Super B Factories

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Outline

- Two possible approaches to achieve L~10^{36}.
  - SuperKEKB (upgraded machine of KEKB)
  - SuperB(synergy with ILC)

- SuperKEKB
  - proposed at KEK

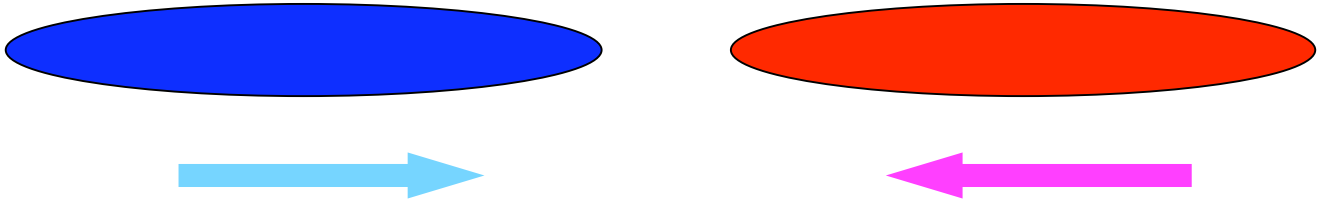
- SuperB
  - proposed at LNF/INFN, SLAC, etc.

- Summary

Two Approaches to achieve L~10^{36}

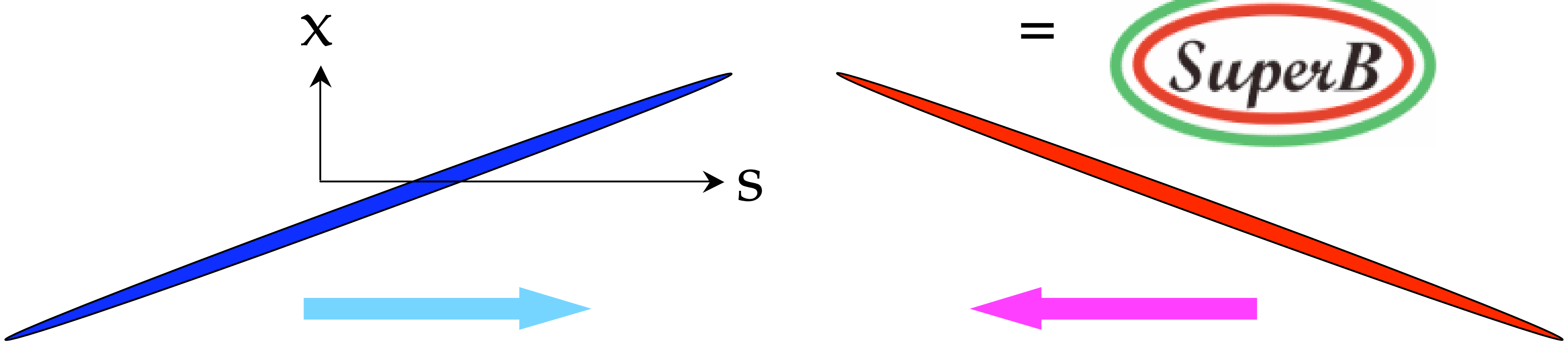
- Ultra-High current, Ultra-High beam-beam parameter, Low beta = Super KEKB Quest for BSM

Crab-crossing



"Ultra-high current scheme"

- Ultra-Low emittance, Ultra-Low beta, Low current = SuperB



"Nano-beam scheme"

Luminosity

- Luminosity can be expressed by the formula:

$$L = \frac{N_+ N_- f}{4\pi\sigma_x^* \sigma_y^*}$$

* means value at IP

- However, we do not use above formula for the machine design. Instead an alternative formula is used.

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

$$\propto \frac{I_{e\pm}\xi_{ye\pm}}{\beta_y^*}$$

(flat-beam case)

- This describes L in terms of the lattice parameter β_y*, beam-beam parameter ξ_y, eliminating the explicit dependence on beam size.

Luminosity (cont'd)

$$L \propto \frac{I_+ \xi_y}{\beta_y^*} \qquad \xi_x \propto \frac{I_-}{\varepsilon_x\left(1+\Phi^2\right)} \qquad \xi_y \propto \frac{I_-}{\sqrt{\varepsilon_x \beta_x^* \left(1+\Phi^2\right)}}\sqrt{\frac{\beta_y^*}{\varepsilon_y}}$$

Piwinski angle: $\Phi \cong \dfrac{\sigma_z \phi_x}{\sqrt{\varepsilon_x \beta_x^*}}$ ϕ_x is half crossing angle

(1) $\Phi < 1$ (SuperKEKB)

$$L \propto \frac{I_+ I_-}{\sqrt{\varepsilon_x \beta_x^* \varepsilon_y \beta_y^*}}$$

$$\xi_x \propto \frac{I_-}{\varepsilon_x}$$

$$\xi_y \propto \frac{I_-}{\sqrt{\varepsilon_x \beta_x^*}}\sqrt{\frac{\beta_y^*}{\varepsilon_y}}$$

- If $\varepsilon_y \beta_y^* \to 0$ while keeping ξ_x and ξ_y constant, $L \to \infty$.
- But $\beta_y^* \geq \sigma_z \neq 0$ (hourglass effect) and $\beta_y^* / \varepsilon_y$ is constant, then L cannot go to ∞.

⬇

- New technique is necessary.
- If $\nu_x \to +0.5$, then $\xi_y \to \infty$ and $L \to \infty$ with increasing I.

"Ultra-high current scheme"

Luminosity (cont'd)

$$L \propto \frac{I_+\xi_y}{\beta_y^*} \qquad \xi_x \propto \frac{I_-}{\varepsilon_x\left(1+\Phi^2\right)} \qquad \xi_y \propto \frac{I_-}{\sqrt{\varepsilon_x\beta_x^*\left(1+\Phi^2\right)}}\sqrt{\frac{\beta_y^*}{\varepsilon_y}}$$

Piwinski angle: $\Phi \cong \frac{\sigma_z\phi_x}{\sqrt{\varepsilon_x\beta_x^*}}$ ϕ_x is half crossing angle

(2) Φ >> 1 (SuperB)

$$L \propto \frac{I_+I_-}{\sigma_z\phi_x\sqrt{\varepsilon_y\beta_y^*}}$$

$$\xi_x \propto \frac{I_-\beta_x^*}{\left(\sigma_z\phi_x\right)^2}$$

$$\xi_y \propto \frac{I_-}{\sigma_z\phi_x}\sqrt{\frac{\beta_y^*}{\varepsilon_y}}$$

- If $\varepsilon_y\beta_y^*\rightarrow 0$ while keeping ξ_x and ξ_y constant, L→∞.
- β_y^* is not limited by $\sigma_z \neq 0$.

$$\beta_y^* \geq \frac{\sqrt{\varepsilon_x\beta_x^*}}{2\phi_x}$$

- If $\varepsilon_y\beta_y^*\rightarrow 0$ while $\beta_x^*,\ \beta_y^*/\varepsilon_y,\ \sqrt{\varepsilon_x}/\beta_y^*$ remain constant, then L can go to ∞.

"Nano-beam scheme"

SuperKEKB

KEK, Tsukuba, Japan

Strategy of SperKEKB

- Target luminosity is 8 x 10^{35} $cm^{-2}s^{-1.}$

- We will use components of KEKB as much as possible
  - magnets, klystrons, tunnel, existing facilities, ...
- Continuous injection and a powerful injection system is necessary.
  - We have considerable experience with the continuous injection, which has been operated successfully at KEKB.

- Ultra-High beam current is a standard concept.
  - RF system for SuperKEKB; ARES and SCC modified to store 9.1 A(LER) and 4.1 A(HER).
  - Electron cloud is the most important issue in the positron ring.
  - Fast ion and CSR, and other collective effects should be evaluated.
  - Ante-chamber, vacuum bellows for chamber connection, HOM absorbers are considered.
- Low beta function at IP to improve luminosity
  - Interaction region(IR) should be designed to satisfy requirements of low beta at IP, physical and dynamic aperture, SR, detector backgrounds, etc.
- Finite crossing and crab crossing scheme is feasible for Ultra-high beam-beam parameter.

Luminosity Improvement

- High Current Scheme -

Beam current

1.8/1.35 A (KEKB)→ 9.4/4.1 A (SuperKEKB)

It correlates with many things.

Beam-beam parameter

(Strength of interaction between colliding beams)

0.056 (KEKB)→ 0.4 (SuperKEKB)

Limited by beam-beam effect

Lorentz factor

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

Geometrical factor due to hour-glass effect and crossing angle
0.8 ~ 1 (short bunch)

Classical electron radius

Beam size ratio
1 ~ 2 % (flat beam)

Vertical beta function at IP

(Focal depth)

6 mm (KEKB)
→ 3 mm (SuperKEKB)

Limited by bunch length

Luminosity

1.7×10^{34} cm^{-2}s^{-1} (KEKB)
→ 8×10^{35} cm^{-2}s^{-1} (SuperKEKB)

Bunch length ($\sigma_z < \beta_y^*$)
5~6 mm (KEKB)→ 3 mm (SuperKEKB)

Limited by HOM, CSR

Luminosity is proportional to

- beam currents,
- beam-beam parameter,
- inverse of vertical beta function at IP.

SuperKEKB Machine Parameters

SuperKEKB			
Emittance	ε_x	9*	nm
	ε_y	0.045	nm
Beta at IP	$\beta_x{}^*$	200	mm
	$\beta_y{}^*$	3	mm
Beam size at IP	$\sigma_x{}^*$	42	μm
	$\sigma_y{}^*$	367	nm
Bunch length	σ_z	3	mm
Synchrotron tune	ν_s	0.025	
Beam current	I_+/I_-	9.4/4.1	A
#bunches	N_b	5000	
Crossing angle	$2\phi_x$	30 → 0 (crab crossing)	mrad
Beam-beam	ξ_x	0.209	
	ξ_y	0.405	
Luminosity	L	$8\text{x}10^{35}$	$\text{cm}^{-2}\text{s}^{-1}$

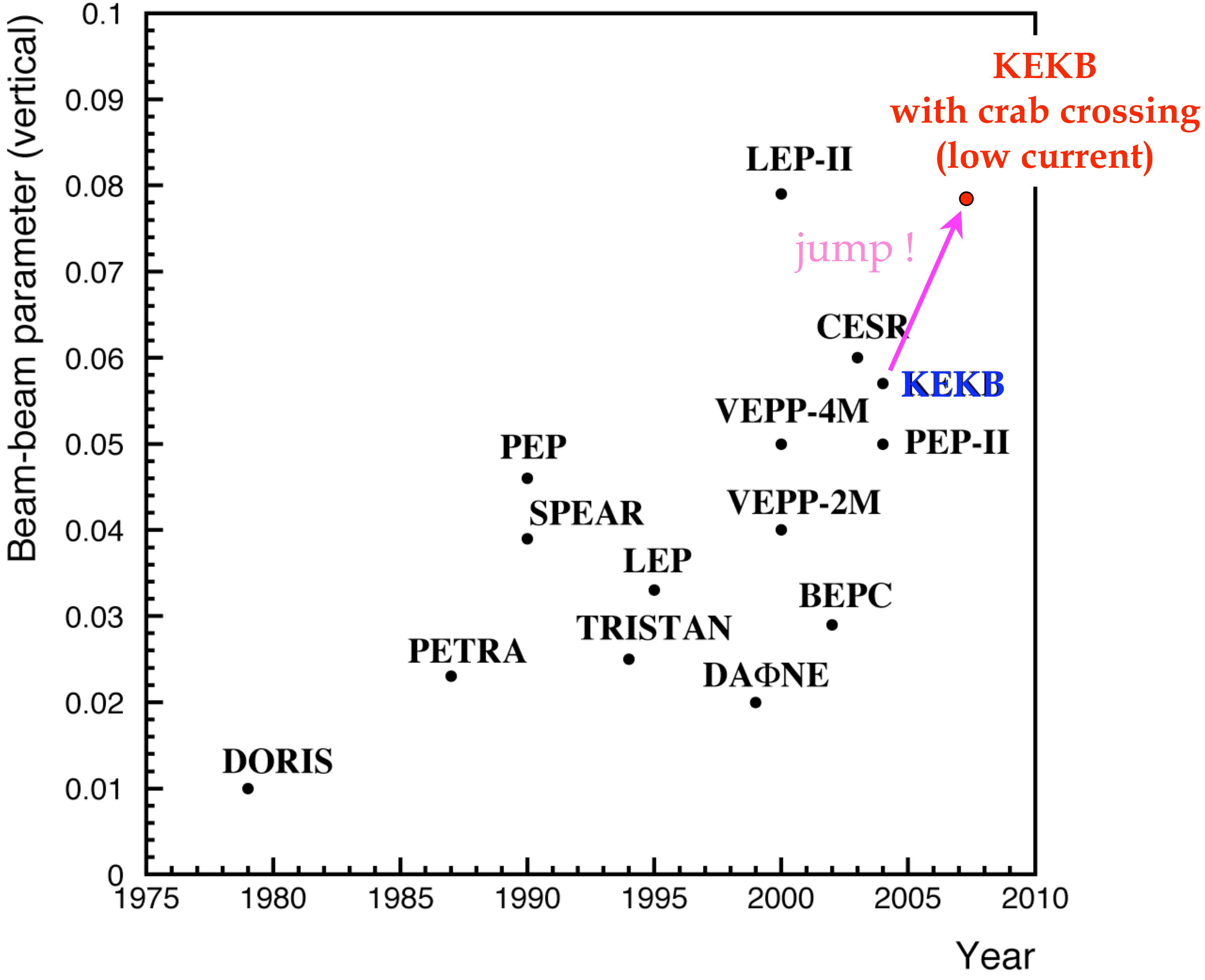
* 24 nm emittance is one of the options because low emittance might be difficult because of beam dynamics issues.
Magnet configuration is same due to lattice flexibility.
In that case, luminosity goes down to $4\text{x}10^{35}$ $\text{cm}^{-2}\text{s}^{-1}$.

Crab Cavities

LER (3.5 GeV, positron)

HER (8 GeV, electron)

History of Beam-beam Parameters



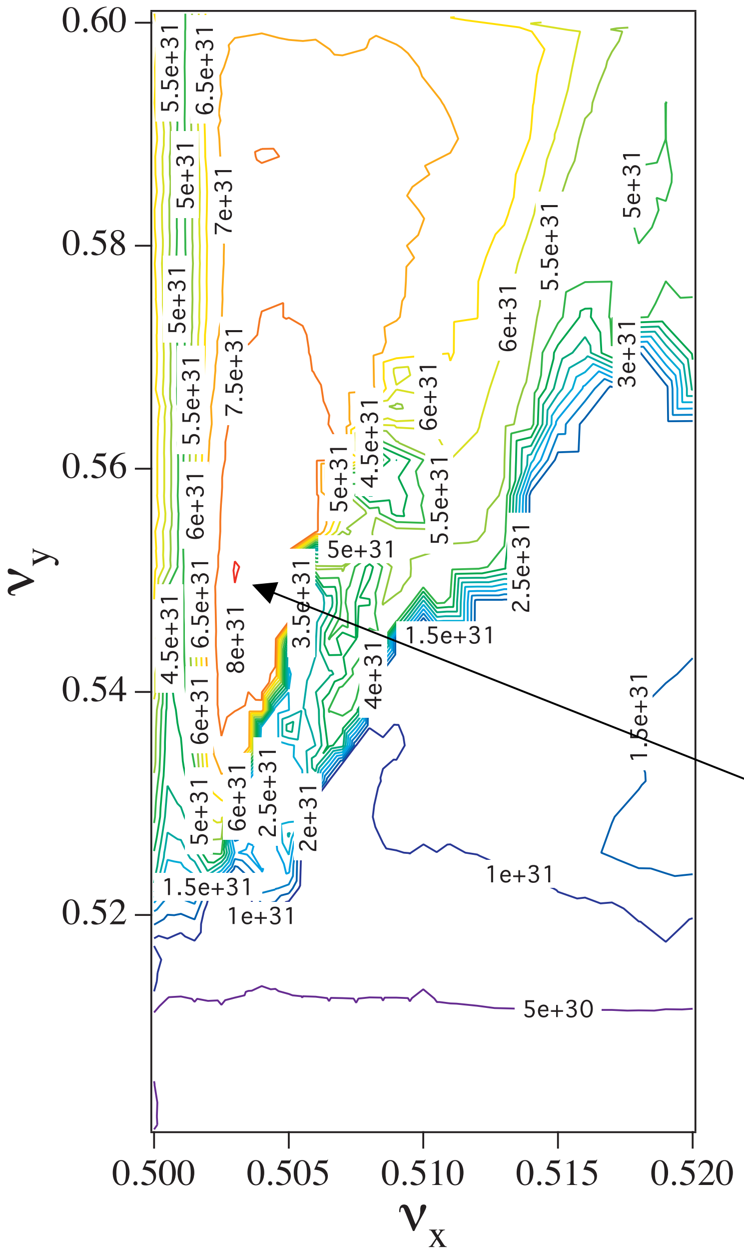
Crab Cavity at KEKB

- Crab crossing was done first at KEKB. Effective head-on collision was basically achieved.

- The highest vertical beam-beam parameter is about ~0.08 so far, which is a little higher than the geometrical gain due to head-on. Expected value is ~0.1.

- Crab cavity operation is still in the tuning phase. High gain in the luminosity needs more time for tuning and development of the method.

Tune Scan with Beam-beam Simulation



Tune Survey in SuperKEKB without parasitic collision effect.

ε_x=24 nm case:

$L_{peak}=4.0\mathrm{x}10^{35}\ \mathrm{cm}^{-2}\mathrm{s}^{-1}$

(L/bunch=$8.0\mathrm{X}10^{31}$, N_b=5000)

Head-on

Betatron tunes

(.503, .550)

}

Beam-beam parameter

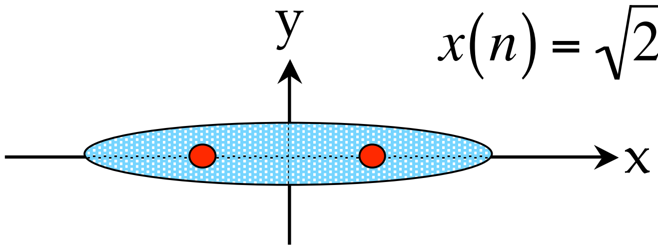
ξ_y ~0.2

Better working point is very close to the half integer !

Simulation by K. Ohmi and M. Tawada

Horizontal Tune close to Half Integer ν_x=0.5

- In the collision of two beams, particles interact with fixed beam at either x or -x for ν_x=0.5.



$$x(n)=\sqrt{2J_x\beta_x}\cos(2\pi\nu_x n+\psi_{x0})$$

n: turn number (integer)

- In the case of crab crossing, the phase space structure in y-p_y at x is the same as that at -x because of symmetry of the fixed beam.

- System becomes one dimensional and avoids bad resonances, the beam-beam parameter can be increased.

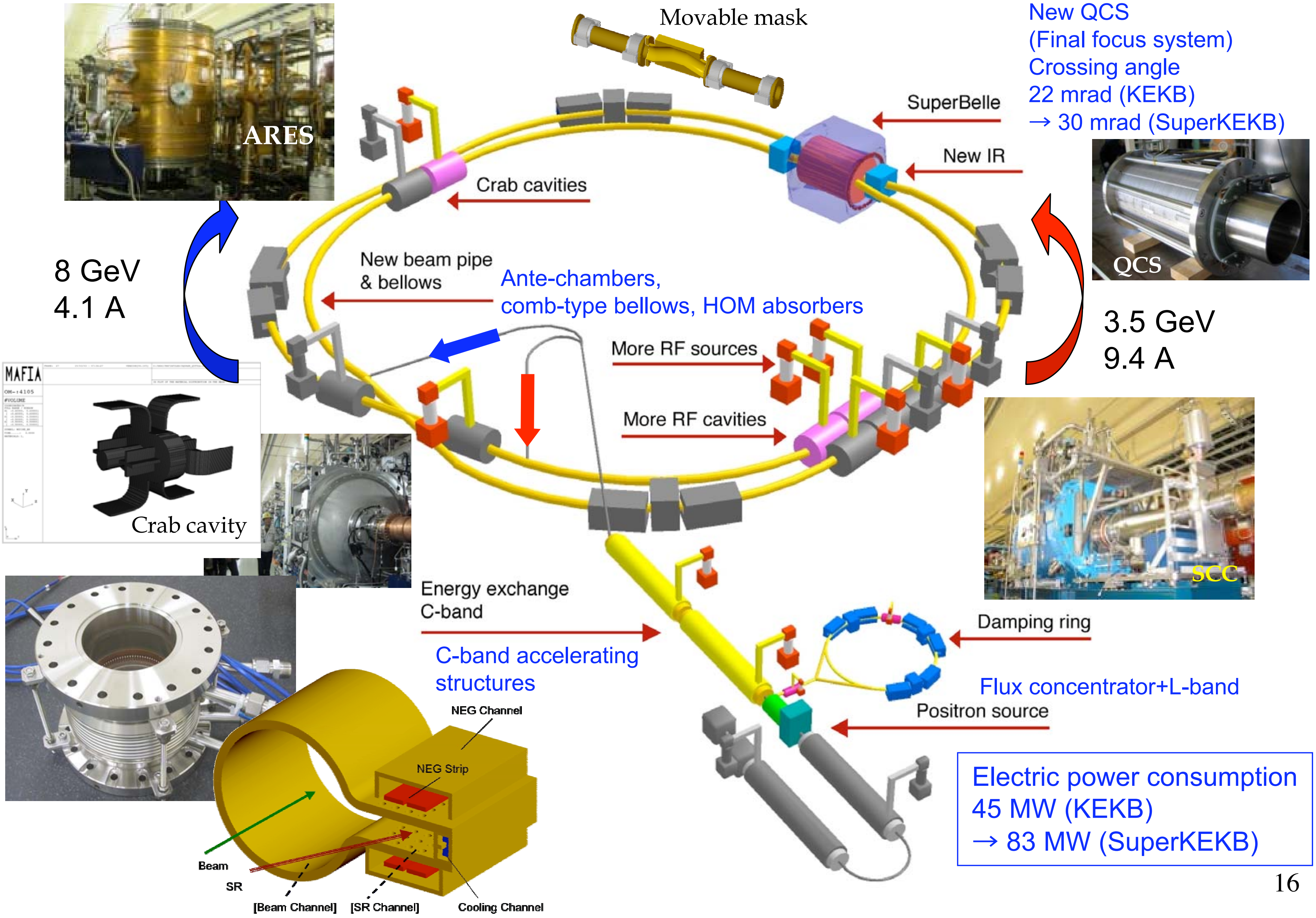
3 DOF → 2+1 DOF → 1+1+1 DOF

Crab-crossing
(resolve xz coupling)

ν_x=0.5
(resolve xy coupling)

- This technique realizes high luminosity at KEKB/SuperKEKB. To make this possible, machine errors must be reduced significantly.

