Overview of Ring Construction Status and Schedule

Contents

- Overall plan
- Construction status
- Schedule in JFY2015 and 2016

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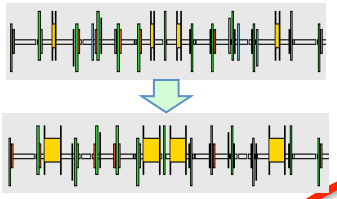
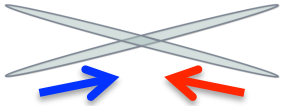
Feb. 23, 2015 @20th KEKB Accelerator Review

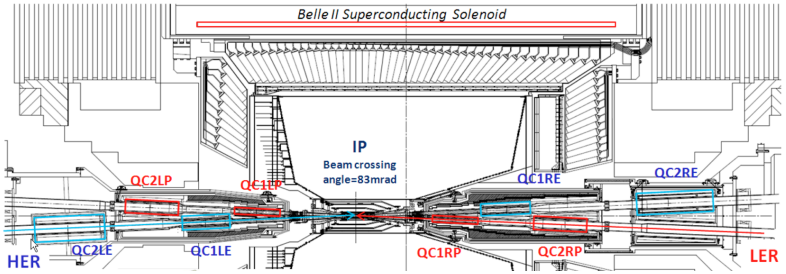
Overall Plan

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

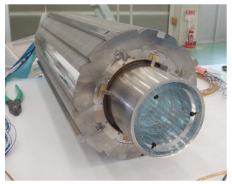


Colliding bunches





New superconducting final focusing magnets near the IP



e^+ 3.6A

e^- 2.6A

SuperKEKB

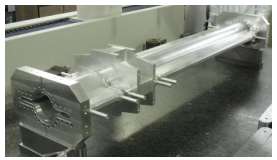
◆Nano-Beam scheme
extremely small β_y^*
low emittance

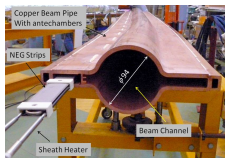
◆Beam current double

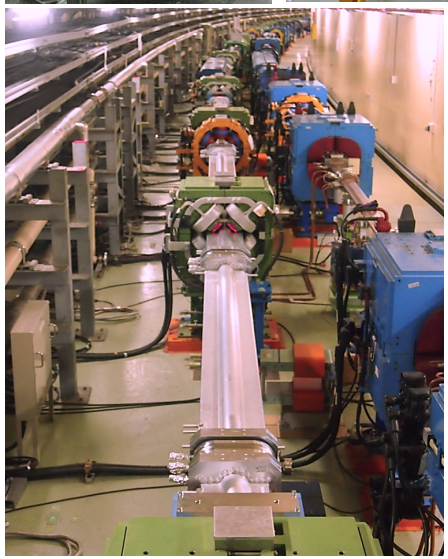
$$L = \frac{\gamma_\pm}{2er_e}\left(1+\frac{\sigma_y^*}{\sigma_x^*}\right)\left(\frac{I_\pm \xi_{\pm y}}{\beta_y^*}\right)\left(\frac{R_L}{R_y}\right)$$

40 times higher luminosity
2.1×10^{34} --> 8×10^{35} $cm^{-2}s^{-1}$

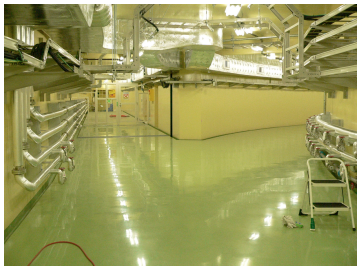
Wiggler sections upgrade







Replace beam pipes with TiN-coated antechamber-type ones



Improve monitors and control system

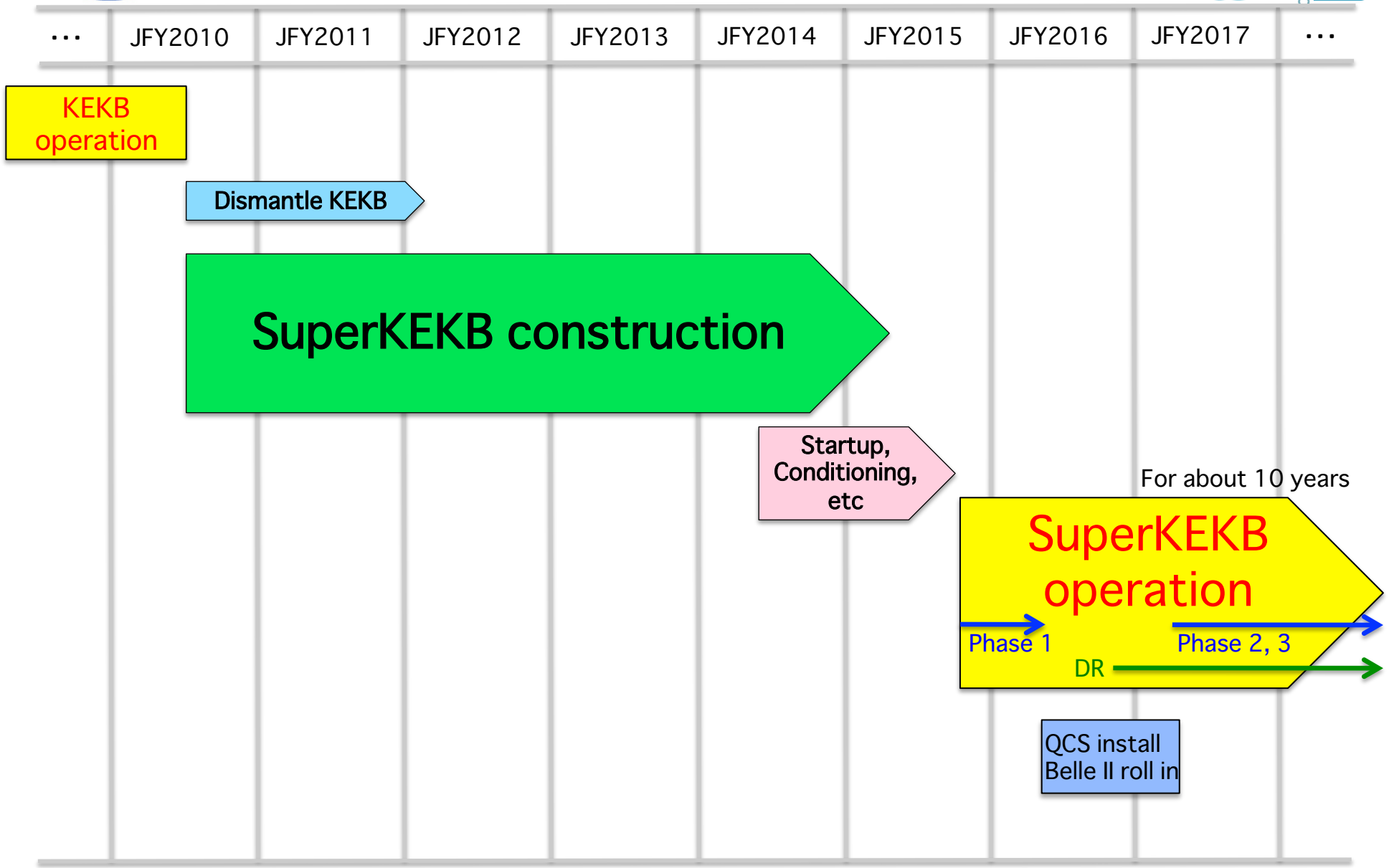
Injector Linac upgrade
- RF electron gun
- improve e+ source

