IR Upgrade Overview

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Choice of machine parameters

Design parameters of KEKB and SuperKEKB

	KEKB (design)		SuperKEKB	
	LER	HER	LER	HER
I [A]	2.6	1.1	9.4	4.1
β_y^*[mm]	10	10	3	3
ξ_y	0.052	0.052	0.14~0.28	0.14~0.28
L [/cm^2/sec]	1×10^{34}		$2.5{\sim}5 \times 10^{35}$	
σ_l [mm]	5	5	3	3

IR basic parameters

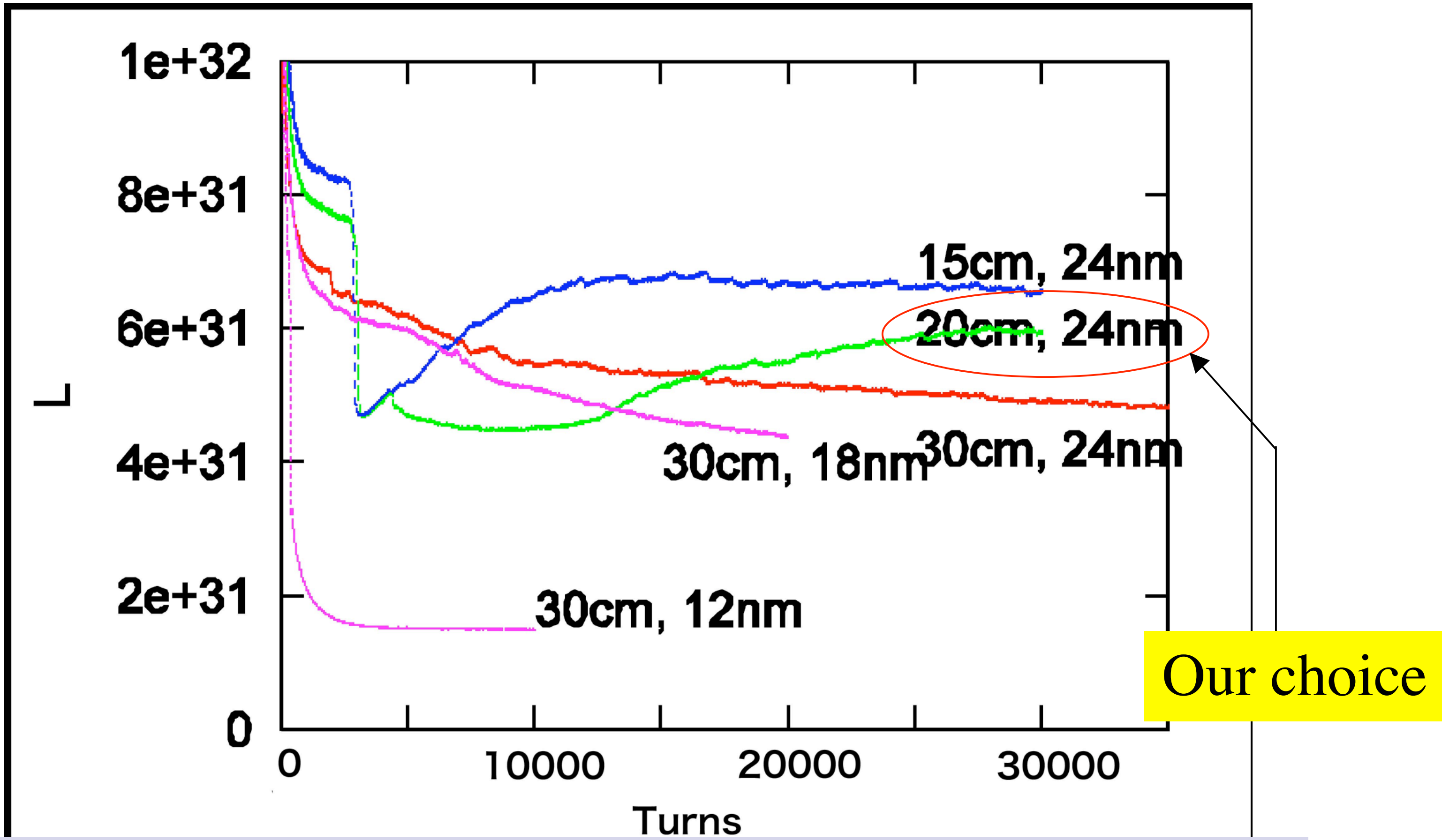
	KEKB (design)		SuperKEKB	
	LER	HER	LER	HER
β_y^*[mm]	10	10	3	3
β_x^*[cm]	33	33	20	20
ε_x [nm]	18	18	24	24
ϕ [mrad]	11		15	

β_y^* : basic assumption of SuperKEKB design
β_x^*, ε_x : from beam-beam simulations
ϕ : assumption for IR design

Choice of β^*_x, ε_x

- β^*_x=30, 20, 15 cm
- ε_x=24, 18, 12 nm

Strong-Strong Beam-Beam Simulations by K. Ohmi



Achievable beam-beam parameters depends on β^*_x and ε_x.

