SuperKEKB Construction Plan

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KEK

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Accelerator Review Committee

Outline

- Introduction
- Budget
- Construction strategy
- Major items for construction
- Schedule
- Cost
- Human Resources

Milestones this year

- 22 Jun. 2010: A budget of 10 Billion Yen announced
  - The MEXT, the Japanese Ministry that supervises KEK, has announced that it will appropriate a budget of 100 oku-yen (approx $110M) over the next three years starting this Japanese fiscal year (JFY2010) for the high performance upgrade program of KEKB. This is part of the measures taken under the new "Very Advanced Research Support Program" of the Japanese government. ("KEKB upgrade plan has been approved", Press Release 23 Jun 2010; KEK web site)
- 30 Jun. 2010: KEKB operation was shut down, and KEKB upgrade started.

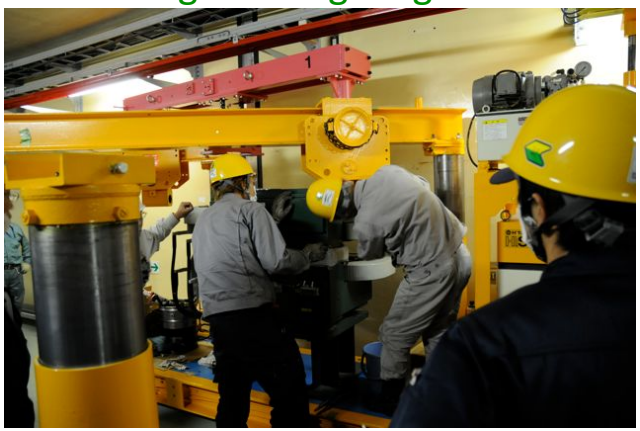
- 24 Dec. 2010: SuperKEKB approved in FY2011 budget
  - The Cabinet of Japan announced the national budget plan of JFY2011 last Friday, where SuperKEKB upgrade was approved as requested by MEXT. This will be final decision of SuperKEKB after approval by the Japanese Diet. ("Green light from the Cabinet", M. Yamauchi to Belle II members)

Dismantle KEKB on going

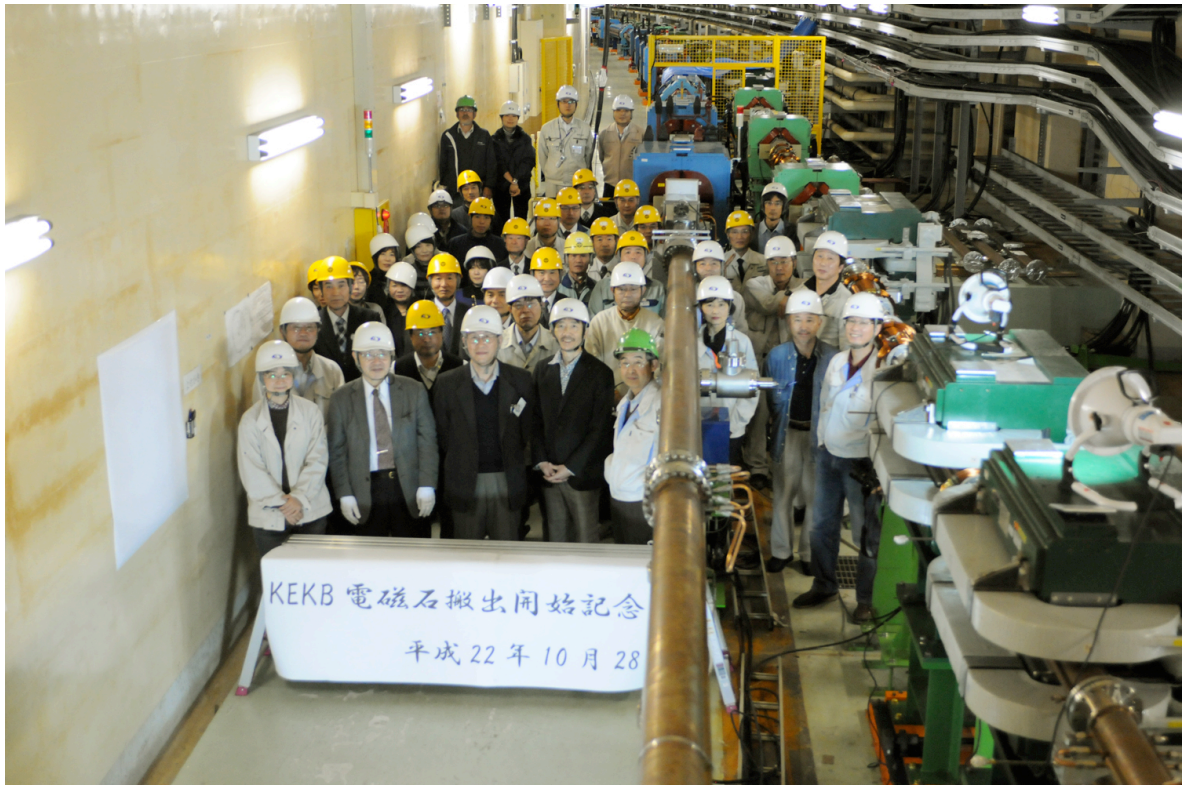
- Dismantle LER arc section (bending magnets, wigglers, beam pipes, etc.) almost done.
- Both rings at Tsukuba straight section will be dismantled in FY2011.
- HER arc section will be kept.

Bellows taken out from LER

Removing bending magnet



Ceremony for starting removal of magnets (M. Masuzawa)

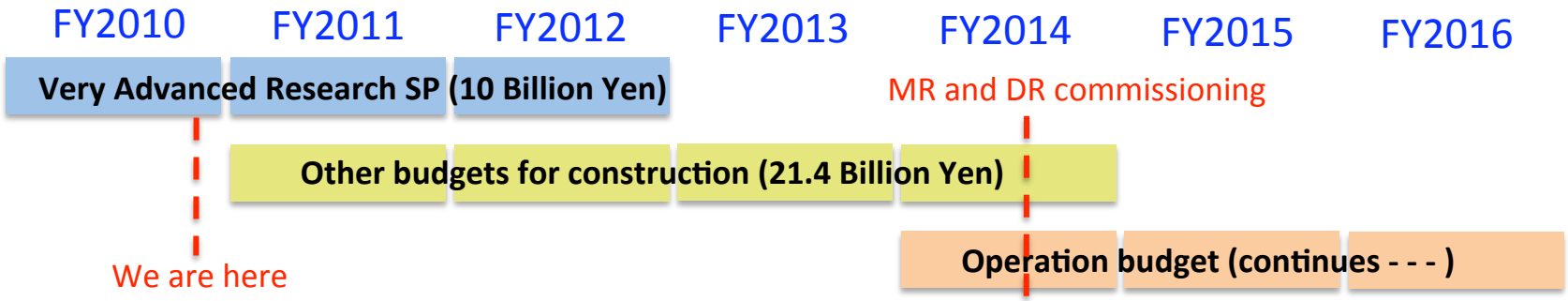


Removing LER bending magnets (107 magnets all done)

Removing LER beam pipes from Q magnets

Budget

- "Very Advanced Research Support Program"
  - MEXT has announced that it will appropriate 10 Billion Yen for three years (FY2010-12).
  - Among this, 7.5 Billion Yen was already appropriated in FY2010.
  - This budget is for upgrading LER vacuum system and LER magnet system.
- Other budgets
  - 21.4 Billion Yen for SuperKEKB construction is expected for FY2011-14.
  - Among this, approval of 4.06 Billion Yen for FY2011 was announced by the Cabinet.
  - They are for various accelerator components and facilities, including DR tunnel, buildings for DR and MR and cooling system.
- Total budget
  - Total construction budget is 31.4 Billion Yen.
  - The operation budget is expected in FY2014 and later.