Injector Linac upgrade

New e+ Damping Ring

Reinforce RF systems for higher beam currents

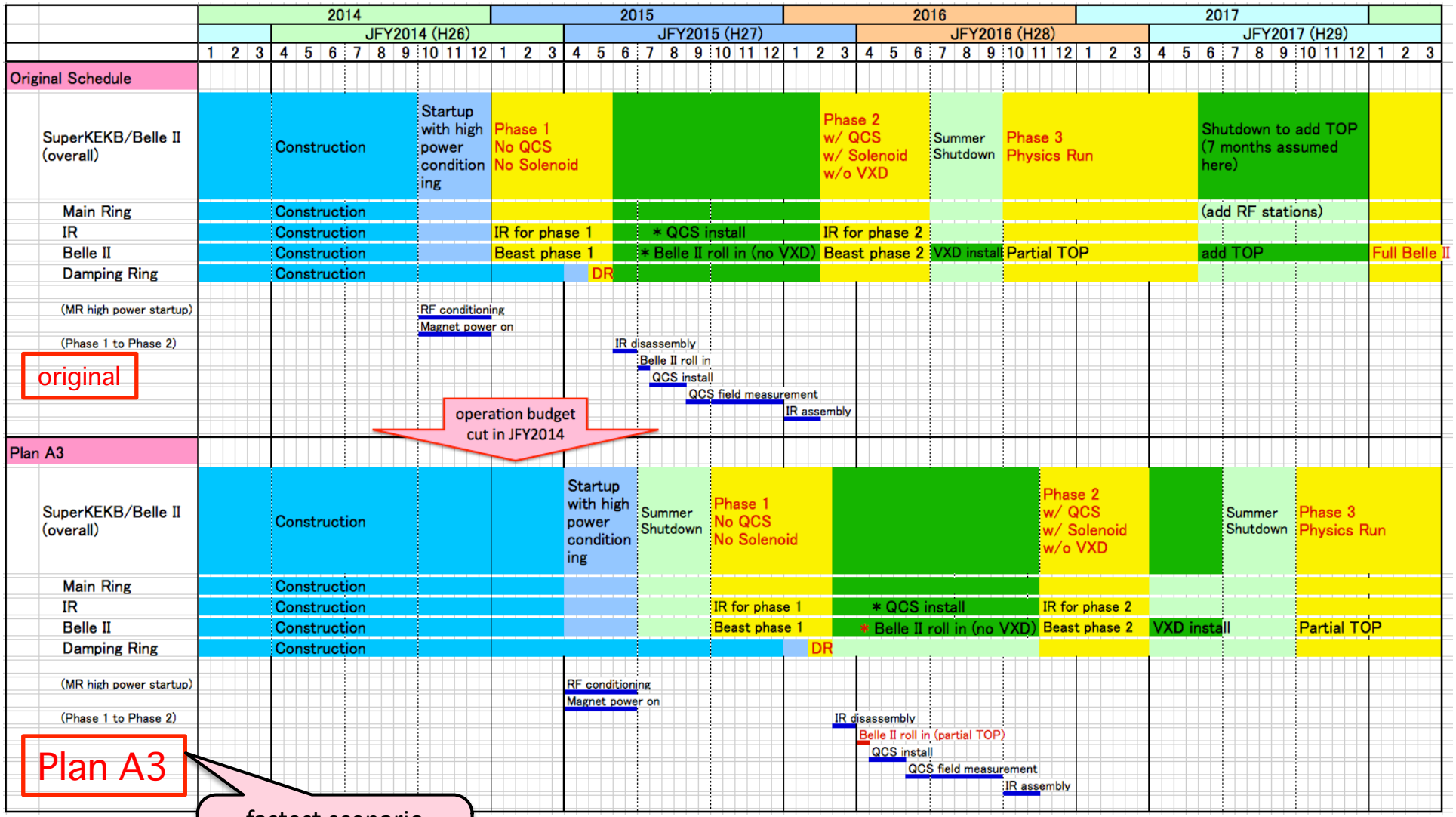
SuperKEKB master schedule



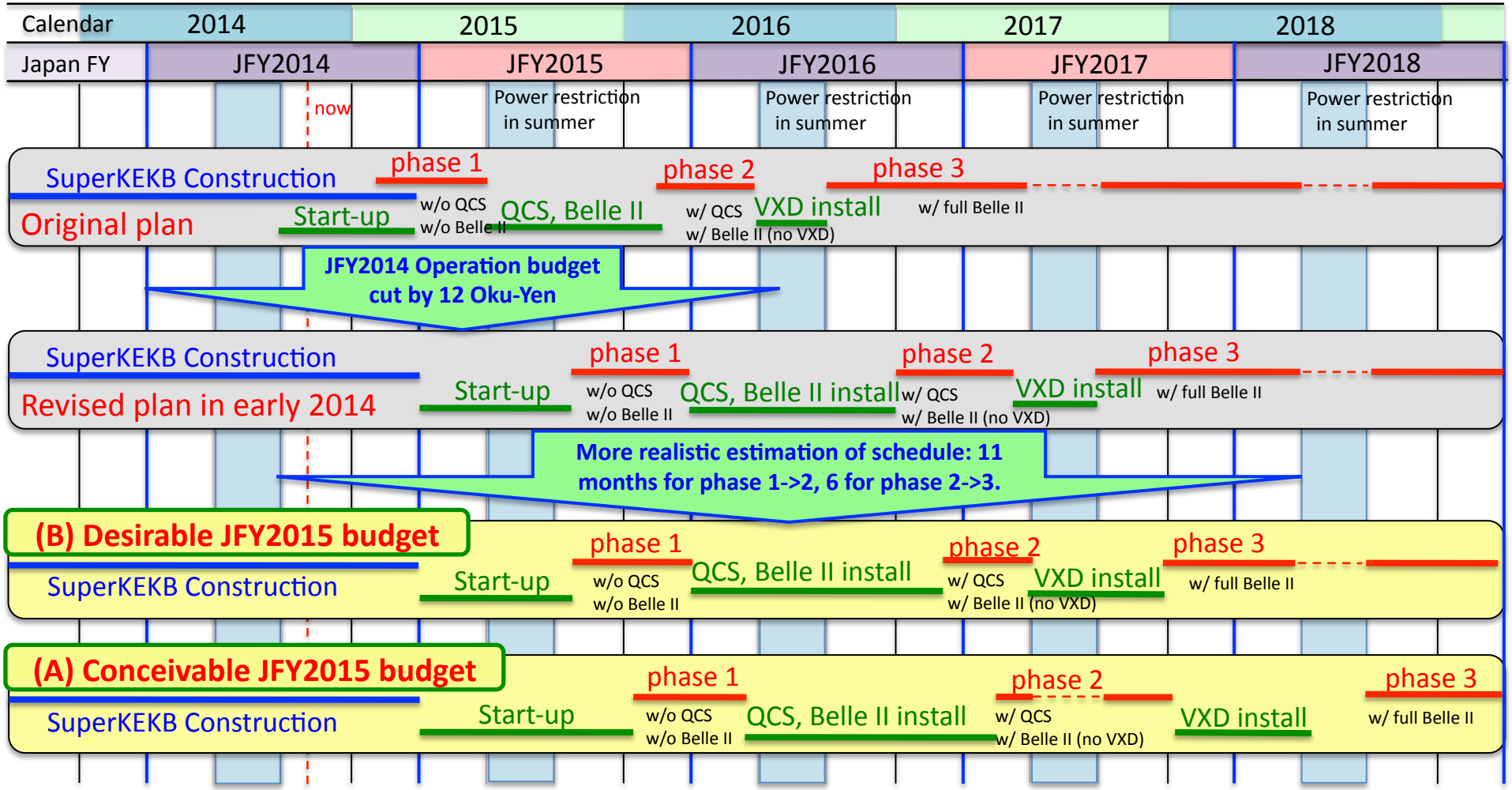
Commissioning phases

- 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 0.5~1A /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 (starts before Phase 2)
  - Target luminosity at this stage is 1 x 1034 cm-2s-1
- Phase 3: Full Belle II detector with VXD installed
  - Physics run
  - Improve luminosity

A possible plan presented at B2GM on 18, Jun. 2014.



SuperKEKB/Belle II Schedule



Possible scenarios discussed in B2EB, B2GM and BPAC on Nov. 2014.
JFY2015 budget situation turned out to be close to senario (A).

Current situation

- In early 2014, the master plan was changed due to the significant cut of JFY2014 operation budget for KEKB.
  - Most of startup work needed before beam operation were postponed to JFY2015.

- JFY2015 budget
  - Budget request was sent from KEK to MEXT with the amount that is needed to perform all preparation works after construction to startup the accelerator components and to start Phase 1 beam operation in autumn 2015 ("desirable" scenario; (B)).
  - JFY2015 budget including strong support from KEK turned out to be close to the "conceivable" scenario; (A), which allows us to start Phase 1 commissioning in early 2016 within the period of JFY2015.

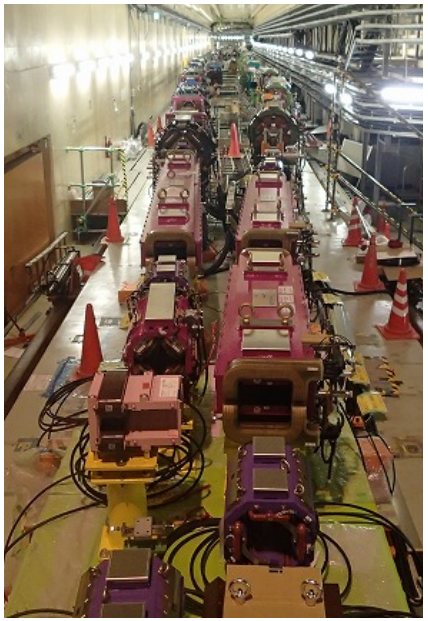
- Construction and startup work has been rearranged and optimized to meet the situation as much as possible.

Construction Status

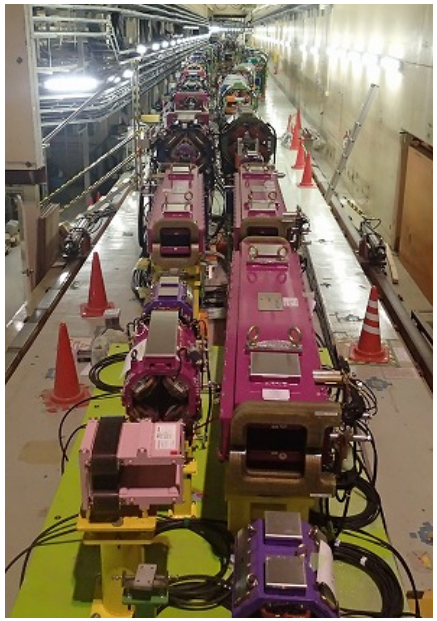
Magnet System

- Magnet installation and alignment
  - Installation of most of normal conducting magnets will be completed by the end of this JFY2014.
  - Remaining magnets are for D1 arc section of length of about 30 m. They will be installed in the beginning of JFY2015.
  - The first round of alignment of magnets has been carried out.
  - Final precise alignment before Phase will be carried out in summer 2015.

Nikko-side (L-side) of IR



Oho-side (R-side) of IR



Removing the top half for vacuum pipe installation

Magnet installation in the mid-arc sections

Magnet System (cont'd)

- Power supplies for MR magnets
  - Production of power supplies needed for Phase 1 has been completed.
  - Cabling, piping, control system check are ongoing.
  - Startup and electrical current test of 1MW class power supplies for wiggler magnets and dipole magnets are ongoing. Startup of smaller PS's has also started.

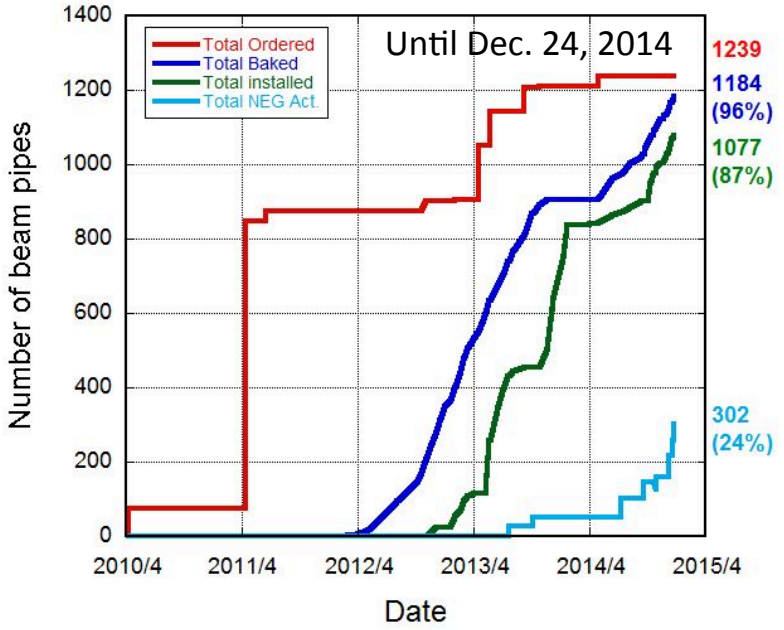
Cabling work

Wiggler magnets

Power supply check

Vacuum System

- Most of vacuum components required for Phase 1 commissioning had been already delivered.
- Pre-baking and TiN coating of beam pipes are on going. Allmost all new beam pipes have been baked.
- Recent installation work is mainly focused to the IR area.
- Approximately 98% of new beam pipes have been installed on the whole.

