IR Imperfection and Dynamic Aperture in SuperKEKB and Dynamic Aperture Study of CEPC

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This Talk

- The effect of IR imperfection on dynamic aperture in SuperKEKB
  - IR Modeling
  - SuperKEKB dynamic aperture (DA)
  - DA and error fields from the final focus magnets

- Dynamic aperture study of CEPC (very preliminary)
  - Preliminary DA study and comments on the CEPC lattice based on the experience of the SuperKEKB lattice design.

IR Imperfection and Dynamic Aperture in SuperKEKB

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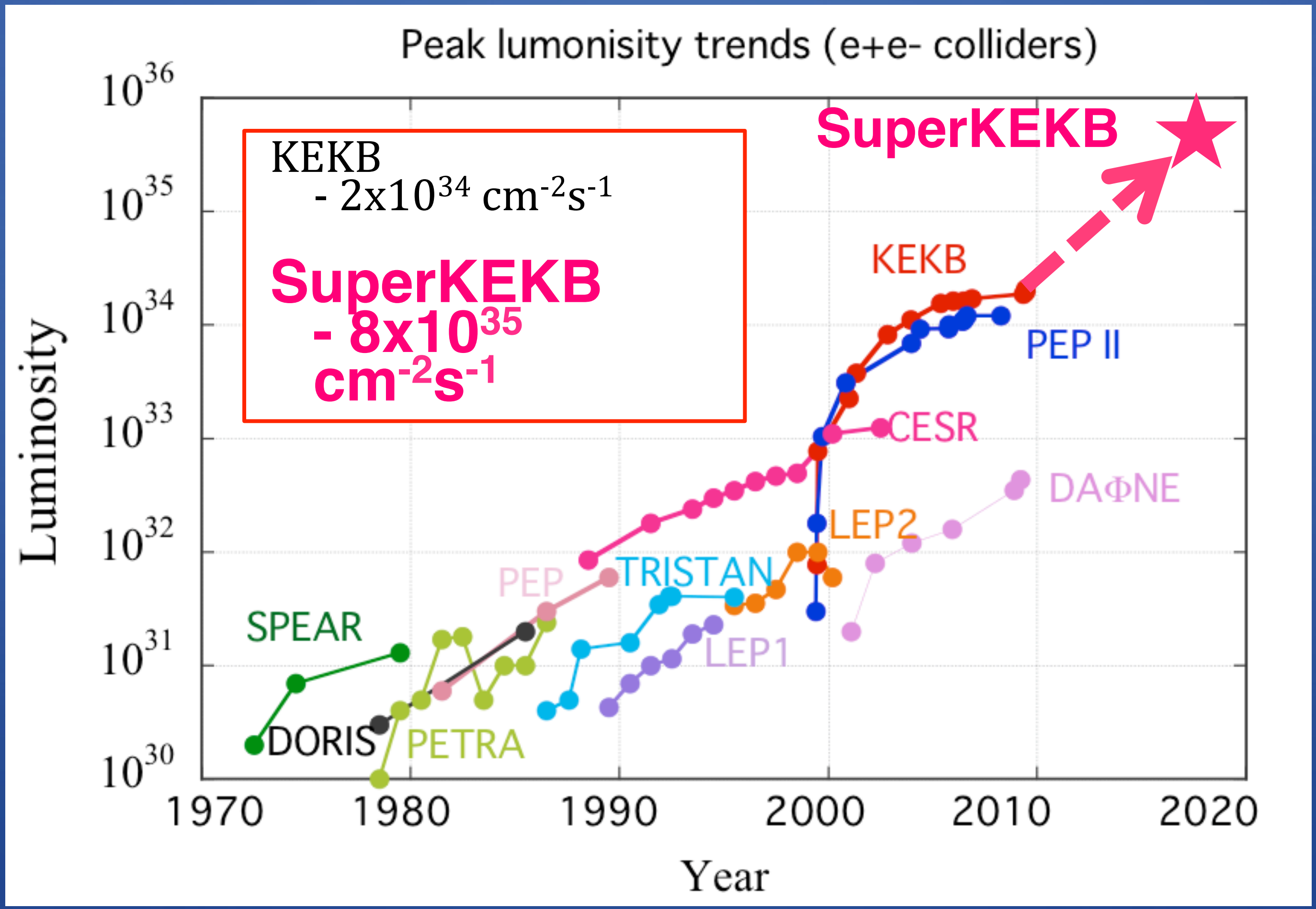
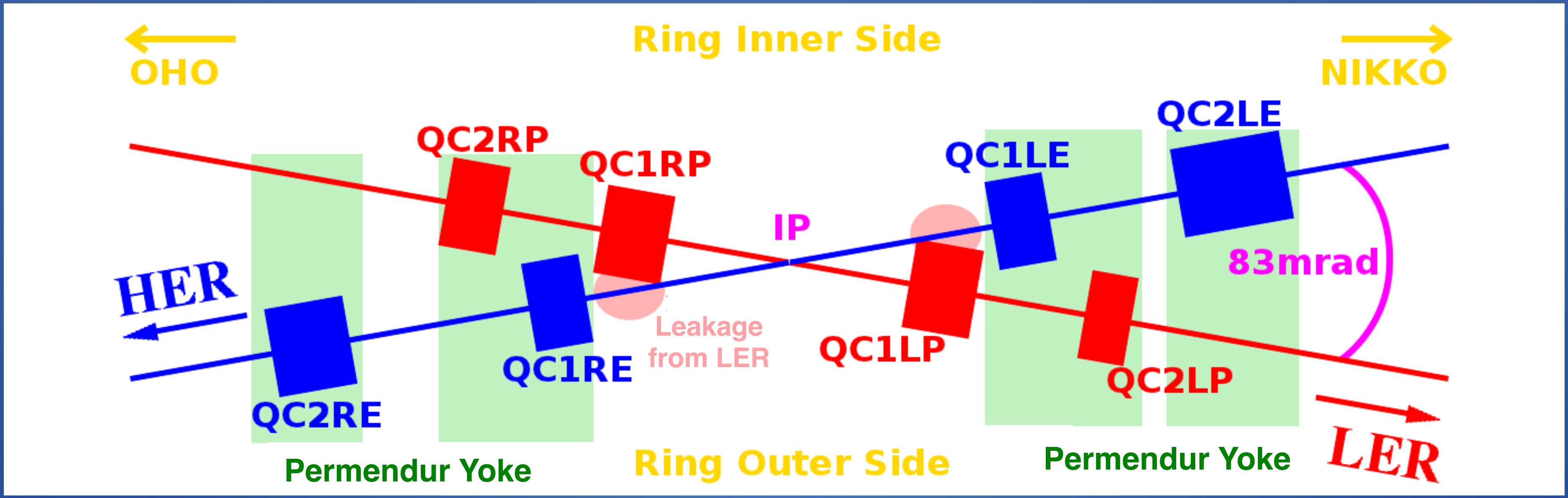
A New Luminosity Frontier



- SuperKEKB
  An upgrade project of KEKB for a new luminosity frontier.

