Optics Issues

2015.02.23

11:35 - 12:15

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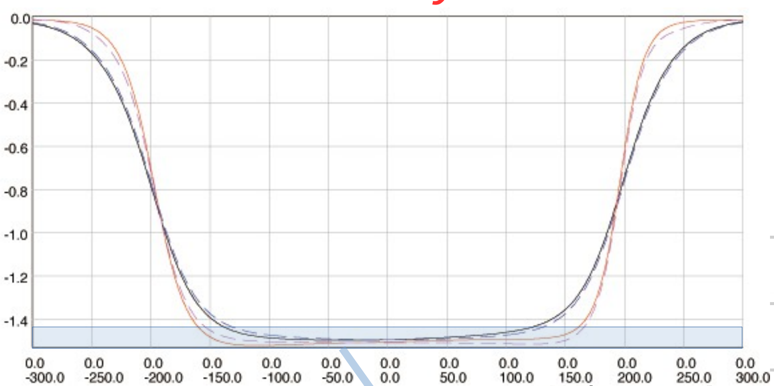
Belle II Solenoid Deformation (1)

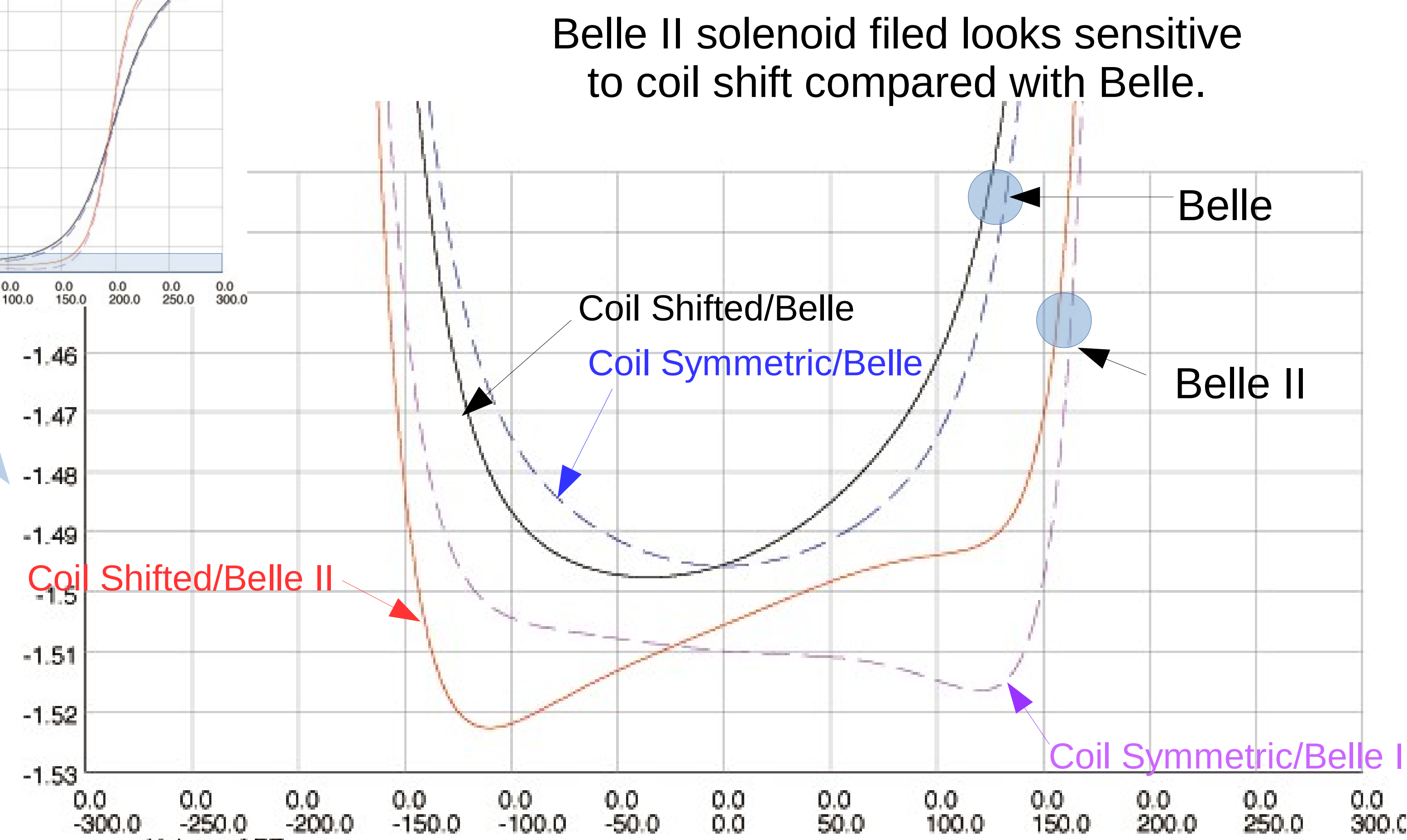
- Belle detector solenoid coil geometry is designed symmetric, but …
  - The center of measured Belle solenoid field is shifted about 440mm toward R-side(Oho side).
    - This field center shift corresponds with 30mm coil shift in 2D magnetic field calculation model.
  - This issue is figured out by Tsuchiya-san @ IR Tech. Meeting #96(2013.10.24)
  - We have to …
    - Re-optimize current density distribution of compensation solenoid coils for adjusting Bz & ∫Bz distribution
      - QCS(QC1 & QC2) geometry is already finalized.

Belle II Solenoid Deformation (2)

