SuperKEKB IR Design

Y. Funakoshi (KEK)

Design strategy

- Natural extension of present KEKB
  - the same boundary between KEKB and Belle
  - conventional flat beam scheme
    - ~~round beam~~
- A baseline design of SuperKEKB IR has been completed.
  - Details are described in LoI (2004).

Machine parameters

	Present KEKB LER/HER	KEKB Design LER/HER	Super KEKB LER/HER
β_x^* [m]	0.59/0.56	0.33	0.2
β_y^* [mm]	6.5/5.9	10	3
ε_x [nm]	18/24	18	9
σ_z [mm]	~8/~7	5	3
ϕ_c [mrad]	11	11	15
I_{beam} [A]	1.7/1.35	2.6/1.1	10.4/4.4
L [10^{34}/cm^2/s]	1.63	1	82.5

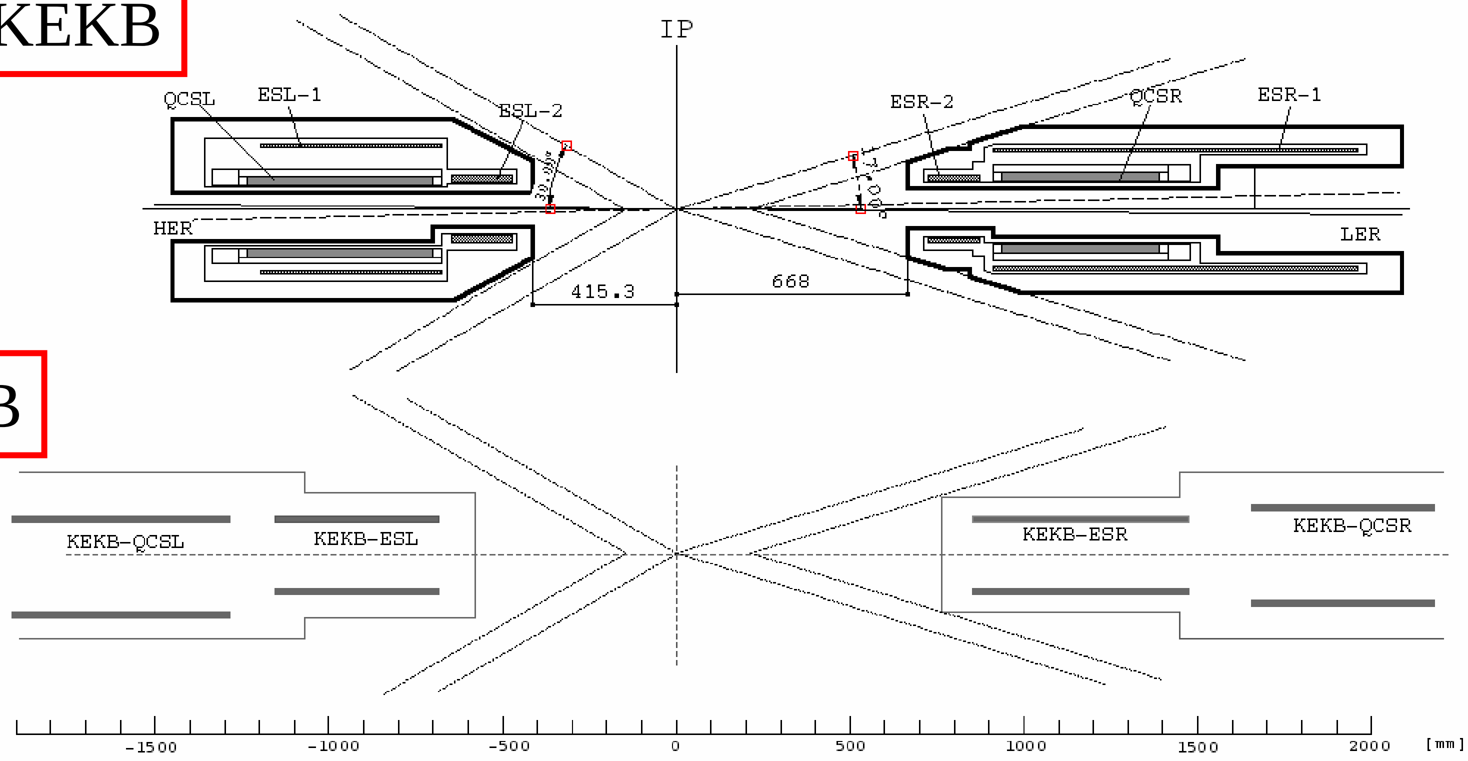
Issues of IR Design

Issues	Causes	Measures
Dynamic aperture	Lower beta's at IP.	Place QCS magnets. closer to IP. Damping ring.
Physical aperture	Lower beta's at IP.	Damping ring. Larger crossing angle. (22mrad -> 30mrad)
Heating of IR components	Higher beam currents. Higher power of SR from QCS magnets. Shorter bunch length (HOM).	Under study.
Detector beam background	Higher power and critical energy of SR from QCS magnets. Higher beam currents. QCS closer to the IP. Higher Luminosity.	Under study by Belle Group.

Place QCS magnets closer to IP

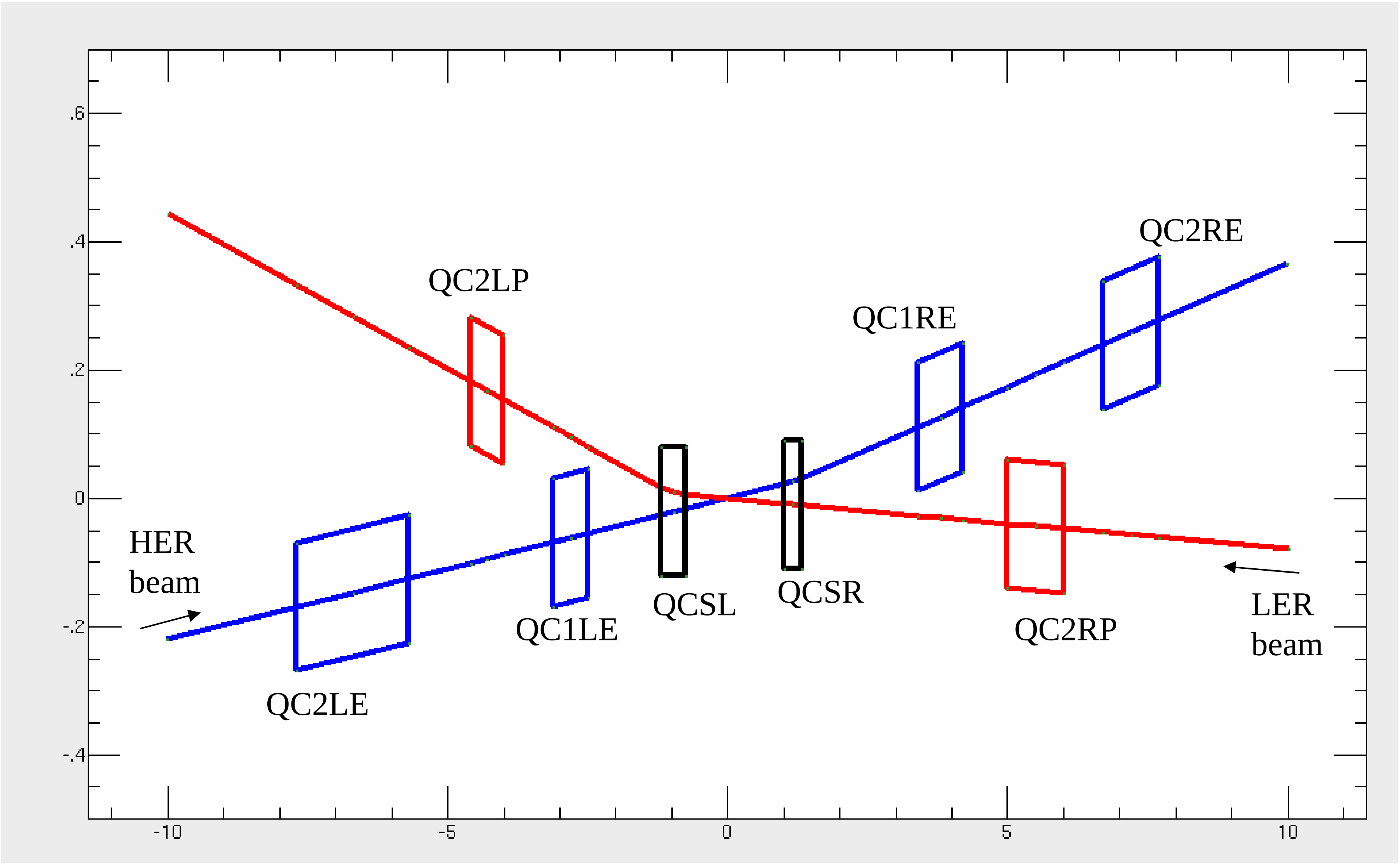
SuperKEKB

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).

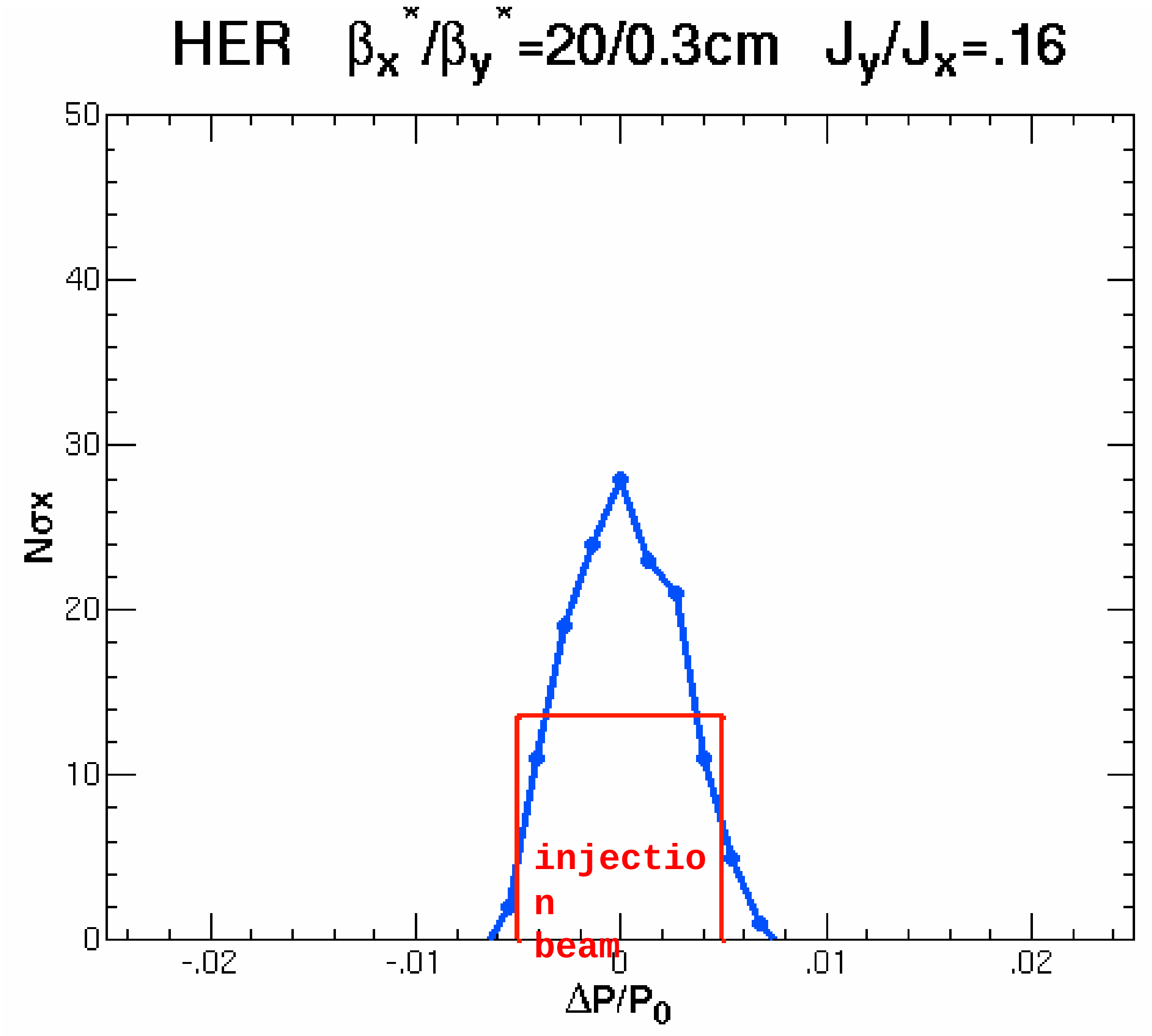
IR magnet layout



H. Koiso

HER dynamic aperture

bare lattice BX/BY=20/.3 cm



Required: H/V 4.5/0.52 ×10^{-6}m

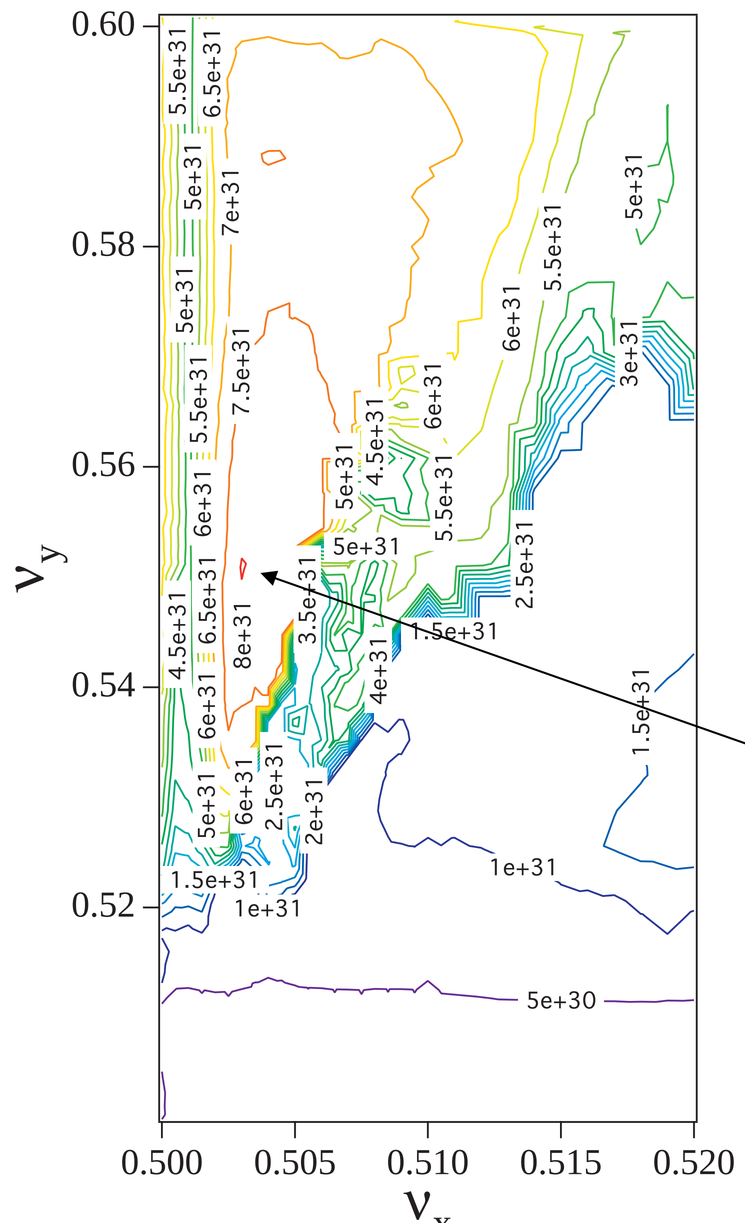
Local correction scheme also in HER?