Upgraded Components for SuperKEKB



8 GeV
4.1 A

3.5 GeV
9.4 A

New QCS
(Final focus system)
Crossing angle
22 mrad (KEKB)
→ 30 mrad (SuperKEKB)

Ante-chambers,
comb-type bellows, HOM absorbers

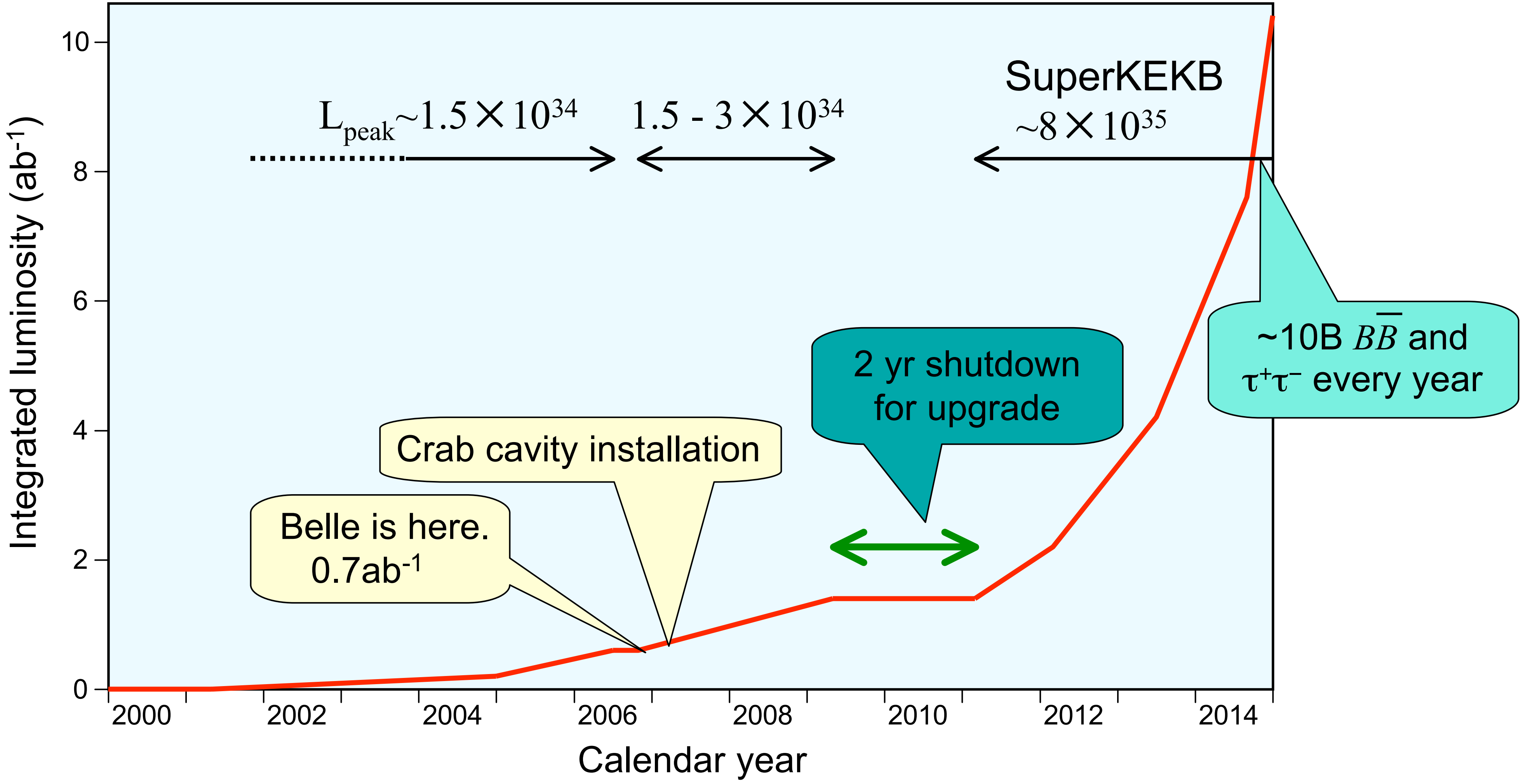
C-band accelerating
structures

Flux concentrator+L-band

Electric power consumption
45 MW (KEKB)
→ 83 MW (SuperKEKB)

Proposed Schedule for SuperKEKB

Total cost ~290M€(~398 M$)



SuperB

Possible site in the Tor Vergata University
close to the Frascati Lab

Concept of SuperB

- Objection for standard scheme of SuperKEKB:
  - Ultra-high beam current, short bunch, ...

  This means:
  - Huge amount of AC plug power is needed.
  - It is difficult to manage SR, HOM and CSR issues.

- Completely different collider scheme is necessary to overcome this situation.

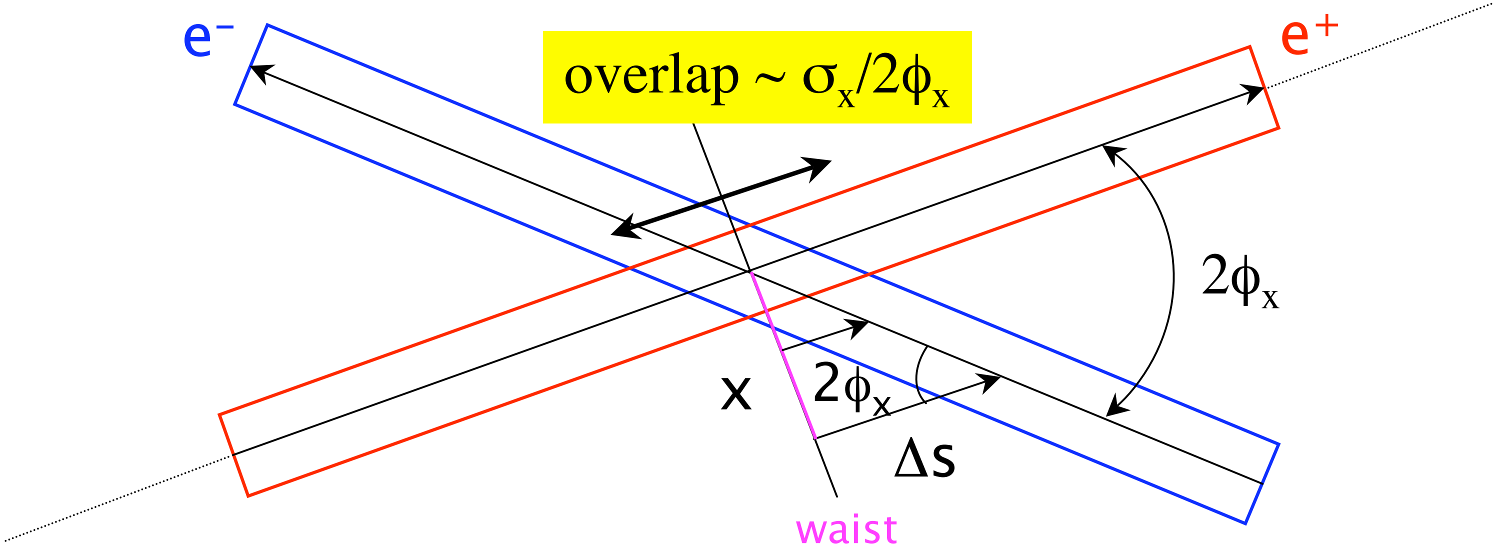
- SuperB chooses an alternative scheme:
  - Ultra-low emittance, Ultra-low beta, large crossing angle
  - Crab waist might be necessary to suppress bad resonances.

  This means:
  - Low current, long bunch while keeping high luminosity
  - less AC plug power
  - It is difficult to manage dynamic aperture(injection rate and Tousheck lifetime) and stabilize beams.

Nano-beam Scheme

"Ultra-low Emittance and Ultra-low Beta Scheme" proposed by SuperB

- Small σ_x and large ϕ_x make small overlap region.
- Overlap area(longitudinal) of colliding bunches is $\sigma_x/2\phi_x$.



$$\Delta s = x/\tan(2\phi_x)$$

$$\sim x/2\phi_x$$

Low Emittance

$$\beta_y \geq \frac{\sigma_x}{2\phi_x} \sim 200\ \mu\text{m}$$

β_y^* can be small, while σ_z is free. ⟺

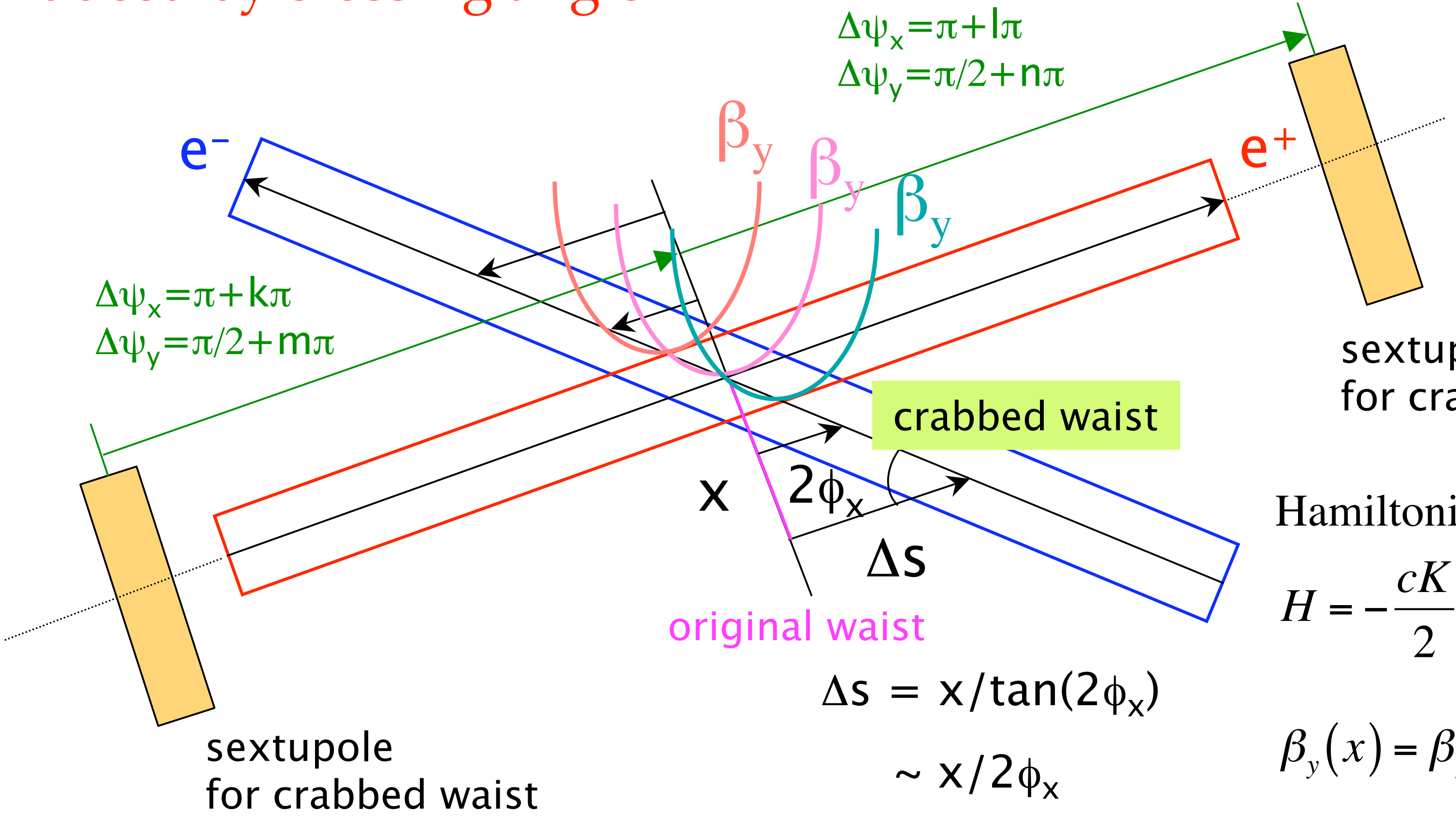
High Current

$$\beta_y \geq \sigma_z \sim 3\ \text{mm}$$

L is proportional to $1/\beta_y^*$.

Crab Waist Scheme

- Waist position is adjusted by kick from sextupoles to suppress hourglass effect. ➡ $\Delta s \sim x/2\phi_x$
- Particles collide another beam at their waist point.
- Crab waist removes beam-beam and betatron coupling terms induced by crossing angle



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

Hamiltonian:

$$H = -\frac{cK}{2} x p_y^2$$

$$\beta_y(x) = \beta_y^* + \frac{(s - cKx)^2}{\beta_y^*}$$

Machine Parameters of SuperB

SuperB CDR

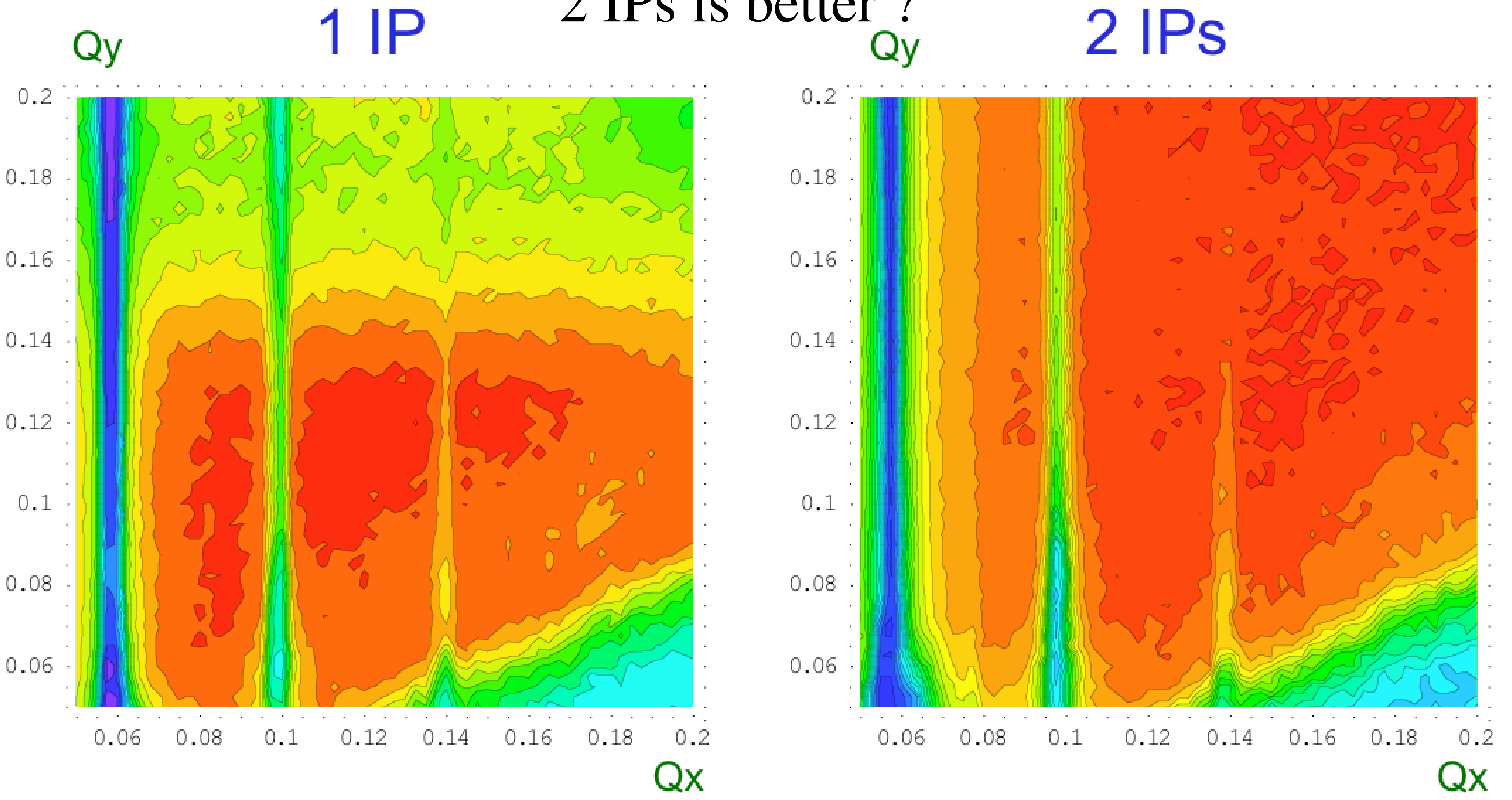
Parameter	Nominal		Upgrade		Ultimate		Unit
	LER	HER	LER	HER	LER	HER	
Energy	4	7	4	7	4	7	GeV
Luminosity	$1x10^{36}$		$2.4x10^{36}$		$3.4x10^{36}$		$cm^{-2}s^{-1}$
Beam current	2.28	1.3	3.95	2.17	4.55	2.6	A
Number of bunches	1733		3466				
Emittance $\varepsilon_x/\varepsilon_y$	1.6/0.004		0.8/0.002				nm
Beta β_x^*/β_y^*	20/0.3		20/0.2				mm
Beam size σ_x^*/σ_y^*	5.7/0.035		4/0.020				μm
Bunch length σ_z	6						mm
Full crossing angle $2\phi_x$	34						mrad
Momentum spread σ_δ	$8.4x10^{-4}$	$9x10^{-4}$	$1x10^{-3}$				
Momentum compaction α_p	$1.8x10^{-4}$	$3x10^{-4}$	$1.8x10^{-4}$	$3x10^{-4}$	$1.8x10^{-4}$	$3x10^{-4}$	
Total V_c	6	18	6	18	7.5	18	MV
Energy loss U_0	1.9	3.3	2.3	4.1	2.3	4.1	MeV
Damping time τ_x/τ_s	32/16		25/12.5				msec

Low beam currents are attractive!

Electron pol. ~80%

Luminosity Tune Scan (1 IP VS 2 IPs)

2 IPs is better ?



L_{min} = 3.95 x 10^{34} cm^{-2}s^{-1}

L_{max} = 1.02 x 10^{36} cm^{-2}s^{-1}

Lmin = 3.37 x 10^{34} cm^{-2}s^{-1}

Lmax = 1.00 x 10^{36} cm^{-2}s^{-1}

M.Zobov, D.Shatilov

Summaries
of
Super B Factories

Comparison between SuperB and SuperKEKB

		SuperB (Nominal)	SuperKEKB (2006)	
Emittance	ε_x	1.6	9	nm
Horizontal beta	β_x^*	20	200	mm
Vertical beta	β_y^*	0.3	3	mm
Horizontal beam size	σ_x^*	5.7	42	μm
Vertical beam size	σ_y^*	35	367	nm
Bunch length	σ_z	6	3	mm
Half crossing angle	ϕ_x	17	15	mrad
Piwinski angle	φ	18	1	rad
Current(LER/HER)	I_b	2.28/1.30	9.4/4.1	A
Luminosity (x10^{35})	L	10	8	$cm^{-2}s^{-1}$
AC Plug Power	P	34	83	MW

One order magnitude smaller than SuperKEKB

AC power for KEKB is already 40 MW. Max site power is 100 MW at KEK.

Emittance is Entropy !

- Entropy can be written by:

Emittance

$$S = \ln \frac{\Delta p \Delta q}{(2\pi\hbar)^s}$$

Text book(L.D. Landau, E.M. Lifshitz)

Entropy can not be negative. $\Delta p \Delta q \geq h$

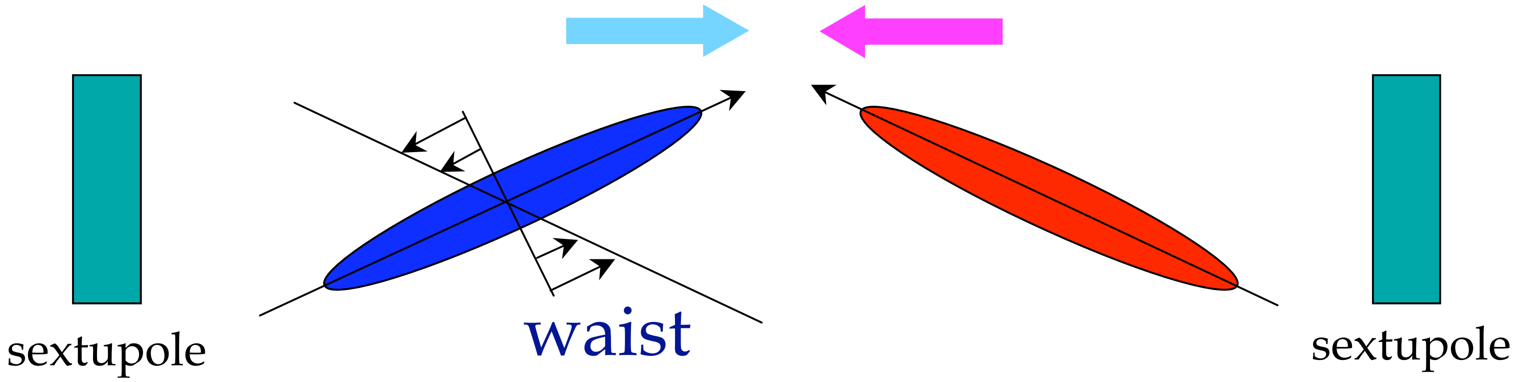
- Emittance can be easily increased.
  - machine errors (magnet alignment, field strength, etc)
  - emittance growth due to nonlinear effects.
    - beam-beam interaction
    - strong sextupoles at high beta function(chaotic effects), etc
  - Ultra-low emittance is not trivial same as ultra-high current.
  - A circular collider is completely different from a damping ring such as ATF or ILC damping ring (no final focus, no colliding beams, no trickle charge or continuous injection).
  - How to manage ultra-low emittance ?