Commissioning plan

- Machine commissioning start
  - Main Ring and Damping Ring commissioning will start in the second half of FY2014.
  - Linac is in operation for PF and PF-AR during the construction period. Test operation for the upgrade will be performed in parallel. Commissioning of Linac for SuperKEKB will start in the beginning of FY2014.
- Detector
  - The detector people want that the machine operation starts without Belle II. So the machine commissioning will start with some dummy chambers with a luminosity monitor at the IR (so called BEAST).
  - Belle II will be installed later in FY2015.
  - IR configuration before Belle II installation is under discussion (for example, "Do we need solenoids or special skew-Q, special radiation shield in the place of Belle, etc. with an extra cost?"). We have no concrete plan for this so far.

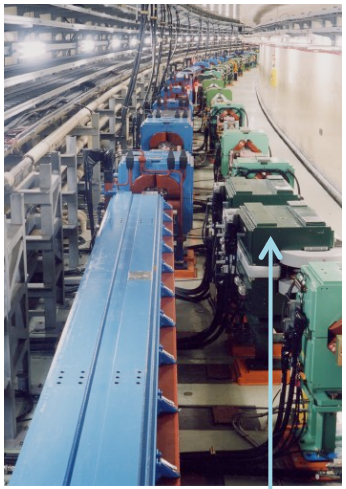
Construction Strategy_1

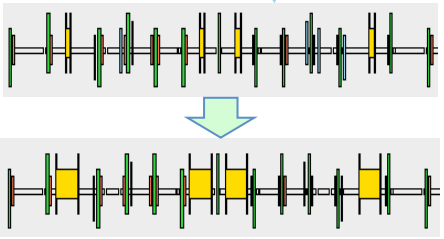
- Design fixed or not fixed
  - Machine design has not been completed, in particular for difficult parts such as IR optics and QCS hardware, chromaticity correction scheme and beam collimation scheme.
  - On the other hand, a large amount of budget has already been appropriated (7.5 Billion Yen for FY2010 and 4.6 Billion Yen for FY2011). The budget must be executed appropriately.
  - We first use the budget for those components that the design is already fixed such as magnets and beam pipes at the arc section and wiggler sections. Fabrication of the components that the design is not fixed yet such as those for the IR, sextupole region and collimation system are postponed to FY2012 or later.
  - The due dates to fix those designs are presented from the viewpoint of construction schedule (shown later).
- Before or after T=0.
  - Considering budget profile and schedule, we make differences between the required performance at T=0 and other requirements that can be postponed for years. Those components indispensable at T=0 must be completed with a higher priority (see, next slide).
  - Large scale works that are difficult to do after the commissioning should also be completed by T=0. This includes rearrangement of ARES cavities and reinforcement of cooling pipes in tunnel.

Construction Strategy_2

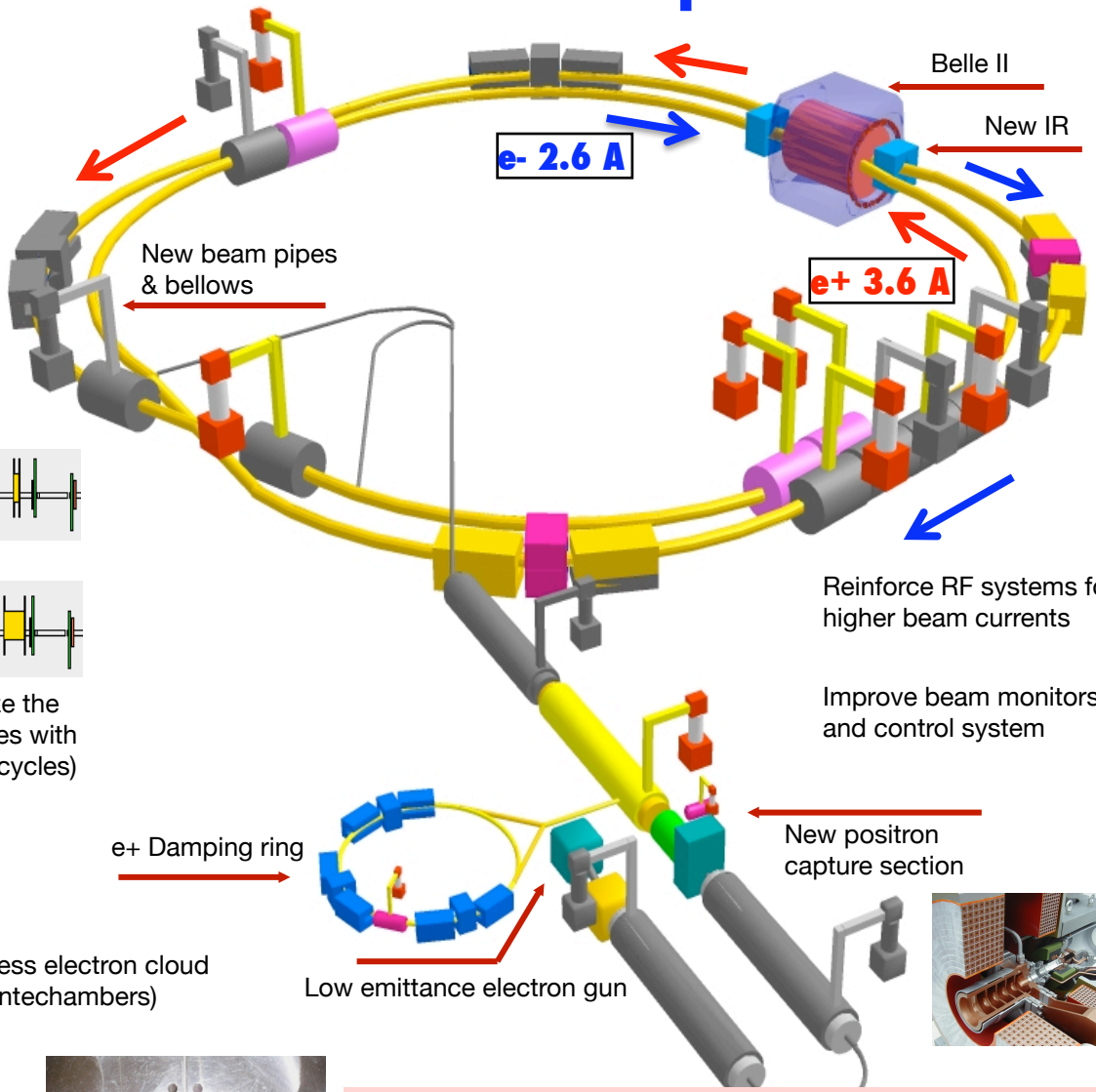
- Emittance
  - The design emittance is targeted from the beginning (at T=0).
  - Main Ring magnets, beam pipes, injection system, etc. should be completed by then.
  - The injector and Damping Ring should satisfy the low emittance at T=0.
- β_y^*
  - We may start with detuned optics, and then gradually squeeze.
  - IR configuration at T=0 is under discussion (as mentioned).
- Beam current
  - Start with low beam current. At T=0 the maximum current is less than the design value (maybe 60~70%). Increase to the design current will take about two years or more.
  - Extensive rearrangement of cavities and RF system will be done during the construction period. Fabrication and installation of additional RF stations will be divided into two phases (before and after T=0)
  - Some of infrastructure (cooling, transformers) may be postponed for one or two years.
  - Charge requirement for Linac and DR is set to match the beam current increase (For example, 1 nC at T=0, 2 nC at +1year, 4nC at +2 years). This is to make a clear target for the RF e-gun and e+ source R&D, and for the Linac and DR construction schedule.
- Beam energy
  - Υ(4S) at T=0. Additional components needed (if any) in Linac for Υ(6S) will be postponed. But necessary change for Beam Transport will be done by T=0.

