Overview of SuperKEKB, issues and commissioning plan

Y. Funakoshi

KEK

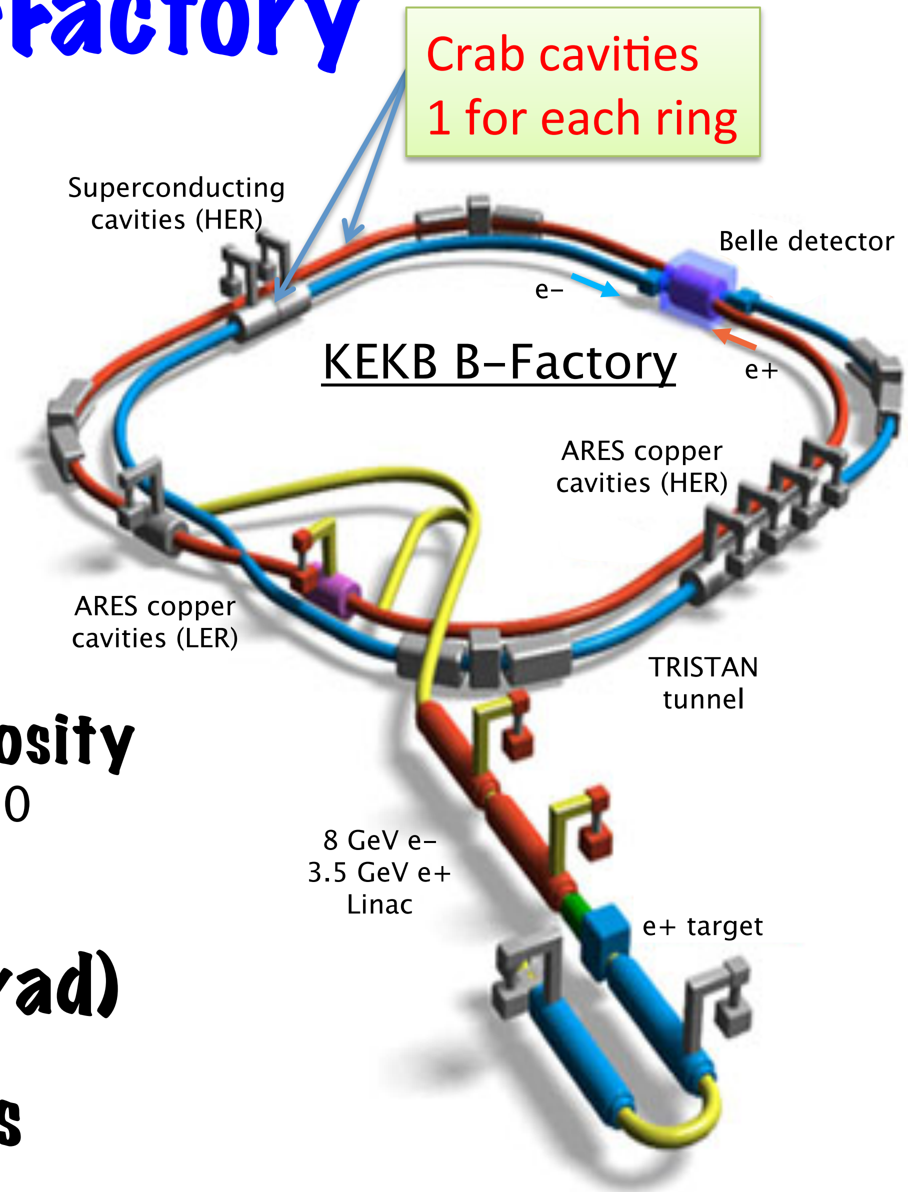
Nov. 11 2013 SuperKEKB commissioning WS@KEK

Contents

- Concept of SuperKEKB
- Issues
- Commissioning plan

CONCEPT OF SUPERKEKB

KEKB B-Factory



♦World-highest Peak Luminosity

- $2.11 \times 10^{34} cm^{-2}s^{-1}$
- Twice as high as design value

♦World-highest Integrated Luminosity

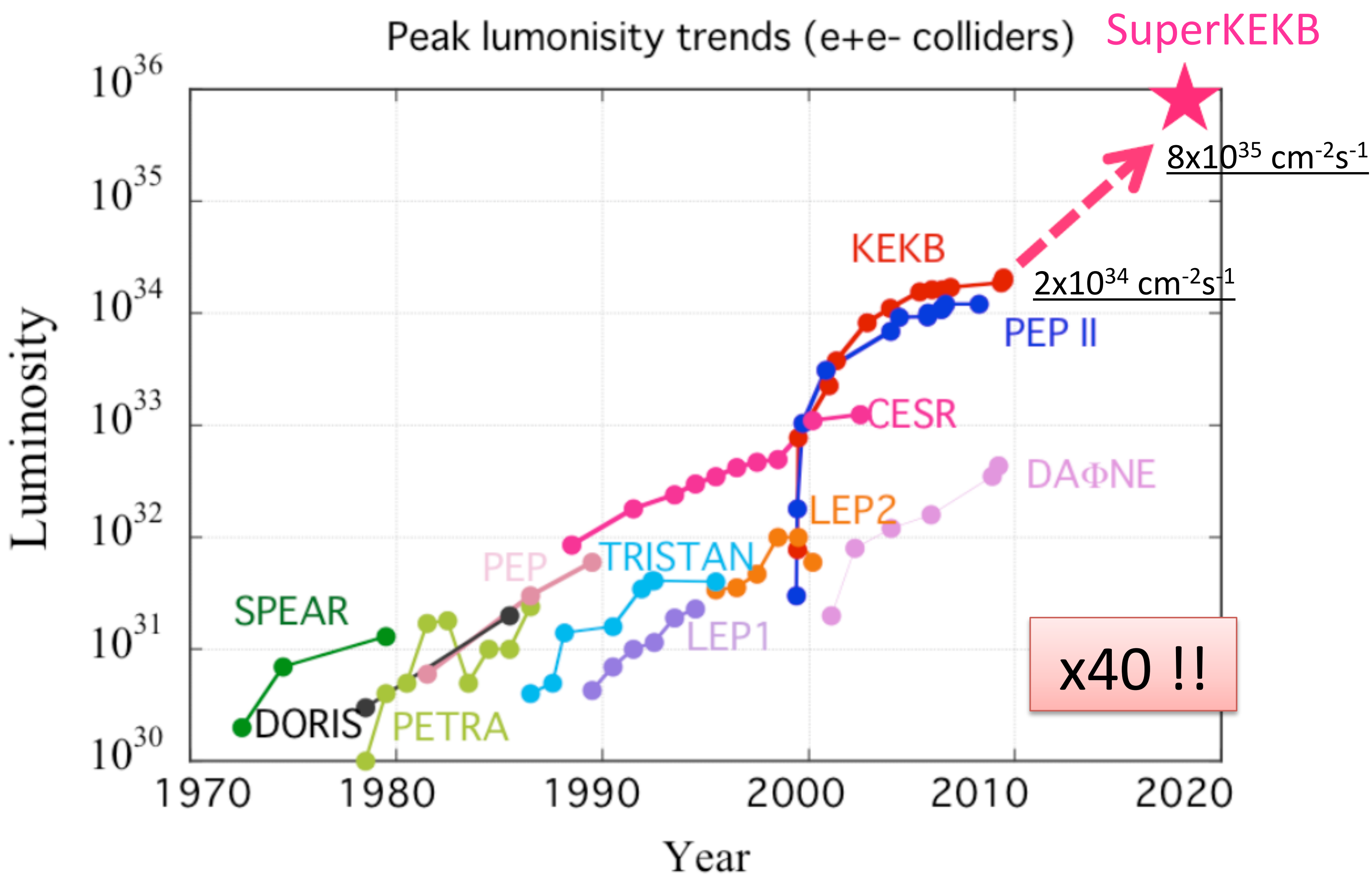
- Total: $1041 fb^{-1}$ as of June 30th 2010

♦Crab crossing (ϕ = 11 mrad)

♦Skew-sextupole magnets

The KEKB operation was terminated at the end of June 2010 for the upgrade toward SuperKEKB. Operation of SuperKEKB will start in Jan. 2015.

SuperKEKB Luminosity Target



Luminosity of KEKB and SuperKEKB

	KEKB Acieved		SuperKEKB Nano-Beam	
	LER	HER	LER	HER
I_{beam} [A]	1.6	1.2	3.6	2.6
β_y^* [mm]	5.9	5.9	0.27	0.30
ξ_y	0.09	0.12	0.088	0.081
Luminosity [cm^{-2} s^{-1}]	2.1×10^{34}		8.0×10^{35}	

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

← Factor 2 (I_{beam})

← Factor 20 (β_y^*)

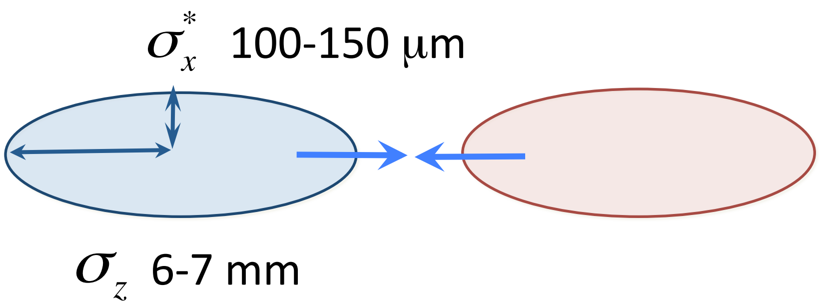
← Almost same (ξ_y)

← 40 times higher (Luminosity)

Collision Scheme

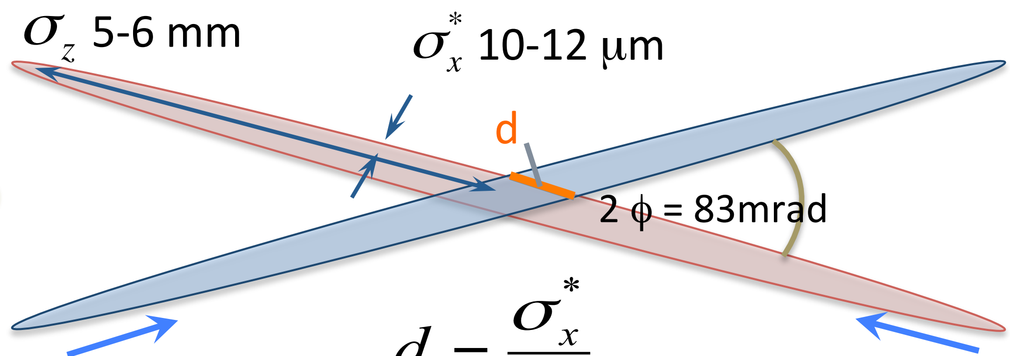
P. Raimondi

KEKB head-on (crab crossing)



overlap region = bunch length

Nano-Beam Scheme SuperKEKB



$$d = \frac{\sigma_x^*}{\phi}$$

Half crossing angle: ϕ

overlap region << bunch length

Hourglass requirement

$$\beta_y^* \geq \sigma_z \quad \sim 6\ \text{mm}$$

$$\beta_y^* \geq \frac{\sigma_x^*}{\phi} \quad \sim 300\ \mu\text{m}$$

Vertical beta function at IP can be squeezed to ~300μm.
Need small horizontal beam size at IP.
→ low emittance, small horizontal beta function at IP.

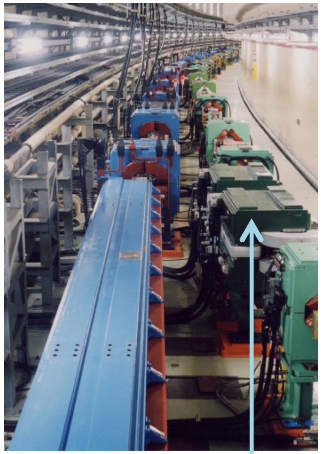
No crab waist scheme has been assumed at SuperKEKB

Machine Design Parameters

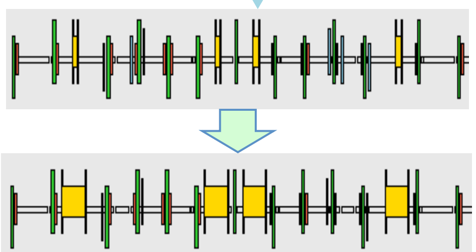
parameters		KEKB		SuperKEKB		units
		LER	HER	LER	HER	
Beam energy	E_b	3.5	8	4	7.007	GeV
Half crossing angle	ϕ	11		41.5		mrad
# of Bunches	N	1584		2500		
Horizontal emittance	ε_x	18	24	3.2	4.6	nm
Emittance ratio	κ	0.88	0.66	0.27	0.25	%
Beta functions at IP	β_x^*/β_y^*	1200/5.9		32/0.27	25/0.30	mm
Beam currents	I_b	1.64	1.19	3.6	2.6	A
beam-beam param.	ξ_y	0.129	0.090	0.088	0.081	
Bunch Length	σ_z	6.0	6.0	6.0	5.0	mm
Horizontal Beam Size	σ_x^*	150	150	10	11	um
Vertical Beam Size	σ_y^*	0.94		0.048	0.062	um
Luminosity	L	2.1×10^{34}		8×10^{35}		$cm^{-2}s^{-1}$

What's new at SuperKEKB

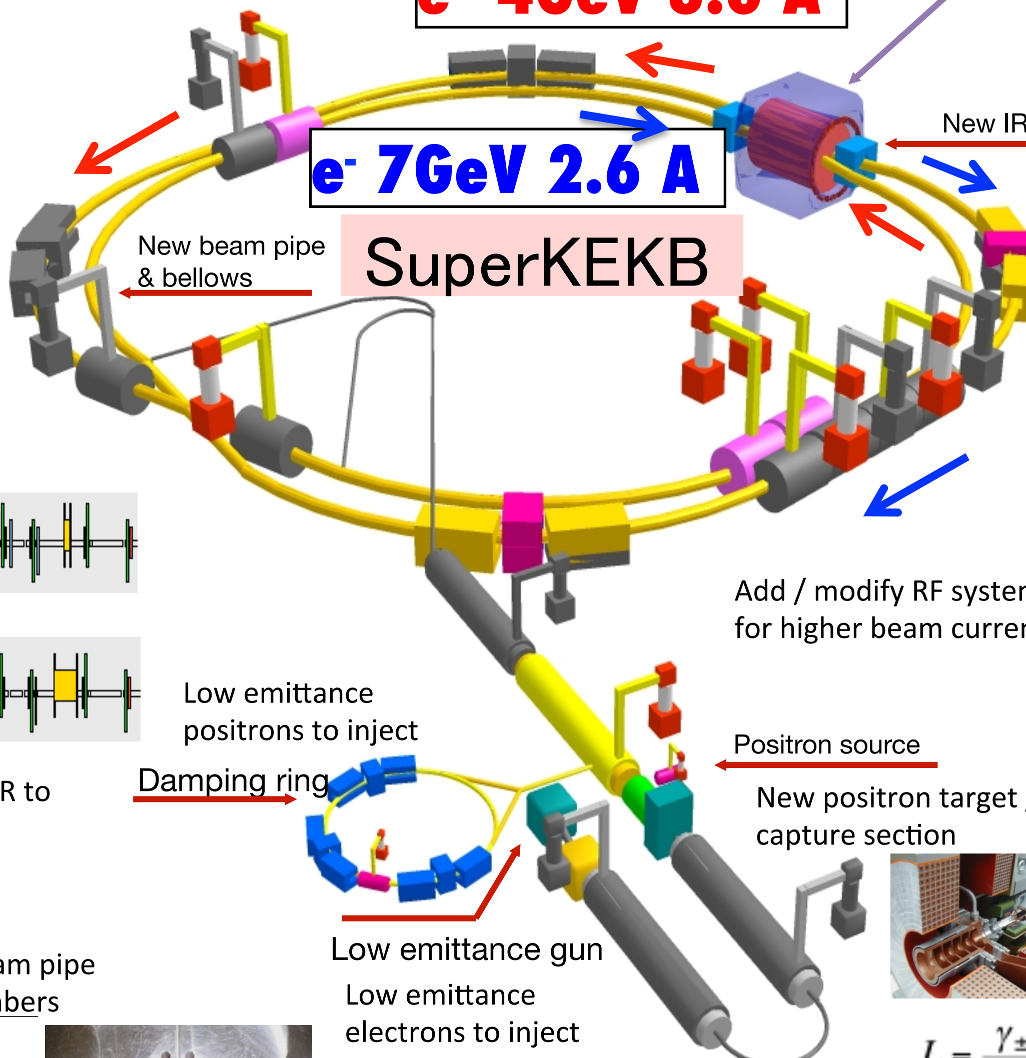
Belle II

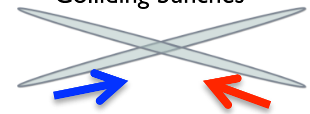


Replace short dipoles with longer ones (LER)

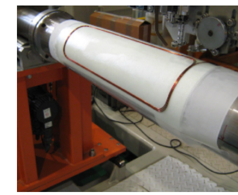


Redesign the lattices of LER to squeeze the emittance

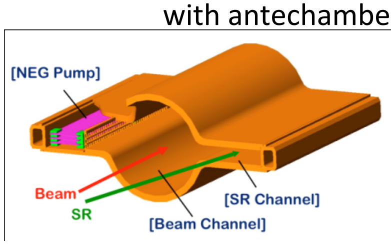


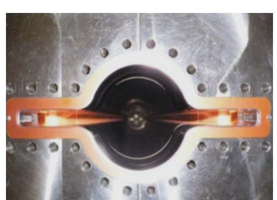


New superconducting final focusing quads near the IP



TiN-coated beam pipe with antechambers





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

Target: $L = 8 \times 10^{35}/cm^2/s$

Issues

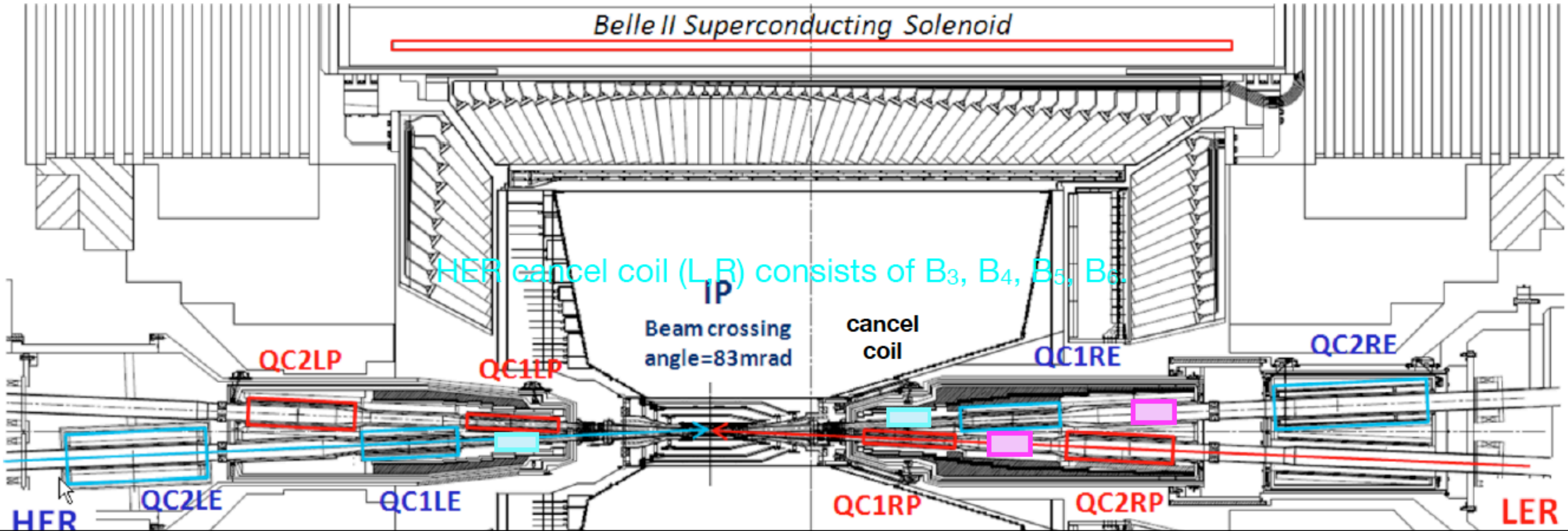
- IR design and dynamic aperture
- Low emittance tuning
- Magnet alignment strategy
- Beam-beam related issues
- IP orbit control
- Beam loss and beam injection
- Electron clouds
- Detector beam background

IR design and dynamic aperture

- One of the key issues at SuperKEKB
  - Success of SuperKEKB largely depends on how low values of IP beta-functions will be achieved with enough dynamic aperture.