Summary of SuperKEKB

- A technically feasible design of SuperKEKB has been made with 8×10^{35} $cm^{-2}s^{-1}$ luminosity.
- SuperKEKB R&D is in engineering phase not in conceptual phase for the ultra-high current scheme.
  - Realistic lattice design, dynamic aperture is OK.
  - Crab cavity, ante-chamber, new bellows, C-band structures, upgraded ARES, development of powerful BxB feedback system, new QCS, ...
  - These items have already been or will be tested at KEKB.
  - See "Letter of Intent for KEK Super B Factory", June 2004. (However, number should be updated.)
- Issues to be difficult
  - In case of ν_x=+0.5, physical aperture around IP, SR fan from QCS might be serious.
  - Many things related to high currents
    - To cure CSR, vacuum chamber design might be reconsidered.
    - We need more accurate evaluation for HOM heating and cooling method.

Crab Waist Optics at KEKB

- Beam-beam simulation by K. Ohmi has shown that the crab waist scheme will boost the luminosity of the present KEKB, as well as the crab cavity.

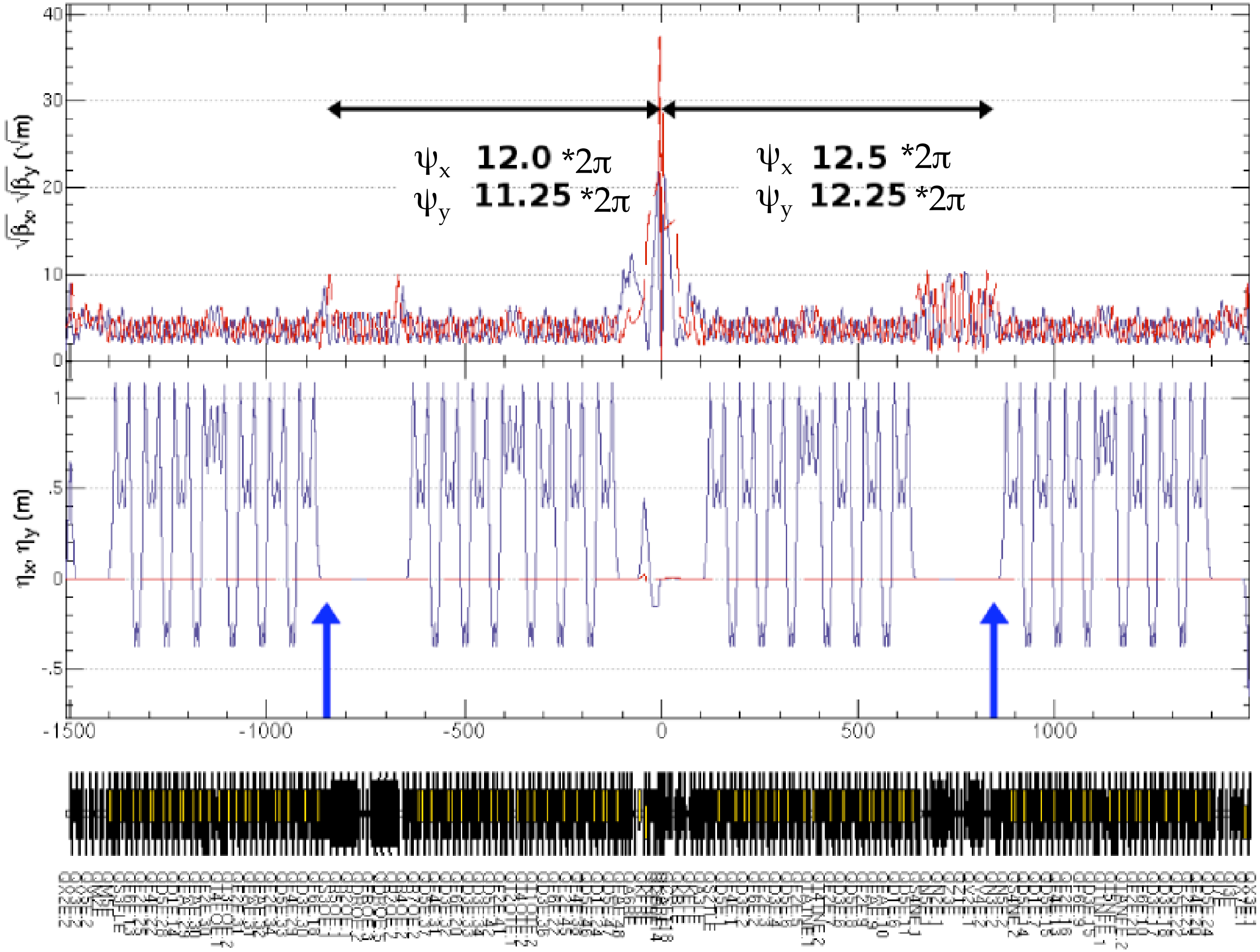


- Several lattice design was tried on the computer.

- As the result, drastic degradation of the dynamic aperture was found. No good solution has been obtained so far.

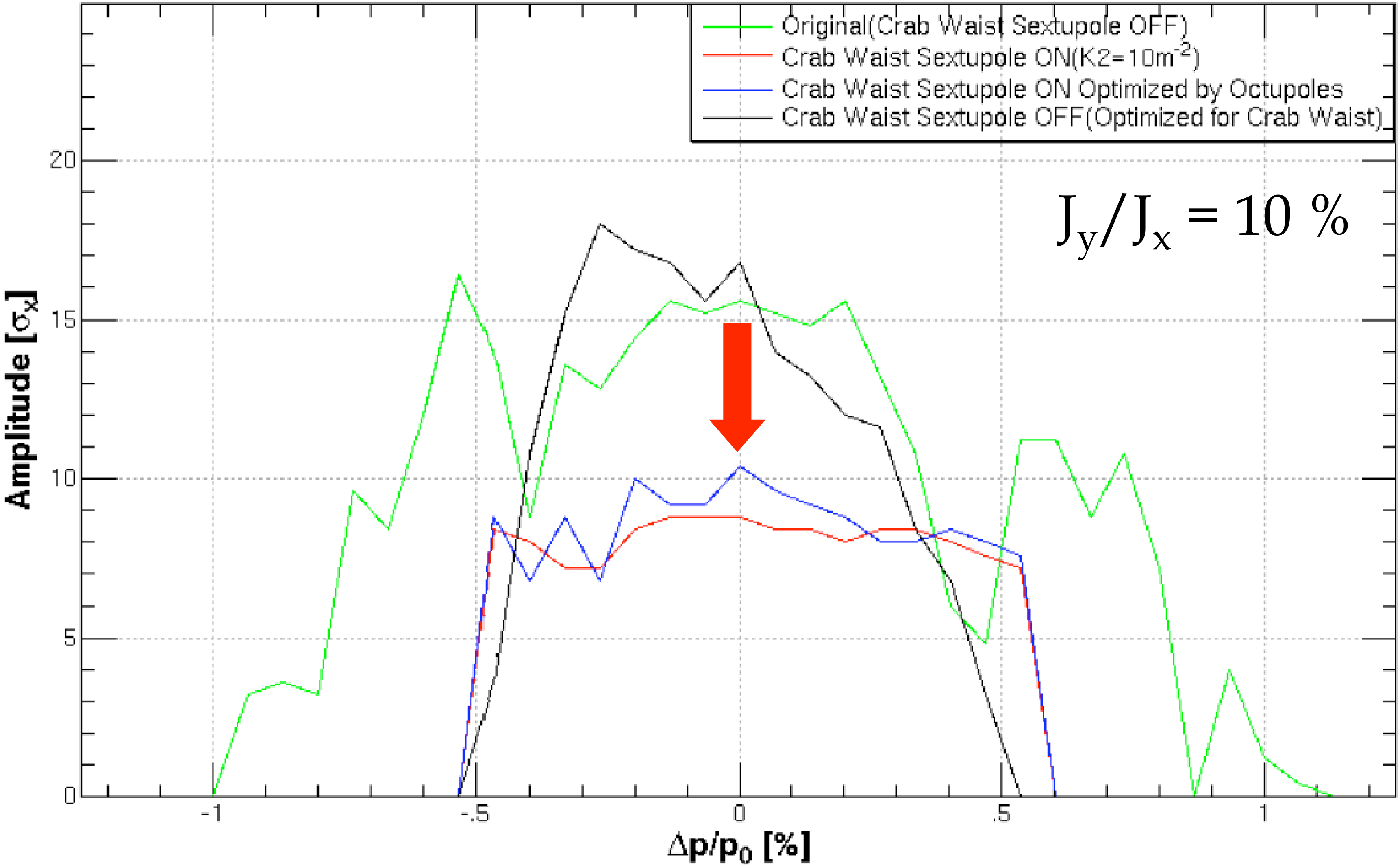
KEKB-HER Model Optics for Crab Waist

A. Morita



Sextupoles are installed in the Nikko and Oho section.

Dynamic Aperture of KEKB-HER



Octupoles(more than 30) are located at RF sections.
These octupoles cannot restore the dynamic aperture.

Summary of SuperKEKB (cont'd)

- Since KEKB is a very flexible accelerator, we also plan to evaluate another option using a "nano-beam scheme" with a "crab-waist".

- As a matter of principle, we will consider all possible machine designs to reach high luminosity.
  The high current scheme is the standard strategy unless and until we find a better scheme that is technically feasible.

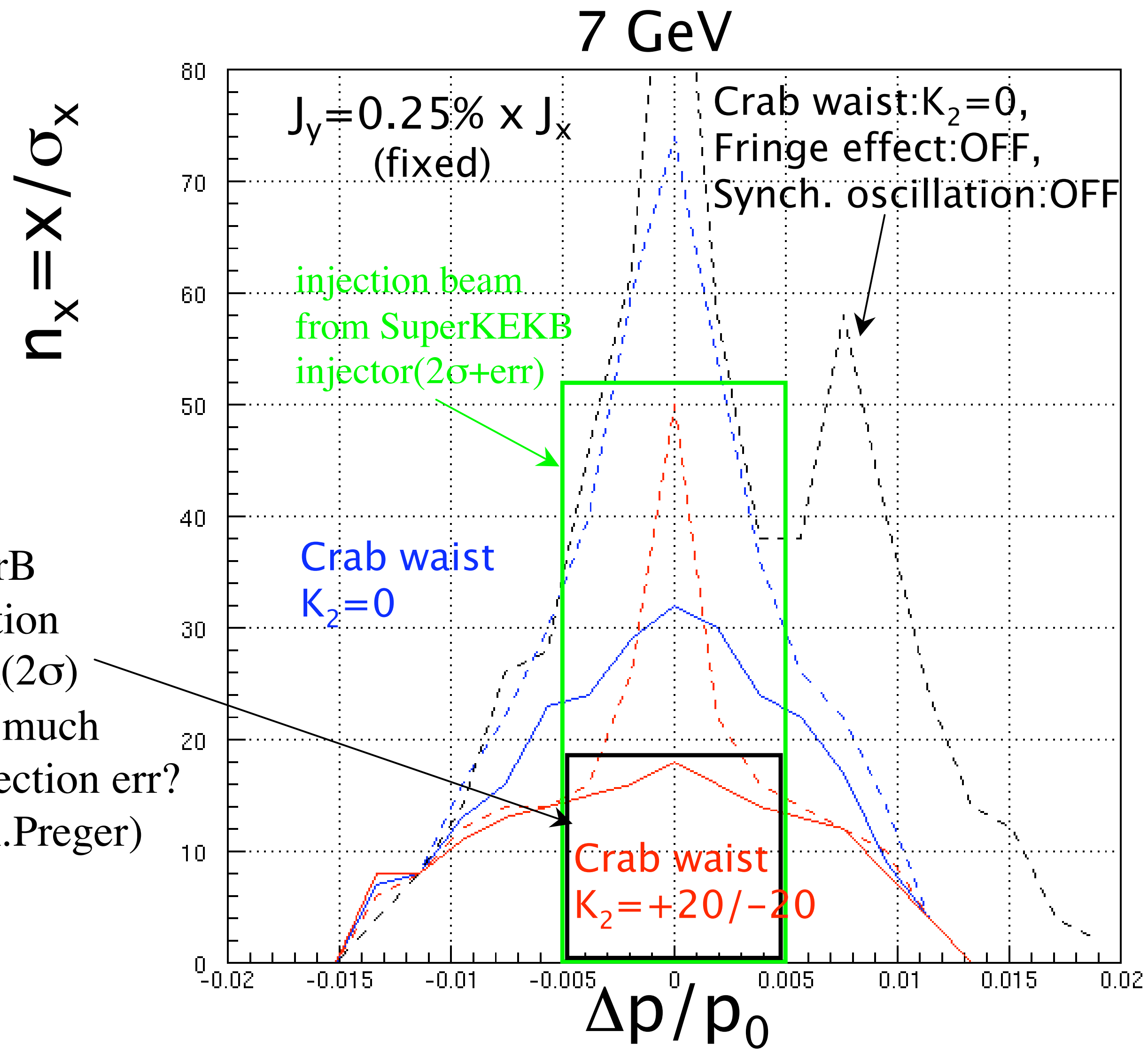
Summary of SuperB

- Target luminosity is >10^{36} cm^{-2}s^{-1}.
- "Conceptual Design Report", based on the reuse of all the PEP hardware, that might fit in one of the existing facilities, or in a new(and available) site near Frascati.

- Very long to do list to for the ring design optimization:
  - Include the injection section, the tunes trombone and the chicane in the ring
  - Optimize the ARC cell
  - Optimize the wigglers
  - Improve the Dynamic Aperture (Mostly FF and Crab Waist Optics optimization)
  - Design for the Injection System
  - Make realistic lattice design includes fringe effects, multipole elements, skew quads, offset of FF quads, matching section, etc.

from P. Raimondi
at SuperB V Workshop

Dynamic Aperture for SuperB-HER



SuperB
injection
beam(2σ)
How much
is injection err?
(M.A.Preger)

Since 1986
SAD
Strategic Accelerator Design

Y. Ohnishi

$\nu_x/\nu_y = 48.57/23.60$
$\beta_x^*/\beta_y^* = 20$ mm/200 μm
$\beta_x^{crab}/\beta_y^{crab} = 14$ m/140 m
(thin-lens sextupole)

Synchrotron oscillation: ON
Radiation damping: OFF
Quantum excitation: OFF
#turns: 1000

Fringe effect for all magnets
Dashed line: OFF
Solid line: ON

Nonlinear Maxwellian Fringe field reduces dynamic aperture.

Octupole optimization might be able to improve dynamic aperture.

Summary of SuperB (cont'd)

from P. Raimondi
at SuperB IV Workshop

- SuperB studies are already providing useful input to the accelerators and particle physics community.

- The INFN will push any solution, but particularly SuperB if DAFNE upgrade(SuperB based) proves successful. A decision to ask for funding to the Italian government might happen as early as next year(About 200MEuros, mostly for the injector and the conventional facilities).

- We hope to gather in the enterprise as many labs and institutions as possible.

We should choose the best way to realize a Super B Factory in the world.

Need a lot of scientific arguments among many physicists...

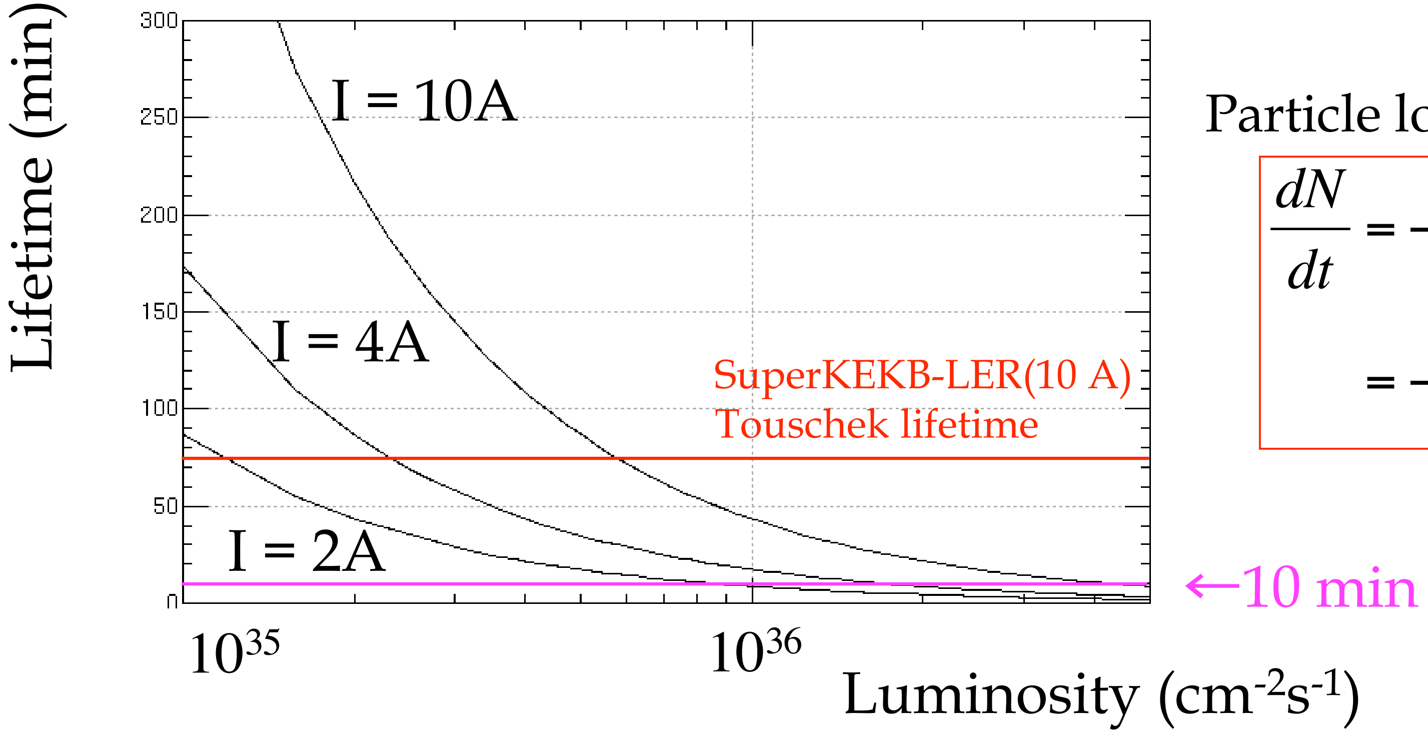
R&D experiments at existing accelerators

(crab cavity at KEKB and crab waist at DAFNE)

Backup Slides

Luminosity Lifetime

σ(radiative Bhabha) = 2.4x10^{-25} cm^2



Particle loss rate:

$$\boxed{\begin{aligned}\frac{dN}{dt} &= -L\cdot\sigma \\ &= -\frac{N}{\tau}\end{aligned}}$$

- ✓ Luminosity lifetime in SuperKEKB-HER is about 45 min and 100 min in SuperKEKB-LER for L=4x10^{35}.
- ✓ For L=10^{36}, lifetime becomes 17 min in SuperKEKB-HER and 40 min in SuperKEKB-LER, which is much shorter than Touschek lifetime .

Crab Crossing and Crab Waist

- Head-on collision is effectively realized by crab cavity, while crab waist controls nonlinear interaction induced by crossing angle.
- For high current scheme, either scheme will work, but not both at once.
- For low emittance scheme, only crab waist is applicable because beam-beam tune shift becomes too high.

- Crab waist can make luminosity comparable to that of crab crossing.