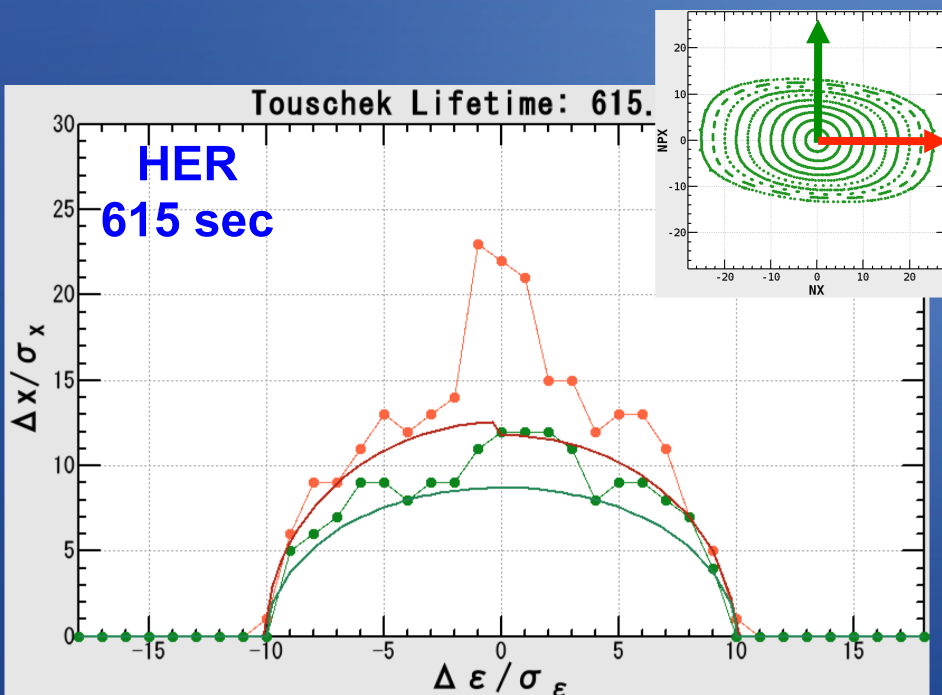
Final Focus System (QCS)

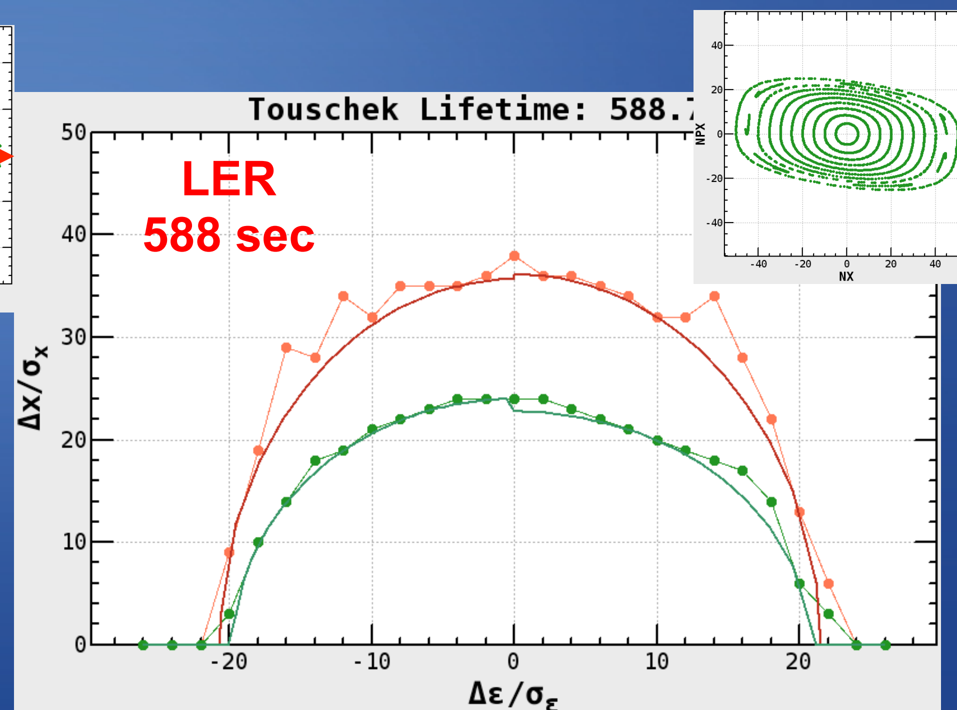


- All magnets except for QC1Ps have iron or permendur yoke for preventing leakage fields to the opposite beam line.
- Canceller coils are installed in the HER beam line to suppress the leakage fields from QC1Ps.
- All magnets have superconducting corrector coils.
  - Normal&Skew Dipole, Skew Quad
- Octcupole and sextupole coils are also available.

DA and Touschek Lifetime

- Touschek lifetime is optimized with Down-hill simplex method.
- Almost reached the target lifetime, 600 sec.