- The effect of the detector solenoid coil shift in 2D solenoid model

Tiny 2D model without compensation solenoid

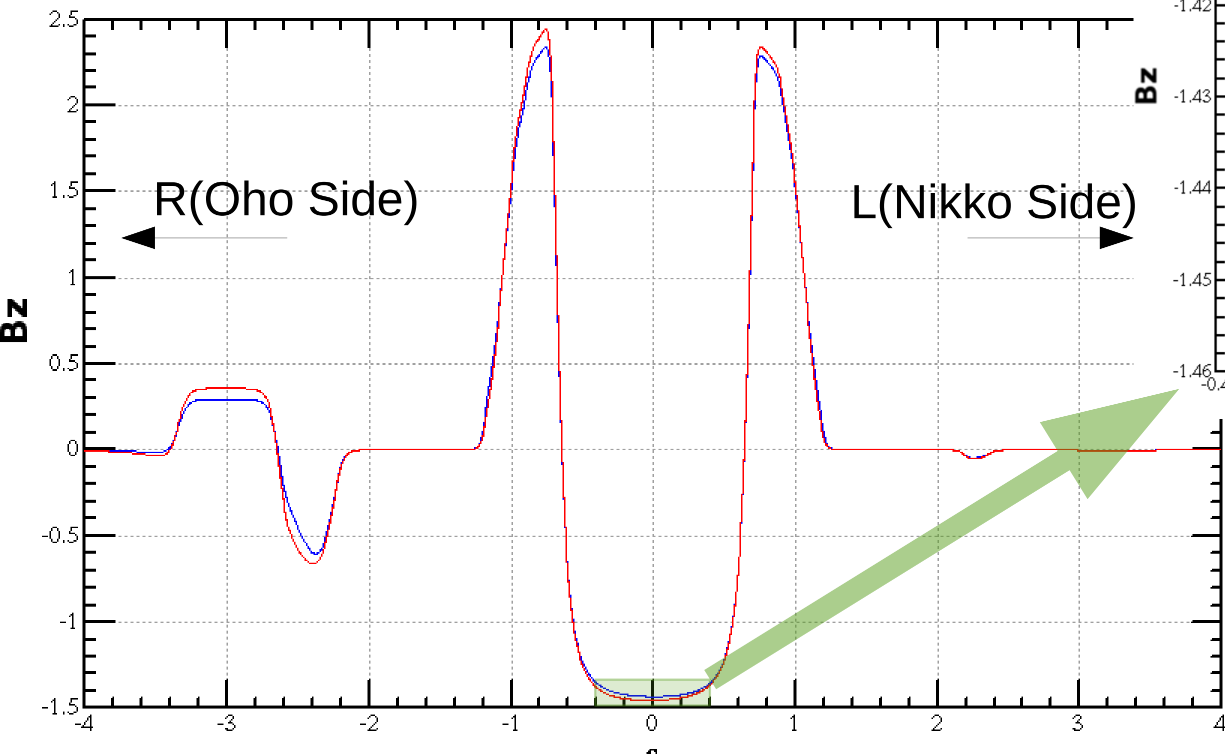


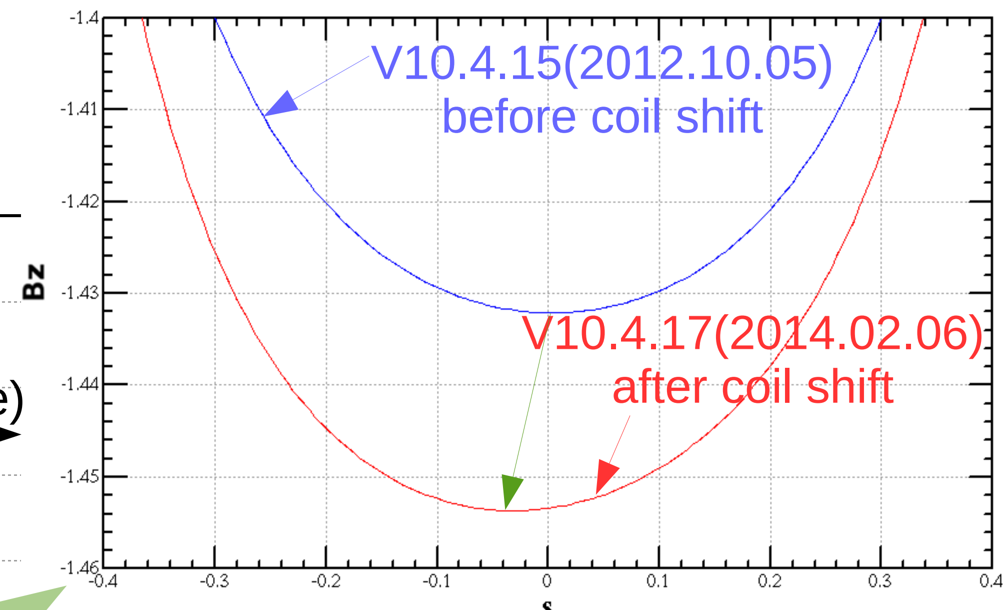


from SuperKEKB IR Tech. Meeting #96(2013.10.24)

Belle II Solenoid Defomation (3)

- 3D solenoid field distribution on HER beam line before & after Belle II detector solenoid coil shift





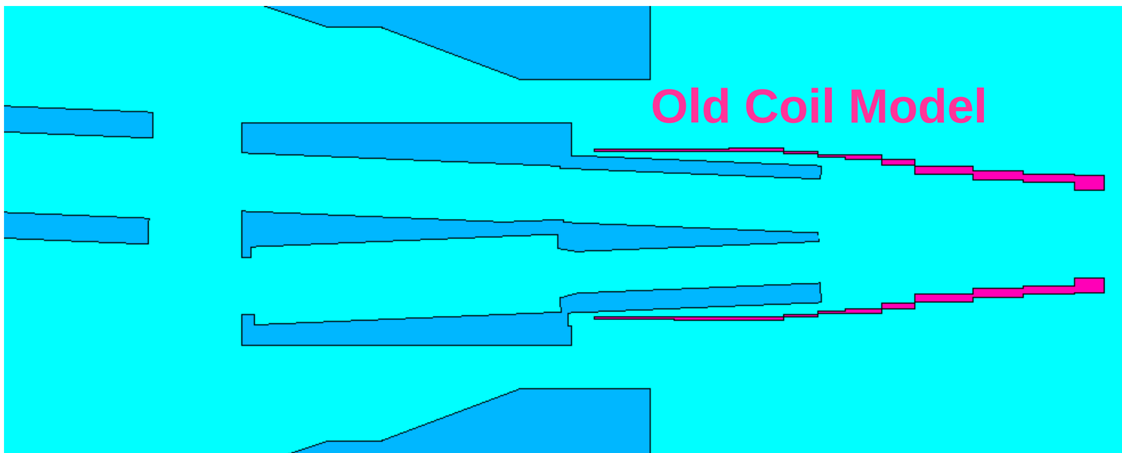
Belle II detector solenoid field is shifted by coil deformation.

