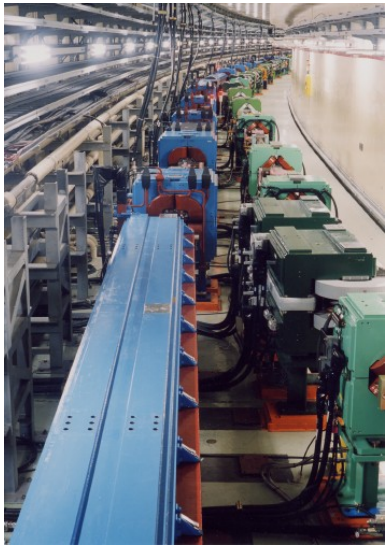
Overview of Ring Construction Status and Schedule

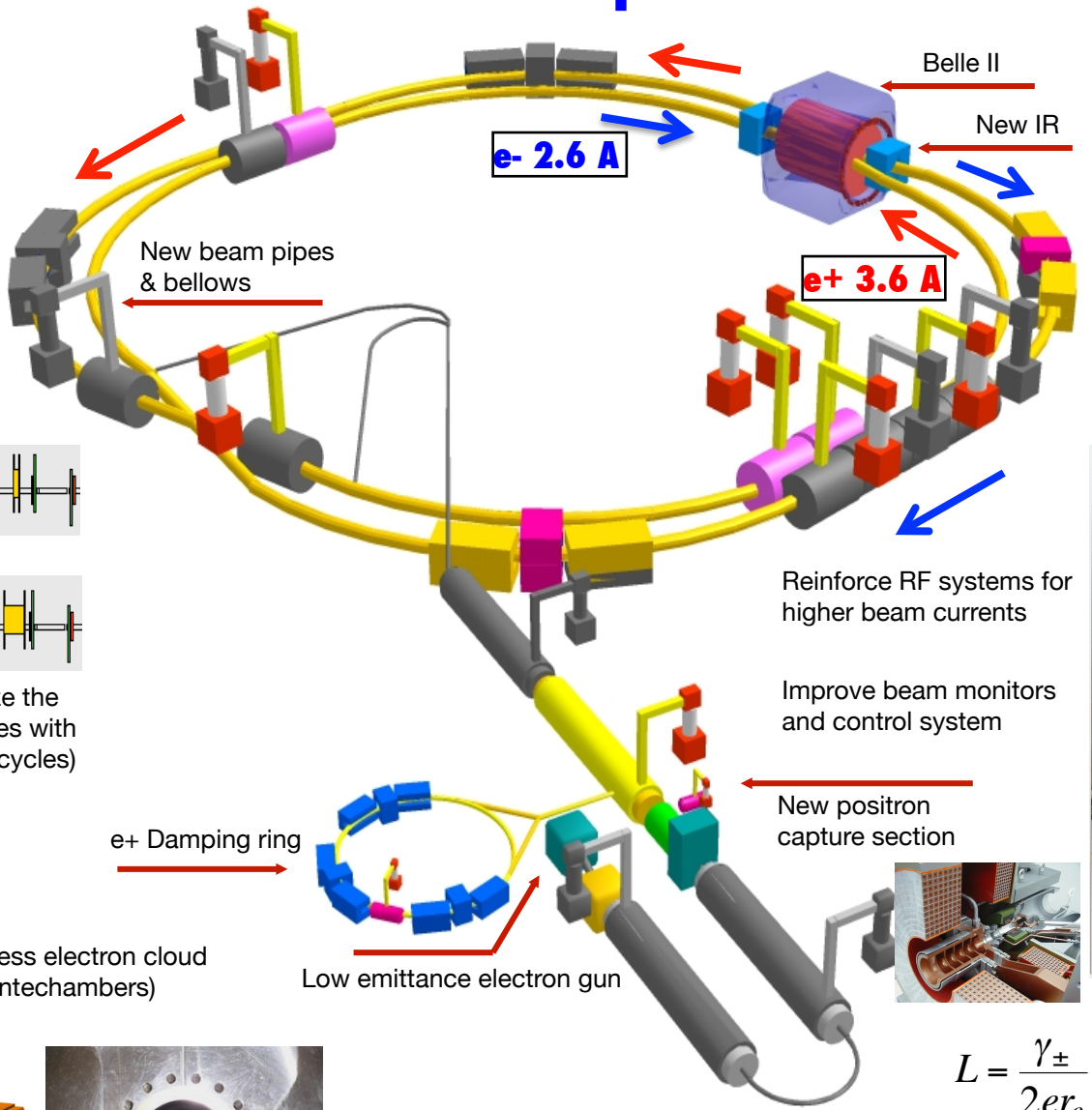
Kazunori AKAI

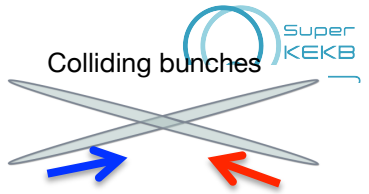
March 4, 2013

18th KEKB Accelerator Review Committee

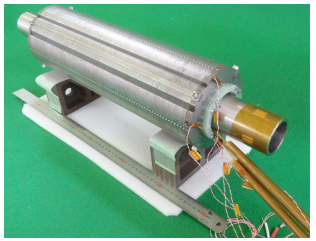
KEKB to SuperKEKB

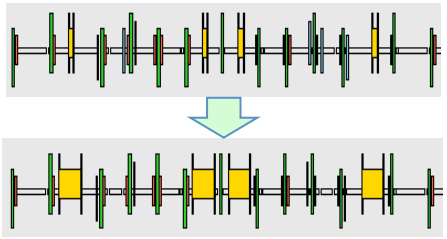




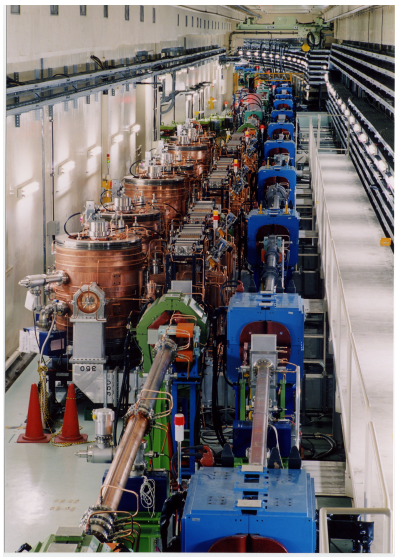


New superconducting final focusing magnets near the IP

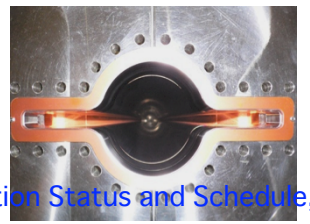




Redesign the lattice to squeeze the emittance (replace short dipoles with longer ones, increase wiggler cycles)



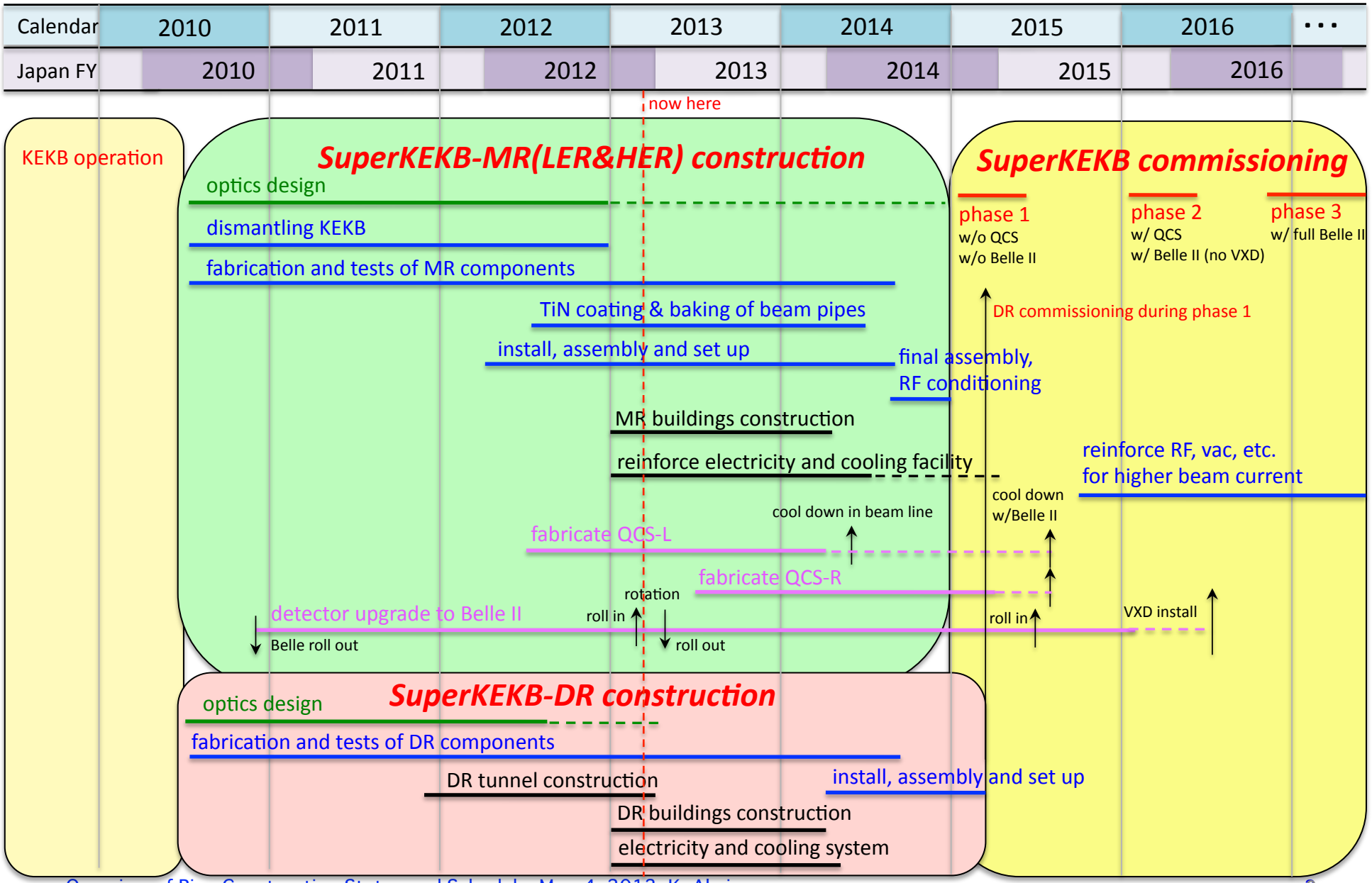
Replace beam pipes to suppress electron cloud (TiN-coated beam pipe with antechambers)



