Upgrade plan of KEKB

Y. Ohnishi / KEK

ICFA Beam dynamics workshop on high luminosity e+e- factories
Budker Institute of Nuclear Physics, Novosibirsk
April 14-16, 2008

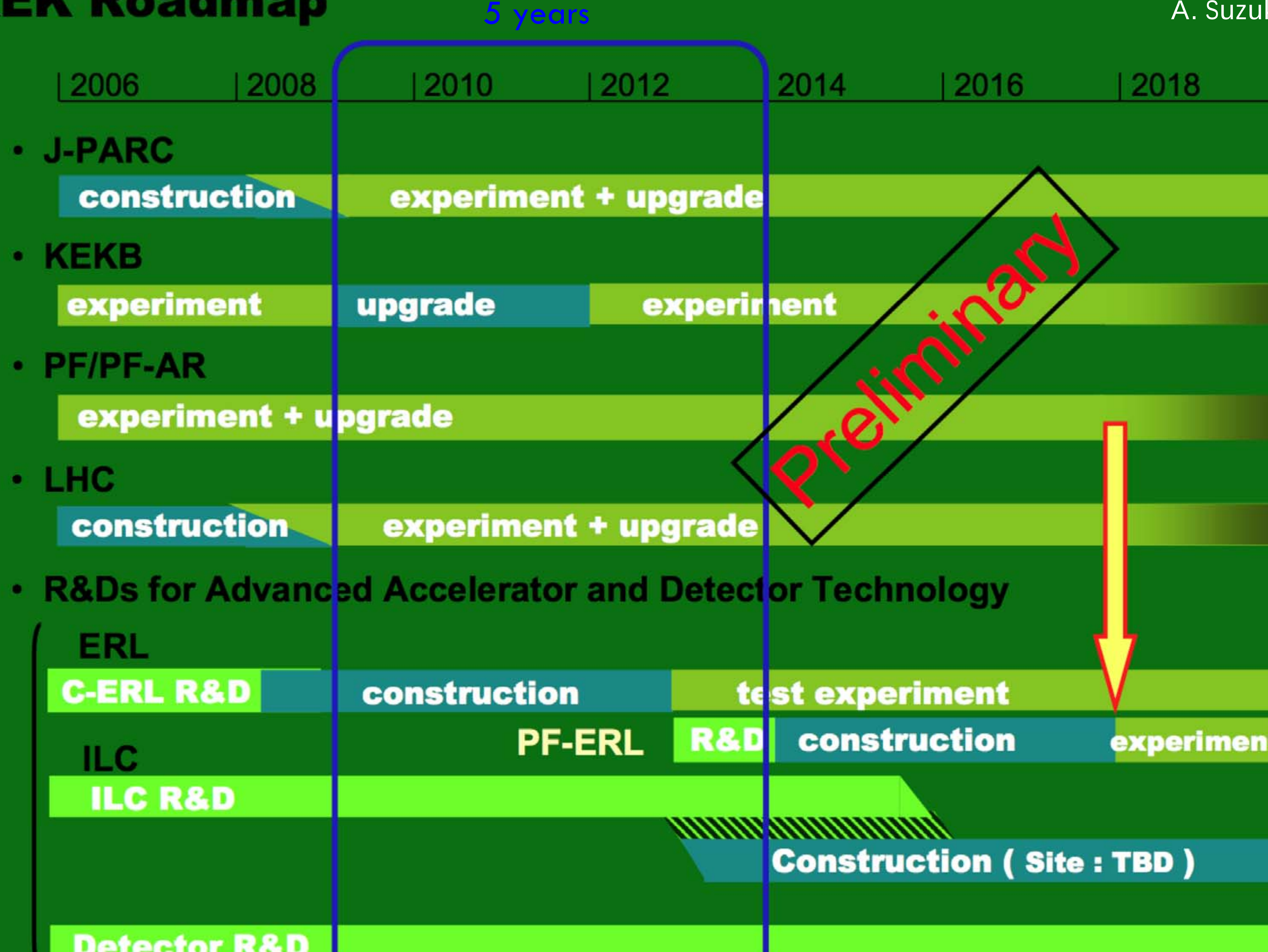
Introduction

KEK roadmap,

Machine parameters

EK Roadmap

A. Suzu



Time schedule is restricted.

Baseline is “HIGH current scheme”.