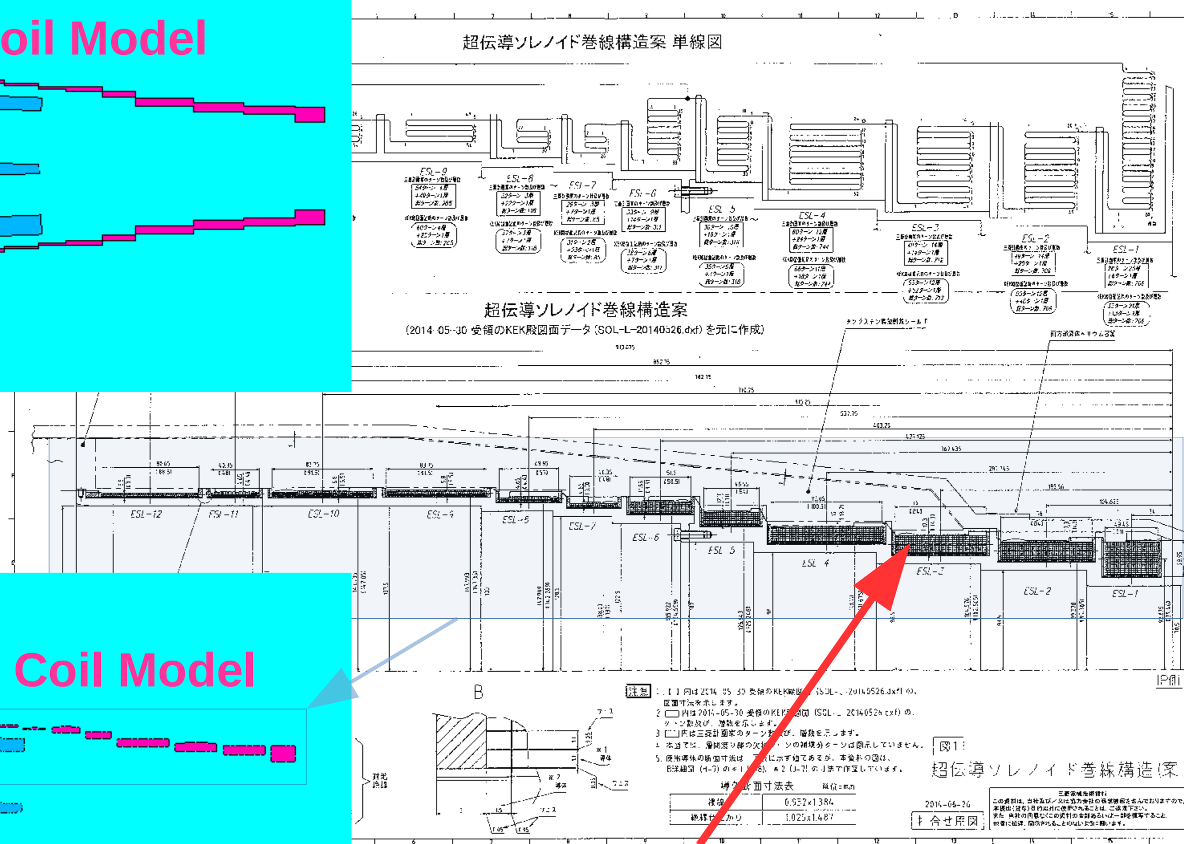
Normalization condition of detector solenoid field strength is changed between 2 models.

Compensation Solenoid Coil Modeling Updates (1)

- The compensation solenoid coil modeling for 3D magnetic field calculation is updated by using coil geometry of hardware design.
  - It changes field distribution around QC1.
  - It changes IR orbit, coupling & dispersion functions.
  - We have to …
    - Re-optimize current density distribution of compensation solenoid coil for adjusting Bz & ∫Bz distribution
      - QC1/2 geometry is already finalized.
    - Re-match IR optics.
    - Re-optimize dynamic aperture & lifetime.

Compensation Solenoid Coil Modeling Updates (2)



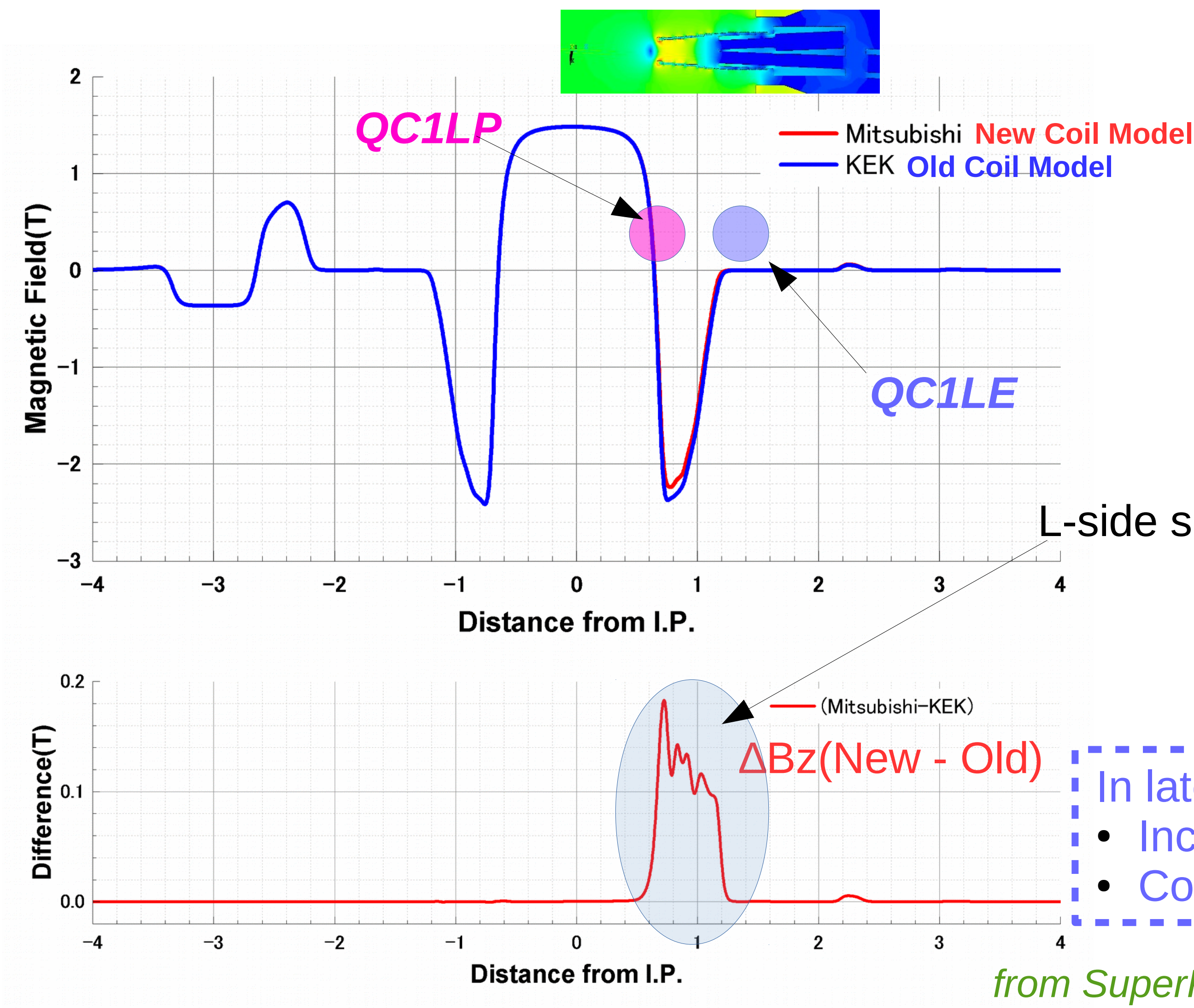


Compensation solenoid is constructed by many coil blocks in hardware design.

from SuperKEKB IR Tech. Meeting #110(2014.7.17)

Compensation Solenoid Coil Modeling Updates (3)

Field distribution before/after L-side compensation solenoid coil modeling update.