Final Focus System: QCS

N. Ohuchi, Y. Arimoto

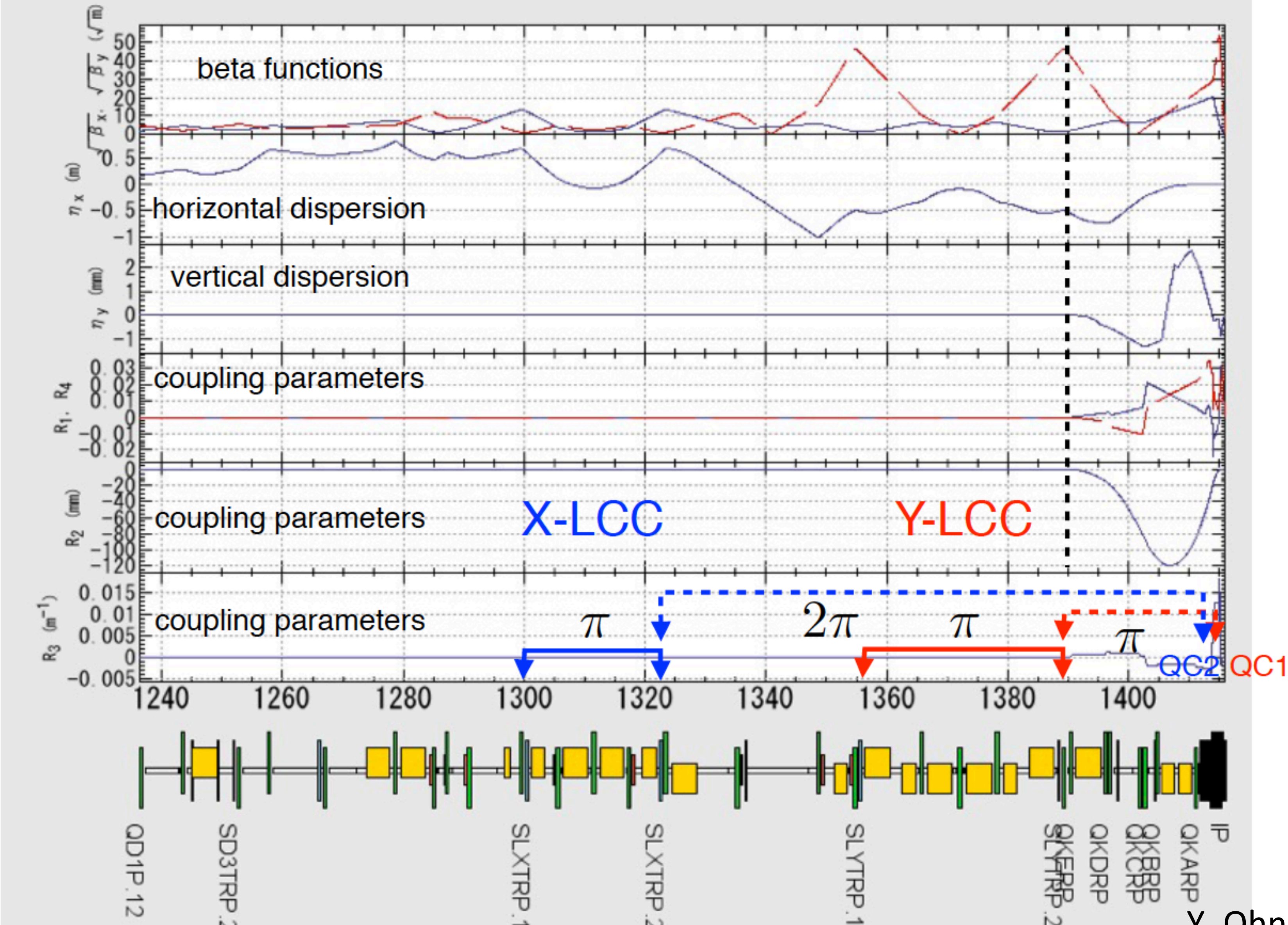


Design param.	Dipole	Skew dipole	Quad	Skew quad	Sextupole	Skew sext	Octupole
	B_1L (Tm)	A_1L (Tm)	B_2L/r_0 (T)	A_2L/r_0 (T)	B_3L/r_0^2 (T/m)	A_3L/r_0^2 (T/m)	B_4L/r_0^3 (T/m^2)
QC1LP	0.004	-0.002	-22.96	-9.50E-05			-27.0
QC2LP	-0.0217	0.022	11.48	0.0095			48.2
QC1RP	0.0050	-0.0086	-22.96	1.92E-05		0.0	-26.7
QC2RP	-0.0023	0.0214	11.54	-6.30E-06		0.0	
QC1RP-QC2RP					0.0		
QC1LE	0.030	0.0092	-26.94	-0.0729			8.9
QC2LE	0.000	-0.0016	15.27	0.0271			23.6
QC1RE	-0.0305	0.0053	-25.39	0.0653		0.0	
QC2RE	0.000	-0.0022	13.04	0.0559		0.0	
QC1RE-QC2RE					0.0		

Y. Ohnishi

IR Optics in LER

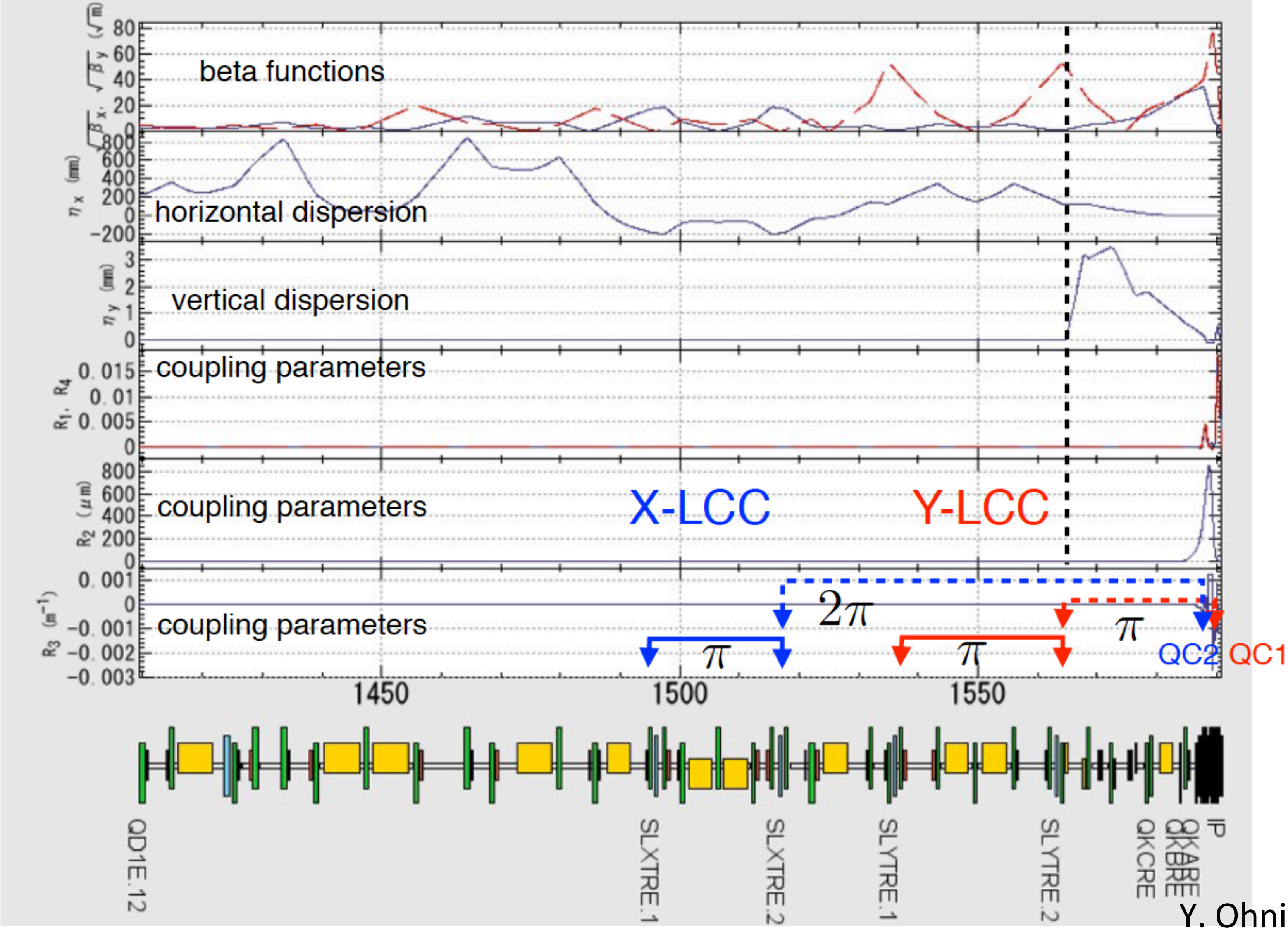
X-LCC corrects QC2 chromaticity and Y-LCC corrects QC1 chromaticity locally.



Y. Ohnishi

IR Optics in HER

X-LCC corrects QC2 chromaticity and Y-LCC corrects QC1 chromaticity locally.



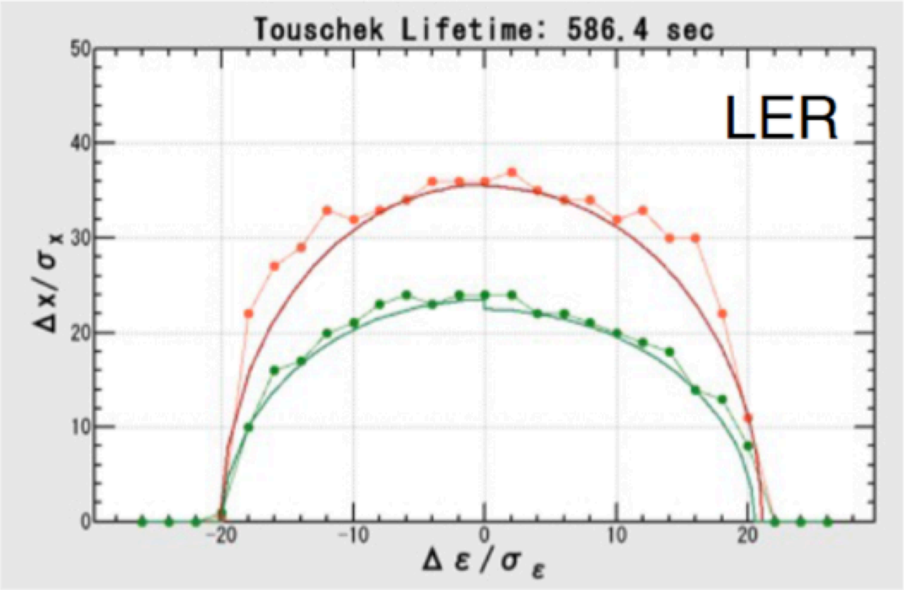
Y. Ohnishi

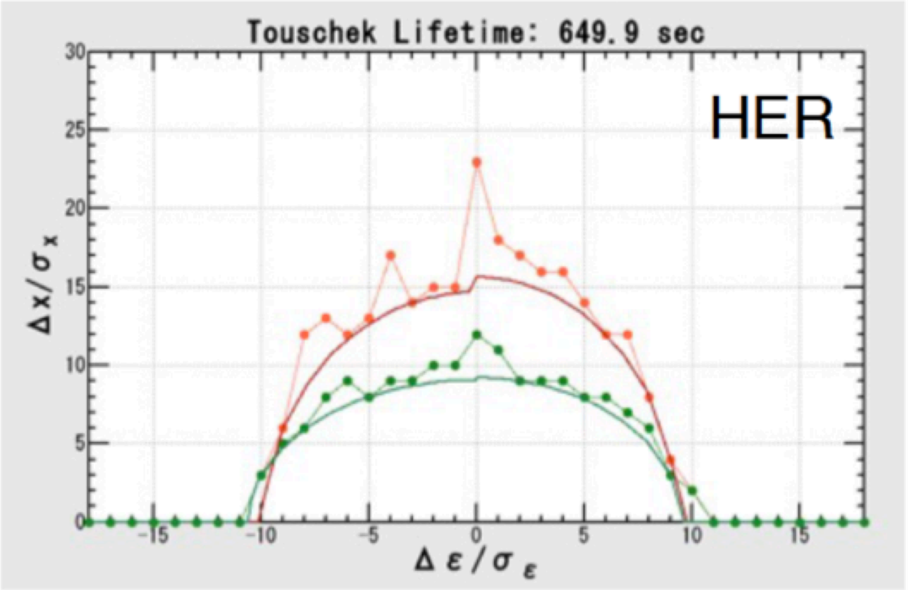
Corrector coils

- Dipole and skew dipole coils make a beam-line geometry and correct dispersions.
- Skew quadrupole coils correct x-y couplings.
- Sextupole and skew sextuple coils correct error field due to a misalignment of quadrupole coils. This error field affects the dynamic aperture significantly.
- Octupole coils at QC1 and QC2 enlarge a transverse aperture.
- HER cancel coils correct sextupole, octupole, decapole and dodecapole leakage field from QC1P in LER.

Touschek Lifetime

- Touschek lifetime depends on dynamic aperture.
- Efforts to widen dynamic aperture
  - Careful design of QCS magnets to minimize higher multipoles etc.
  - Careful IR design: LCC, x-y coupling correction etc.
  - Optimization of octupoles, ARC sextupoles, skew-sextupoles





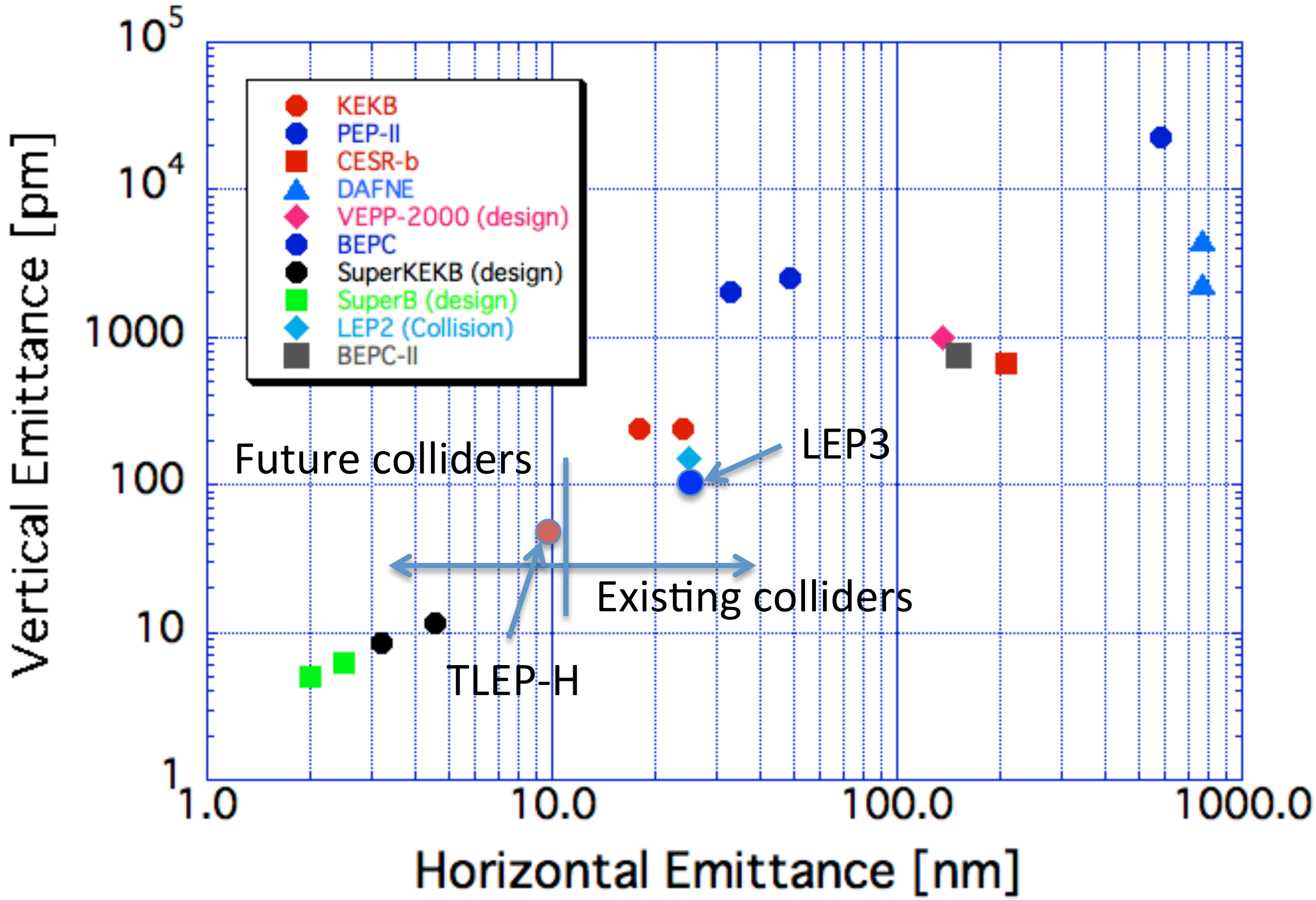
Y. Ohnishi

w/o machine errors

Low emittance tuning

- The design vertical emittance of SuperKEKB is very small compared to those of existing colliders.
- The low vertical emittances have been achieved in SR machines. However, low emittance tuning in colliders is much more difficult.
- One of the key tuning issues at SuperKEKB will be low emittance tuning.

Comparison of emittances of colliders

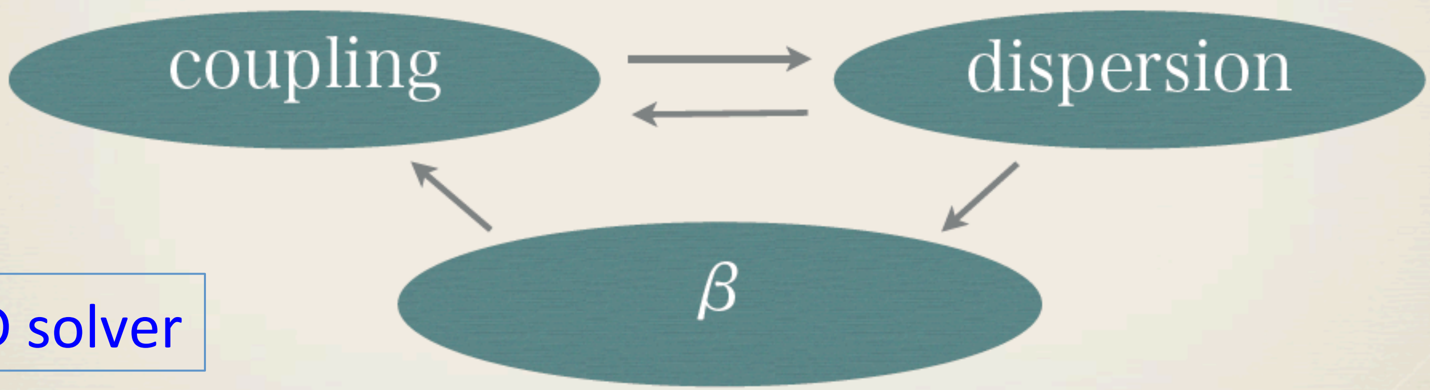


From Beam Dynamics Newsletter No. 31
Courtesy of F. Zimmermann, H. Burkhardt and Q. Qin

Iteration

2008_06_19_19_06_29fop	Fill-Length Optimization
2008_06_19_19_06_32luh	Beam Collision Panel
2008_06_19_19_09_12XY_Coupling	MeasOptHER
2008_06_19_19_12_59Dispersion	MeasOptHER
2008_06_19_19_18_27XY_Coupling	MeasOptHER
2008_06_19_19_21_34Dispersion	MeasOptHER
2008_06_19_19_22_29Dispersion	MeasOptHER
2008_06_19_19_23_29Dispersion	MeasOptHER
2008_06_19_19_31_36Global_Beta	MeasOptHER
2008_06_19_19_38_29Global_Beta	MeasOptHER
2008_06_19_20_16_46_amsad8	amsad8 screen capture
2008_06_19_20_34_16_amsad8	amsad8 screen capture

* A loop of coupling, dispersion, β corrections takes **30-60 minutes** per ring to converge. (1 correction takes 3.5 to 7 minutes)



SVD solver

* We do not have to solve the entire problem at once by a single big matrix.
* Although these corrections are not independent, their cross-talks are smaller than the diagonal parts, so the iteration converges quickly.

Simulation for SuperKEKB with machine errors

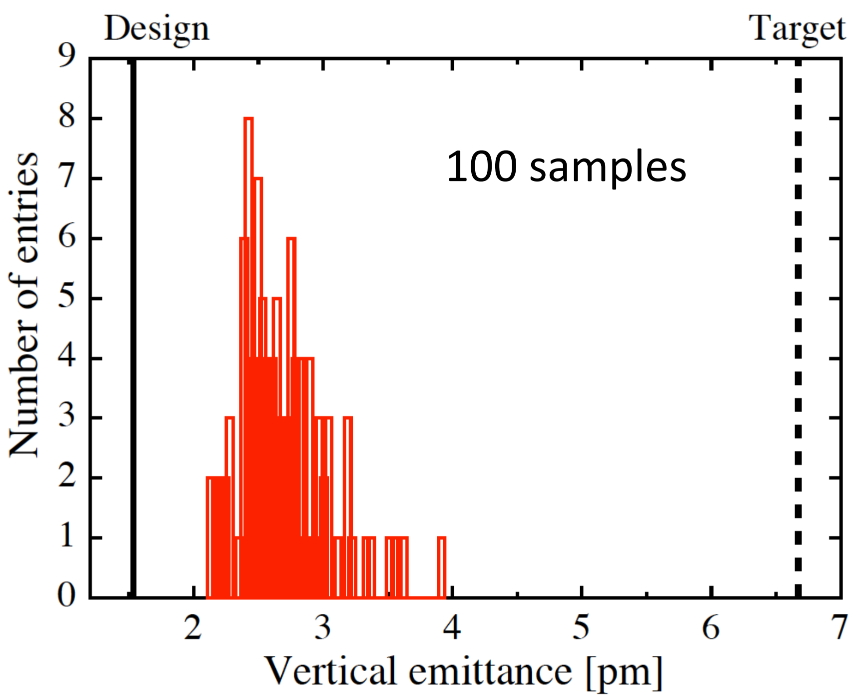
- Simulation was done by H. Sugimoto in case of HER.
- Assumed machine errors

	$\sigma_x = \sigma_y$ [μm]	σ_θ [μrad]	ΔK/K
Normal Quad	100	100	2.5×10^{-4}
Sextu.	100	100	2.5×10^{-4}
Bend.	0	100	0
QC1, QC2	100	0	0
BPM	0	10×10^3	2μm (resolution)

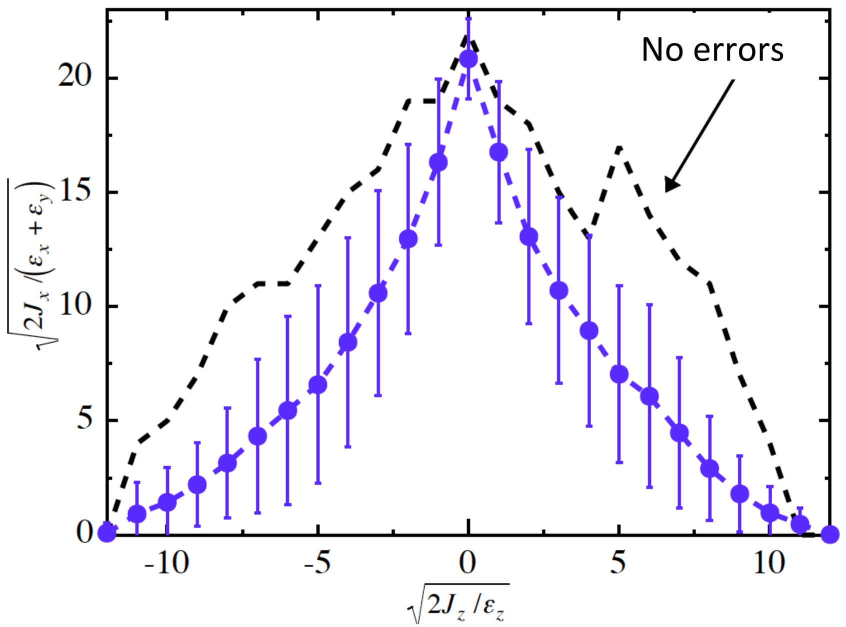
Machine errors are created randomly with gaussian distributions.