- HER local chromaticity correction scheme is not compatible with installation of crab cavities in Tsukuba section.
- If we want to install crab cavities in Tsukuba, we can not adopt the local correction scheme in HER.
- We need to wait for the results of the experiment with the crab cavities in Nikko section next year.

New issues

- Horizontal tune very close to half-integer
  - SR fan
  - Physical aperture in IR
- Idea of waist control
  - Traveling focus
  - Crab waist

Beam-beam simulation



Tune Survey in SuperKEKB without parasitic collision effect.

L_{peak}=8.3x10^{35}cm^{-2}s^{-1}
(L/bunch=1.66X10^{32}, Nb=5000)

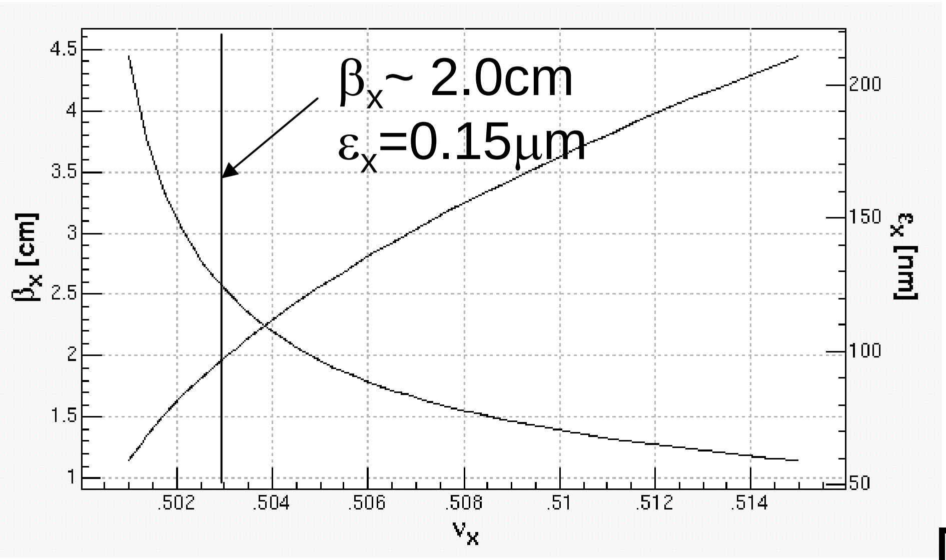
Head-on

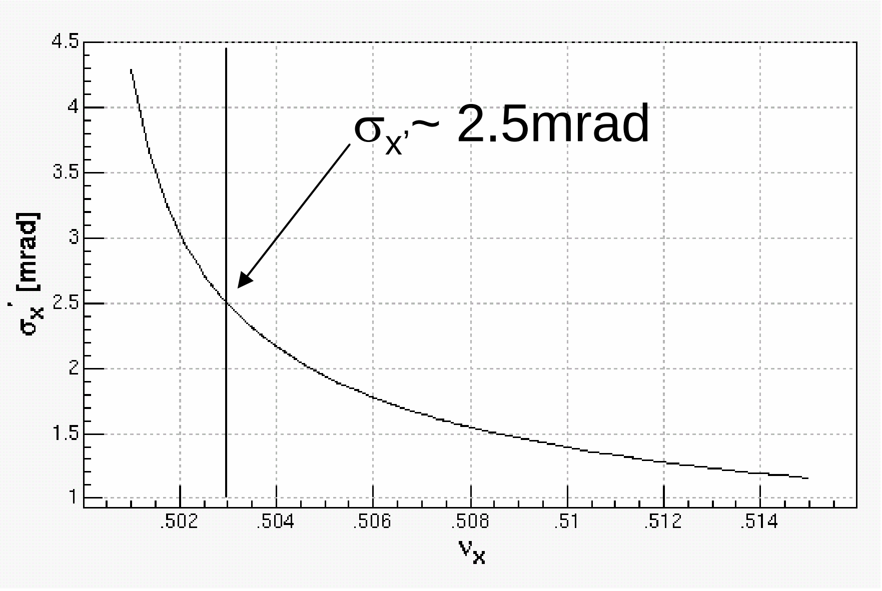
(.503, .550)

ξ_y ~0.33

Simulation by K. Ohmi

Estimation of dynamic effects





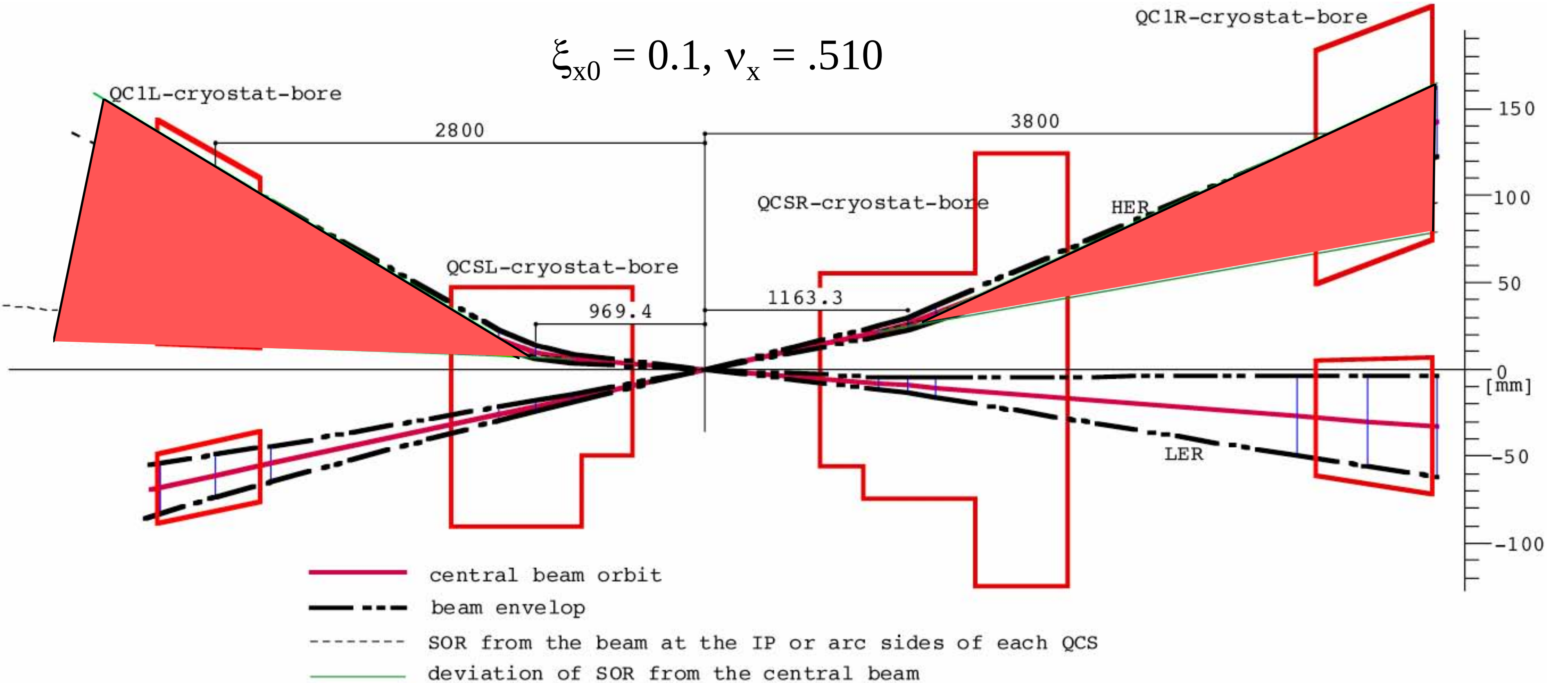
- Input parameters
  - ξ_{x0} = 0.152
  - ν_x = variable(0.503)
  - ε_x = 24 nm
  - β_x^* = 20 cm

	β_x [cm]	ε_x [μm]	$\sigma_{x'}$ [mrad]
SAD	2.0	0.125	2.5
B-B 1σ_x, $\sigma_{x'}$	2.30	0.128	2.49
B-B 3σ_x , $\sigma_{x'}$	4.18	9 x 0.209	3 x 2.23

Fan of SR with dynamic effects

$9\varepsilon_x$ ($3\sigma_x$, $3\sigma_{x'}$) is taken into account.

$\xi_{x0} = 0.1$, $\nu_x = .510$



$\nu_x = .510 \rightarrow \sigma_x' \sim 1.4$mrad

$\nu_x = .503 \rightarrow \sigma_x' \sim 2.5$mrad

Power of SR 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)

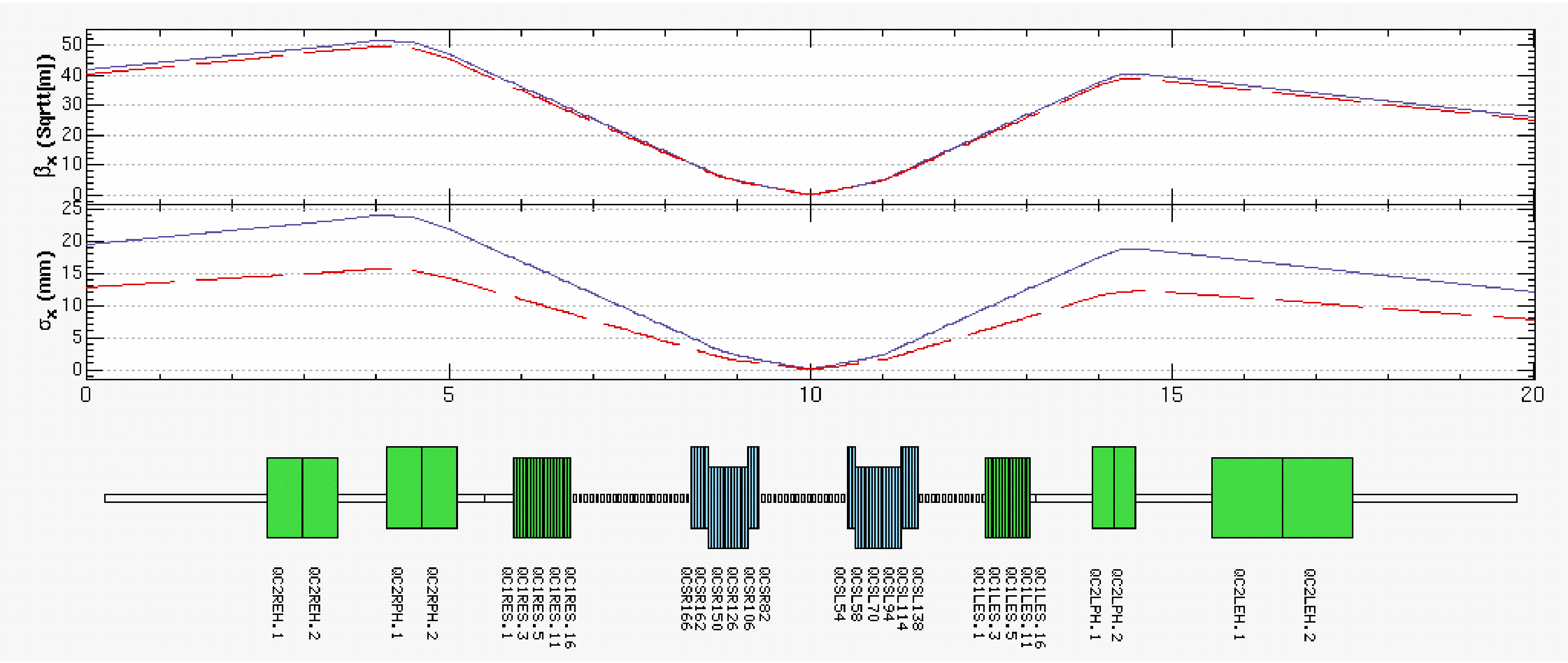
( ): present KEKB Design

σ_x in IR with dynamic effects

LER IR

$\beta_x^* = 4.78$cm, $\varepsilon_x = 98.7$nm ($\beta_{x\ 0}^* = 40$cm, $\varepsilon_{x0} = 12$nm)(red)