Crossing angle (ϕ)

	±11mrad	± 15mrad
Physical aperture of IR magnets	very tight	tight
Power of SR from QCS magnets	lower	higher
Required voltage of crab cavities	lower	higher
Parasitic collision effects	maybe o.k.	maybe o.k.

Issues

Issues of IR Design

Issues	Causes	Measures
Dynamic aperture	Lower beta's at IP	Place QCS magnets closer to IP.
Physical aperture	Lower beta's at IP Energy switch	Damping ring
Heating of IR components	High beam currents. High power of SR from QCS magnets. Short bunch length.	To be studied.
Detector beam background	High critical energy of SR from QCS magnets. High beam currents.	Under study in Belle Group

Design Work Overview

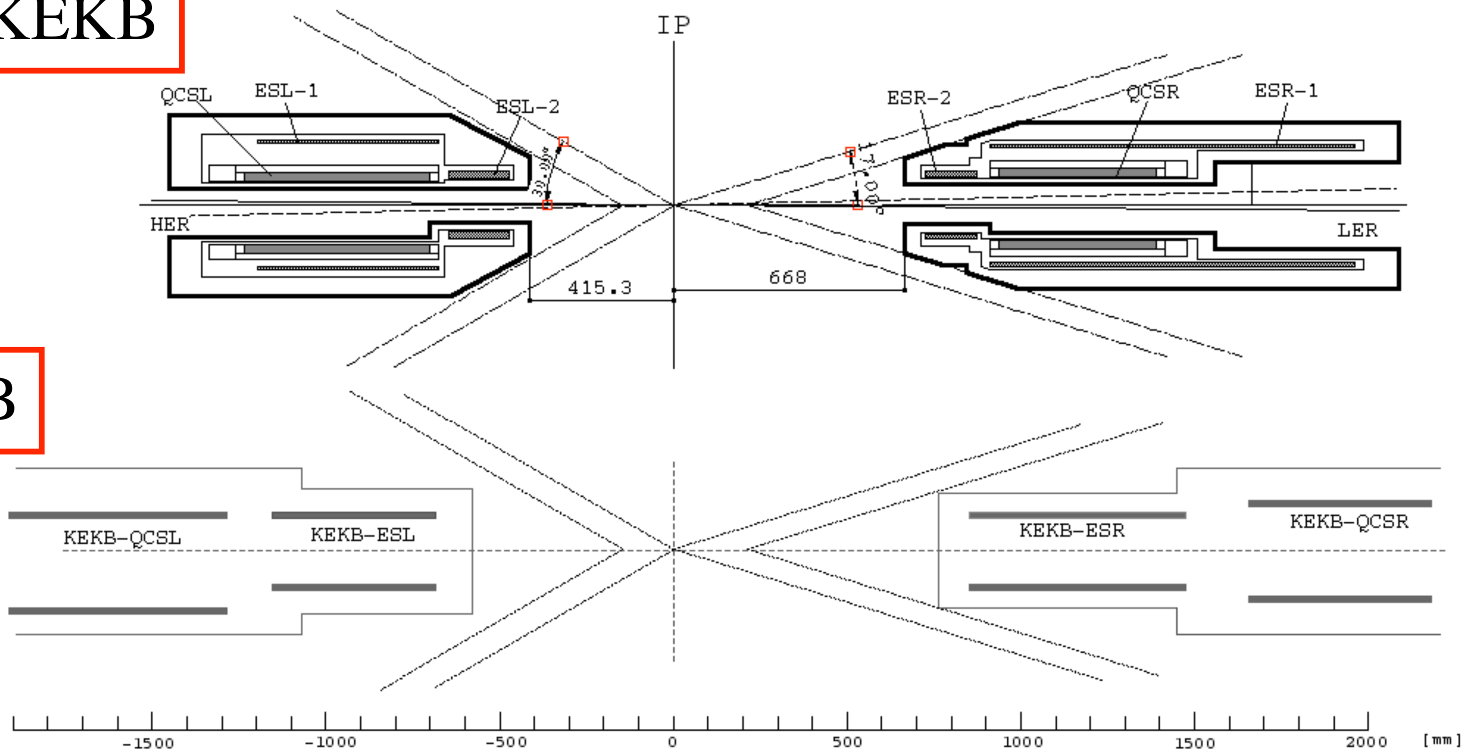
IR Design Works

- We have to concurrently pursue the following design works until we find a consistent set of solutions.
  - **Estimation of required physical aperture from the viewpoint of beam injection**
  - **IR Magnet Design (Talks by Tawada and Ohuchi)**
  - **IR Optics (Talk by Koiso)**
- Requirements
  - **To realize the required machine parameters.**
    - β_y^*, β_x^*, ϕ
  - **To keep enough dynamic and physical aperture.**