SuperKEKB

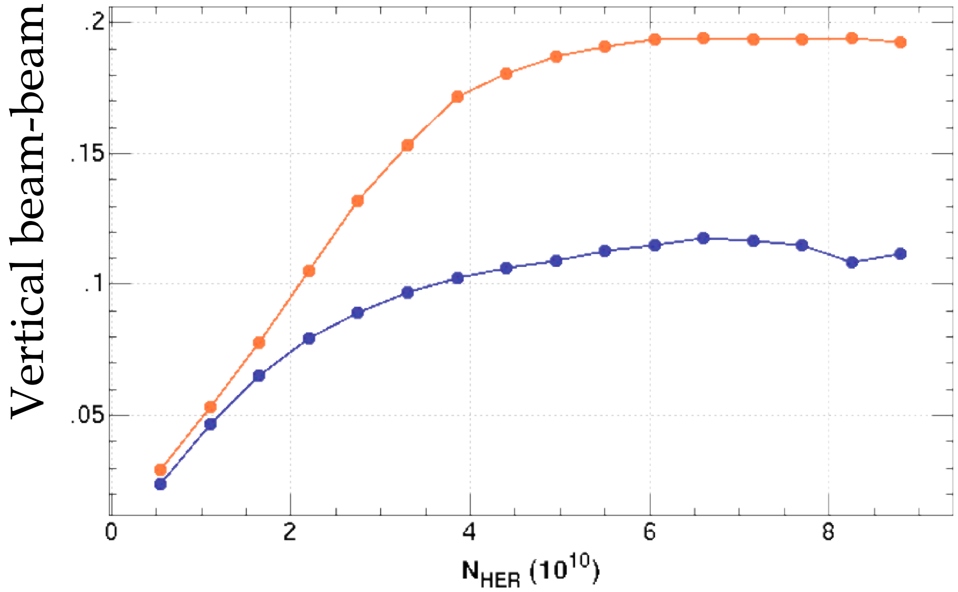
SuperKEKB Machine Parameters

SuperKEKB					
Option		High Emittance	Low Emittance	Crab Waist	
Emittance	ε_x	24	9	6	nm
	ε_y	0.18	0.045	0.06	nm
Beta at IP	$\beta_x{}^*$	200		50	mm
	$\beta_y{}^*$	3		0.5	mm
Beam size at IP	$\sigma_x{}^*$	69	42	17.3	μm
	$\sigma_y{}^*$	735	367	173	nm
Bunch length	σ_z	3		6	mm
Synchrotron tune	ν_s	0.03	0.025	0.01	
#particles/bunch	n_+/n_-	12.6/5.5			10^{10}
#bunches	N_b	5000			
Crossing angle	$2\phi_x$	30 → 0 (crab crossing)		30	mrad
Beam-beam	ξ_x	0.135	0.209	0.017	
	ξ_y	0.215	0.405	0.133	
Luminosity	L	$4\text{x}10^{35}$	$8\text{x}10^{35}$	$9\text{x}10^{35}$	$\text{cm}^{-2}\text{s}^{-1}$

Crab-crossing

Crab crossing will increase the beam-beam parameter by a factor of 2.

K. Ohmi, et al.



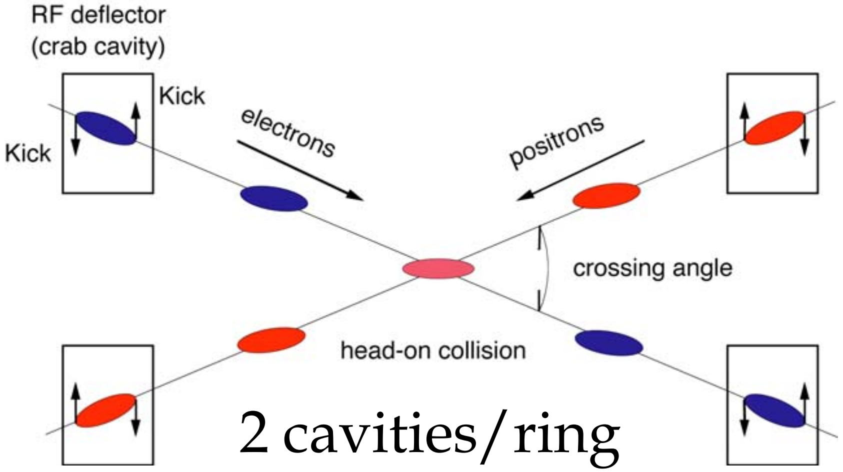
Head-on(crab)

(Strong-strong simulation)

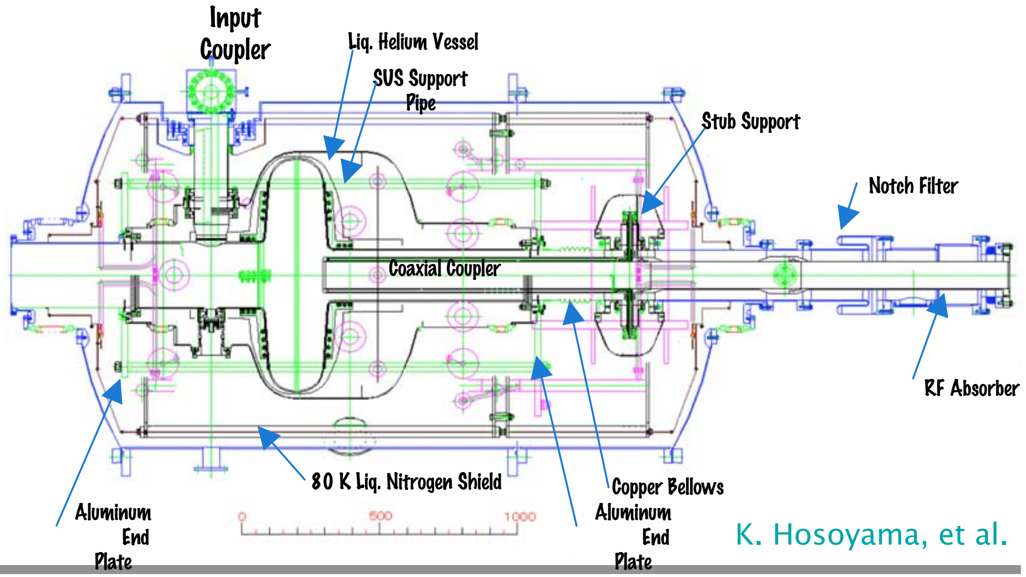
Crossing angle 30 mrad

(at the optimum tune)

Superconducting crab cavities have been produced, and under beam test at KEKB.



2 cavities/ring



K. Hosoyama, et al.

Toward Ultra-high Beam Current

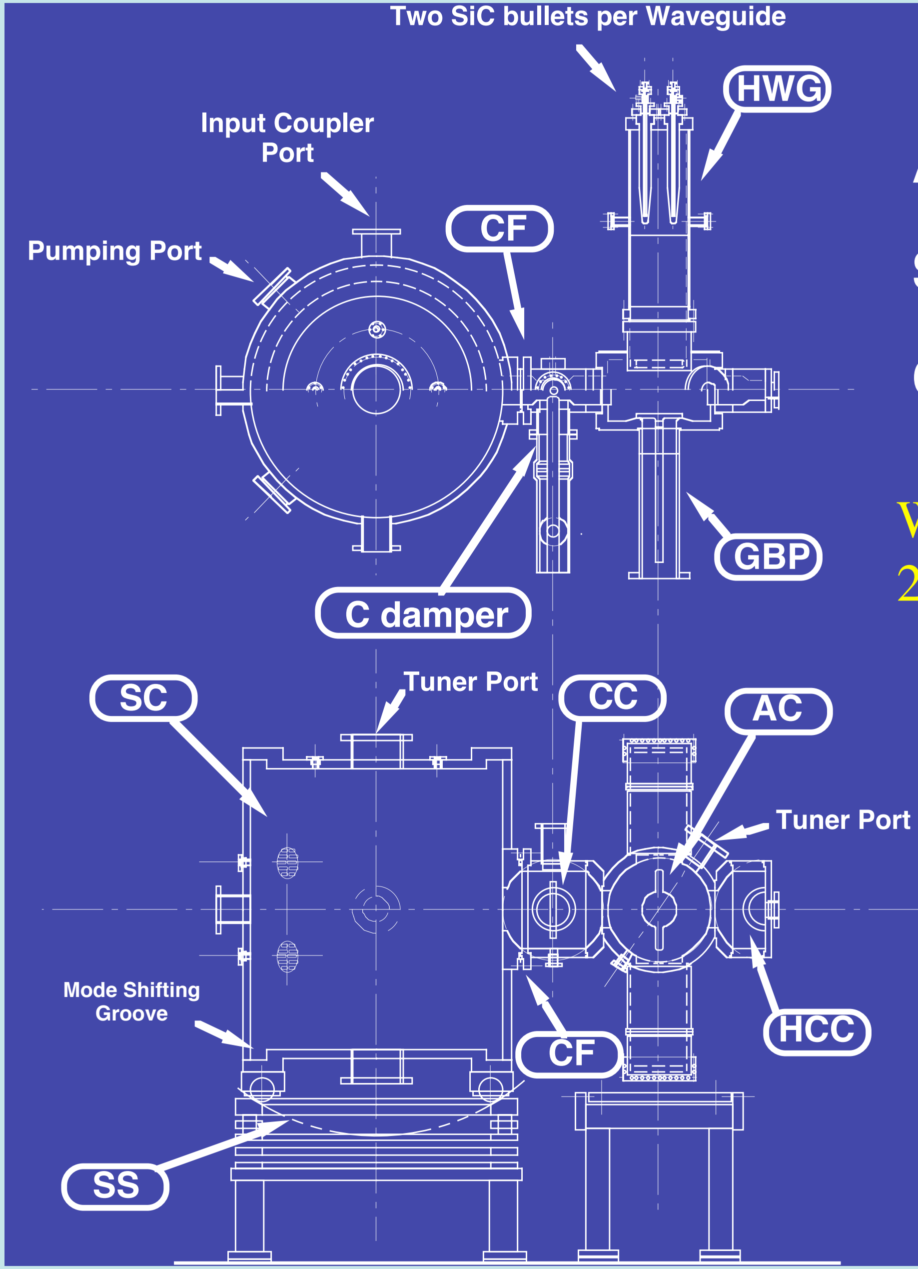
- RF system
  - ARES cavity is a state of the art normal-conducting cavity developed at KEK. Long. FB is not necessary up to ~3 A.
  - SCC cavity is the first superconducting cavity in the world that has stored a beam current greater than 1 A .
  - RF system will be upgraded and doubled for ultra-high currents.

- Vacuum system
  - We adopt an ante-chamber design to absorb strong SR power and also to suppress photoelectron cloud effects.

Accelerator Resonantly coupled with Energy Storage

ARES

3-cavity system stabilized with the $\pi/2$-mode operation



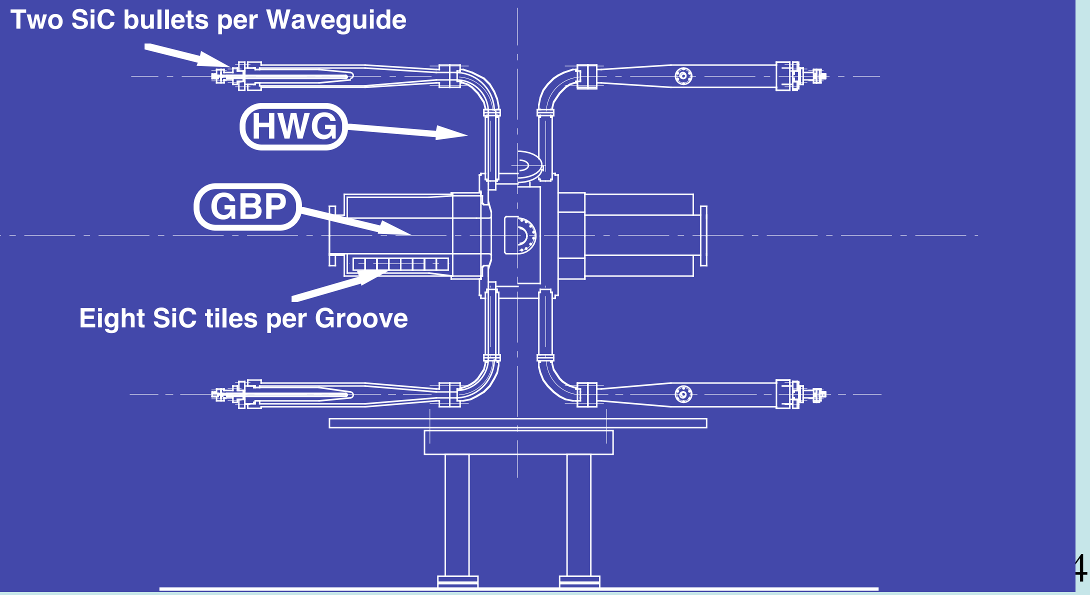
Large beam power can be supplied and make beam stable !

AC: Accelerating Cavity (HOM-damped)

SC: Storage Cavity (TE013)

CC: Coupling Cavity damped with an antenna-type coupler (C damper)

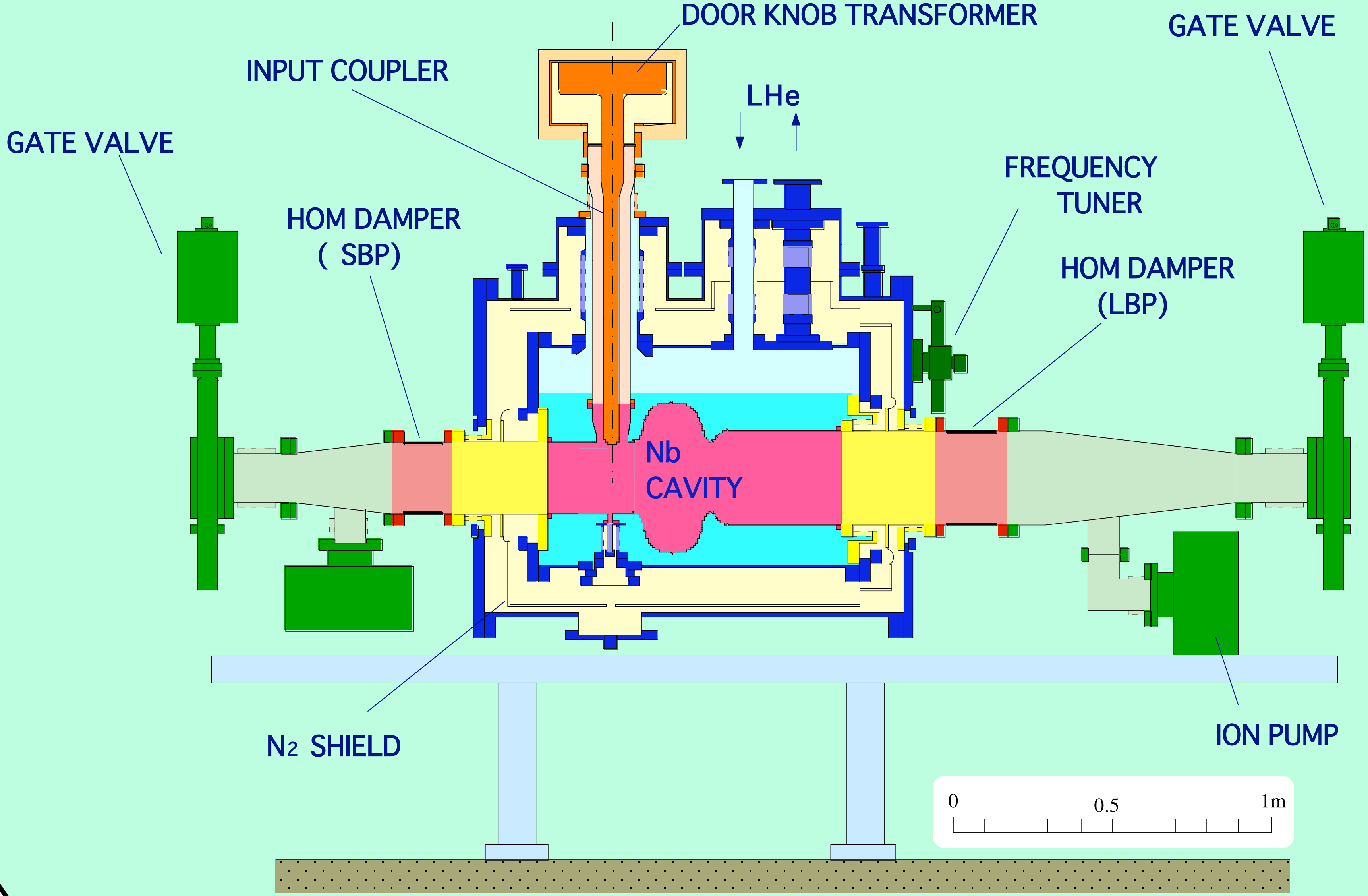
We DO NOT NEED longitudinal feedback at 2~3 A due to excellent performance of the cavity.



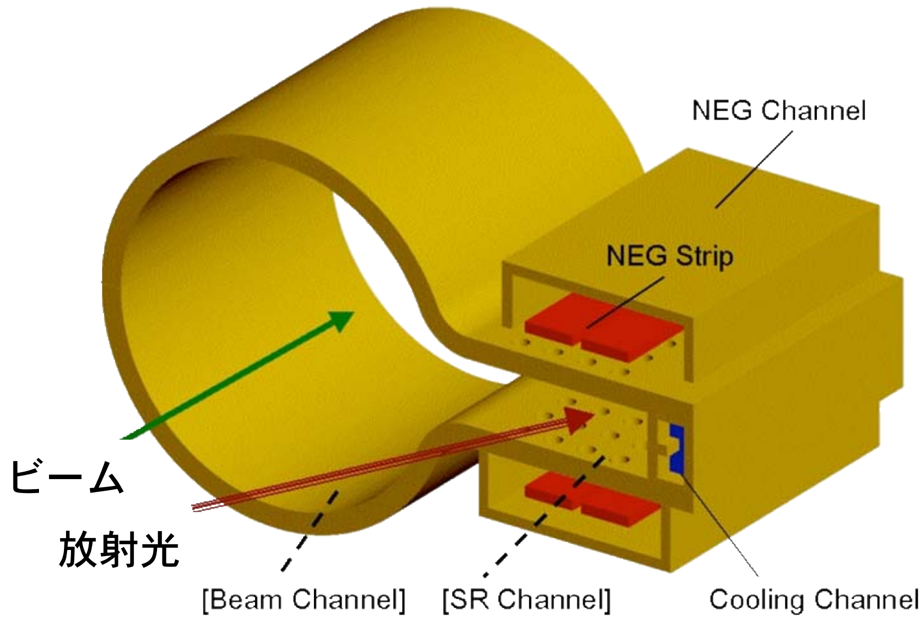
Superconducting Damped Cavity for KEKB

T. Furuya

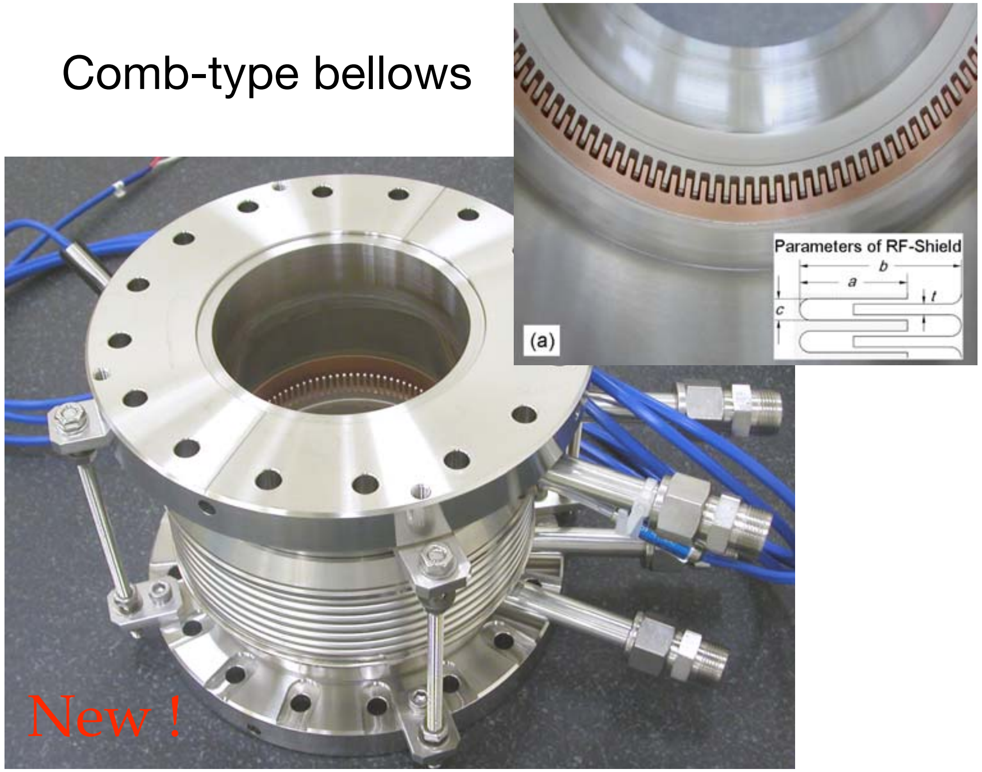
Higher cavity voltage can be supplied and make beam stable !