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

To get x40 higher luminosity

SuperKEKB rings master schedule

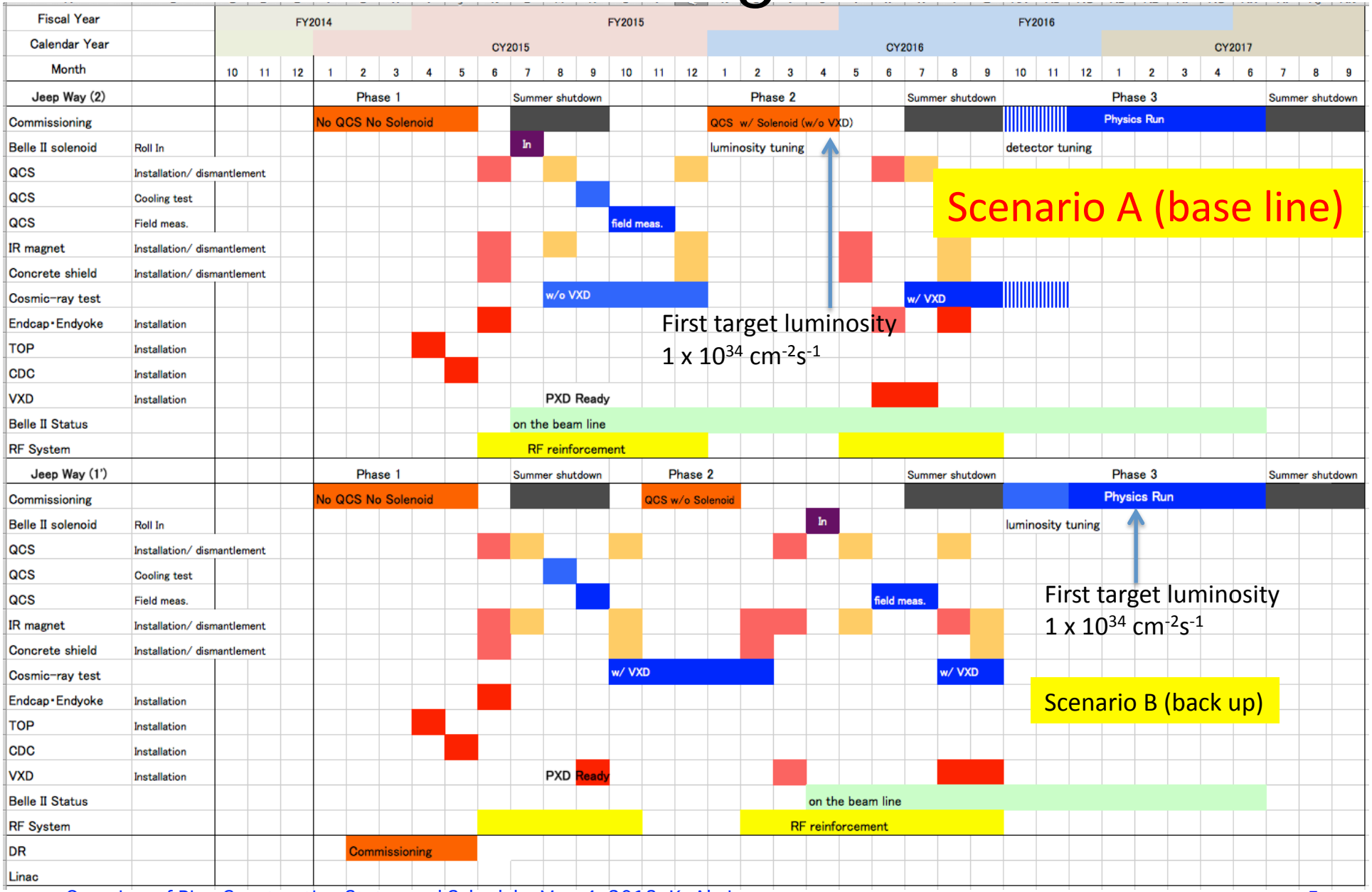


Commissioning Scenario

- Commissioning will be performed in three phases.
  - Phase 1: w/o QCS, w/o Belle II
    - basic machine tuning
    - low emittance beam 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 0.5~1A.
    - DR commissioning
  - Phase 2: with QCS and Belle II, but no VXD
    - low beta* beam tuning
    - small x-y coupling tuning
    - collision tuning
    - study beam background
      - Belle II people want to carefully check beam background before VXD installation.
  - Phase 3: with QCS and full Belle II
    - physics run
    - luminosity increase
- This scenario was agreed between KEKB and Belle II.

● We keep another scenario (scenario B in the next slide) as a back up in case of delay of Belle II construction.

Commissioning schedule

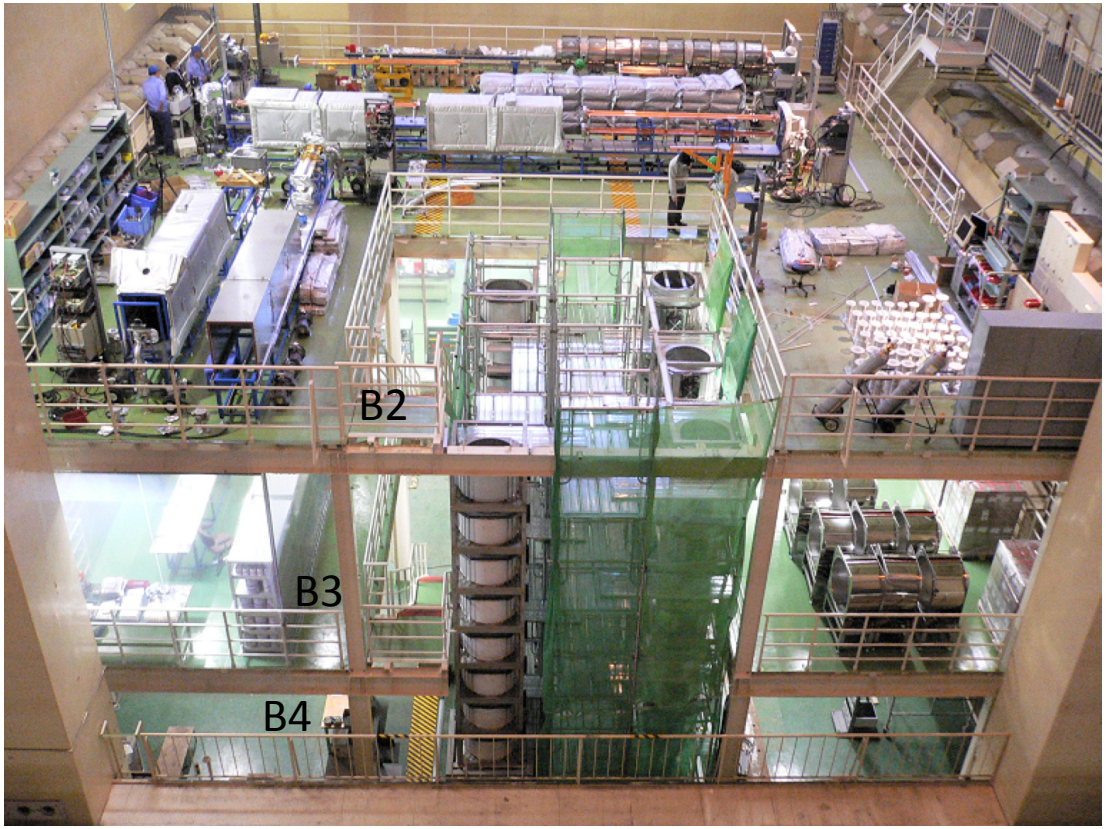


Fabrication status of beam pipes, etc.

Fabrication year	Ring, location	Material	Number	Length (m)
JFY2010	LER wiggler beam pipes	Cu	77	223
JFY2011	HER wiggler beam pipes	Cu	22	64
JFY2011	Chicane, wiggler downstream beam pipes	Cu	70	177
JFY2011	HER symmetry point beam pipes	Cu	24	35
JFY2011	LER RF straight section beam pipes	Cu	4	12
JFY2011	LER arc section bellows	Al	690	
JFY2010-11	Wiggler section and HER arc section bellows	Cu	259	
JFY2011	LER arc section gate valves		24	
JFY2011	LER arc section beam pipes	Al	687	1861
JFY2012 ongoing(+2013)	LER Tsukuba straight section bellows		135	
JFY2012 ongoing(+2013)	HER Tsukuba straight section bellows		135	
JFY2012 ongoing	LER Tsukuba straight section gate valves		7	
JFY2012 ongoing	HER Tsukuba straight section gate valves		6	
JFY2012 ongoing	DR arc section beam pipes	Al		
JFY2012 ongoing	LER arc skew sextupole beam pipes	Al		~ 32
JFY2013 scheduled	LER Tsukuba straight section beam pipes	Cu and Al		~ 330
JFY2013 scheduled	HER Tsukuba straight section beam pipes	Cu		~ 330
JFY2013 scheduled (+2014)	LER Fuji straight section beam pipes	Al or Cu		~ 30
JFY2013 scheduled (+2014)	HER Fuji straight section beam pipes	Al or Cu		~ 30
JFY2013 scheduled (+2014)	IR section beam pipes, collimators, SRM chambers			
JFY2013 scheduled (+2014)	DR straight section and transport line beam pipes	Al		

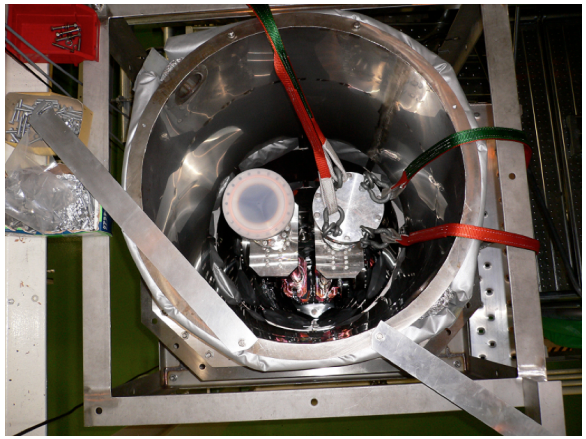
Beam pipes treatments

- Baking and TiN coating system have been constructed at Oho experimental hall in KEK. Treatment of beam pipes is well ongoing.
  - About 1000 beam pipes will be baked and TiN-coated in two years.



Vacuum group working deck in Oho exp. building
- Four baking systems operating on the upper floor (B2).
- Checking and preparation work on the middle floor (B3).
- Five vertical TiN coating systems from B4 to B2 through.

A part of beam pipes in a stock house

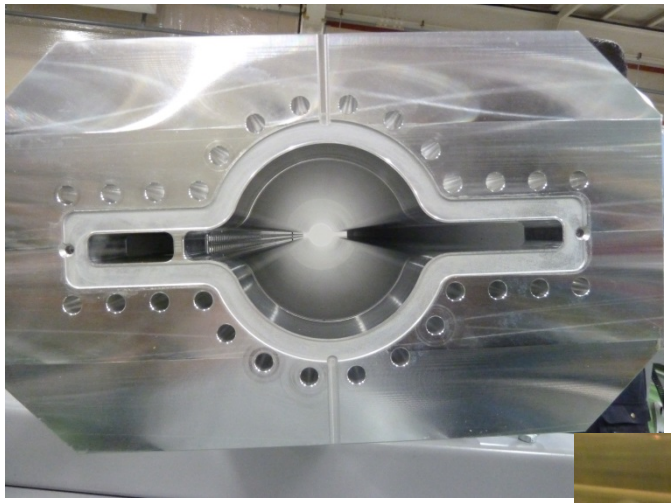


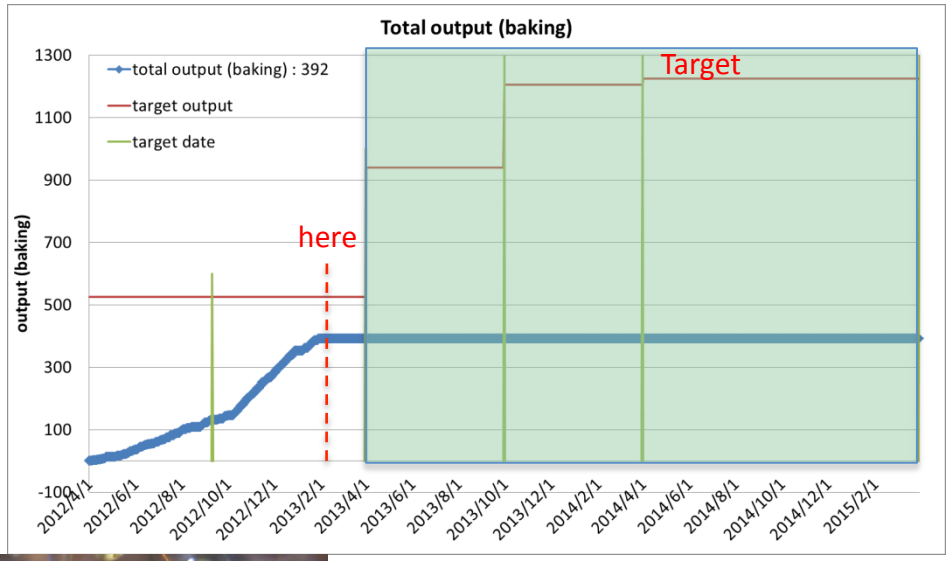
K. Shibata

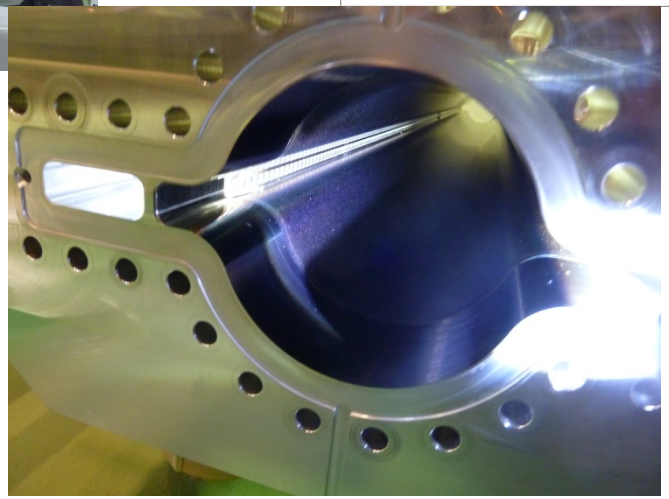
(upper): Inserting ante-chambers into a vertical TiN coating system. (lower): Top-side view of ante-chambers in two lines set in the coating system.