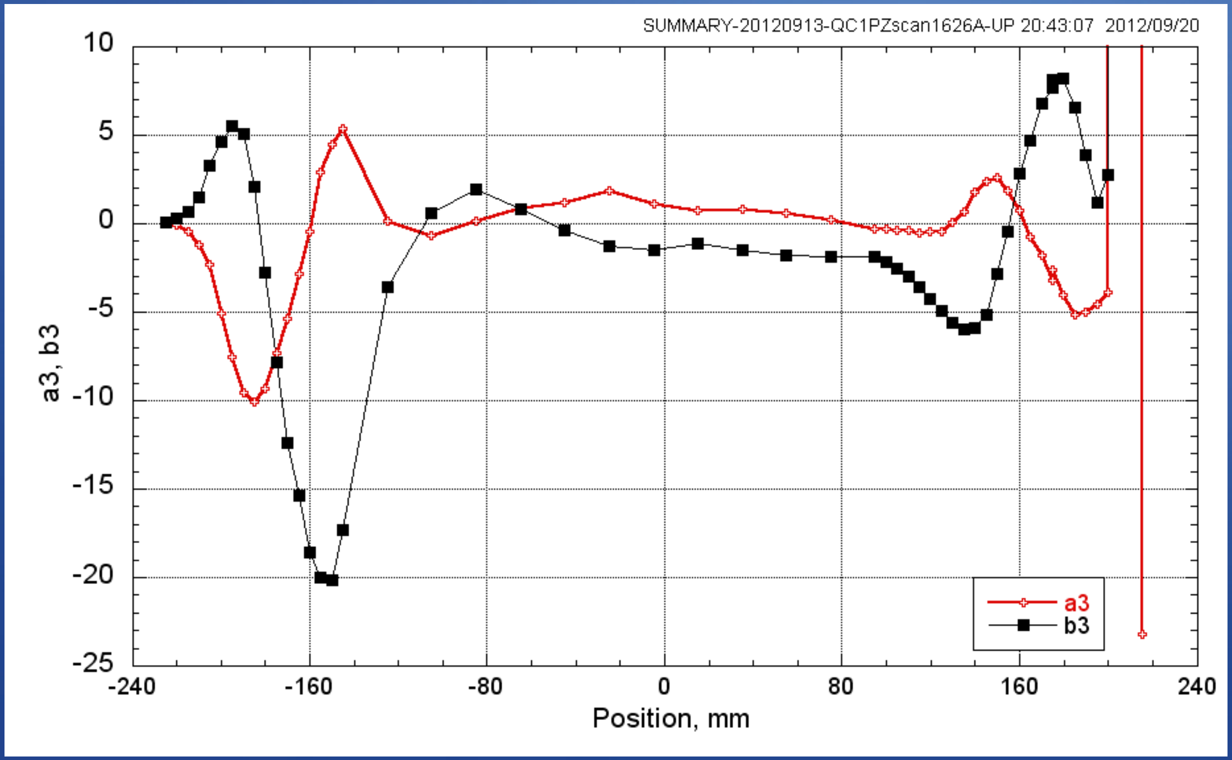


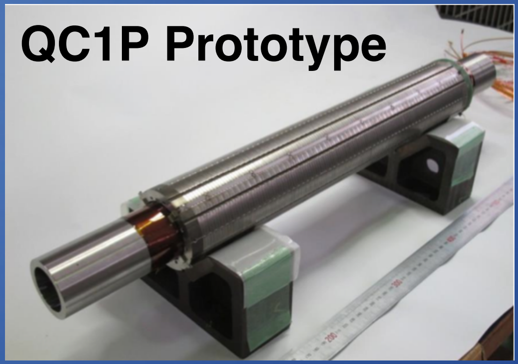


QCS Imperfection

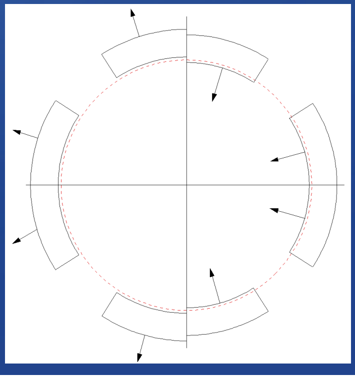
- Unexpected normal and skew sextupole have been observed.
- Amplitude is ~0.1% of the quadrupole field.
- Likely due to misalignment of the main coils of a few tens of μm.

Field profile along QC1P prototype





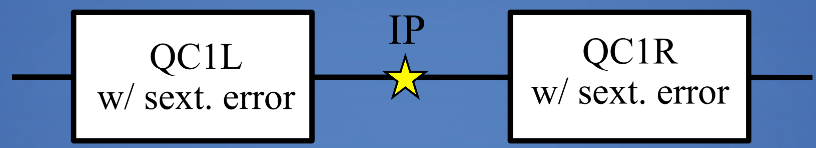
Coil misalignment model (Transverse plane)

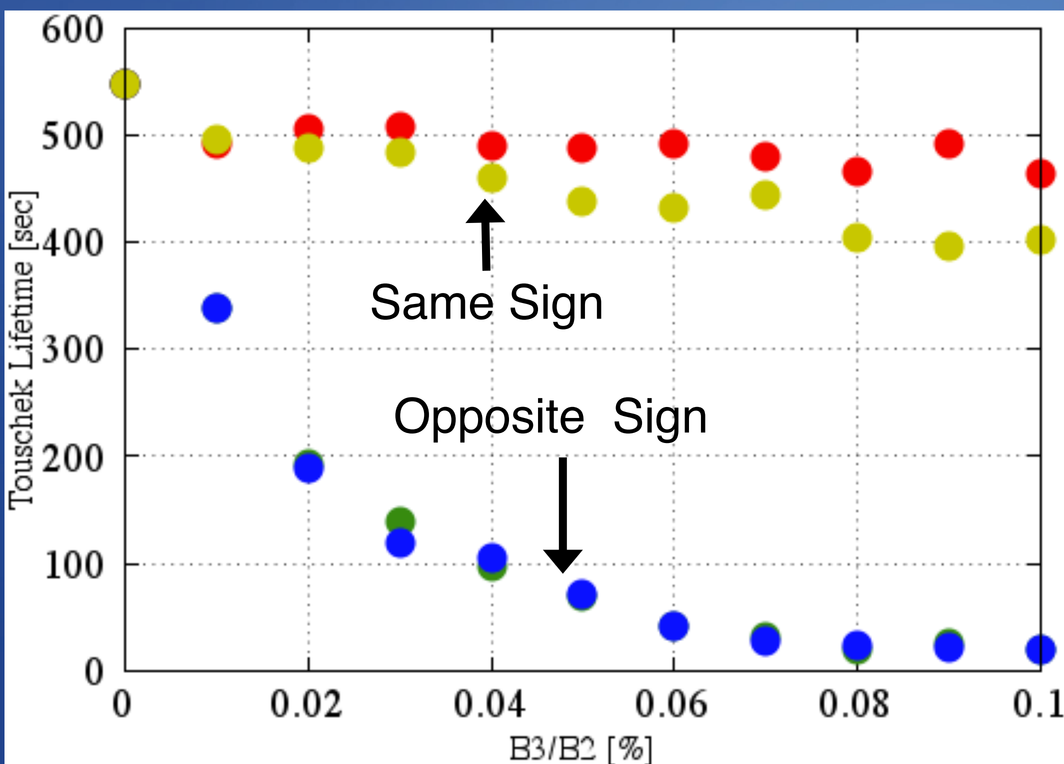


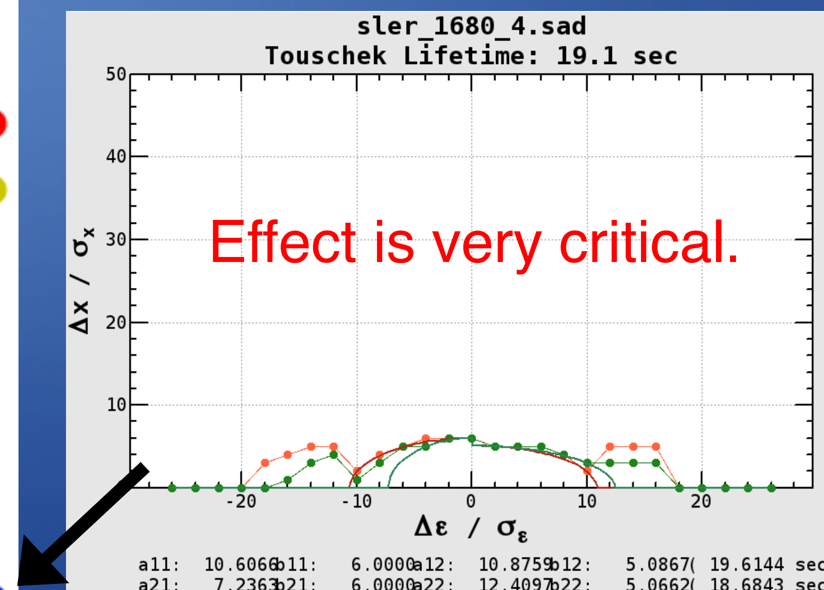
- How much impact on the dynamic aperture?