KEKB to SuperKEKB

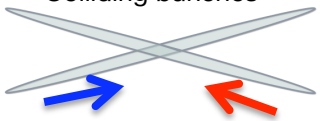




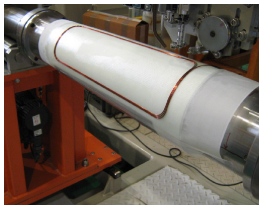
Redesign the lattice to squeeze the emittance (replace short dipoles with longer ones, increase wiggler cycles)



Colliding bunches

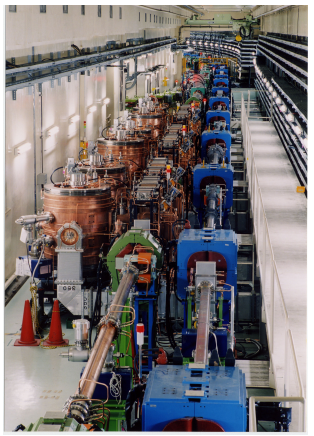


New superconducting final focusing magnets near the IP

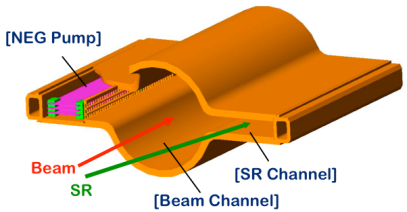


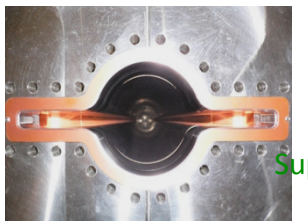
Reinforce RF systems for higher beam currents

Improve beam monitors and control system



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





To get x40 higher luminosity

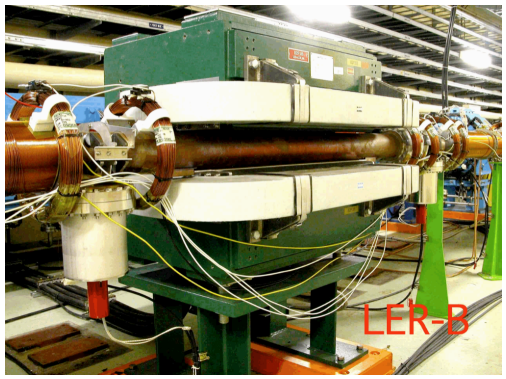
Major items for construction

- A large number of magnets need to be rearranged, replaced, and added to reduce the horizontal emittance of both beams to one-fifth to one-tenth of their present values.
- To cope with the electron cloud issues and heating problems, ante-chamber type beam pipes will be adopted with a combination of TiN coatings, grooved shape surfaces, and clearing electrodes.
- A new final focus magnet system is being designed to squeeze βy^*.
- The RF system will be strengthened, and the accelerating cavities modified and rearranged to cope with the increased beam currents.
- The beam monitor and control system will also be improved.
- Upgrades to the injector linac and beam transport system, including a new, low-emittance RF electron gun, improvements to the positron source, and installation of a 1.1 GeV positron damping ring, are designed to improve the rate and quality of injected beams to deliver the required beams with increased injection efficiencies.
- Cooling system will be reinforced for the magnets and vacuum system.
- Tunnel and buildings, additional transformers.
- Dismantle KEKB and install base plates. R&D, design, fabricate, and install components. Check and adjust them for system commissioning.

In my talk, some of the items are briefly introduced.
Details will be given in the following talks by our colleagues.

Magnets for LER arc

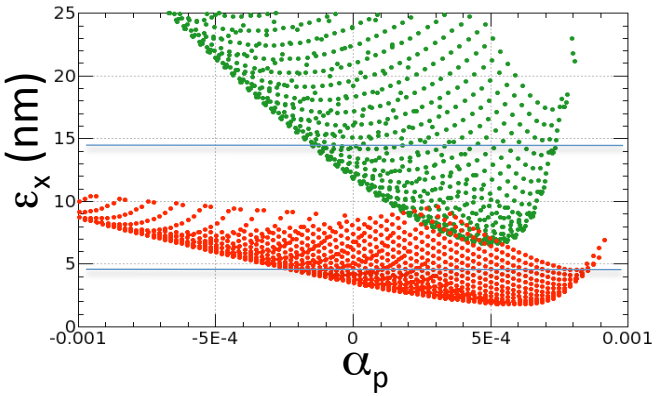
- Replace bending magnets (~100) with new longer ones to reduce horizontal emittance.