(upper and lower): Copper and Aluminum beam pipes after baking and TiN coating. They are temporary stocked in Oho B4 until moved to tunnel or other stock houses.

Al ante-chamber before coating





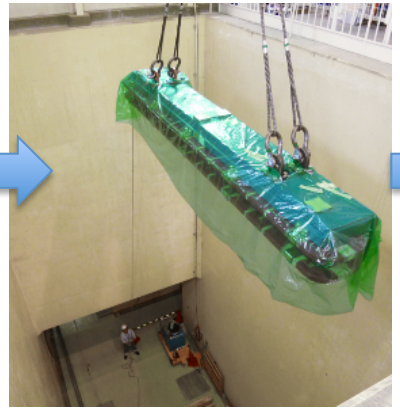


After TiN coating
before baking

After baking

100 new LER bend magnets installation completed

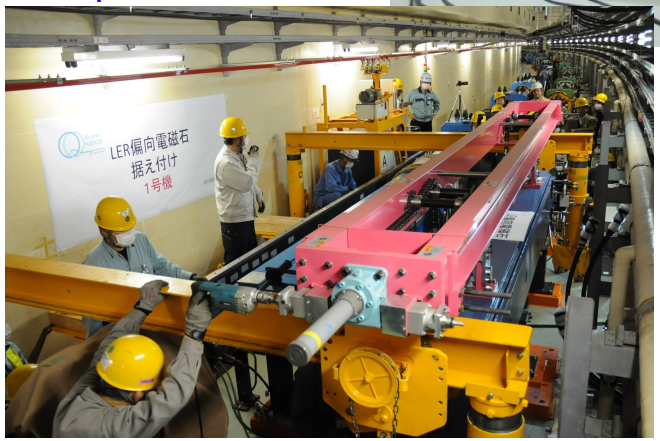
field measurement



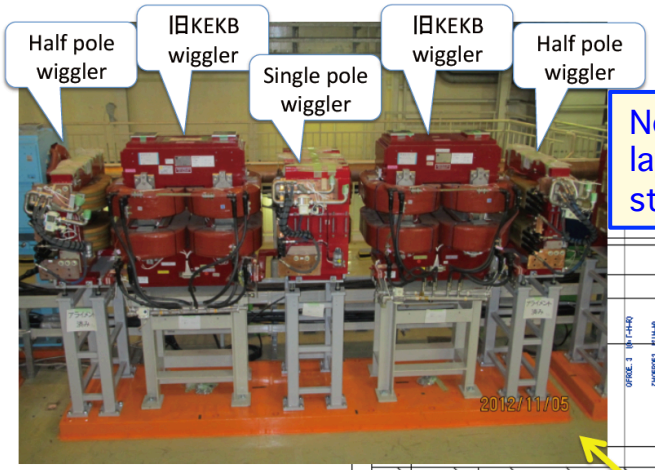
move into tunnel

carry on an air-pallet

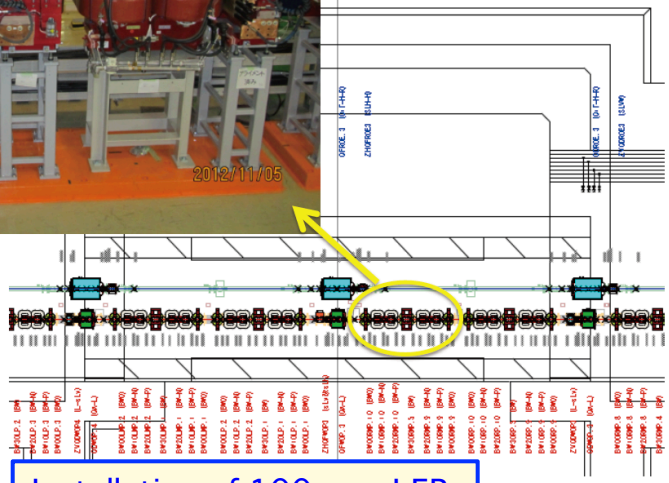
carry over existing HER dipole



install done



New LER wiggler layout in Oho D4 straight section



Installation of 100 new LER bending magnets done

Construction of new beam lines in Tsukuba straight section.

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

4m偏向電磁石100台

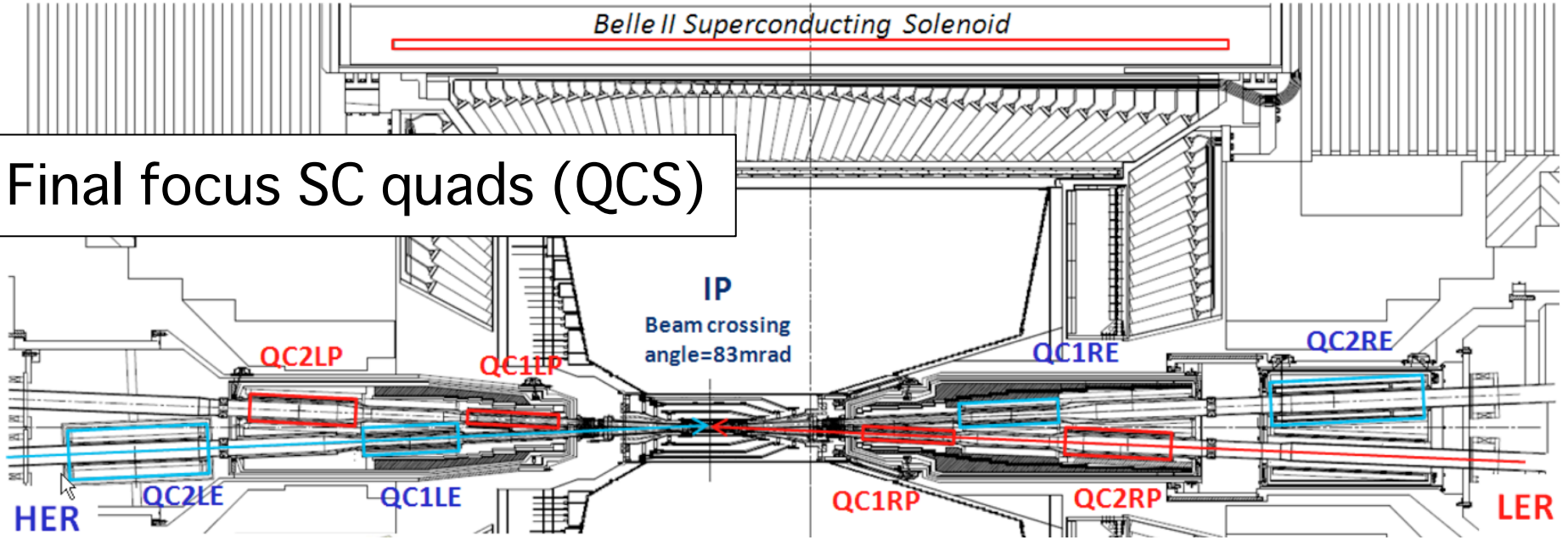
V-steering magnet

Wiggler sections

Installation of LER wiggler chambers in Nikko and Oho straight sections will be completed in March.

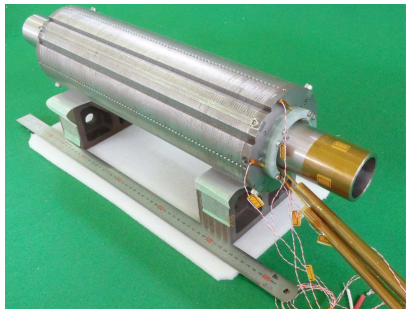
Installation of HER wiggler chambers in Oho straight section is done.

Final focus SC quads (QCS)



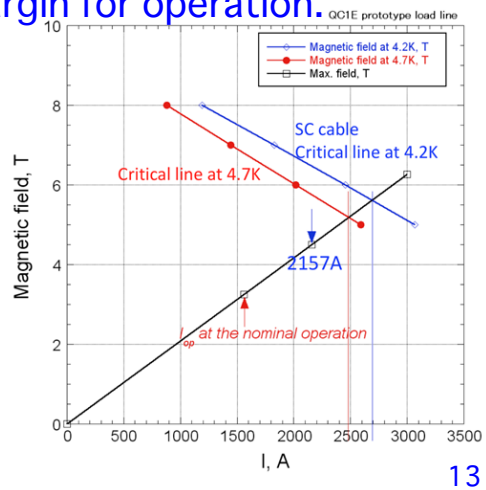
- Eight final focus QCS with 40 corrector coils are to be used.
- Fabrication of QCS-L started in July 2012, and will be completed in JFY2013.
- Fabrication of QCS-R is scheduled in JFY2013 and 2014.
- Corrector coils are being wound at BNL under BNL/KEK collaboration.
- Prototype magnet was made at KEK. Test results show sufficient margin for operation.

QC1LE prototype magnet



Successfully tested without any quench up to 2157A, well over the design current (1560A) for nominal operation.

$I_{4S}/I_{c@4.7K}$ = 62.8%
$I_{12GeV}/I_{c@4.7K}$ = 87.0%
Sufficient margin for operation