- Corrections
  - Closed orbit, x-y coupling, beta-beat, dispersions (KEKB methods)
    - SVD threshold = 10^{-2}

Results of simulation



Vertical emittance distribution after LET

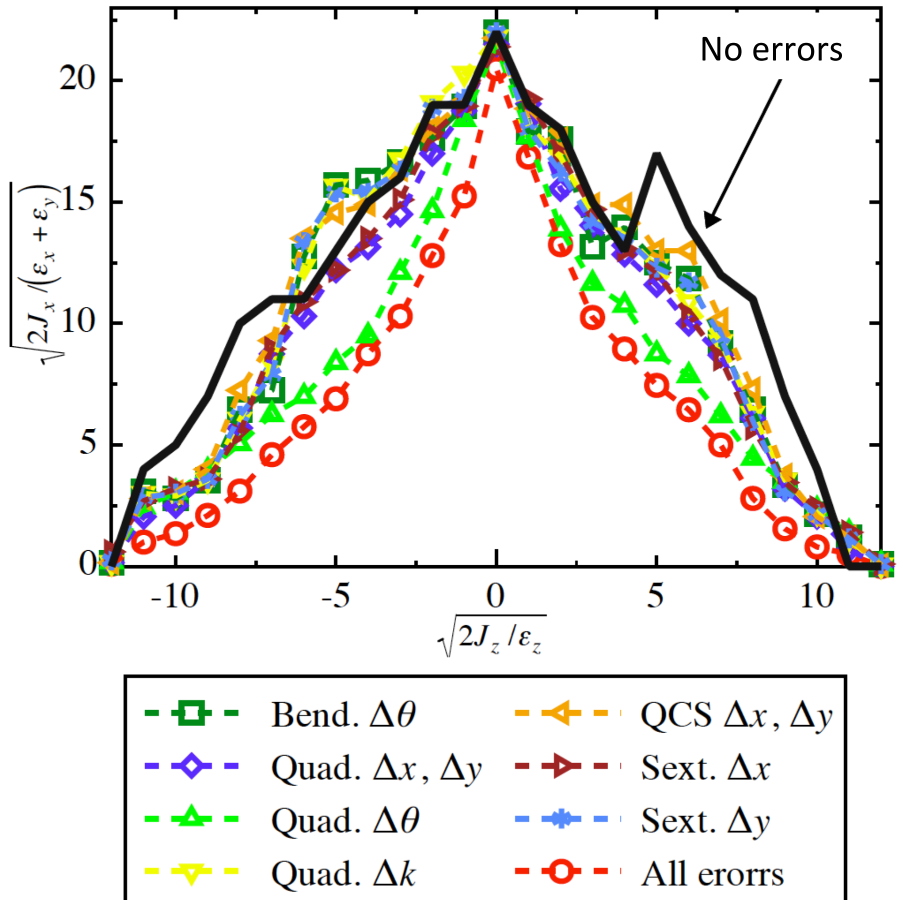


Dynamic aperture after LET.

This simulation shows that the target vertical emittance is achievable.
(This simulation does not include alignment error in LCC section.)

H. Sugimoto

Dynamic aperture with different types of errors



Rotation errors of quadruples seems most dangerous.

Each sextuple has a skew quadrupole corrector coil.

We may have to rethink tolerance of rotation errors of normal quadrupoles.

Nov. 12 13:20
Ring optics design and correction *20′*
Speaker: Hiroshi Sugimoto (KEK)

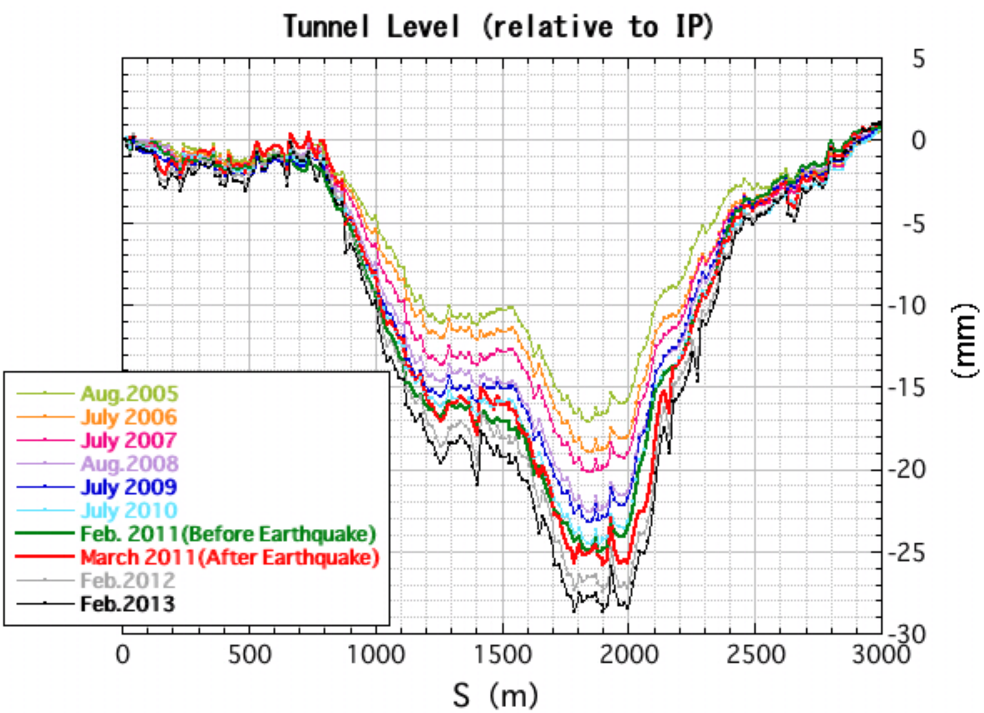
Nov. 12 14:40
Beam sizes *20′*
Speaker: John FLANAGAN (KEK)

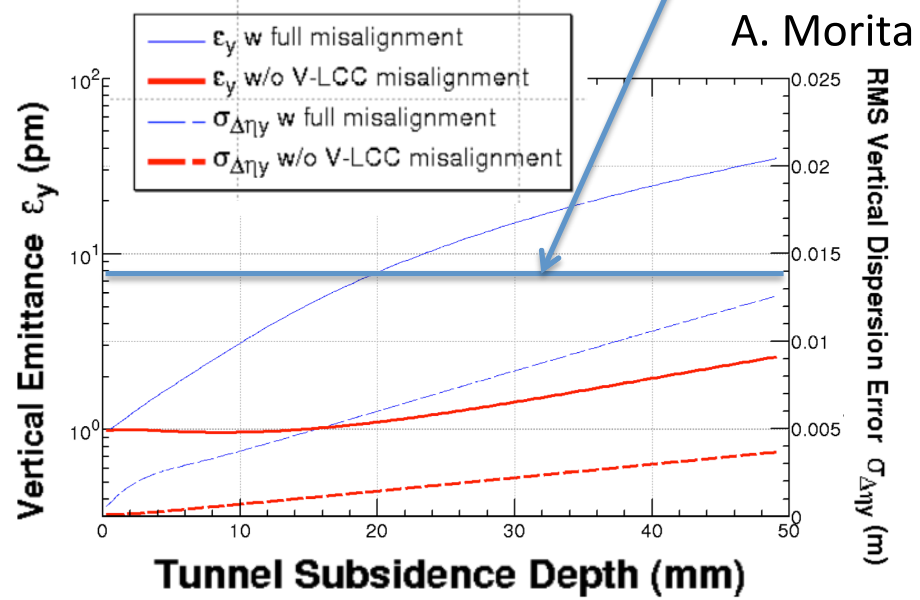
H. Sugimoto

Magnet alignment strategy at SuperKEKB

- The target positions of the initial alignment of SuperKEKB is a smoothed curve made from present (2013)magnet positions (not on a plane).
- The tolerance of magnets alignment around the target curve is the same as KEKB.
  - Position error: 100 μm (1 σ)
  - Rotational error: 100 μrad (1 σ)
    - We have to rethink about this?
- We will need special care for the alignment of the magnets around the local chromaticity correction.

Effects of Tunnel deformation at SuperKEKB HER





Tunnel deformation observed at KEKB
- A large subsidence has been observed: ~ 2mm/year and still in progress.
- In the construction period of KEKB (1998), all magnets were aligned on the same plane.

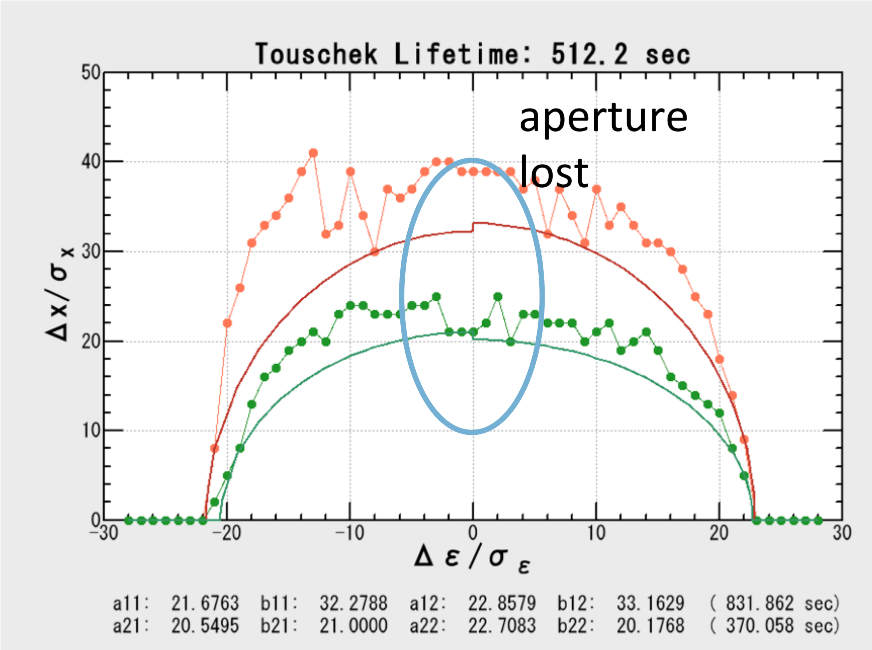
Vertical emittance
- If the alignment error around the V-LCC (vertical local chromaticity correction) area is excluded, the vertical emittance can be preserved well below the target value with optics corrections.
- As for the alignment error of V-LCC, we will need a special care. This is a remaining problem.

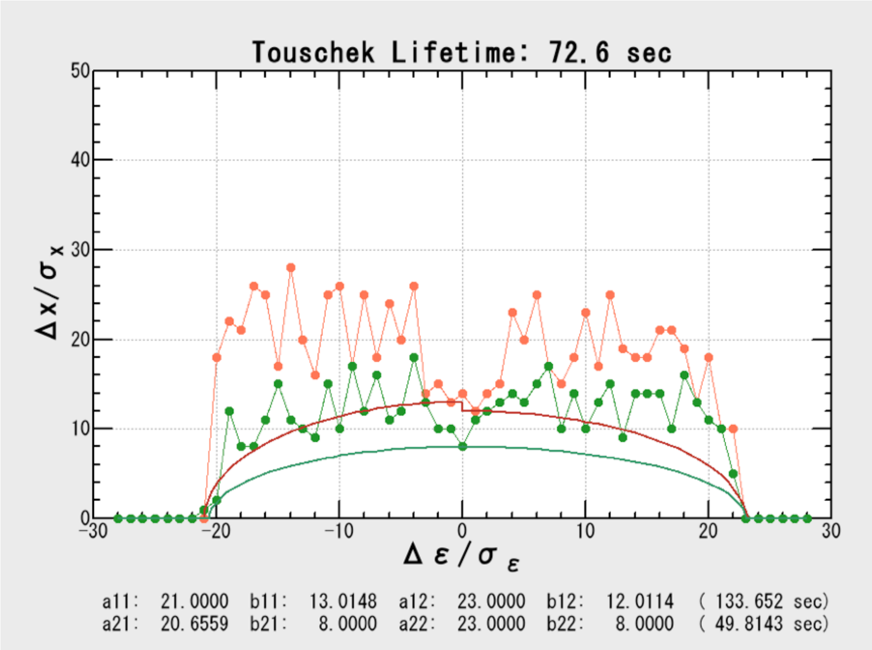
Beam-beam related issues

- Beam lifetime shortening with beam-beam effects
- Luminosity degradation
  - The design luminosity was determined based on the strong-strong beam-beam simulation.
  - Beam-beam + lattice nonlinearity and space charge effect

LER Dynamic Aperture

beam-beam





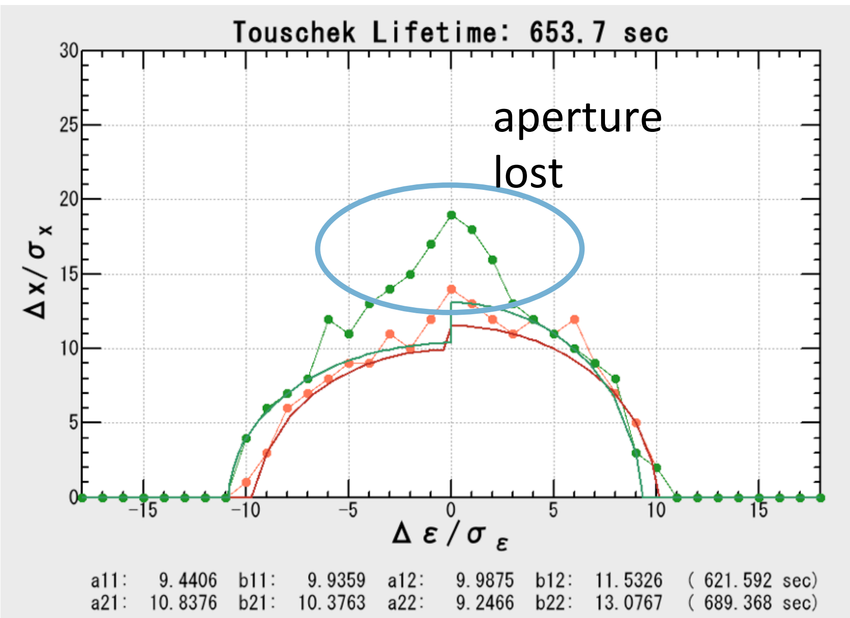
Nov. 12 13:40

Beam-beam + dynamic aperture *20'*

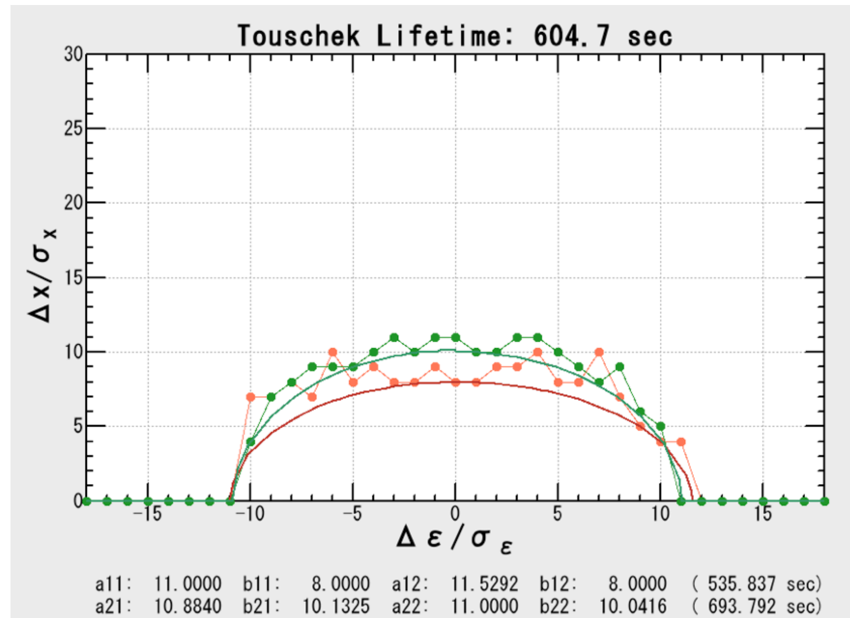
Speaker: Akio Morita (KEK)

Y. Ohnishi

HER Dynamic Aperture

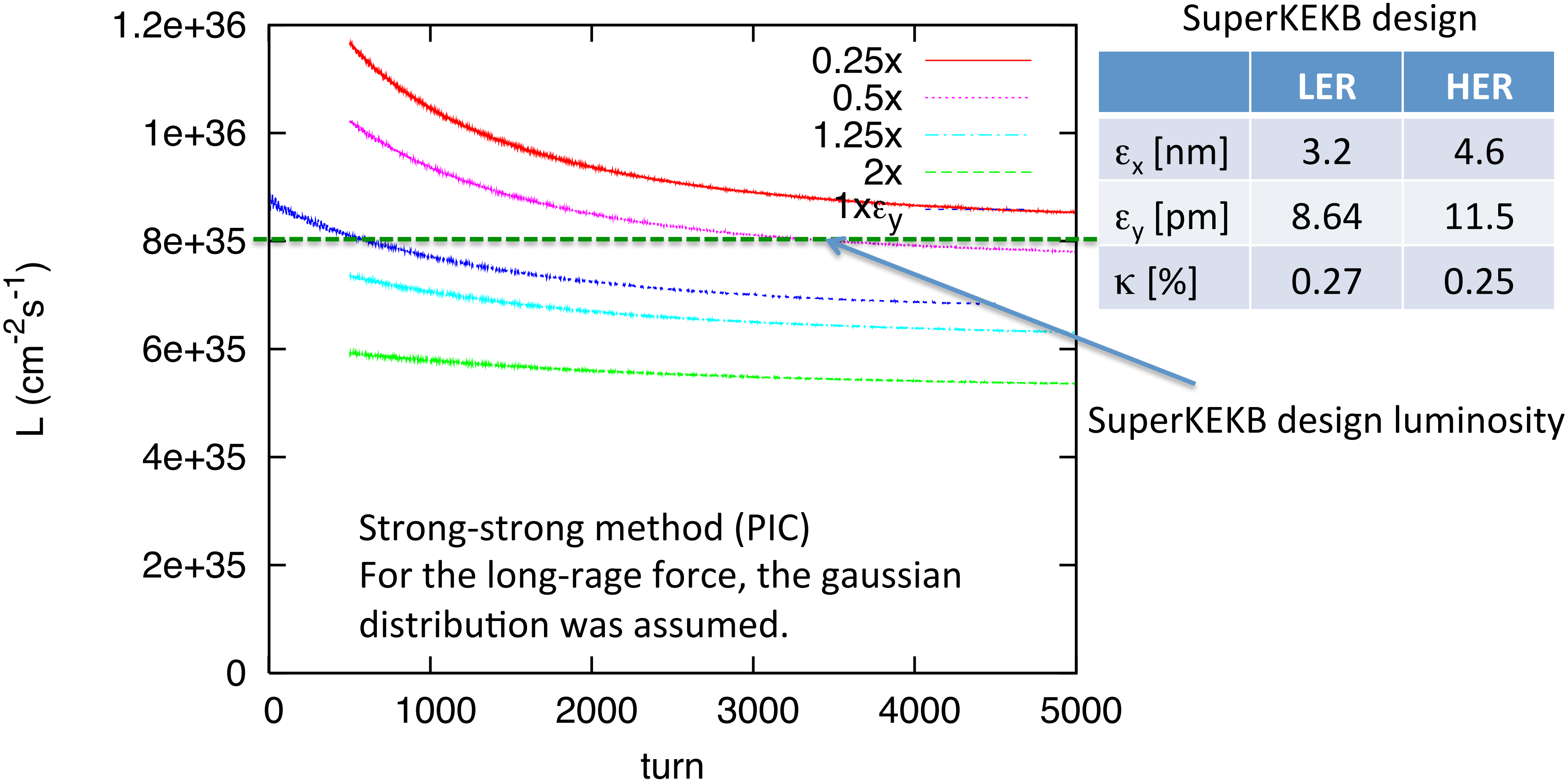


beam-beam



Y. Ohnishi

SuperKEKB beam-beam simulation



SuperKEKB design

	LER	HER
ε_x [nm]	3.2	4.6
ε_y [pm]	8.64	11.5
κ [%]	0.27	0.25

Smaller (single beam) vertical emittance gives higher luminosity.
Much lower vertical emittance than the design (about half) will be needed to achieve the design luminosity.