Numerical Study

- Thin lens sextupoles are inserted to QC1L and QC1R.
- Their magnitudes are identical, while signs are independent.
- Evaluate DA for 4 possible combinations of signs at each error amplitude.

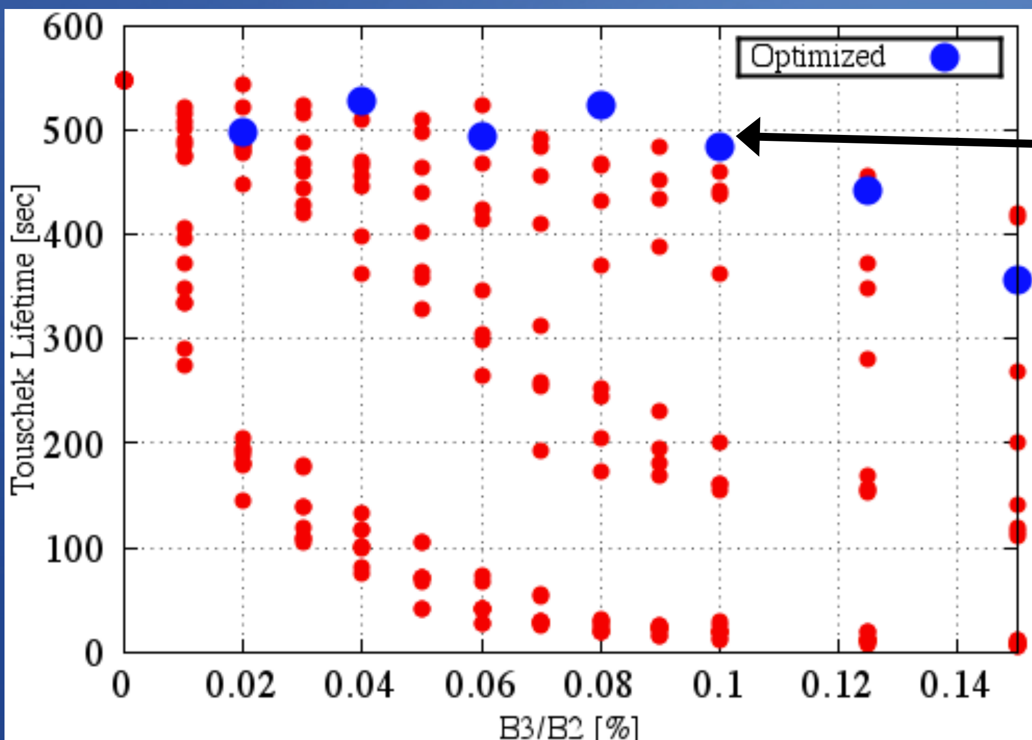


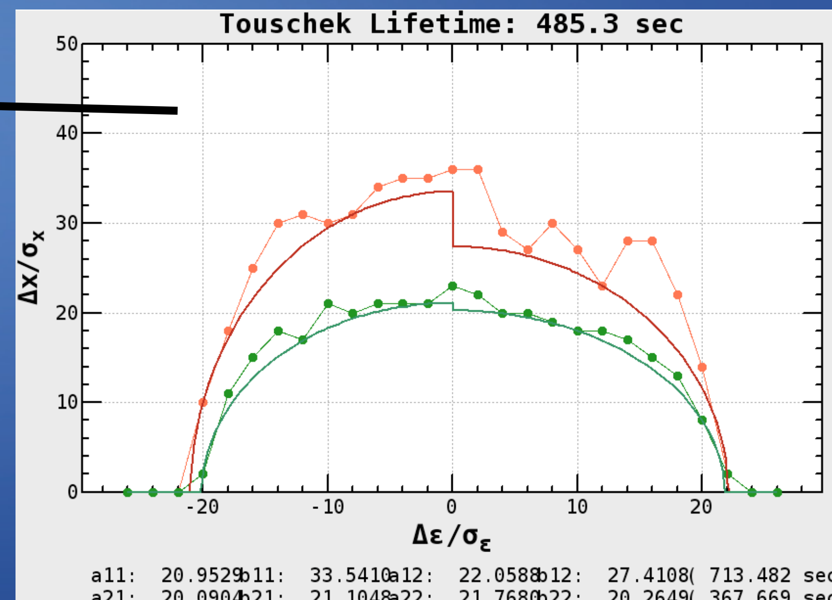




DA Improvement by Corrector Coil

- Introduce sextupole error to ALL QCs.
- Check whether we can mitigate DA degradation by optimizing the corrector strength.





- DA degradation is improved, but B3/B2 < 0.1% is preferable.

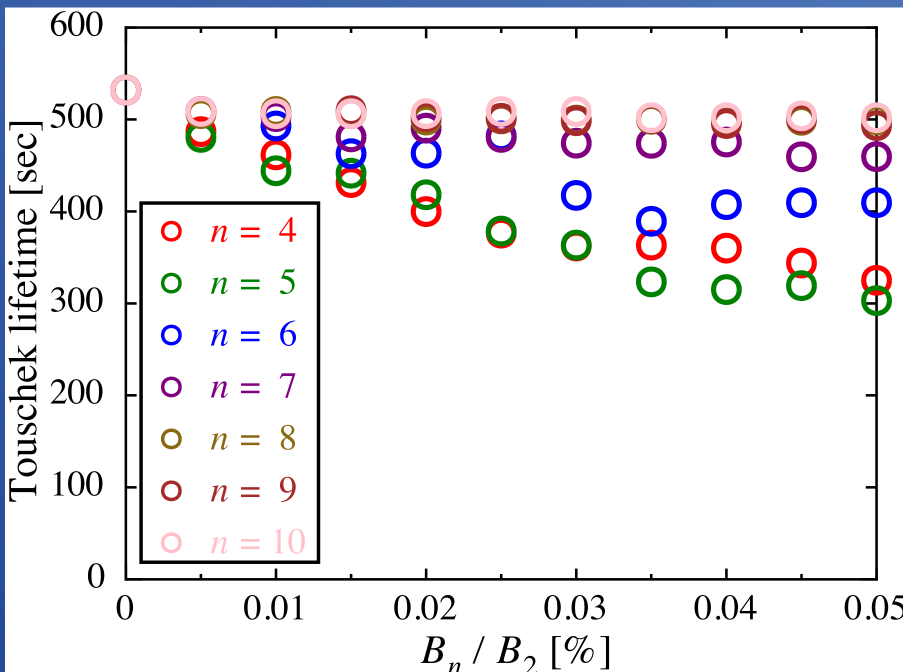
Recent Field Measurement

- Magnet group improved the assembling process of the coil.
- Now the sextupole field strength is much smaller.