L-side solenoid field integral is not adjusted.

In latest IR model(V10.4.25 2014.12.22)

- Includes L & R-side new coil modeling
- Coil current density is optimized

from SuperKEKB IR Tech. Meeting #110(2014.7.17)

Modeling Parameter Updates for Normal Conducting Magnets (1)

- Magnet group gives us the magnetic field measurement results of new magnets(dipoles and quadrupoles).
  - We have to update lattice modeling parameters for new magnets(We used temporary values for such magnets).
  - Effective length(L) and fringe length(F1) paramters change orbit geometry around dipole magnet, ring circumference and optical functions.

Modeling Parameter Updates for Normal Conducting Magnets (2)

- Status of model lattice updates
  - LER model update is completed.
  - HER model update is not complated yet.

Table of LER magnet parameter updates

Type	Old L_{eff} *(m)*	New L_{eff} *(m)*	$\lvert\Delta x_{center}\rvert$(μm)
B2P	4.189544	4.159654	210
BLC1LP1	1.59	1.603162	40.8
BLC1LP2	2.23029	2.235386	6.18
BLCWRP	2.23029	2.235386	9.50
BLC1RP	2.23029	2.235386	17.7
BLA1LP	3.989597	3.961671	118
BLX4RP	3.989597	3.961671	160
BLA6RP	3.989597	3.961671	176
BC1LP	0.3444	0.281105	5.50
BC1RP	0.3444	0.281105	2.84

Displacement of horizontal orbit at the center of the magnet

Δx_{center} is acceptable.

It is negligible small compared with good field region.

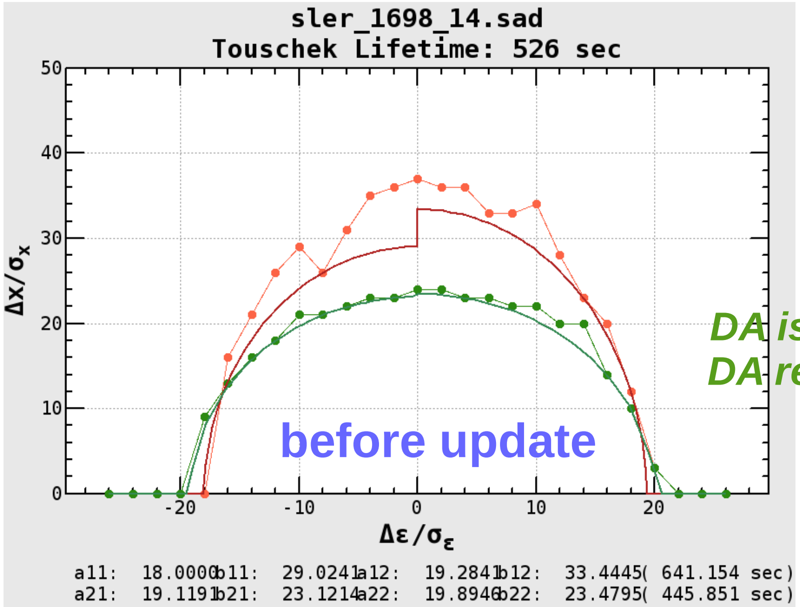
Realigement is not required!

But, we MUST pay attention to this displacement for comparing magnet alignment with model geometry.

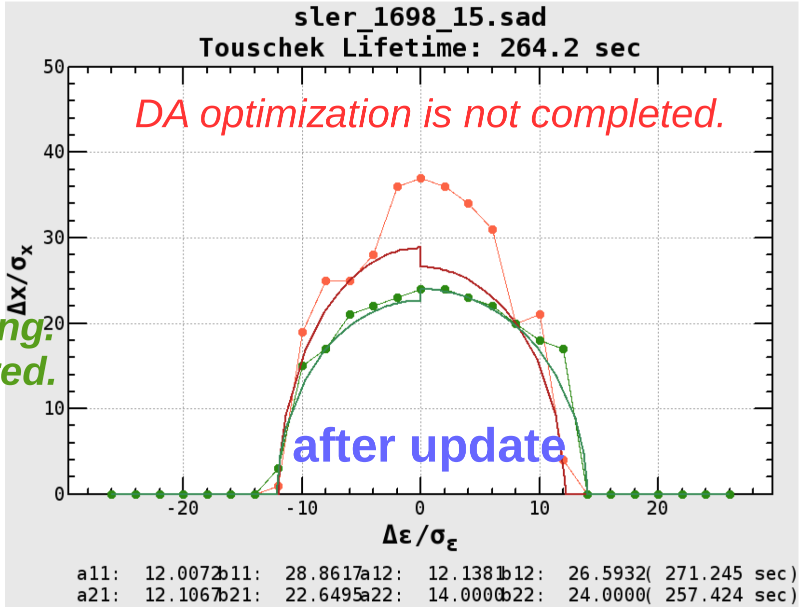
Calculated by H.Sugimoto

Modeling Parameter Updates for Normal Conducting Magnets (3)

- LER circumference is extended about 800μm by dipole modeling parameter updates.
  - This displacement is not negligible compared with ±3mm tuning range of the LER chicane for adjusting circumference.
  - Total circumference difference between LER and HER is not confirmed because HER model updates is not completed yet.
  - We have extra circumference adjustment option by using wiggler K_0.



DA is reduced by rematching.
DA reoptimization is required.



Touschek Lifetime with QCS Non-linear components (1)

- QC1LP & QC2LP multipole measurement results are released from SC group.
  - We have to check that the measured error is acceptable or not.
    - Both dynamic aperture & Touschek lifetime with multipole errors are evaluated by inserting thin multipole element to describe error field into every QCSs.