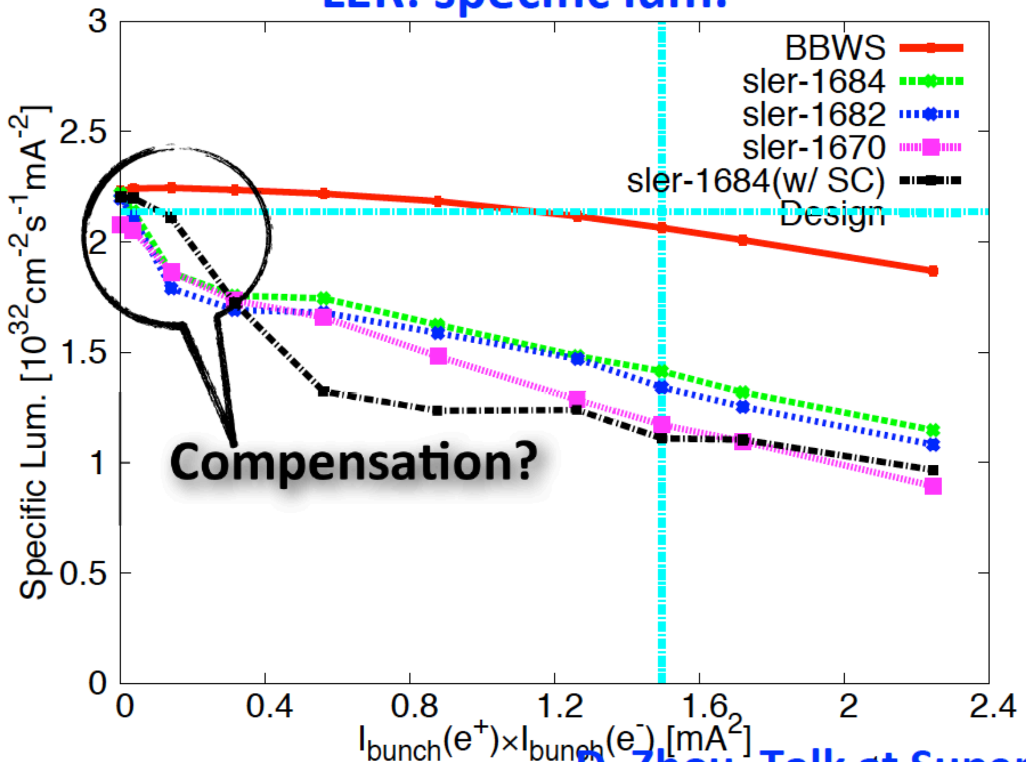
K. Ohmi

1. Lum.: LER: BB + LN + SC

- SC causes lum. degradation
- BB + SC: compensate at low current?

Nov. 1214:00
Beam-beam + lattice nonlinear + space charge *20'*
Speaker: Demin Zhou (KEK)

LER: specific lum.



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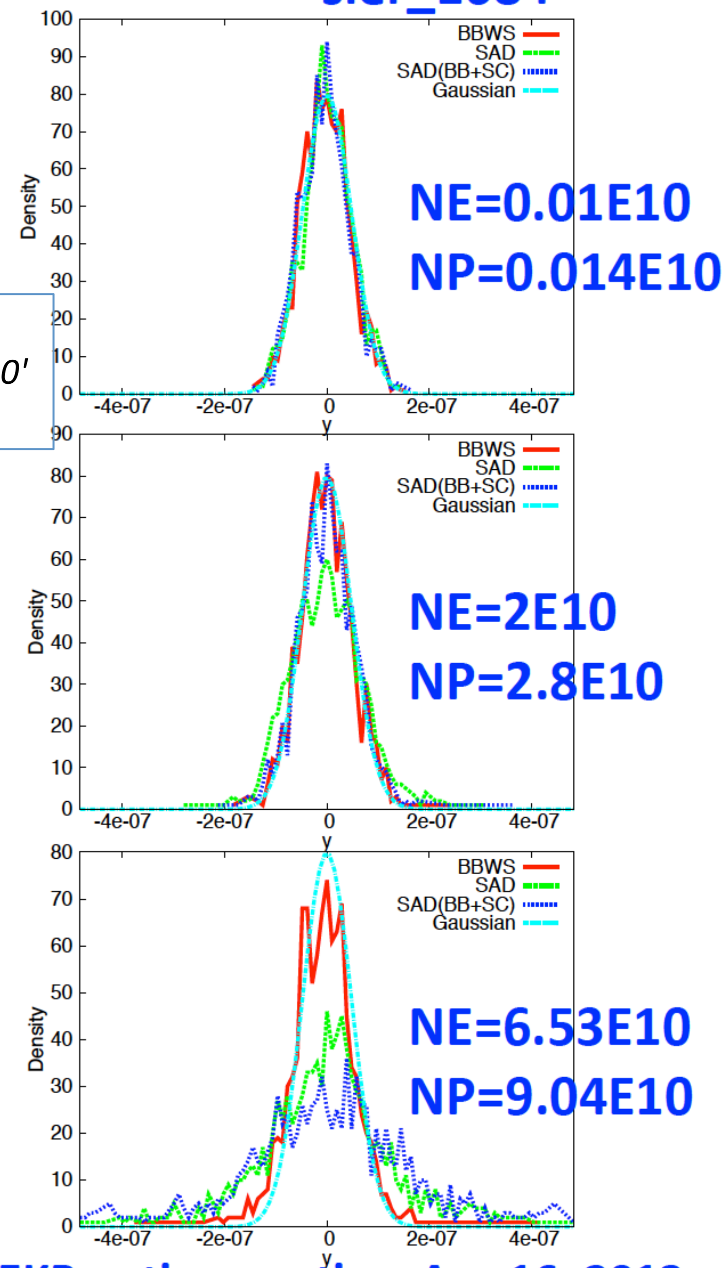


D. Zhou, Talk at SuperKEKB optics meeting, Apr.16, 2013

IP orbit control

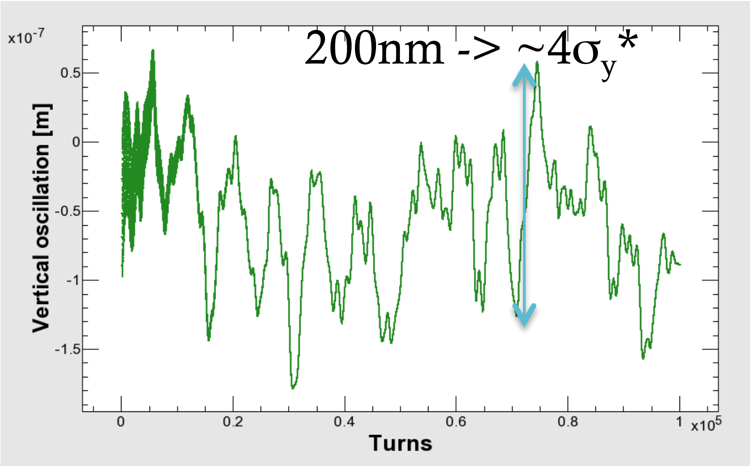
- The IP orbit control to maintain an optimum beam collision is more difficult than the KEKB case.

	KEKB	SuperKEKB
ε_y	150pm	~8.6pm (LER)
β_y^*	5.9mm	0.27mm(LER)
σ_y^*	940nm	48nm

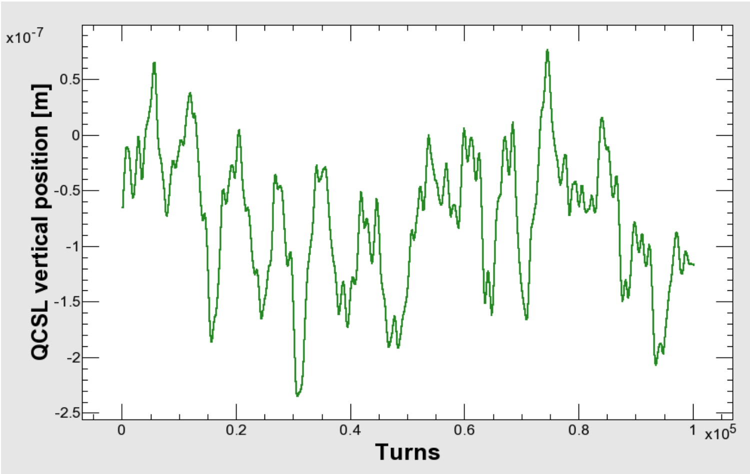
- IP orbit is very sensitive to the vibration of QCS (QC1, QC2) magnets.

QCSL vertical position oscillation (measurement) and orbit change (tracking) : SuperKEKB HER

Vertical orbit at IP (simulation)



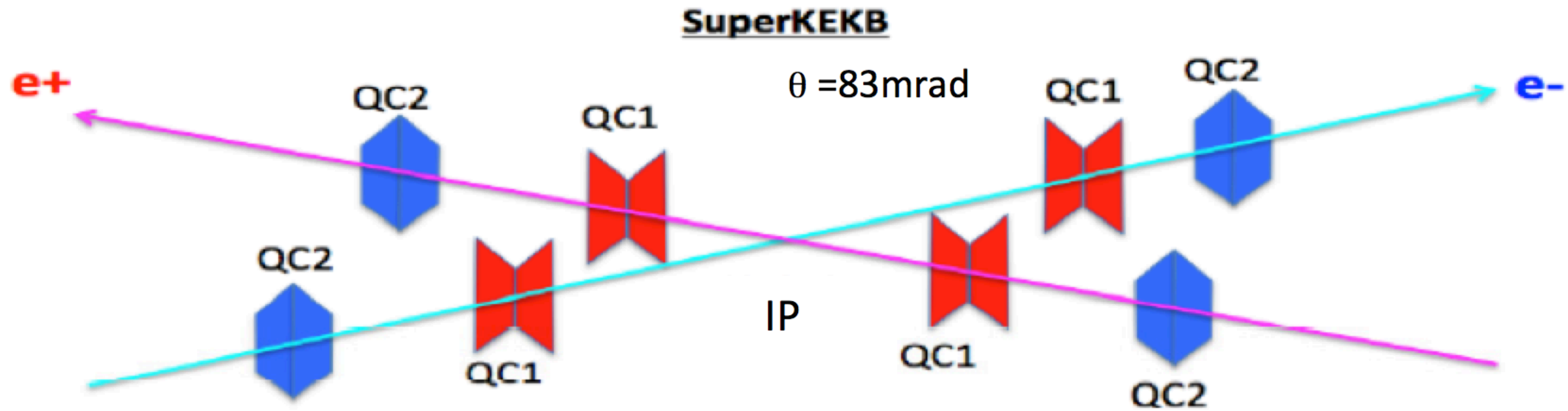
QCSL vertical position (measurement) -> QC1L (HER)



If the QC1L magnets of SuperKEKB vibrates with the same amplitude of the QCSL of the KEKB, the orbit change at IP amounts to $4\sigma_y^*$.

Countermeasures

- Reinforcement of supports for QCS magnets
- Rely on the coherency of the oscillation of QC1P and QC1E (QC2P and QC1E).
- Fast orbit feedback



Nov. 12 16:20 **IP feedback** *20'* Speaker: Toshiyuki Oki (KEK)
Nov. 12 16:00 **IR magnet measurements** *20'* Speaker: Yasushi Arimoto (KEK)

Electron cloud issues

Y. Suetsugu

- The single bunch instability is main concern.
  - Leads to increase in emittance
  - Coupled bunch instabilities will be cured by feedback system.
- Simulation and calculation by Ohmi, et al.

K. Ohmi , KEK Preprint 2005-100 (2006)

Threshold of density

$$\rho_{e,th} = \frac{2\gamma\nu_s\omega_{e,y}\sigma_z/c}{\sqrt{3}KQr_e\beta L}.$$

Here,

$$\omega_{e,y} = \sqrt{\frac{\lambda_+ r_e c^2}{\sigma_y(\sigma_x+\sigma_y)}}$$

E [GeV]	= 4.0			
γ	= 7828	N_b	= 6.25E+10	
ν_s	= 0.026	Q_b[C]	= 1.4E-08	(1.4 mA/bunch)
		S_b [m]	= 1.2	(4ns)
σ_z [m]	= 6.E-03	λ [C/m]	= 5.2E+12	($Q_b/2/\sigma_z$)
c [m/s]	= 3.E+08	σ_y [m]	= 2.E-05	
K	= 11	σ_x [m]	= 2.E-04	
Q	= 7			
r_e [m]	= 2.80E-15	ω_e	= 5.46E+11	$K = \omega_e \sigma_z/c$
β_y [m]	= 25	$\omega_e \sigma_z/c$	= 10.9	$Q = \mathrm{Min}(Q_{nl}, \omega_e \sigma_z/c)$
L [m]	= 3016			Q_{nl} ~7

ρ_{th} [e^-/m^3] =1.59E11 → **Target: 1E11**

Latest simulation result on the threshold value of instability

- Simulation with PEHTS2 by D. Zhou and K. Ohmi
  - With uniform beta functions and uniform electron cloud density along the ring, the threshold for electron cloud density is about 5.0 x 10^{11} m^{-3}.
  - With realistic beta functions and uniform electron cloud density along the ring, the threshold reduces to about 1.6 x 10^{11} m^{-3}.
  - With realistic beta functions and estimated s-dependent electron cloud density along the ring, the threshold is about 5.0 x 10^{11} m^{-3}.

Nov. 12 14:20
Beam-beam and e-cloud *20'*
Speaker: Kazuhito Ohmi (KEK)

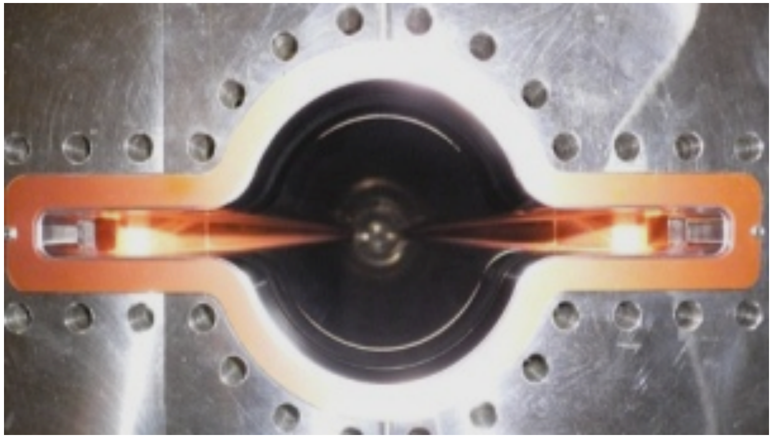
Countermeasures

Y. Suetsugu

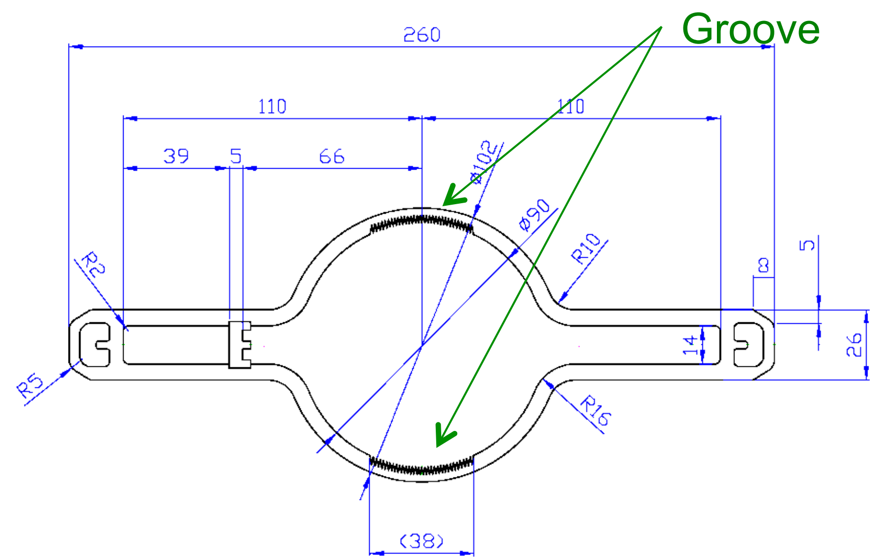
- For the upgrade of the vacuum system for SuperKEKB, the electron cloud is a key issue.
- Countermeasures are carefully chosen based on the various studies.

Drift section	Antechamber +Solenoid +TiN Coating
Q and Sx mag.	Antechamber +Solenoid +TiN Coating
Bend section	Antechamber +Groove+ TiN Coating
Wiggler section	Antechamber +Electrode (Cu)

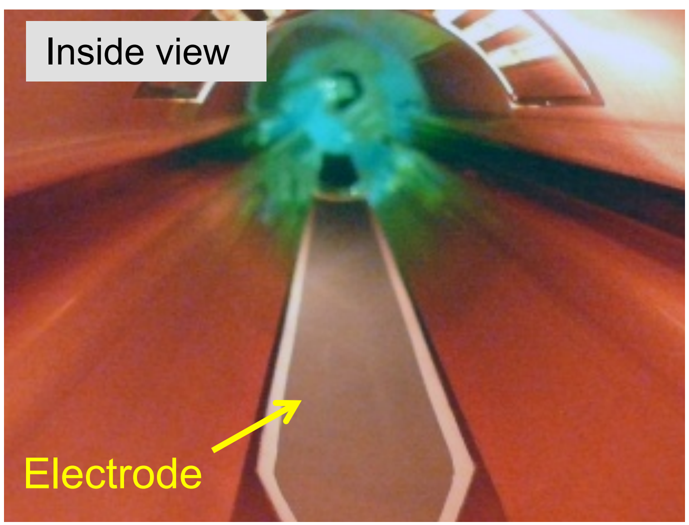
Countermeasures for electron clouds



Drift section: Antechamber + TiN coating



Arc Bend Cross Section



Wiggler section:
Antechamber + Clearing electrode

Y. Suetsugu

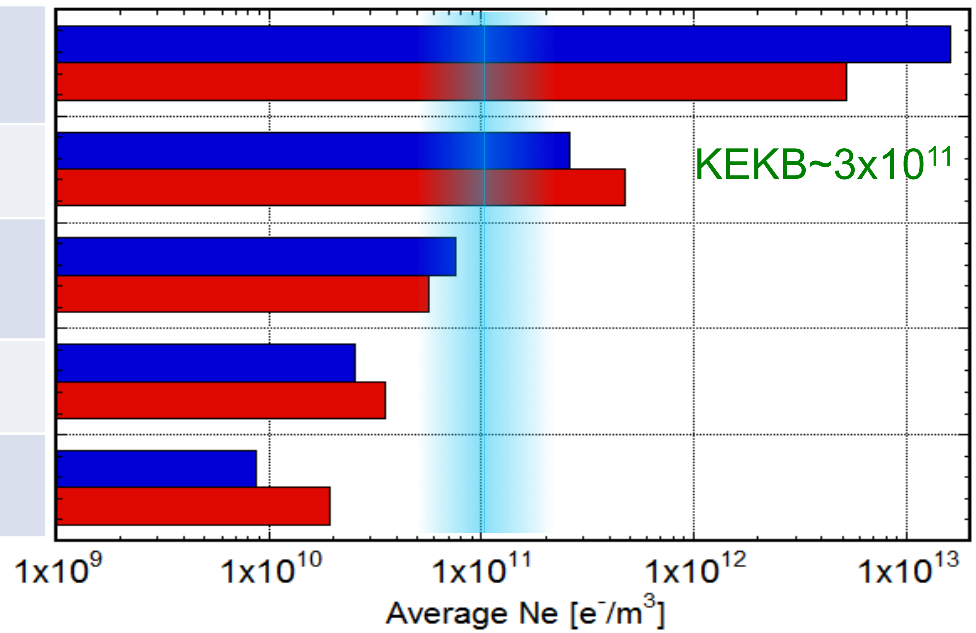
Expected electron density

Y. Suetsugu

- n_e after applying countermeasures: estimated from experiments (Red)
- Compared with results of CLOUDLAND (Blue)
  - δ_{max}=1.2, Solenoid field=50G (→n_e=0), Antechamber; photoelectron yield =0.01 (1/10)
- n_e of approx. 1/5 of the target value is expected.

Condition	ne [m^{-3}]
Circular Cu chamber [KEKB beam pipe]	5.2E12
+Solenoid at Drift (1/50)	4.7E11
+Antechamber (1/5)+TiN (3/5)	5.7e10
+Electrode in Wiggler (1/100)	3.5e10
+Groove in Bend (1/4)	2.0E10

Target value for ne: ~1×10^{11}



If the latest simulation result on the threshold is true, there is a margin of a factor 25!

