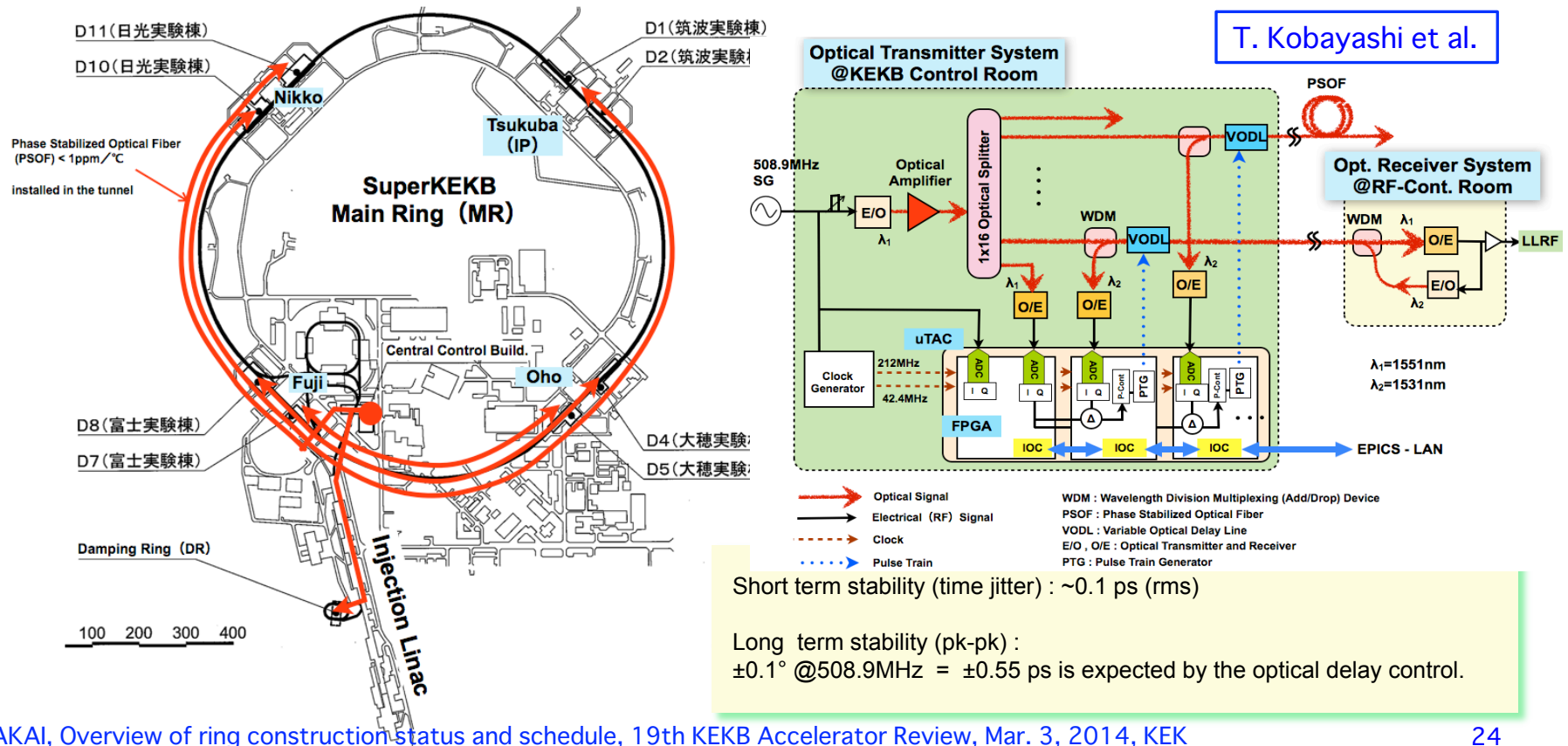


## Features

- Optical distribution by means of “Star” configuration from the central control room (CCR).
- “Phase Stabilized Optical Fiber (PSOF)”, which has small thermal coefficient, is adapted :  $< 1 \text{ ppm}/^\circ\text{C}$  ( $5 \text{ ps}/\text{km}/^\circ\text{C}$ )
- Furthermore, optical delay control of thermal drift compensation is applied at CCR for all transfer lines.