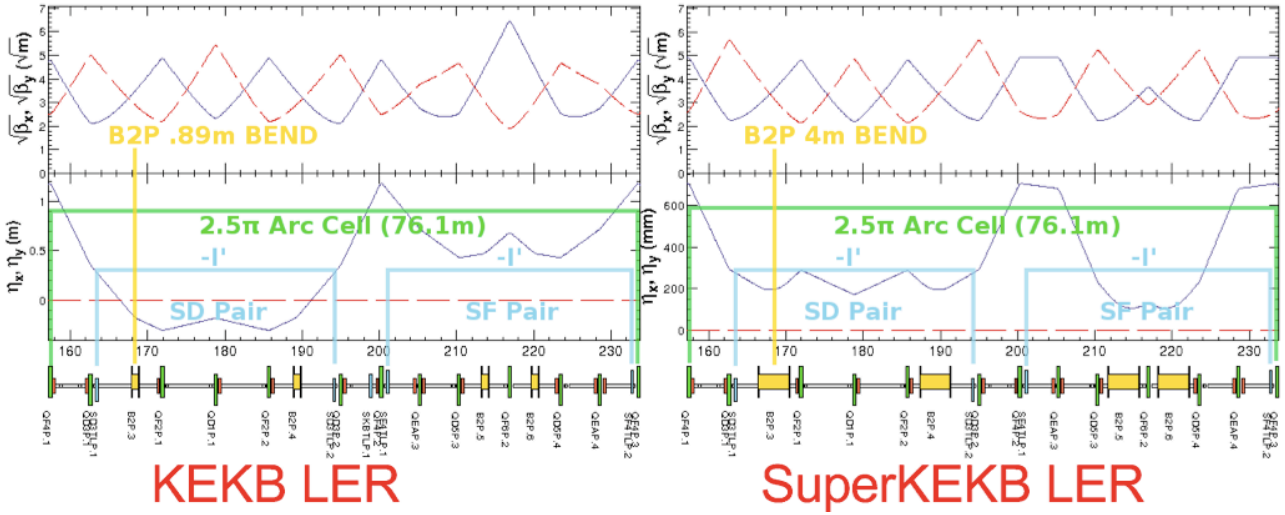


L= 0.89 m → 4 m

A. Morita, Y. Ohnishi, et al

Tunability of the LER cell

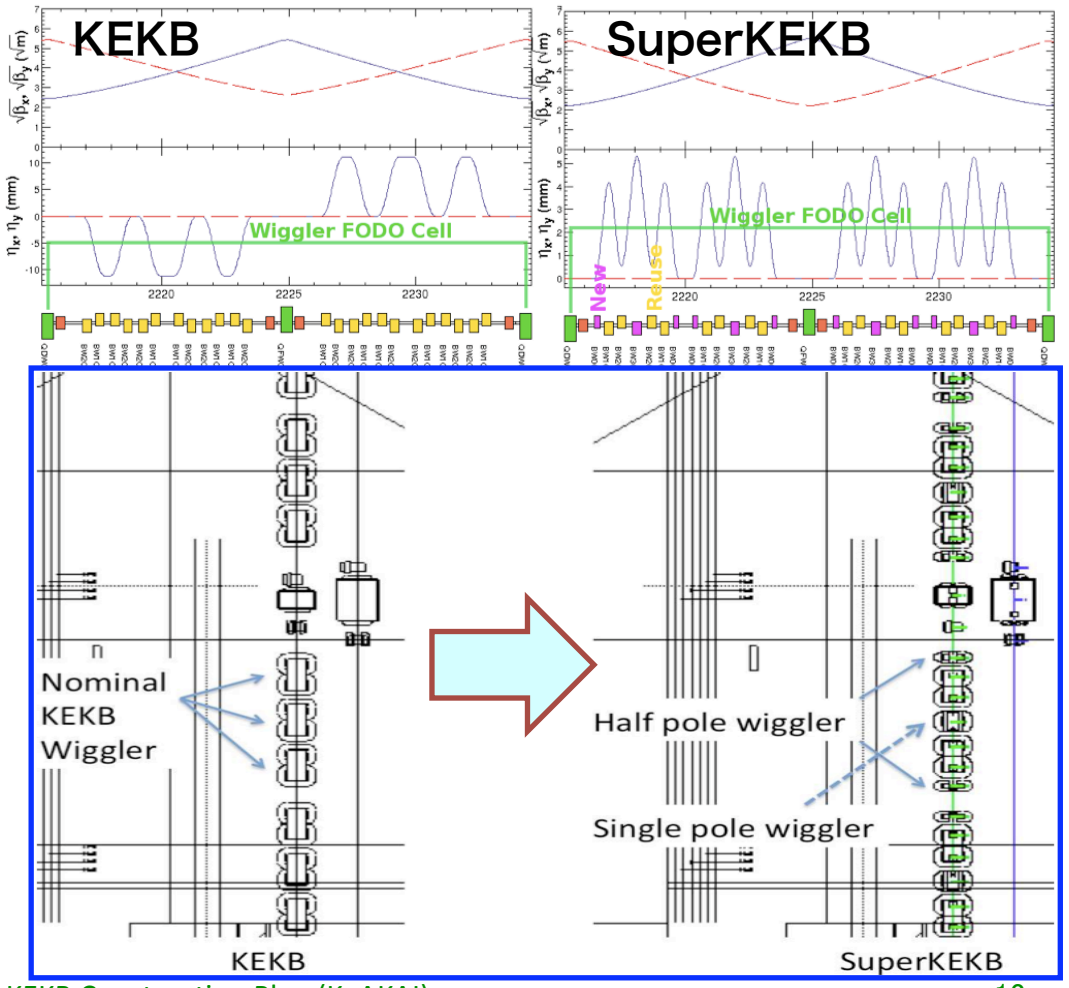




LER wiggler section

- New 56 single pole wigglers and 112 half pole wigglers will be added to the existing normal ones to double the wiggler cycles.

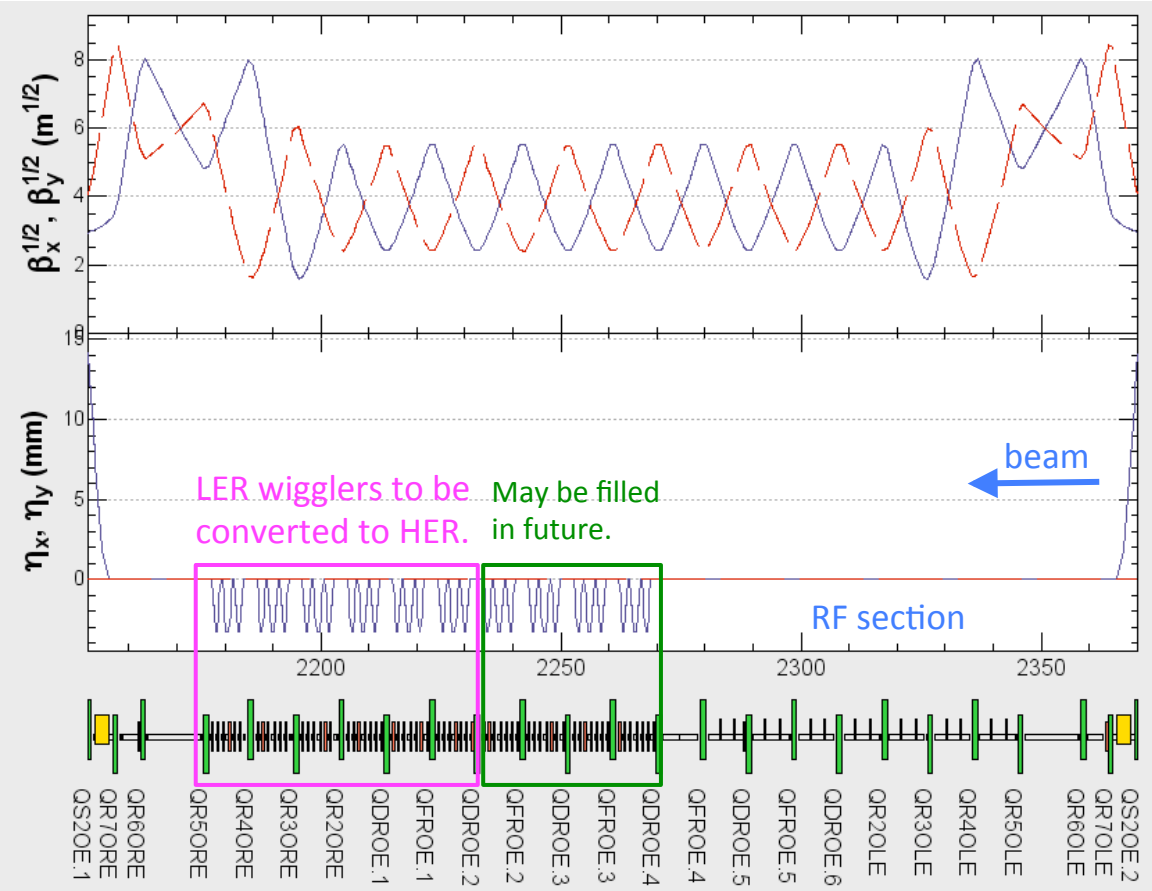
existing normal wigglers



HER wiggler section

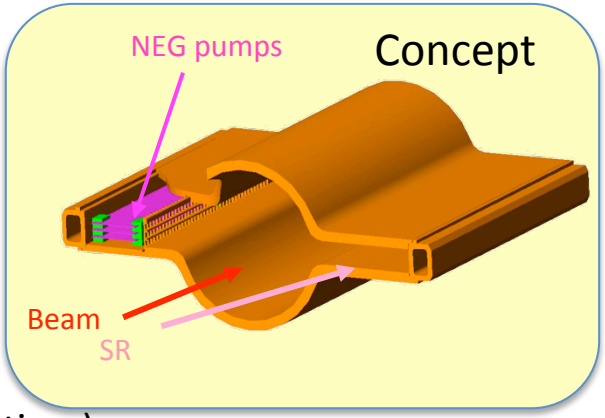
H. Koiso

- Wiggler magnets will be installed to reduce the HER horizontal emittance. For 6 wiggler sections among 10, present LER wiggler magnets will be reused. The rest 4 sections may be filled in future.



Ante-chamber type beam pipe

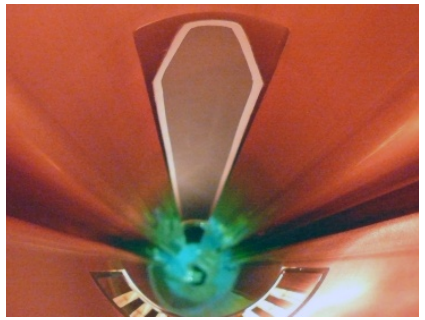
- **Structure**
  - SR from beam is guided to the ante-chamber.
  - NEG pumps in the ante-chamber.
  - TiN coating inside.
- **Merits**
  - **Suppress electron clouds.**
  - Reduce beam impedance.
  - Reduce SR power density at the wall.
- **Material**
  - Copper at wiggler magnet section.
  - Aluminum alloy at arc section (reduce cost and manufacture time).



Arc section (aluminum)

Wiggler section (copper)

Inside view
(clearing electrode for wiggler section)



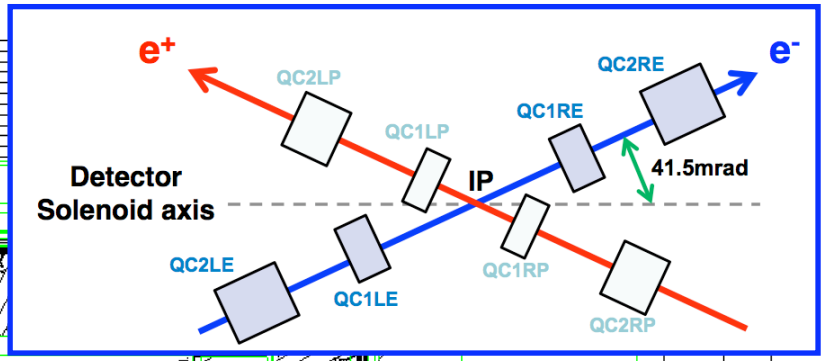
Vacuum system

- Beam pipes at LER arc section will be replaced with new aluminum-alloy ante-chamber pipes (~2000m).
  - Fabrication starts this year. We have called for vendors.
- Copper ante-chambers will be used at wiggler sections in LER and HER.
  - With clearing electrodes for LER.
- Present copper beam pipes at HER arc section will be reused.
  - Since the HER energy is reduced from 8.0 to 7.0 GeV, SR power at normal arc section for the design beam current will be about the same as present KEKB.
  - This reduces construction cost and work largely.
  - Some of the HER components will be replaced with more robust ones such as comb-type gate valves and comb-type bellows for higher beam currents in future.
- Tsukuba straight section for both rings will be made new.
  - Optics changes. Ante-chambers will be used, copper for most part.
- Collimation scheme is under discussion. R&D of movable masks is underway.