Place QCS magnets closer to IP

SuperKEKB

KEKB

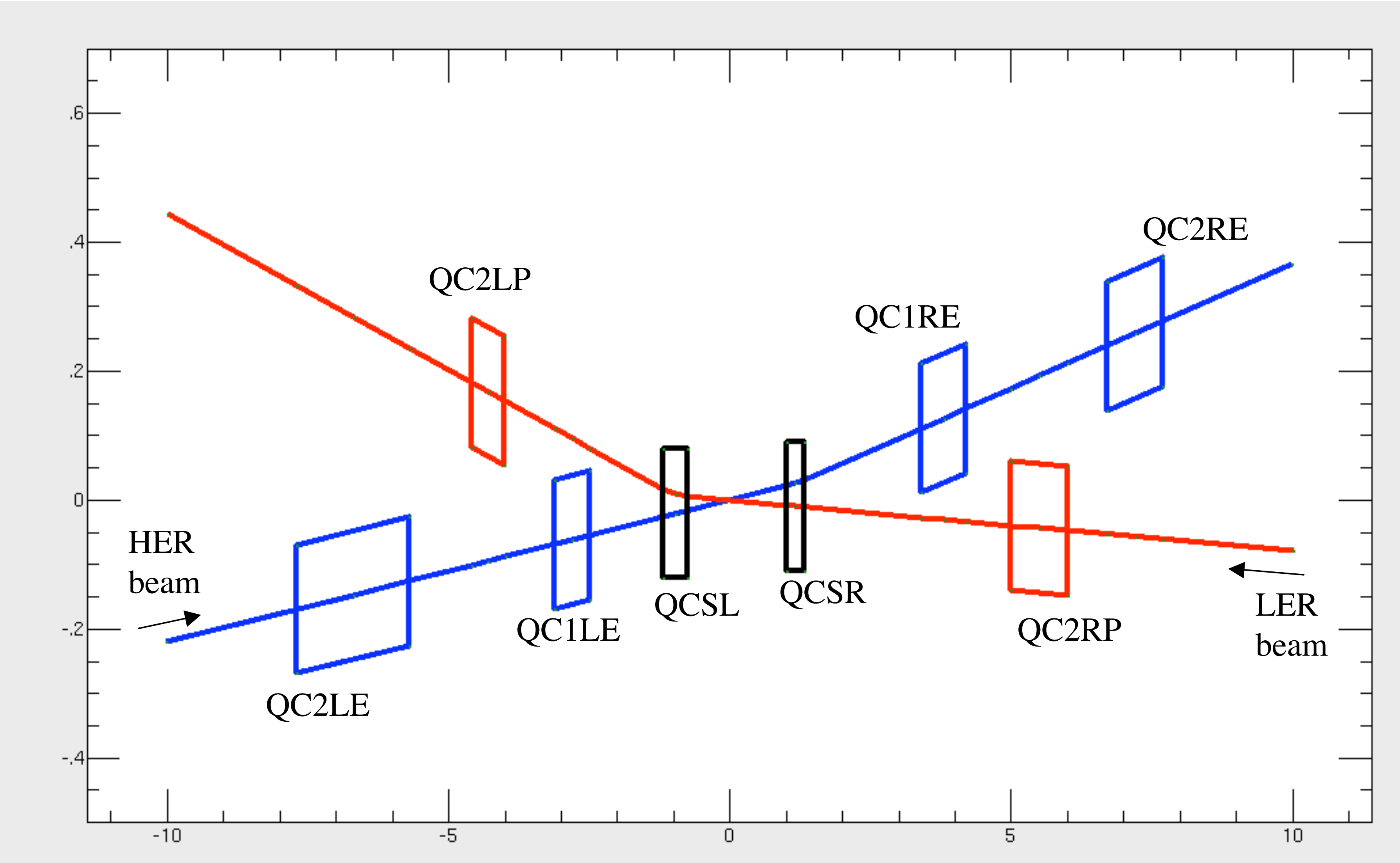


The boundary between KEKB and Belle is the same.
ESL and ESR will be divided into two parts (to reduce E.M. force).
QCSL (QCSR) will be overlaid with (the one part of) ESL(ESR).

Crossing angle (ϕ)

- QCS (defocusing quadrupole) magnets are placed closer to IP.
- β_x^* is smaller.
  - **The maximum value of β_x around IP becomes very large.**
    - Physical aperture will be an issue particularly in the horizontal direction.
    - To mitigate this problem, the crossing angle will be increased from ±11mrad to ±15mrad.