## Status

- Installation of the PSOF cables to all RF sections and Tsukuba-B3 was completed.
- Optical transceivers and the drift compensation system will be install in this month.
- Connection into the electronics hut of the Belle-II and extension to the DR will be done this year (next JFY).



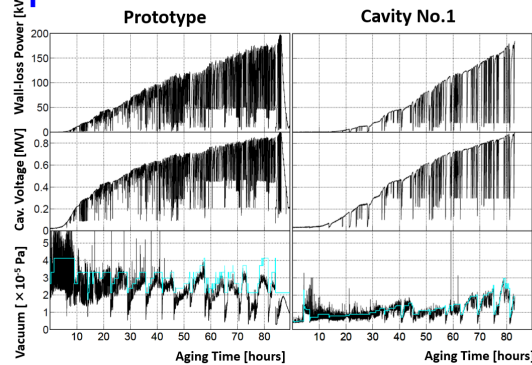




# RF cavity for Damping Ring



- DR Cavity #1 (1<sup>st</sup> Production Version) has passed the High Power Test (HPT) up to  $V_c=0.95\text{MV/cav}$  over the Spec.:  $0.8\text{MV/cav}$ .

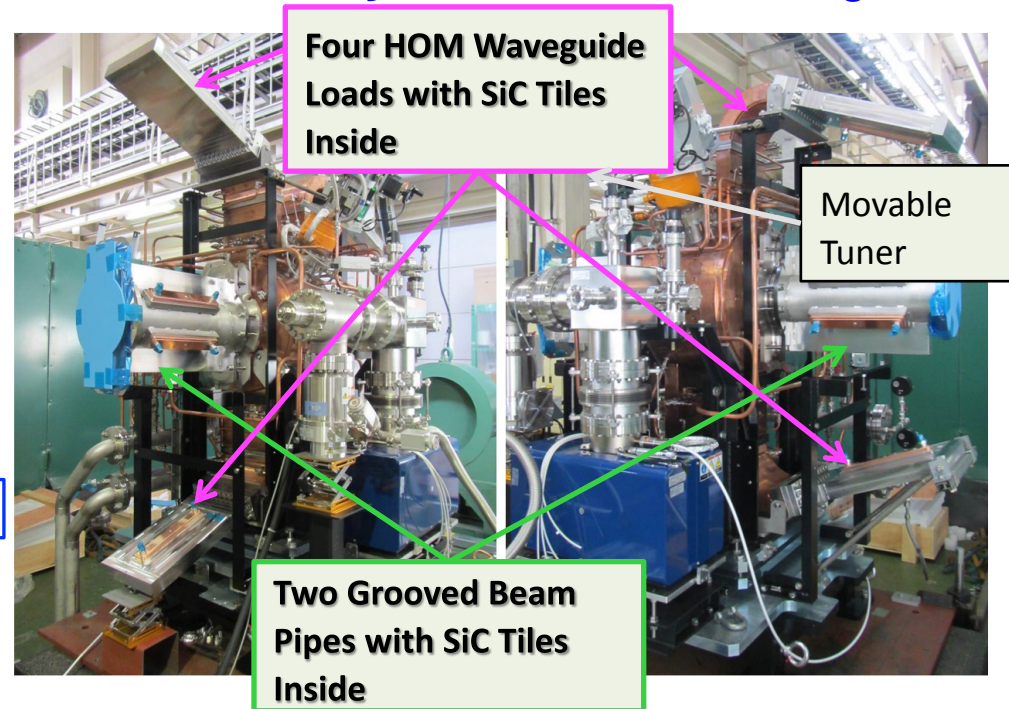


T. Abe et al.

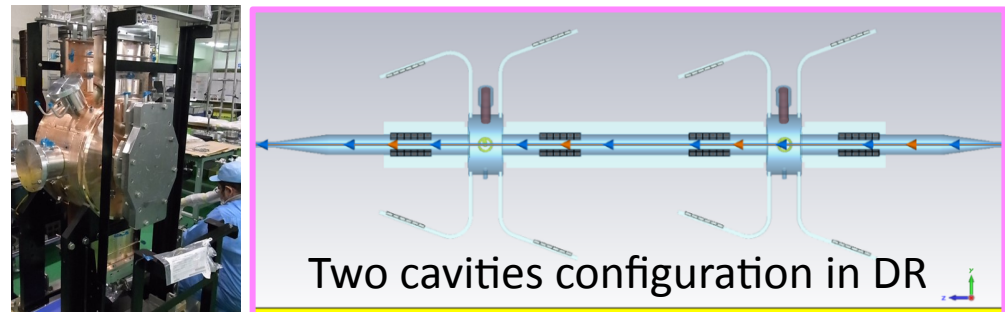
## $V_c$ -Holding Endurance Test

$V_c$ [MV/cav]	Wall-loss Power [kW]	Total Holding Time [hours]	Number of Trips
0.80	144	30.5	1
0.85	164	18	0
0.90	186	14.5	3
<b>0.95</b>	<b>210</b>	<b>8</b>	<b>1</b>