Beam lifetime

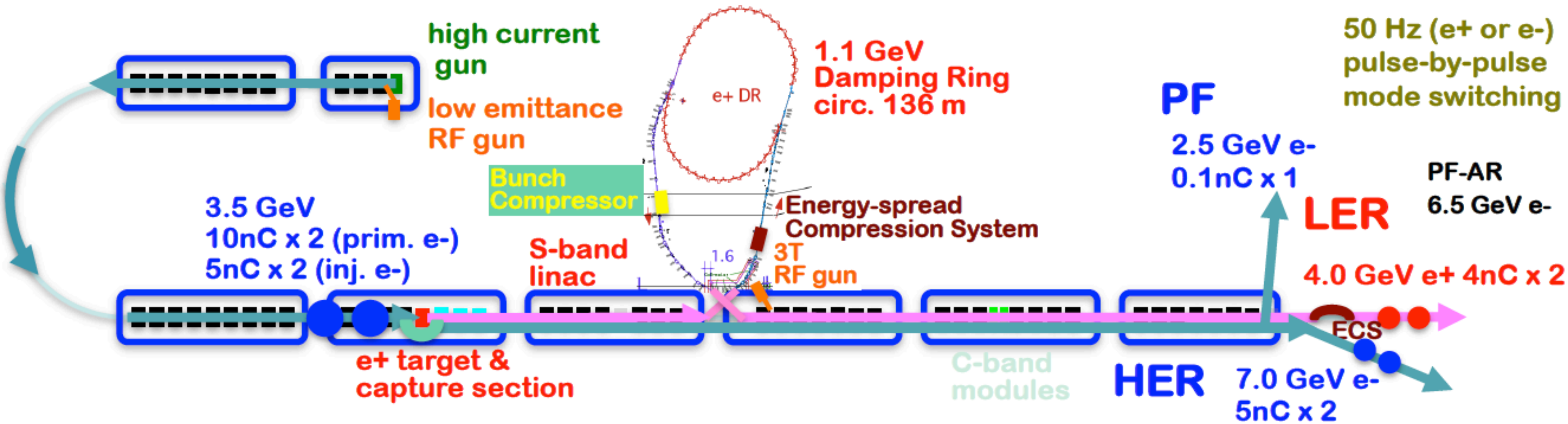
	KEKB (design)		KEKB (operation)		SuperKEKB	
	LER	HER	LER	HER	LER	HER
Radiative Bhabha	21.3h	9.0h	6.6h	4.5h	28min.	20min.
Beam-gas	45h[a)]	45h[a)]			24.5min.[b)]	46min. [b)]
Touschek	10h	-			10min.	10min.
Total	5.9h	7.4h	~133min.	~200min.	6min.	6min.
Beam current	2.6A	1.1A	1.6A	1.1A	3.6A	2.6A
Loss Rate	0.12mA/s	0.04mA/s	0.23mA/s	0.11mA/s	10mA/s	7.2mA/s

4nC@25Hz 2.9nC@25Hz

a) Bremsstrahlung
b) Coulomb scattering, sensitive to collimator setting

As for loss rate, beam loss accompanied with the beam injection should be added.

Linac



Positron capture section 920 kVA, 900 lit/min	Damping ring BT (LTR, RTL) 310 kVA	Switch yard (3SY) 300 kVA, 460 lit/min

- RF low-emittance gun for 5 nC
- Improve positron source for 4 nC
- Low-emittance transport
  - alignment error tolerance is 0.1 mm locally (0.3 mm global).
- Simultaneous and top-up injection (accompany PF and PF-AR)

SuperKEKB requirements (tentative)

	KEKB (e+/e-)	SuperKEKB (e+/e-)
Charge [nC]	1/1	4/5
Normalized emittance[μm]	2100/300	100/50 (H)
		20/20 (V)

09:50 **Injector commissioning and issues** *30'*
Speaker: Masanori Satoh (KEK)

K. Furukawa, M. Satoh, M. Yoshida, T. Kamitani

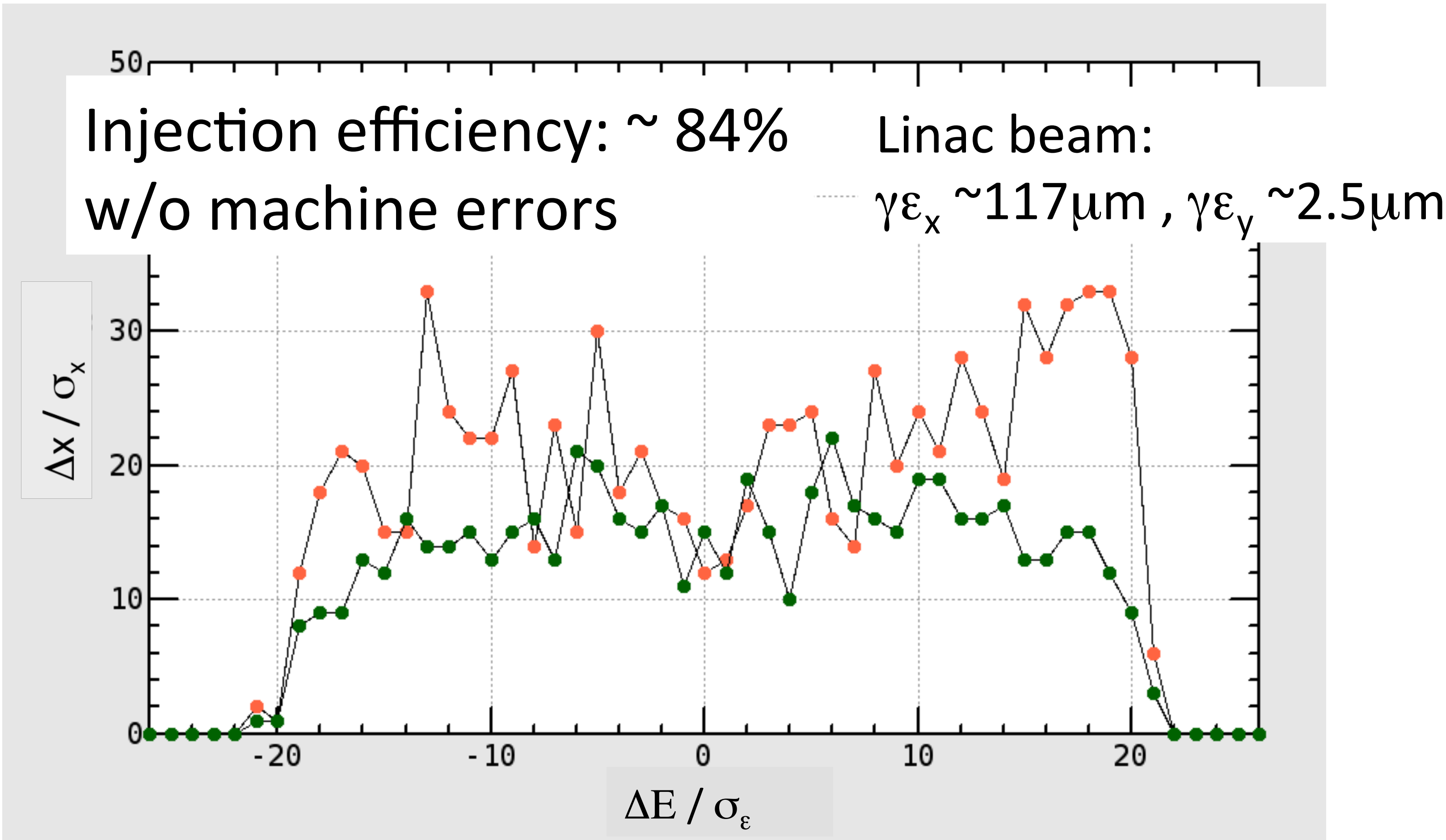
Beam injection issues

- Dynamic aperture with beam-beam effect in LER
  - Estimated injection efficiency with beam-beam
    - ~84% w/o machine errors
    - Requirements to Linac beam (emittance etc.) will be considered after we finish the investigation on dynamic aperture with beam-beam effects.
- HER injection
  - Transverse ring acceptance is marginal with the design optics to keep enough injection efficiency.
  - Maybe, we will need to switch to the "synchrotron injection" in the process of squeezing beta functions at IP.
- Synchronization issue between Linac and SuperKEKB rings
  - We will introduce a damping ring.

Nov. 12 11:00 **Injection, beam abort** *20'*
Speaker: Takashi Mori (KEK)

Nov. 11 11:30 **Synchronization** *20'*
Speaker: Hiroshi Kaji (KEK)

Dynamic Aperture with beam-beam LER : w/ damping

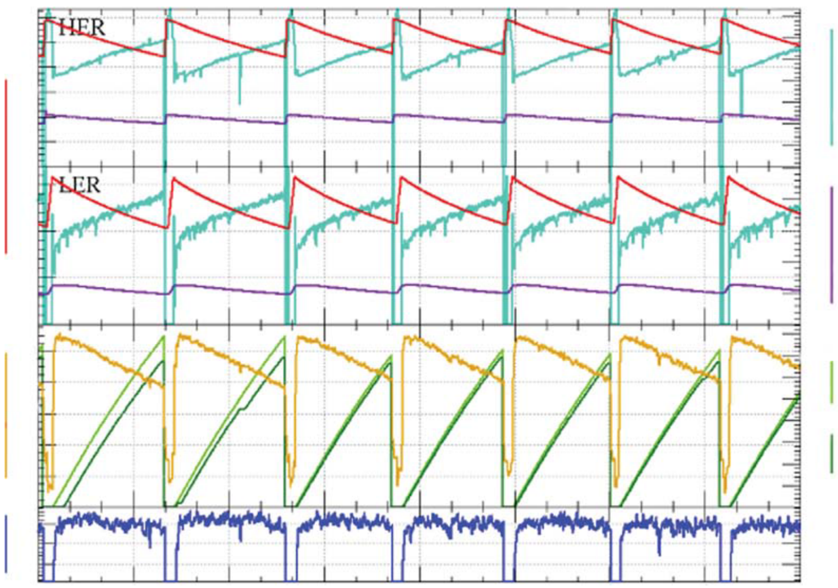


σ_x@Injection = 0.55mm
-> 12σ_x ~ 6.6mm

sler_1686

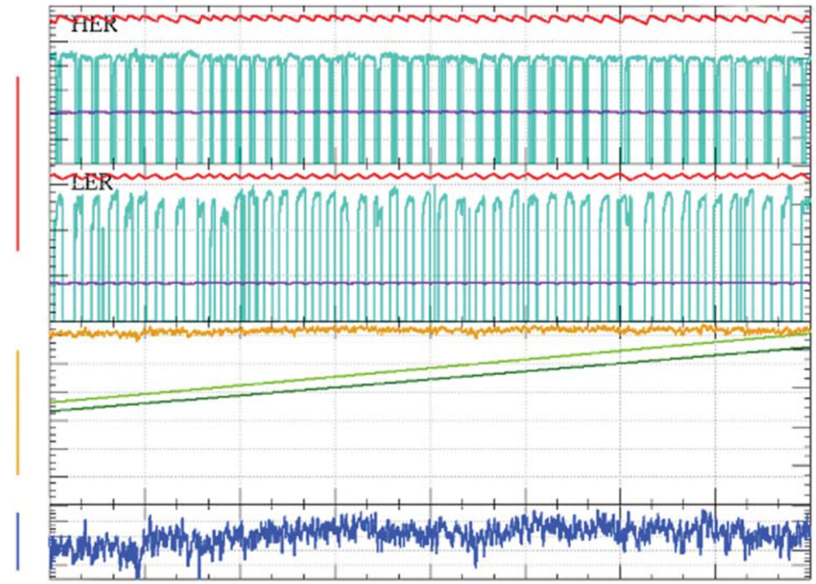
Continuous injection

- At SuperKEKB, the continuous injection (top-up injection) is indispensable, since the beam lifetime is very short.
  - Max. 50 Hz (e- + e+)
  - Azimuthal VETO (at KEKB not azimuthal 3.5msec after injection)



8 hours

Before continuous injection



8 hours

After continuous injection

Gain in integrated luminosity at KEKB: ~30%

Beam background

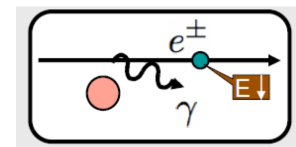
- At SuperKEKB with x40 larger Luminosity, beam backgrou o increase drastically.

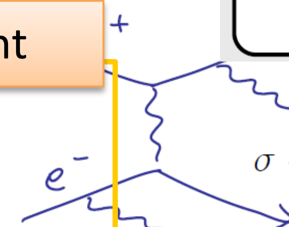
Beam-origin

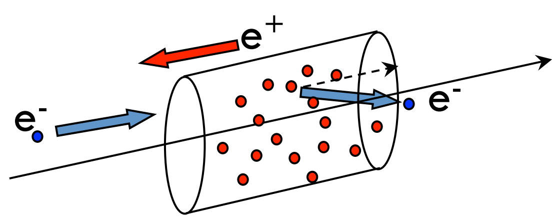
  - Touschek scattering
  - Beam-gas scattering
  - Synchrotron radiation

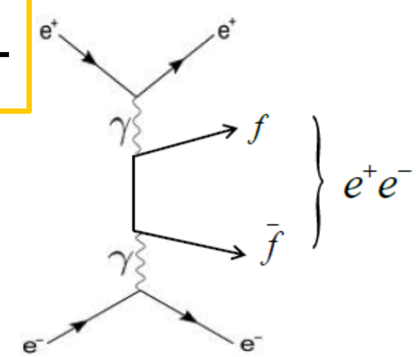
Luminosity dependent

  - Radiative Bhabha event: emitted γ
  - Radiative Bhabha event: spent e+/e-
  - 2-photon process event: e+e-→e+e-e+e-
  - etc…







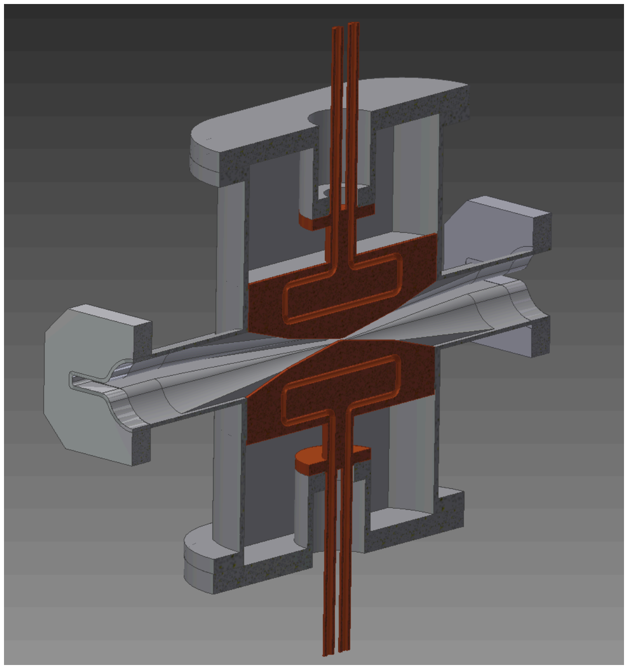


Nov. 12 17:00
Background estimation *20'*
Speaker: Hiroyuki Nakayama (KEK)

Collimators

Nov. 12 16:40
Beam collimators *20'*
Speaker: Takuya Ishibashi (KEK)

Vertical collimator



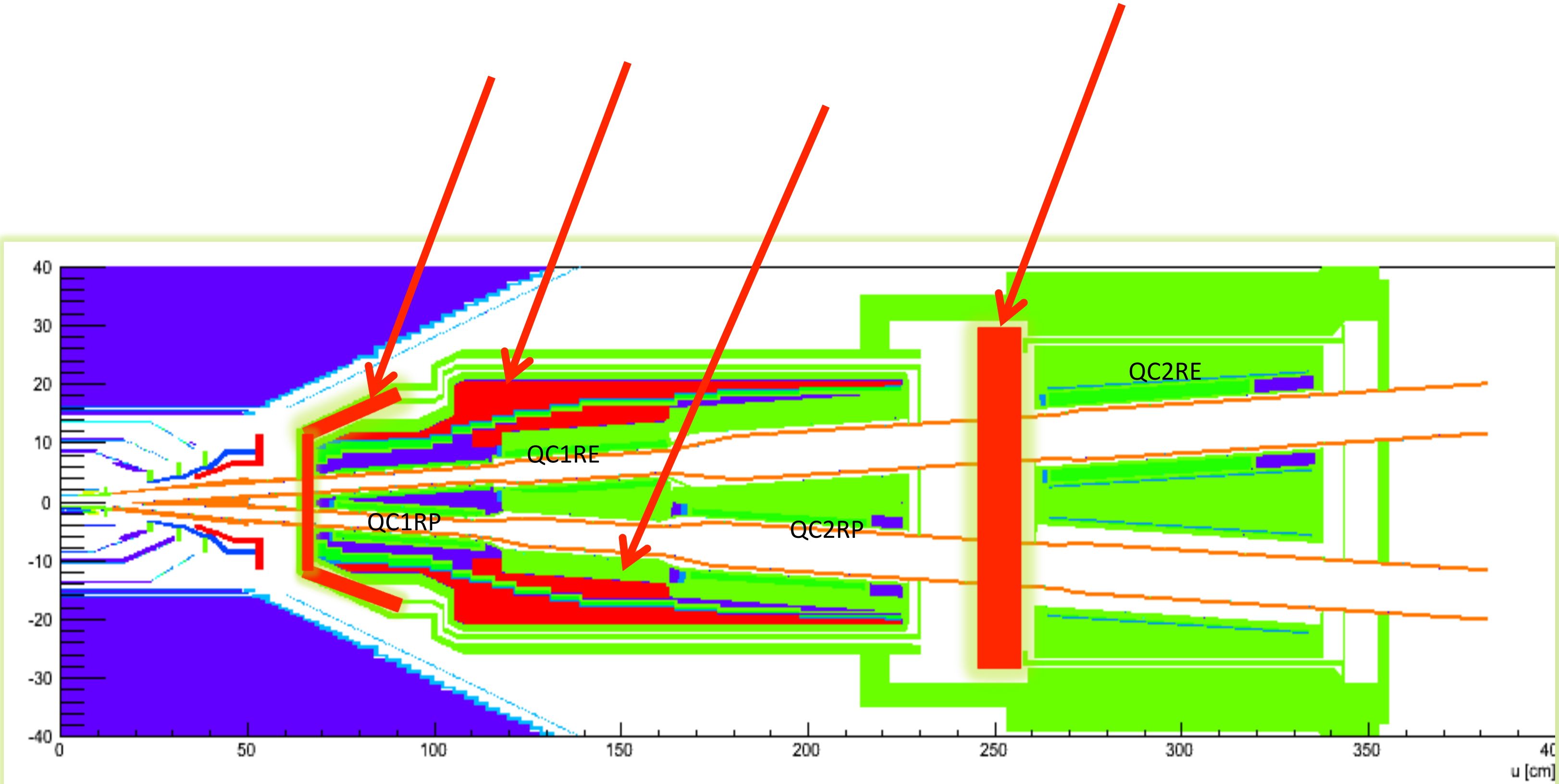
- Horizontal collimators are effective to reduce Touschek BG in IR area
- To reduce IR loss of beam-gas Coulomb BG, very narrow (~2mm half width) vertical collimator is required
- TMC instability is an issue, low-impedance design of collimator head is important
- Should withstand ~100GHz loss (tungsten)
- Precise control of collimator width is important (otherwise IR loss rapidly increase)

Life time	Touschek	Beam-gas Coulomb	Rad. Bhabha
LER	10 min.	25 min	28 min.
HER	10 min.	46 min.	20 min.

IR loss |s|<4m	Touschek	Beam-gas Coulomb	Rad. Bhabha
LER	250 MHz	90 MHz	0.6GHz*
HER	30 MHz	<10 MHz	0.5GHz*

*Effective rate

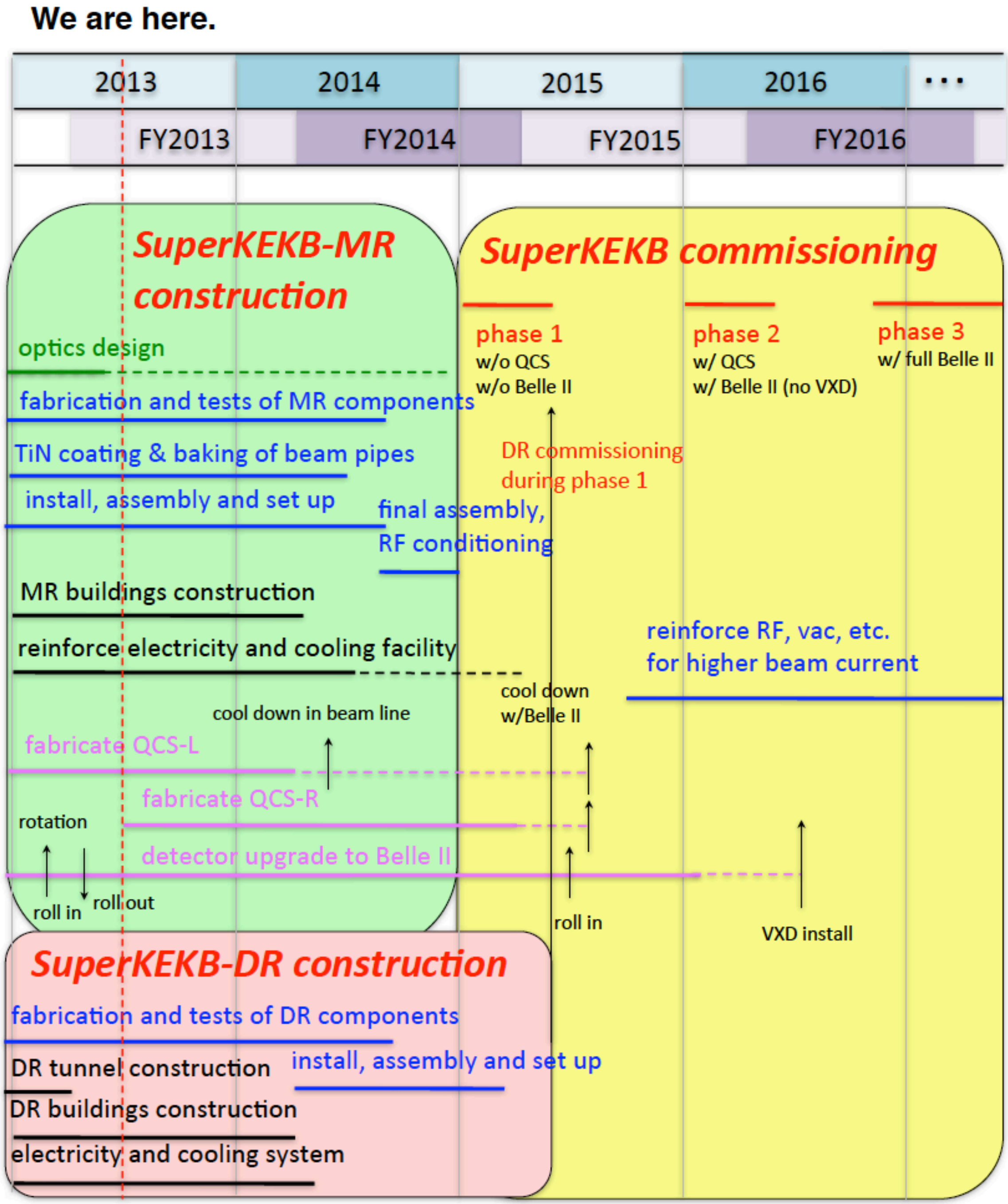
Tungsten shield inside QCS cryostat



Put as much tungsten as possible around the beam pipe to stop showers generated by beam loss

COMMISSIONING PLAN

Master Schedule



K. Akai

Phase-1
w/o QCS and Belle II

2015 Jan.–June

Phase-2
with QCS and Belle II

2016 Jan.–May

Phase-3
Physics Run

2016 Oct.–

Commissioning phase 0 (2013 Sep. ~ 2014 Dec.)