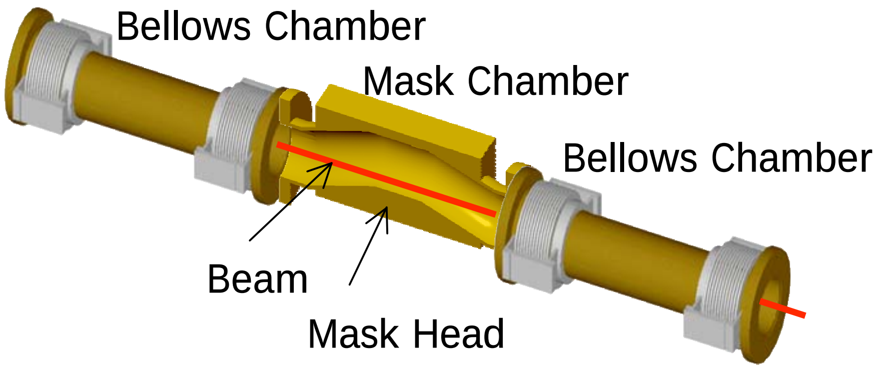
Ante-chamber



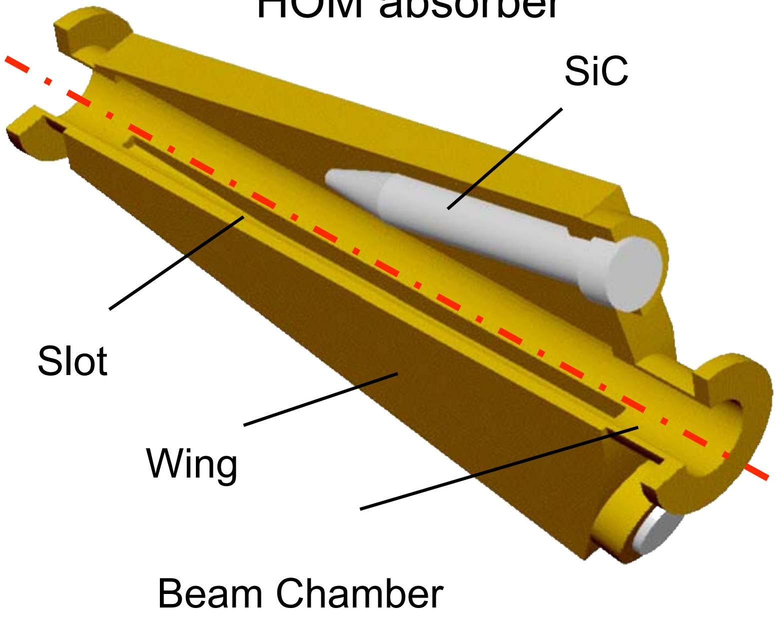
Comb-type bellows



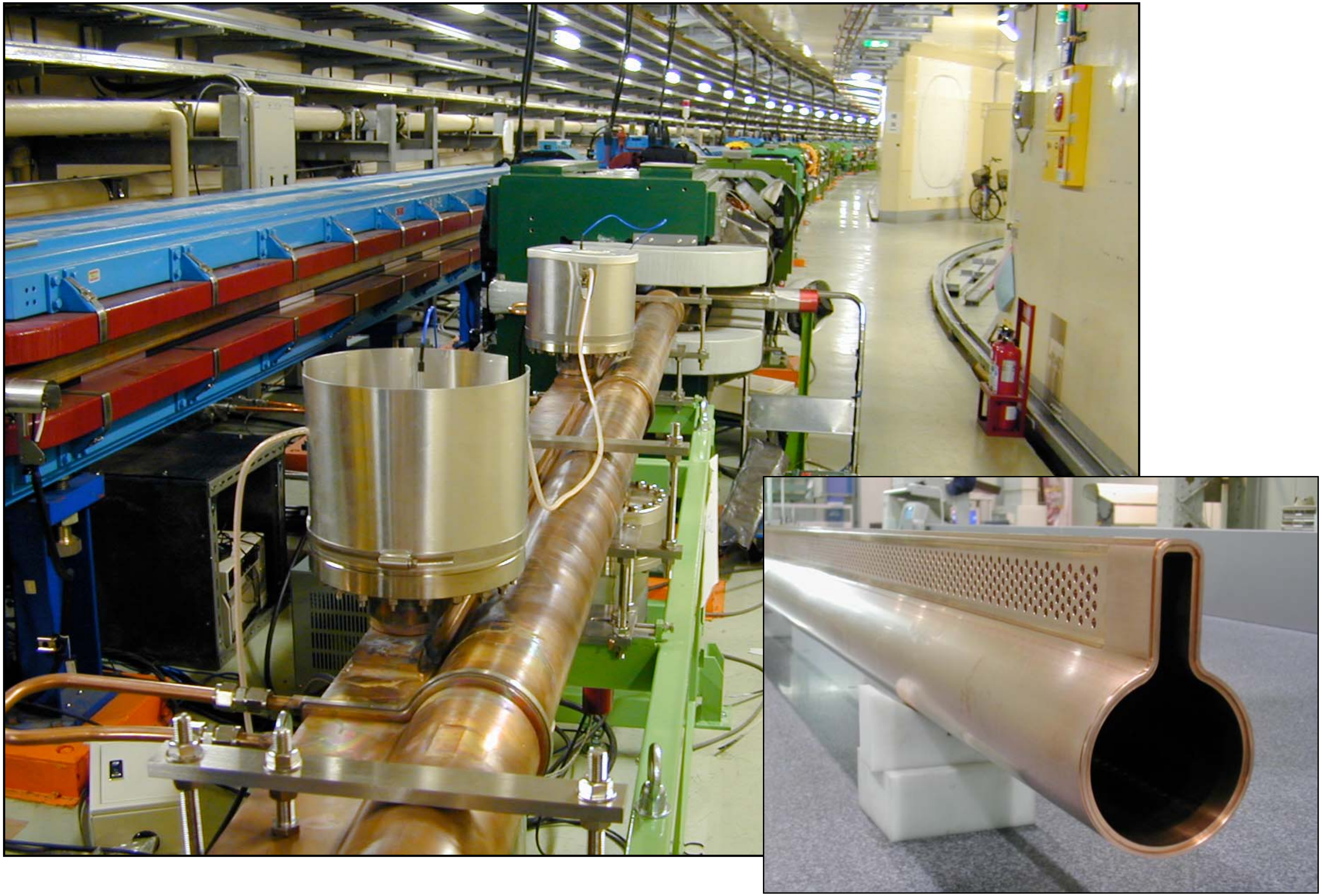
Movable mask



HOM absorber

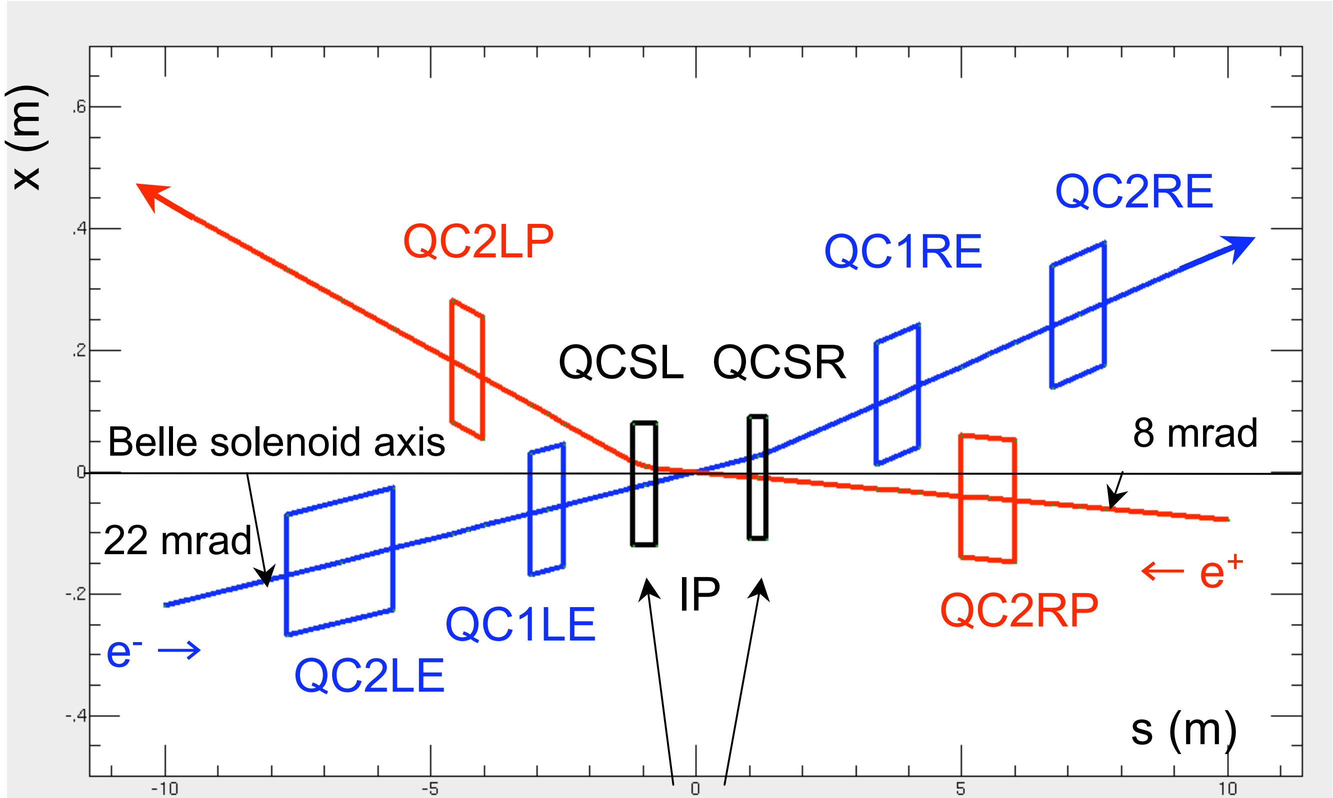


Test of Prototype Ante-chamber at KEKB(LER)



Squeezing Beta Function at IP

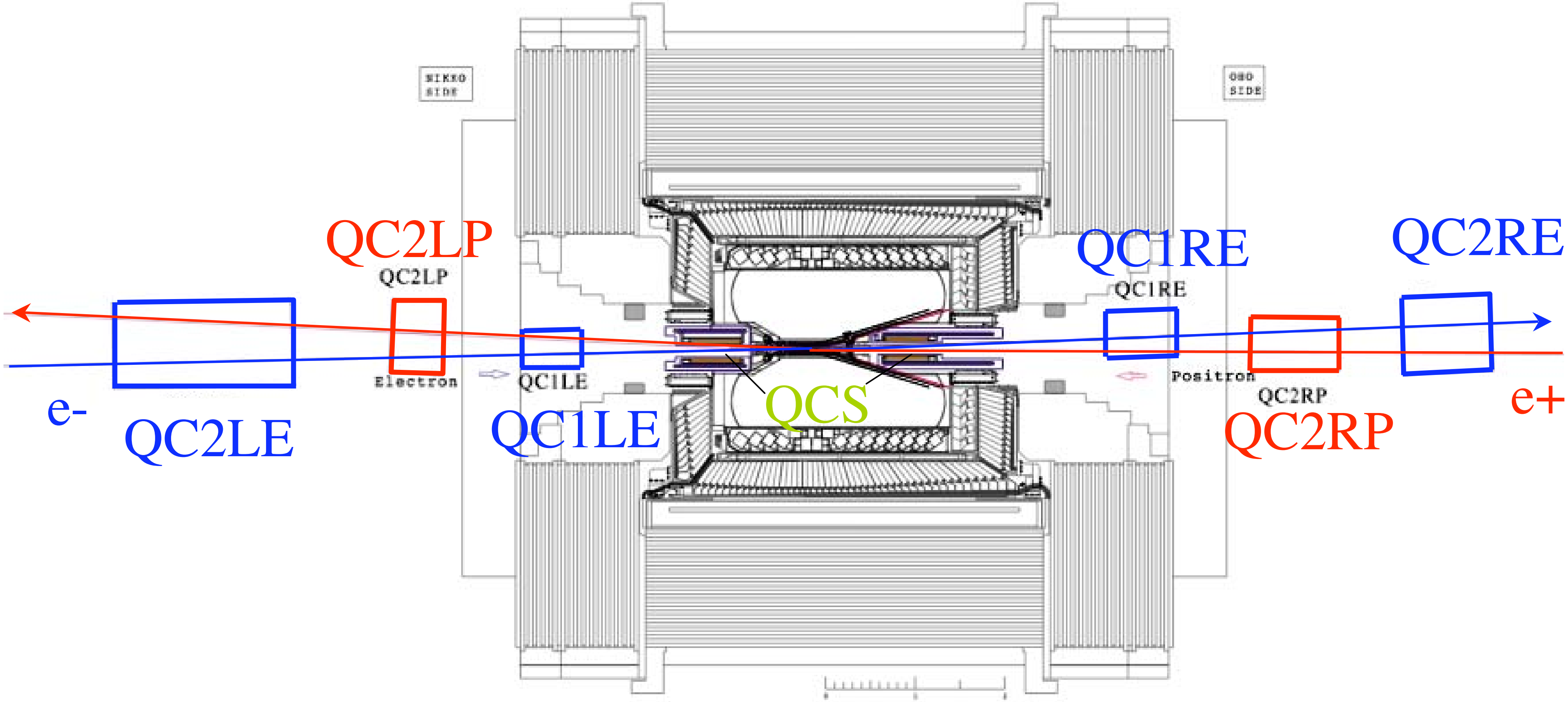
- Beta function at IP is 20 cm in the horizontal and 3 mm in the vertical.
- New QCS magnets are placed closer to IP
  - Special magnets vicinity of IP are also moved closer to IP than KEKB.
  - 30 mrad finite-crossing (22 mrad at KEKB)



Incoming beam passes through the center of QCS, outgoing beam passes off center and is kicked outside.

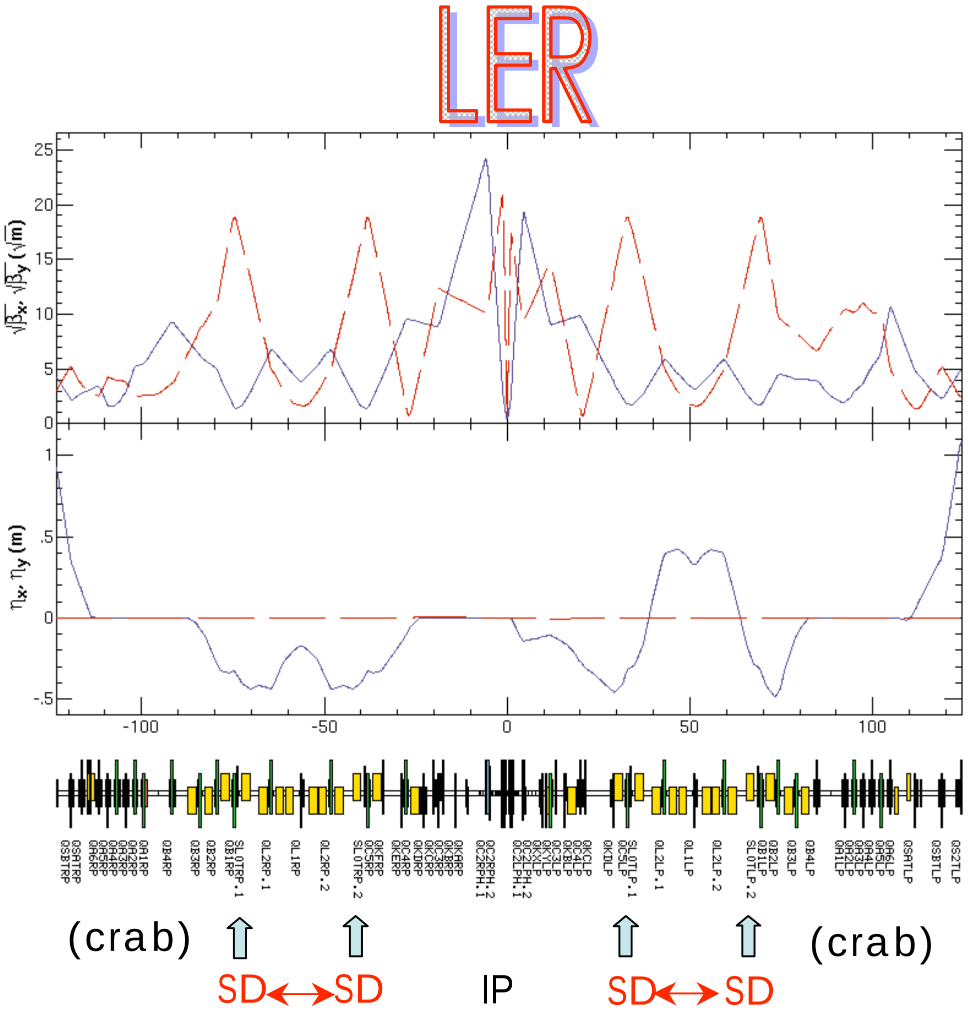
Realistic Drawing of IR magnets

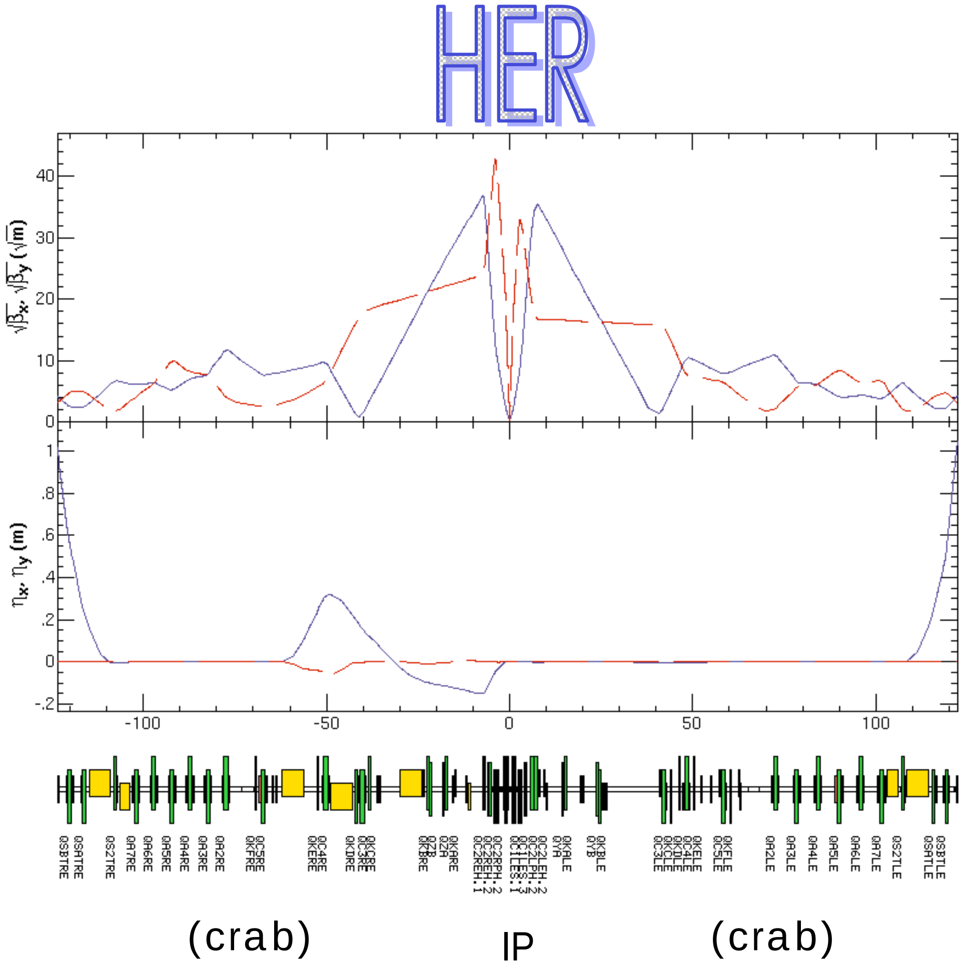
BELLE detector



Incoming beam passes through the center of QCS,
outgoing beam passes off center and is kicked outside.

Interaction Region for SuperKEKB

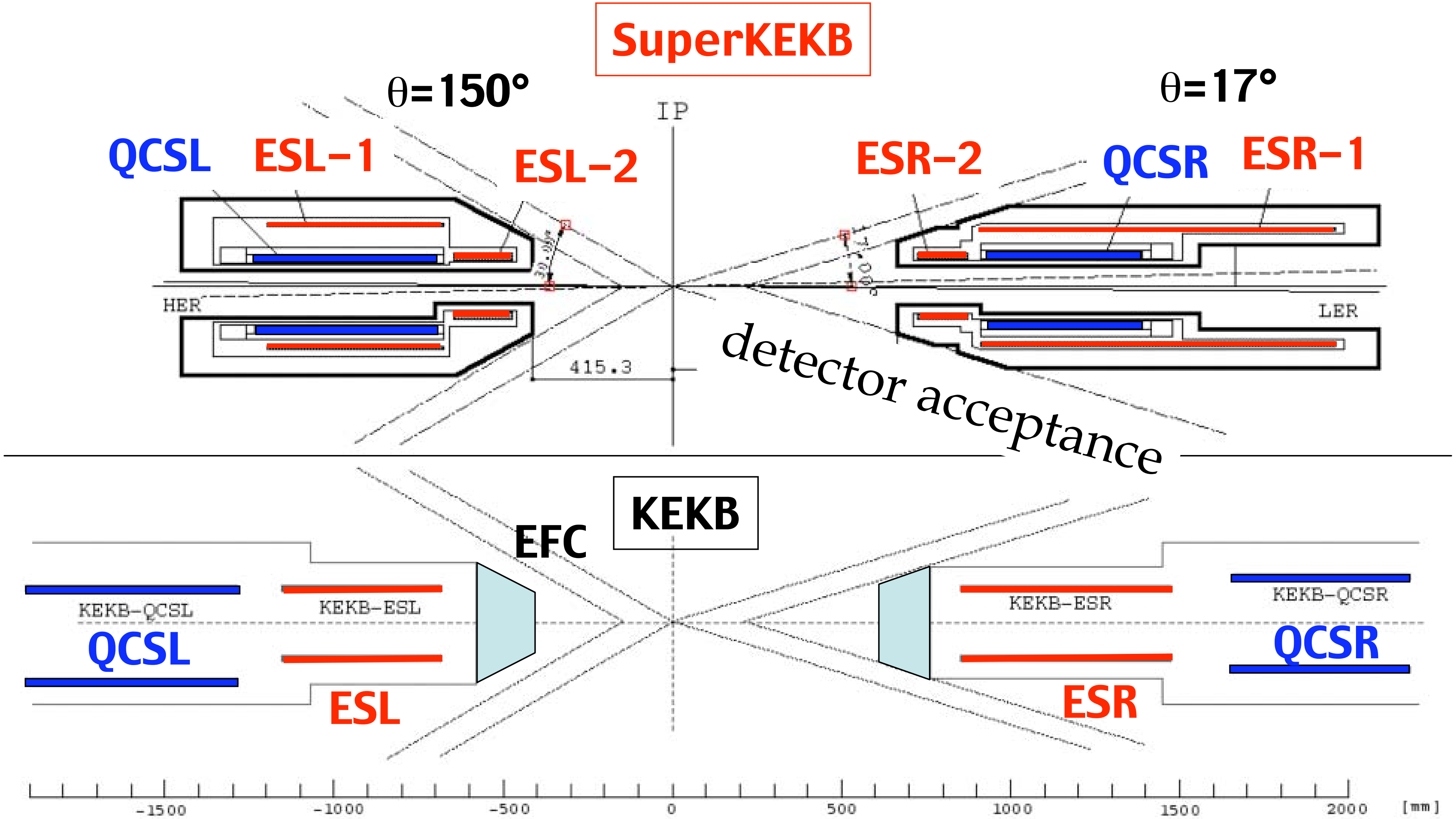




Local chromaticity correction

The lattice is realistic model includes offset of QCS, compensation solenoid, skew Quads, multipole elements, etc.