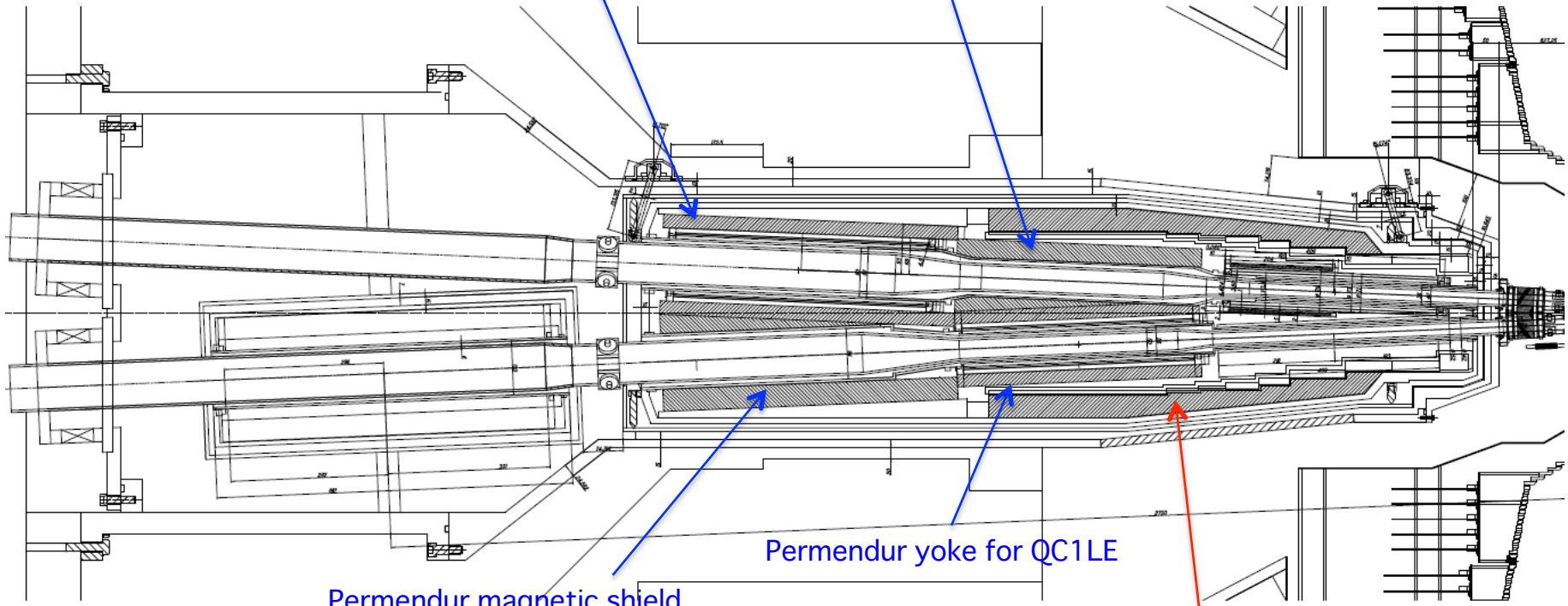


Design improvement of QCS since last ARC

- Radiation shield is implemented in the QCS cryostat to reduce background to Belle II.
  - It turned out that Radiative Bhabha scattering seriously deteriorates photo-multiplier of Belle II TOP detector: the life time reduces unacceptably (~1/20).
  - To solve the problem, more radiation shield is added. In particular, Tungsten alloy is used as a part of vacuum vessel of QCS for shielding.
- Permendur yokes and shields are adopted to reduce leak fields.
  - The yokes of QC1E and QC2P have the magnetic field from -0.5 T to 0.5T in the good canceling condition of Belle solenoid field by the accelerator SC solenoids. With 1% change in the Belle solenoid field, the magnetic field in the yokes reaches 1T.
  - In order to reduce leak field on the other beam, Permendur yokes and shields that have higher saturation field were adopted.
- Corrector coils
  - It was found that dynamic aperture is deteriorated by possible skew-sextupole component of QC1 field.
  - Corrector coils in QCS-R is being reconsidered to have sextupole cancellation. (No change can be made for QCS-L, which already started fabrication.)
- Optics design
  - IR optics design has been almost finalized so that fabrication of magnets and beam pipes in Tsukuba straight section can start in early JFY2013.

Permendur yoke for QC2LP

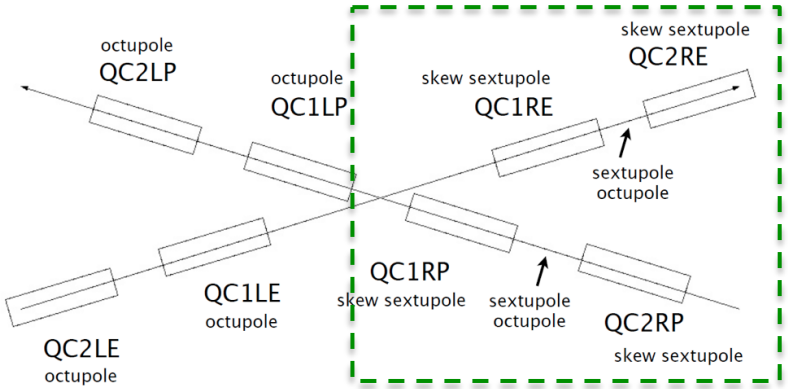
Permendur magnetic shield
for LER beam



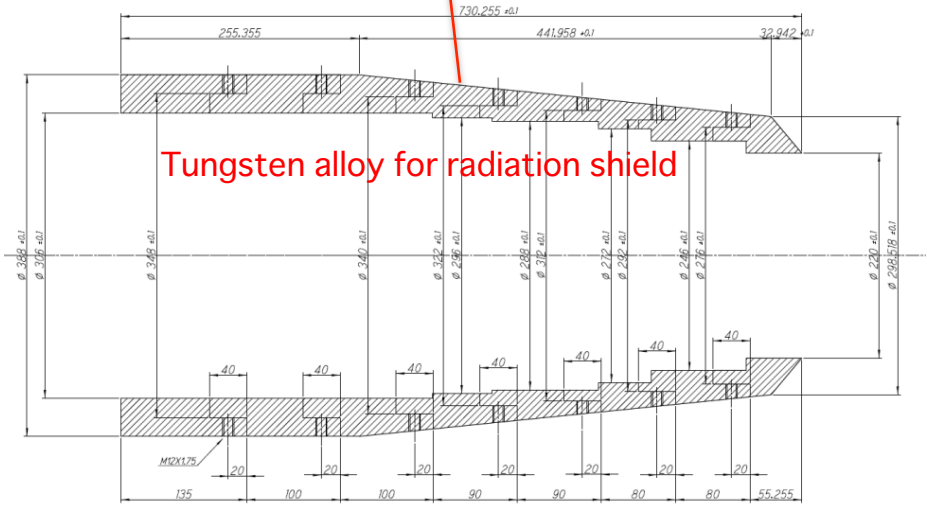
Permendur yoke for QC1LE

Permendur magnetic shield
for HER beam

Reconsider collector coils in QCS-R



Tungsten alloy for radiation shield

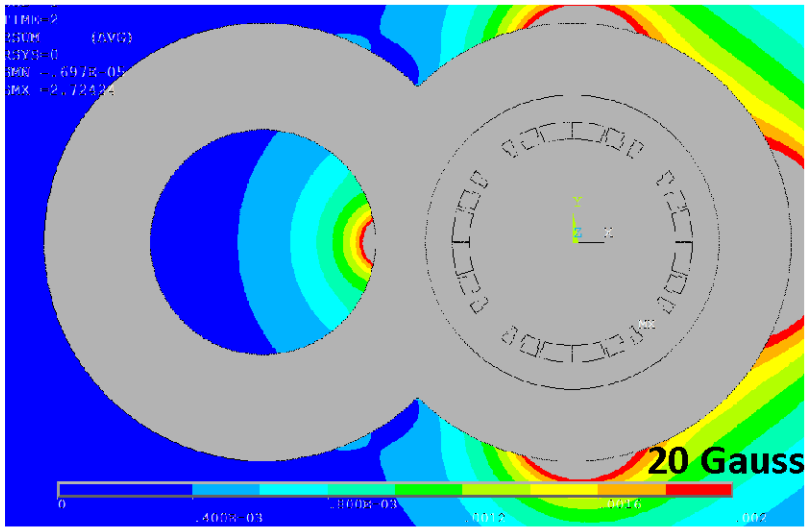


2. Design progress in QCS magnetic model (Permendur)

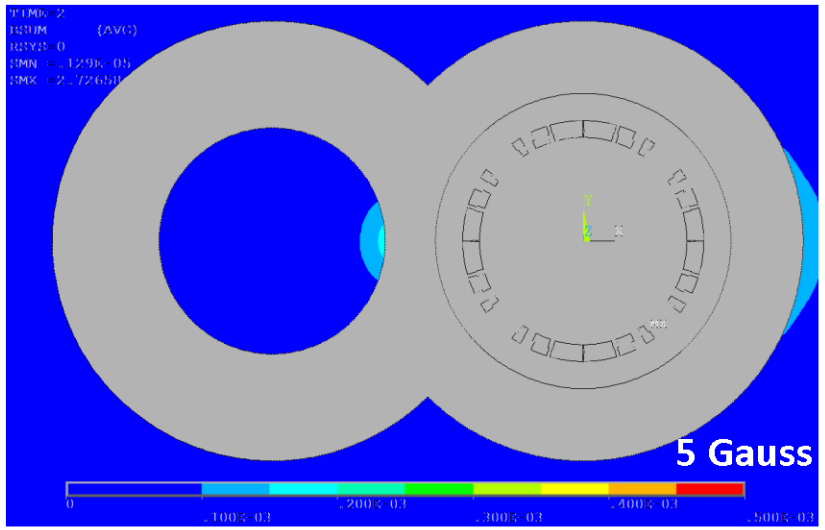
3. 2D magnetic calculation of QC1E (4s)