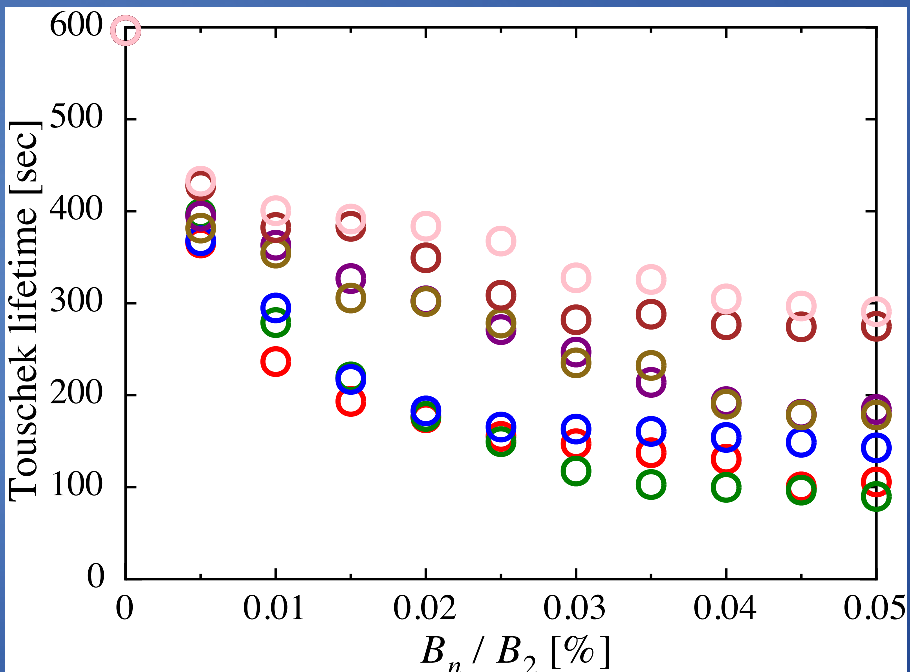
	Measurement		Design	
n	**Skew** A_n/B_2 **(x10^{-4})**	**Normal** B_n/B_2 **(x10^{-4})**	**Skew** A_n/B_2 **(x10^{-4})**	**Normal** B_n/B_2 **(x10^{-4})**
3(sextupole)	0.40	3.16	0.0	0.0
4	1.57	0.75	0.0	0.24
5	-0.07	-0.42	0.0	0.0
6	-0.41	0.06	0.0	0.54
7	0.05	0.05	0.0	0.0
8	0.19	0.07	0.0	0.01
9	-0.07	-0.04	0.0	0.0
10	0.00	0.03	0.0	-0.21

How about Higher Order Multipoles?

HER



LER



- The LER DA is more sensitive to the higher order multipoles.
- We have to deal with the particle with larger amplitude in LER to obtain the target Touschek lifetime due to lower energy.

On-momentum DA $40\sigma_x\,(\mathrm{LER})$ $20\sigma_x\,(\mathrm{HER})$

Dynamic Aperture Study of CEPC
- Preliminary -

H. Sugimoto

Thanks to…

KEK: Y. Ohnishi, A. Morita

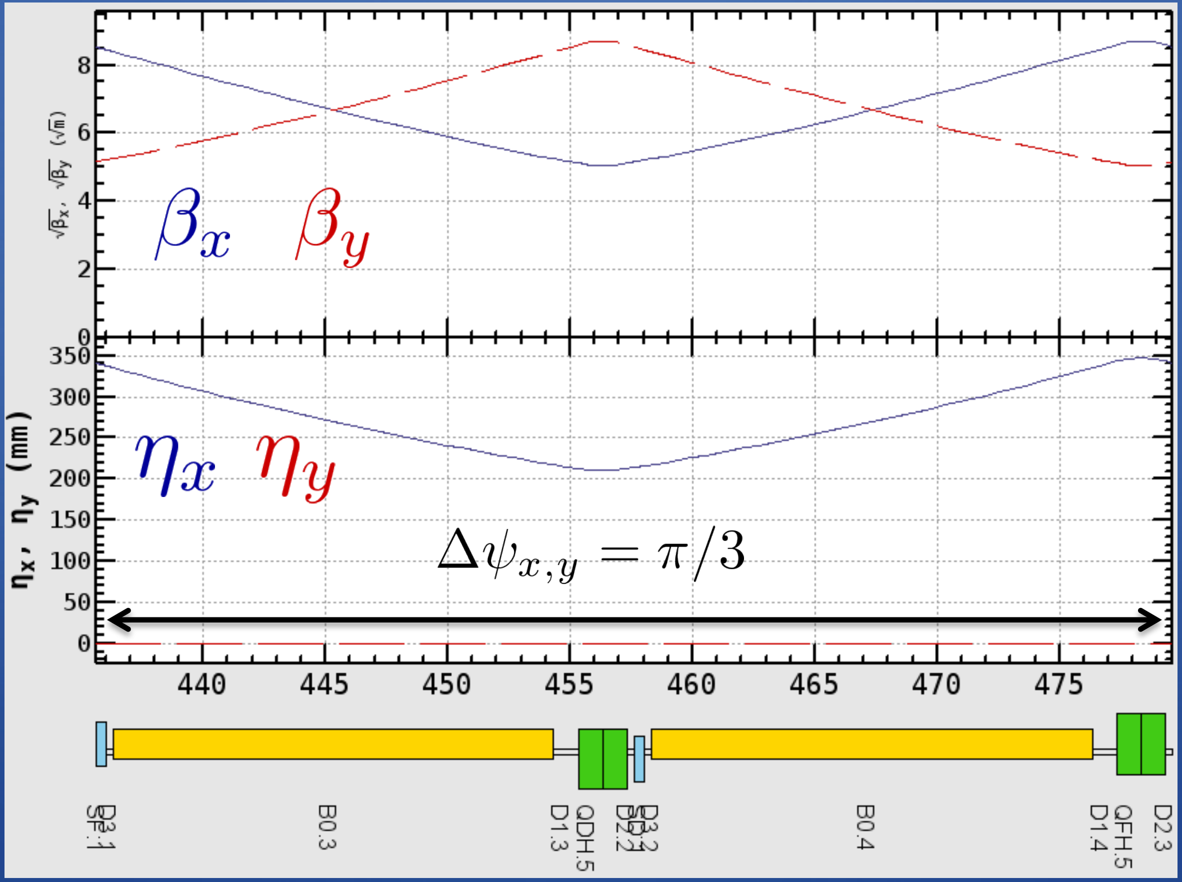
IHEP: W. Chou, D. Wang, Y. Wang, H. Geng, S. Bai

Introduction

- DA optimization of the CEPC lattice has been started.
  Required DA
  - Transverse: > 40 σ
  - Momentum: > +- 2% ($15\sigma_\delta$)
- This talk
  - The fist survey on a tentative CEPC lattice.
- First impression
  - Need more work to optimize beam optics.
- NOTE: This talk is based on a tentative lattice provided by the IHEP group last August.
  - The current situation may be different.