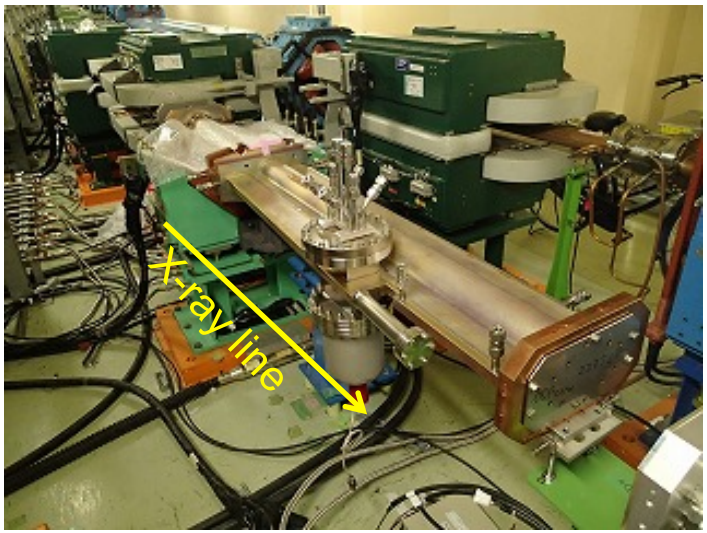


Beam pipes installed in Tsukuba IR area (Nikko side)

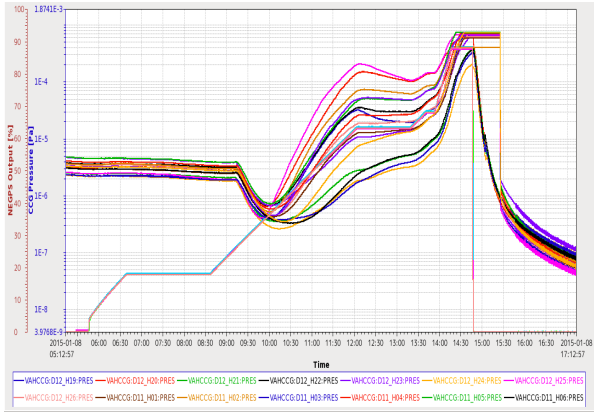
Vacuum System (cont'd)

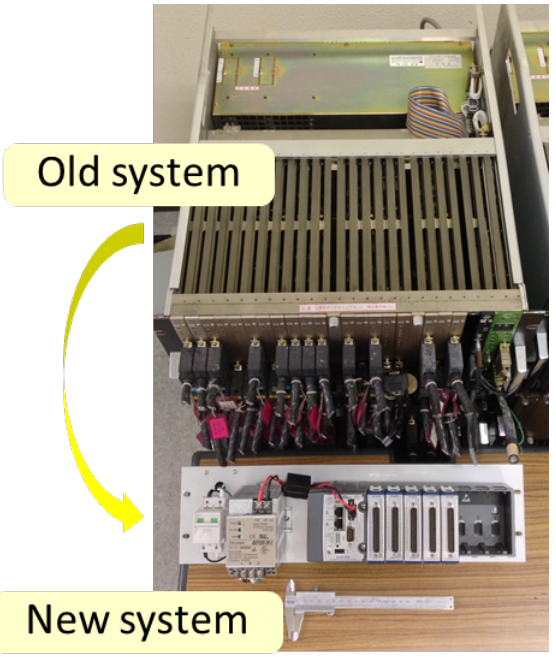
- Control system of various vacuum components has been upgraded.
- The activation of NEG pumps has begun in the tunnel from arc sections by using the new control system.
- Special beam pipes such as beam size monitors using visible light and X-ray, beam pipes with a Ti window for beam abort, beam pipes for beam injection are being installed step by step. They will be completed in the beginning of JFY2015.

X-ray extraction chamber



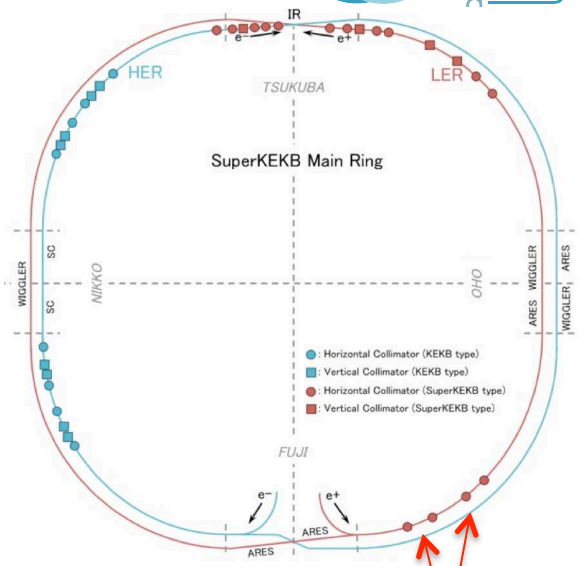
Average pressure of less than 1×10^{-7} Pa is obtained after NEG activation.

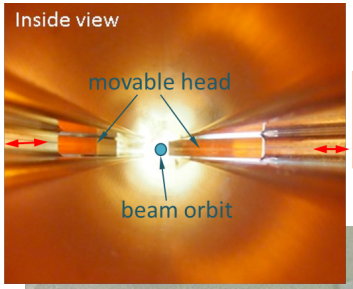




Vacuum System (cont'd)

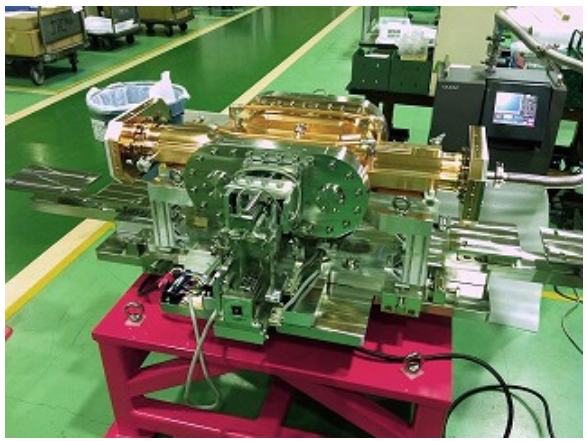
- New low-impedance collimators
  - Beam collimators are devices to cut off halos around the beam orbit and reduce backgrounds in Belle-II detector.
  - The new low-impedance collimators, which fit antechamber scheme, are being developed in collaboration with SLAC. It has a pair of horizontally or vertically opposed movable heads, which approach the beam orbit.
  - Two horizontal collimators are being manufactured for Phase 1, which will be installed at an arc section for test with beams.
  - Mass production is scheduled from JFY2015 to JFY2016 to be in time for Phase 2.



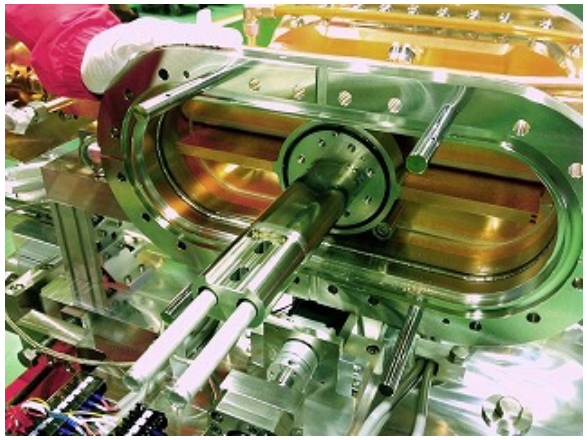


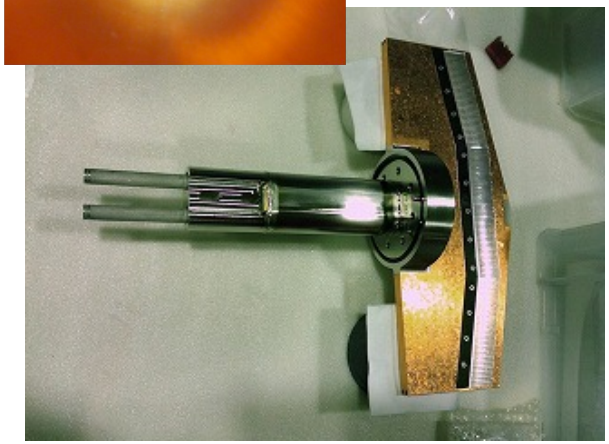
New collimators in LER for Phase 1

Horizontal type collimator



Collimator head



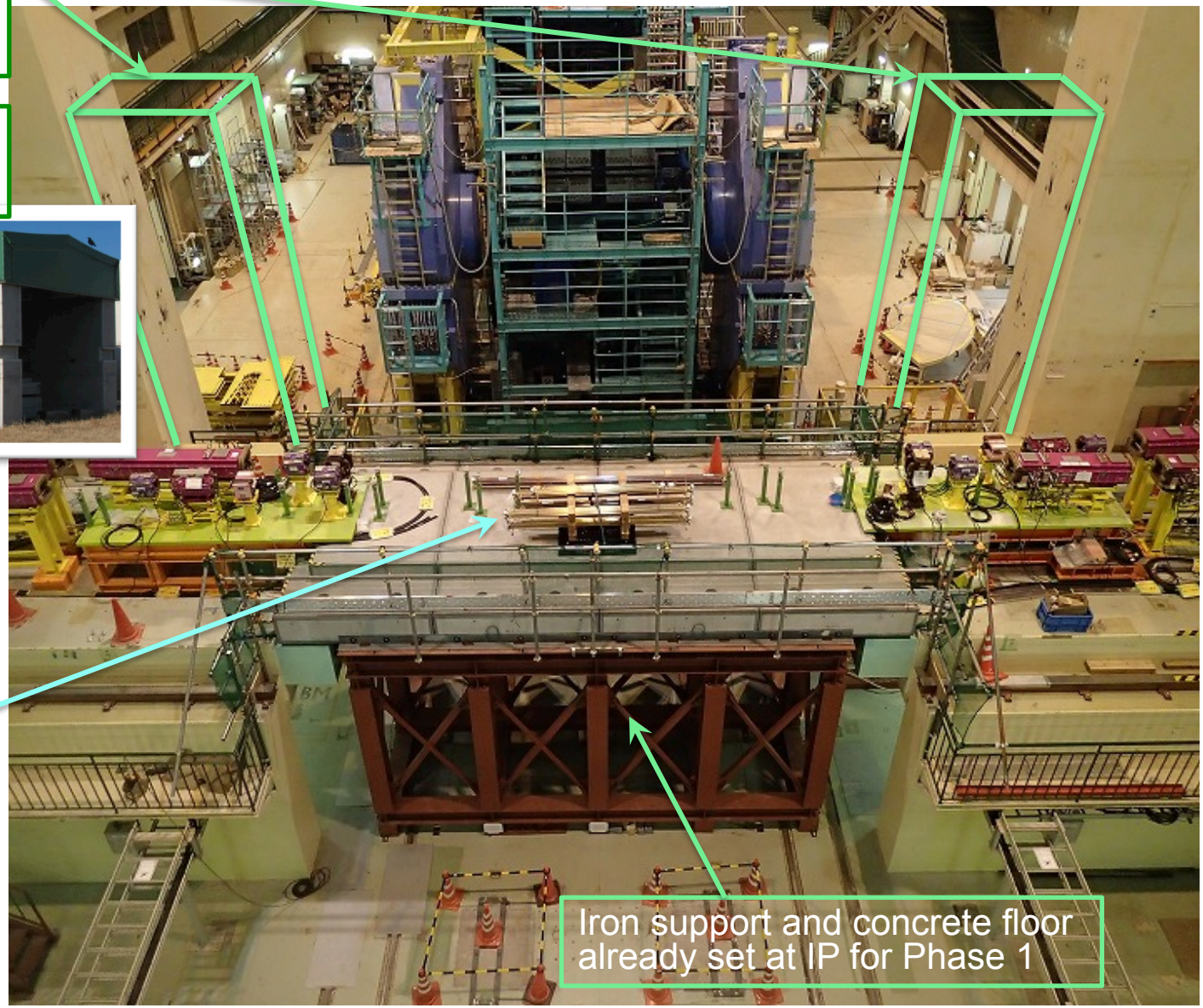


Interaction Region (IR)

Additional shielding walls will be constructed by the end of autumn 2015.