N. Ohuchi, et al.

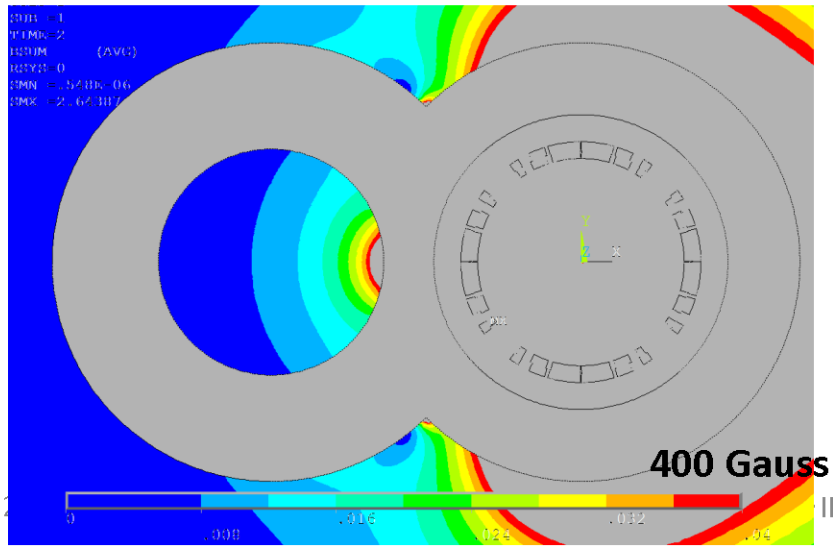
Iron with 0T



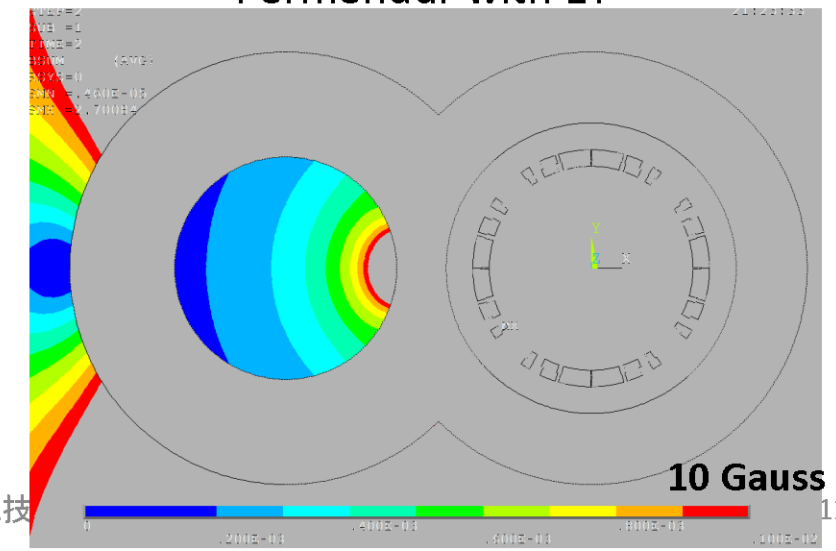
Permendur with 0T



Iron with 1T

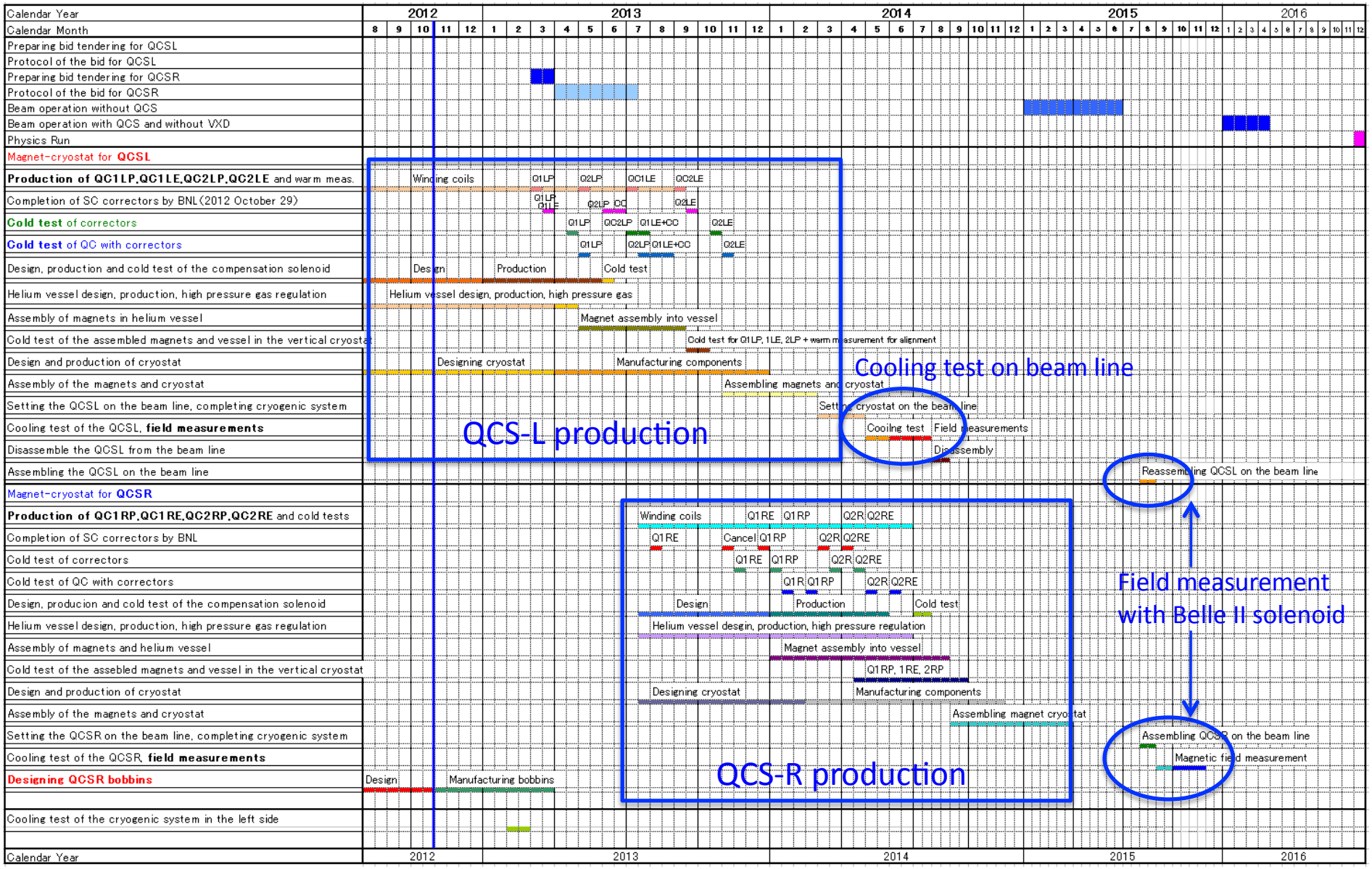


Permendur with 1T



SuperKEKB QCS const. and commissioning schedule

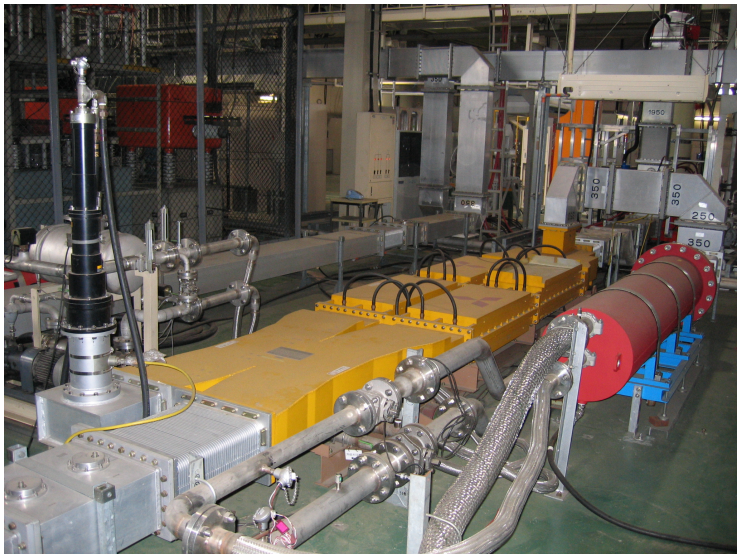
N. Ohuchi



RF system

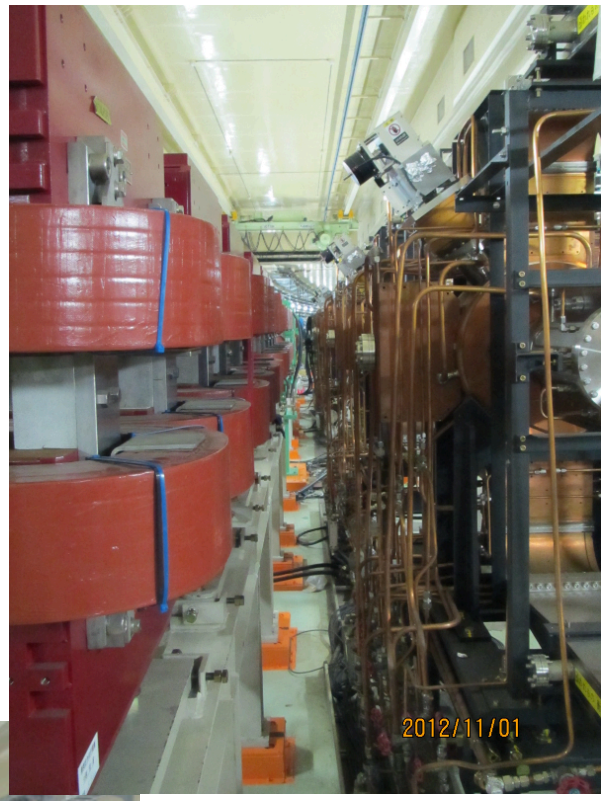
Upgrade of RF system to cope with twice beam currents and 2.5 times beam power

- Change to 1 klystron : 1 ARES cavity scheme from 1:2
  - RF stations are being added.
  - ARES cavities are rearranged, and the input couplers are replaced with improved ones.
- Measures for HOM power increase in SC cavities
  - Existing HOM dampers are considered marginal at about 2A in HER.
  - Measures are being investigated for the design current of 2.6A:
    - Replacing tapers and gate-valves with larger bore ones to reduce loss factor.
    - Adding dampers to disperse HOM power for each damper.
- New Low-Level RF control system
  - A prototype system has been completed. It was operated with a klystron and an ARES cavity, and good performance was demonstrated.
  - LLRF for eight stations will be replaced with new ones. Fabrication will start in May this year.