Arc Lattice

- Composed of sextupole magnets next to quadrupoles



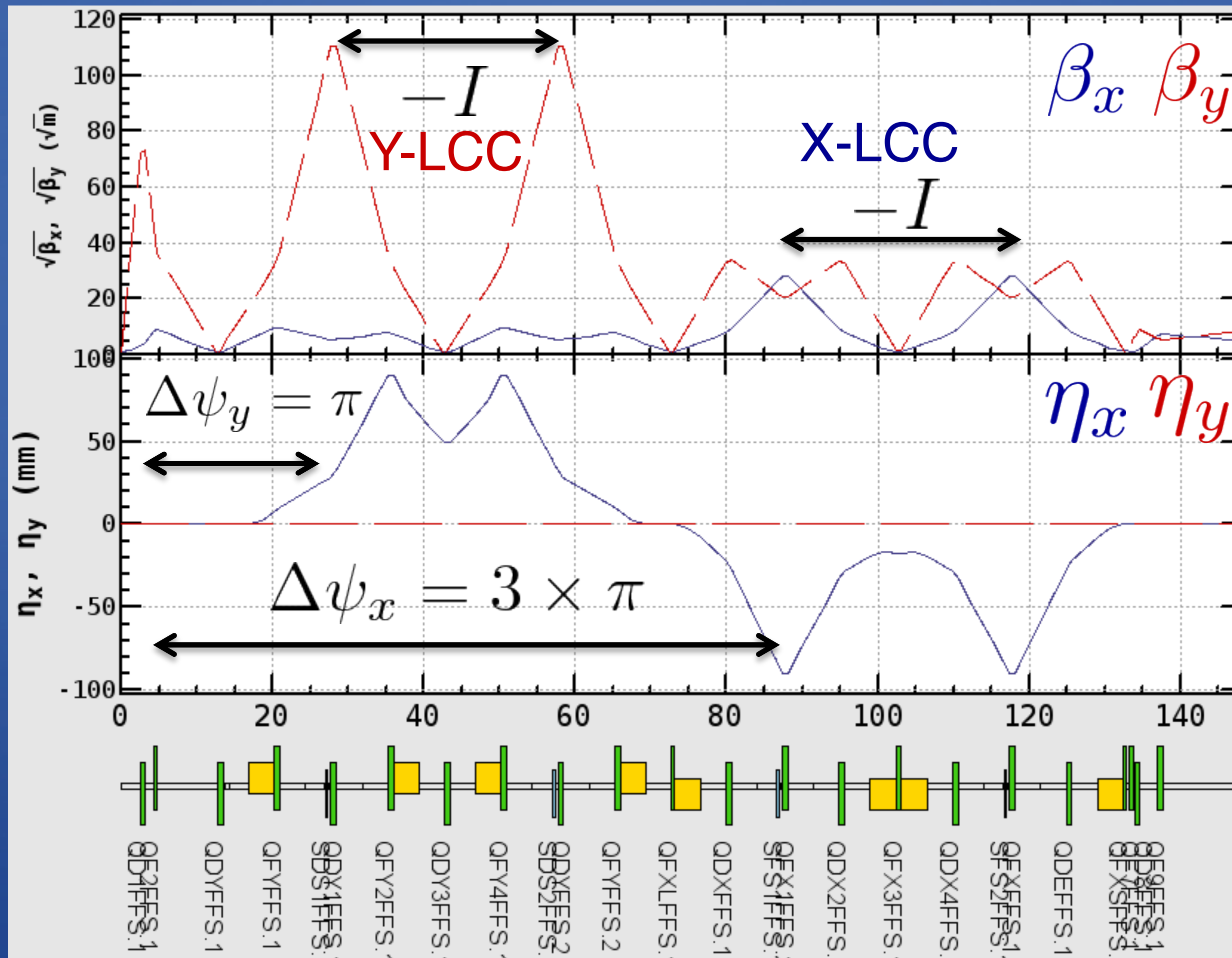
Comment: Is it possible to apply KEKB-type cell with non-interleaved sextupole pairs? It is more preferable to obtain wide momentum acceptance.

Natural Chromaticity

	SuperKEKB		CEPC
	LER	HER	
FFS (ξ_x, ξ_y)	(-54,-721)	(-108,-1022)	(-108,-2404)
ARC	(-31,-33)	(-38,-29)	(-182,-188)
OTHERS	(-19,-35)	(-23,-19)	(-31,25)
TOTAL	(-104,-789)	(-169,-1070)	(-321,-2617)

- More than 90% is originated in FFS.
- Similar amount of natural chromaticity/one IP compared to SuperKEKB.
- Chromaticity correction tends to be more difficult owing to 2IPs.
- Is the 2IPs really essential for the project?

FFS with Local Chromaticity Correction

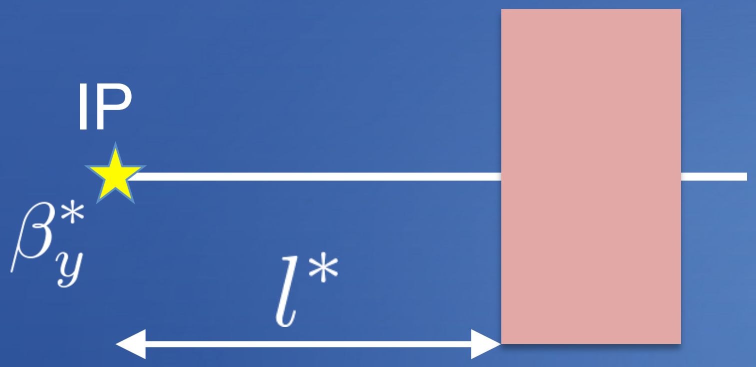


Comments: Why the horizontal phase advance between QF2FFS.1 and SFS1FFS.1 is 3*pi rather than 2*pi?

[1] K. Oide and H. Koiso, Phys. Rev. E47 2010 (1993)