IR magnet layout



QC1 magnet design

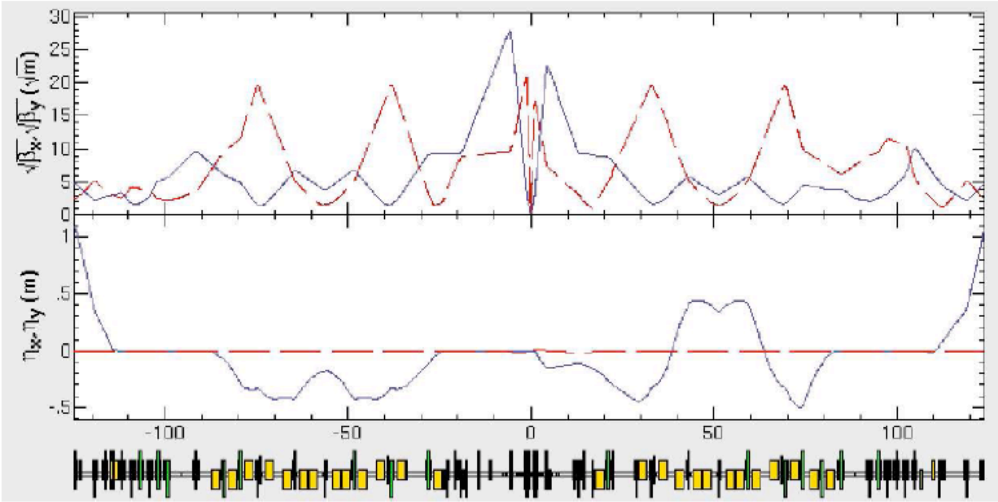
- Severe physical aperture requirement
- Two options (-> Ohuchi and Tawada's talk)
  - **Normal quadruple**
  - **Superconducting**
  - **If we find a solution of the normal quadruple magnets, we will take this solution.**

IR Lattice Design

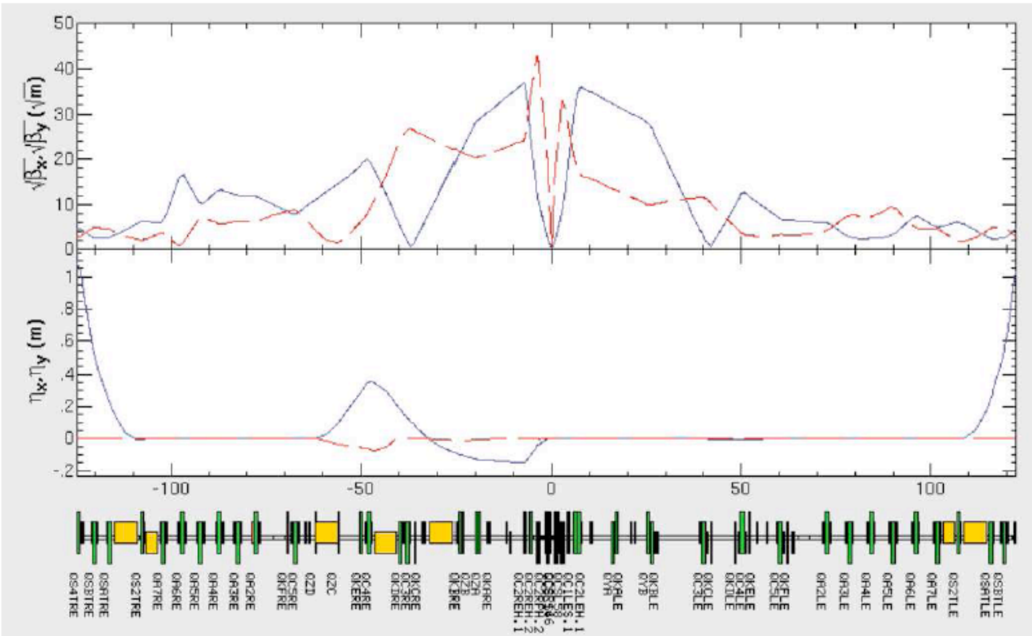
H. Koiso

Tracking studies showed acceptable dynamic aperture.