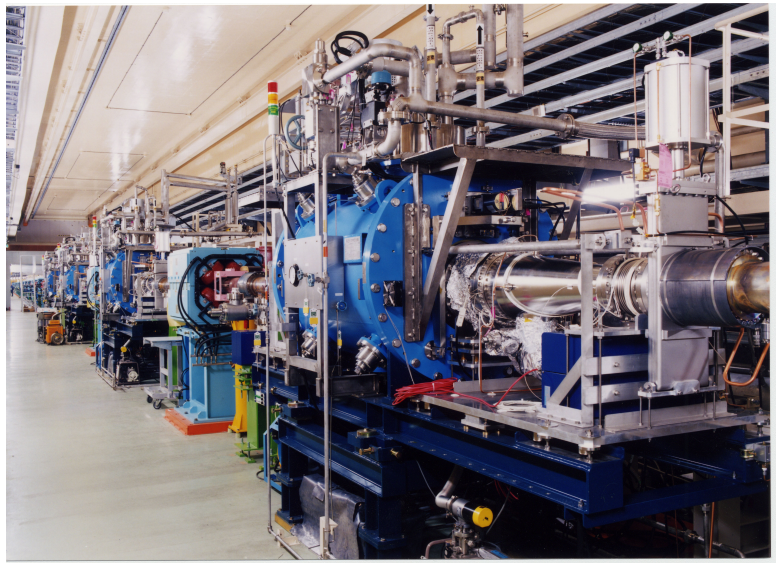


RF high power system

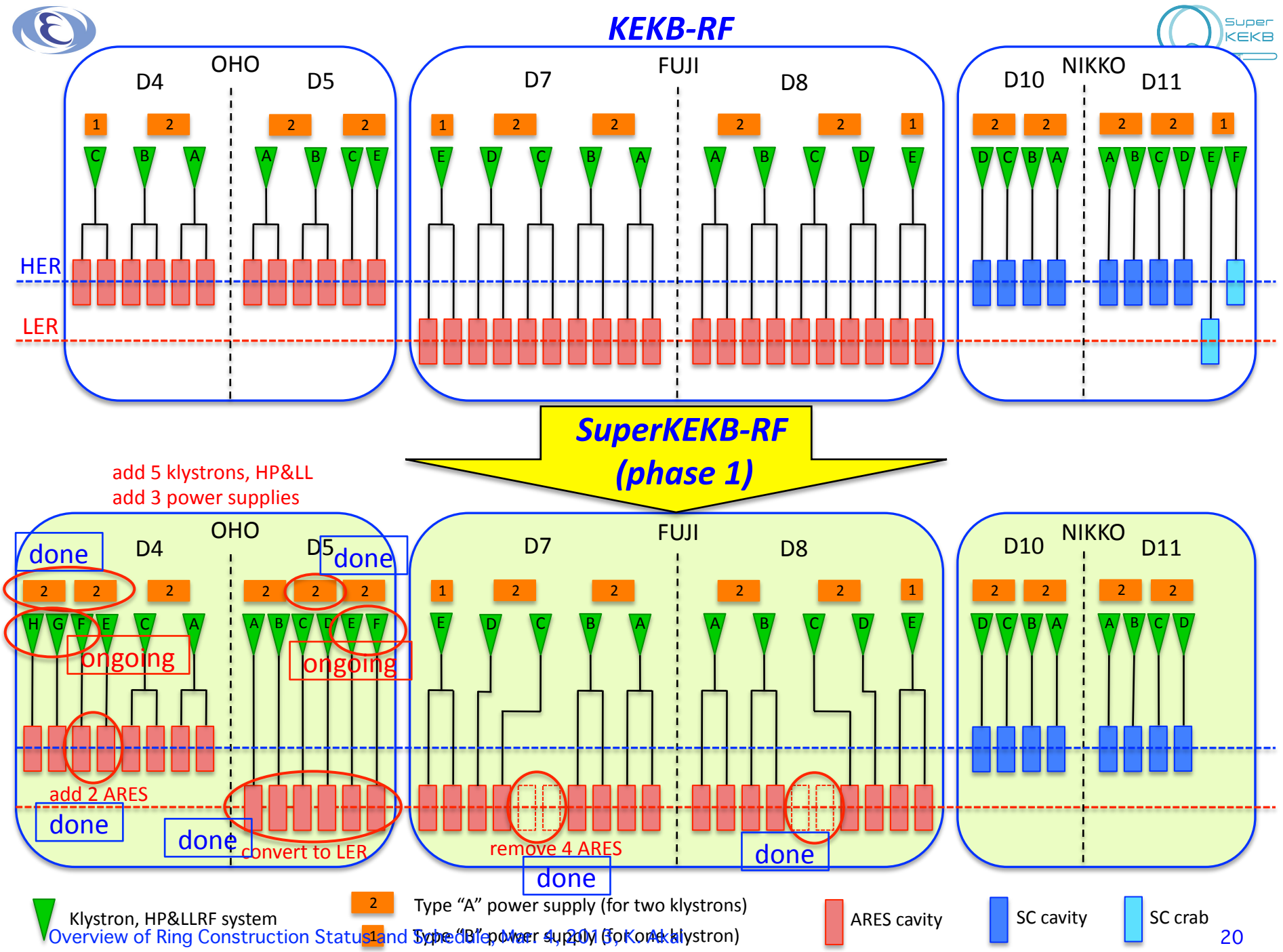
1.2MW CW kystron

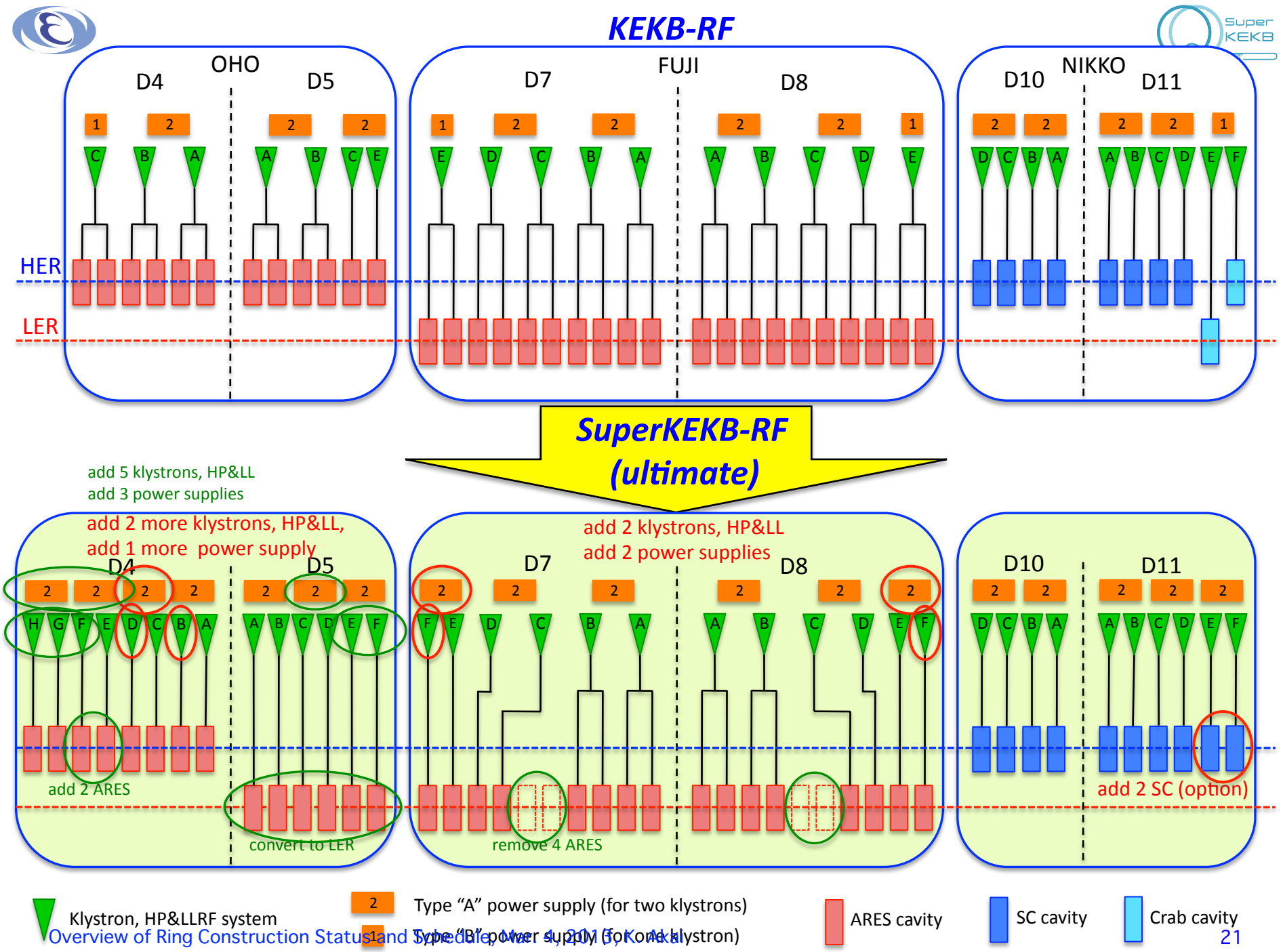


Superconducting cavities



Six ARES cavities in D5 moved from HER to LER. HER wiggler magnets were installed close to the ARES.


KEKB-RF
OHO
D4
D5
FUJI
D7
D8
NIKKO
D10
D11
HER
LER
SuperKEKB-RF
(phase 1)
add 5 klystrons, HP&LL
add 3 power supplies
done
ongoing
add 2 ARES
convert to LER
remove 4 ARES
Klystron, HP&LLRF system
Type "A" power supply (for two klystrons)
Type "B" power supply (for one klystron)
ARES cavity
SC cavity
SC crab


KEKB-RF
OHO
FUJI
NIKKO
D4
D5
D7
D8
D10
D11
HER
LER
SuperKEKB-RF
(ultimate)
add 5 klystrons, HP&LL
add 3 power supplies
add 2 more klystrons, HP&LL,
add 1 more power supply
add 2 klystrons, HP&LL
add 2 power supplies
add 2 ARES
convert to LER
remove 4 ARES
add 2 SC (option)
Klystron, HP&LLRF system
Type "A" power supply (for two klystrons)
Type "B" power supply (for one klystron)
ARES cavity
SC cavity
Crab cavity

Prototype of New LLRF System for the SuperKEKB

A prototype of new digital LLRF system (α-version) was produced in last year. And the performance was evaluated.

PLC : EPICS Sequencer (F3RP61)

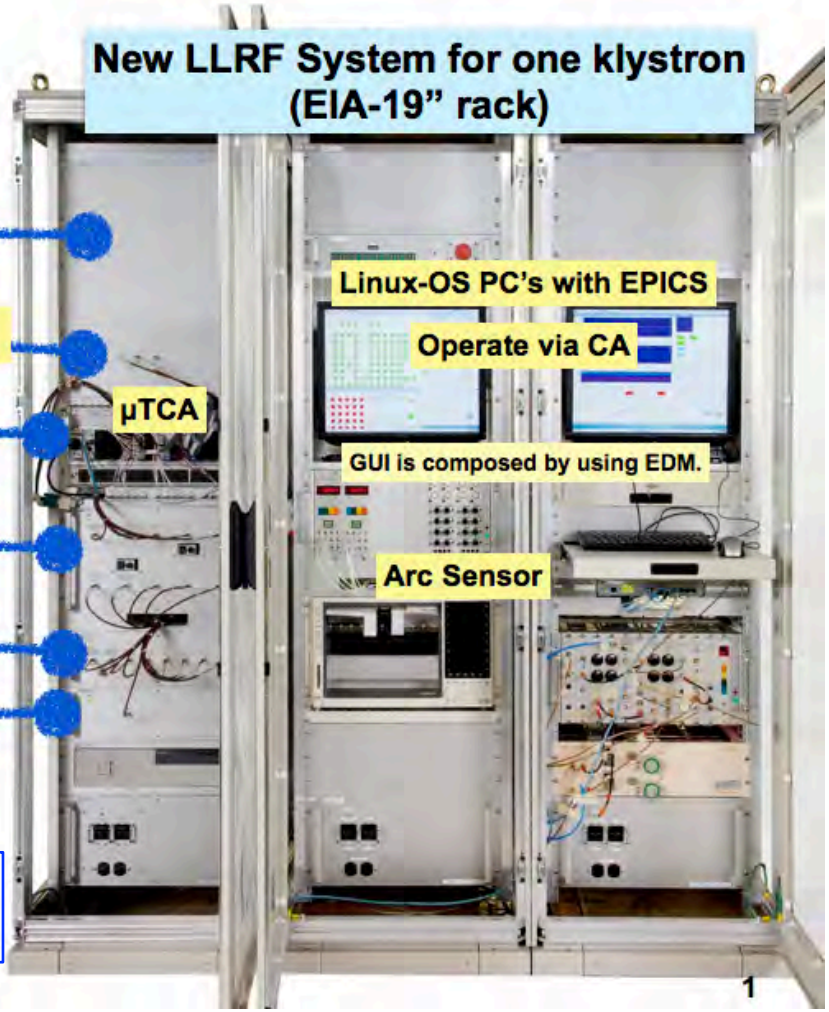
RF-Output Unit (IQ-Modulator & RF-SW)

μTCA-based Digital FB unit

Down Converter Unit (IF out)

RF Interlock Unit

Distribution Unit
(LO & CLK generation and distribution)



Demonstration test in high-power operation at D8-D station successfully done in November last year.

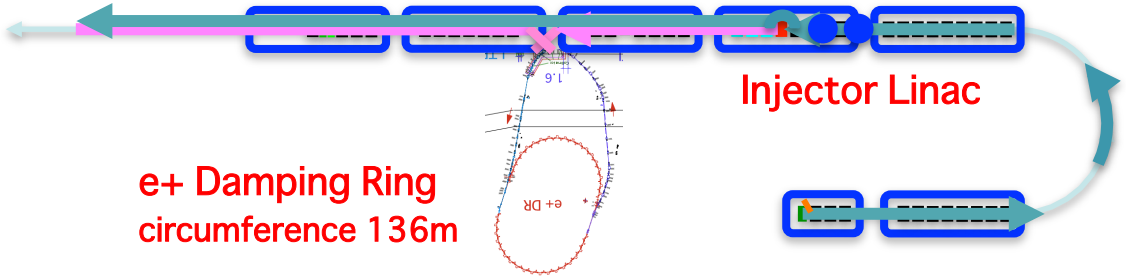
Beam instrumentations

- BPM
  - Mass production of new narrow band detectors at 509MHz will go in JFY2013.
  - Turn-by-turn detectors of the minimum required number for T=0 (35 per ring) will be fabricated in JFY2013.
  - Fabrication of button electrodes and cables is ongoing.
  - Installation of the electrodes on vacuum chambers has started.


Button electrode

- Feedbacks
  - Two sets of short strip line kickers which cover two transverse feedback loops with 90 degrees phase difference will be installed in each ring.
  - iGp digital filters have been already purchased.
  - Longitudinal feedback system will be installed in LER to suppress the instability caused by ARES cavities. Four DAFNE type kickers will be used.
  - IP orbit feedback system is being developed.
- Beam size monitors
  - (Visible light monitor) Development of a diamond extraction mirror is in progress to reduce the heat deformation of the mirror due to synchrotron radiation power.
  - (X-ray monitor) A coded aperture imaging method for the measurement of the transverse beam size has been successfully tested at CesrTA at Cornell university.
  - (Large Angle Beamstrahlung Monitor) LABM is being built mostly at Wayne State University (G. Bonvicini et al.).

Positron Damping Ring



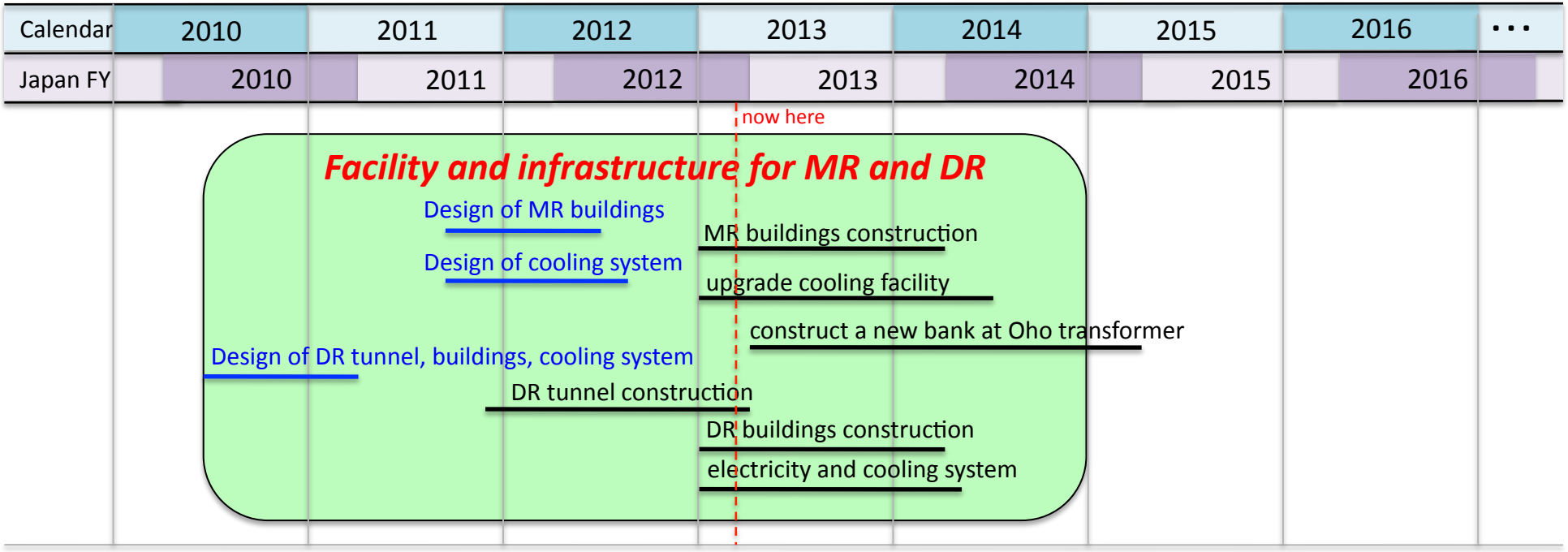
Tunnel construction

- Tunnel construction under way in 2012-13; half year delay due to budget suspend caused by the earthquake.
- Buildings will be constructed in JFY2012-13 after tunnel completed.
- Fabrication of accelerator components ongoing. Installation starts in 2014.
- DR commissioning will start in 2015.