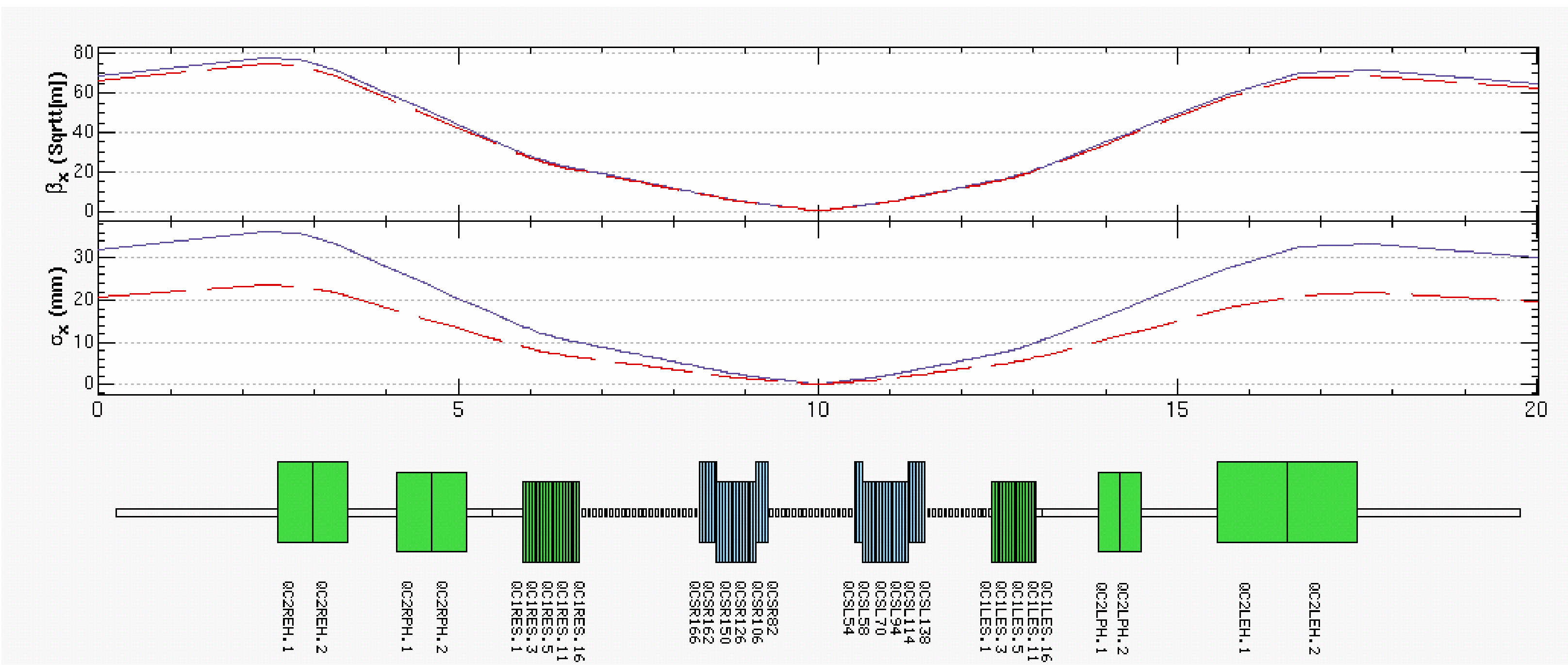
$\beta_x^* = 4.45$cm, $\varepsilon_x = 217$nm ($\beta_{x\ 0}^* = 20$cm, $\varepsilon_{x0} = 24$nm)(blue)



HER IR

$\beta_x^* = 4.78\text{cm}$, $\varepsilon_x = 98.7\text{nm}$ ($\beta_{x0}^* = 40\text{cm}$, $\varepsilon_{x0} = 12\text{nm}$)(red)

$\beta_x^* = 4.45\text{cm}$, $\varepsilon_x = 217\text{nm}$ ($\beta_{x0}^* = 20\text{cm}$, $\varepsilon_{x0} = 24\text{nm}$)(blue)



Parameters of IR quad (LoI)

		QC1LE	QC2LE	QC1RE	QC2RE	QC2LP	QC2RP
Field gradient	T/m	15.5	3.4	12.0	8.8	6.7	3.4
Pole length	m	0.64	2.0	0.75	0.8	0.6	1.0
b bore radius	mm	25	50	48	90	80	40
Current	AT	3920	3400	11050	28400	17100	1980
coil turns	/pole	3	8	3	16	15	3
Current density of Septum conductor	A/mm^2	30	10	70	24	31	15
Field in the area for couter-circulating beam	Gauss	0~-0.65	0~-0.4	0~-1.1	0~-0.35	0~-0.85	0~-0.35

Table 3.3: Parameters of special quadrupole magnets

σ_x (mm) →	8	21	10	22	12	16
b/σ_x →	3.1	2.4	4.8	4.1	6.7	2.5

Waist control

- To avoid effects of "Hourglass" effect
  - Traveling focus
    - Sextupole magnets + crab cavities
    - RF quadruple
    - Energy difference (RF cavity) + chromatic effect
  - Crab waist
    - Sextuple magnets + crossing angle + small x size

Kick by sextuple

$$H_2 = \frac{1}{6} S\left(x^3 - 3xy^2\right)$$

$$\frac{dp_y}{ds} = -\frac{\partial H_2}{\partial y} = Sxy$$ ← vertical focus depending on x

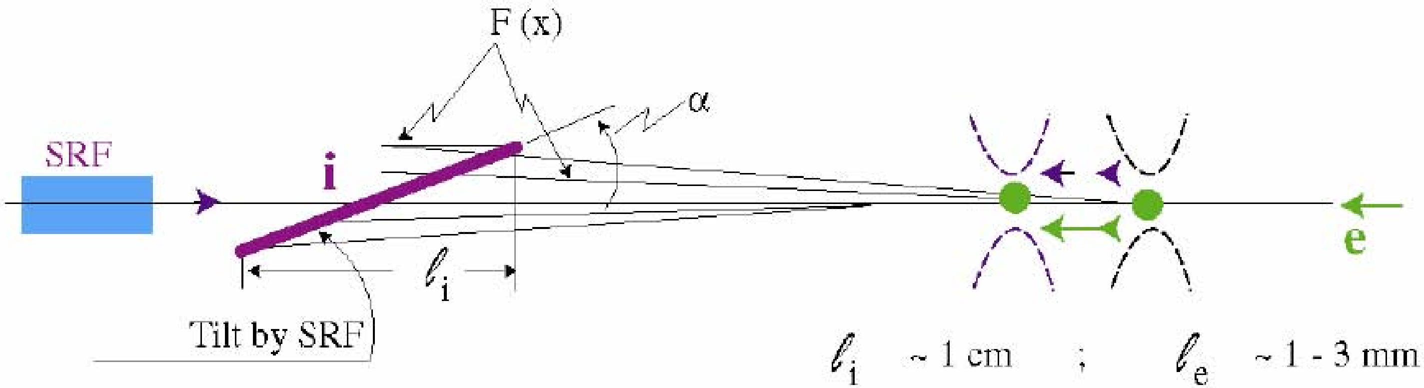
$$\frac{dp_x}{ds} = -\frac{\partial H_2}{\partial x} = -\frac{1}{2} S\left(x^2 - y^2\right)$$ ← harmful or not?

Traveling Ion Focus

/R. Brinkmann, 1995, general idea /

SRF deflectors (the same as for crab crossing) also can be used for arrangement of Traveling Focus (at $l_i >> l_e$), in cooperation with sextupole non-linearity introduced in the final focusing magnets

- **Traveling Focus allows one to decrease N_i or use bunches of a larger ε_i**



$\varphi = \frac{\omega}{c} s \quad \alpha = \frac{dx}{ds} \quad \beta_i^* << l_i$

Matching condition: $\frac{dF}{ds} = \frac{1}{2}$ **hence,** $\frac{dF}{dx} = \frac{1}{2\alpha}$

$\Delta F_b \sim \frac{1}{2} l_i$ **(over the bunch)**

ΔF **over the aperture:**

$$\Delta F_A = \frac{A}{2\alpha}$$

The feasibility condition:

$$\Delta F_A << F \quad \Rightarrow \quad \alpha >> \frac{A}{2F}$$

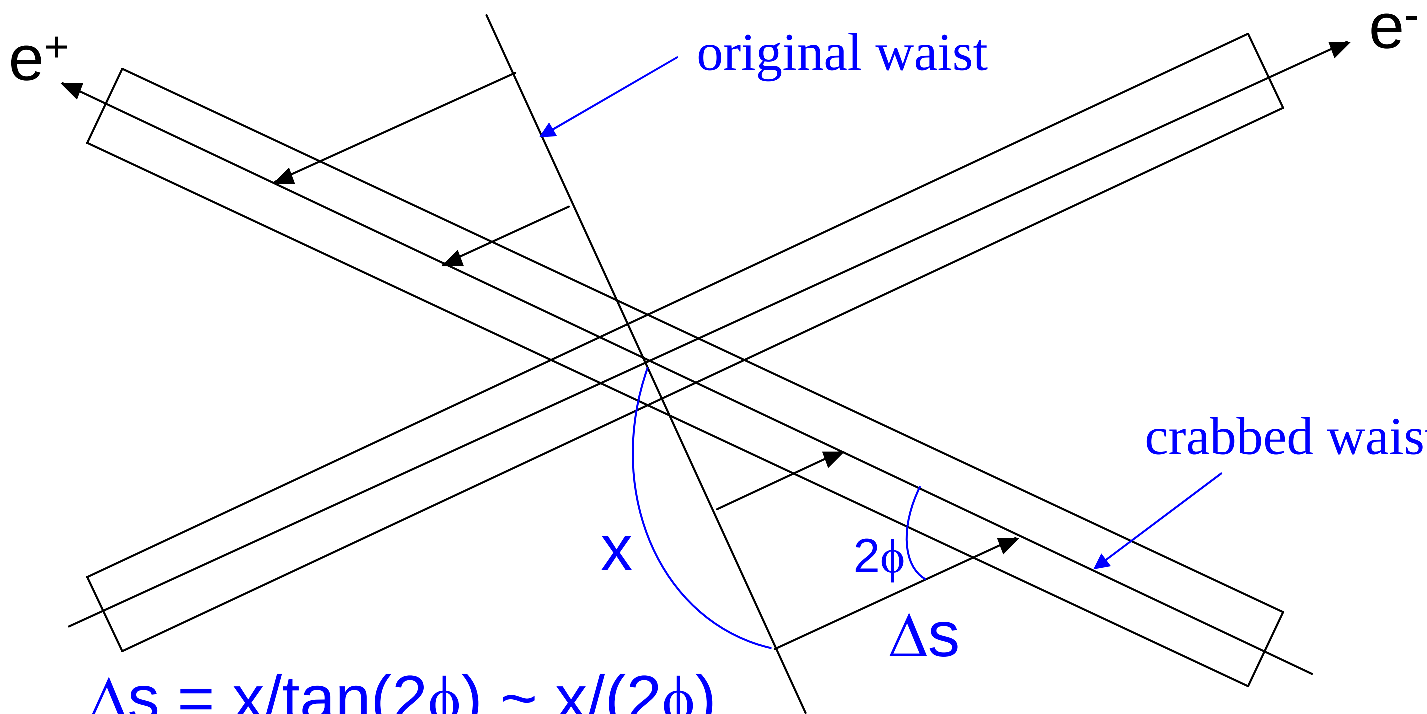
Ease to satisfy

Crab waist (SuperB workshop @ LNF)

Basic scheme

- crossing angle
- small x size
- crab waist

- Smaller area of interaction
  - -> effectively short bunch
  - -> smaller beam is needed to keep ξ_y high
- Smaller beam-beam tuneshift (Hor.)
  - Cancellation of main and long range force
- Still crab waist is needed.
  - Shift of waist points
  - Harmful effect of crossing angle is partially canceled.



$\Delta s = x/\tan(2\phi) \sim x/(2\phi)$

One turn map with sextupoles

- Kick by sextuple (vertical)

$$S_1 = \begin{pmatrix} 1 & 0 \\ A_1 x & 1 \end{pmatrix} \qquad A_1 = K_2(S_1)$$

$$S_2 = \begin{pmatrix} 1 & 0 \\ A_2 x & 1 \end{pmatrix} \qquad A_2 = K_2(S_2)$$

- One turn map (IP - > IP)

Original :

$$M_0 = M_1 M_3 M_2$$

With sextupole kick :

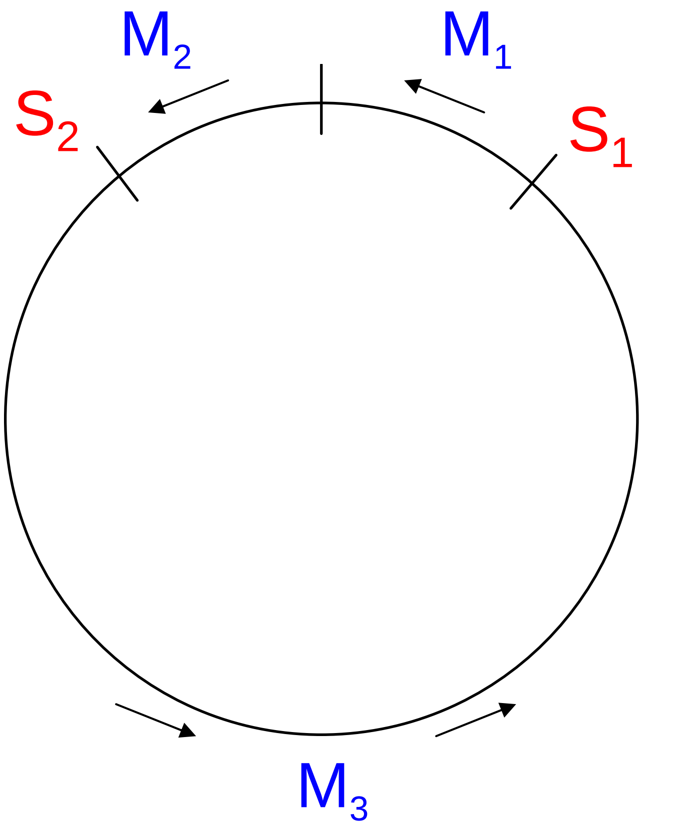
$$M = M_1 S_1 M_3 S_2 M_2 = \left(M_1 S_1 M_1^{-1}\right)\left(M_1 M_3 M_2\right)\left(M_2^{-1} S_2 M_2\right)$$