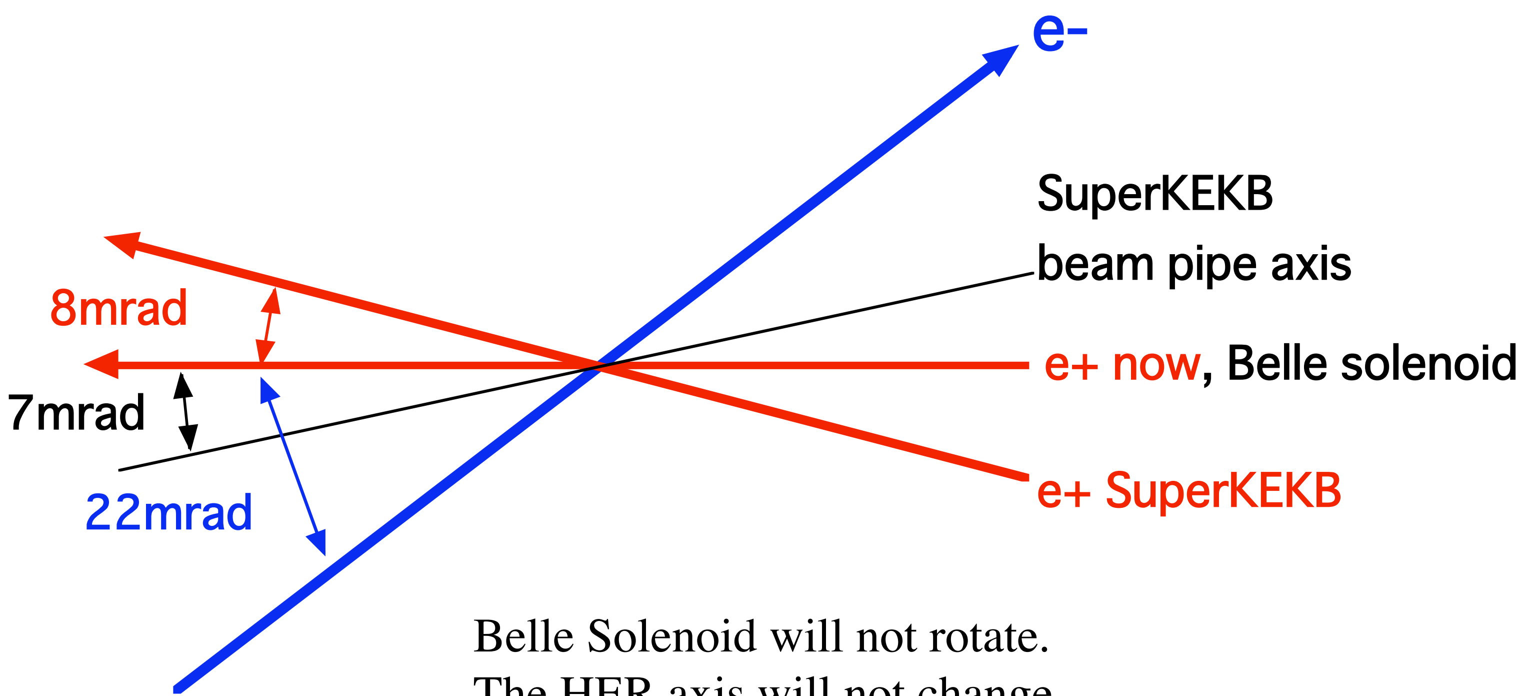
LER



HER



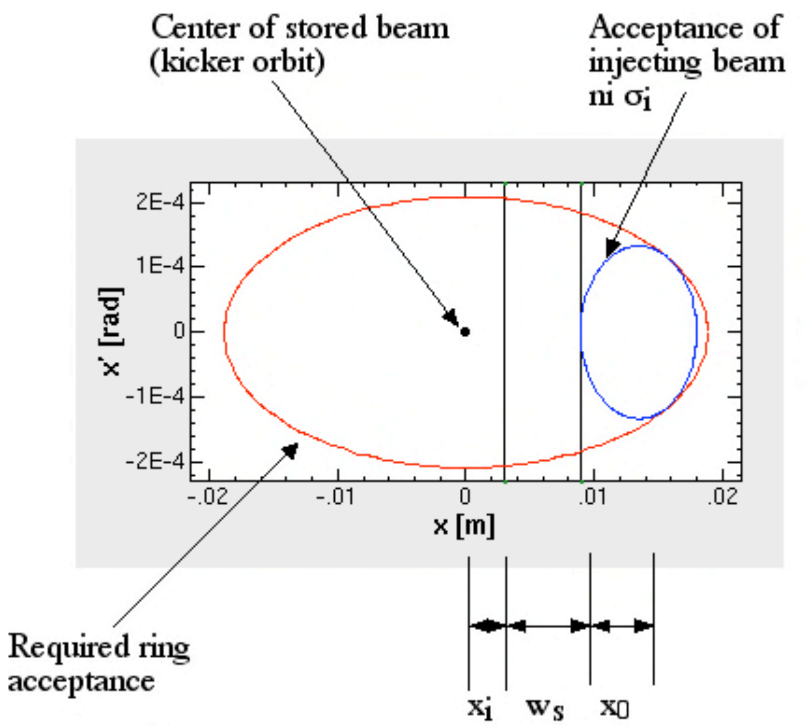
Geometrical Relationship between SuperBelle and SuperKEKB



Belle Solenoid will not rotate.
The HER axis will not change.
The LER axis will rotate by 8mrad.
The beam pipe (and SVD) have a finite angle of 7mrad with respect to Belle Solenoid.
QCS magnets will be set parallel to Belle Solenoid.