- Mounting test has been performed successfully with vacuum sealing.



- DR #2 cavity is in fabrication this FY.





# Beam Monitor System



- **Beam Position Monitors**

- All button electrodes have been fabricated and partly installed in the tunnel.
- A hundred twenty 508 MHz narrowband detectors will be delivered by this March.
- Gated turn-by-turn detectors are being fabricated. 117 units will be available by phase 1 commissioning.
- R&D of IP orbit feedback system is in progress. A down-converter for signal detection has completed.

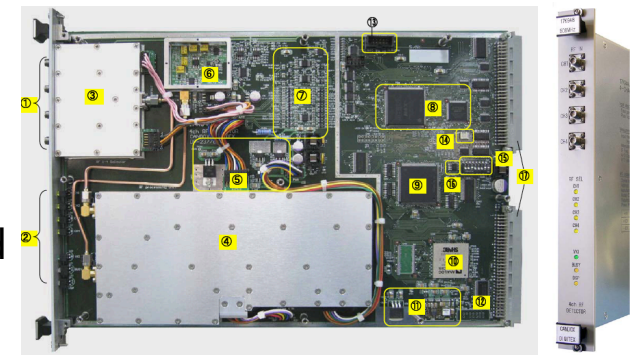
- **Bunch-by-bunch Feedback System**

- Transverse kickers, button electrodes, power cables and power amplifiers have been installed.
- LER longitudinal kickers have been ordered and will be installed in August 2014.