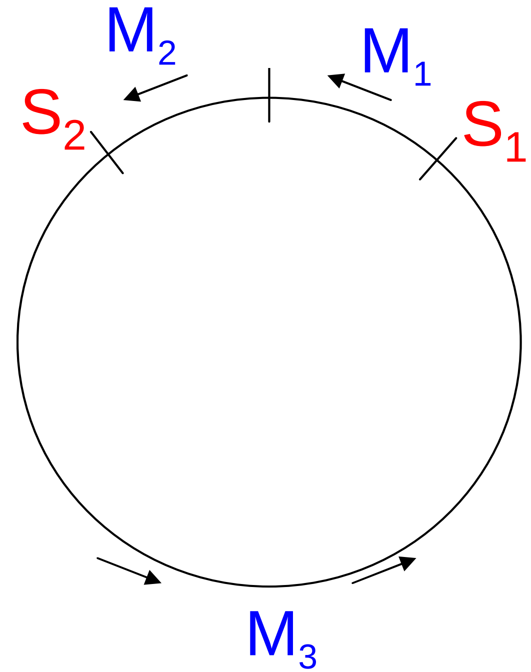
We assume $\left(M_2^{-1} S_2 M_2\right) = \left(M_1 S_1 M_1^{-1}\right)^{-1} = \left(M_1 S_1^{-1} M_1^{-1}\right)$.

$$M_2 = M_1^{-1} \text{ and } S_2 = S_1^{-1} \; (A_2 = -A_1)$$

Then,

$$M = M_{1S} M_0 M_{1S}^{-1} \qquad M_{1S} = M_1 S_1 M_1^{-1}$$





- Phase advance (S_1- >IP) (vertical) : ψ_1

$$\psi_1 = \frac{\pi}{2}$$

- Transformation of S_1

$$M_1 = \begin{pmatrix} \alpha_y^{S1}\sqrt{\dfrac{\beta_{y0}^*}{\beta_y^{S1}}} & \sqrt{\beta_y^{S1}\beta_{y0}^*} \\ -\dfrac{1}{\sqrt{\beta_y^{S1}\beta_{y0}^*}} & 0 \end{pmatrix}$$

$$M_{1S} = M_1 S_1 M_1^{-1} = \begin{pmatrix} 1 & -A_1\beta_y^{S1}\beta_{y0}^* x_{S1} \\ 0 & 1 \end{pmatrix}$$

- Twiss Parameters @ IP

$$\begin{pmatrix} \beta_{\mathrm{y}}^* & -\alpha_y^* \\ -\alpha_y^* & \gamma_y^* \end{pmatrix} = M_{1S} \begin{pmatrix} \beta_{\mathrm{y0}}^* & -\alpha_{y0}^* \\ -\alpha_{y0}^* & \gamma_{y0}^* \end{pmatrix} M_{1S}^t$$

$$= \begin{pmatrix} \beta_{\mathrm{y0}}^* + \dfrac{\left(A_1\beta_y^{S1}\beta_{y0}^* x_{S1}\right)^2}{\beta_{\mathrm{y0}}^*} & -A_1\beta_y^{S1} x_{S1} \\ -A_1\beta_y^{S1} x_{S1} & \dfrac{1}{\beta_{\mathrm{y0}}^*} \end{pmatrix}$$

- Twiss Parameters (distance s from IP)

$$\begin{pmatrix} \beta_{\mathrm{y}}(s) & -\alpha_y(s) \\ -\alpha_y(s) & \gamma_y(s) \end{pmatrix} = M(s) \begin{pmatrix} \beta_{\mathrm{y}}^* & -\alpha_y^* \\ -\alpha_y^* & \gamma_y^* \end{pmatrix} M^t(s)$$

$$M(s) = \begin{pmatrix} 1 & s \\ 0 & 1 \end{pmatrix}$$

$$\beta_{\mathrm{y}}(s) = \beta_{\mathrm{y0}}^* + \frac{\left(s - A_1\beta_y^{S1}\beta_{y0}^* x_{S1}\right)^2}{\beta_{\mathrm{y0}}^*}$$

- Shift of waist

$$\Delta \mathrm{s} = A_1\beta_y^{S1}\beta_{y0}^* x_{S1}$$

•Phase advance (S_1- >IP) (vertical) : ψ_1

$$\psi_1 = \pi$$

•Transformation of S_1

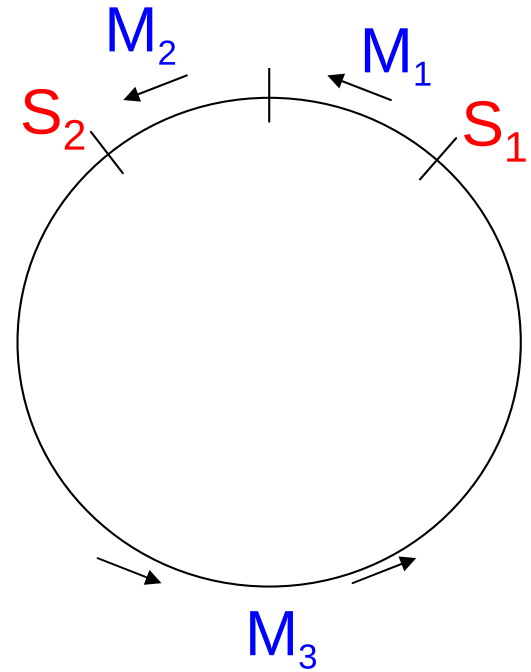
$$M_1 = \begin{pmatrix} -\sqrt{\dfrac{\beta_{y0}^*}{\beta_y^{S1}}} & 0 \\ -\dfrac{\alpha_{y0}^{S1}}{\sqrt{\beta_y^{S1}\beta_{y0}^*}} & -\sqrt{\dfrac{\beta_y^{S1}}{\beta_{y0}^*}} \end{pmatrix}$$

$$M_{1S} = M_1 S_1 M_1^{-1} = \begin{pmatrix} 1 & 0 \\ -A_1 \dfrac{\beta_y^{S1}}{\beta_{y0}^*} x_{S1} & 1 \end{pmatrix}$$

•Twiss Parameters @ IP

$$\begin{pmatrix} \beta_y^* & -\alpha_y^* \\ -\alpha_y^* & \gamma_y^* \end{pmatrix} = M_{1S} \begin{pmatrix} \beta_{y0}^* & -\alpha_{y0}^* \\ -\alpha_{y0}^* & \gamma_{y0}^* \end{pmatrix} M_{1S}^t$$

$$= \begin{pmatrix} \beta_{y0}^* & -A_1 \beta_y^{S1} x_{S1} \\ -A_1 \beta_y^{S1} x_{S1} & \dfrac{1}{\beta_{y0}^*} \end{pmatrix}$$



• Twiss Parameters (distance s from IP)

$$\begin{pmatrix} \beta_y(s) & -\alpha_y(s) \\ -\alpha_y(s) & \gamma_y(s) \end{pmatrix} = M(s) \begin{pmatrix} \beta_y^* & -\alpha_y^* \\ -\alpha_y^* & \gamma_y^* \end{pmatrix} M^t(s)$$

$$M(s) = \begin{pmatrix} 1 & s \\ 0 & 1 \end{pmatrix}$$

$$\beta_y(s) = \beta_{y0}^* + \frac{\left(s - A_1 \beta_y^{S1} \beta_{y0}^* x_{S1}\right)^2}{\beta_{y0}^*} - A_1^2 {\beta_y^{S1}}^2 \beta_{y0}^* x_{S1}^2$$

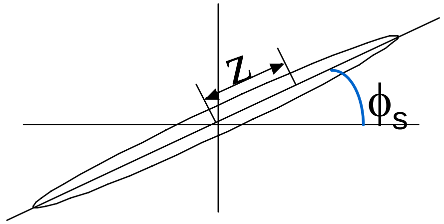
$$\frac{\Delta s^2}{\beta_{y0}^*}$$

• Shift of waist

$$\Delta s = A_1 \beta_y^{S1} \beta_{y0}^* x_{S1}$$

SX strength and phase advance (hor.)

- Traveling focus with crab



- Phase advance (S$_1$-> IP) (hor.): ψ_{1x}

$$\psi_{1x} = n\pi$$

- Crab angle at S_1 : ϕ_S

$$\phi_S = \sqrt{\frac{\beta_x^{S1}}{\beta_x^*}}\phi_c$$

- Required shift of waist

$$\Delta s = \frac{z}{2}$$

$$z\phi_S = x_{S1}$$

$$\frac{x_{S1}}{2\phi_S} = A_1\beta_y^{S1}\beta_y^* x_{S1}$$

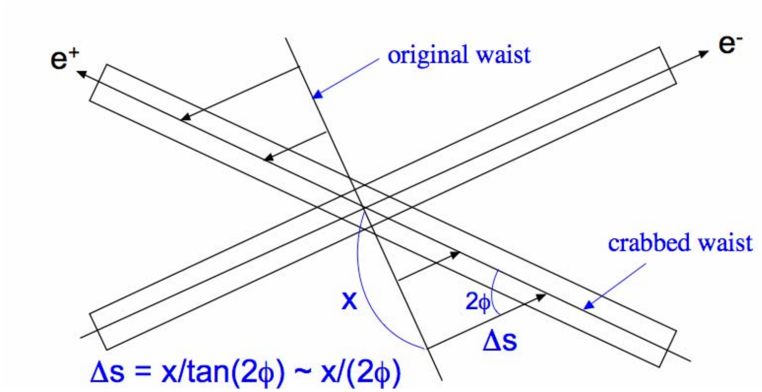
- Required K2 value of S$_1$

$$K2(S1) = A_1 = \frac{1}{2\phi_c}\frac{1}{\beta_y^{S1}\beta_y^*}\sqrt{\frac{\beta_x^*}{\beta_x^{S1}}}$$

same

same

- Crab waist



- Phase advance (S$_1$-> IP) (hor.): ψ_{1x}

$$\psi_{1x} = n\pi$$

- Horizontal Position at S_1 : x_{S1}

$$x_{S1} = \sqrt{\frac{\beta_x^{S1}}{\beta_x^*}}x^*$$

- Required shift of waist

$$\Delta s = \frac{x^*}{2\phi_c} = A_1\beta_y^{S1}\beta_y^* x_{S1}$$

- Required K2 value of S$_1$

$$K2(S1) = A_1 = \frac{1}{2\phi_c}\frac{1}{\beta_y^{S1}\beta_y^*}\sqrt{\frac{\beta_x^*}{\beta_x^{S1}}}$$

Issues

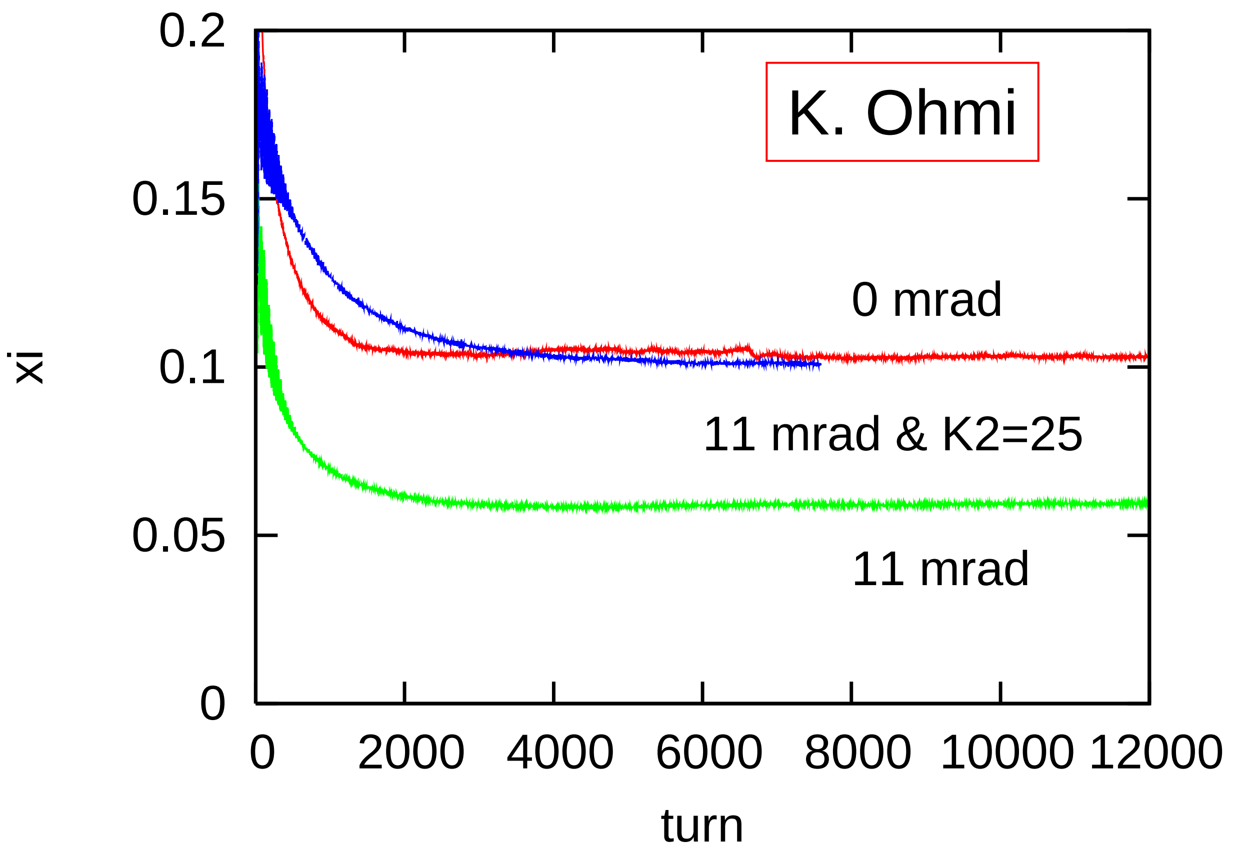
- Effectiveness of the traveling focus and crab waist schemes at KEKB or SuperKEKB
  - Beam-Beam simulation
  - Geometrical luminosity with traveling focus
- Lattice design
  - Studies under way
- Effects of the other nonlinear terms of SX (Sx^3)
  - To be studied
- How to localize SX nonlinearity in the presence of the beam-beam kick
  - To be studied

Effectiveness of waist control on KEKB or SuperKEKB performance

- Results of beam-beam simulations
  - Traveling focus
    - No remarkable improvement in the luminosity (K. Ohmi, Y. Ohnishi)
    - The beam lifetime may be improved.
  - Crab waist
    - With the present KEKB parameters, a remarkable improvement is expected.
    - At SuperKEKB, a higher luminosity would be obtained, if very small β_x^* and β_y^* are realized.