IR cover and large gate concrete shields will be set to IR in autumn 2015.

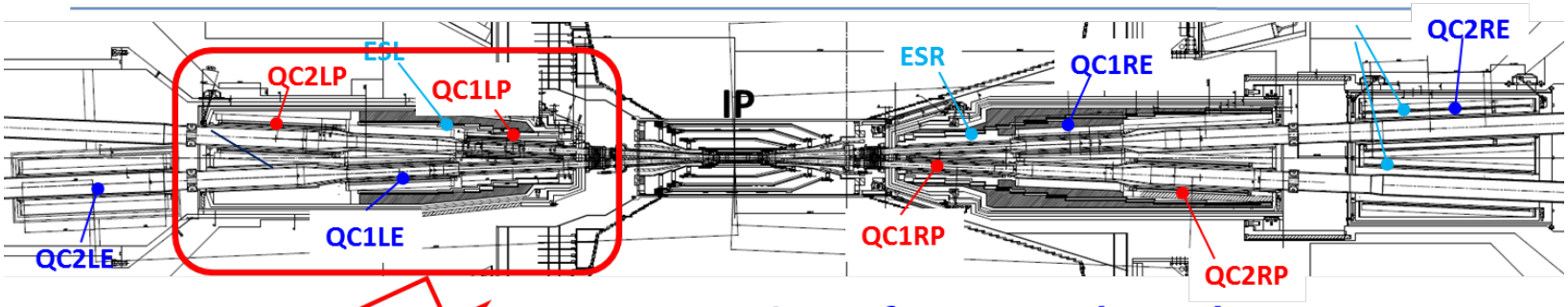
Beam pipes at IP



Iron support and concrete floor already set at IP for Phase 1

Final focus SC magnets (QCS)

- Assemblies of the quadrupole magnets and corrector magnets are progressing for the construction of the QCSL cryostat.



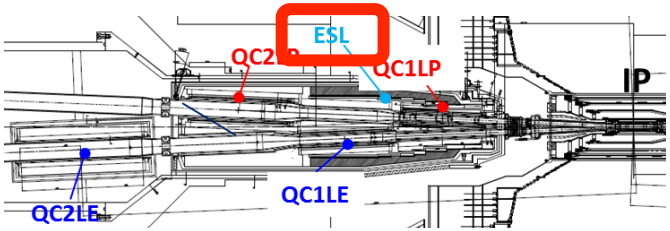
Construction of S.C. quadrupole magnets

QC2LP+QC1LP

QC1LE + QC1LP leak field cancel magnet

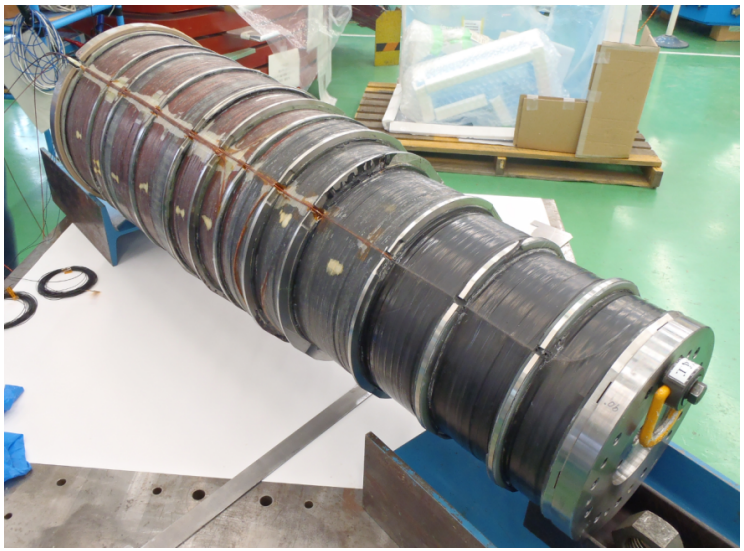
QCS (cont'd)

- Construction of S.C. compensation solenoid (ESL) is on going.
  - Although the solenoid had a damage of the electrical insulation between the superconducting cable and the support bobbin, Mitsubishi well recovered the damage, and the solenoid was delivered to KEK in Dec. 2014.



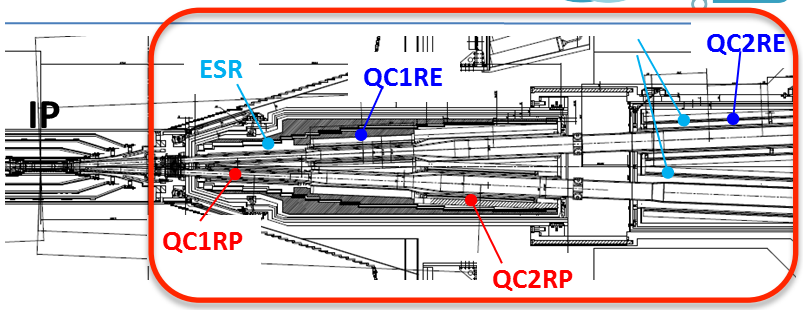
Cold test of ESL was performed at KEK from Jan. 5th 2015. The ESL was successfully excited to the design current without any quench.

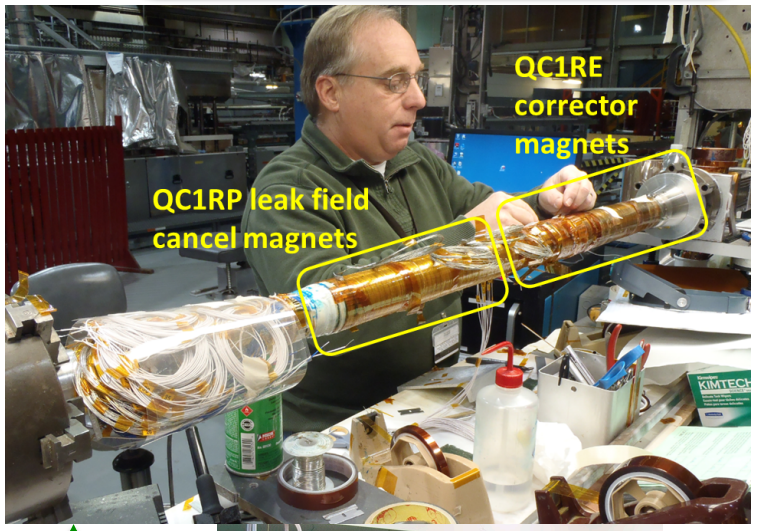
Completed ESL compensation solenoid.
The solenoid was divided into 12 small solenoids.



QCS (cont'd)

- Fabrication of QCSR
  - Main quads and solenoid coils have already been fabricated.
  - Fabrication of QCSR cryostat started July 2014. Will be completed by the end of 2015.
  - The final assembly of QC1RE corrector coils and QC1RP leak field cancel coils on the same support bobbin is being carried out at BNL. Will be delivered to KEK in February.
- Power supply for QCS
  - Two PS's for main quads and four PS's for corrector coils have been delivered.
  - Test to check performances started in a test bench at KEK.
  - Mass production is scheduled from JFY2015 to 2016 to be in time for tests of QCS in beam line.





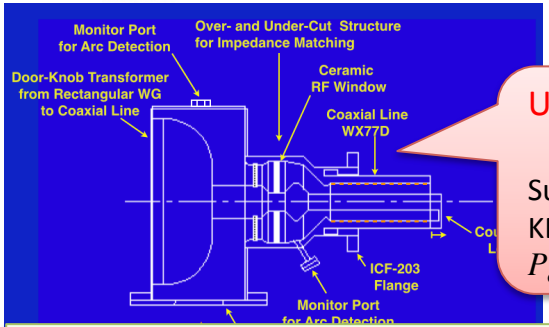
Final assembly of the corrector magnet in BNL. A technician is handling the cables from 8 magnets on the support bobbin.

Test stand for power supply for QCS

RF System

- RF reinforcement for Phase 1 is almost completed.
  - Add klystrons, power supplies and HPRF system
  - Relocation for optimizing the ARES cavities
  - Mass production of upgraded input couplers and installation to the ARES cavities
  - Nine new LLRF control systems for D4 and D5 stations
- Startup and adjustment work continues in JFY2015, followed by cavity conditioning in autumn and winter of JFY2015.
  - This matches to SuperKEKB Phase 1 commissioning plan.
- The RF system with reinforcement done for Phase 1 can support 70% beam current in LER and HER.
  - From our experience in KEKB, beam currents can only be gradually increased with improving luminosity tuning and also by overcoming various issues arising from the high current beams.
  - We believe possible limitation of machine performance due to RF power would only come much later after Phase 2 commissioning.
- We have a senario to reinforce RF more to further increase beam currents after Phase 2.
  - Schedule depends on demand, budget and machine performance.

RF System (cont'd)



Upgrade of Input couplers for ARES cavities

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 cavity.