Estimation of required ring acceptance

- Required ring acceptance is determined by the beam injection conditions.
- Required acceptance is determined by the following parameters.
  - **Ring emittance:** ε_{xr}
  - **nr**
  - **w_s**
  - **ns**
  - **ni**
  - **Ring** β at the injection point: β_{xr}
  - **Linac beam emittance :** ε_{xi}
  - **Injection line** β: β_{xi}



$X_{inj} = x_i + w_s + x_0$ (injection error)

x_i: Distance between the center of stored beam and Septum wall -> nr σ_r

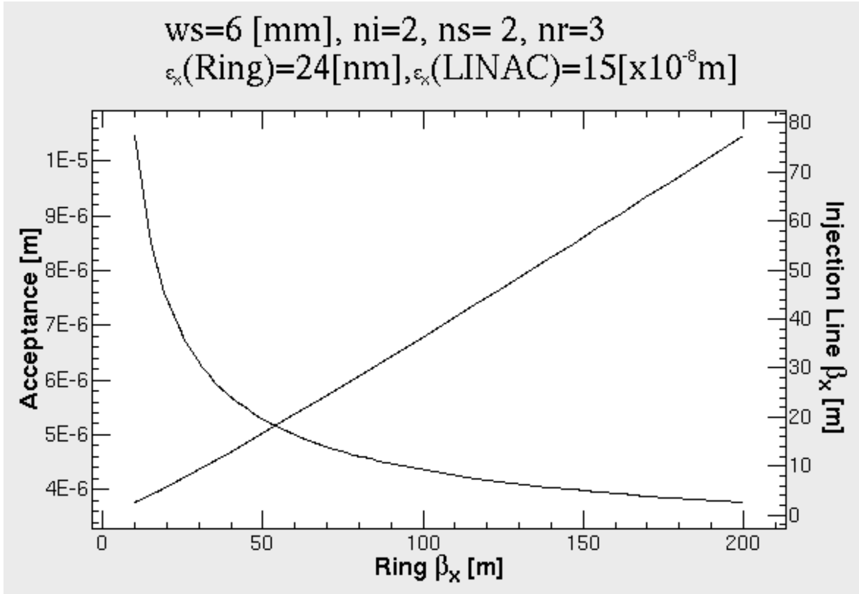
w_s: Septum thickness

x_0: Distance between the center of injecting beam and Septum wall ->ns σ_i

Of the parameters above, Ring β and Linac beam emittance can be chosen relatively freely or can be changed with our efforts.

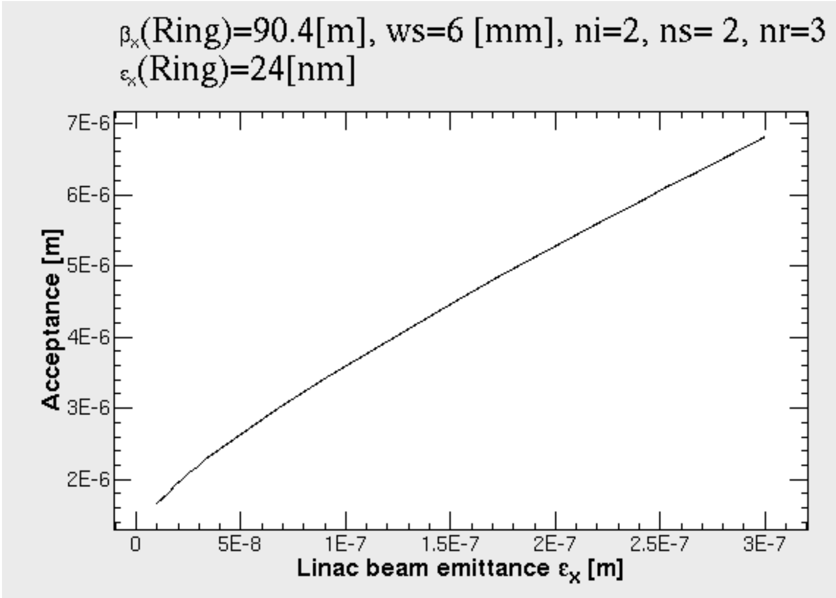
Ring β function

- A higher ring beta function at the injection point reduces required ring acceptance.
- However, with higher β_x than about 100m, required ring acceptance does not change very much.
  - **We took Ring β_x of 90.4m which is the same value of the KEKB design.**



Linac beam emittance

- Required acceptance depends strongly on the Linac beam emittance.
- In our present situation, required ring acceptance is almost determined by the Linac beam emittance.



Strategy on ring acceptance

- In our present strategy, beam energy switch between e+ and e- will be done at some time after the IR upgrade.
- This means that both rings have to accept the beam which has higher emittance.
- We considered two cases.
  - **Case 1: Estimate the Linac beam emittane based on the values achieved at the present Linac.**
    - The positron beam determined required ring acceptance of both rings.
    - The positron beam emittance is 3.5 x 10^{-7}m at 3.5GeV.
    - We could not find solutions of the IR magnet design with this condition.
  - **Case 2: We will introduce a damping ring for the e+ beam.**
    - The electron beam determined required ring acceptance of both rings.
    - The electron beam emittance is 2.0 x 10^{-8}m at 8GeV.
    - We found solutions of the IR magnet design with this condition.

We need a damping ring for the positron beam.