- Machine condition
  - SuperKEKB rings: construction
  - Linac commissioning in parallel with its construction
- Tuning items
  - To be covered by the next talk.

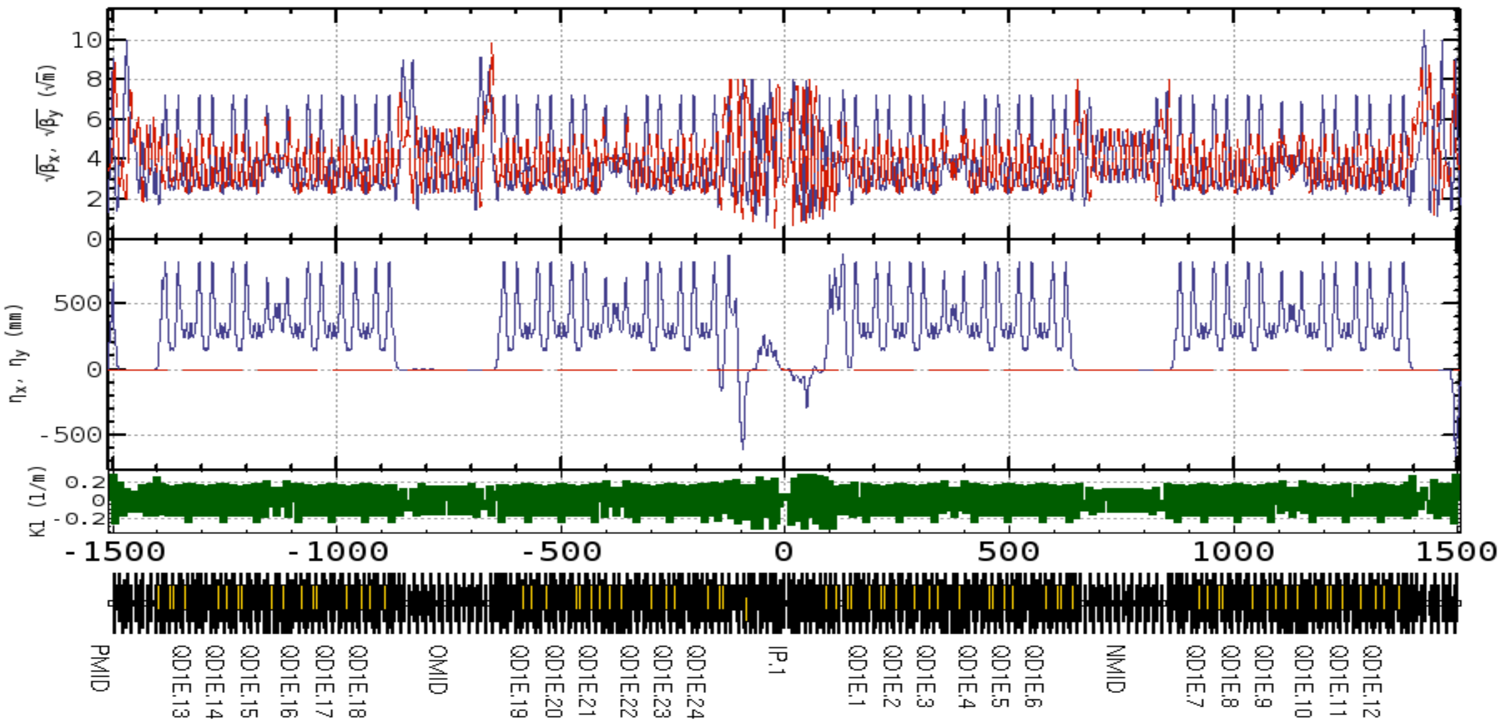
Nov. 11 09:50
Injector commissioning and issues *30'*
Speaker: Masanori Satoh (KEK)

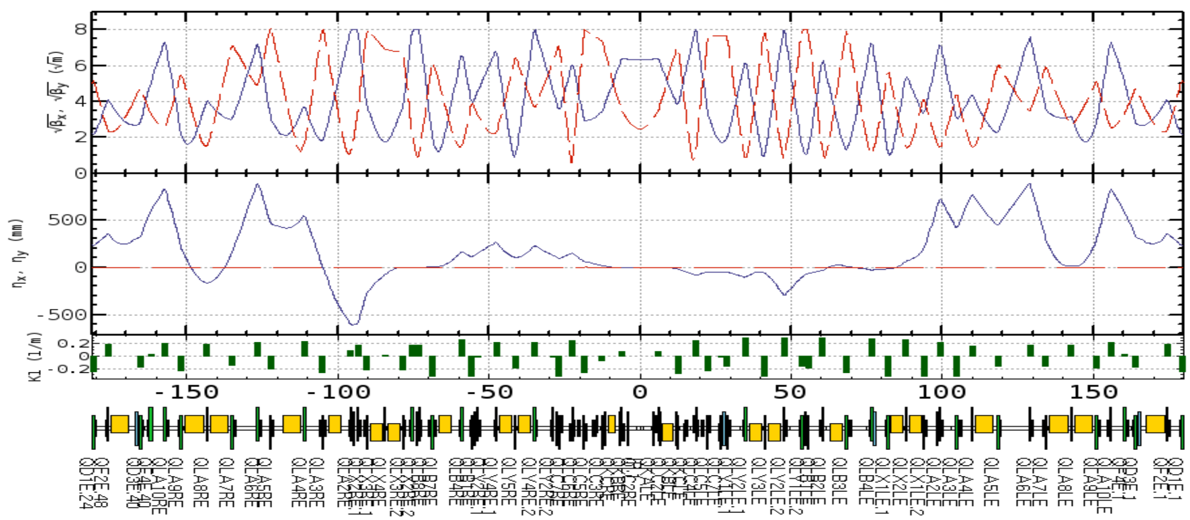
Commissioning phase 1 (2015 Jan. ~ June)

- Machine condition
  - No QCS, No solenoid (no Belle II), No beam collision
- Tuning items
  - Linac tuning (if necessary)
  - Basic commissioning of machine (~ 1.5 month)
    - Injection tuning, Hardware check and bug fix, software bug fix
  - Vacuum scrubbing (>~3 months)
    - Belle II people request enough vacuum scrubbing in this stage (before Belle II roll-in). At least one month with beam currents of 0.5 ~ 1 A.
  - Damping ring commissioning (start from May 2015)
    - Beam injection with damping ring
  - Detector beam background
    - Study with Beast detectors, check of collimator system (two new-type collimators in LER)
  - Some optics tuning
    - With day-1 optics
    - Low emittance tuning w/o Belle-II solenoid
  - Study of beam instability (FII, e-cloud)
    - Tuning on bunch-by-bunch feedback

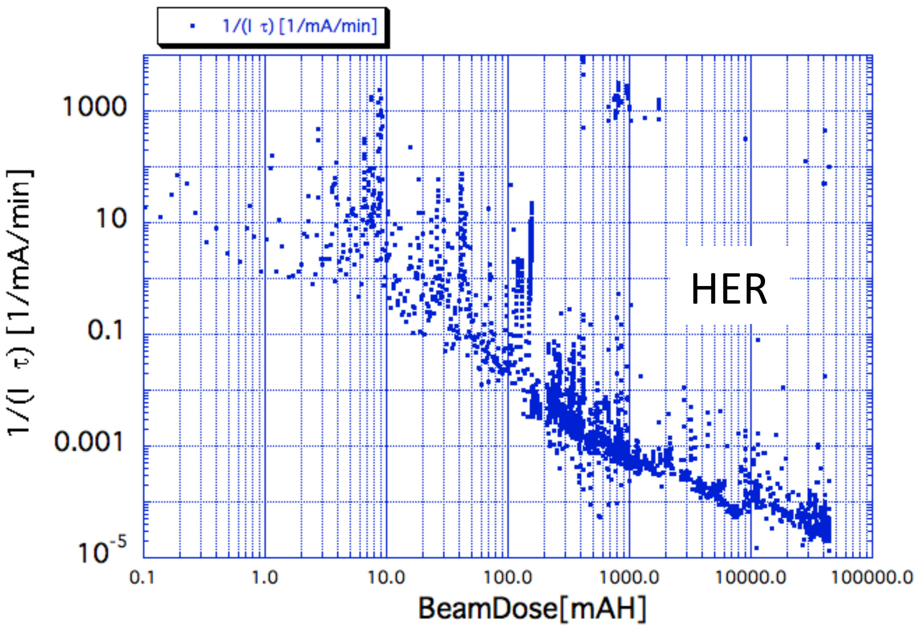
Nov. 13 09:20
Bunch-by-bunch feedback *20'*
Speaker: Makoto Tobiyama (KEK)

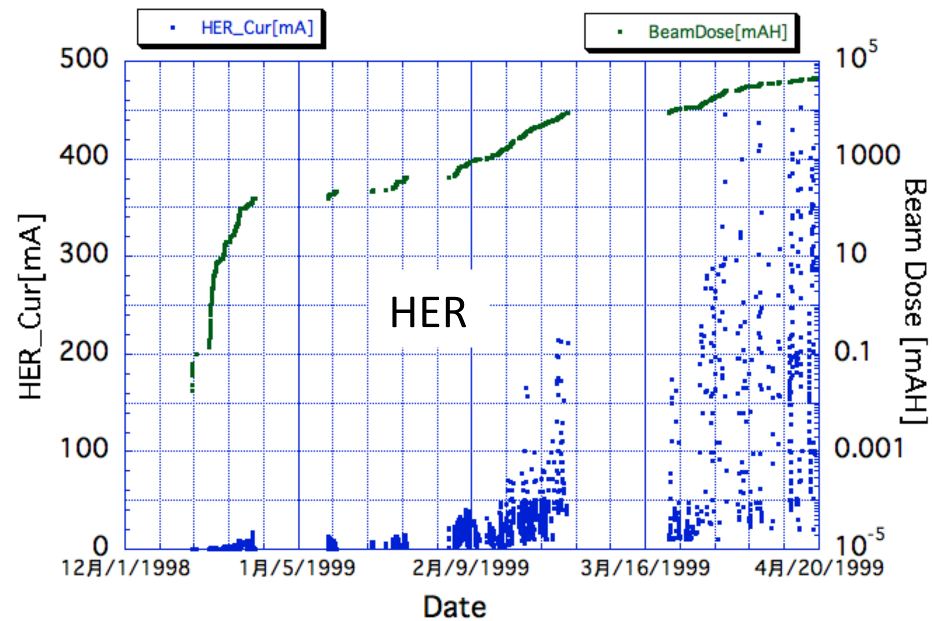
Phase 1 optics (HER)

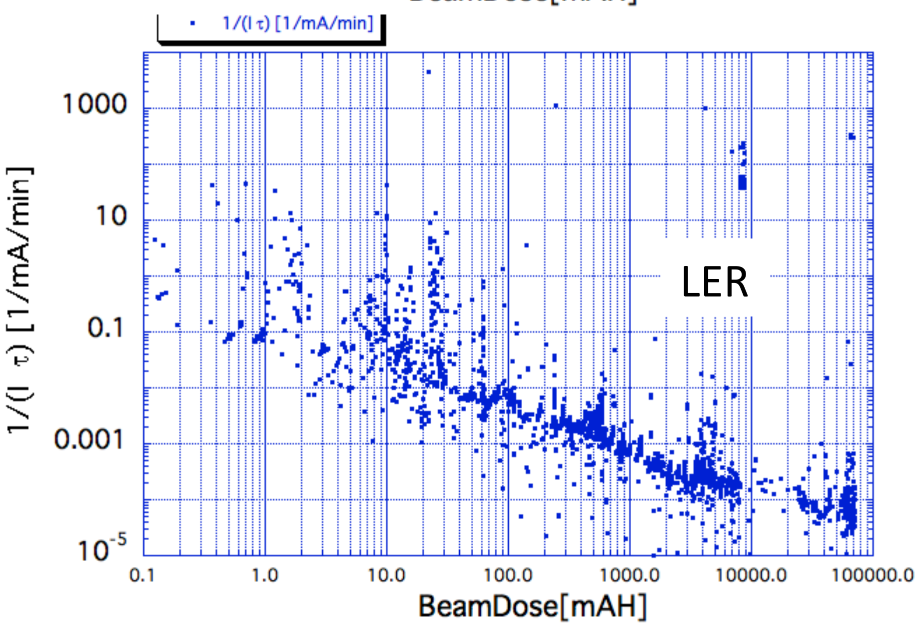


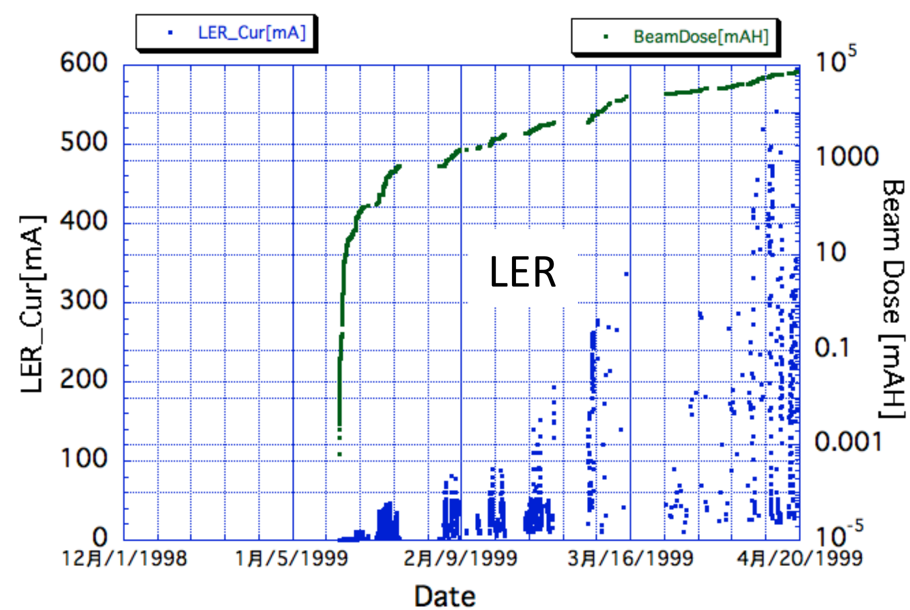


Vacuum scrubbing at KEKB（HER/LER）









Damping ring commissioning

- We have no concrete commissioning plan so far. We need to make a plan.

Nov. 12 11:20 **DR LTR, RTL** *20'*
Speaker: Mitsuo Kikuchi (KEK)
Nov. 12 11:40 **DR beam monitors** *20'*
Speaker: Hitomi Ikeda (KEK)

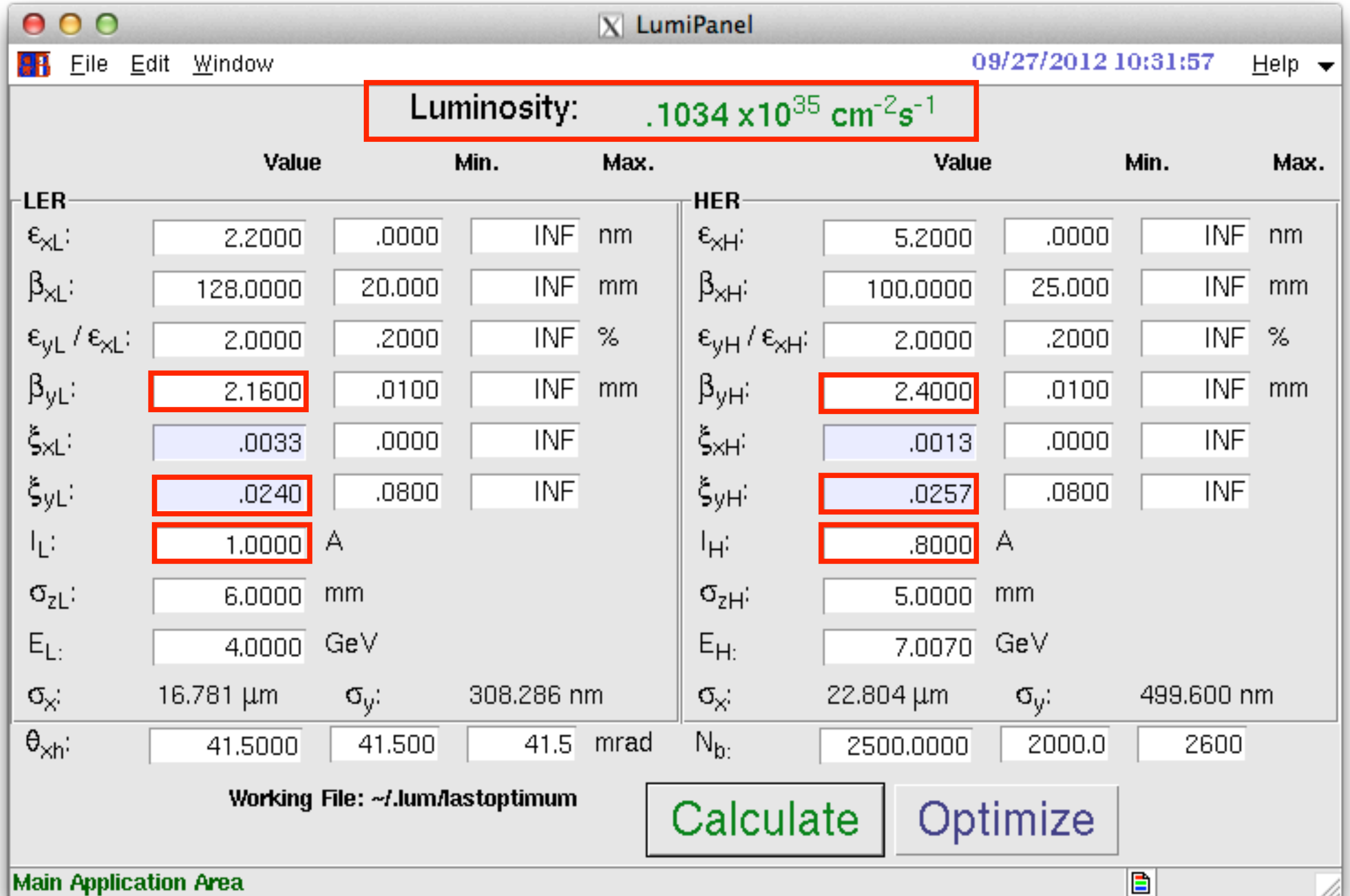
Commissioning phase 2 (2016 Jan. ~ May)

Feb. ~ June

- Machine condition
  - w/ QCS, w/ Belle II (w/o VXD),TOP detectors partially installed, full accelerator tuning, no physics experiment
- Tuning items
  - Optics tuning
    - Tentative target values of IP beta's: β_x^*: x4, β_y^*: x8
    - Optics tuning with QCS and Belle II solenoid
    - Low emittance tuning w/ Belle II solenoid
    - Optics tuning w/ beam collision
  - Detector beam background
    - Study with Belle II detector, test of continuous injection
  - Increase of beam currents (instability, RF power, vacuum issues)
    - Detector background may possibly give some restriction.
    - Continue upgrade for RF system (support ~70% of design beam currents)
  - Beam collision tuning
    - Orbit feedback (fast feedback, dithering system)
    - Collision tuning w/ "Nano-Beam" scheme
  - Luminosity tuning
    - Tuning knobs (x-y coupling at IP etc.)
    - Target luminosity: 1×10^{34} cm^{-2} s^{-1} (design of KEKB)

Detuned Optics (4x8)

Example of machine parameters for 10^{34} $cm^{-2}s^{-1}$



β_x^*: x4, β_y^*: x8, x-y coupling =2 %, ξ_y ~ 0.025, I_{LER} = 1 A.