Details will be given by Y. Suetsugu.

Superconducting final Q

- Final SC quads will be located as close to the IP as possible.
- Independent magnets in the LER and HER.



IR components

- Design
  - Optics design including the effect of leakage field of QCS and other error sources to make sufficient dynamic aperture has not been finalized yet.
  - Local chromaticity correction scheme has not been determined.
  - Hardware design including QCS, beam pipes, monitors and supports are under way.
  - Assembly procedure is under discussion.
  - Evaluation of background issues are under way. This may require serious change for the IR design.
  - T=0 scenario is not determined yet.
- Construction
  - Fabrication of magnets in the Tsukuba straight section including the IR and local chromaticity correction is postponed to FY2012.
  - Fabrication of other IR components such as beam pipes and pumps is also postponed to FY2012.
  - In order to be ready for the commissioning in the second half of FY2014, fabrication of QCS should start in the second half of FY2011.
- The IR design needs to be fixed until the autumn this year.

Details will be given by N. Ohuchi, K. Kanazawa and H. Nakayama.

RF system

	unit	KEKB (operation)		SuperKEKB (design)			
Ring		LER	HER	LER	HER	HER (base line)	HER
Wiggler		Full	None	Full	None	6/10	Full
Beam Energy	GeV	3.5	8.0	4.000	7.007	7.007	7.007
Beam Current	A	1.8	1.4	3.6	2.6	2.6	2.6
Number of Bunches		1585	1585	2500	2500	2500	2500
Bunch Length	mm	6 ~ 7	6 ~ 7	6	5	5	5
Energy loss/turn	MV	1.5	3.5	1.87	2.07	2.43	2.67
Momentum compaction				3.49E-4	4.55E-4	4.55E-4	4.54E-4
Radiation Loss	MW	2.7	4.9	6.73	5.38	6.32	6.94
Loss factor, assumed	V/pC			30	40	40	40
Parasitic Loss	MW			1.56	1.09	1.09	1.09
Total Beam Power	MW	~ 3.5	~ 5.0	8.30	6.47	7.41	8.03
RF Voltage	MV	8.0	15.0	9.4	12.4	14.7	15.8

twice

twice

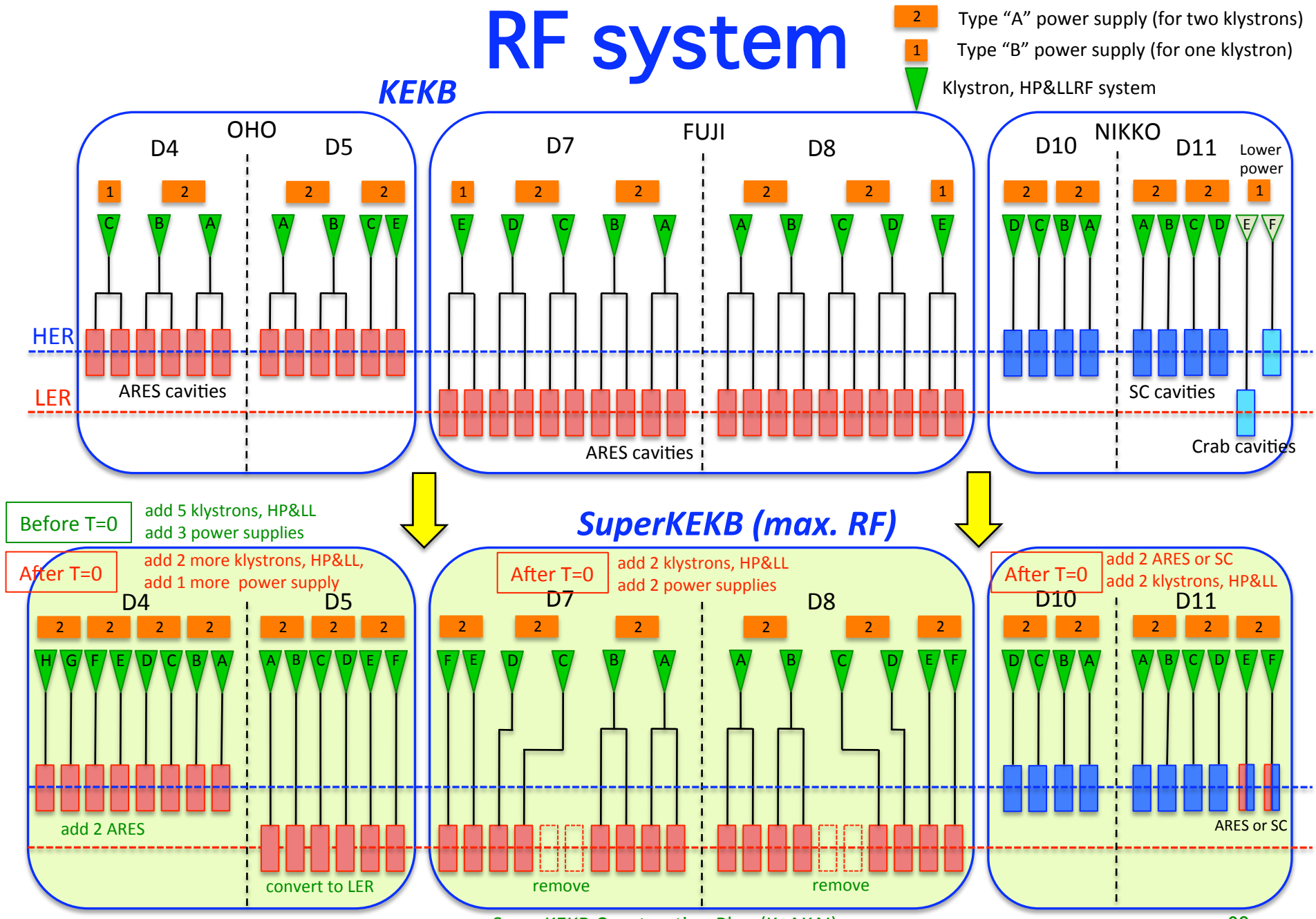
three times

- Add HP&LL RF system and rearrange ARES cavities.
- Change ARES input couplers to larger coupling ones.
- Improve HOM dampers (ARES, SCC).

} Change to 1 Kly: 1ARES system (currently 1 Kly: 2 ARES)

Details will be given by T. Kageyama

RF system


2 Type "A" power supply (for two klystrons)
1 Type "B" power supply (for one klystron)
Klystron, HP&LLRF system
KEKB
OHO
FUJI
NIKKO
D4
D5
D7
D8
D10
D11
Lower power
HER
LER
ARES cavities
SC cavities
Crab cavities
Before T=0
add 5 klystrons, HP&LL
add 3 power supplies
SuperKEKB (max. RF)
After T=0
add 2 more klystrons, HP&LL,
add 1 more power supply
add 2 klystrons, HP&LL
add 2 power supplies
add 2 ARES or SC
add 2 klystrons, HP&LL
add 2 ARES
convert to LER
remove
remove
ARES or SC