Effect of crab waist at KEKB

- H=25 x p_y^2.



Without crab cavities, a similar luminosity improvement is expected with the crab waist.

Super KEKB (K. Ohmi, F. Tawada)

	SuperKEKB	Crab waist			
εx	9.00E-09	6.00E-09	6.00E-09	6.00E-09	6.00E-09
εy	4.50E-11	6.00E-11	6.00E-11	6.00E-11	6.00E-11
βx (mm)	200	100	50	100	50
βy (mm)	3	1	0.5	1	0.5
σz (mm)	3	6	6	4	4
νs	0.025	0.01	0.01	0.01	0.01
ne	5.50E+10	5.50E+10	5.50E+10	3.50E+10	3.50E+10
np	1.26E+11	1.27E+11	1.27E+11	8.00E+10	8.00E+10
$\phi/2$ (mrad)	0	15	15	15	15
ξx	0.397	0.0418	0.022	0.0547	0.0298
ξy	0.794->0.33	0.1985	0.179	0.178	0.154
Lum (W.S.)	8E+35	6.70E+35	1.00E+36	3.95E+35	4.80E+35
Lum (S.S.)	8.25E35	4.77E35	9E35(ν)	3.94E35	4.27E35

↑ SuperKEKB design

↑ SuperKEKB alternative

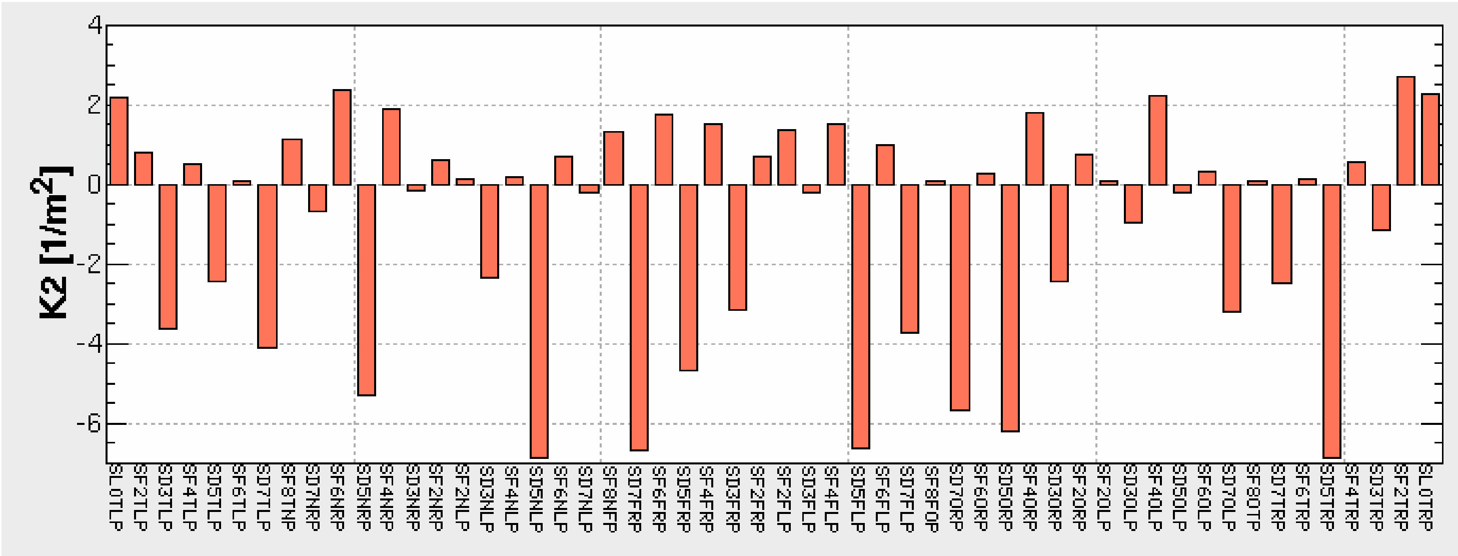
Study of crab waist optics

- Estimation of sextupole strength
- Optics design (under way)
  - Optics requirements
    - Phase advance S_1 -> IP
      - $N\pi$ (horizontal)
      - $(2N+1)/2\ \pi$ (vertical)
    - High β_y and β_x at S_1
    - S_1->S_2: connected with I or -I transformer
  - Dynamic aperture with crab waist
    - To be studied

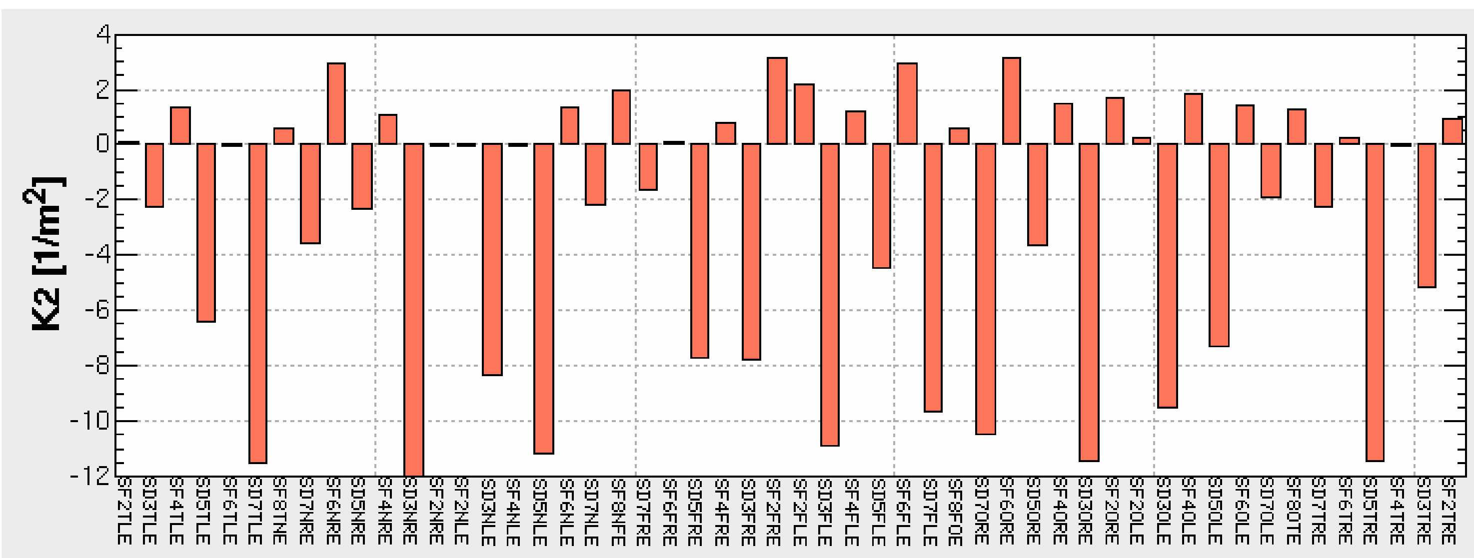
Estimation of SX strength

	KEKB (LER)	SuperKEKB
ϕ_c [mrad]	11	15
β_y^* [mm]	6.5	3
β_y^{S1} [m]	100	100
β_x^* [m]	0.59	0.2
β_x^{S1} [m]	5	5
K2(S1)	27.9	22.2

$$K2 = \frac{B''L}{B\rho}$$

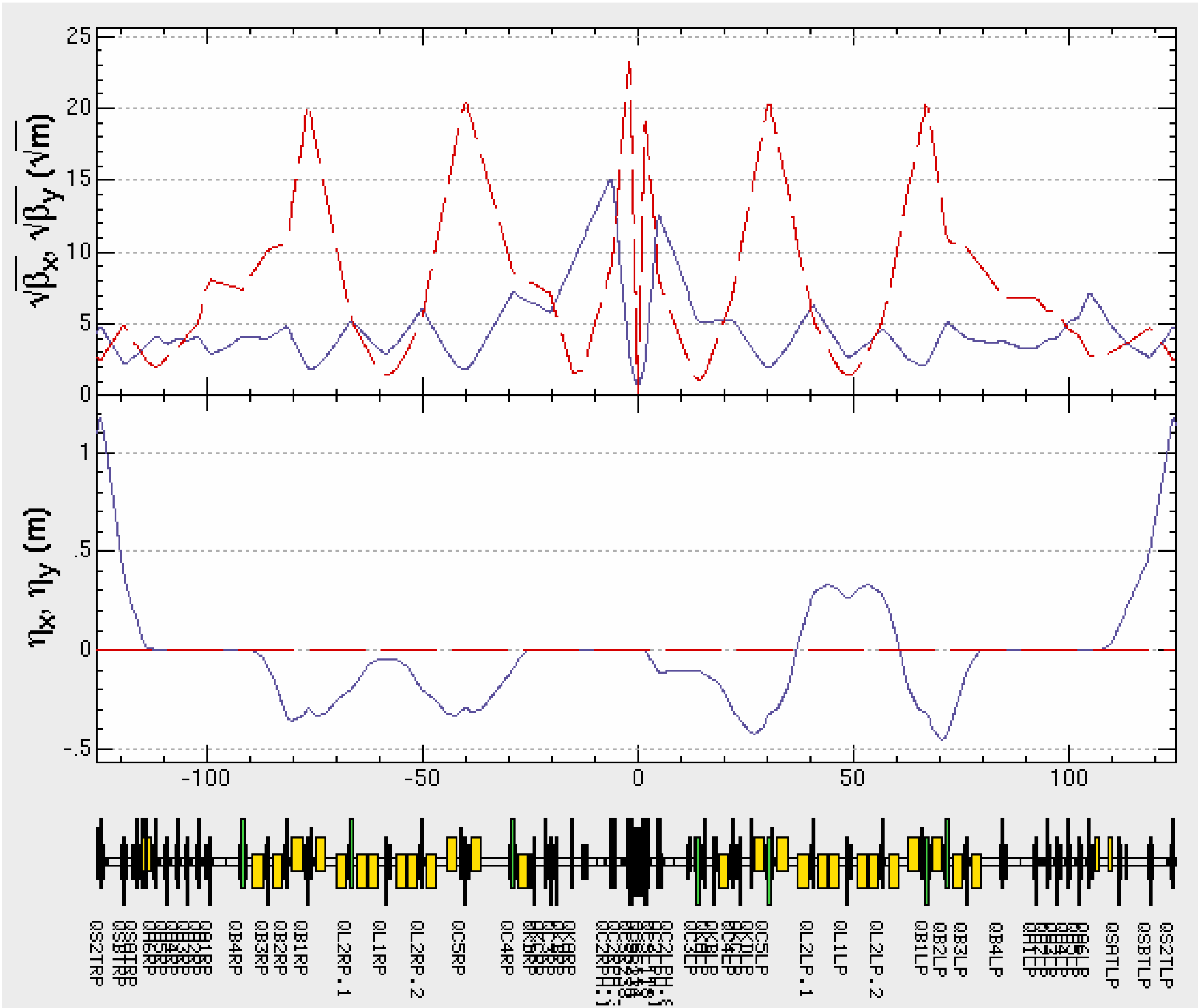

K2 [$1/m^2$]
4
2
0
-2
-4
-6
SL0TLP SF2TLP SD3TLP SF4TLP SD5TLP SF6TLP SD7TLP SF8TNP SD7NRP SF6NRP SD5NRP SF4NRP SD3NRP SF2NRP SF2NLP SD3NLP SF4NLP SD5NLP SF6NLP SD7NLP SF8NFP SD7FRP SF6FRP SD5FRP SF4FRP SD3FRP SF2FRP SF2FLP SD3FLP SF4FLP SD5FLP SF6FLP SD7FLP SF8FOP SD7ORP SF6ORP SD5ORP SF4ORP SD3ORP SF2ORP SF2OLP SD3OLP SF4OLP SD5OLP SF6OLP SD7OLP SF8OTP SD7TRP SF6TRP SD5TRP SF4TRP SD3TRP SF2TRP SL0TRP