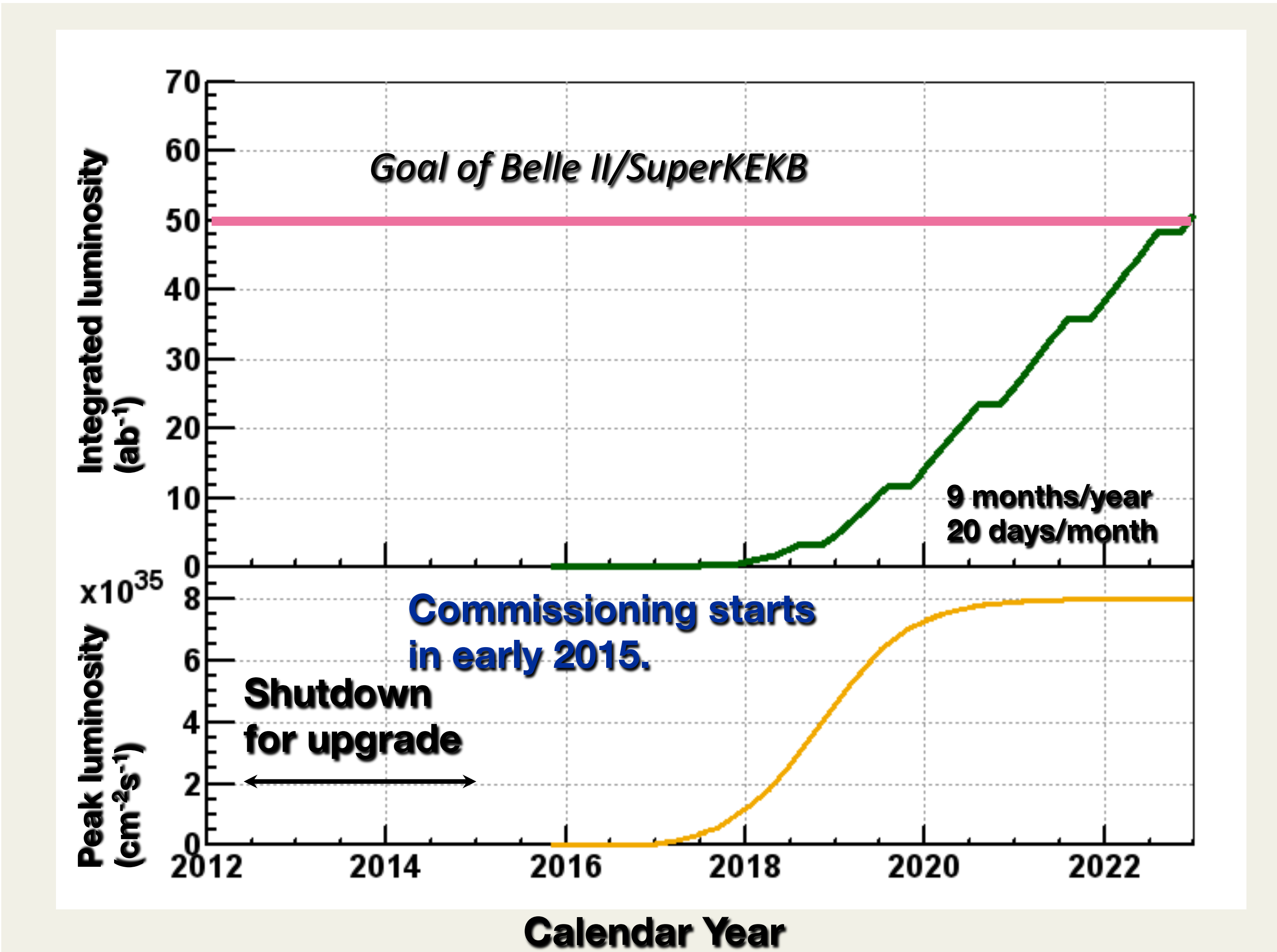
Commissioning phase 3 (2016 Oct. ~)

- Machine condition
  - Full set of Belle II, Physics experiment will start.
    - Maybe some TOP counters will be delayed.
- Tuning items
  - Optics tuning
    - Toward design values of IP beta's
      - Maybe it will take several years.
    - Low emittance tuning:
      - Design values for vertical emittances are very small. Demonstration of feasibility of TLEP.
    - Optics tuning w/ beam-beam effect
  - Detector beam background
    - Establishment of continuous injection (azimuthal VETO)
  - Increase of beam currents
    - Design values are as twice high as those of KEKB.
  - Luminosity tuning
    - Study on effects of lattice non-linearity and space-charge
    - Stability of tuning will be an important issue. (continuous optics correction?)

Difficulty of SuperKEKB

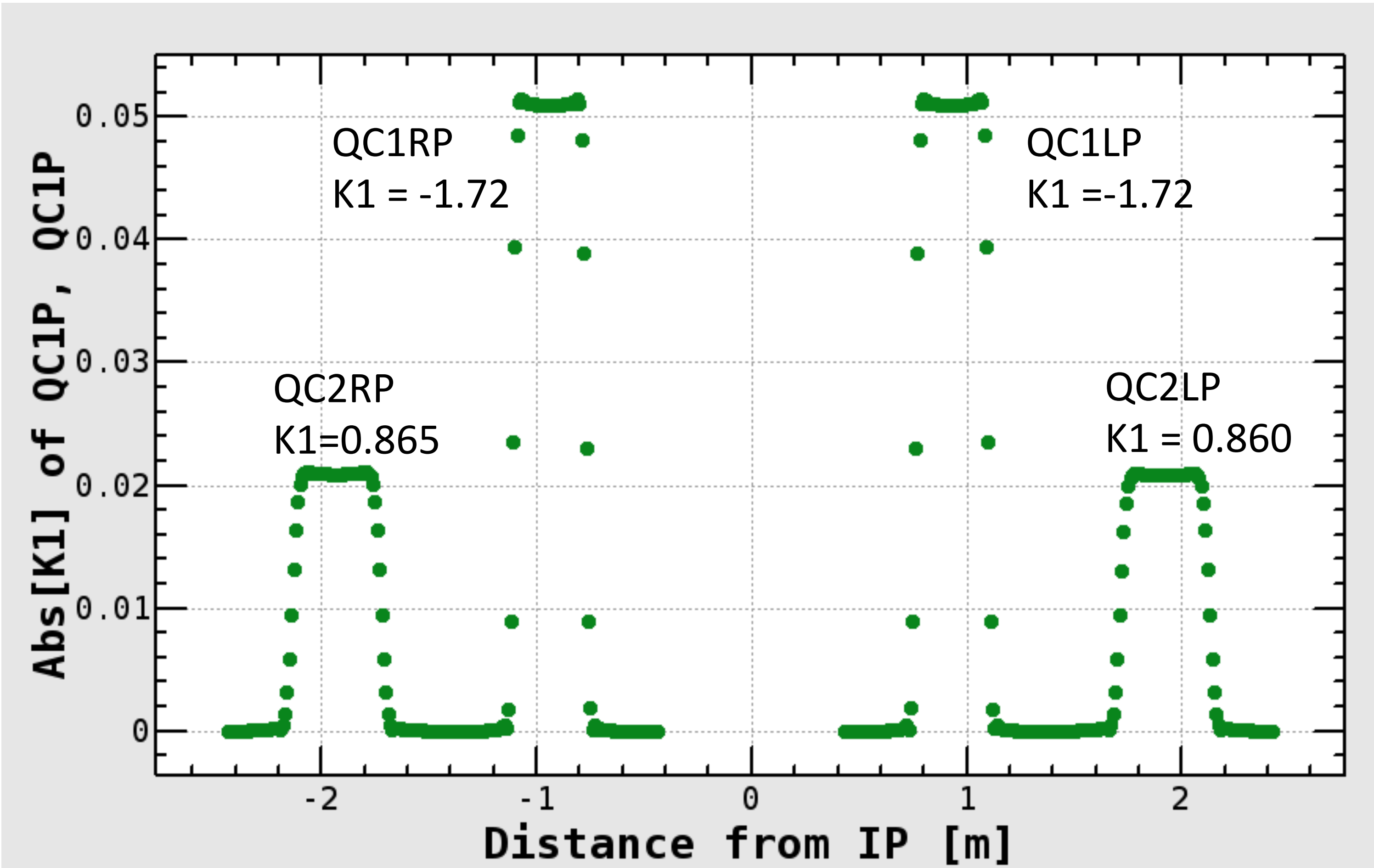
- The commissioning phase 3 will be the most critical phase.
  - The true difficulty of SupeKEKB will be recognized in this phase.
    - Corrections of machine errors seem the key issue.
    - Stability of machine condition seems important.
      - Continuous optics correction?
  - Some unknown difficulties will possibly appear.
  - My personal impression: Important milestone of luminosity: 1×10^{35} cm^{-2} s^{-1}.

SuperKEKB luminosity projection



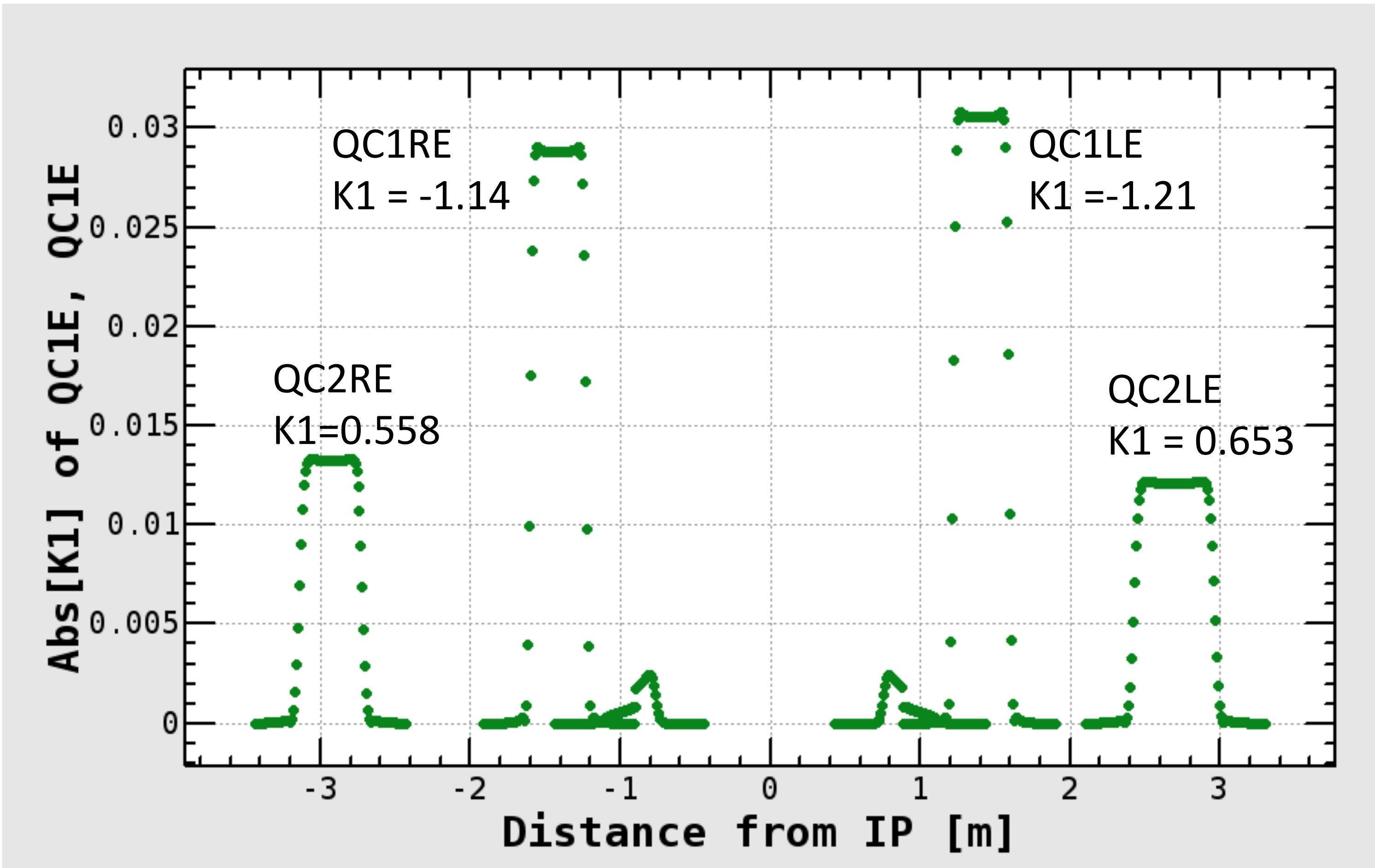
BACKUP SLIDES

QC1P, QC2P



QC1RP
K1 = -1.72
QC1LP
K1 =-1.72
QC2RP
K1=0.865
QC2LP
K1 = 0.860
0.05
0.04
0.03
0.02
0.01
0
-2
-1
0
1
2
Abs[K1] of QC1P, QC1P
Distance from IP [m]

QC1E, QC2E


QC1RE
K1 = -1.14
QC1LE
K1 =-1.21
QC2RE
K1=0.558
QC2LE
K1 = 0.653
Abs[K1] of QC1E, QC1E
Distance from IP [m]
0.03
0.025
0.02
0.015
0.01
0.005
0
-3
-2
-1
0
1
2
3

M. Ono

Facilities

- Storage and staging areas needed for magnet and vacuum components.
- Need increased cooling water for klystrons and magnets:
  - 24 klystrons for ARES cavities, 8 klystrons for SCC
  - Magnet cooling water needs double (4 plants -> 8)
- Electricity:

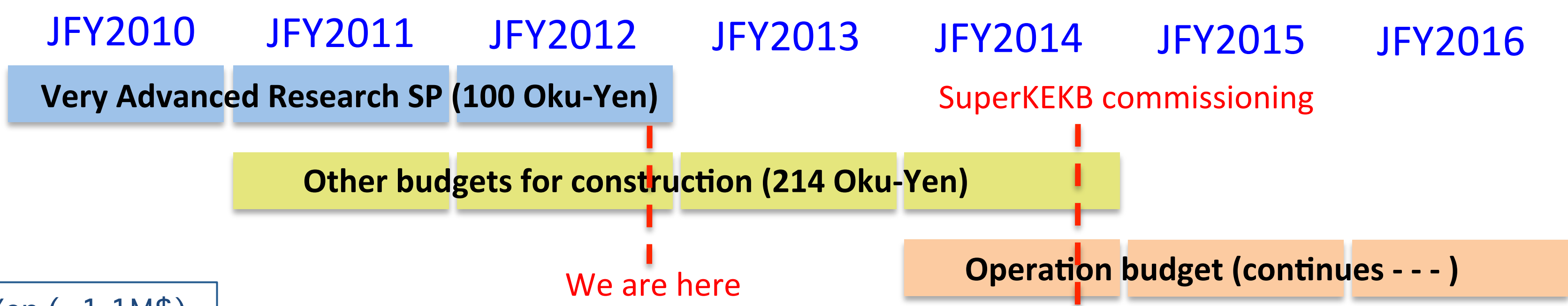
Electricity Consumption: June-09 KEKB/KEK total

(Design option)	KEKB:MW	ΔMW	KEK:MW	ΔMW
Present(Average)	45		64	
Nano Beam: June-09	70.7	24.3	96	32
Upgrade: Feb.-09	94.8	49.8	120	56
Super: '07-July	102.6	57.6	128	64

Recent Design(Feb.-10): Add 2 ARES units--> +(3~4)MW

Overall budget (original)

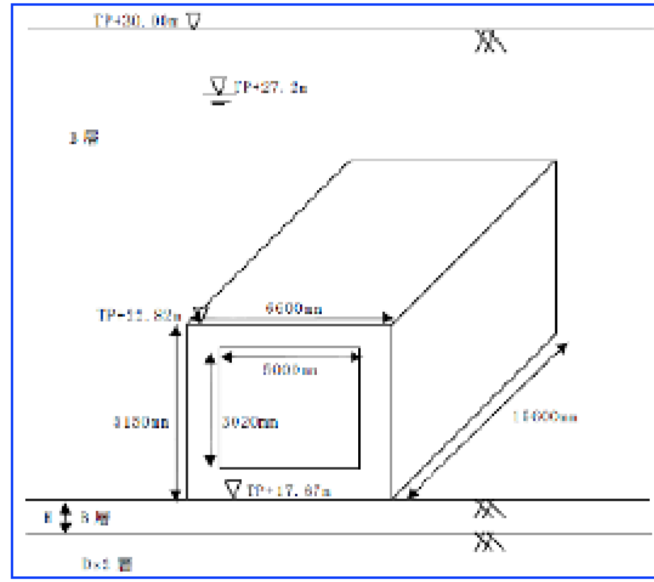
- Budget
  - Total construction budget is 314 Oku-Yen for Rings, Injector, and Belle-II.
  - Most of the budget comes year-by-year based.
  - Operation budget is expected in FY2014 and later.



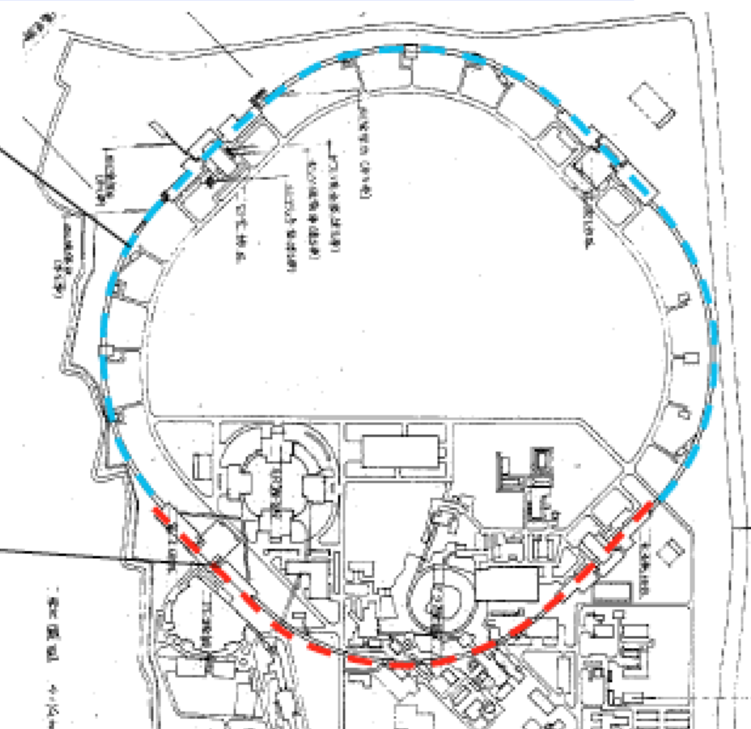
Unit: Oku-Yen (~1.1M$)

	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			

Configuration of the KEKB tunnel



- No piling under the floor at arc-section.
- Refilled soil after complete the tunnel.



Walls to prevent a landslide .

IR Design Features

- Natural chromaticity:

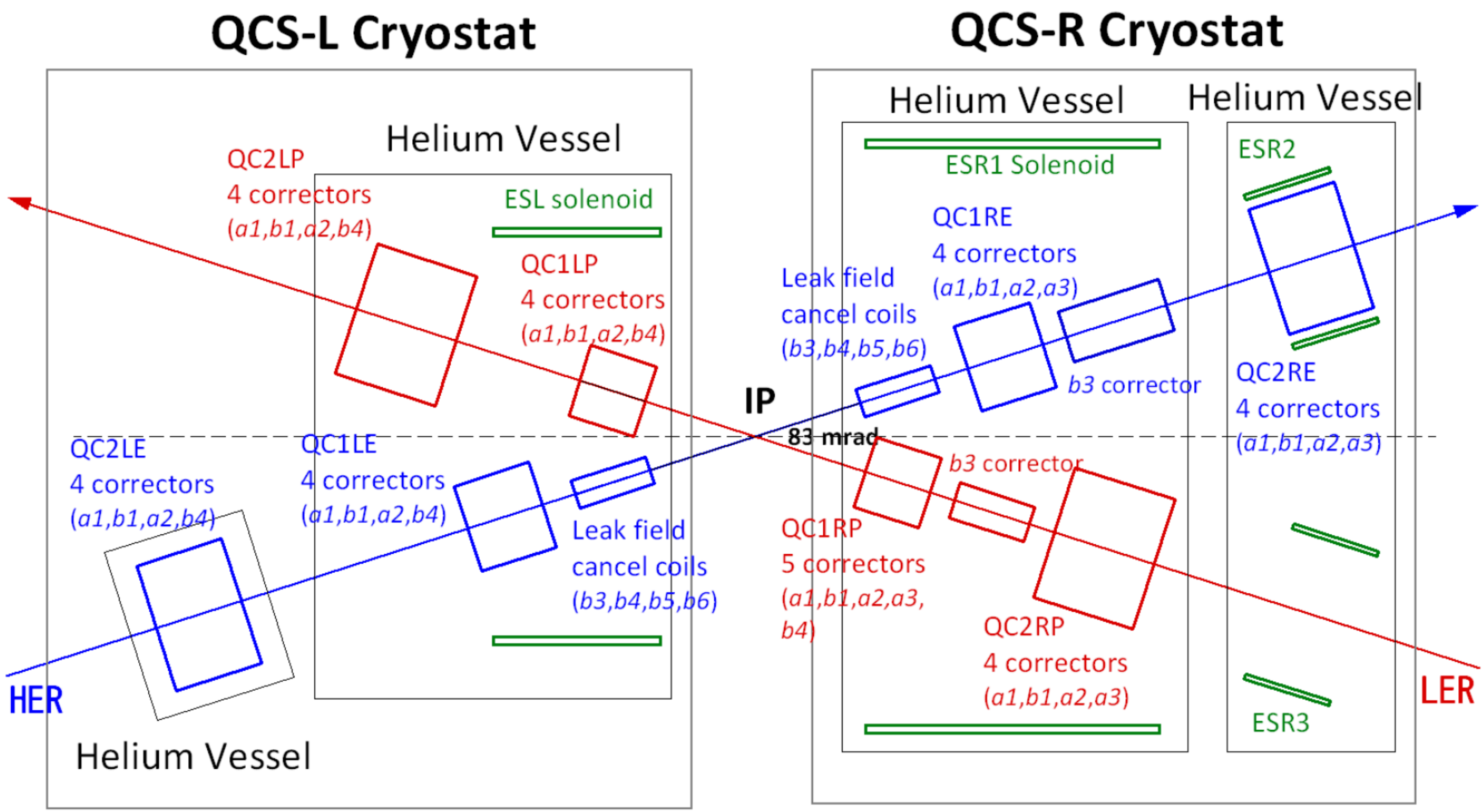
	SuperKEKB		KEKB	
	LER	HER	LER	HER
ξ_{x0}	**−105**	**−171**	−72	−70
ξ_{y0}	**−776**	**−1081**	−123	−124

- Approximately *80 %* of the natural chromaticity in the vertical direction is induced in the Final Focus. A "*local chromaticity correction*" is adopted to correct it.