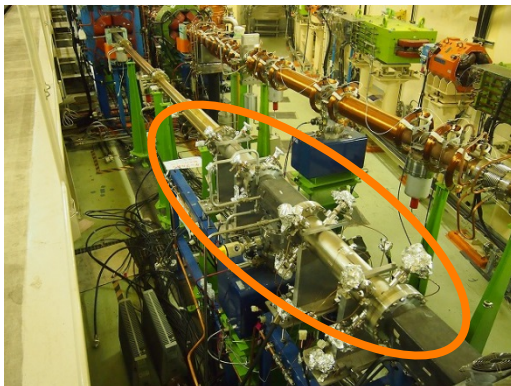
Button electrode



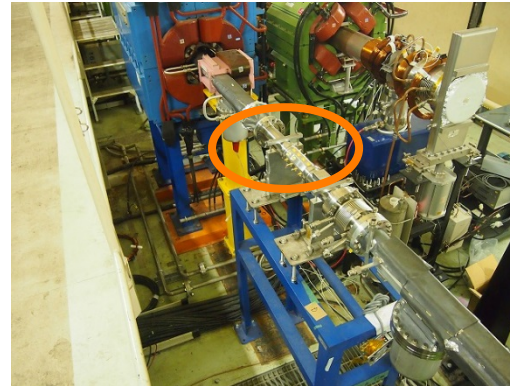
508MHz narrowband detector



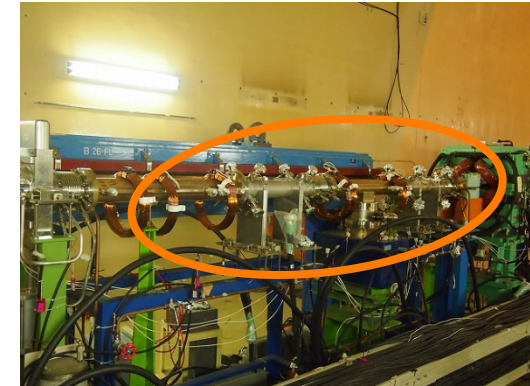
HER transverse kicker



HER button electrode



LER transverse kicker

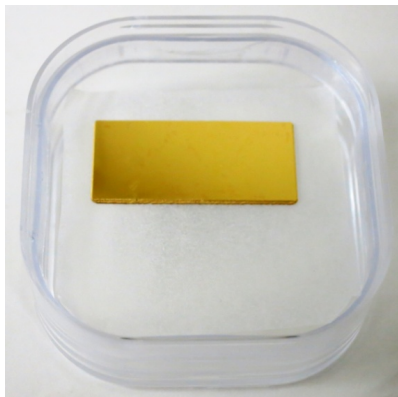




# Beam Monitor (cont'd)



- Photon Monitors
  - 1) Visible light monitors (horizontal and longitudinal size measurements)
    - Design of the mirror, the holder and the chamber have been finalized.
    - Fabrication of the mirrors and the holders will finish in this FY.
  - 2) X-ray monitors (vertical size measurements)
    - Beam line design have been finalized.
    - Under fabrication are downstream section of beam line vacuum components, high-efficiency pixel detectors and 64-channel readout system.
  - 3) Large-Angle Beamstrahlung Monitor (collision size/position offsets monitor)
    - Design of the extraction chamber has been finalized.
    - Optics boxes, optical-transfer-line components and extraction mirrors are being fabricated.



Diamond mirror for visible light monitors



64-channel readout system for x-ray monitors



Optics box and extraction mirror for LABM





# Replacing pipes around the ring for reinforcing cooling system -> completed



Adopted sliding pipes method to minimize the number of magnets to be moved.