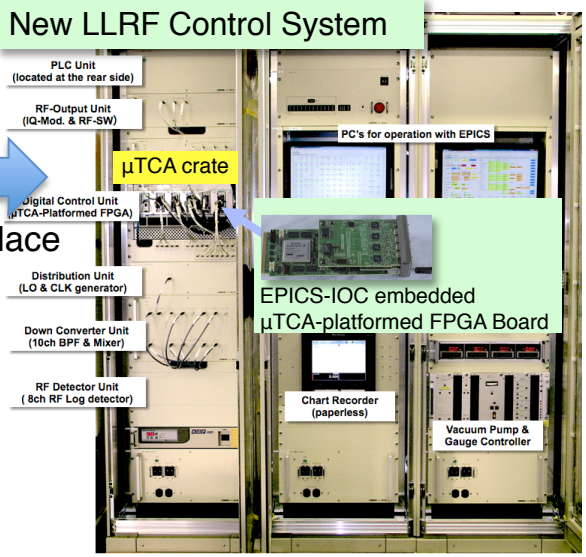
Status & Plans

- So far, 13 input couplers have been processed up to 750-800 kW.
- Every ARES cavity in Oho D5 has been equipped with an upgraded coupler.
- Additionally in Oho D4 before T=0, upgraded couplers will be installed in the RF stations each configured as one klystron driving one ARES cavity.

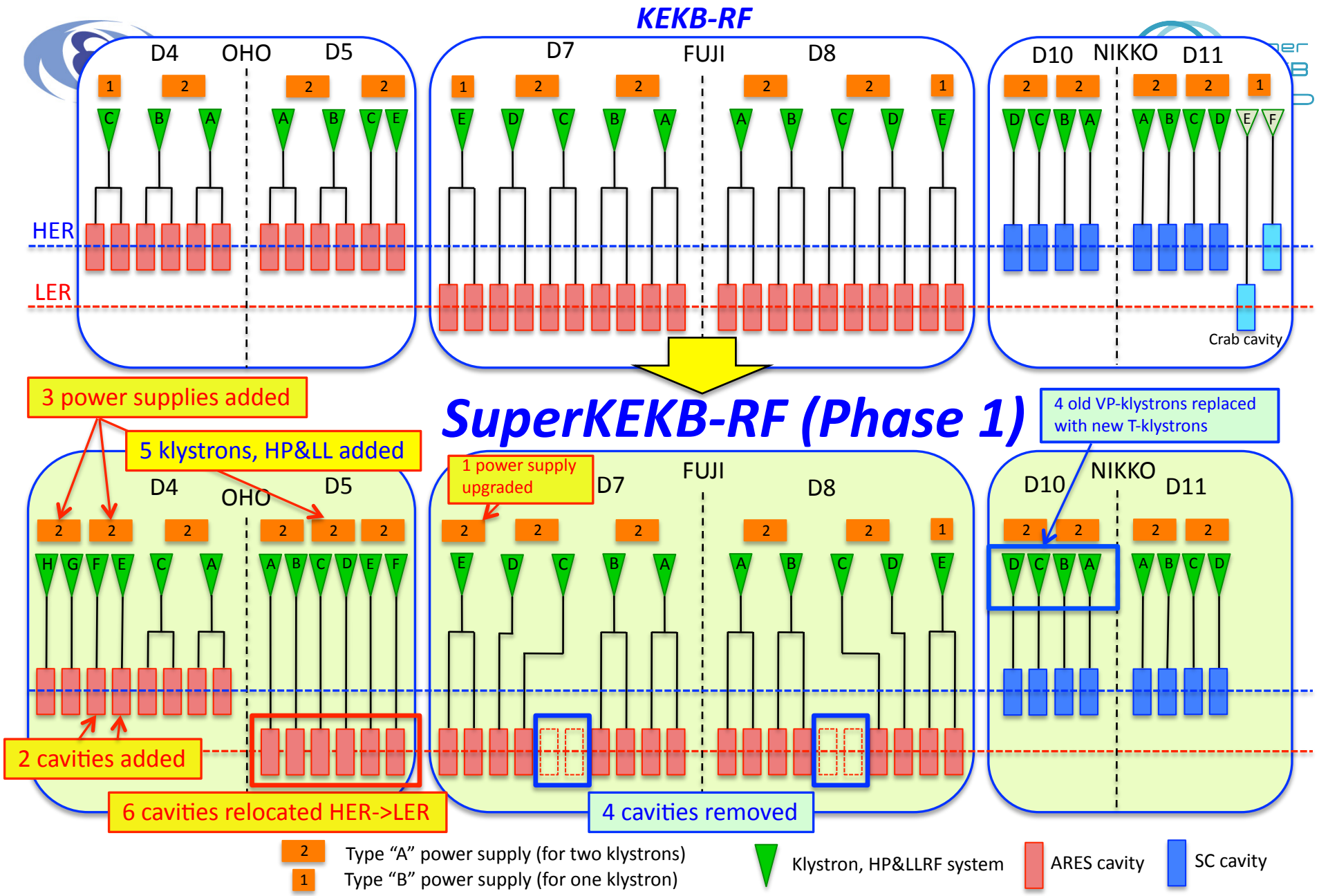
Existing KEKB Analog LLRF System

Replace

New LLRF Control System



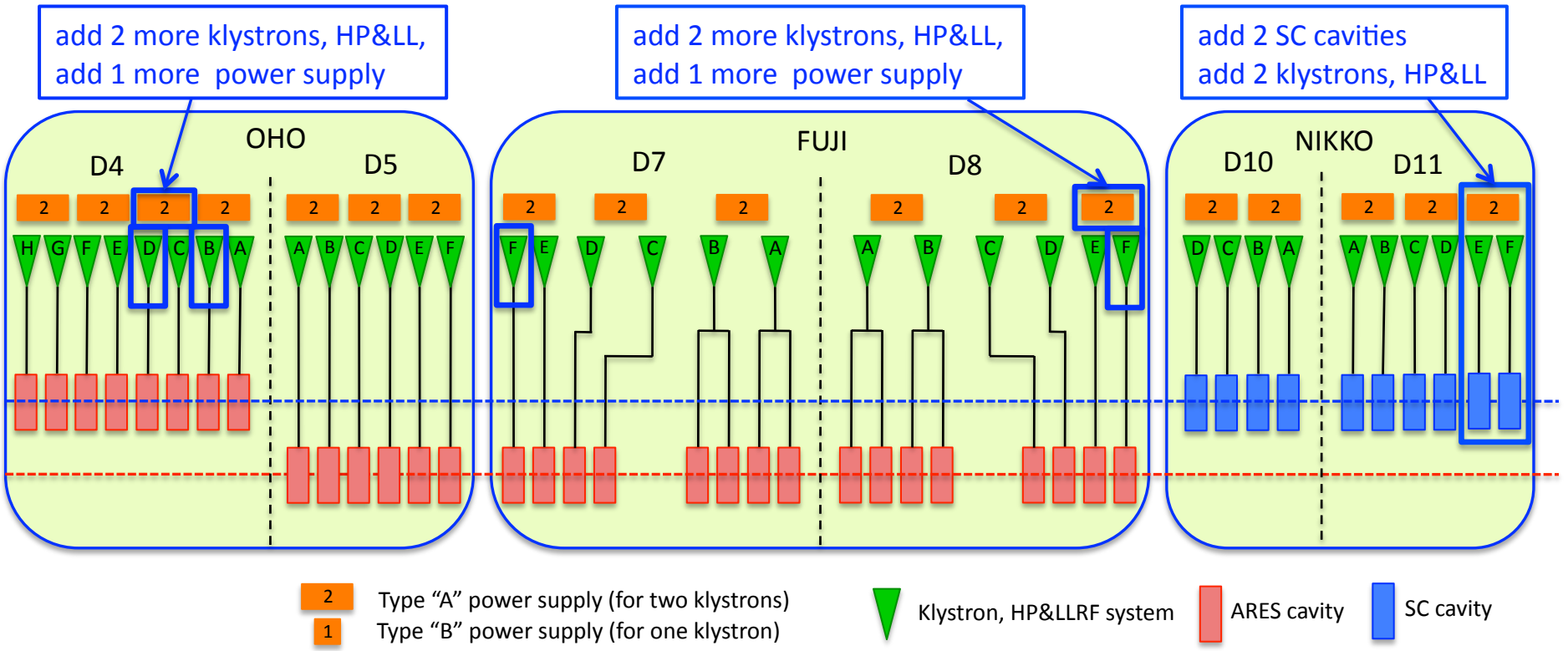
New LLRF Control Systems @OHO D5 Control Room



The RF system with reinforcement done for Phase 1 can support 70% design beam current.

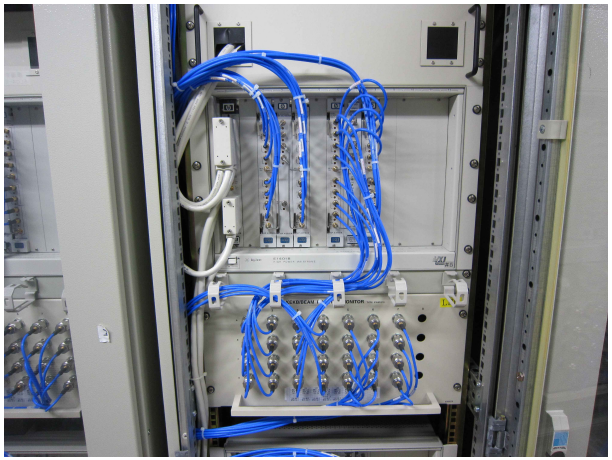
More RF reinforcement plan to further increase beam current after Phase 2,

depending on budget, demand and machine performance.

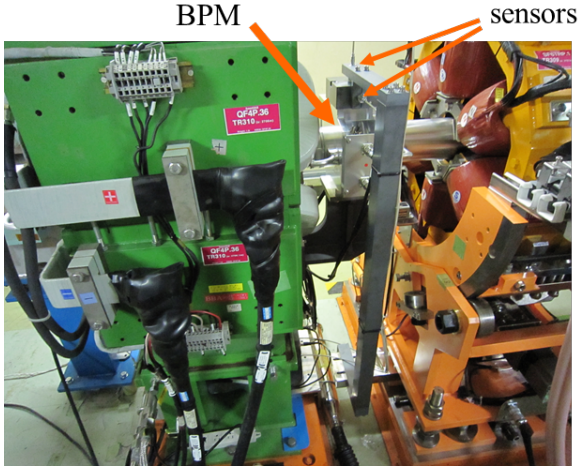


Beam Instrumentation

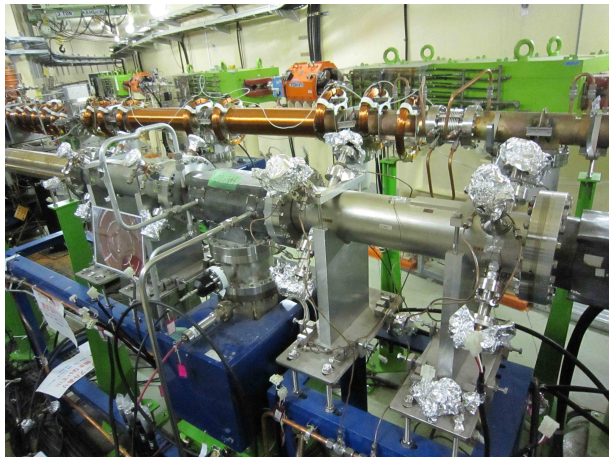
- BPM
  - Installation of BPM heads, restoration of BPM cables and installation of BPM displacement sensors are in progress.
  - New narrowband detectors have been installed at the site buildings.
  - Calibration of turn-by-turn BPM's continues at a test bench.
  - Several displacement sensors for BPM near rotatable sextupoles have been installed.
- Feedback System
  - Most components of the bunch feedback system have been installed in the tunnel.
  - Control system for the collision feedback system is being fabricated.