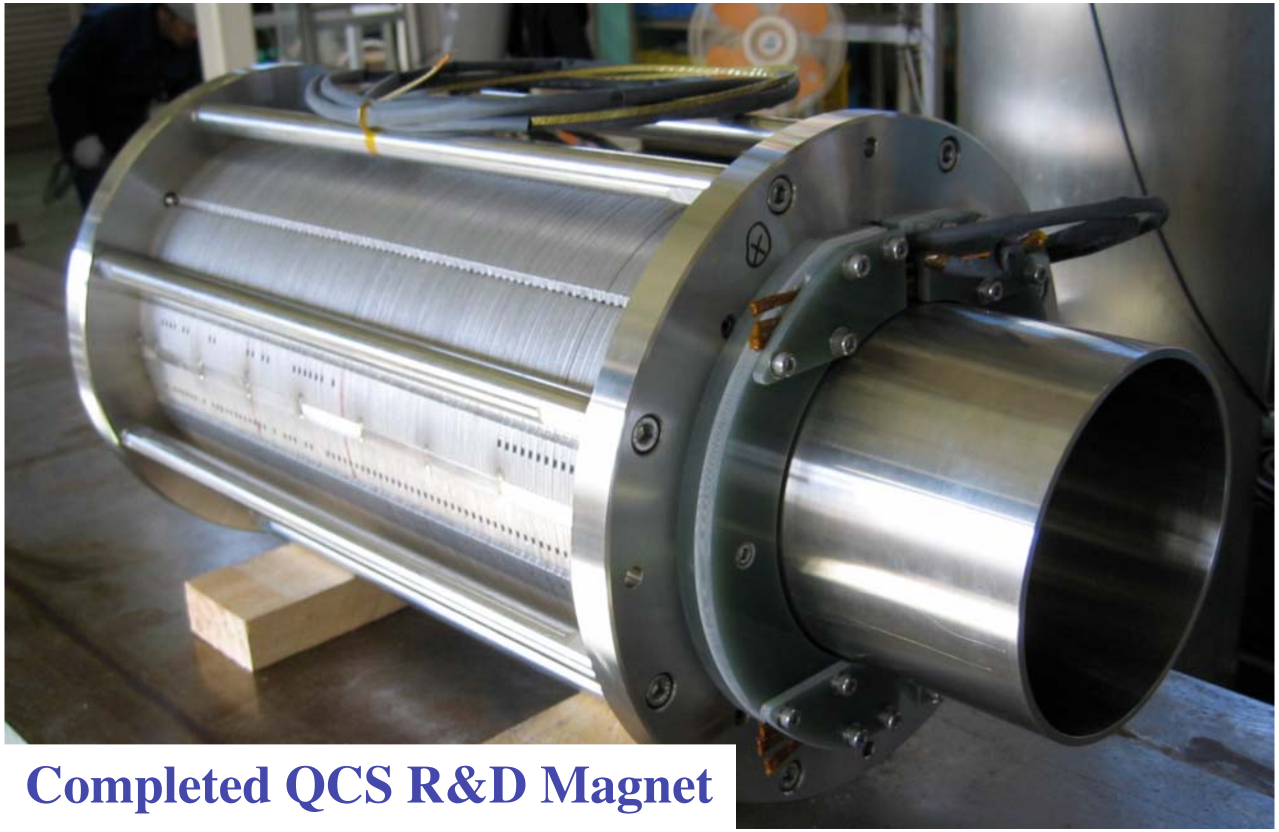
QCS for SuperKEKB and KEKB



Move **QCS** closer to IP and **compensation solenoid (ES)** is divided into two parts; one is overlaid with QCS, the other is in front of QCS. (Magnetic force on ES becomes weak.)

Construction of QCS Realtype Magnet R&D

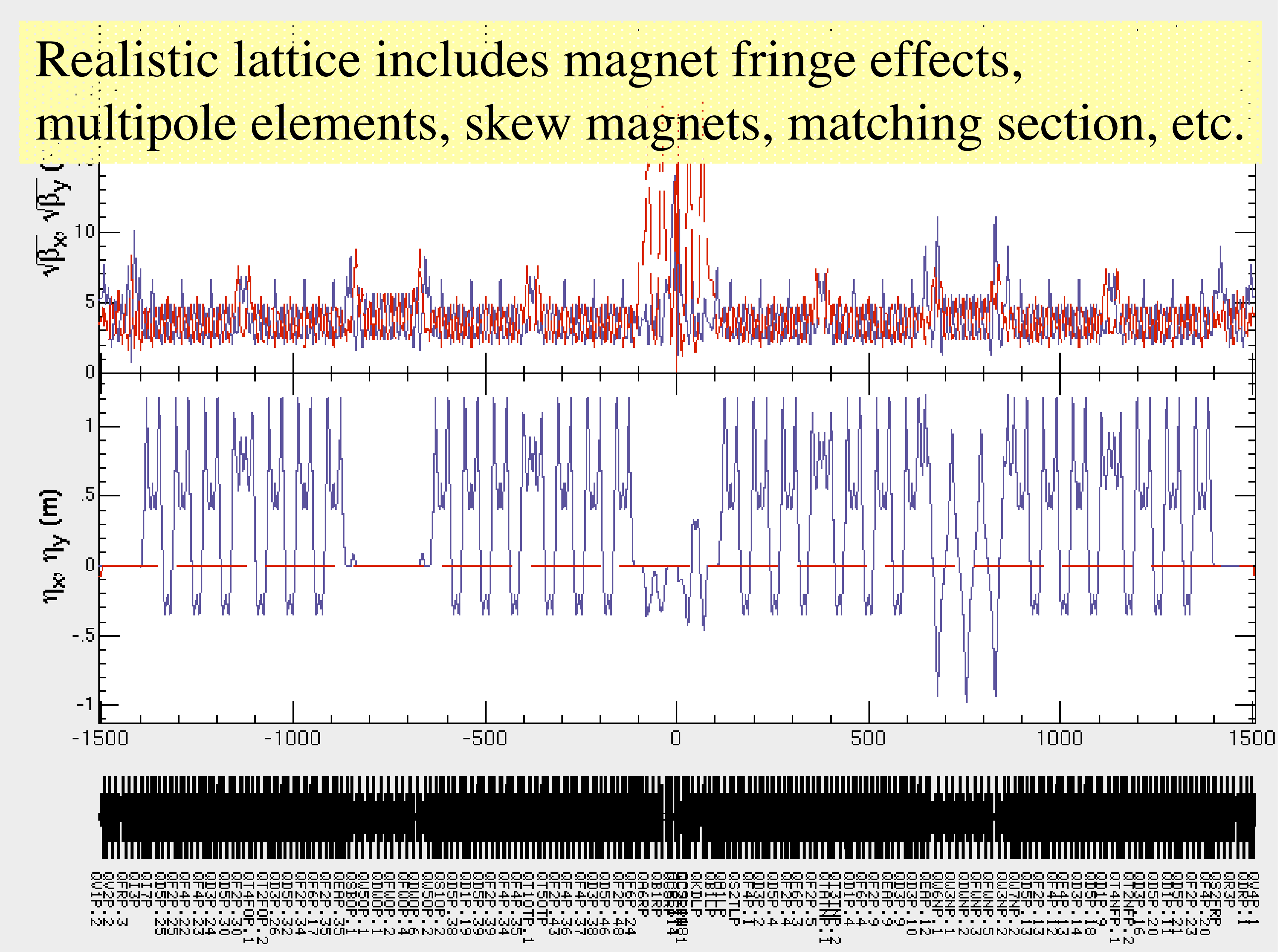
We have real QCS magnet to squeeze beta at IP up to 3 mm.



Completed QCS R&D Magnet

The vertical test has already finished.

SuperKEKB LER (3.5 GeV)

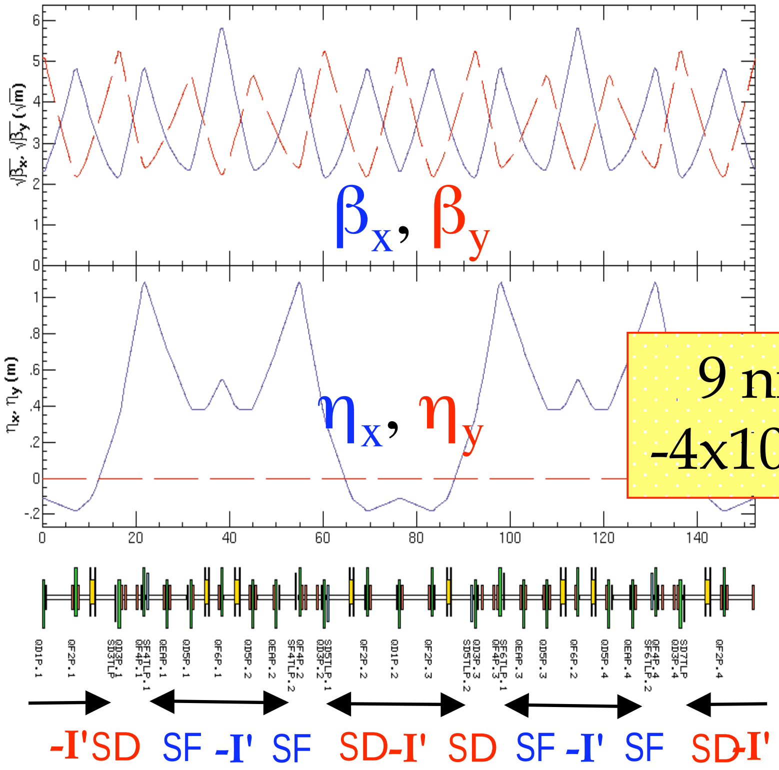


Realistic lattice includes magnet fringe effects, multipole elements, skew magnets, matching section, etc.

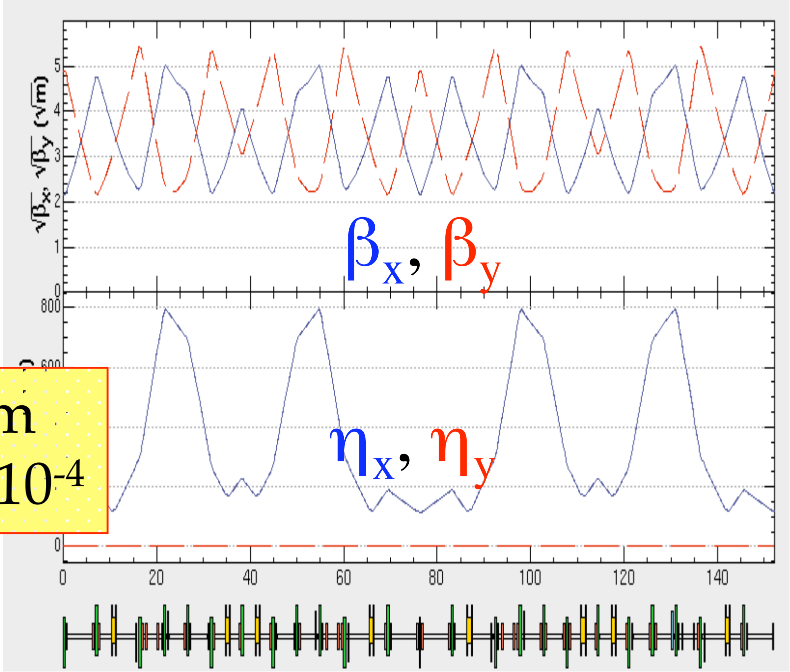
Large Flexible Arc Lattice

Magnet configuration is exactly same.

ε_x=24 nm



ε_x=9 nm



9 nm < ε_x < 36 nm

$-4\times10^{-4} < \alpha_p < +4\times10^{-4}$

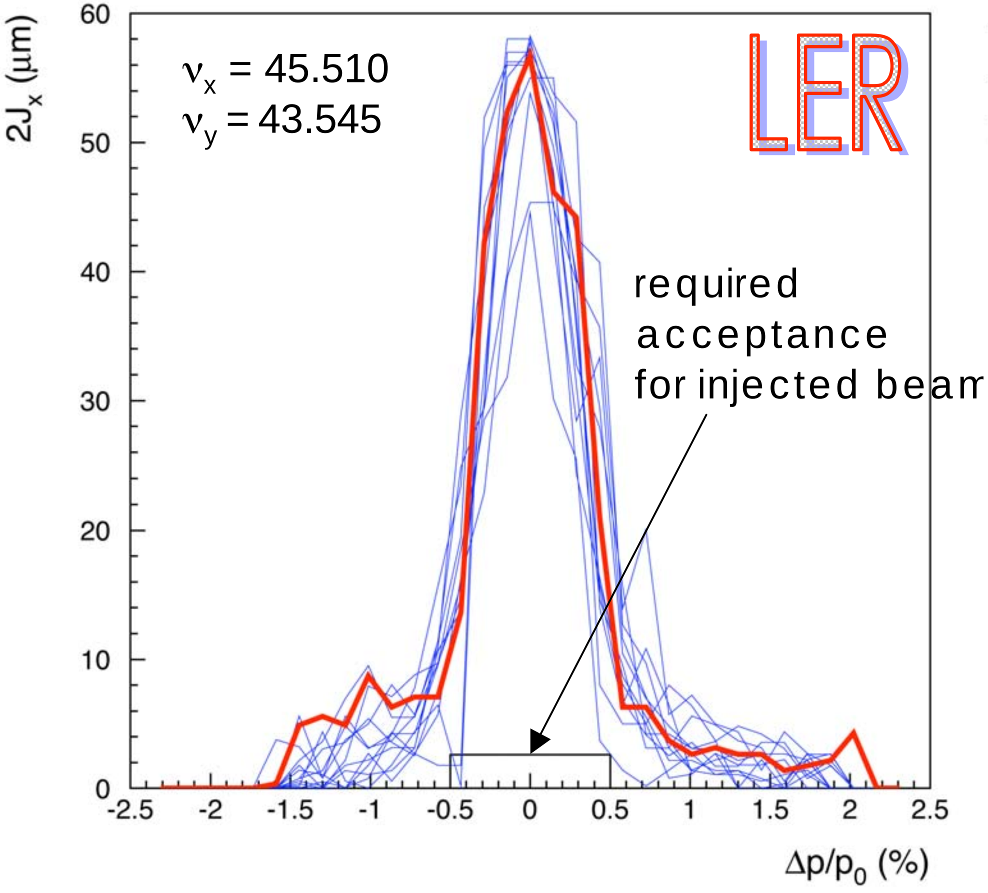
Lattice has large flexibility.

ε_x and α_p can be adjusted independently.

Dynamic Aperture for Injected Beam (SuperKEKB)

ε_x=24 nm case

Injected beam J_y/J_x = 7 %

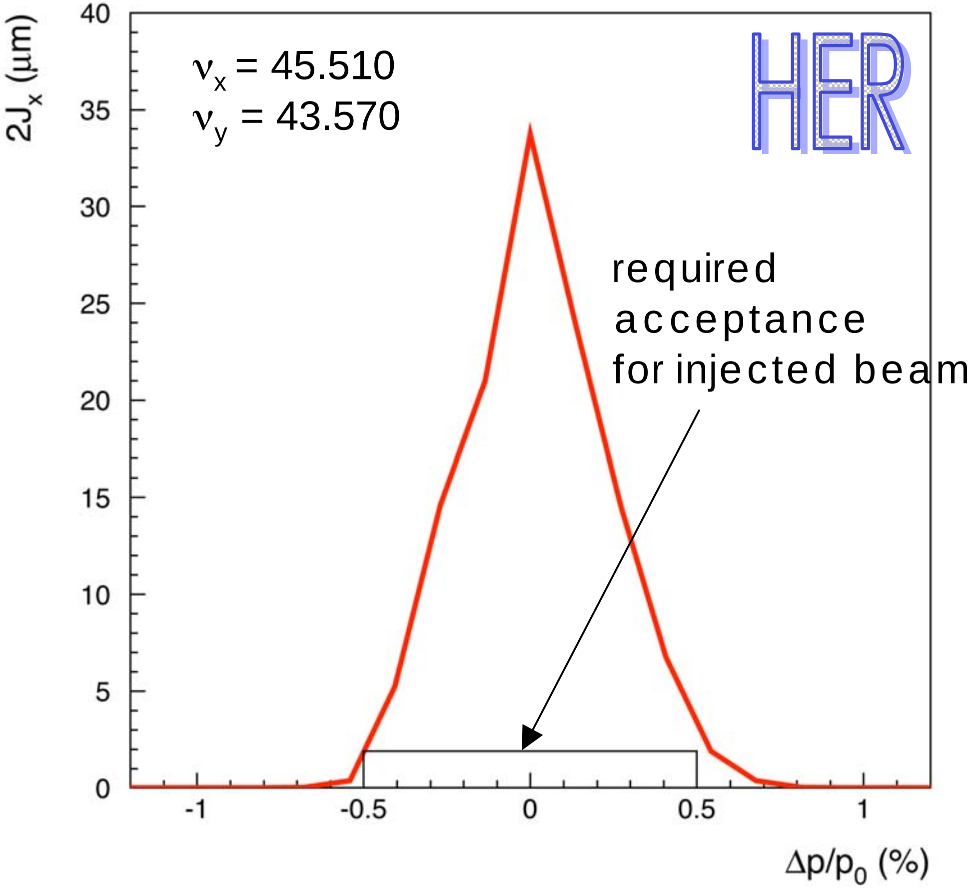


red: no machine error

blue: machine error + optics correction

(12 lines indicate different seed numbers.)

Injected beam J_y/J_x = 4 %



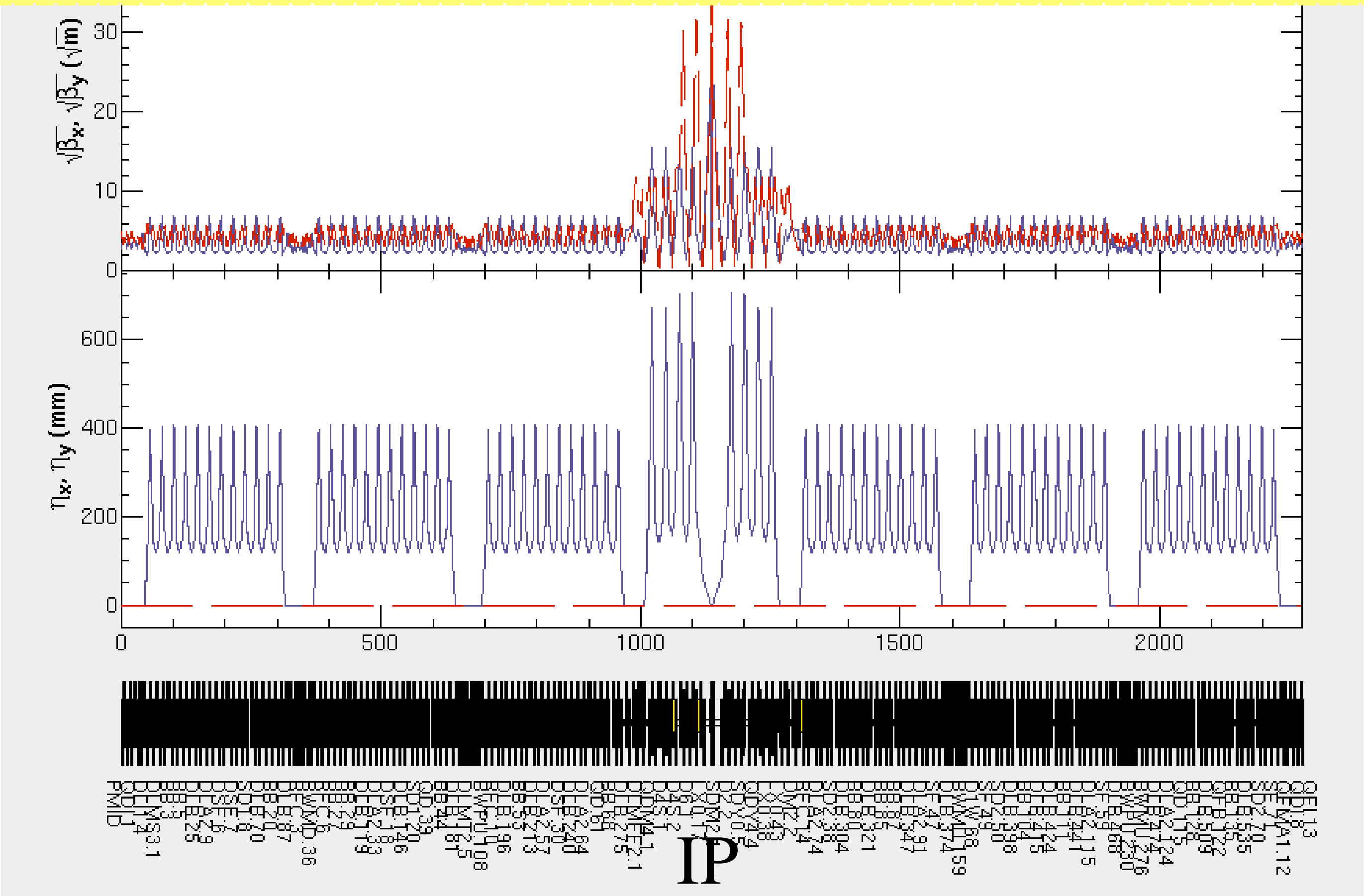
Dynamic aperture satisfies injected beam.