Touschek Lifetime with QCS Non-linear components (2)

QCS field measurement results by using harmonic coil

QC1LP with harmonic coil radius 12mm

	@ *R* = 10 mm , 4.2K and 1.8 kA		Design @ *R*= 10 mm	
	a_n skew	b_n normal	a_n	b_n
n=1	0.0	0.0	0.0	0.0
2	0.0	**10000**	0.0	**10000**
3	**0.40**	**3.16**	**0.0**	**0.0**
4	1.57	0.75	0.0	0.24
5	-0.07	-0.42	0.0	0.0
6	-0.41	0.06	0.0	0.54
7	0.05	0.05	0.0	0.0
8	0.19	0.07	0.0	0.01
9	-0.07	-0.04	0.0	0.0
10	0.00	0.03	0.0	-0.21

reference (n=2)

QC2LP with harmonic coil radius 20mm

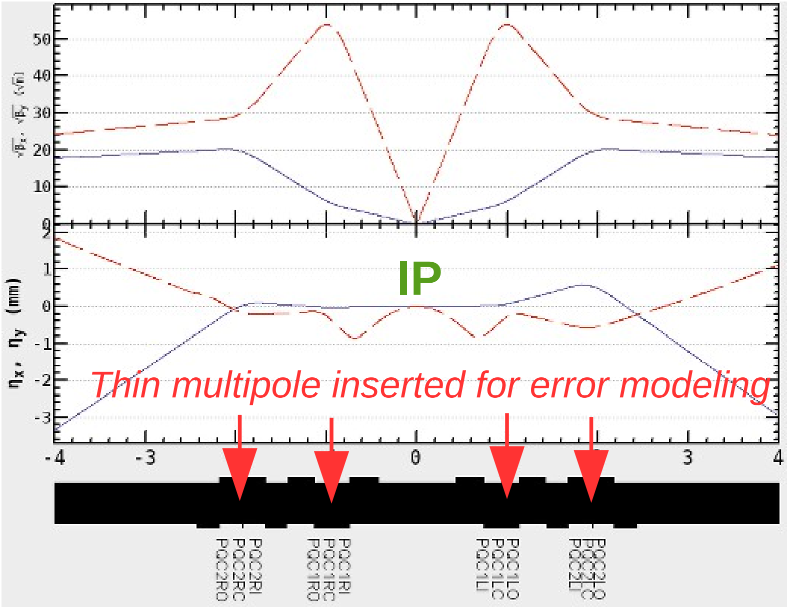
	@ *R* = 30 mm , 4.2K and 1 kA		Design @ *R*= 30 mm	
	a_n	b_n	a_n	b_n
n=1	0.0	0.0	0.0	0.0
2	0.0	**10000**	0.0	**10000**
3	**1.79**	**-0.59**	**0.0**	**0.0**
4	0.00	0.45	0.0	-0.06
5	-0.39	-0.17	0.0	0.0
6	-0.14	3.54	0.0	0.28
7	0.32	-0.10	0.0	0.0
8	0.14	-0.23	0.0	0.11
9	0.22	0.03	0.0	0.0
10	0.15	-1.41	0.0	-1.43

Large errors are found in sextupole & octupole mode(n=3,4).
- We CAN re-optimize dynamic aperture by using normal & skew sextupole coil and normal octupole coil in QCS and sextupole families in arc section.

from SuperKEKB IR Tech. Meeting #107(2014.6.5)

Touschek Lifetime with QCS Non-linear components (3)

- Touschek lifetime is evaluated by using model lattice with 4 thin multipole element to describe multipole errors for QC2R, QC1R, QC1L and QC2L.
  - The error field strength is fixed.
  - The worst set of the error field sign is selected from possible combinations.(evaluate worst case)

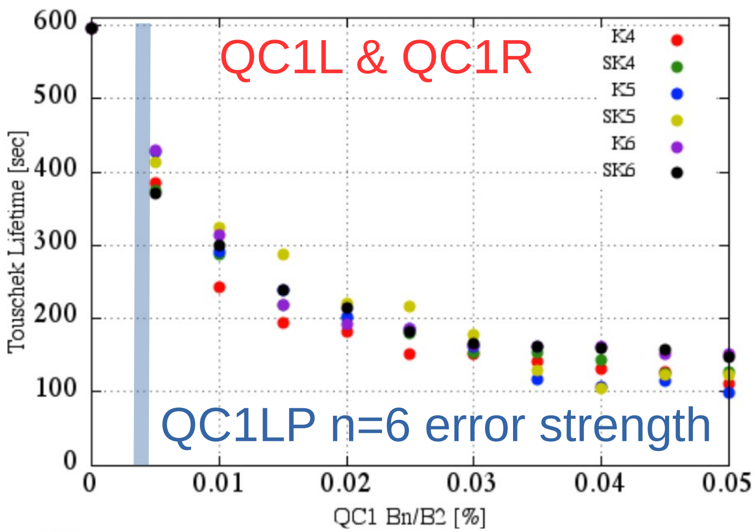


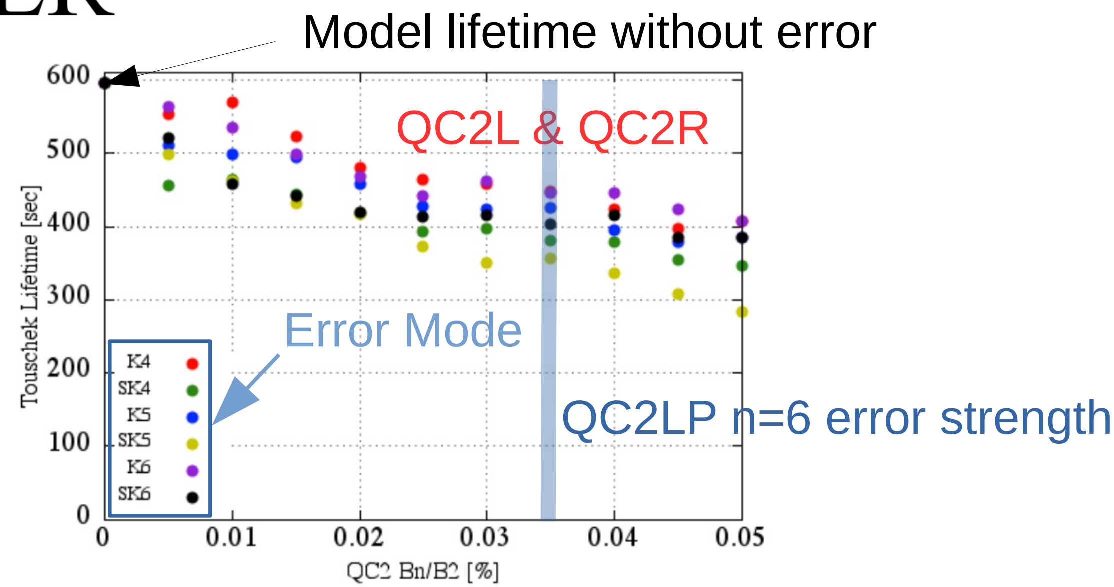
from SuperKEKB Optics Meeting #106(2014.9.17)