# New Damping Ring for positrons



## DR tunnel construction

Jun. 2012



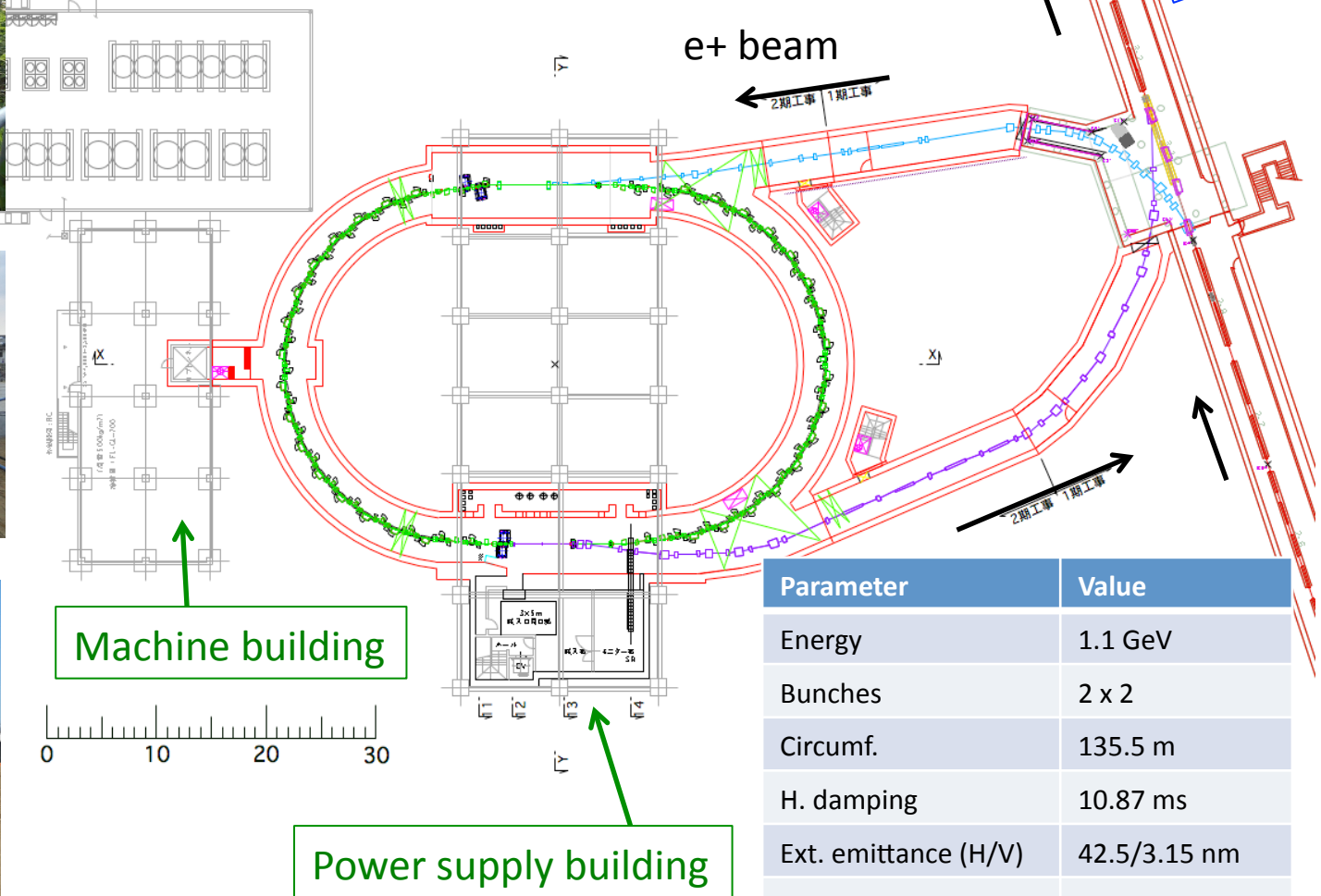
Dec. 2012



Mar. 2013  
Completed



- Fabrication of accelerator components ongoing.
- Installation will start in FY2014.
- DR commissioning will start in 2015.



Parameter	Value
Energy	1.1 GeV
Bunches	2 x 2
Circumf.	135.5 m
H. damping	10.87 ms
Ext. emittance (H/V)	42.5/3.15 nm
Max. current	70.8 mA

- **Magnets**
  - Fabrication of most of magnets and power supplies have completed.
  - Field measurement is ongoing.
  - Fabrication of sextupole magnets, H-steering magnets, some of power supplies on going in JFY2013.
- **Vacuum system**
  - Regular beam pipes of the ring were already fabricated.
  - Septum, SR monitor chambers, NEG and ion pumps will be ordered in JFY2014.
- **RF system**
  - #1 cavity has been high-power tested successfully.
  - #2 cavity fabrication ongoing in JFY2013.
  - Low-Level and High Power RF system to be constructed after buildings completed.
- **Monitors**
  - Most hardware components are ready for installation (BPM, FB, SRM, etc.).
  - To be prepared in FY2014 are electronics for beam loss monitors, signal cables and air-conditioned racks.
- **Injection system**
  - Kickers and power supplies will be ordered in JFY2014.
- **Control and timing system**