Required Ring Acceptance

	LER	HER	Unit
Linac beam emittance (Horizontal)	3.5	1.5	10^{-7} m
Linac beam emittance (Vertical)	3.0	1.3	10^{-7} m
Required acceptance (Horizontal)	7.5	4.5	10^{-6} m
Injection Error (Horizontal)	3.4	2.4	10^{-6} m
Required acceptance (Vertical)	1.2	0.52	10^{-6} m

Without damping ring

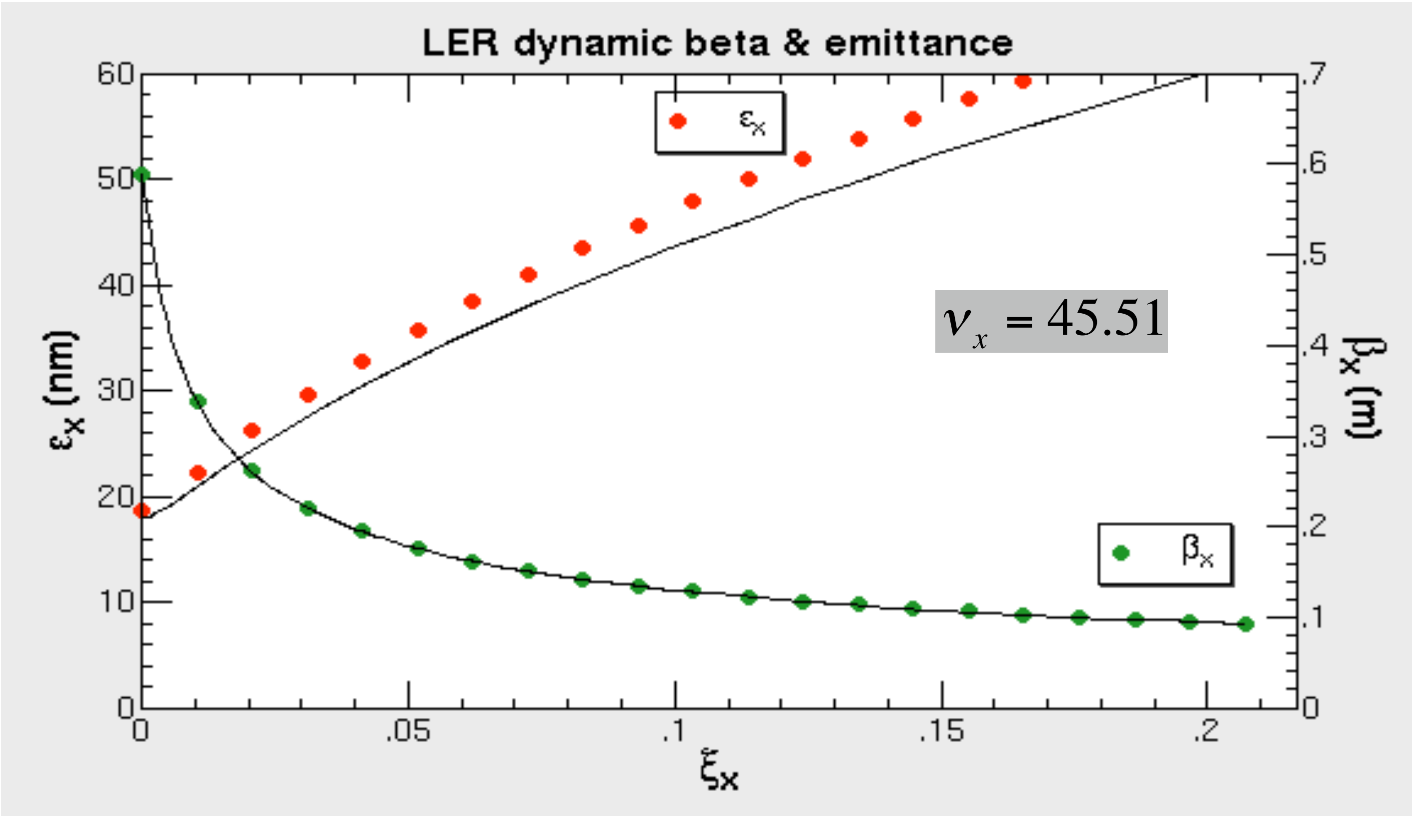
	LER	HER	Unit
Linac beam emittance (Horizontal)	4.6	2.0	10^{-8} m
Linac beam emittance (Vertical)	4.6	2.0	10^{-8} m
Required acceptance (Horizontal)	2.6	1.9	10^{-6} m
Injection Error (Horizontal)	1.8	1.5	10^{-6} m
Required acceptance (Vertical)	1.8	0.80	10^{-7} m