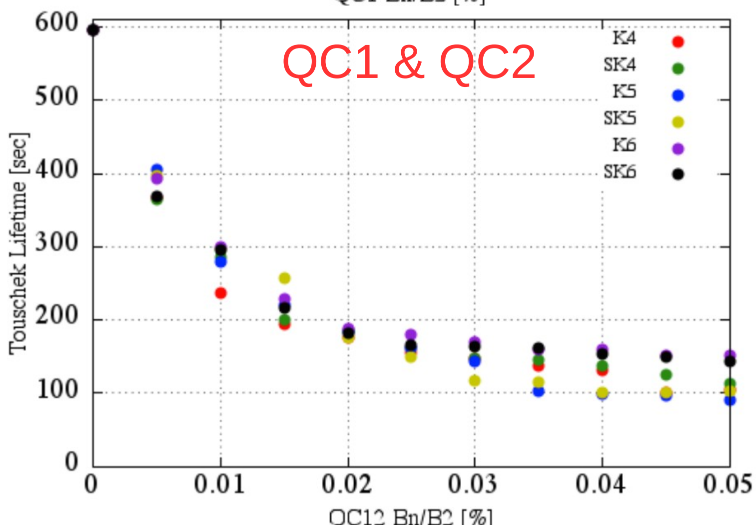
Touschek Lifetime with QCS Non-linear components (4)

sler_1689.sad

LER







$$K_n = \frac{n!}{r_0^{n-1}} \frac{B_{n+1}}{B_2} K_1$$

$r_0 = 10$ mm for QC1P

$r_0 = 30$ mm for QC2P

The measured error is not critical, but it has serious impact to lifetime under the assumption that QC*RP have same order error field with the worst sign configuration.

The lifetime of real machine depends on QC*RP field quarity.

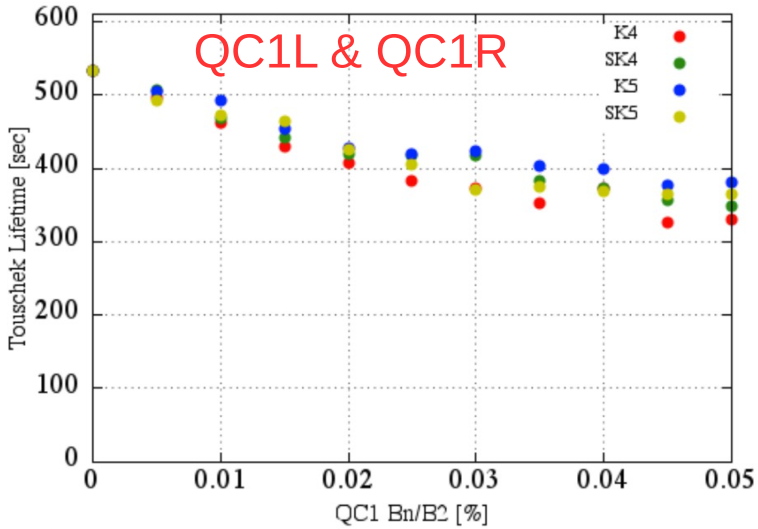
from SuperKEKB Optics Meeting #106(2014.9.17)

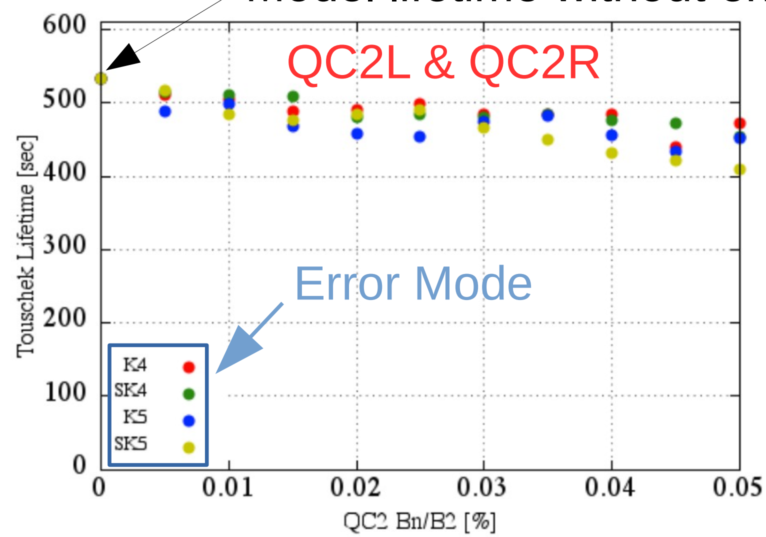
Touschek Lifetime with QCS Non-linear components (5)

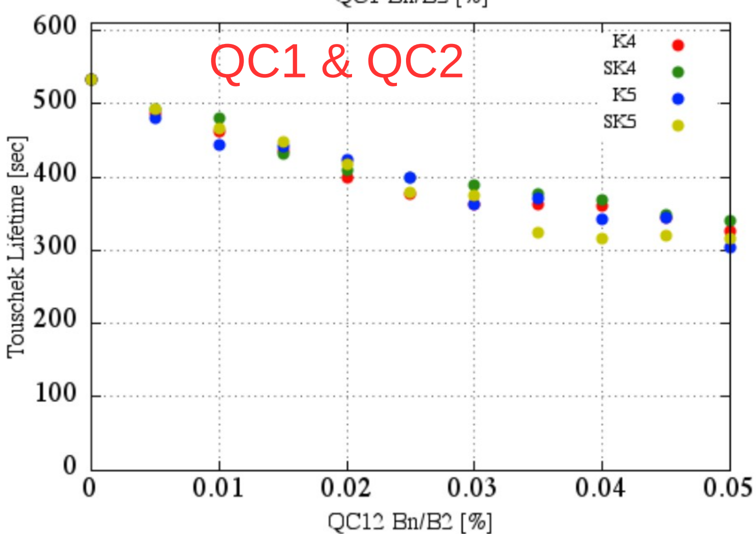
Sher_5769.sad

HER

Model lifetime without error







$$K_n = \frac{n!}{r_0^{n-1}} \frac{B_{n+1}}{B_2} K_1$$

10^{-4} error is acceptable.

$r_0 = 15$ mm for QC1E

$r_0 = 35$ mm for QC2E

from SuperKEKB Optics Meeting #106(2014.9.17)

Dynamic Aperture with Crab Waist (1)

- The crab waist optics designs for Higgs factory collider were reported with enough dynamic aperture.
  - In those design, a set of sextupoles is used instead of single sextupole for compensating the thickness effect of the sextupole magnet.

Question

- Is those compensation scheme applicable to SuperKEKB?
- What is the difference between SuperKEKB and other collider?

Dynamic Aperture with Crab Waist (2)

- Those compensation scheme WOULD be inapplicable to SuperKEKB.
  - Compensation for crab waist sextupoles
    - The on-momentum aperture of SuperKEKB lattice with crab waist constructed by thin sextupoles is degraded.
  - Compensation for local chromaticity correcoters
    - The on-momentum aperture of SuperKEKB lattice with crab waist that does not contain LCC between crab waist sextupoles is degraded.
    - In the SuperKEKB design, $K_2\beta_y$ product at the LCC sextupole was reduced by increasing the horizontal dispersion function η_x in order to avoid the on-momentum aperture degradation by the sexutpole thickness effect.