DA Restriction due to Nonlinear Terms around IP

Final quadrupole $k_1 \equiv \frac{B'}{B\rho}$



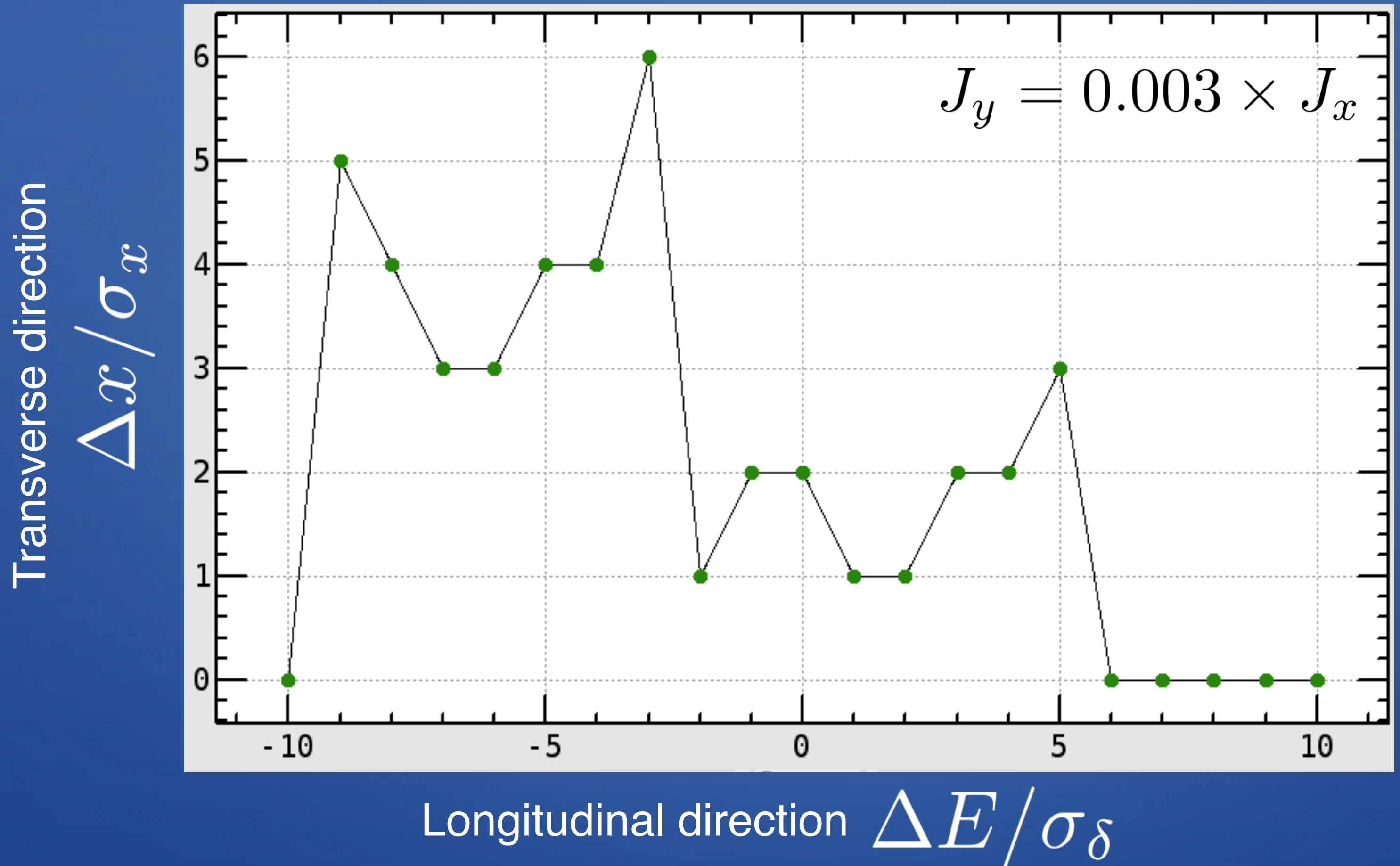
DA formula given in Ref.[1]

$$J_{y0} = \frac{\beta_y^{*2}}{\left(1 - \frac{2}{3}k_1 l^{*2}\right) l^*} A(\mu_y)$$

μ_y: Fractional part of the tune

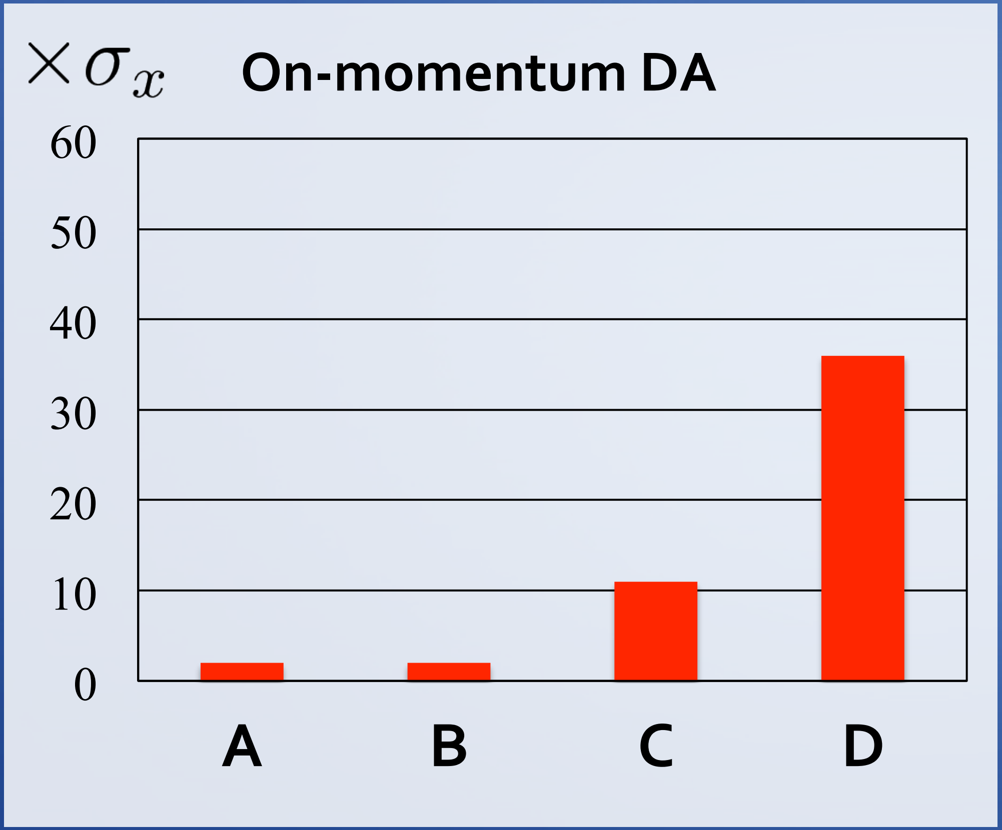
	KEKB	SuperKEKB		CEPC	Units
		LER	HER		
β_y^*	5900	270	300	1200	μm
k_1	-1778	-5.104	-3.0539	-1.2881	1/m^2
l^*	1.762	0.766	1.221	2.5	m
$J_{y0}/A(\mu_y)$	4.22	0.0317	0.0183	0.0904	μm

Dynamic Aperture (DA)



- Even the on-momentum DA is very poor.
- Need to start with study of the on-momentum DA.