Accelerator components for DR

- Magnets
  - Fabrication of most of magnets and power supplies have completed.
  - Field measurement is ongoing.
  - Sextupole magnets, H-steering magnets, some of power supplies will be fabricated in JFY2013.
- Vacuum system
  - Fabrication of ante-chamber beam pipes for arc sections is ongoing this year.
  - Beam pipes for straight section and transport line will be fabricated next year.
- RF cavity
  - A prototype cavity has been high-power tested successfully.
  - Two cavities will be ready by the commissioning.
- Monitors
  - Fabrication of BPM, feedbacks, loss monitors, etc. is ongoing.
- Injection system
- Control and timing system

Facility and infrastructure



- Construction of DR tunnel, new buildings, upgrading cooling system and electricity, etc., are ongoing by the facilities department of KEK with close communication with the accelerator group.

Upgrade MR cooling system

- Cooling system needs to be reinforced due to:
  - the increase of beam power on vacuum chambers, in particular on wiggler chambers at Oho and Nikko straight sections.
  - the increase of wiggler magnets and other magnets in both rings.

System		unit	KEKB	SuperKEKB	comment
Vacuum	Flow rate	l/min	6400	12800	
	Power	MW	4.5	17.8	ΔT = 10→20℃
Magnet	Flow rate	l/min	15200	23270	
	Power	MW	10.6	16.2	ΔT = 10℃

Cooling pipes removed from tunnel

- Upgrade
  - Construction of four new buildings for cooling system starts this FY.
  - Replacing cooling pipes and renewing valves around the ring are ongoing.

Replacing cooling pipes in the arc section

Reinforce electricity facility

- Due to the increase of RF stations and wiggler magnets in the Oho section, an electricity bank of 15 MW needs to be added at the Oho transformer.
- The new bank at Oho will be constructed in JFY2013 and 2014. At T=0 only the existing facility is used, and the new bank will be connected in summer 2015.

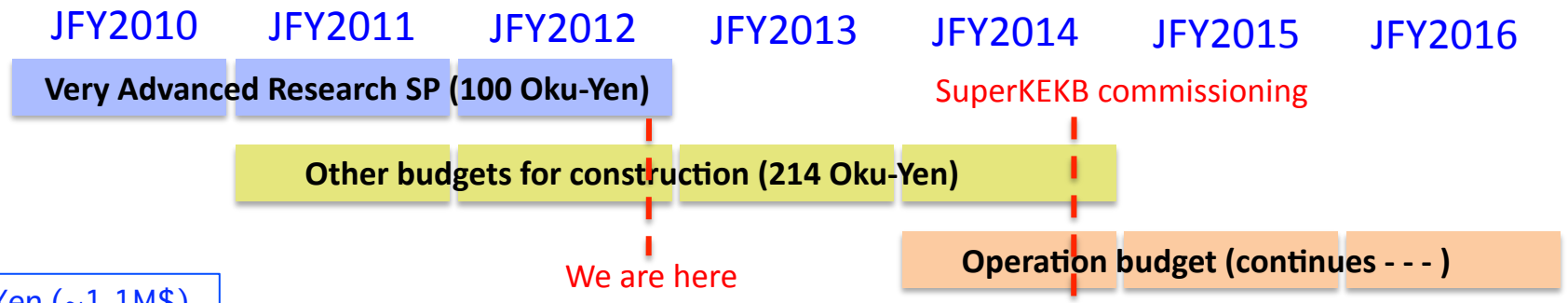
Data provided by M. Ono.

Transformer	power	KEKB	SuperKEKB	comment
Tsukuba	MW	5.1	9.0	the existing facility can provide
Oho	MW	10.4	25.3	a 15 MW bank needs to be added
Fuji *	MW	15.4	22.9	the existing facility can provide
Nikko	MW	14.3	16.3	the existing facility can provide

* AR is not included.

Overall budget (original)

- Budget
  - Total construction budget is 314 Oku-Yen for Rings, Injector, and Belle-II.
  - Most of the budget comes year-by-year based.
  - Operation budget is expected in FY2014 and later.



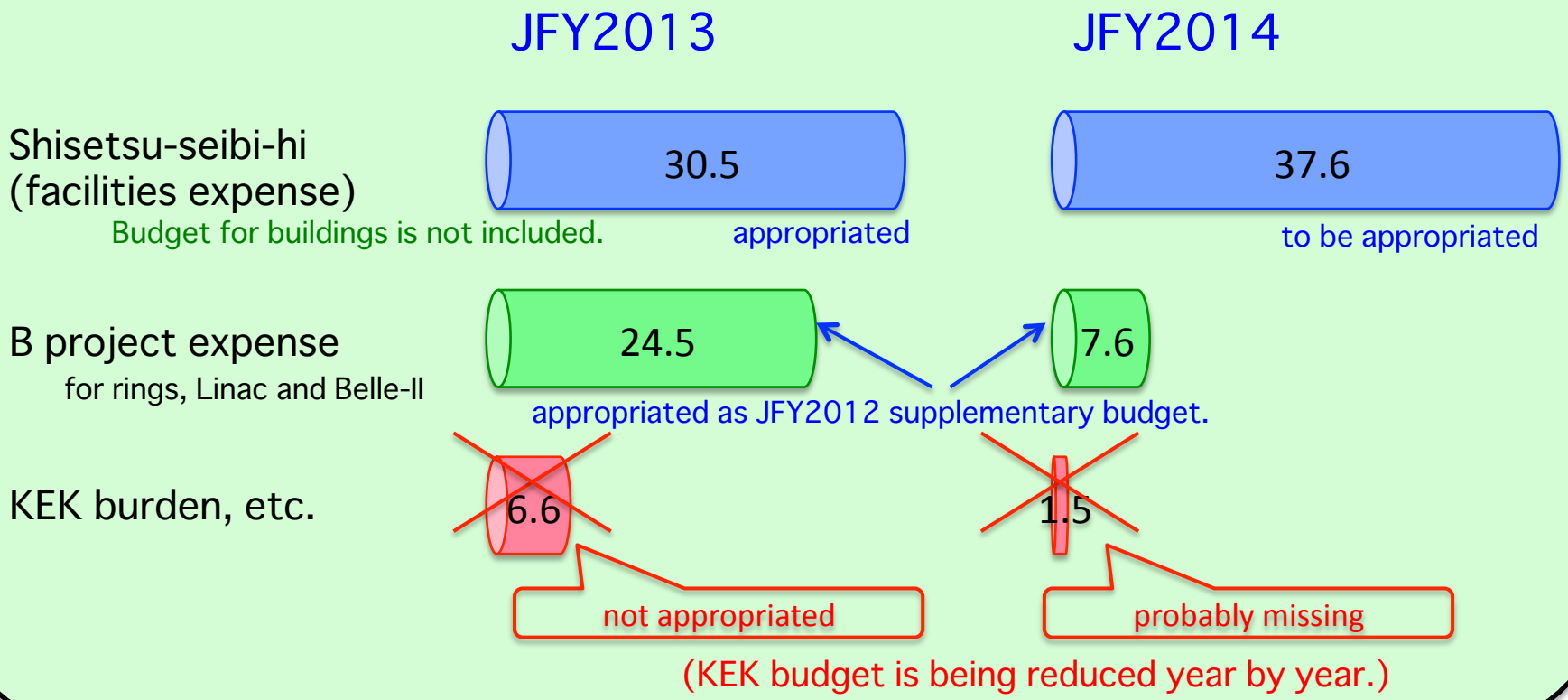
Unit: Oku-Yen (~1.1M$)

	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
Total	75.0	56.6	67.1	68.8	46.7	314.1
Status	Supplied	Supplied	Supplied			

Budget situation in JFY2013-14

Construction budget

unit: Oku-yen (~1.1M$)



Operation budget

not fixed

Cost up since last ARC

- As the optics and hardware design is improved, higher performances are required for some of the accelerator components, which increases fabrication cost.
  - radiation shield in the QCS cryostats
  - Permendur yokes of QC1E and QC2P and shields on the other beam line
  - improving corrector coils in the QCS
  - power supplies for magnets
- Estimation of fabrication cost of some other components also increased.
  - Some of the reasons are due to cost up for materials and/or changes in the exchange rate. Some others may be related to the effects of the Earthquake.

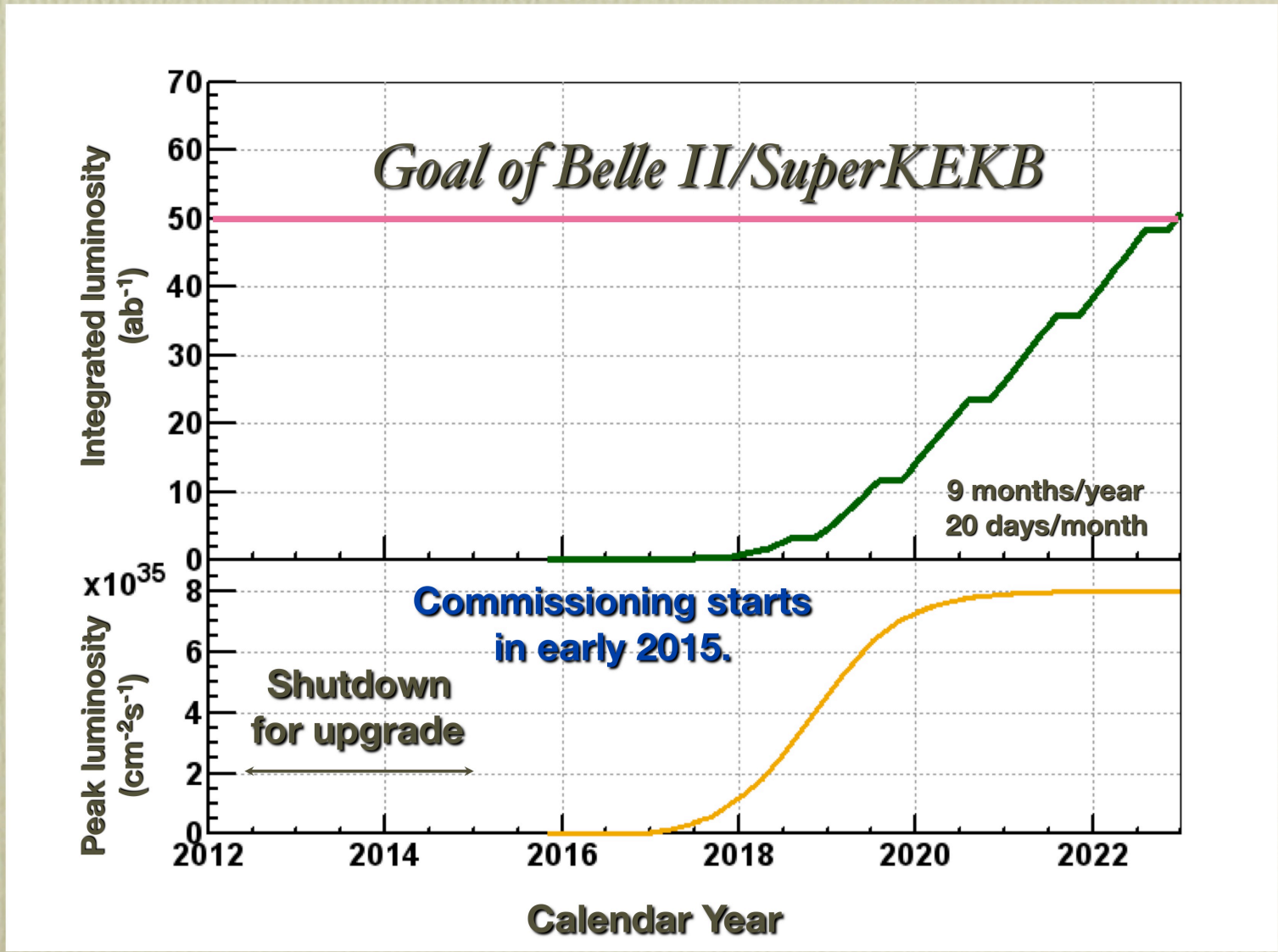
Plans for MR

- MR commissioning as planned.
  - We understand that we should start first beam operation of MR (hopefully LER and HER both, at least one of them) during JFY2014 (by March 2015). This is important since JFY2014 is the last year when the official construction budget is supplied.
  - The commissioning scenario that was agreed with Belle II group should be respected.
  - We plan to start MR beam commissioning in January 2015, so every components and works necessary for this has the highest priority.