Dynamic Aperture with Crab Waist (3)

Comparison of dynamic aperture limit
by the fringe field of final focus quadrupole

$$J_y \leq \frac{\beta_y^{*2}}{(1+2|K|L^{*2}/3)L^*} A(\mu_y)$$

A(μ): universal function

K. Oide et al, Phys. Rev. E47 (1993)

Ring	β_y^* [μm]	K=k_1 [m^{-2}]	L* [m]	J_y/A [μm]
SuperKEKB HER	300	-3.1	1.22	0.018
SuperKEKB LER	270	-5.1	0.76	0.032
CEPC	1200	-0.176	1.5	0.76
TLEP(BINP design)	1000	-0.16	0.7	1.36
KEKB	5900	-1.779	1.762	4.22

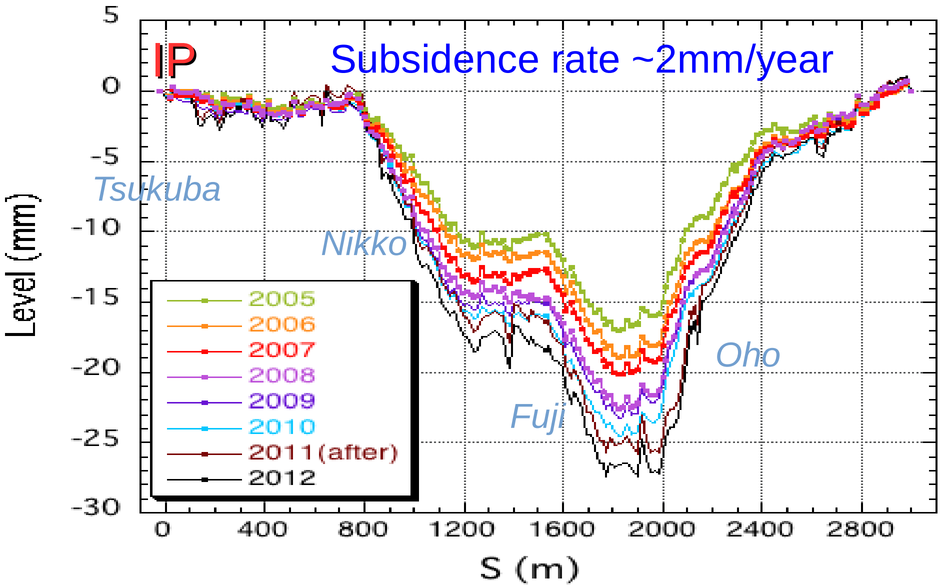
~ 1/20 (SuperKEKB LER vs. CEPC)

< 1/100 (SuperKEKB LER vs. KEKB)

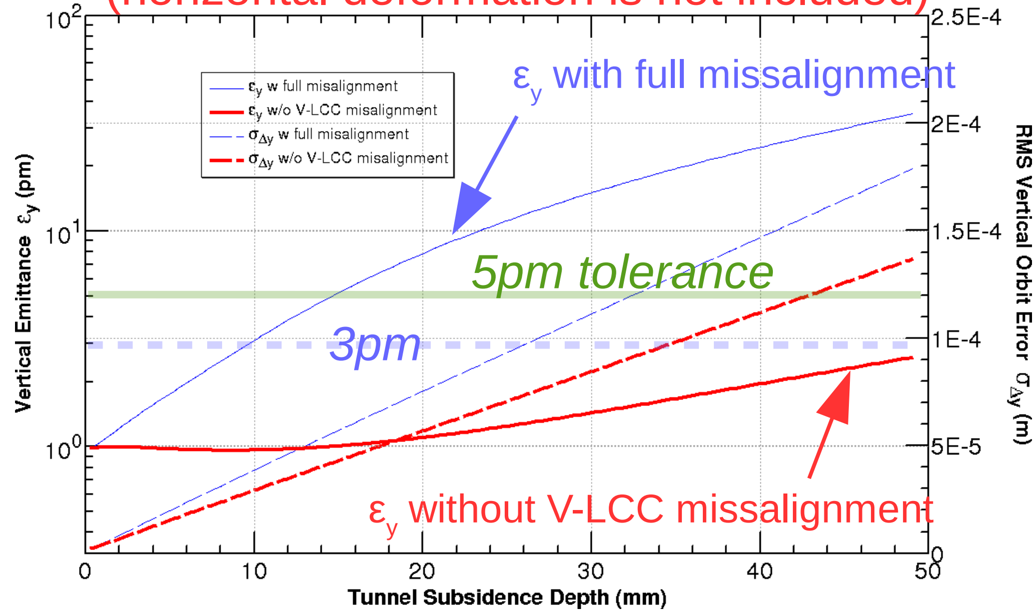
- The final focus fringe of SuperKEKB is very strong compared with other e^- - e^+ colliders.
- This strong fringe effect WOULD be the source of dynamic aperture difference under crab waist.

Emittance with Tunnel Subsidence

Measured tunnel level



Vertical emittance after orbit & dispersion correction on tunnel subsidence model (horizontal deformation is not included)



Tunnel subsidence model is generated from latest measurement with LPF(λ_{cut}~100m).

Vertical emittance after correction WOULD be improved into acceptable level by improving both local aligment around V-LCC and correction algorithm.

(high β_y region)

Already reported in 18th Review

from TUPPC018 @ IPAC '12

Emittance with Machine Error (1)

Assumption of Machine Error(Random Error) Simulation

Machine Error

Element Type	Δx_{rms} [μm]	Δy_{rms} [μm]	θ_{rms} [mrad]	$(\Delta K/K)_{rms}$
Main dipole	-	-	0.1	3.5×10^{-4}
Quadrupole	100	100	0.1	7×10^{-4}
Sextupole	100	100	-	1.3×10^{-3}
QC1 & QC2	100	100	-	-
BPM	75	75	1.0	-

\# of Correctors

Corrector Type	HER	LER	Maximum Rating
H-Dipole	218	208	$\Delta\theta$ = 1.0 mrad
V-Dipole	196	215	$\Delta\theta$ = 1.0 mrad
H-Backleg Dipole	33	39	$\Delta\theta$ = 0.5 mrad
Quadrupole	292	254	$\Delta K_1/K_1 = 5 \times 10^{-3}$
Skew Quadrupole*	64	56	$\Delta K_1 = 5 \times 10^{-3}$ m^{-1} for SD,SL