Beam monitors

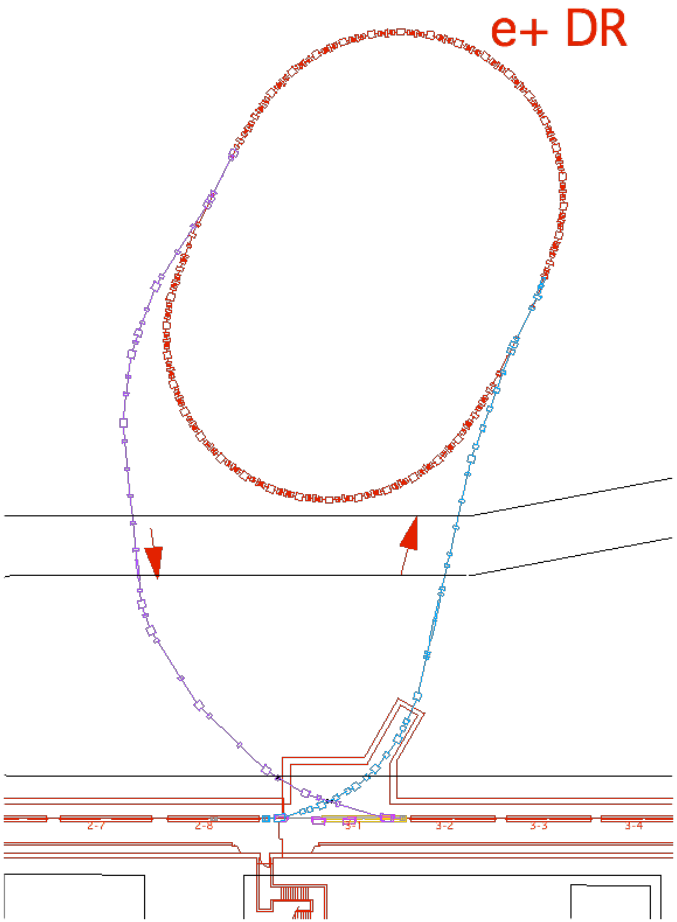
- Beam position monitors
  - Medium band detectors
  - Turn by turn detectors
  - New narrow band detectors (1GHz→509MHz)
    - R&D of these detectors are going on.
    - Requirements from optics design should be fixed.
    - Number of minimum detectors needed at T=0 should be determined.
  - Button electrodes
    - Mass fabrication is scheduled in FY2011 and 2012.
  - Displacement detection system
- Bunch by bunch feedback system
  - Transverse
  - Longitudinal feedback system is also required in LER.
- Profile monitors
  - Visible light monitor
  - X-ray beam size monitor
  - Beamstrahlung monitor
- Gated measurement
- Loss monitors, etc.

Details will be given by H. Fukuma

New positron damping ring

We construct a positron damping ring for the very low emittance beam injection

Details will be given by M. Kikuchi



Beam energy (GeV)	1.1		
Circumference (m)	135		
# of train	2		
# of bunches/train	2		
Maximum stored current (mA)	70.8		
Horizontal damping time (ms)	11		
Injected-beam emittance (μm)	1.7		
Emittance @ extraction (H/V) (nm)	42.5 / 2.07		
Cavity voltage (Vc) (MV)	0.5	1.0	1.4
Bunch length (mm)	11.1	7.7	6.5
Momentum compaction (α)	0.0141		
Energy spread (%)	0.055		

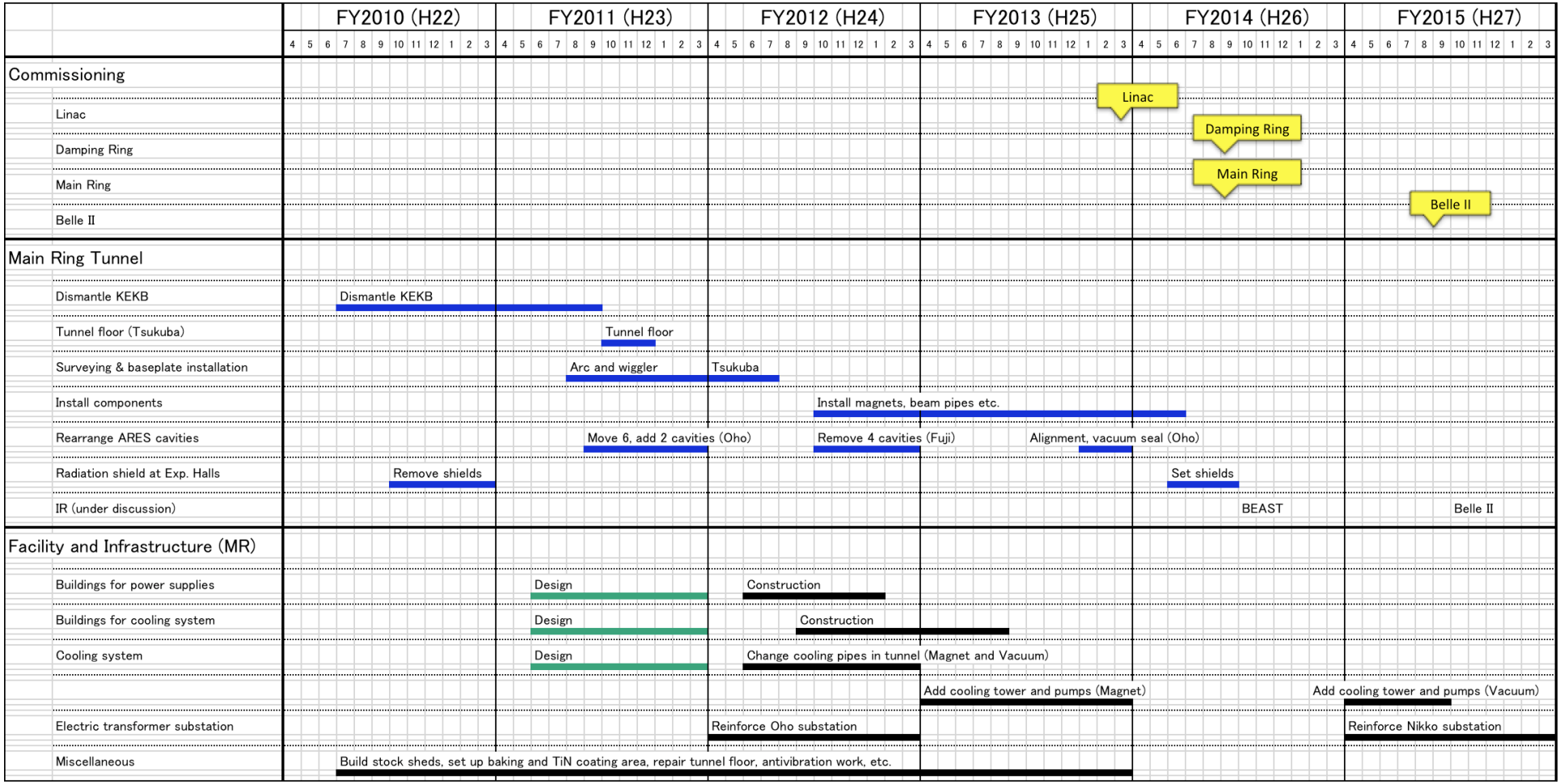
Electron cloud will be mitigated by TiN coated ante-chambers and solenoid windings. Fabrication of magnets started in FY2010.