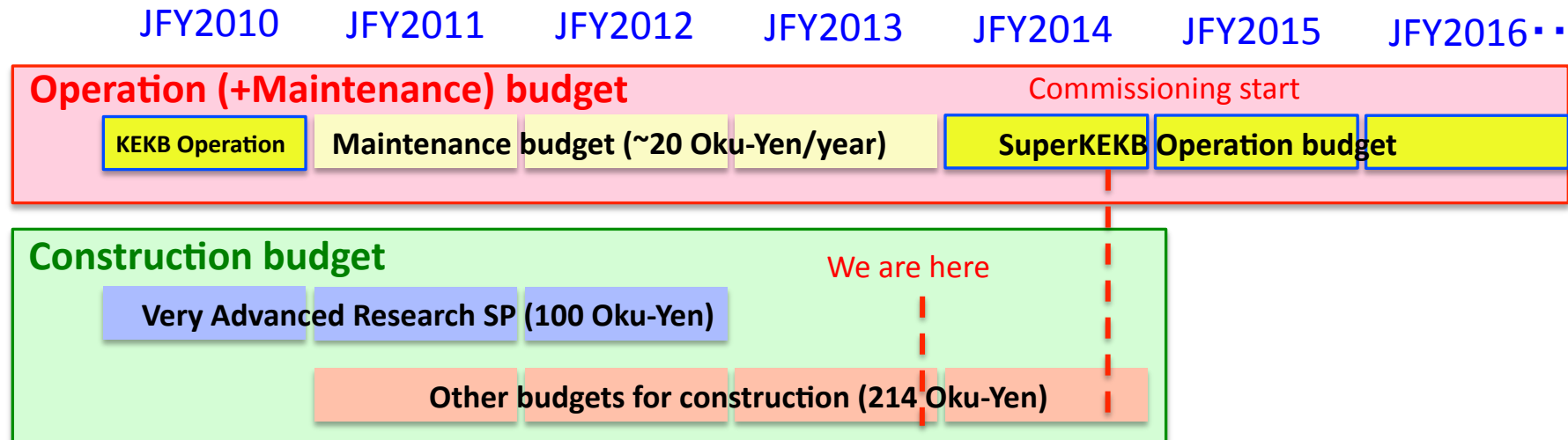
# Budget, Schedule and HR



# Budget



- Total construction budget is 314 Oku-Yen for Rings, Injector, and Belle-II.
- Most of the budget comes year by year-based.



**Construction budget** Unit: Oku-Yen (~1.1M\$)

	JFY2010	JFY2011	JFY2012	JFY2013	JFY2014	Total
VARSP	75.0	10.5	14.5	0	0	100.0
Others	0	41.6	40.2	61.6	46.7	190.0
Buildings	0	4.5	12.4	7.2	0	24.1
<b>Total</b>	<b>75.0</b>	<b>56.6</b>	<b>67.1</b>	<b>68.8</b>	<b>46.7</b>	<b>314.1</b>
<b>Status</b>	Supplied	Supplied	Supplied	see, next page	see, next page	





# Budget situation in JFY2013-14



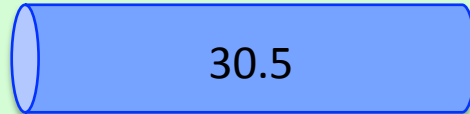
## Construction budget

unit: Oku-yen (~1.1M\$)

Shisetsu-seibi-hi  
(facilities expense)

Budget for buildings is not included.

JFY2013



30.5  
appropriated

JFY2014

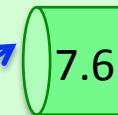


37.6  
to be appropriated

B project (construction)  
for rings, Linac and Belle-II

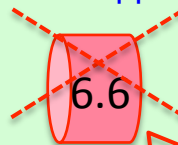


24.5  
appropriated as JFY2012 supplementary budget.

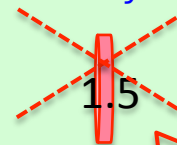


7.6

KEK burden, etc.



6.6  
not appropriated



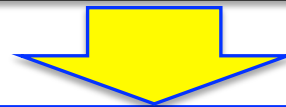
1.5  
probably missing

**Last ARC in Mar. 2013**

not appropriated

probably missing

(KEK budget is being reduced year by year.)



KEK management promised to supply remaining KEK burden of 8.1 Oku-Yen.  
(6.1 Oku-Yen in FY2014 and 2.0 Oku-Yen in FY2015)

Then, planned construction budget will be fully supplied. This is good news, but . . .