New narrowband detectors for the BPM system.



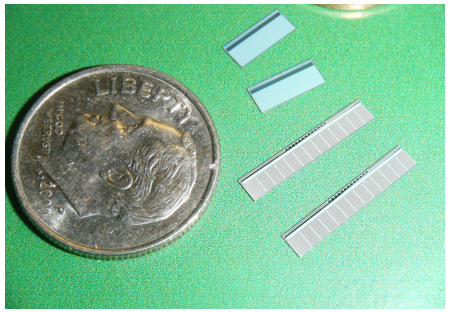
Displacement sensor near a rotatable sextupole magnets.



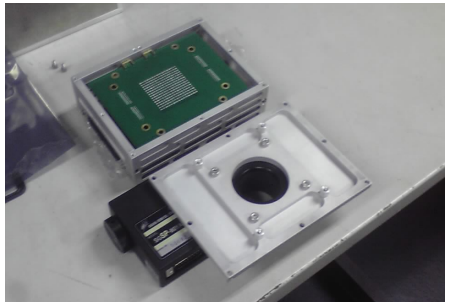
Transverse kickers of the bunch feedback system in HER.

Beam Instrumentation (cont'd)

- X-ray and visible light beam size monitors
  - Final vacuum components of the X-ray beam size monitor are being fabricated.
  - Readout and detector development is continuing in collaboration with Univ. of Hawaii and SLAC.
  - Diamond mirrors for visible light monitors have been installed in extraction chambers and aligned.
  - X-ray and visible beam lines will be installed in 2015.
- Large-Angle Beamstrahlung Monitor (LABM)
  - Components of the LABM are being prepared at Wayne State University. Its installation is planned in summer 2015.



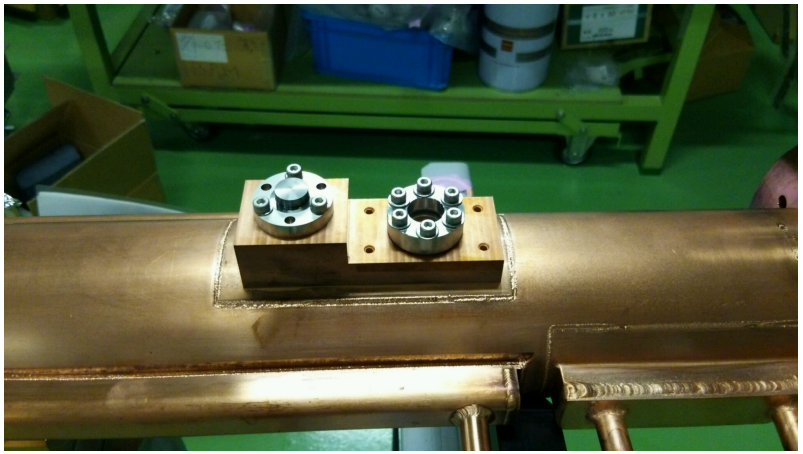
Detector mount for the X-ray monitor. (U of Hawaii)



Si deep-pixel detectors and spectrometers for the X-ray monitor. (SLAC)

Extraction mirror

Test fit of LABM extraction mirror (left) and extraction window (right) on IR beam pipe.



Control System

- Software framework: EPICS (Experimental Physics and Industrial Control System)
- Upgrades of the distributed IOC (I/O Controller), networks, servers, consoles, timing system and software are in progress.

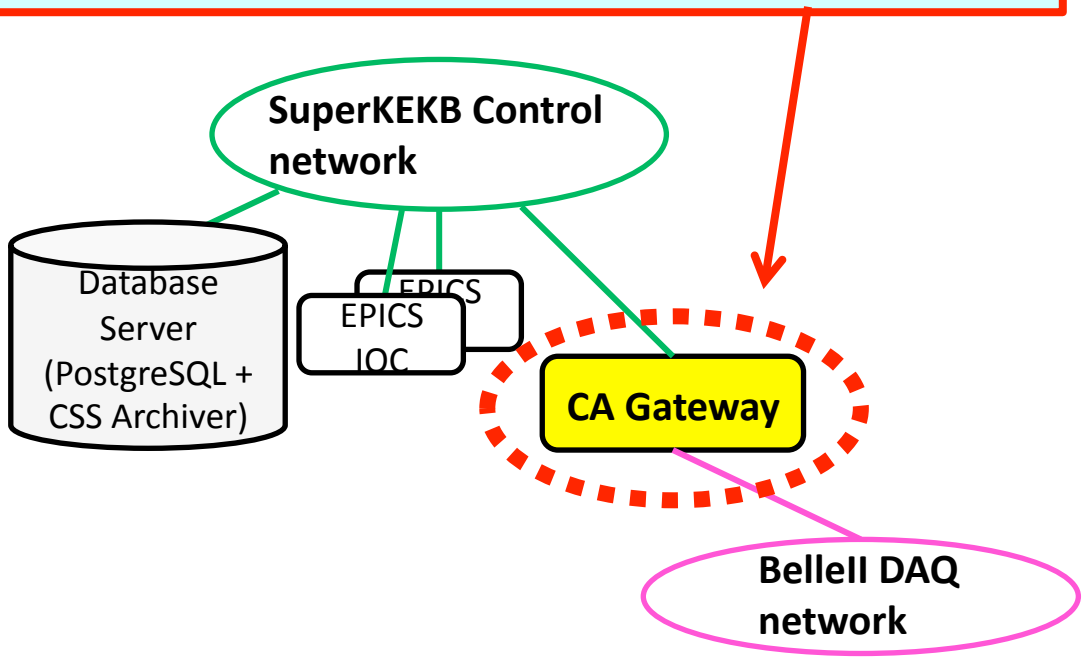
EPICS Embedded PLC as the IOC

Example: Renewal of the Vacuum Control System

Upgrade of the VME-based IOC

Example: Renewal of the Abort Trigger System

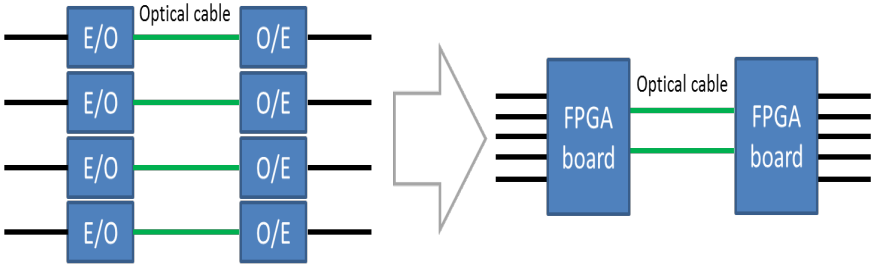
With a CA gateway, we directly exchange EPICS data btw SuperKEKB and BelleII. The CA gateway (Linux PC) is installed at Tsukuba B3, in September 2014.



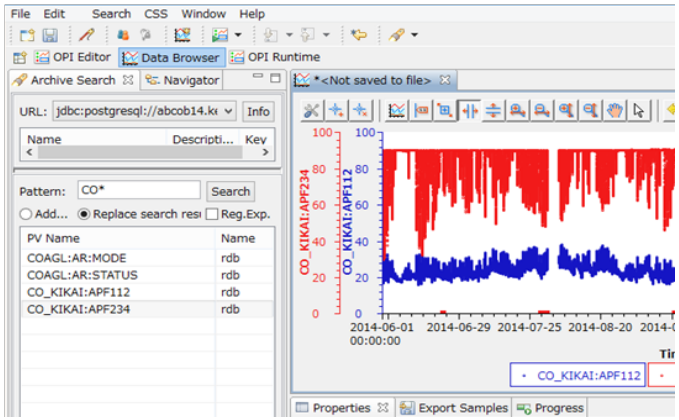
Control System (cont'd)

- Hard-wired signal between Belle2 and SuperKEKB:
  - Optical cables for the hard-wired signal (abort, injection control, timing) between Belle2 and SuperKEKB were installed in September 2014.
  - Currently, on demand from Belle2, we have developed the new signal transfer scheme based on the sampling and parallel/serial conversion using FPGA in order to increase signal lines.
- Operator interface tools were prepaired:
  - To access the EPICS record to control / monitor the accelerator
  - To access the archived data in KEKBLog (main archived database) and/or RDB stored with the CSS archiver.