Facility and Infrastructure

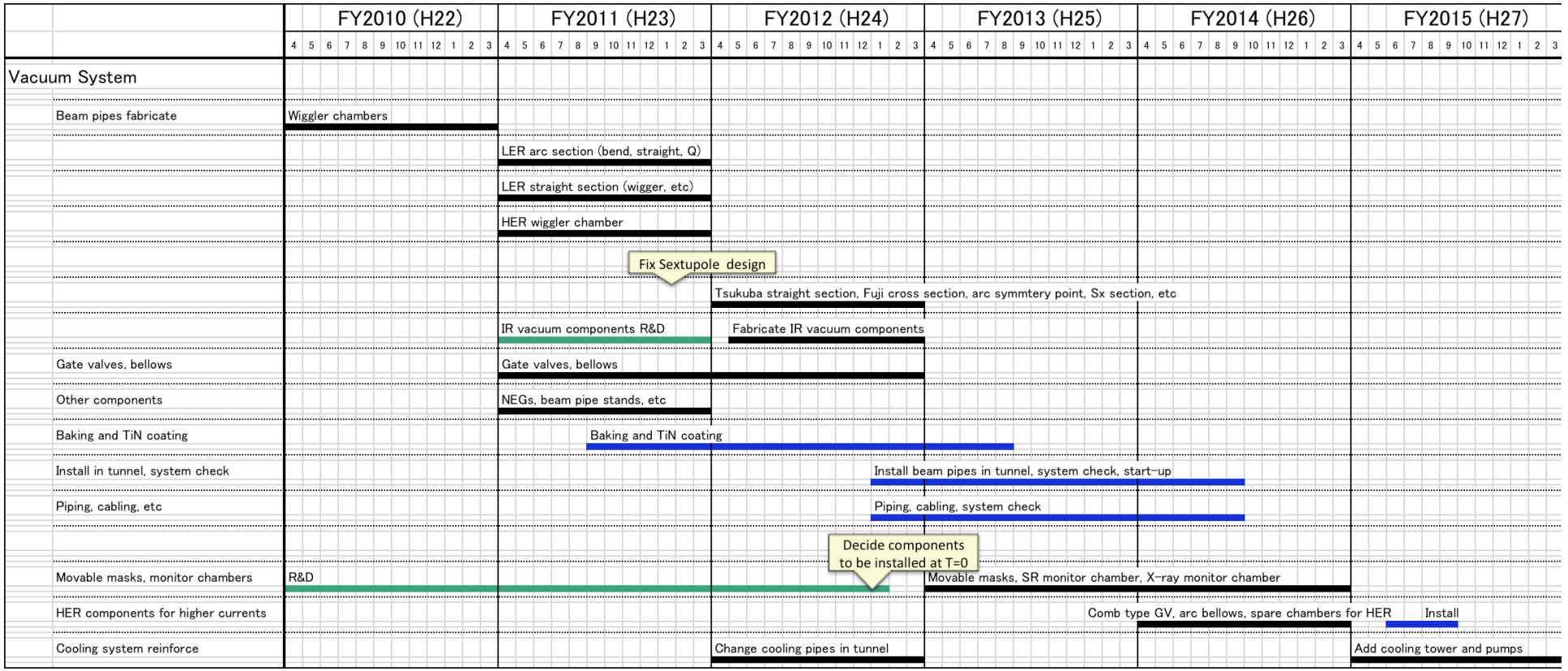
- Main Ring
  - Add buildings for power supplies and cooling system
  - Reinforce cooling system
  - Reinforce transformers
  - Repair floor
  - Stock area and working space
- Damping Ring
  - New tunnel
  - New buildings for power supplies and cooling system
  - Cooling system
  - Electricity

Injector upgrade will be presented by T. Higo.

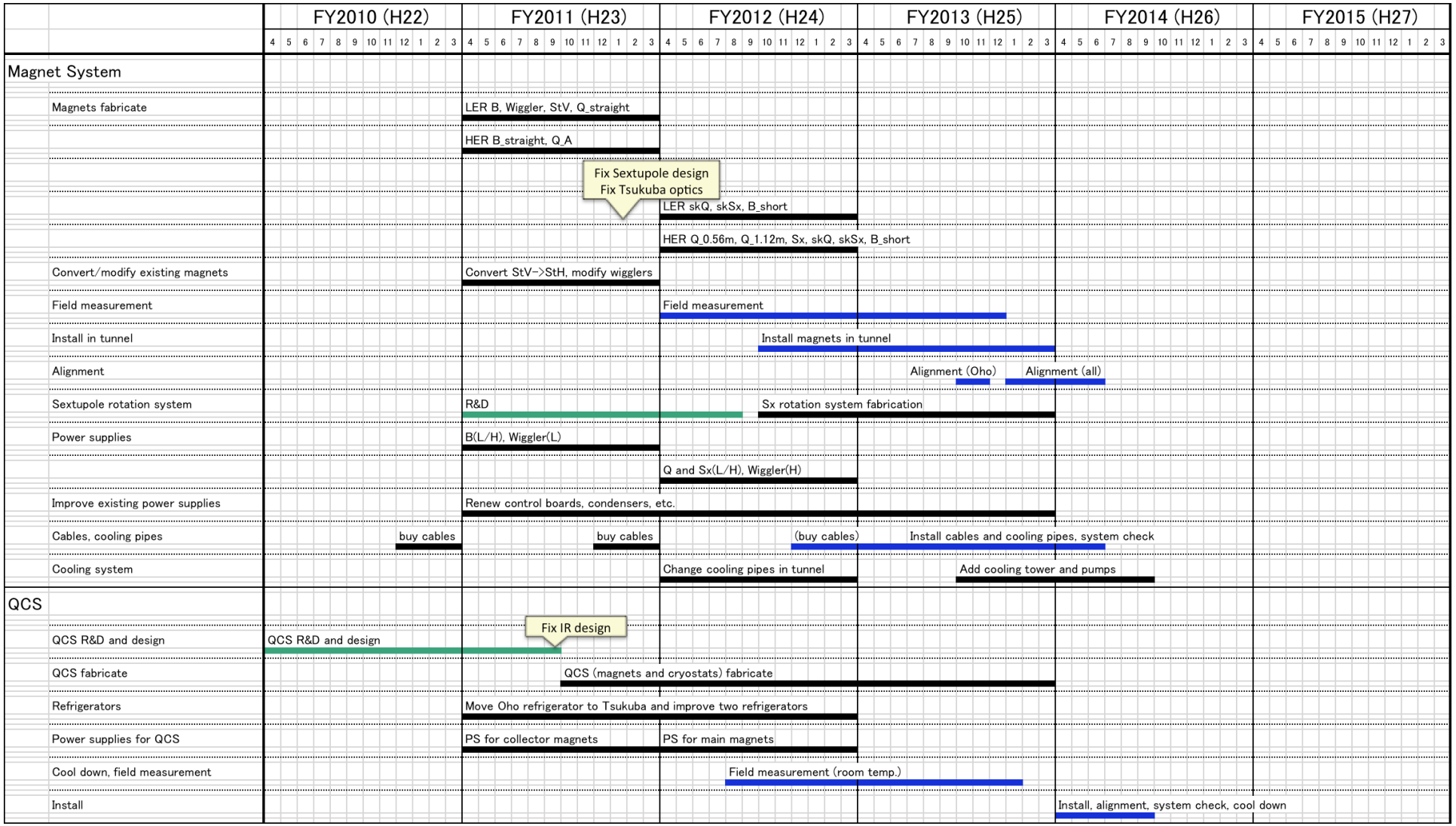
SuperKEKB Ring construction schedule (1)



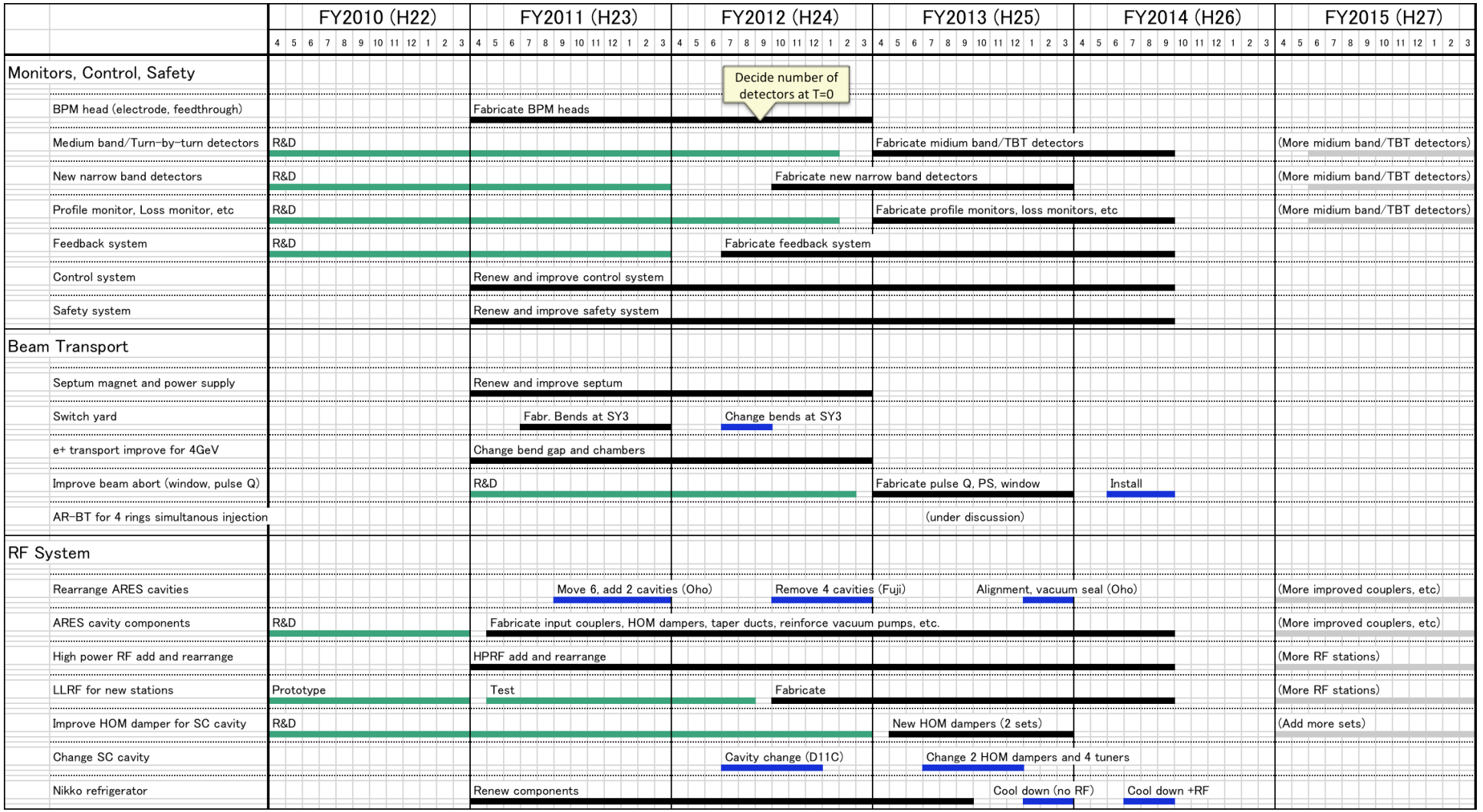
SuperKEKB Ring construction schedule (2)