LER

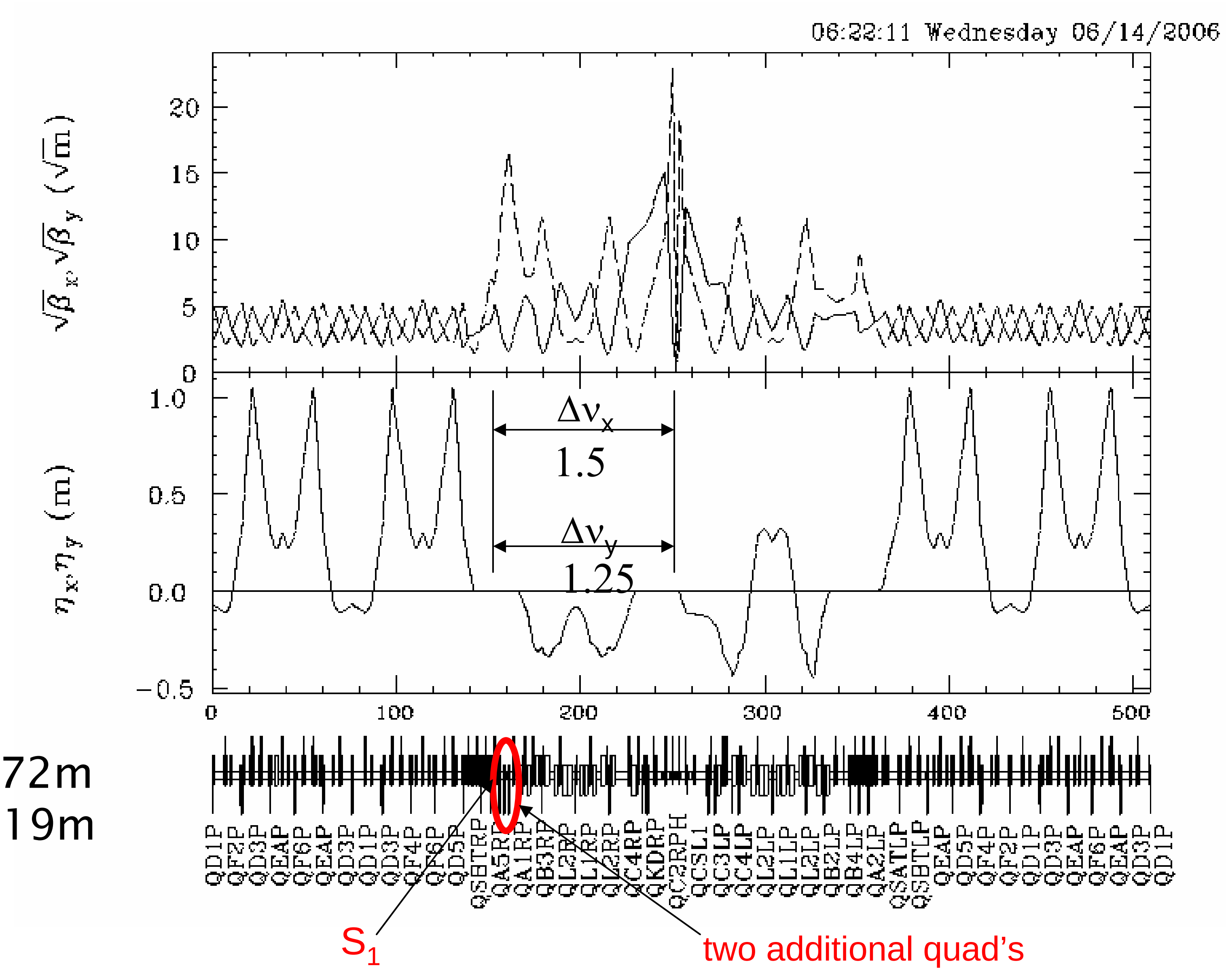

K2 [$1/m^2$]
4
2
0
-2
-4
-6
-8
-10
-12
SF2TLE SD3TLE SF4TLE SD5TLE SF6TLE SD7TLE SF8TNE SD7NRE SF6NRE SD5NRE SF4NRE SD3NRE SF2NRE SF2NLE SD3NLE SF4NLE SD5NLE SF6NLE SD7NLE SF8NFE SD7FRE SF6FRE SD5FRE SF4FRE SD3FRE SF2FRE SF2FLE SD3FLE SF4FLE SD5FLE SF6FLE SD7FLE SF8FOE SD7ORE SF6ORE SD5ORE SF4ORE SD3ORE SF2ORE SF2OLE SD3OLE SF4OLE SD5OLE SF6OLE SD7OLE SF8OTE SD7TRE SF6TRE SD5TRE SF4TRE SD3TRE SF2TRE

HER

KEKB (LER)

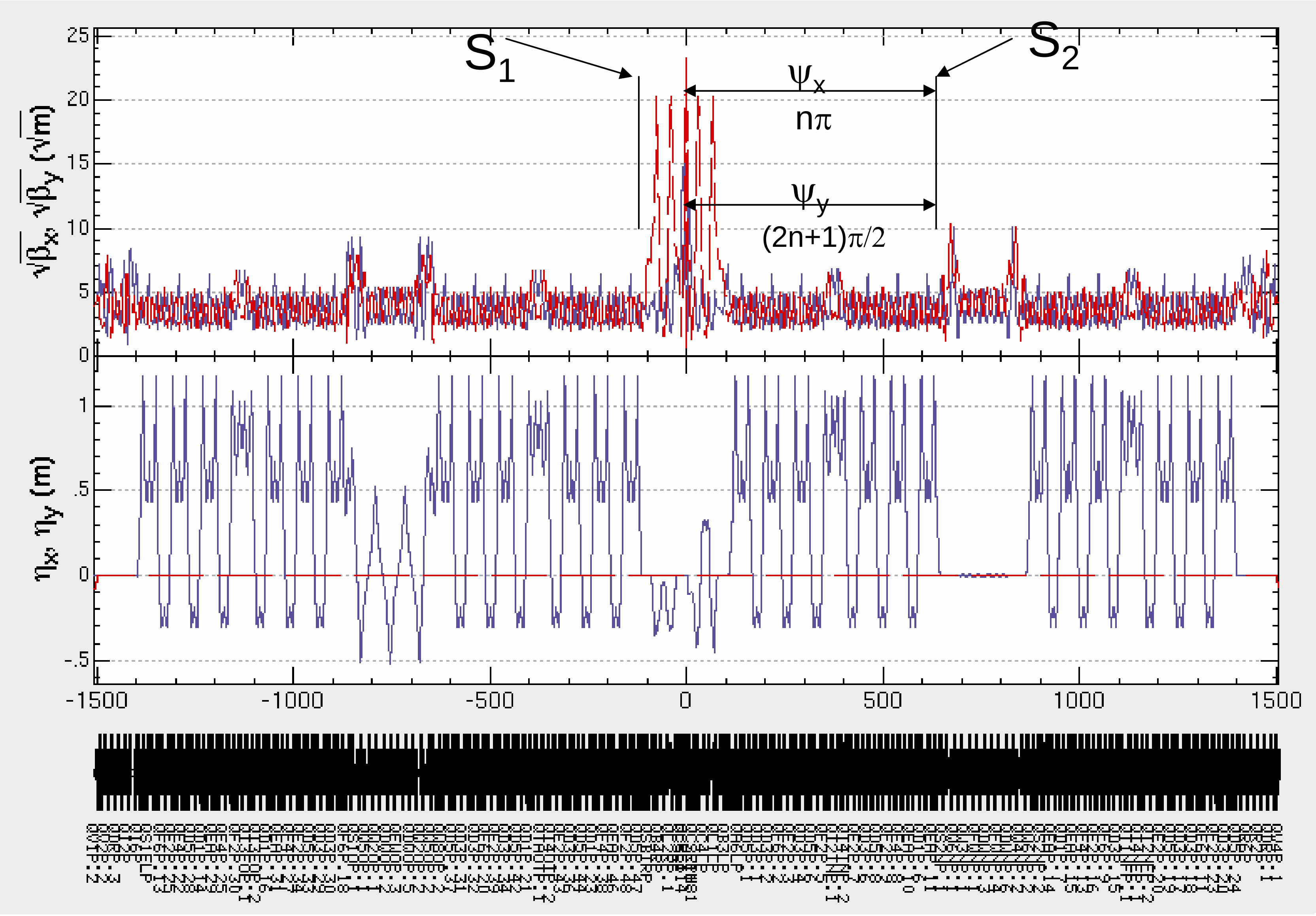


Modified optics (LER) example

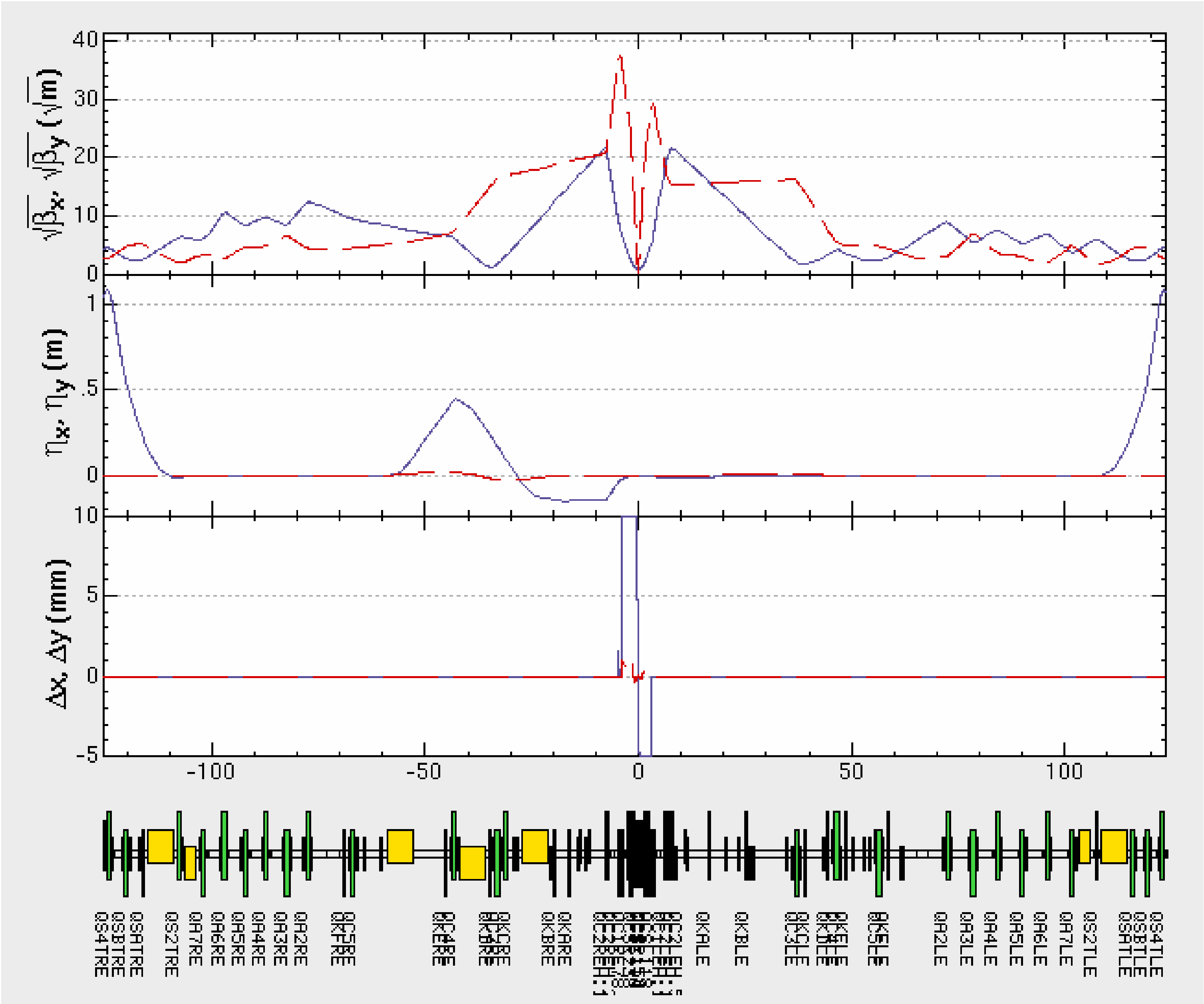


β_y^{S1}=72m
β_x^{S1}=19m

Possible choice of S_2 location



KEKB (HER)



Summary

- A baseline design of SuperKEKB IR has been completed (LoI).
- Dynamic aperture of HER is still marginal and more studies are needed.
- The present design luminosity of 8.3 x 10^{35} is obtained with a combination of head-on collision and horizontal tune of .503.
- With this tune, the physical aperture around IP and SR fan of QCS are serious and without solving these problem, the design luminosity would not be realized.

Summary [cont'd]

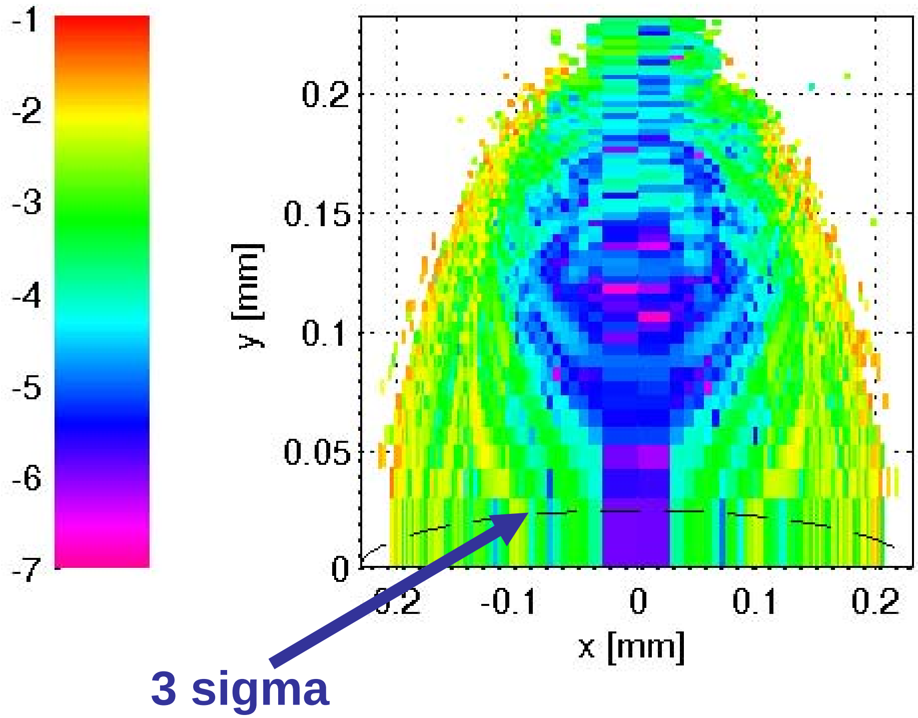
- As new ideas, we have considered two schemes of "traveling focus" and "crab waist".
- The beam-beam simulation showed that a luminosity gain by the traveling focus is small, although the beam lifetime may be improved.
- On the other hand, the luminosity gain from the crab waist seems big even with the present KEKB parameters.
- We are studying the optics of the crab waist and are considering a beam test of this scheme.