SuperB

Luminosity x 10^{36}	1		2,4		3,4	
Circumference (m)	2250	2250	2250	2250	2250	2250
Revolution frequency (MHz)	0,13	0,13	0,13	0,13	0,13	0,13
Eff. long. polarization (%)	0	80	0	80	0	80
RF frequency (MHz)	476	476	476	476	476	476
Harmonic number	3570	3570	3570	3570	3570	3570
Momentum spread	8,4E-04	9,0E-04	1,0E-03	1,0E-03	1,0E-03	1,0E-03
Momentum compaction	1,8E-04	3,0E-04	1,8E-04	3,0E-04	1,8E-04	3,0E-04
Rf Voltage (MV)	6	18	6	18	7,5	18
Energy loss/turn (MeV)	1,9	3,3	2,3	4,1	2,3	4,1
Number of bunches	1733	1733	3466	3466	3466	3466
Particles per bunch x10^{10}	6,16	3,52	5,34	2,94	6,16	3,52
Beam current (A)	2,28	1,30	3,95	2,17	4,55	2,60
Beta y* (mm)	0,30	0,30	0,20	0,20	0,20	0,20
Beta x* (mm)	20	20	20	20	20	20
Emit y (pmr)	4	4	2	2	2	2
Emit x (nmr)	1,6	1,6	0,8	0,8	0,8	0,8
Sigma y* (microns)	0,035	0,035	0,020	0,020	0,020	0,020
Sigma x* (microns)	5,657	5,657	4,000	4,000	4,000	4,000
Bunch length (mm)	6	6	6	6	6	6
Full Crossing angle (mrad)	34	34	34	34	34	34
Wigglers (#)	4	2	4	4	4	4
Damping time (trans/long)(ms)	32/16	32/16	25/12.5	25/12.5	25/12.5	25/12.5
Luminosity lifetime (min)	10,4	5,9	7,4	4,1	6,1	3,5
Touschek lifetime (min)	5,5	38	2,9	19	2,3	15
Effective beam lifetime (min)	3,6	5,1	2,1	3,4	1,7	2,8
Injection rate pps (100%)	4,9E+11	2,0E+11	1,5E+12	5,0E+11	2,1E+12	7,2E+11
Tune shifts (x/y) (from formula)	0.004/0.17	0.004/0.17	0.007/0.16	0.007/0.16	0.009/0.2	0.009/0.2
RF Power (MW)	17		35		44	

SuperB-HER

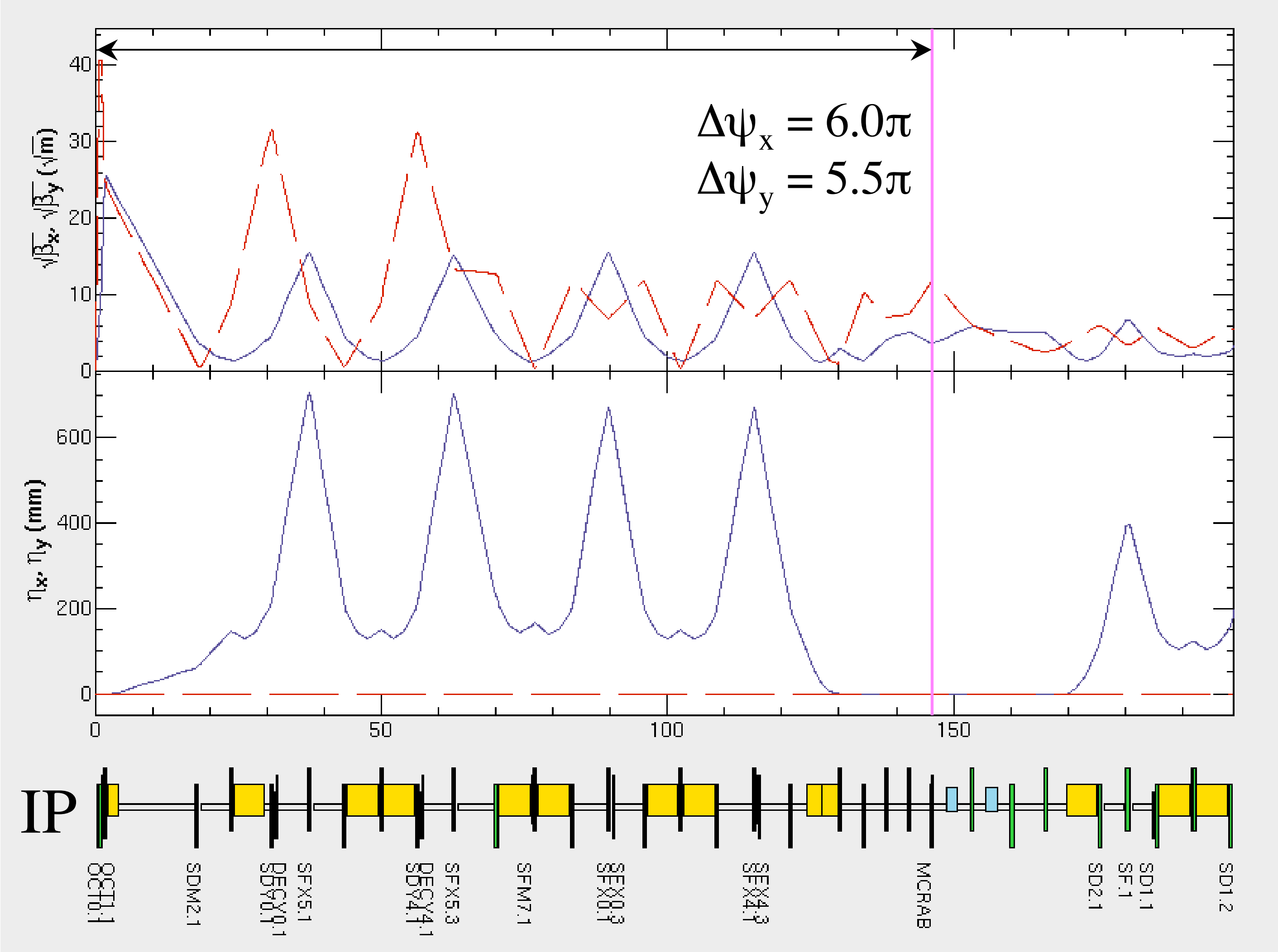
Conceptual lattice, no fringe effect, no multipole elements, no skew quads, no crossing angle... etc.



All PEP-II magnets are used to make the low emittance lattice, modifying the ILC DR design.

Final Focus with Crab Waist

P. Raimondi



$\beta_x{}^*/\beta_y{}^*$ = 20 mm/200 μm

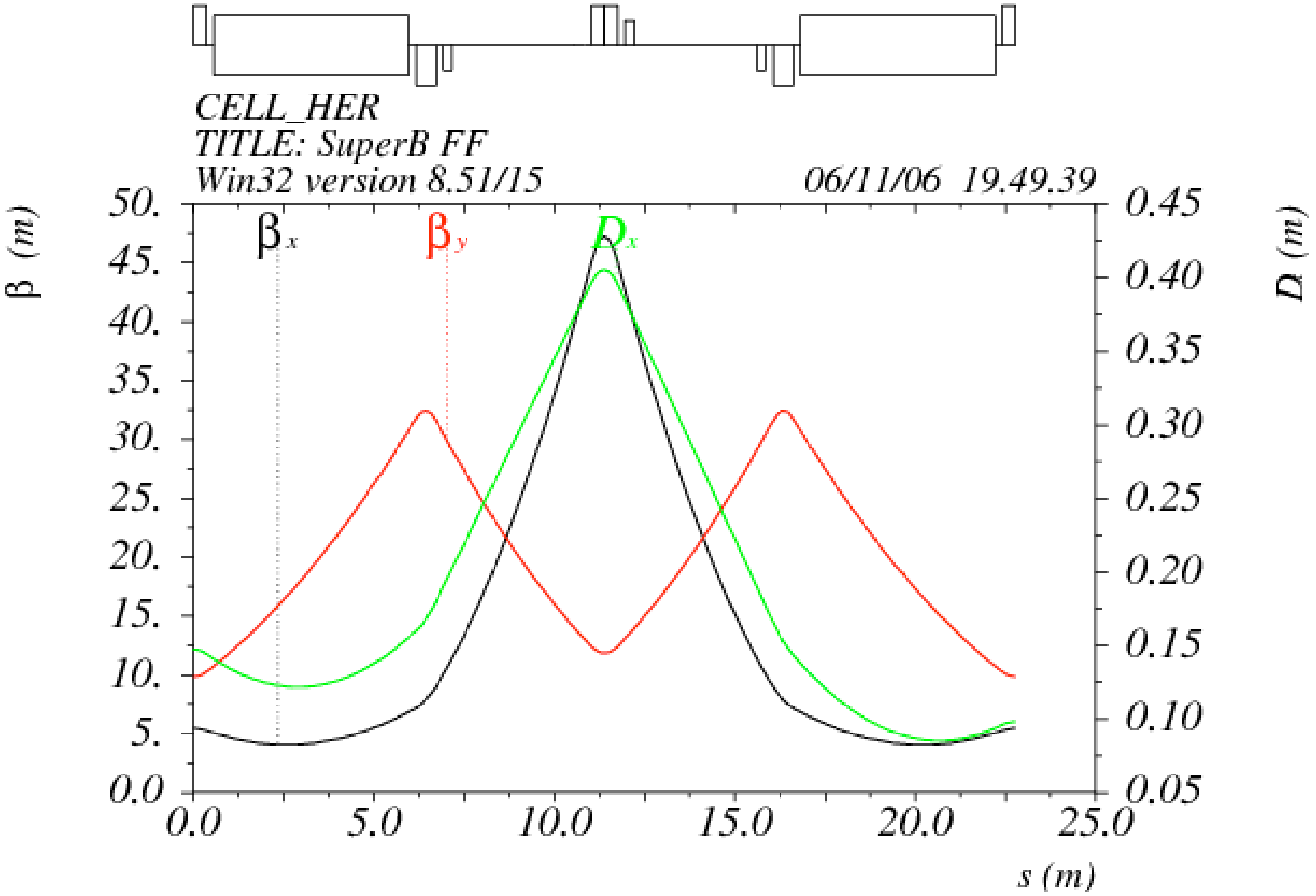
$\beta_x{}^{crab}/\beta_y{}^{crab}$=14 m/140 m

Sextupole(thin) for crab waist

Ultra-low Emittance Arc Lattice

Similar lattice type to ILC damping ring

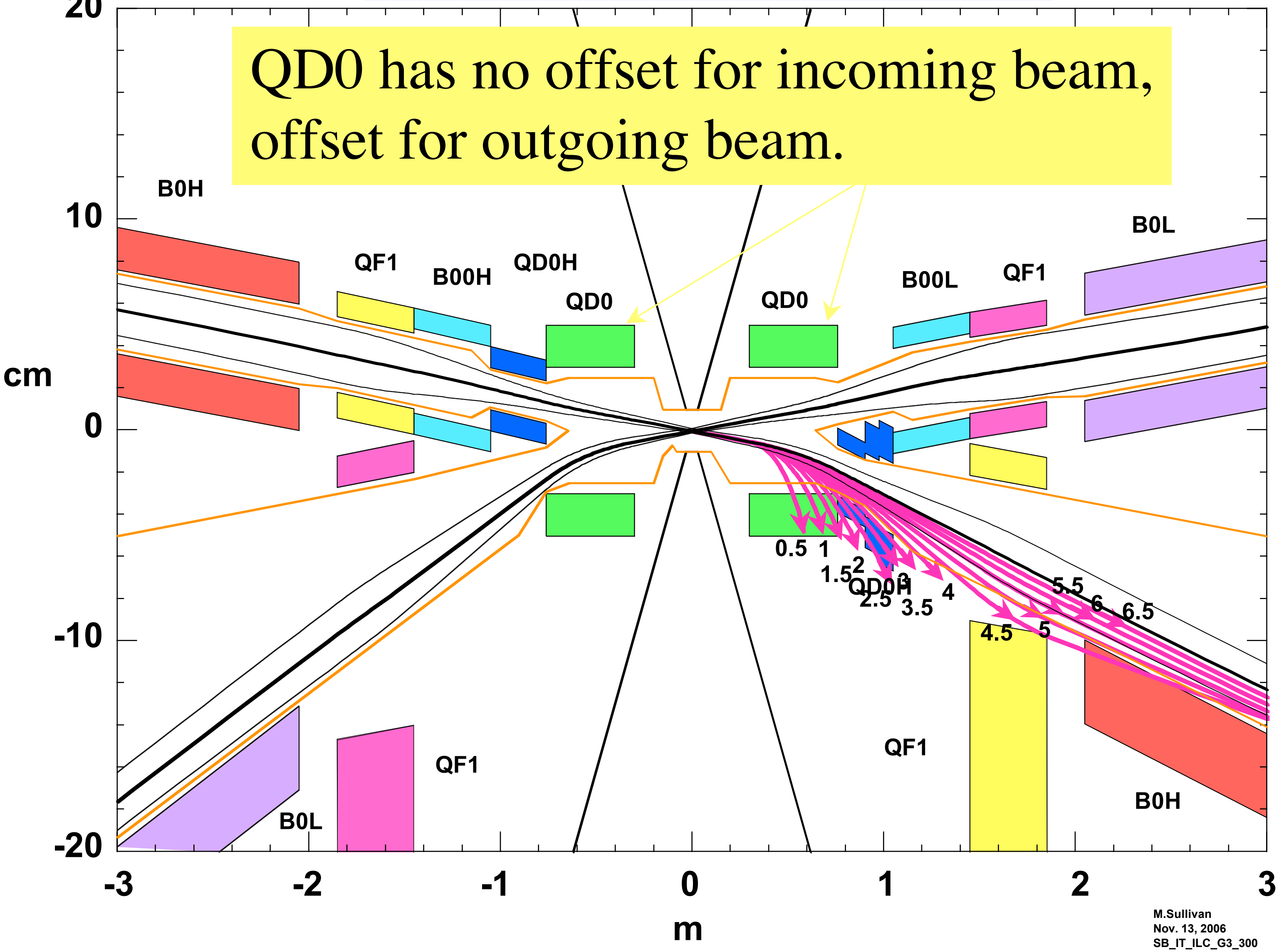
M. Biagini



Emittance ε_x can not be adjusted independent on momentum compaction α_p.

SuperB Interaction Region

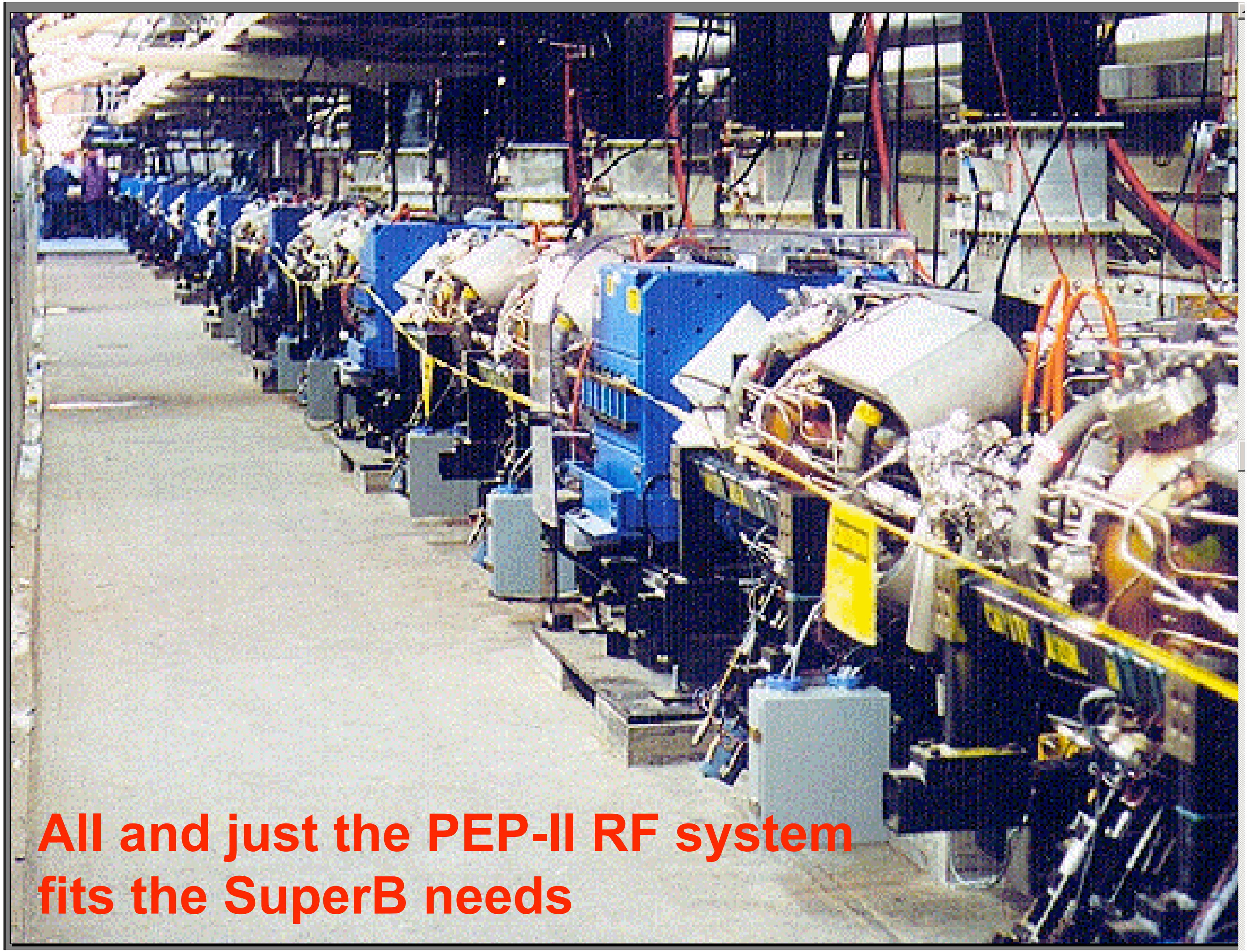
HER radiative bhabhas



QD0 has no offset for incoming beam, offset for outgoing beam.