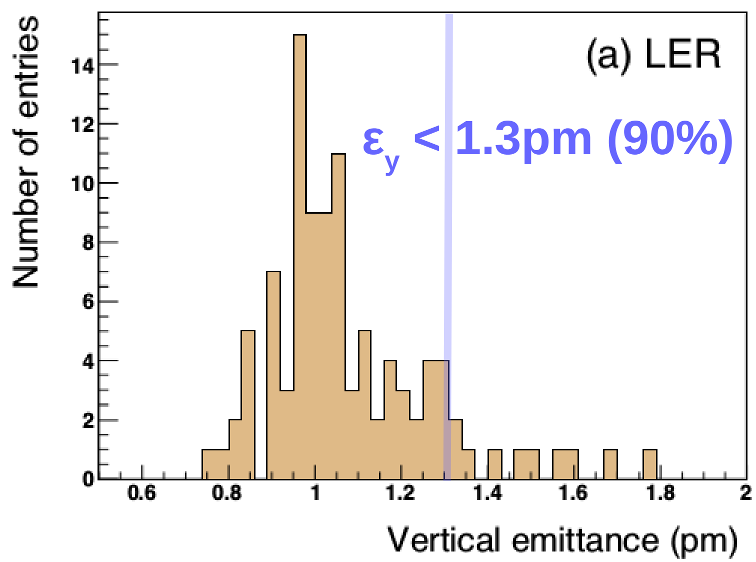
* We have additional skew quadrupole coil on SF type sextupole, but power supply for skew quadrupole on SF is not ready at T = 0.

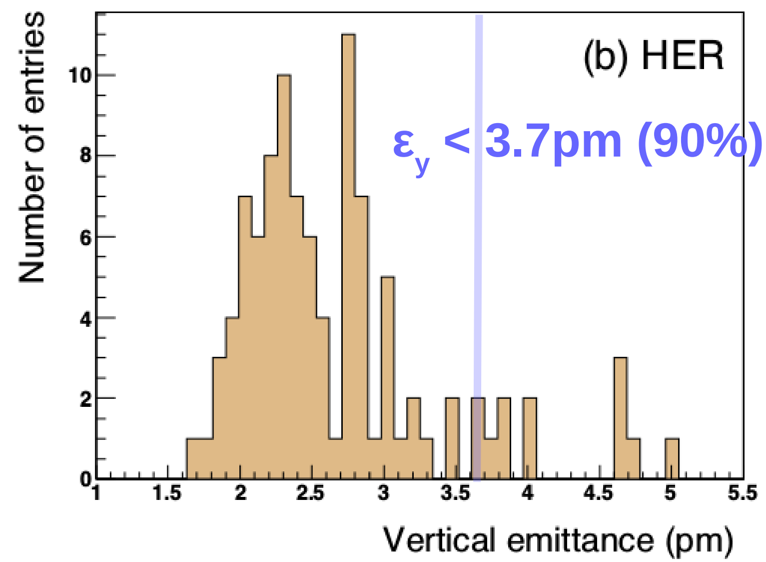
Already reported in 19th Review

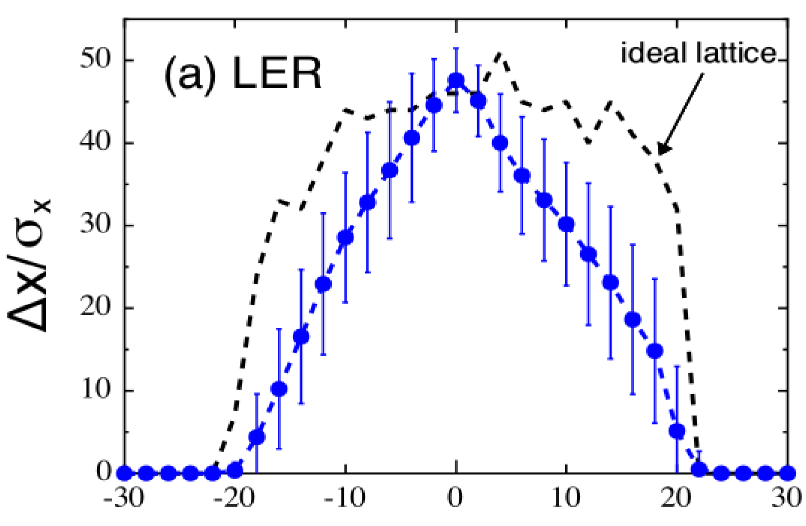
from SuperKEKB TDR draft

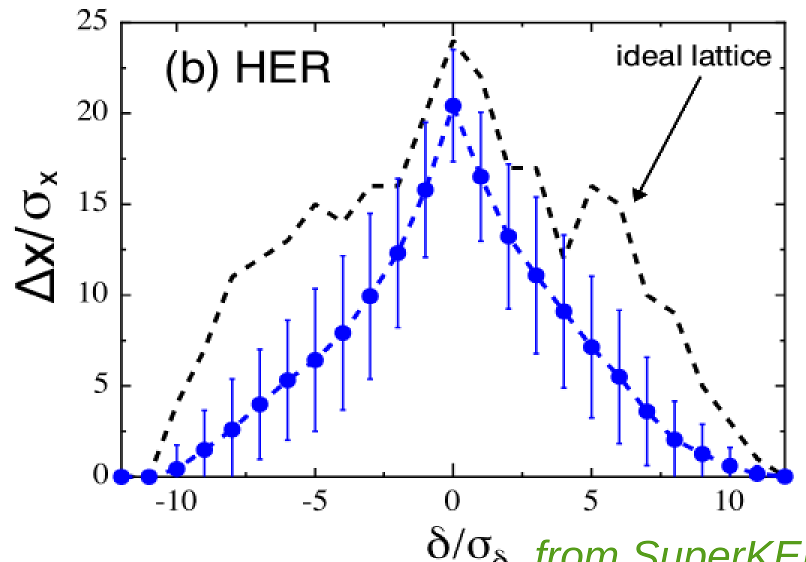
Emittance with Machine Error (2)

Vertical emittance and dynamic aperture after orbit & optics correction









Already reported in 19th Review

from SuperKEKB TDR draft

Summary of Past Emittance Study

- From orbit & optics correction study fortunnel subsidence
  - Vertical emittance WOULD be controled within acceptable level by taking extra care to V-LCC region.
- From orbit & optics correction study for random machine error
  - Vertical emittance reachs design target.
  - The sextupole tuning is required to obtain longer lifetime.

Tasks toward Machine Operation

- We have started to develop operation & commissioning softwares.
  - Optics & Orbit parameter management framework *under development*
  - Operation & Tuning Tools
    - Programable Tune Changer *under development*
    - Optics Measurement & Correction Toolset
    - Chromaticity Tuning Tool
    - Continuous Orbit Corrector
    - Local Orbit Bump Tool
    - Luminosity tuning Knobs(Waist, IP coupling, beam size...) *under development*
    - Calibration Tools(3-BPM, BBA...)
    - etc...

We plan to share framework software between MR and DR.