# Operation budget issue



- **Deep cut in JFY2014 operation budget**
  - Only 25.0 Oku-Yen was appropriated, much lower than 36.9 Oku-Yen that has once been sent from MEXT in the request for budgetary appropriations.
- **The B project operation/maintenance budget during construction period was 20.0 Oku-Yen/year. This is annually used for:**
  - Electricity charges for Linac operation, facility and infrastructure
  - Operators for Linac, AR, BT, control, and refrigerator
  - Computer lease fee
  - Radiation safety (subcontracting)
  - Facility and infrastructure (subcontracting)
  - Minimum maintenance of KEKB, Linac and Belle
  - Minimum electricity charges during shut down of KEKB
- **In addition to the annual maintenance, 17 Oku-Yen was requested to conduct beam operation from 2015 January to March. A part of this is needed before beam operation starts:**
  - Electricity charges for high power RF conditioning, magnet system adjustment with high power operation, test operation of Nikko refrigerator and Belle solenoid, etc.
  - Additional cost for operators and various subcontractings.



# Impact on schedule



- The impact of the operation budget cut in JFY2014 on schedule:
  - Unable to start beam operation in JFY2014 unless additional budget of at least 10 Oku-Yen that could be used for electricity charges comes.
  - Test operation of the refrigerator and Belle solenoid could be done in this FY. Also it is possible to start RF conditioning, magnet system adjustment with high power, etc.
  - With this budget, possible situation at the end of JFY2014 would be that construction is done and starting up of machine components started, but beam operation is not started.
- Effort is being made in high level people to recover the budget cut.
- Urgent needs:
  - It takes 3 - 4 months to make contracts. Procedure for major contracts for JFY2014 already started. This can be proceeded only within available budget.
- In case no budget recovery:
  - Possible plans to meet the reduced budget are being discussed in accelerator group. An example will be shown next.