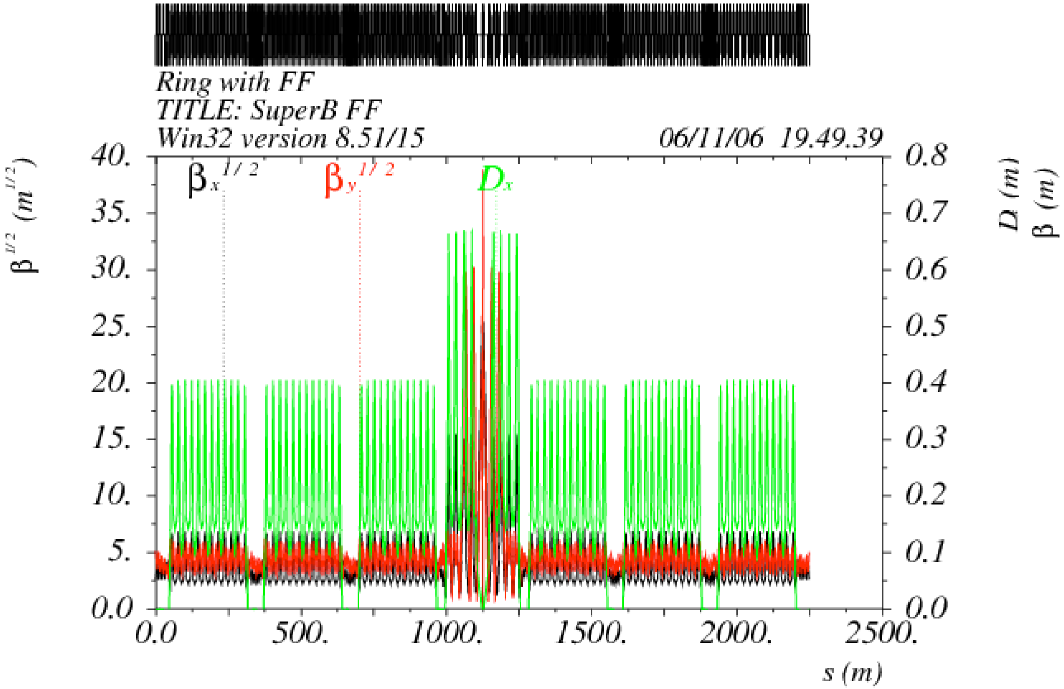
M.Sullivan
Nov. 13, 2006
SB_IT_ILC_G3_300

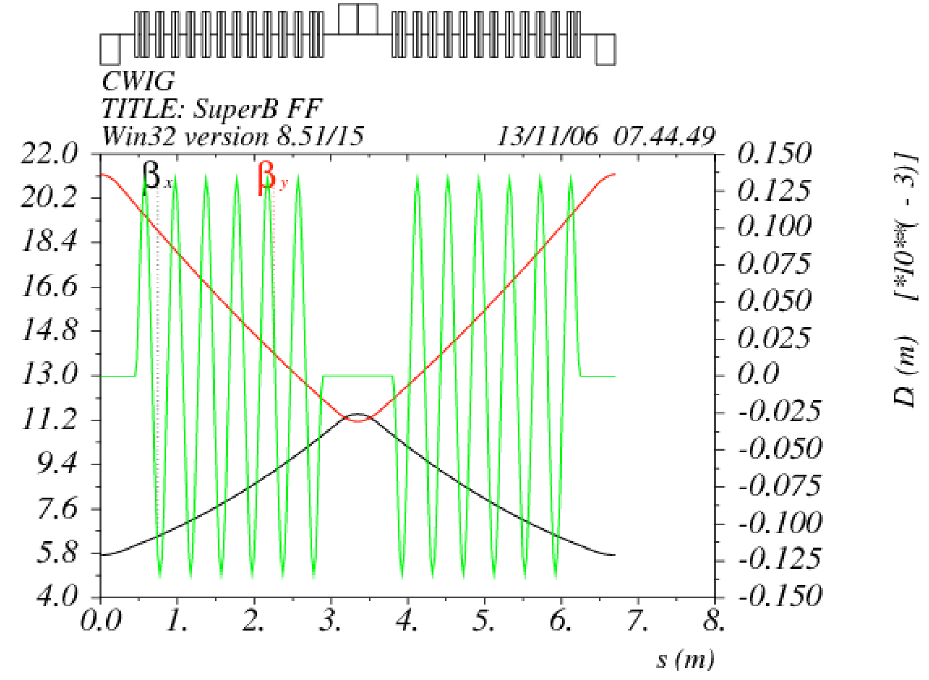
RF System

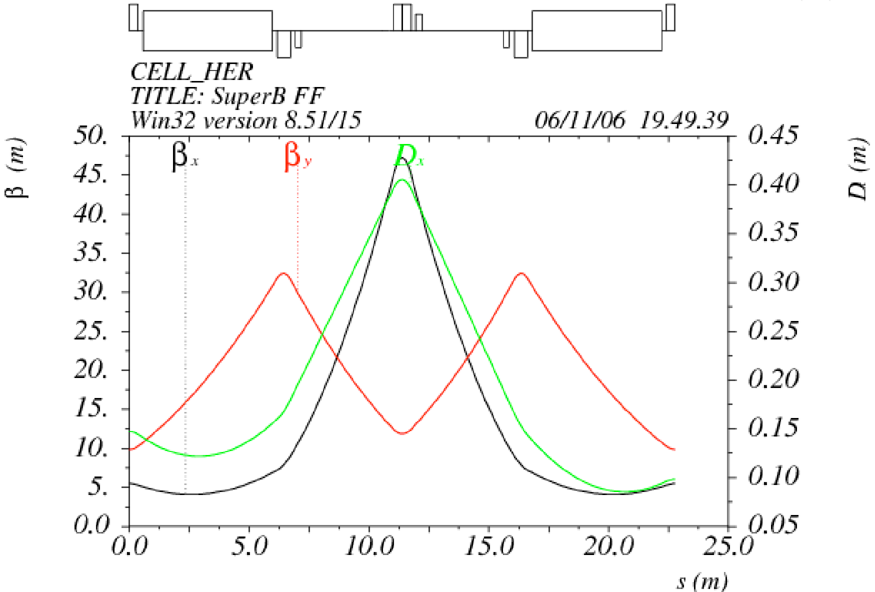


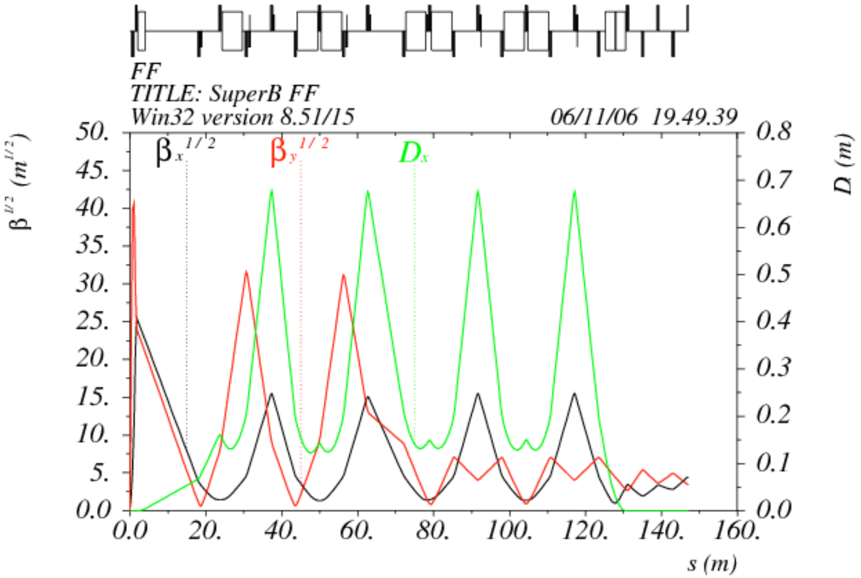
All and just the PEP-II RF system fits the SuperB needs

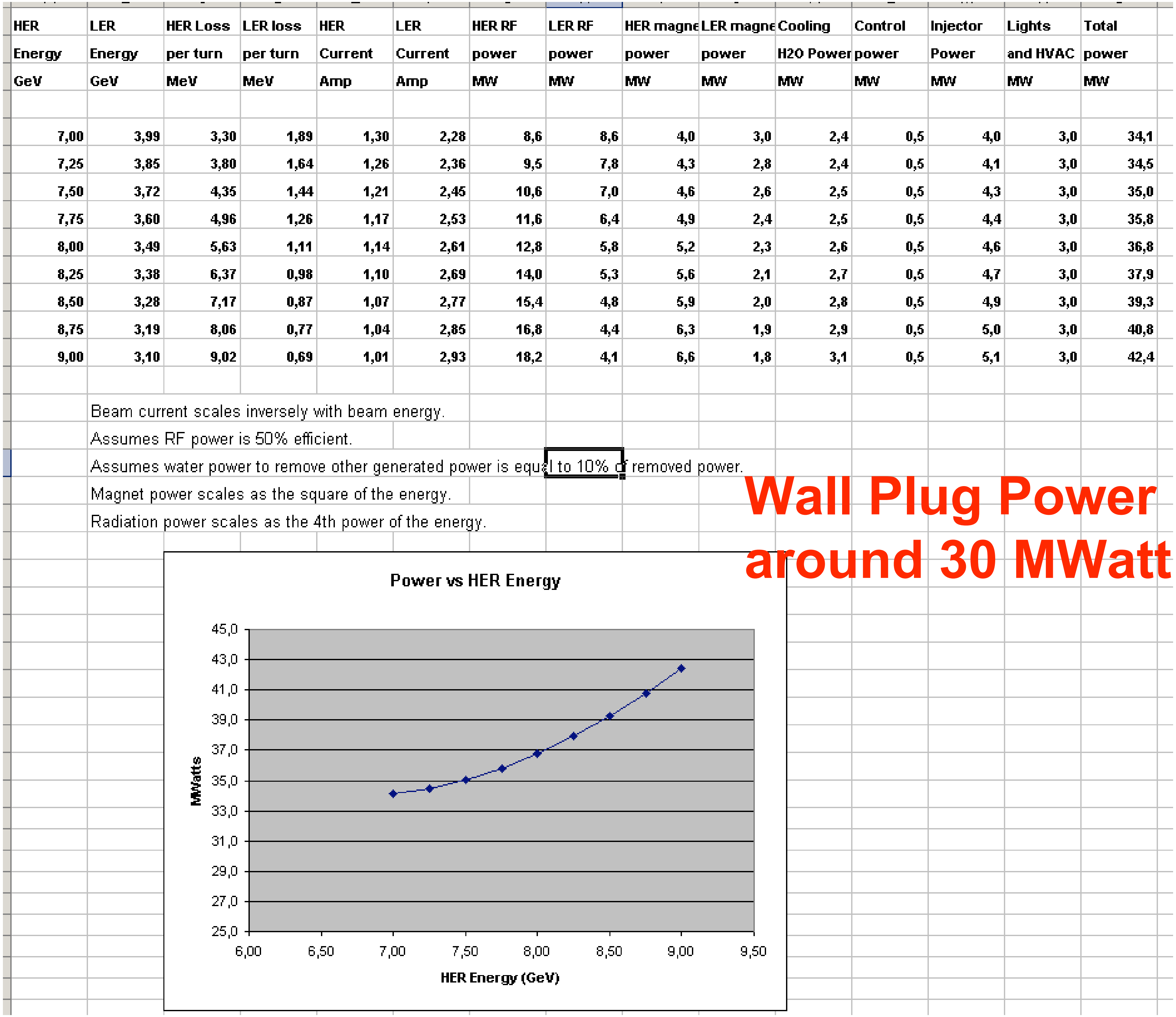
HER Ring Lattice











HER Energy GeV	LER Energy GeV	HER Loss per turn MeV	LER loss per turn MeV	HER Current Amp	LER Current Amp	HER RF power MW	LER RF power MW	HER magne power MW	LER magne power MW	Cooling H2O Power MW	Control power MW	Injector Power MW	Lights and HVAC MW	Total power MW
7,00	3,99	3,30	1,89	1,30	2,28	8,6	8,6	4,0	3,0	2,4	0,5	4,0	3,0	34,1
7,25	3,85	3,80	1,64	1,26	2,36	9,5	7,8	4,3	2,8	2,4	0,5	4,1	3,0	34,5
7,50	3,72	4,35	1,44	1,21	2,45	10,6	7,0	4,6	2,6	2,5	0,5	4,3	3,0	35,0
7,75	3,60	4,96	1,26	1,17	2,53	11,6	6,4	4,9	2,4	2,5	0,5	4,4	3,0	35,8
8,00	3,49	5,63	1,11	1,14	2,61	12,8	5,8	5,2	2,3	2,6	0,5	4,6	3,0	36,8
8,25	3,38	6,37	0,98	1,10	2,69	14,0	5,3	5,6	2,1	2,7	0,5	4,7	3,0	37,9
8,50	3,28	7,17	0,87	1,07	2,77	15,4	4,8	5,9	2,0	2,8	0,5	4,9	3,0	39,3
8,75	3,19	8,06	0,77	1,04	2,85	16,8	4,4	6,3	1,9	2,9	0,5	5,0	3,0	40,8
9,00	3,10	9,02	0,69	1,01	2,93	18,2	4,1	6,6	1,8	3,1	0,5	5,1	3,0	42,4

Beam current scales inversely with beam energy.

Assumes RF power is 50% efficient.

Assumes water power to remove other generated power is equal to 10% of removed power.

Magnet power scales as the square of the energy.

Radiation power scales as the 4th power of the energy.

Wall Plug Power around 30 MWatt

3 Super-B Accelerator

3.1 Accelerator overview (Seeman+Raimondi)
- 3.1.1 History of B-Factories
- 3.1.2 Key issues for a Super-B Factory (Raimondi)
  - Key items:
    - Luminosity
    - Crossing angle/crab waist/ip
    - Beam lifetime and injection
    - Backgrounds
    - Beam emittances and stability
    - Polarization
    - Power
    - Costs
- 3.1.3 Site requirements

3.2 Parameters (Seeman)
- 3.2.1 Nominal parameters for 1 x 1036 at the 4S
- 3.2.2 Upgrade parameters at 2.4 x 1036 at the 4S
- 3.2.3 Luminosity at the Psi' (3.8 GeV cm)
- 3.2.4 Yearly integrated luminosity
- 3.2.5 Energy asymmetry (Raimondi)

3.3 Layout
- 3.3.1 HER (Biagini)
- 3.3.2. LER (Biagini)
- 3.3.3 Interaction region (Sullivan)
- 3.3.4 Injector (Seeman+Raimondi)

3.4 Interaction region (Sullivan)
- 3.4.1 Geometry
- 3.4.2 Beam trajectory
- 3.4.3 Magnets
- 3.4.4 Vacuum chambers
- 3.4.5 Synchrotron radiation
- 3.4.6 Lost particles (detector)
- 3.4.7 Backgrounds (detector)
- 3.4.8 Vacuum profile

3.5 Magnet lattice and optics
- 3.5.1 LER lattice (Biagini)
- 3.5.2 HER lattice (Biagini)
- 3.5.3 Interaction region (Raimondi)
- 3.5.4 Detector solenoid compensation (Biagini+Raim
- 3.5.5 Dynamic aperture (Cai, Wolski)

3.6 Imperfections and errors
- 3.6.1 Tolerances and errors (Cai)
- 3.6.1 Vibrations and stability (Seeman,Seryi)
- 3.6.1 Low emittance tuning (Wolski)
- 3.6.1 Final Focus tuning (Raimondi,Seryi)

3.7 Intensity dependent effects
- 3.7.1 Beam-beam interaction (Shatilov)
- 3.7.2 Lifetimes (Boscolo+Wienands+Paoloni)
- 3.7.3 Intra Beam Scattering (Wienands+Wolski)
- 3.7.4 Electron cloud instability (Heifets, Pivi)
- 3.7.5 Fast ion instability (Heifets,Wang)
- 3.7.6 Space charge (Heifets)
- 3.7.7 Higher order modes (Novokhatski)
- 3.7.8 Single bunch impedance effects (Heifets)
- 3.7.9 CSR (Agoh)
- 3.7.10Multi-bunch instabilities (Wienands)

3.8 Magnet systems (Wienands+Yocky+Biagini)
- 3.8.1 LER dipoles
- 3.8.2 LER quadrupoles
- 3.8.3 LER sextupoles
- 3.8.4 LER octupoles
- 3.8.5 HER dipoles
- 3.8.6 HER quadrupoles
- 3.8.7 HER sextupoles
- 3.8.8 HER octupoles
- 3.8.9 Correction magnets
- 3.8.9 Damping wigglers (Koop →Levichev)
- 3.8.10 Interaction region magnets (Ecklund)

3.6 RF systems (Wienands+Seeman)
- 3.7.1 RF parameters
- 3.7.2 RF cavities
- 3.7.3 Klystrons
- 3.7.4 Power supplies
- 3.7.5 RF controls
- 3.7.6 RF feedback
- 3.7.7 High current beam loading

3.7 Vacuum system (Wienands,....)
- 3.8.1 Arc vacuum system
- 3.8.2 Straight section vacuum system
- 3.8.3 Expansion bellows
- 3.8.4 Collimation

3.8 Instrumentation and controls (Fisher)
- 3.9.1 Beam position monitors (Fisher)
- 3.9.2 Beam size monitors (Fisher)
- 3.9.4 Longitudinal feedback (Drago)
- 3.9.5 Transverse feedback (Drago)
- 3.9.6 IP feedback (Sullivan+Decker)
- 3.9.7 Beam abort system (Fisher)
- 3.9.8 Temperature monitor (Ecklund)
- 3.9.9 Temperature control (Ecklund)
- 3.9.10 Control system (Fisher, Stecchi)

3.11 Injection system (Vaccarezza+Seeman)
- 3.11.1 Requirements
- 3.11.2 Layout
- 3.11.3 Components
- 3.11.4 Timing

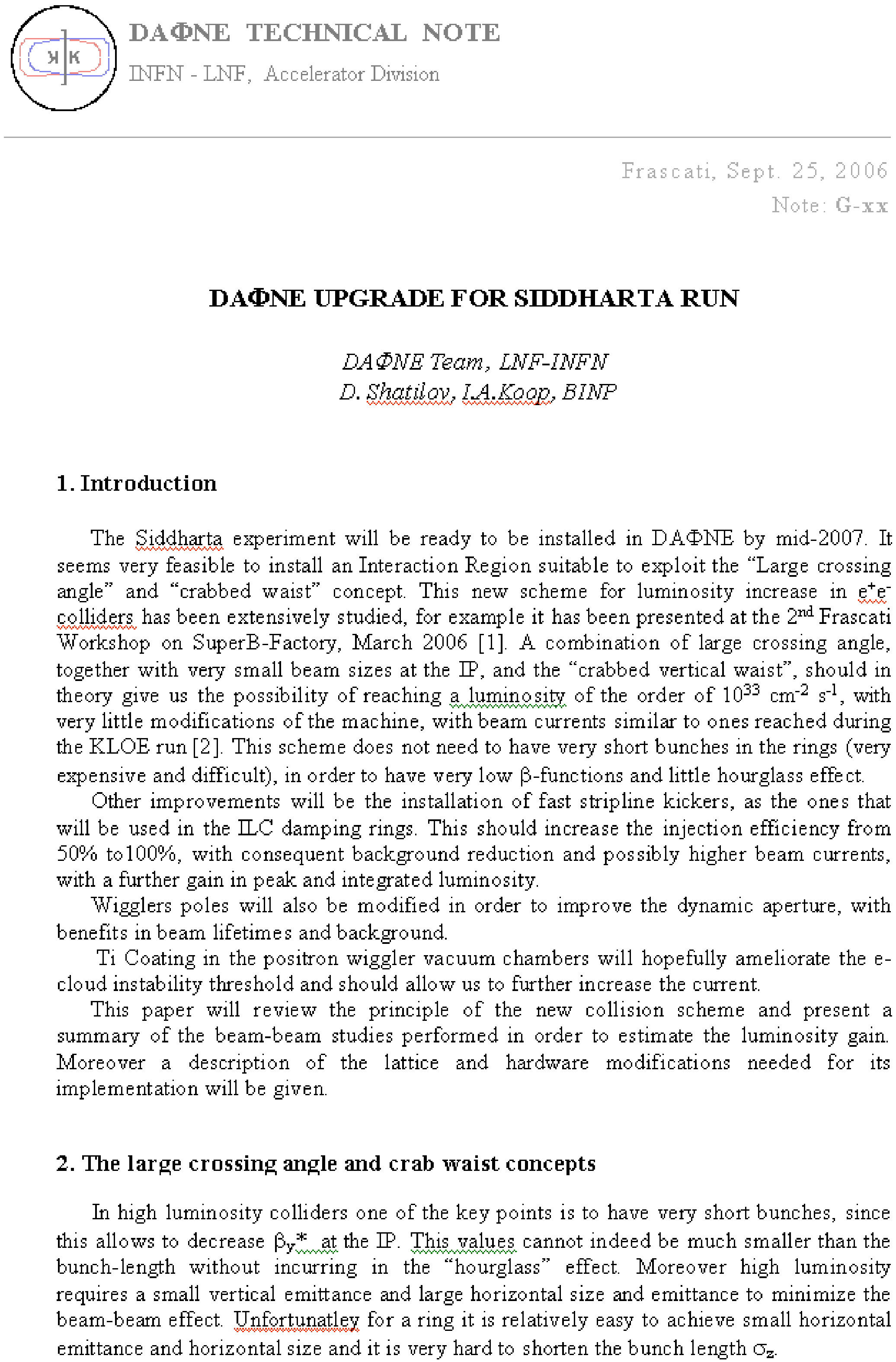
3.12 Polarization (Koop)
- 3.12.1 Geometry
- 3.12.2 Spin rotators
- 3.12.3 Spin transport
- 3.12.4 Measurement

3.13 Site and Utilities
- 3.13.1 Tunnel (Seeman)
- 3.13.2 AC Power (Seeman)
- 3.13.3 Cooling system (Seeman)
- 3.13.4 Air conditioning (Seeman)

3.14 References

CDR ready

Novosibirsk is designing a tau-charm factory based On The Crab-Waist



DAΦNE TECHNICAL NOTE
INFN - LNF, Accelerator Division

Frascati, Sept. 25, 2006
Note: G-xx

DAΦNE UPGRADE FOR SIDDHARTA RUN

DAΦNE Team, LNF-INFN
D. Shatilov, I.A.Koop, BINP

1. Introduction

The Siddharta experiment will be ready to be installed in DAΦNE by mid-2007. It seems very feasible to install an Interaction Region suitable to exploit the "Large crossing angle" and "crabbed waist" concept. This new scheme for luminosity increase in e^+e^- colliders has been extensively studied, for example it has been presented at the 2nd Frascati Workshop on SuperB-Factory, March 2006 [1]. A combination of large crossing angle, together with very small beam sizes at the IP, and the "crabbed vertical waist", should in theory give us the possibility of reaching a luminosity of the order of 10^{33} cm^{-2} s^{-1}, with very little modifications of the machine, with beam currents similar to ones reached during the KLOE run [2]. This scheme does not need to have very short bunches in the rings (very expensive and difficult), in order to have very low β-functions and little hourglass effect.

Other improvements will be the installation of fast stripline kickers, as the ones that will be used in the ILC damping rings. This should increase the injection efficiency from 50% to100%, with consequent background reduction and possibly higher beam currents, with a further gain in peak and integrated luminosity.

Wigglers poles will also be modified in order to improve the dynamic aperture, with benefits in beam lifetimes and background.

Ti Coating in the positron wiggler vacuum chambers will hopefully ameliorate the e-cloud instability threshold and should allow us to further increase the current.

This paper will review the principle of the new collision scheme and present a summary of the beam-beam studies performed in order to estimate the luminosity gain. Moreover a description of the lattice and hardware modifications needed for its implementation will be given.

2. The large crossing angle and crab waist concepts

In high luminosity colliders one of the key points is to have very short bunches, since this allows to decrease β_y^* at the IP. This values cannot indeed be much smaller than the bunch-length without incurring in the "hourglass" effect. Moreover high luminosity requires a small vertical emittance and large horizontal size and emittance to minimize the beam-beam effect. Unfortunatley for a ring it is relatively easy to achieve small horizontal emittance and horizontal size and it is very hard to shorten the bunch length σ_z.

Large piwinski angle and Crab Waist will be used in the Dafne run next fall to try to improve the luminosity by a factor > 3