Side Effect of Sextupole Magnets

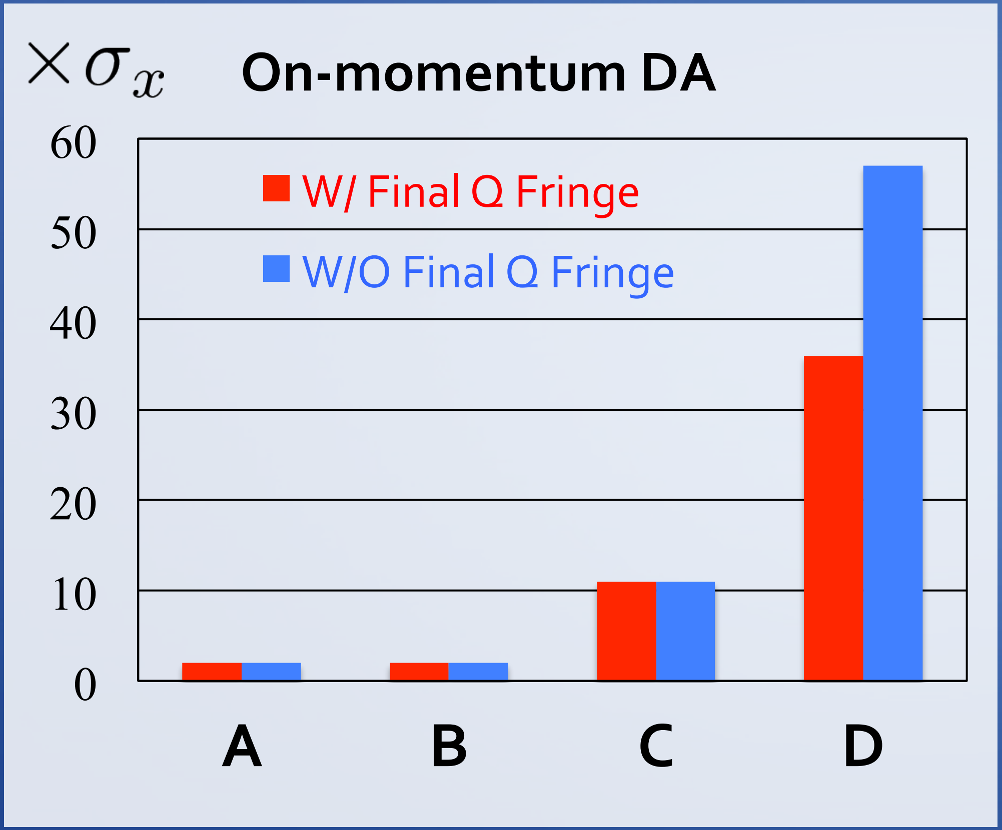


Case	Arc Sext.	LCC Sext.
A	***On***	***On***
B	Off	***On***
C	***On***	Off
D	Off	Off

Synchrotron motion is frozen out.

- Geometrical aberration of the sextupole should be minimized.

Side Effect of Sextupole Magnets



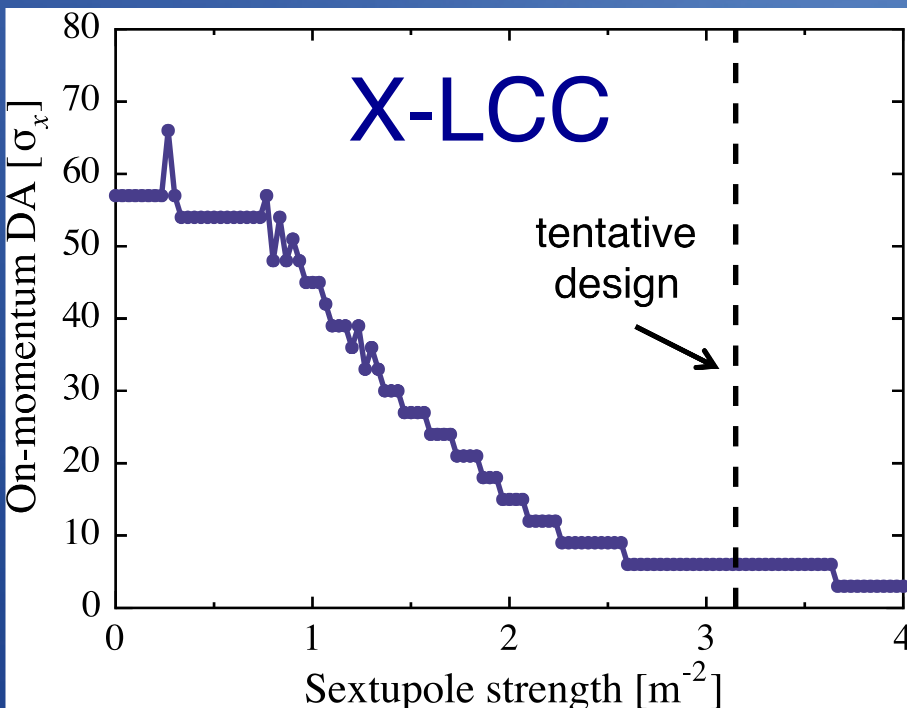
Case	Arc Sext.	LCC Sext.
A	***On***	***On***
B	Off	***On***
C	***On***	Off
D	Off	Off

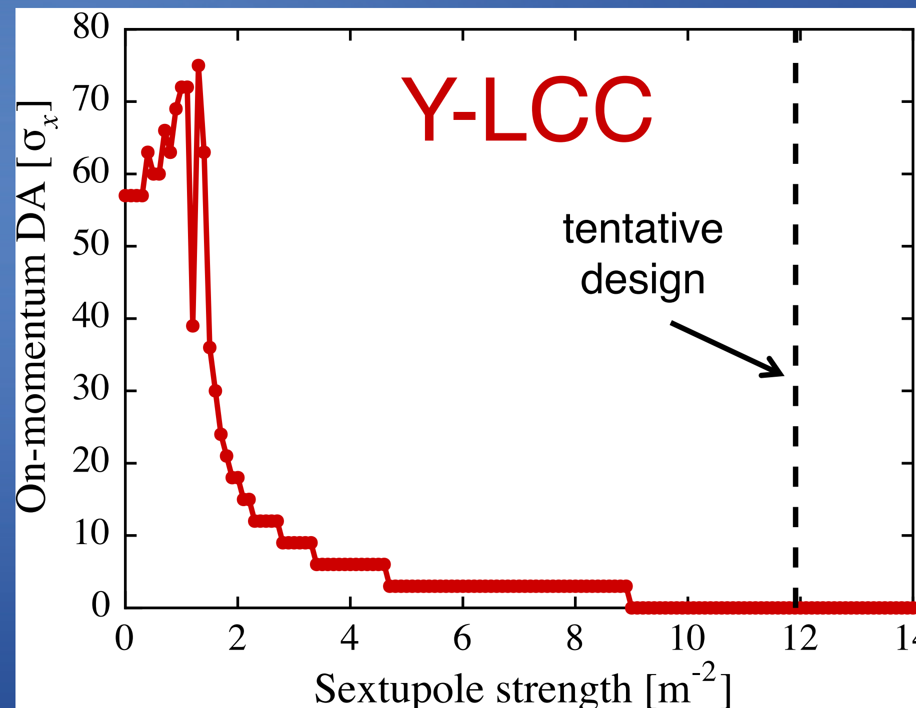
Synchrotron motion is frozen out.

- Suppression of the fringe effect will be important when the side effect of the sextupole is minimized.
- We may have to install octupole magnets.

DA and LCC Sextupole Strength

Arc Sextupoles are turned off.
Final focus magnet w/o fringe effect
Synchrotron motion is frozen out





- The LCC sextupole field looks too strong.
- Need to reduce the sextupole strength by increasing horizontal dispersion.

Summary

- DA optimization of the CEPC lattice has been started.
- The lattice looks still tentative, and need more work to optimize it.
- The lattice with 2IPs should evolves more complicated beam dynamics.
  - Question: Is it really essential for the project?
- The dominant cause of the on-momentum DA reduction is the too large field strength of the sextupole installed in FFS.
  - Proposal: Increase horizontal dispersion.

Summary (Cont'd)

- The final quadrupole fringe will be troublesome.
  - Proposal: Install the octupole magnets.

- Energy acceptance of +- 2% is challenging.
  - Proposal: Apply KEKB-type cell with non-interleaved sextupole pairs.

Thank you for your attention!