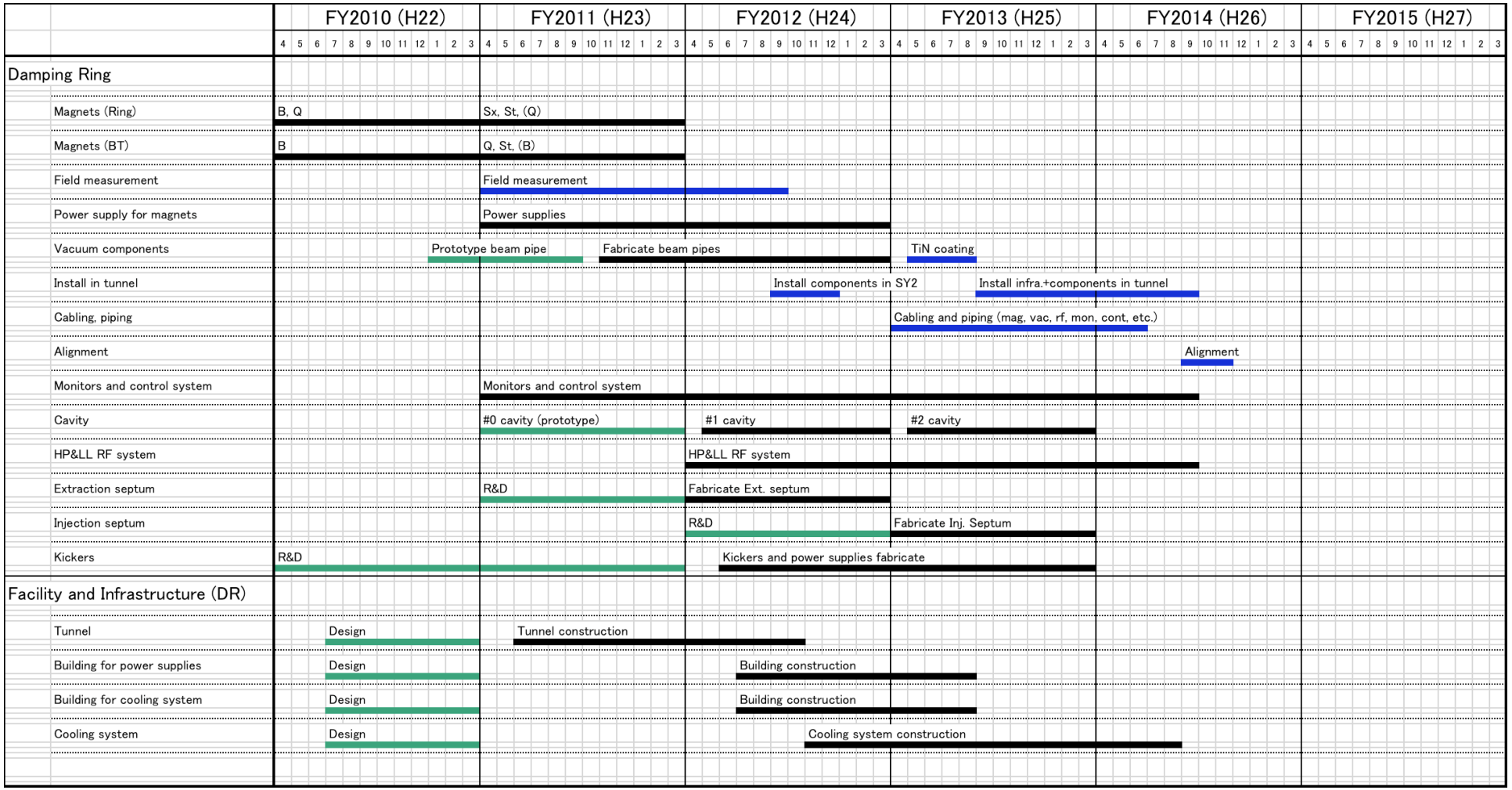
SuperKEKB Ring construction schedule (3)



SuperKEKB Ring construction schedule (4)



SuperKEKB Ring construction schedule (5)



Cost estimation

1 (Billion Yen) = 12.3 M USD = 8.8 M EUR (as of 6 Nov., 2010)

Components	Cost (Billion Yen)	Remarks
Vacuum System	7 - 8	beam pipes (ante-chambers, electrodes, etc), pumps and other vacuum components
Magnet System	5 - 6	magnets, power supplies, cables
IR upgrade	1 - 2	QCS and other IR hardware
RF System	2 - 3	reinforce RF stations, rearrange and improve cavities
Beam monitor and control	2 - 3	BPM, profile monitors, feedback, control system, safety system, improve beam transport, etc.
Damping Ring	2 - 3	Damping Ring components (magnets, vacuum, RF, monitors, control, etc.)
Reinforce cooling system	4 - 5	Change cooling pipes in tunnel, add cooling tower and pumps.
Tunnel and buildings	2 - 3	DR tunnel, buildings for Linac upgrade, DR and MR

- Cost for the Injector and Belle upgrade is not included in the list.
- Discussion is going on to optimize the plan between the Ring, Injector and Belle II.

Human Resources

Date	Status	Needed FTE (A)	Available FTE (B)	Comments on (B)	FTE short (A) - (B)
Apr. 2011	under construction	77.1	60.1	Retirement in Mar. 2011 and new persons expected in April are taken into account.	17.0
Apr. 2013	under construction	77.1	55.1 + new members (x)	5 persons will be retired	22.0 -x
Apr. 2015	0.5 year after commissioning	70.0	47.1 + new members (y)	8 more persons will be retired	22.9 –(x+y)

- About this table
  - Needed FTE is for the number of staff members.
  - The HR for the Linac is not included in the list.
- How to fill the short FTE?
  - Since some new persons are expected to join KEKB in April, the situation looks a little better compared with the estimation last year.
  - Still about 20 people are short for construction.
  - Collaboration with other project members and other laboratories.
    - Field measurement of DR magnets by PF ring group.
    - LLRF development with control group and cERL group
  - More new members, more help by retired persons, more collaborations are welcome.

Summary

- SuperKEKB construction has started. Dismantle KEKB is going on. Mass fabrication of magnets, beam pipes, etc. has started.
- Commissioning will start in the second half of FY2014.
- Discussion and optimization between machine design and construction is going on extensively.
- Required performance and priorities, budget and cost, schedule and human resources are presented.