Plans for DR

- Original plan
  - The DR commissioning start in Feb. 2015, about one month later than the MR commissioning start.
- Issues with the original plan
  - Many components need to be fabricated in JFY2013, but as mentioned, we should manage reduced budget situation and cost up of MR components.
  - Tunnel construction delayed by half year due to the Earthquake. Buildings construction will delay accordingly. Then schedule of installation, alignment, cabling and piping, system check and conditioning became much tighter.
- New plan under discussion
  - The DR commissioning start in May or June 2015. It is about three months delay from the original plan, but still during phase 1 commissioning period.
  - DR will be operated for about one month in phase 1, which keeps benefit to operate the DR prior to phase 2 when QCS and Belle II is installed.
- Merits with the new plan
  - Production of some components can be put off to JFY2014. This relaxes the budget situation.
  - Schedule of installation and other works also relaxes.

SuperKEKB luminosity projection



Summary

- Construction is well ongoing.
  - Budget is tight. Schedule is also very tight. But we keep commissioning start in JFY2014 (target is Jan. 2015).
- Design is improved.
  - In particular, the IR region optics and hardware design.
  - Beam loss estimation ongoing (not mentioned in this talk).
- Commissioning will go in three phases.
  - Main Ring commissioning will start w/o QCS in Phase 1.
  - QCS and Belle II (w/o VXD) will be commissioned in Phase 2.
  - Physics run with full Belle II (with VXD) will start in Phase 3.
  - This scenario was agreed between the accelerator group and Belle II.
- New plan for DR
  - It manages the budget reduction and cost up of MR components.
  - It also relaxes the very tight schedule for the DR construction.
  - This plan is under discussion.

Back up slides

Comparison of two scenarios during commissioning phase 2

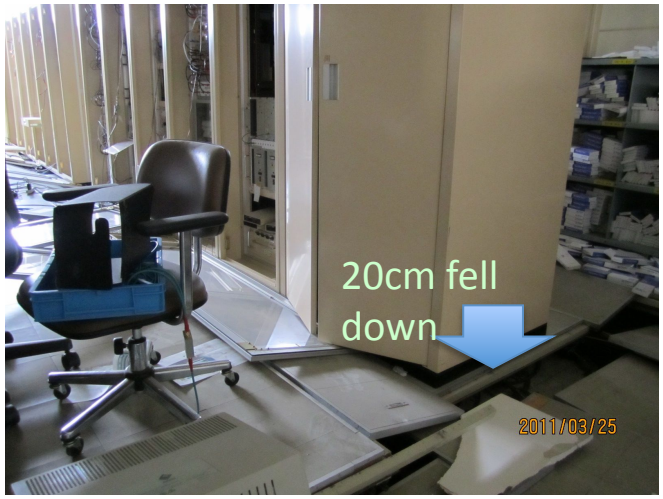
	Scenario A (w/ solenoid)	Scenario B (w/o solenoid)
Optics correction(1) Squeezing IP beta functions	We can do full tuning.	We can do something. But we will have to do tuning w/ Belle II solenoid almost from scratch.
Optics correction(2) Achieving a small x-y coupling	We can do full tuning.	We can do something. But we will have to do tuning w/ Belle II solenoid again anyway.
Collision tuning	We can do full tuning.	The beam collision may not be possible w/o Belle II solenoid.
Belle II background Study and tuning	The real beam background can be studied. Also some test detectors can be installed at the place of VXD.	Some studies can be possible.
Risk to Belle II	Maybe we can avoid the risks by adiabatic tuning (start from small beam currents, with detuned optics).	Less risk

Comparison of two scenarios (cont'd) during commissioning phase 2 (cont.)

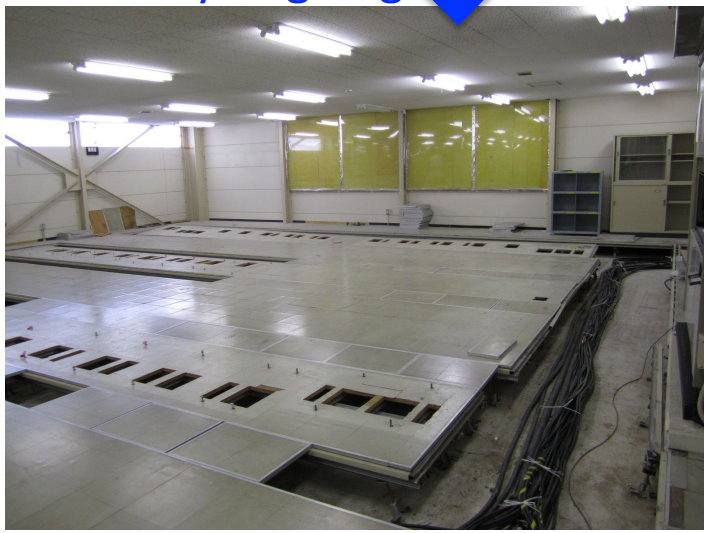
	Scenario A (w/ solenoid)	Scenario B (w/o solenoid)
Works for accelerator setup	Less works.	One more QCS field measurement. (heavier load to QCS group)
Cosmic-ray run w/ VXD	Less time before phase 3. Can also be done in the beginning of phase 3.	More time before phase 3.
Expected time for the first target luminosity (1×10^{34} $cm^{-2}s^{-1}$)	Earlier (maybe during phase 2).	Later (3～5 months after phase 3 start).

Recovery from the earthquake_1

RF control system



Recovery ongoing



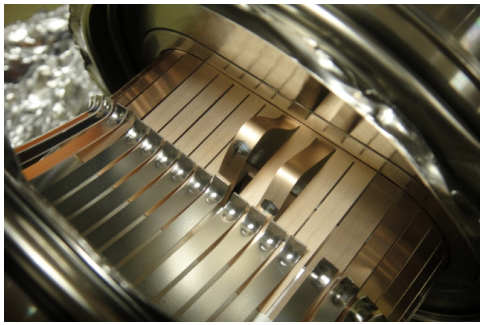
Control systems and cables were removed, floors renewed.

New control system will be built.

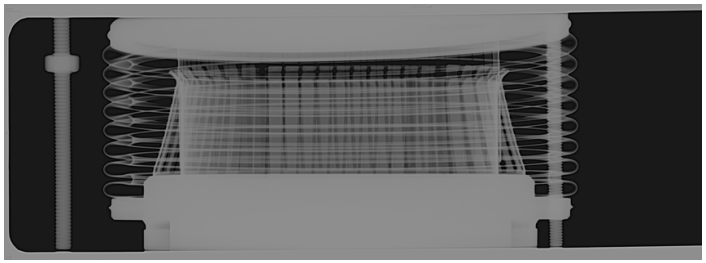
Air-fin cooler for klystrons

Recovery almost done

Bellows chambers



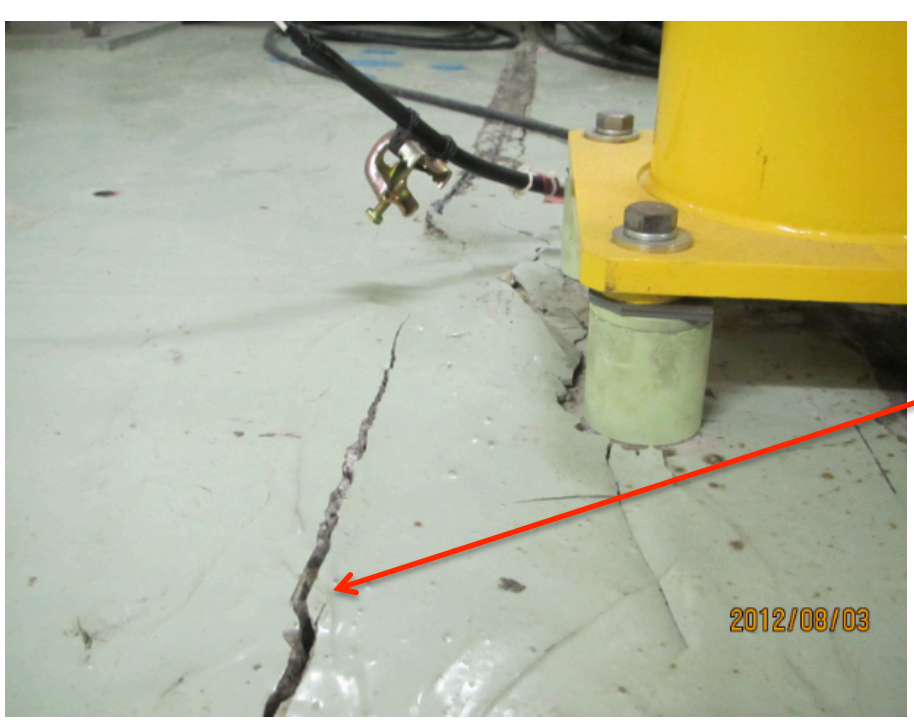
X-ray check

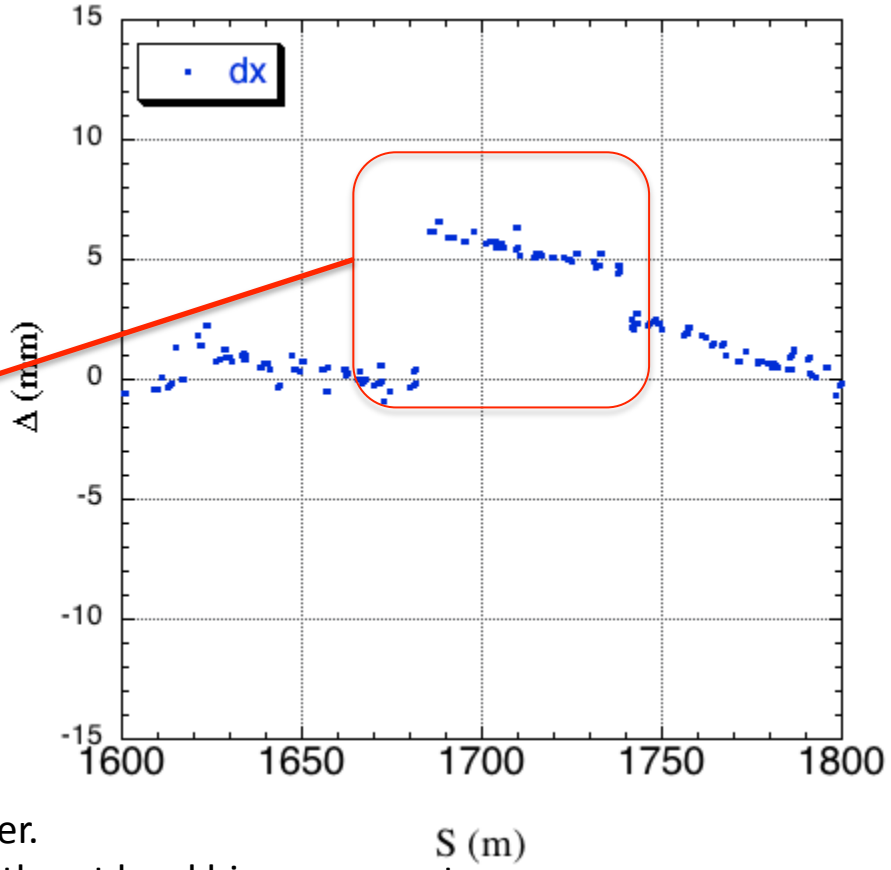


Recovery from the earthquake_2

M. Masuzawa

Rough measurements and adjustments after the big earthquake are in progress.





Measurement in horizontal direction using a laser-tracker.
This year rough adjustments will be performed to smooth out local big movement.
Precise alignment will be performed in 2013 and 2014 at better conditions.