- The angle between Belle II Solenoid(1.5 T) and beam-axis is 41.5 mrad. Anti-solenoids are overlaid with QC1 and QC2 to compensate the Belle II solenoid field. The vertical emittance (about 1.5 pm) is generated due to the solenoid fringe field. To reduce them, skew coils and/or rotation of QC1 and QC2 are used.

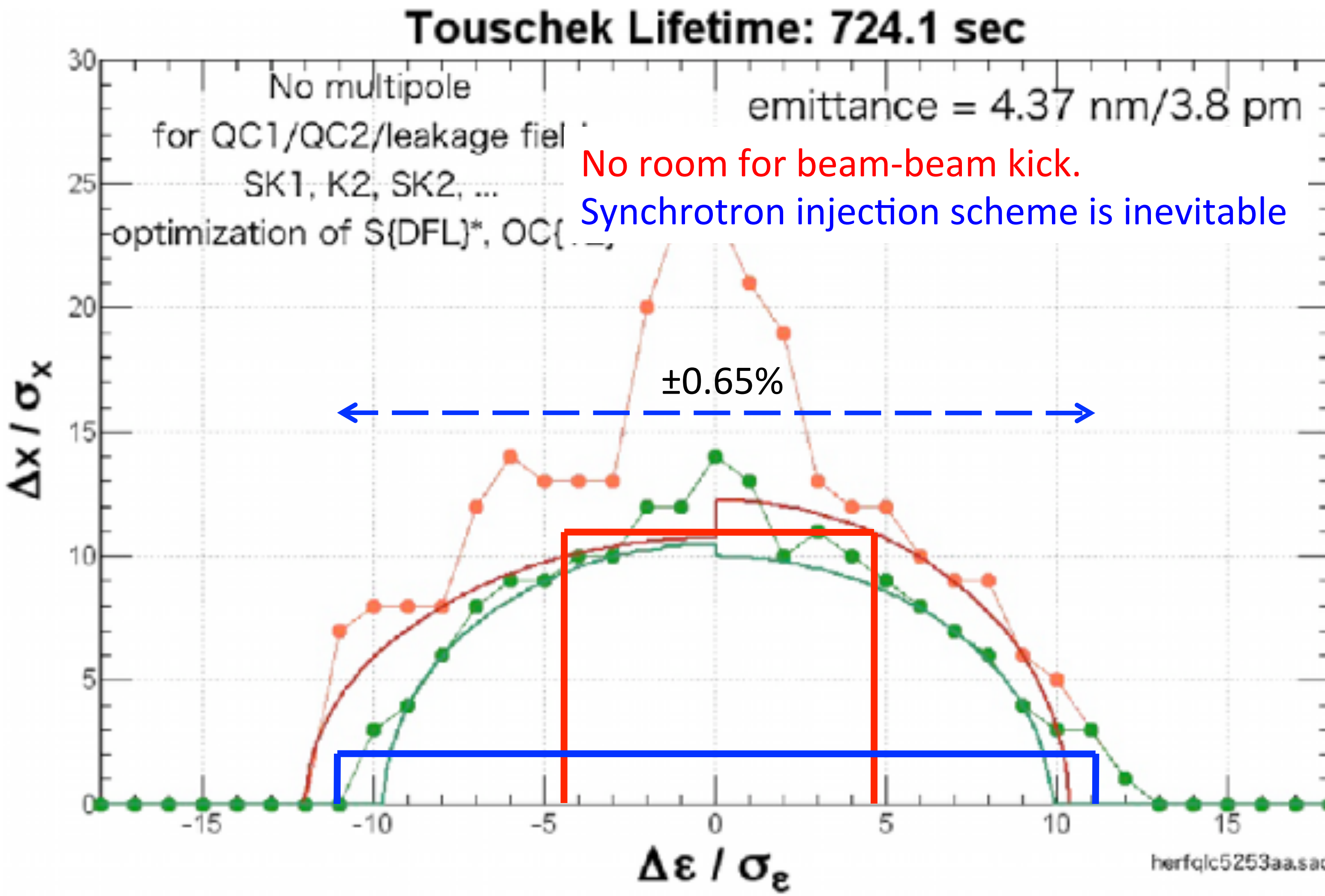
SC correctors by BNL

Revised corrector scheme in the right side:



from A. Morita

Improvement plan for HER Aperture



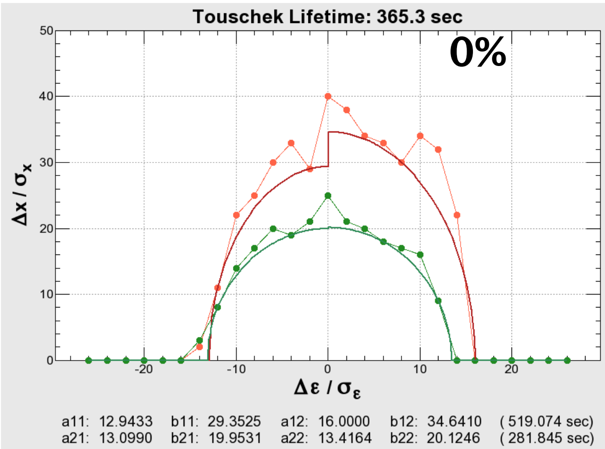
Impact on detector

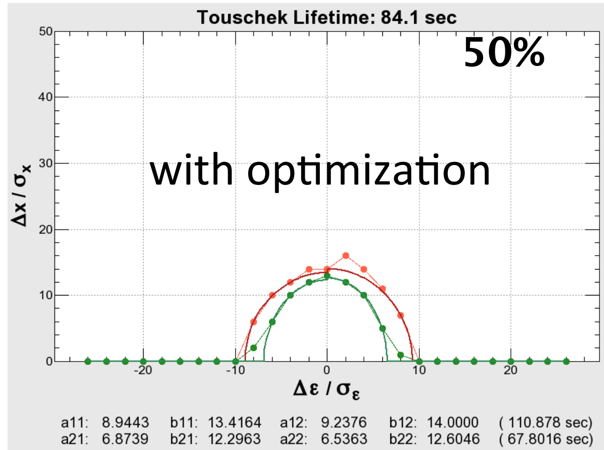
- Assuming design luminosity, BG impact on detector performance(occupancy, tracking/PID performance etc..) is tolerable.
- Assuming 10 years operation at design luminosity, most of our detector components are safe for radiation damage/neutron flux.
  - except for TOP PMT photocathode lifetime, which needs further x2 reduction.

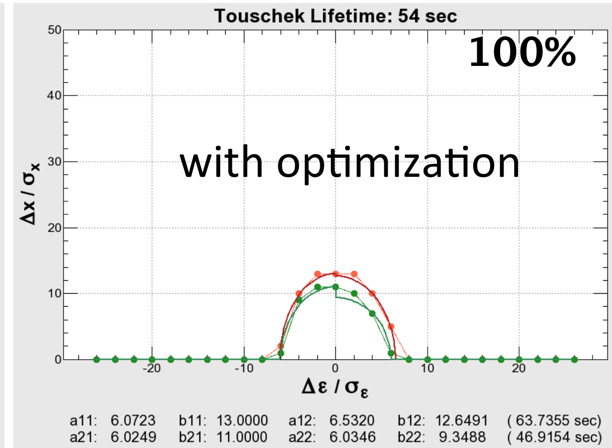
Gammas in BGshower reach TOP quartz bar and generate electrons by Compton scattering and etc.. Those electrons emit Cerenkov photons and those photons reach PMT photocathode.

TOP: Time-of-Propagation counter, detect ring image Cerenkov radiation for particle ID

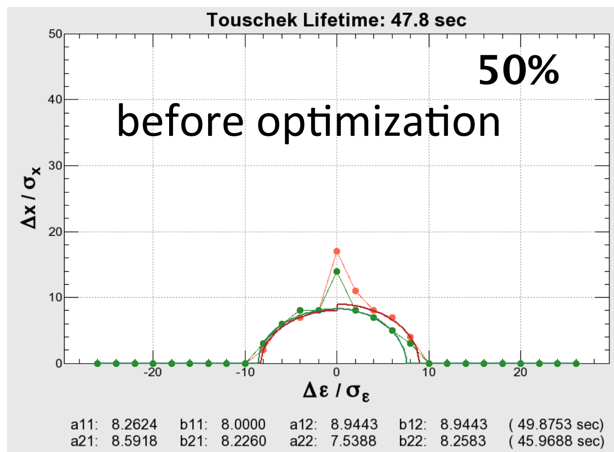
Preliminary results on dynamic aperture study with sextupoles for crab waist

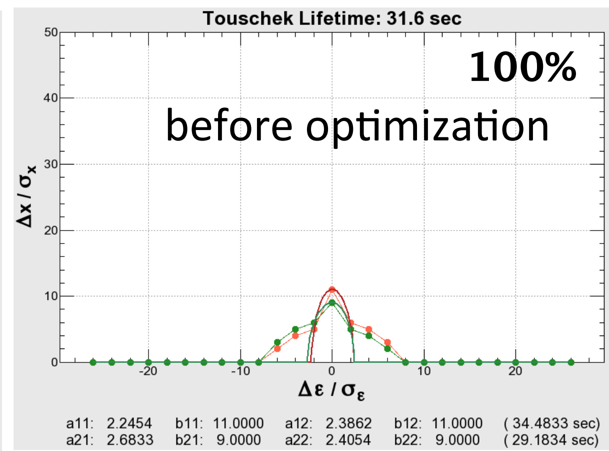






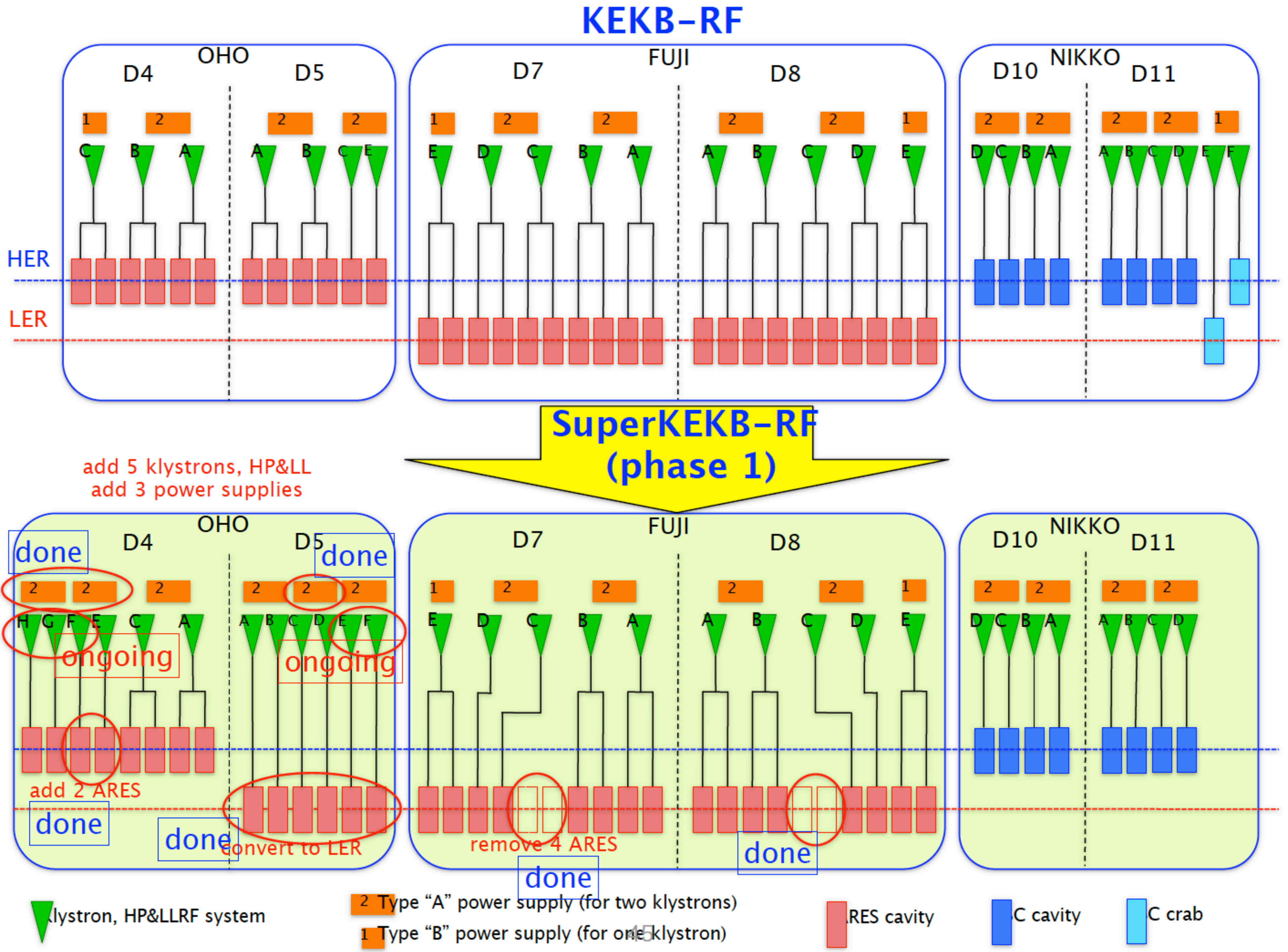
H. Koiso



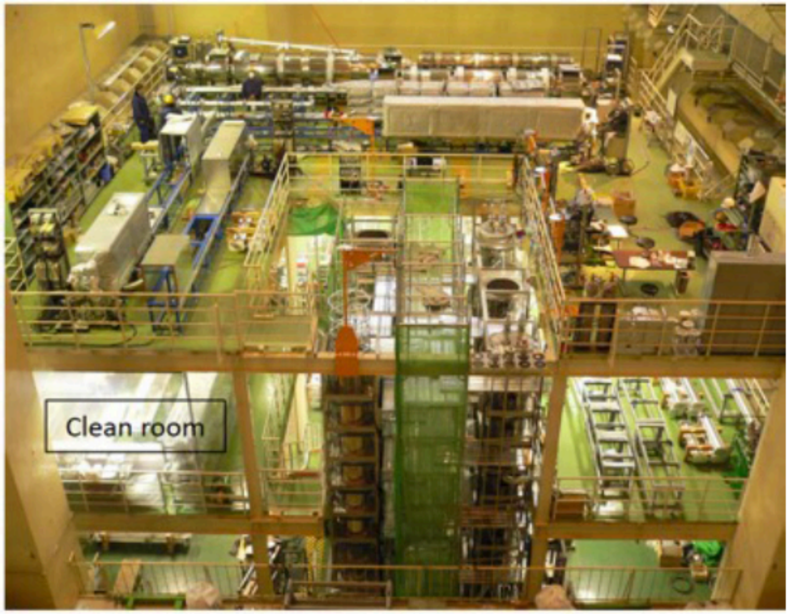


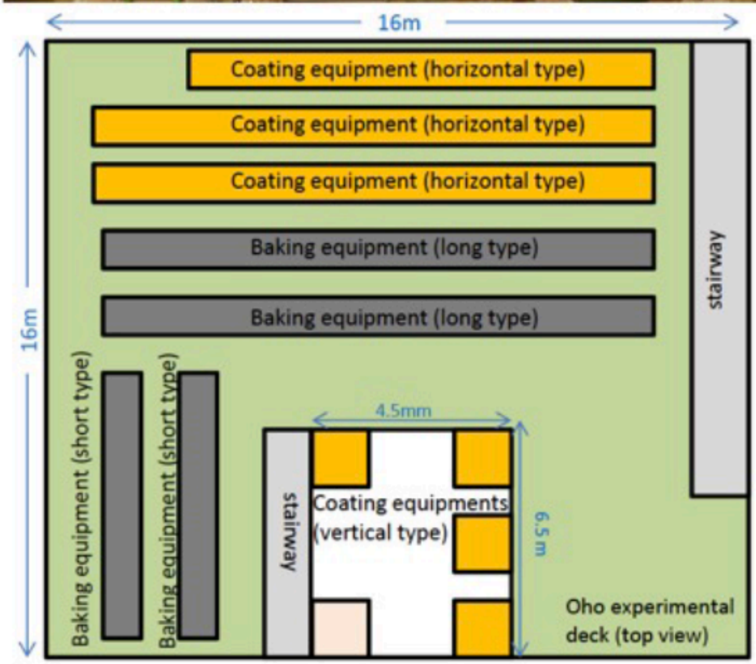
We have considered that the crab waist scheme can not be used at SuperKEKB due to the degradation of dynamic aperture. Now, we have started to study this scheme more seriously.

We are collaborating with people in BINP.


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
2 Type “A” power supply (for two klystrons)
1 Type “B” power supply (for one klystron)
ARES cavity
SC cavity
SC crab

TiN Coating and Baking at OHO Lab.





Visual check on the beam pipe

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TiN Coating (LER pipe)

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Assembling (NEG pump and BPM electrode)

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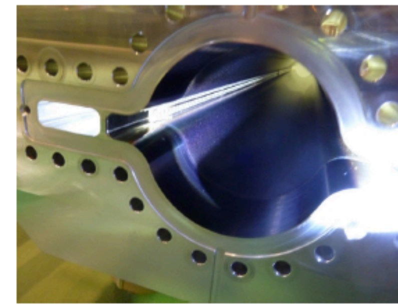
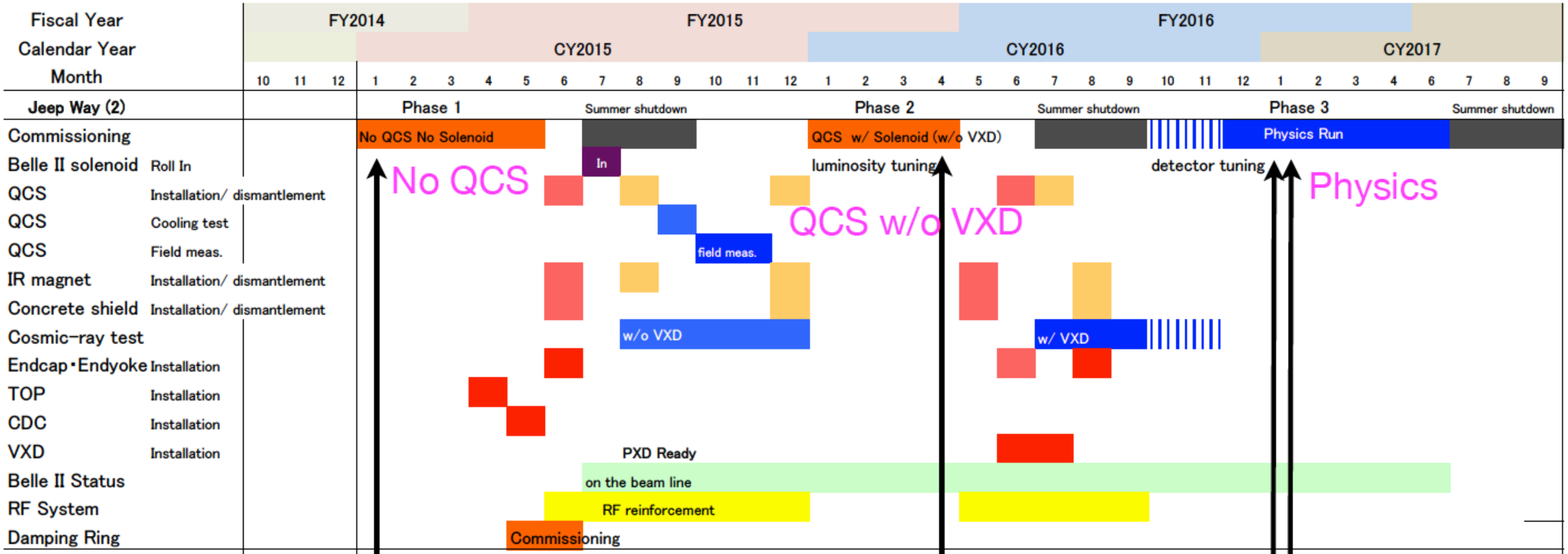
Baking process



After TiN coating before baking

K. Shibata

Commissioning Schedule: Baseline



Phase-1

Target: > 500 mA

Positron injection w/o Damping Ring.

Vacuum scrubbing
Optics tuning
Detector background

Phase-2

Target: 10^{34} cm^{-2}s^{-1}

Detuned: 10 x nominal β*
Squeezing β* gradually

Optics tuning
Detector background
Increase currents