Signal transfer scheme using FPGA



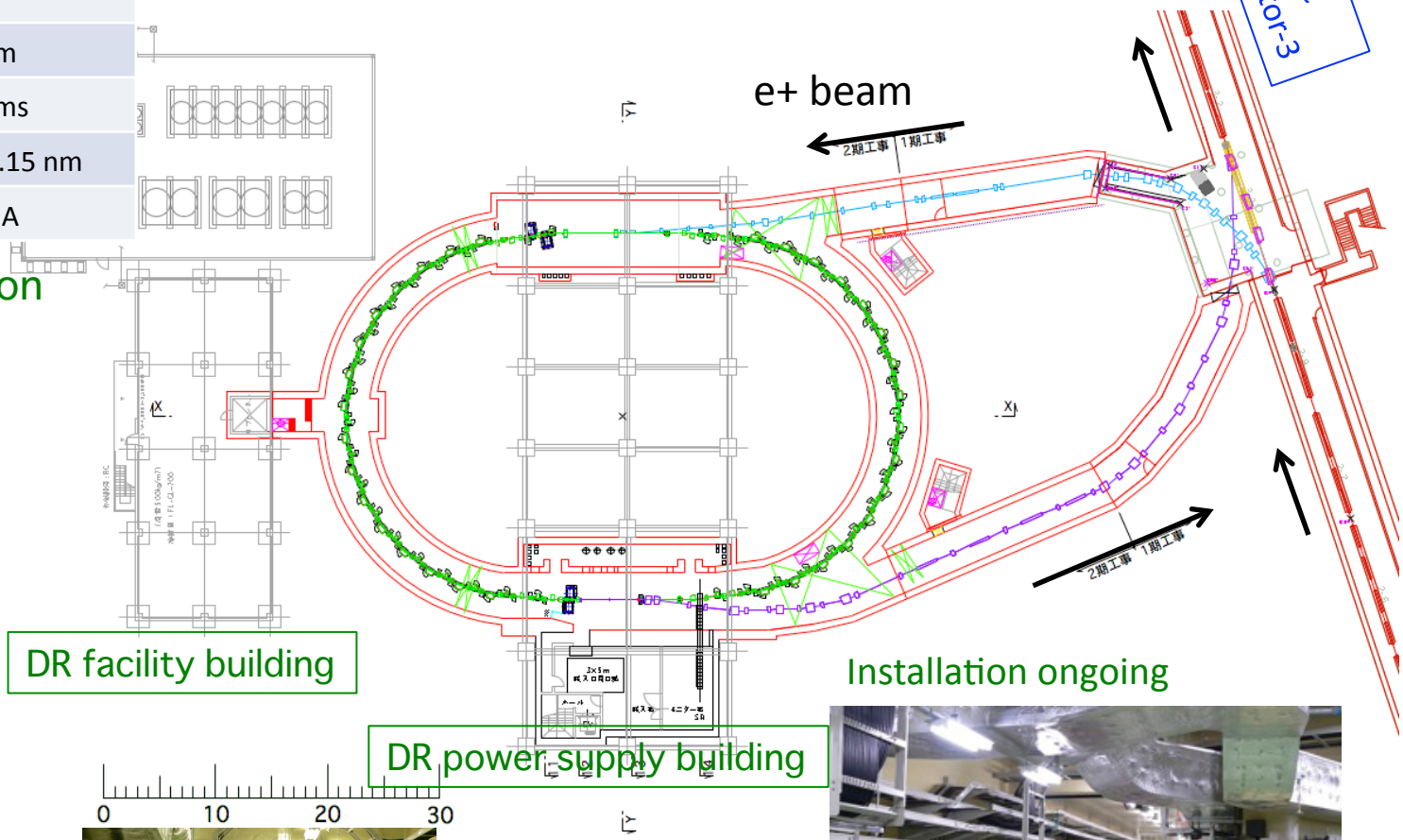
Data browser based on CSS



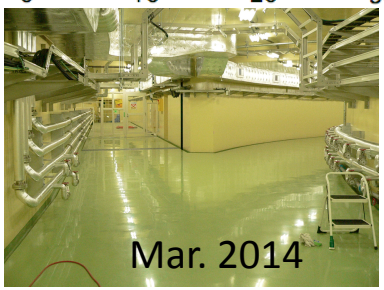
Damping Ring

Design parameters

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



DR tunnel construction

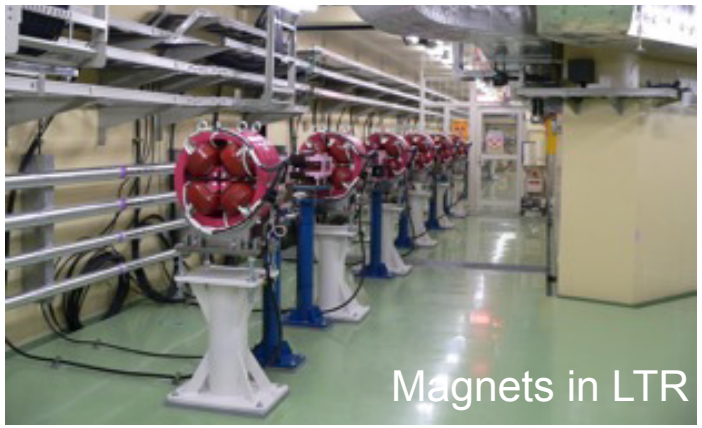


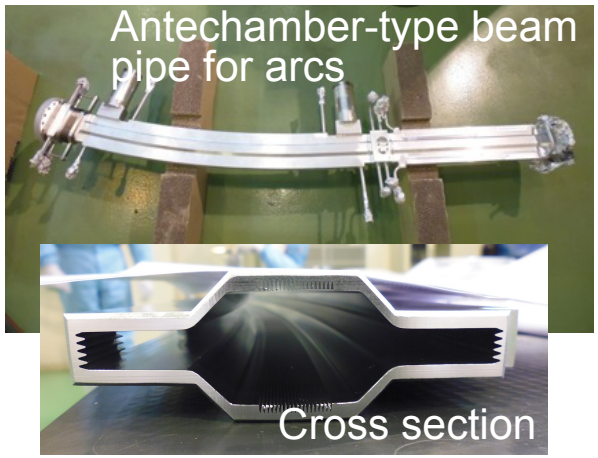
DR tunnel and buildings completed in Mar. 2014.

Installation ongoing

Damping Ring (cont'd)

- Construction status
  - Construction of the tunnel and buildings was completed.
  - Magnet installation was completed for the beam transport lines (LTR and RTL).
  - Installation of high power cables in the ring was completed.
  - All power supplies for the magnets were delivered. (except for steerings)
  - Beam pipes for the arcs were delivered and TiN coating is going on.
  - Beam pipes for straights are in fabrication.
  - Two RF cavities have been fabricated. Results of HP test exceeded specifications.
- Plan
  - Installation and startup work continues in JFY2015.
  - Commissioning of DR will start in JFY2016 in the transition period between Phase 1 and 2.





Summary of construction status

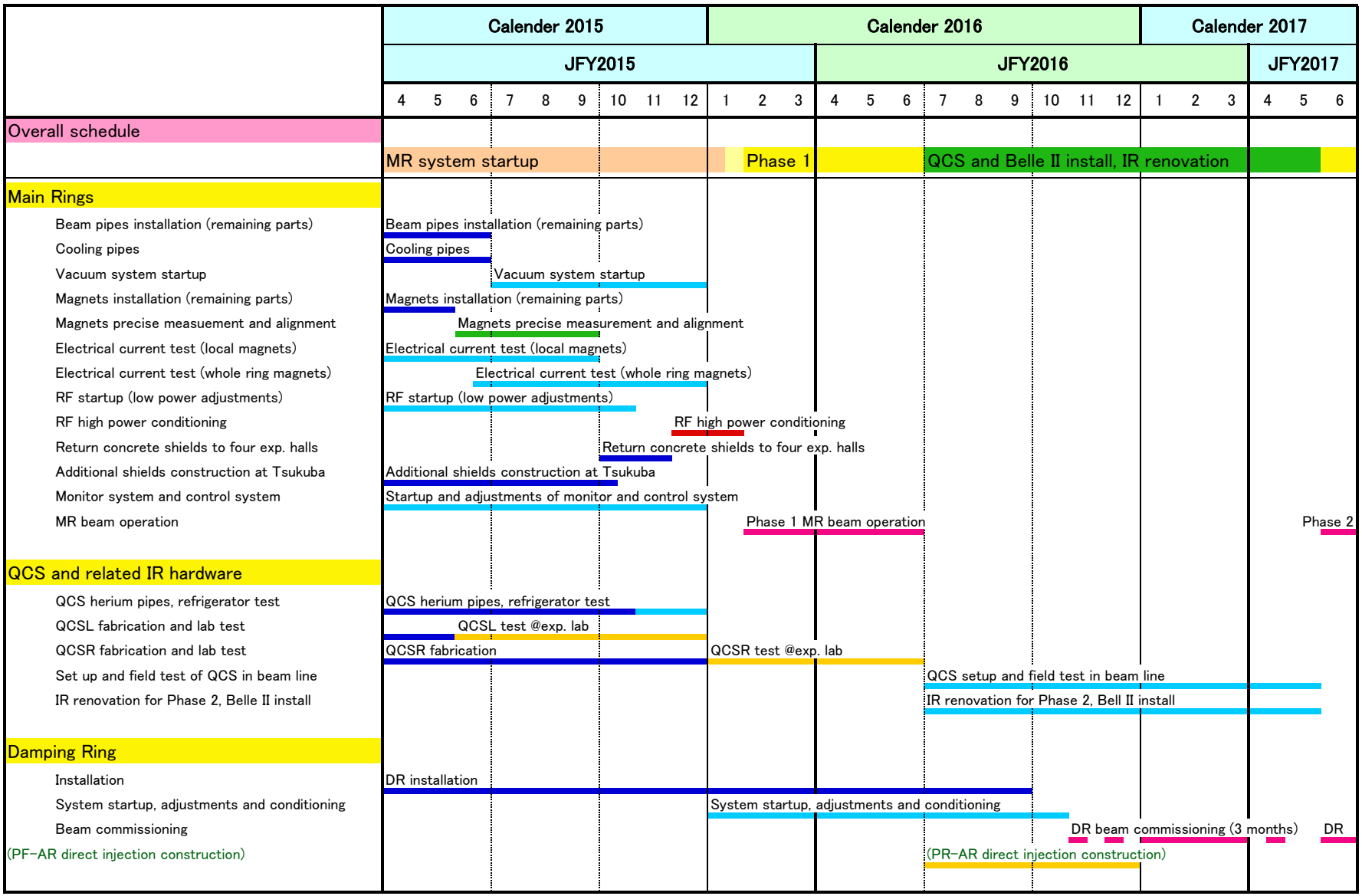
- Most of hardware improvements required for Phase 1 operation will be completed in this JFY2014, as scheduled. Appropriate rearrangements and optimization has been made to fit to the operation budget situation.
  - Installation of magnets and beam pipes and other related components will be completed in this JFY2014 except some parts (ex. in IR and injection).
  - Evacuation and activation of NEG pumps started in the arc sections.
  - Startup of magnet power supplies and electrical current tests are ongoing.
  - RF hardware improvements will almost be done in this JFY2014.
  - Monitor and control system hardware improvements are also steadily ongoing.
  - All major facility and infrastructure-related construction works have been completed.
- Hardware improvements needed for Phase 2 are also ongoing to be in time for phase 2.
  - QCS and other components for the IR
    - Fabrication of QCSL cryostat will be completed in May 2015. Preparation for the test is ongoing.
    - Fabrication of QCSR cryostat is ongoing. To be delivered by the end of 2015.
    - Test of power supplies for QCS main and corrector magnets are ongoing. Mass production will be carried out in JFY2015 and 2016 to be in time for the QCS test in the beam line.
  - DR
    - Fabrication of all magnets was already done, and field measurement is ongoing. They will be installed in JFY2015, together with beam pipes.
    - High-power test of two accelerating cavities has been finished successfully.
    - Installation of magnets at transport lines between DR and Linac and cabling for the power supplies of ring magnets finished last summer.