With damping ring

Issues related to SR from QCS magnets

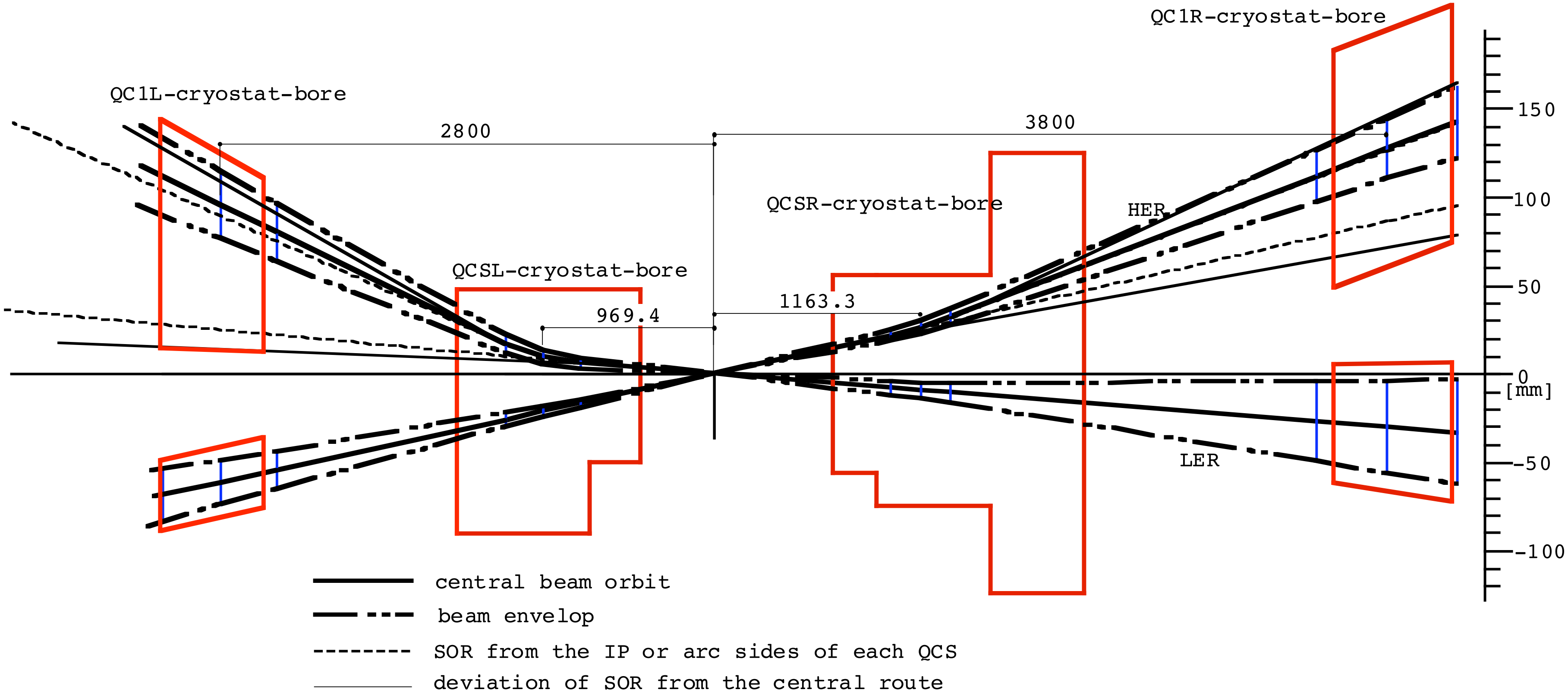
- Fan of SR
  - **Effects of COD and beam size**
    - We found that the dynamic beta and dynamic emittance effect due to the beam-beam interaction are important for the estimation.
    - The smaller β_x^* and the larger emittance make the angular divergence of beam very large.
- How to deal with the power of SR
  - **Much higher power than KEKB**

Dynamic β and emittance



Calculations with analytic formula and by using SAD (KEKB)

Fan of SR



QC1R-cryostat-bore
QC1L-cryostat-bore
2800
3800
QCSR-cryostat-bore
HER
QCSL-cryostat-bore
969.4
1163.3
LER
150
100
50
0
[mm]
-50
-100
central beam orbit
beam envelop
SOR from the IP or arc sides of each QCS
deviation of SOR from the central route

Power of SOR from QCS Magnets

	QCSR	QCSL
Magnet length [m]	0.33	0.42
Δx [mm]	34.5	29.1
G [T/m]	37.2	35.4
B [T]	1.28	1.03
E_b [GeV]	8.0	3.5
I [A]	4.1	9.4
P [kW]	179 (27)	64.6 (10)

(): present KEKB Design

Summary of Future works

Summary

- Prior to starting the IR design, we determined some machine parameters related to the IR design.
- Main issues of the IR design are dynamic and physical aperture.
- To keep enough dynamic aperture, the QCS magnets will be placed closer to the IP and overlaid with the ESR(ESL).
- A damping ring for the positron beam is vital to reduce the required value of ring acceptance.
- We found a consistent set of solutions of the IR magnet design, the IR optics design and the injecting beam quality which provide sufficient physical aperture and acceptable dynamic aperture.
- Feasibility of SuperKEKB IR has been confirmed.

Future works

- How to deal with very high power of SR from QCS's
- Heating of IR components
- Design of vacuum system
- 3D design of IR magnets
- Estimation of HOM power and its counter-measure
- Mechanical support of the magnets
- Solution of spatial confilicts among components
- Design of IR special beam monitor system
- Detector beam background and design of IP beam pipe (under study)
- Etc.