Comments on crab waist with very small beta's and emittance

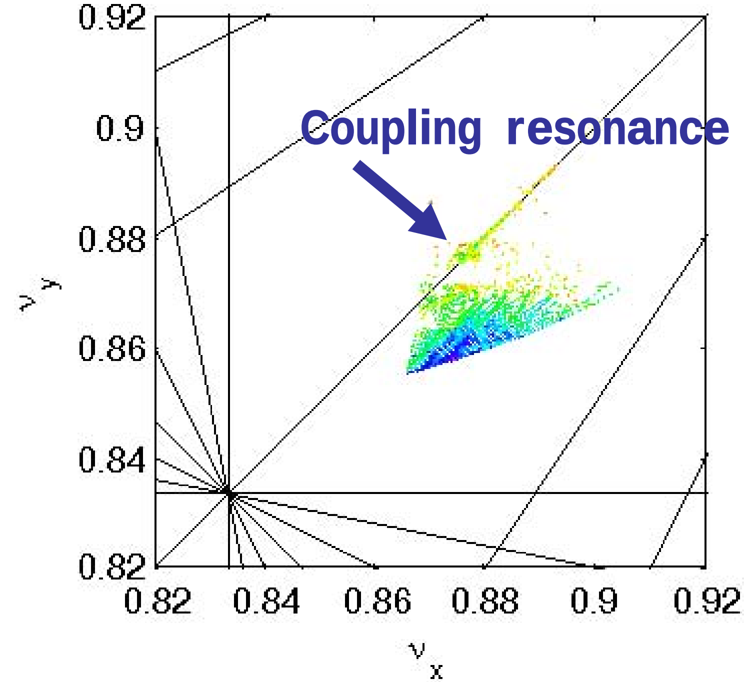
- K. Ohmi's simulation showed that a higher luminosity is obtained by using the crab waist with very small beta's and conventional tunes.
- However, I haven't considered this possibility seriously, since the dynamic (physical) aperture problem seemed serious.
- M. Biagini's talk showed that the dynamic aperture issue is within a range of study if combined with very small emittance.
  - More studies on dynamics aperture issue are needed.
    - Optimization of various parameters
    - Injection scheme
    - Effects of machine errors (and beam-beam)
- We will consider the crab waist scheme as an alternative option of SuperKEKB.

Dynamic aperture for “ideal” lattice with FF (3 Km, 7 GeV)

A. Wolski



Coordinate space



Tune space

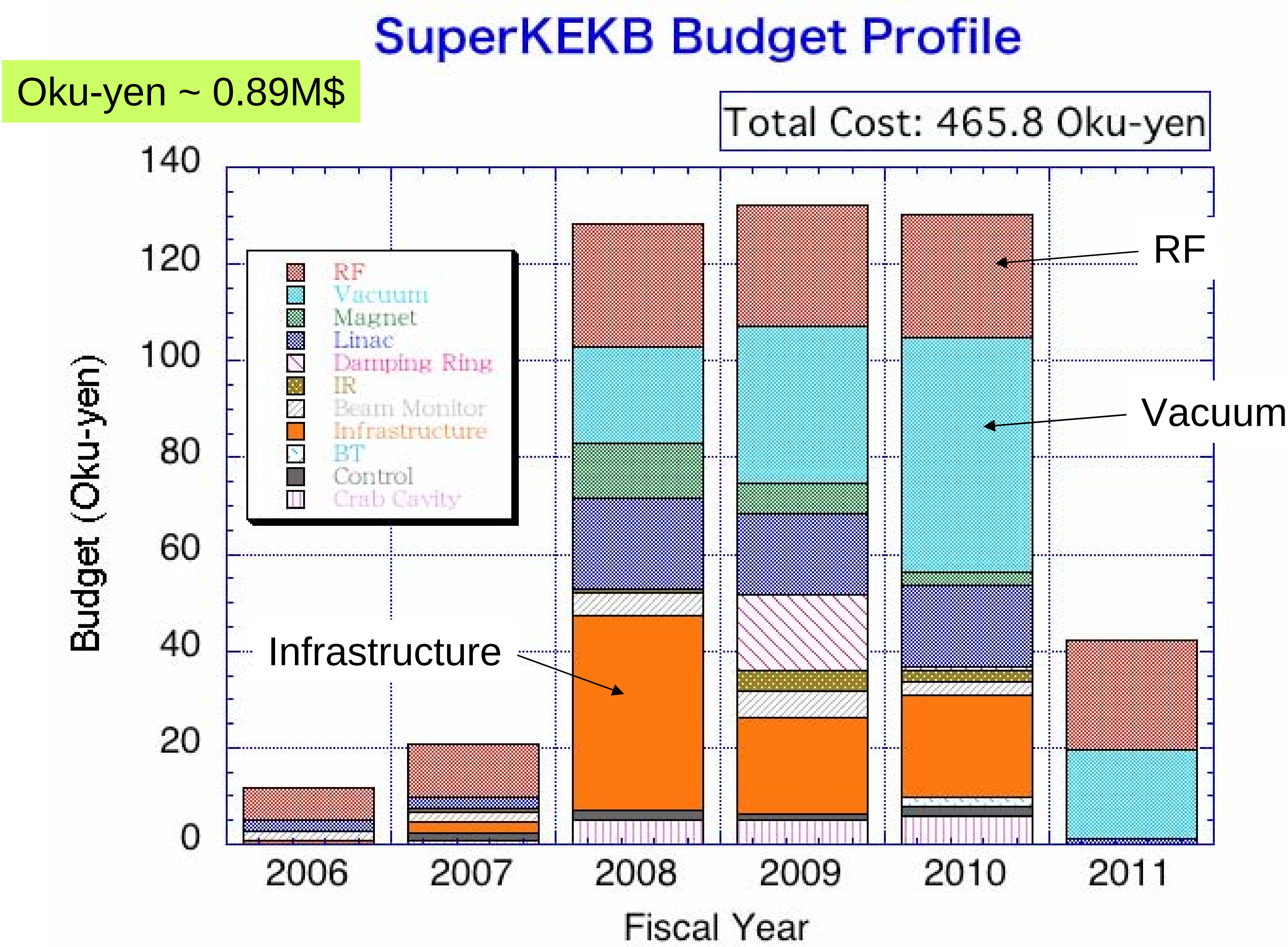
Frequency map analysis, sextupoles tuned for 0 chromaticity

	SBF 4 GeV	*SBF 7 GeV*
C (m)	3251.	3251.
B_w (T)	1.4	1.4
L_{bend}(m)	5.6	10.6
N. bends	96	96
B_{bend} (T)	0.155	0.144
Uo (MeV/turn)	4.4	6.4
N. wigg. cells	8	4
τ_x (ms)	19.8	24.
τ_s (ms)	10.	12.
ε_x (nm)	0.38	0.565
σ_E	1.1×10^{-3}	1.32×10^{-3}
I_{beam} (A)	2.5	1.4
P_{beam}(MW)	11.	9.

M. Biagini

cm $\sigma_E = 0.85 \times 10^{-3}$

Total Wall Power (60% transfer eff.): 32 MW



SuperKEKB Budget Profile
Oku-yen ~ 0.89M$
Total Cost: 465.8 Oku-yen
Budget (Oku-yen)
140
120
100
80
60
40
20
0
RF
Vacuum
Magnet
Linac
Damping Ring
IR
Beam Monitor
Infrastructure
BT
Control
Crab Cavity
RF
Vacuum
Infrastructure
2006
2007
2008
2009
2010
2011
Fiscal Year

Spare slides

Fan of SR

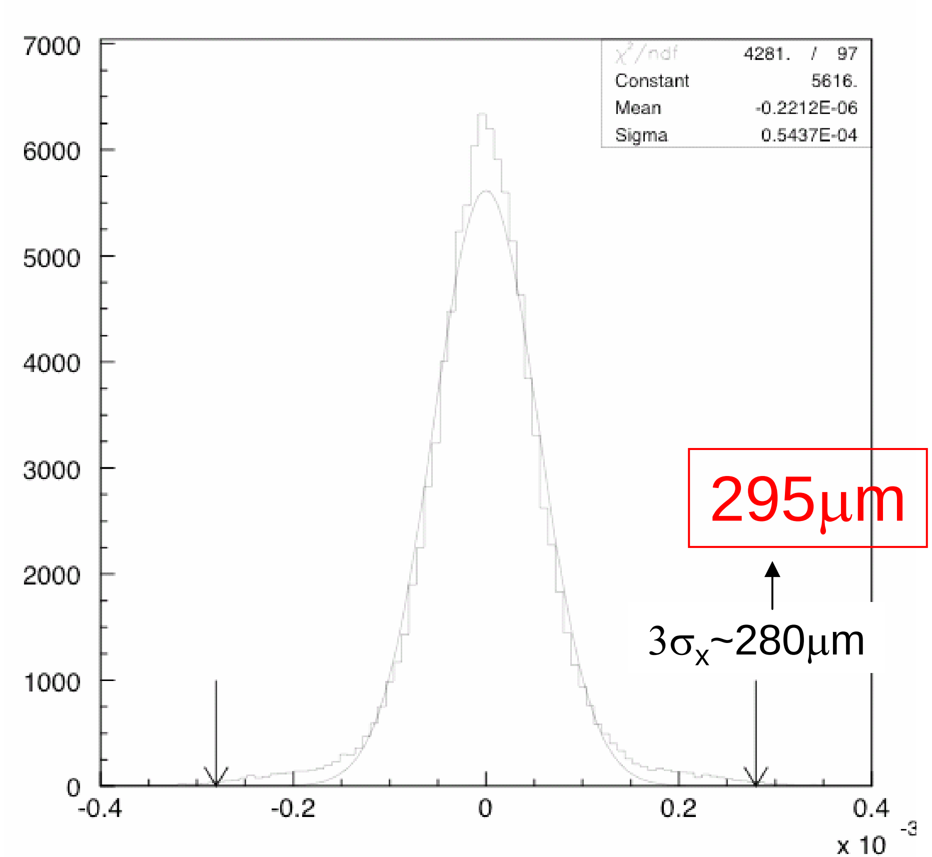
- Consideration of the particle distribution in the phase space
- Effects of dynamic-β and dynamic-emittance
  - These effects are very large with the horizontal tune very close to the half integer.
- We took $9\varepsilon_x$ ($3\ \sigma_x$, $3\sigma_{x'}$) into consideration.

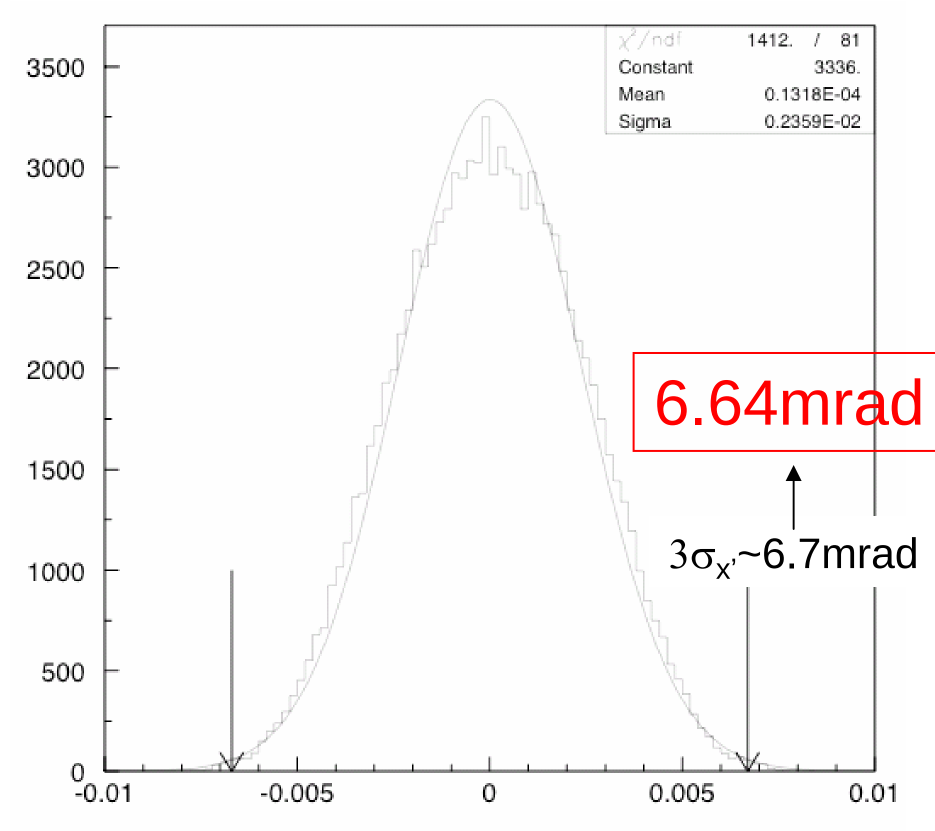
Enlargement of SR fan due to dynamic effects

	without dynamic effects		with dynamic effects	
Source point	QCSRE(Arc side) HER	QCSLE(Arc side) LER	QCSRE(Arc side) HER	QCSLE(Arc side) LER
Observation point	Exit of QC1RE	Exit of QC1LE	Exit of QC1RE	Exit of QC1LE
ε_x[nm]	24		58	
γ_x^* $(1/\beta_x^*)$ [/m]	5		22.5	
Distance from a source point [m]	2.87	1.94	2.87	1.94
Δx[mm] COD	5.2	5.5	5.2	5.5
Δx[mm] $3\sigma_x$, $3\sigma_{x'}$	5.1	5.4	17.7	18.3
Δx[mm] Total	10.3	10.9	22.9	23.8

$\xi_x = 0.1$, $\nu_x = .510$

IP σ_x, $\sigma_{x'}$ from beam-beam simulation (Ohmi, Ohnishi)