Schedule in JFY2015 and 2016

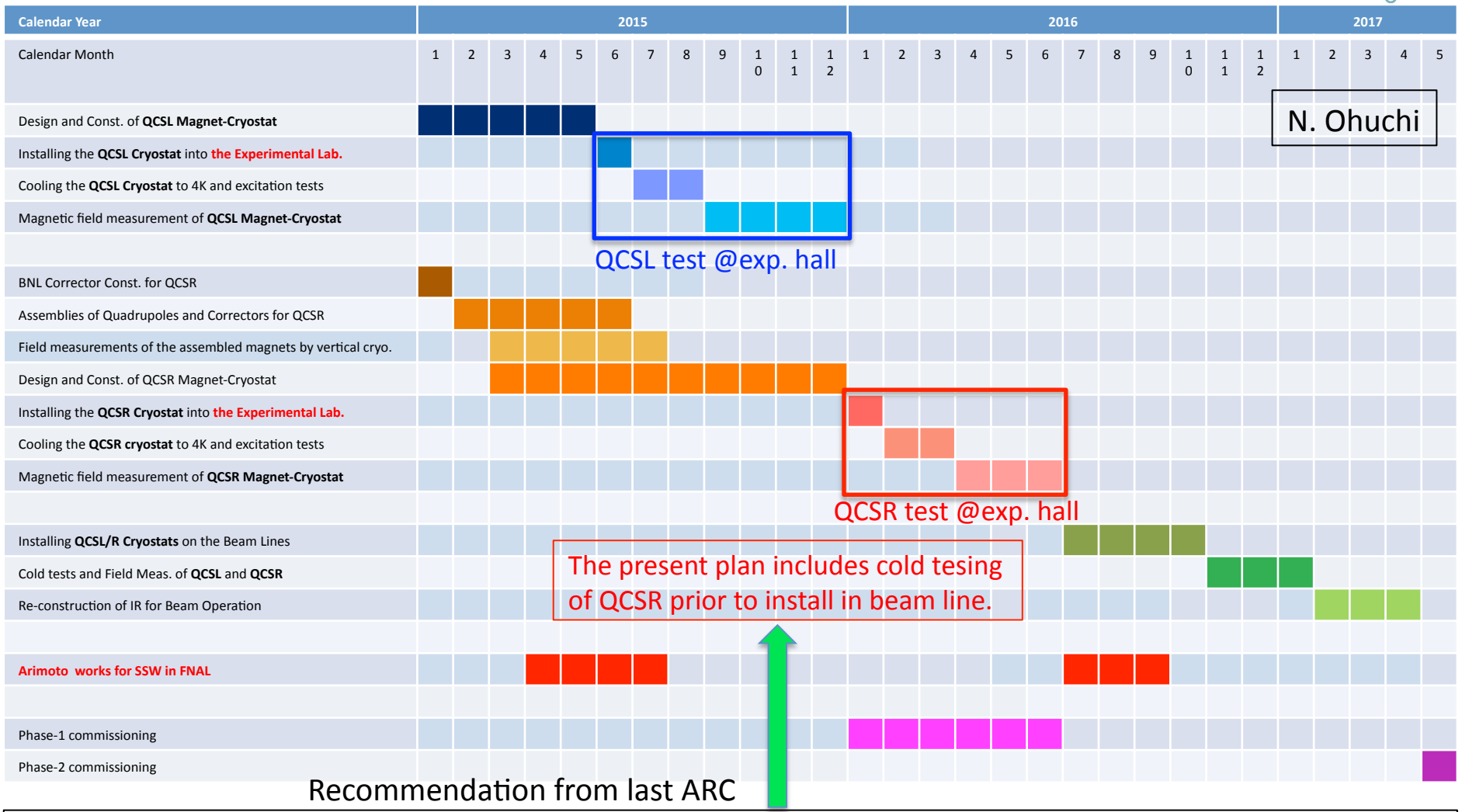
Plan for Rings in JFY2015

- Preparation work needed to start Phase 1
  - Startup and electric current tests of magnets and power supplies.
  - Final precise survey and alignment of magnets all around the ring.
  - Complete improvements of safety and control system.
  - Reinstall concrete radiation shield blocks at four experimental halls.
  - Operate refrigerators and cool down superconducting cavities.
  - Startup klystrons and condition the ARES and SC cavities with high RF power.
  - Startup vacuum, monitor, control and other systems.
- Work for Phase 2 that should be conducted in JFY2015
  - Install accelerator components in the DR, and startup them.
  - Fabrication of QCSR and cooling pipes for QCS, cooling test of QCS at an experimental hall, and startup of refrigerator at Tsukuba.
  - Improvements for Phase 2 IR (more readiation shields, fabrication of beam pipes, etc.)
  - Fabrication of more collimators
  - Improvements of LER injection components.
- Phase 1 beam operation
  - Based on latest estimation, it is possible to start Phase 1 beam operation early 2016 within the period of JFY2015.

Schedule of JFY2015-16

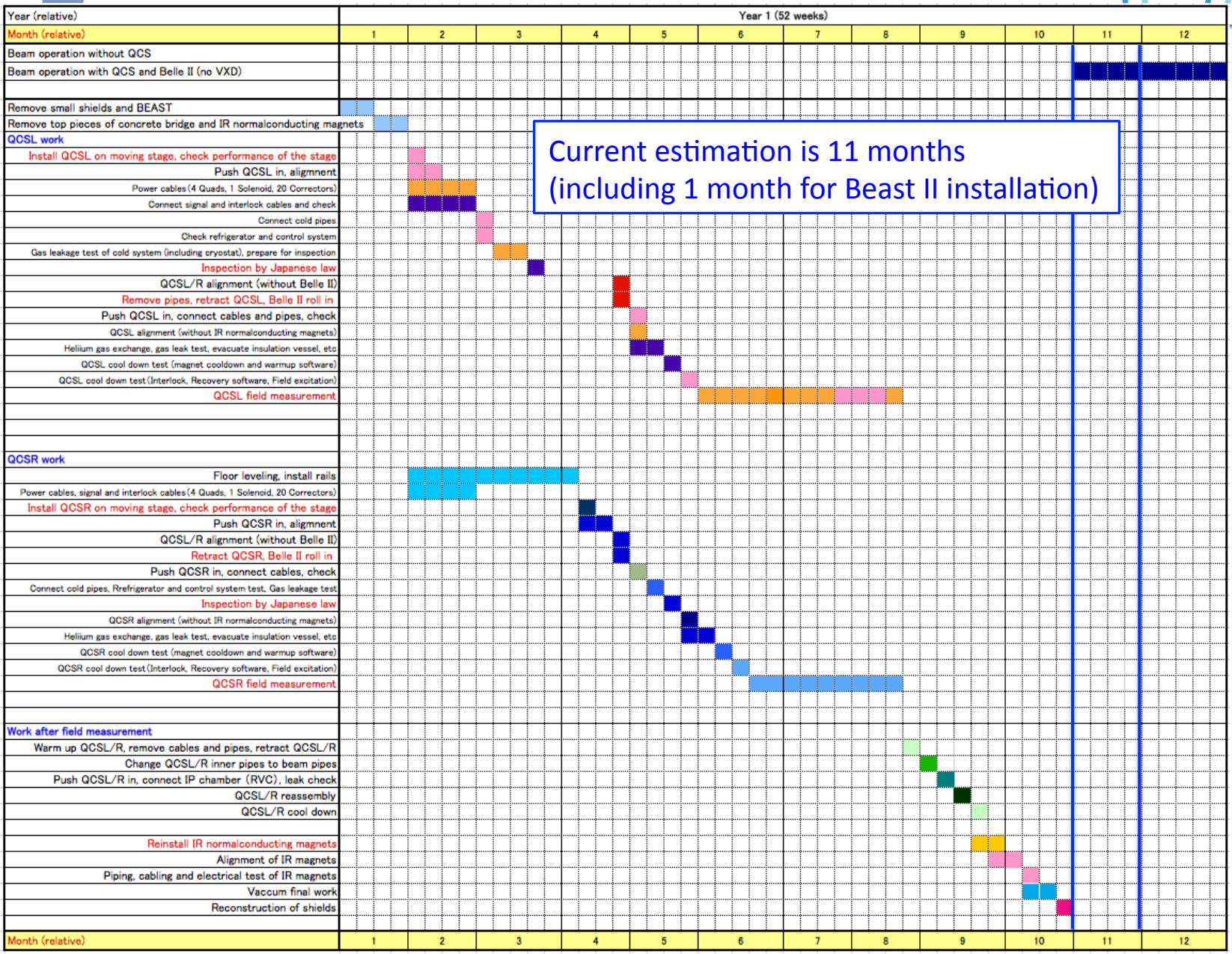


QCS construction schedule



The schedule to complete SuperKEKB construction and the start of beam commissioning is complicated by potential changes in the expected funding of beam operation. The schedule can be firmed up a lot after the new JFY2014 budget is finalized in April-May 2014. In case the FY2014 budget cut remains unchanged, a modified schedule should aim at profiting as much as possible from the additional 4 or 7 months, e.g. so as to include the cold testing of right-side IR magnets prior to installation and to complete the vacuum-system set up.

QCS and IR-related work in the transition from Phase 1 to 2



Current estimation is 11 months
(including 1 month for Beast II installation)

Human Resources (KEKB ring staff)

17th ARC in Feb. 2012

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

Change in three years (2012 – 2015)

	New (Δ FTE = +1/ person)	Retire(1) (FTE decrease)	Retire(2) (FTE no change)	tenure to permanent (FTE no change)	Change of FTE (Total FTE change)
Apr. 2012	+3	-0.5	(2)	(2)	+2.5
Jul. 2012	+2				+2
Apr. 2013	+1	-0.5	(3.5)	(2)	+0.5
Apr. 2014	+2	-1.0	(3)	(1)	+1.0
Apr. 2015	+2	-1.5	(4)	(1)	+0.5
Total FTE change	+10	-3.5	0	0	+6.5

Slow improvement

Summary

- Construction for Phase 1 commissioning is in the final stage. Startup work continues in JFY2015.
  - Most of hardware improvements required for Phase 1 MR operation will be completed in this JFY2014, as scheduled.
  - The master plan of construction and startup was changed due to the significant cut of the KEKB operation budget in JFY2014. Rearrangements and optimization of construction and startup works have been made to fit to the situation.
  - Preparation works to start beam operation, including high-power conditioning of RF cavities, final alignment of magnets around the ring, restore radiation shielding, and startup magnet, vacuum and beam monitor system, will be continued in JFY2015.
- Based on latest estimation of budget allocation in KEK, it is possible to start Phase 1 beam commissioning early 2016 within the period of JFY2015.
- In parallel, works required to prepare for Phase 2 continues to proceed the Phase 2 commissioning on time.
  - QCS, IR renovation, LER injection improvement, beam collimators and the DR.