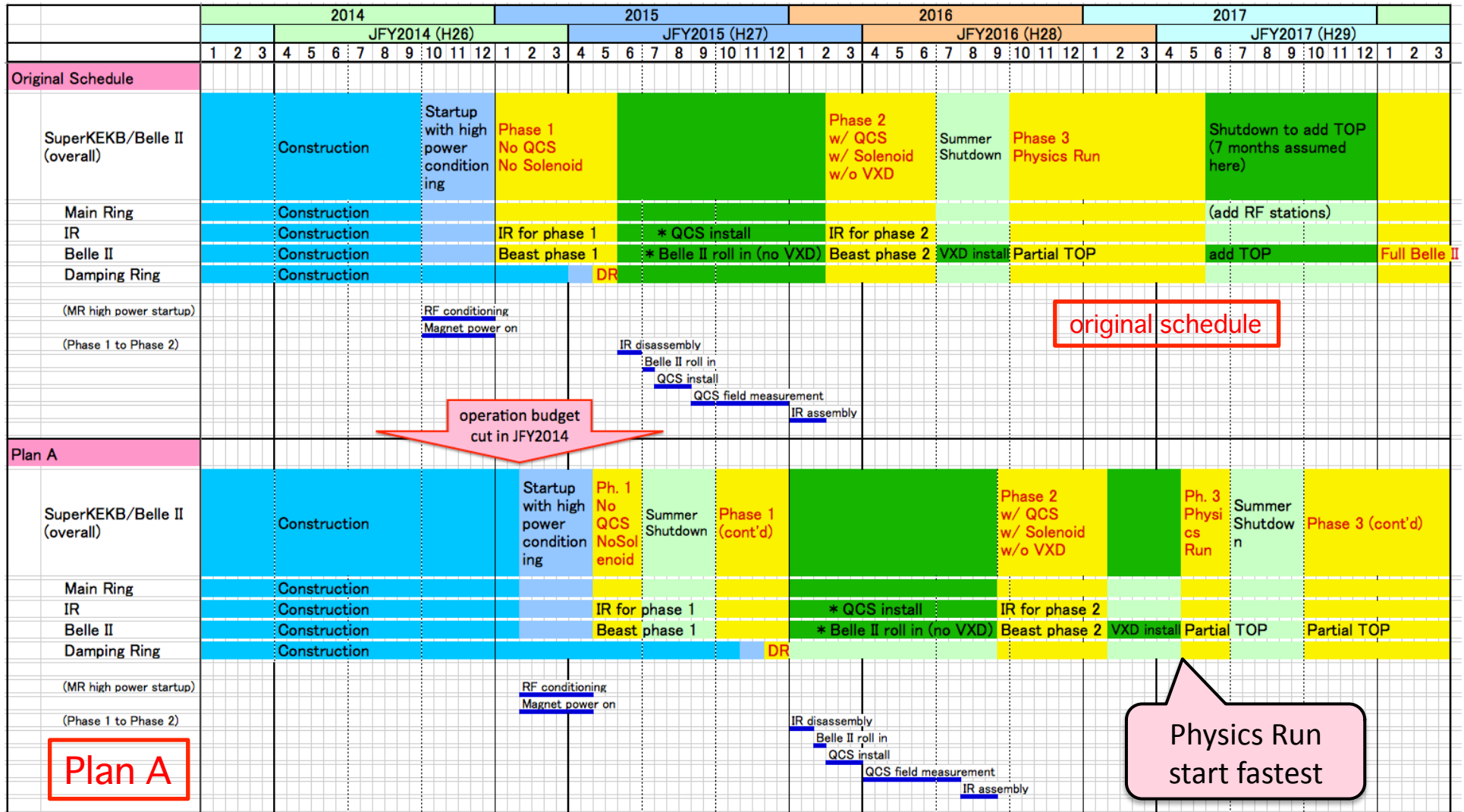


	2014												2015												2016												2017																													
	JFY2014 (H26)												JFY2015 (H27)												JFY2016 (H28)												JFY2017 (H29)																													
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3															
Original Schedule																																																																		
SuperKEKB/Belle II (overall)	Construction												Startup with high power conditioning			Phase 1 No QCS No Solenoid									Phase 2 w/ QCS w/ Solenoid w/o VXD			Summer Shutdown			Phase 3 Physics Run						Shutdown to add TOP (7 months assumed here)																													
Main Ring	Construction																														(add RF stations)																																			
IR	Construction												IR for phase 1			* QCS install						IR for phase 2																																												
Belle II	Construction												Beast phase 1			* Belle II roll in (no VXD)						Beast phase 2			VXD install			Partial TOP						add TOP			Full Belle II																													
Damping Ring	Construction															DR																																																		
(MR high power startup)													RF conditioning Magnet power on																																																					
(Phase 1 to Phase 2)																IR disassembly			Belle II roll in			QCS install			QCS field measurement			IR assembly																																						

original schedule



# A possible plan in case no recovery of budget.





# Human Resources (KEK staff)



## 17th ARC in Feb. 2012

Date	Status	Needed FTE	Available FTE (permanent staff)
Dec. 2010	under construction	77	56
Apr. 2011	under construction	77	60
Apr. 2012	under construction	77	62

## Change in two years (2012 – 2014)

	New (FTE increase)	Retire(1) (FTE decrease)	Retire(2) (same FTE counted here)	tenure to permanent (same FTE counted here)	Change of FTE	Remarks
Apr. 2012	+3	-2	2	2	+1	One of the new staff came from other project
Jul. 2012	+2				+2	
Apr. 2013	+1		3.5	2	+1	
Apr. 2014	+2	-1	3	1	+1	
<b>Total change</b>					<b>+5</b>	<b>Slow, but steady improvement</b>



# Last ARC recommendation



- There are number of components which must be systematically checked for their impact on the impedance budget. It is recommended that a single person be assigned as the “impedance police” responsible for checking and controlling every component which has an impedance contribution to MR.



D. Zhou "Impedance issues" to be presented today



# Summary



- Construction is well ongoing.
  - We had various kinds of troubles (not reported here in detail), but they have been solved or mitigated not to make significant schedule delay.
  - As a whole, construction is on schedule so far to start Phase 1 commissioning in 2015.
- A serious issue is operation budget cut in JFY2014.
  - We are considering possible plans to meet the situation.
- As for HR shortage, we had slow, but steady improvement since construction started in 2010.