$\beta_x=(3\sigma_x)/(3\sigma_{x'}) \sim 4.18\text{cm}$

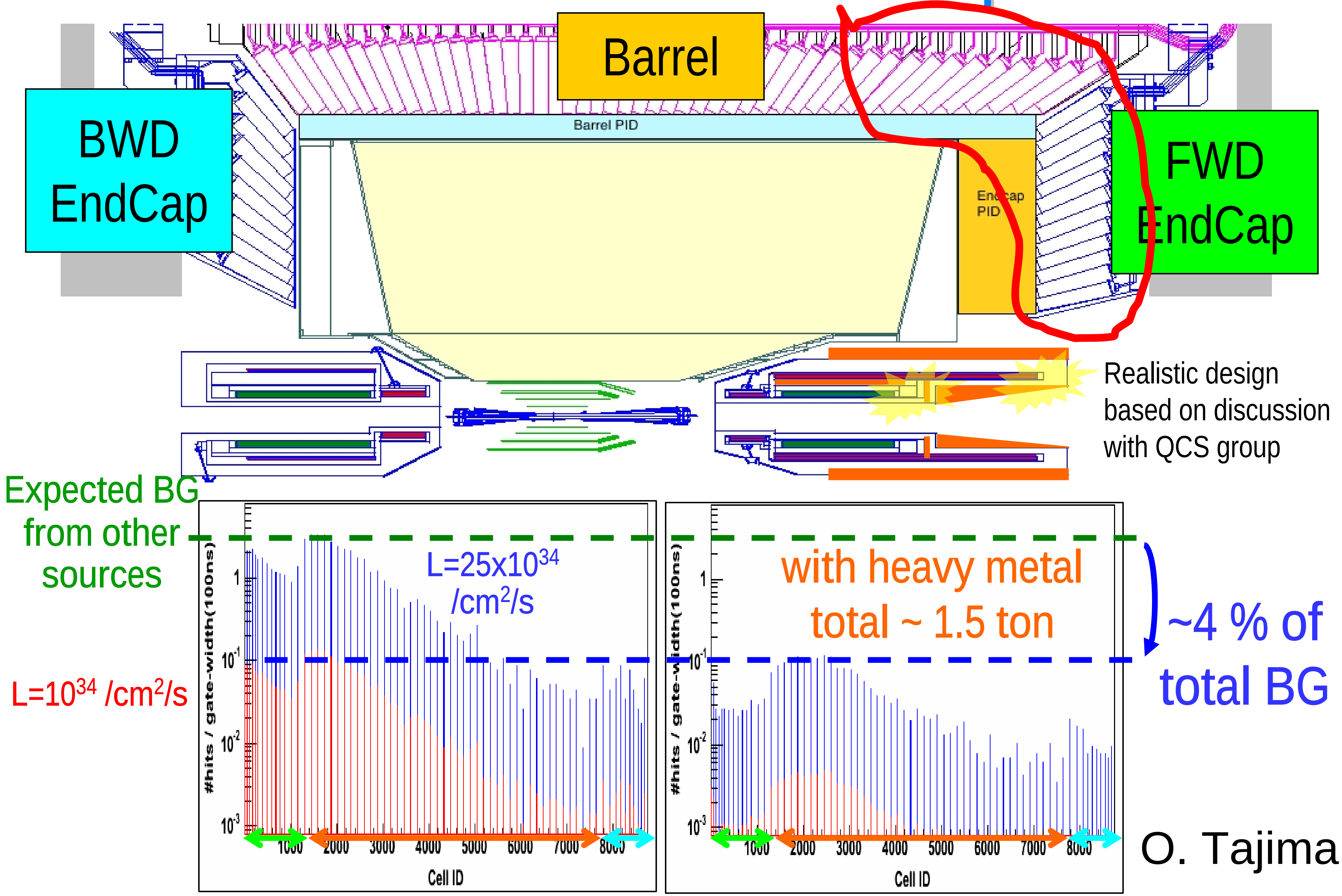
$9\varepsilon_x=(3\sigma_x)*(3\sigma_{x'}) \sim 1.88\mu\text{m}$

$\beta_x=\sigma_x/\sigma_{x'} \sim 2.30\text{cm}$

$\varepsilon_x=\sigma_x*\sigma_{x'} \sim 0.128\mu\text{m}$

$3\sigma_{x'} \sim 7.46\mu\text{m}$

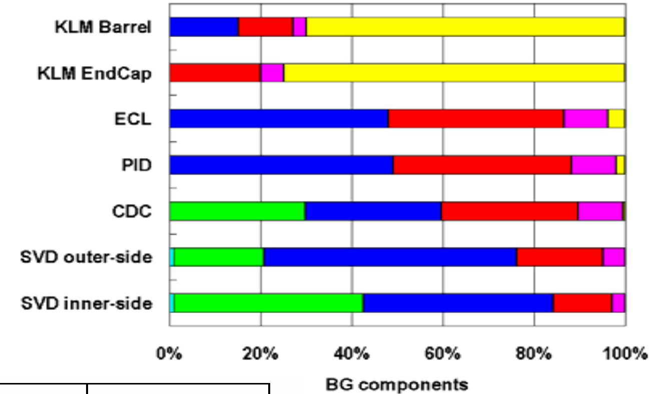
Rad. Bhabha BG sim. for Super-KEKB

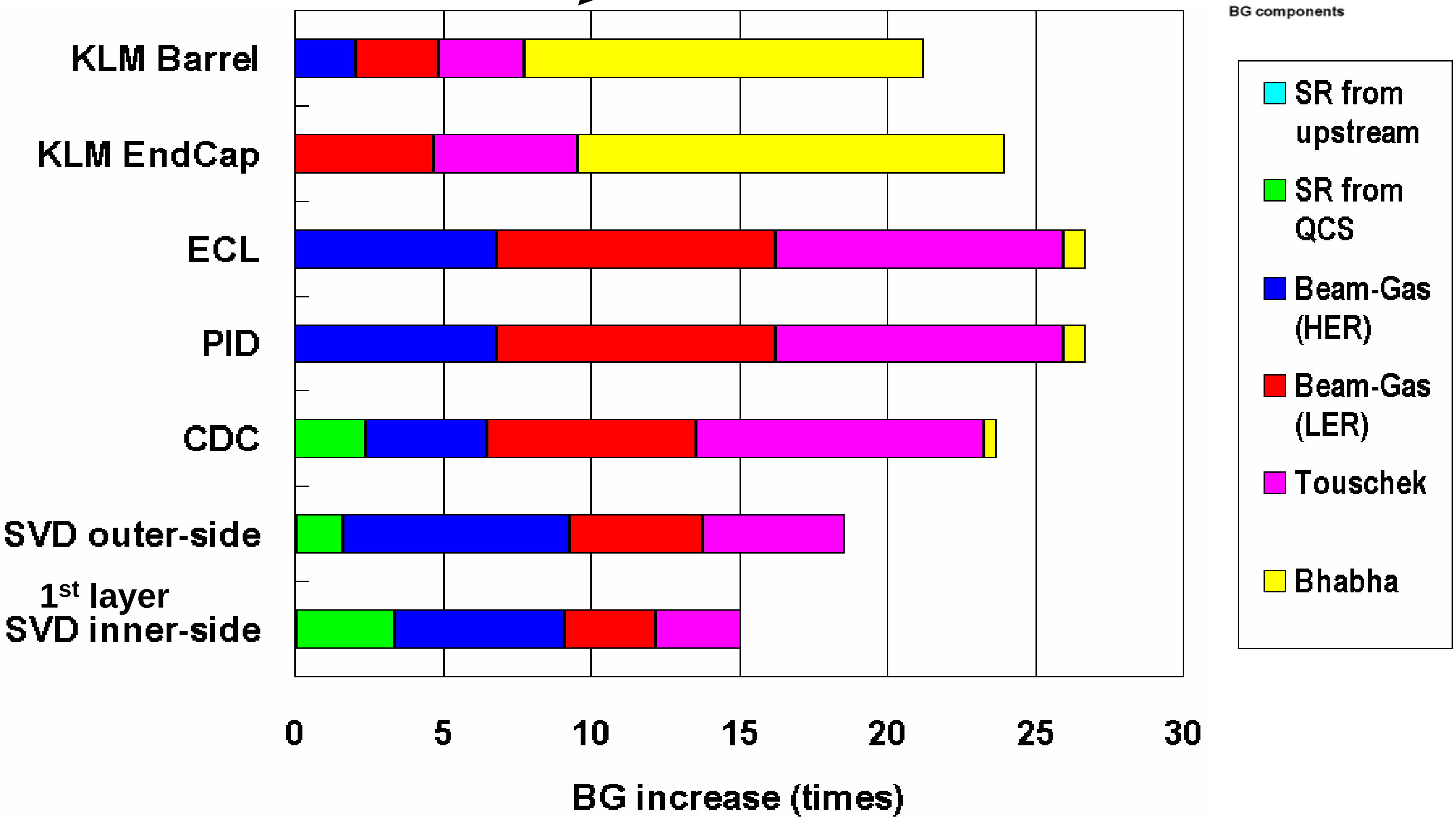


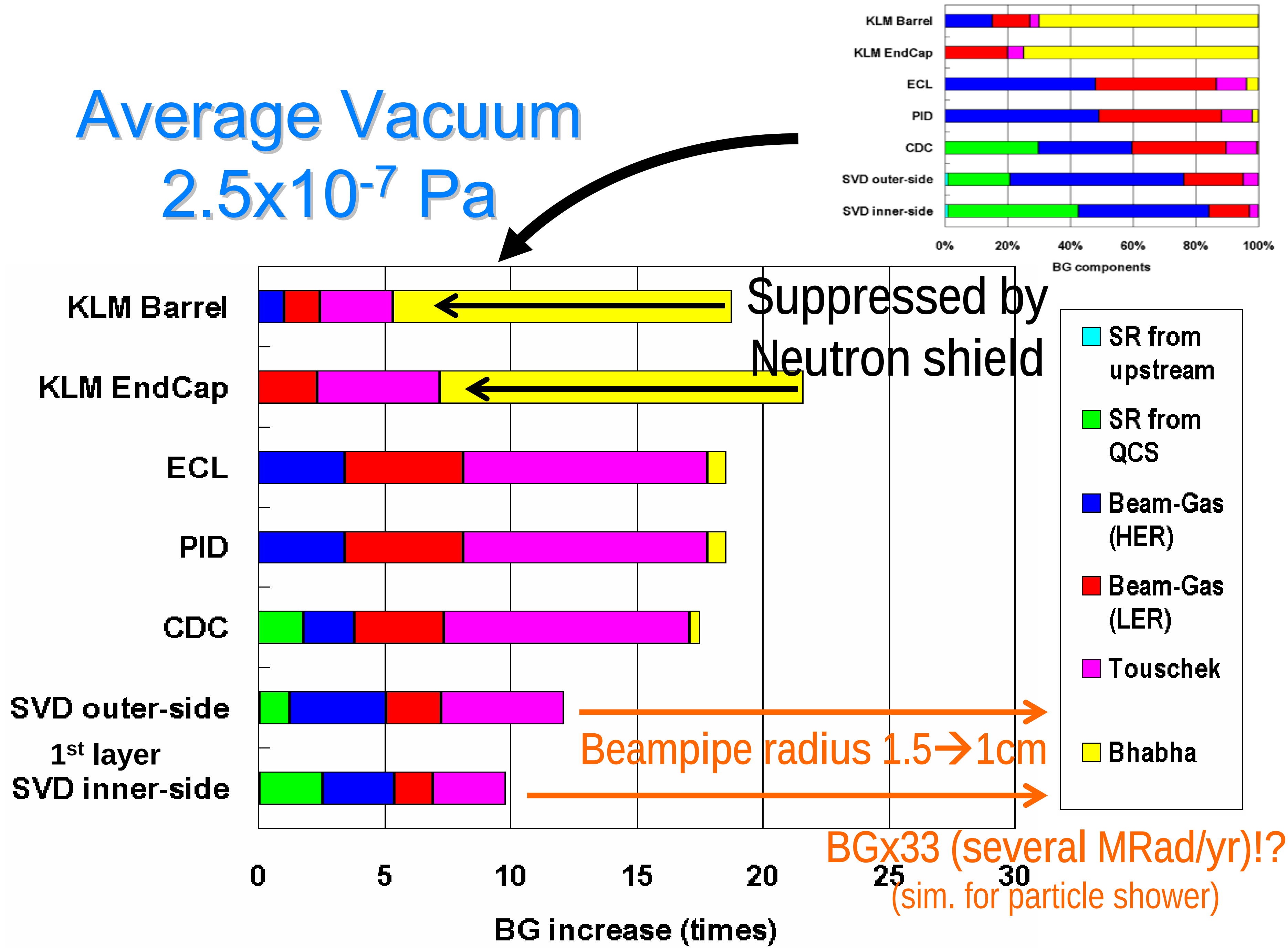
O. Tajima

Super-KEKB (current) design

Average Vacuum
5×10^{-7} Pa







Average Vacuum
2.5x10-7 Pa
KLM Barrel
KLM EndCap
ECL
PID
CDC
SVD outer-side
SVD inner-side
0%
20%
40%
60%
80%
100%
BG components
Suppressed by
Neutron shield
SR from upstream
SR from QCS
Beam-Gas (HER)
Beam-Gas (LER)
Touschek
Bhabha
1st layer
Beampipe radius 1.5→1cm
BGx33 (several MRad/yr)!?
(sim. for particle shower)
0
5
10
15
20
25
30
BG increase (times)

Summary

- Backscattering of QCS-SR is not serious, but strongly depends on IR chamber configuration
- Vacuum level is very important
  - Original design (5×10^{-7} Pa) is serious → BGx25
  - w/ further effort (2.5×10^{-7} Pa) → BGx18 ← **-30%**
- Increasing of Touschek origin BG
  - Smaller bunch size & higher bunch currents are reason
  - Might be reduced by further study
- Radiative Bhabha origin BG can be suppressed
- Beampipe radius 1.5cm → 1cm
  - Further simulation study of shower particles into SVD is important

From KEKB to SuperKEKB
Synchrotron Radiation (SR) (2)

KEKB

- The exact path of the SR from QCS and its spread were not strictly taken into account in the first design.
- This caused a high temperature at unexpected portions of a vacuum chamber.
  - Deformation of vacuum chamber
  - Motion of magnets.

SuperKEKB

- The design of QC magnets in the LoI looks trying to give a sufficient clearance for the SR down to QC2.
- The design of the beam duct layout also tried to avoid the SR.
- However, the design should be checked against the fact that the two beams and the SR don’t lie in the same plane.

From KEKB to SuperKEKB
Detector Background

KEKB

- Back scattering of the SR from QCS by a HER Al beam duct became a noise source. (Cu has a smaller cross section of the back scattering than that of Al.)
- Shields against the detector background should have been incorporated from the first design.

SuperKEKB

- Chamber material: Cu (cooling, shielding, small back scatter of SR)
- Beam ducts avoid the SR down to 8m (HER downstream) and 5m (LER downstream) from IP.
- Shield should be taken into consideration from the first design.

From KEKB to SuperKEKB
Higher Order Mode (HOM) (1)

KEKB

- The HOM power turned into heat in IR is, in the unit of the loss factor, around 474 V/nC. (Estimated from the temperature rise of cooling water)
- Heat up of the bellows will be unacceptable level in Super KEKB

SuperKEKB

- Extrapolation from KEKB gives as a heat by HOM about 100kW $\times$(bunch length factor).
- Is the compact HOM absorber possible?
- The cooling for HOM will be a big problem.
- The comb type bellows is expected to be durable.

QCS offset

QCSR: 1/2 (LER/HER)

QCSL: 2/1 (LER/HER)