Alternative is low beta+low emittance+crab waist scheme

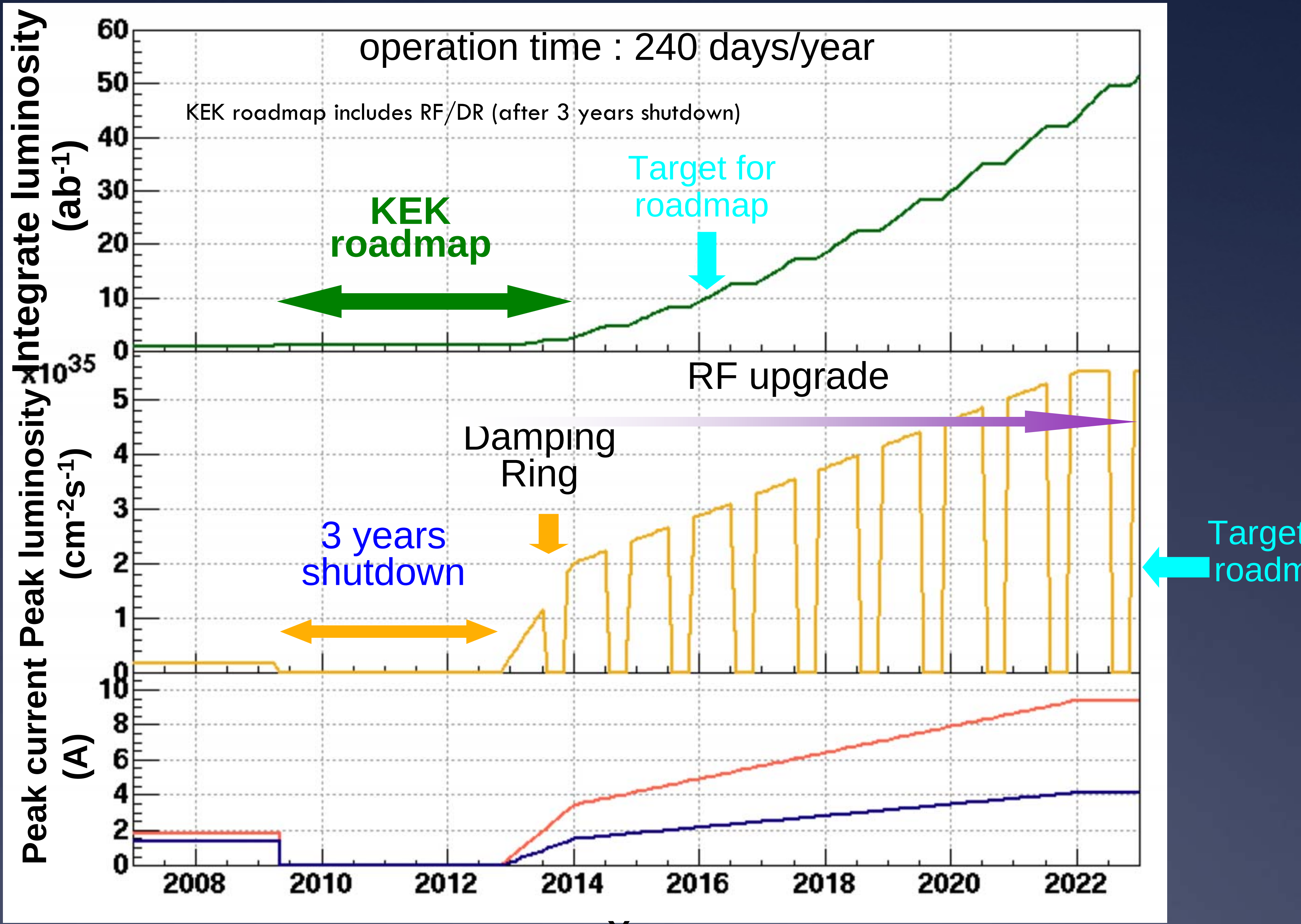
Luminosity upgrade

Luminosity gain and upgrade items (preliminary)

3 years shutdown

Item	Gain	Purpose
beam pipe	x 1.5	high current, short bunch, electron cloud
IR($\beta^*_{x/y}$=20cm/3 mm)	x 1.5	small beam size at IP
low emittance(12 nm) & $\nu_x \to 0.5$	x 1.3	mitigate nonlinear effects with beam-beam
crab crossing	x 2	mitigate nonlinear effects with beam-beam
RF/infrastructure	x 3	high current
DR/e^+ source	x 1.5	low β^* injection, improve e^+ injection
charge switch	x ?	electron cloud, lower e^+ current

Projected Luminosity (preliminary)



Machine parameters

		LER	HER	
Energy	E	3.5	8.0	GeV
Current	I_b	9.4	4.1	A
#particles/bunch	N	1.18×10^{11}	5.13×10^{10}	
#bunches	n_b	5018		
Emittance	ε_x	12		nm
Coupling	$\varepsilon_y/\varepsilon_x$	0.5		%
Beta at IP	β_x^*	20		cm
	β_y^*	3		mm
Bunch length (0A)	σ_z	3		mm
Crossing angle	θ_x	30→0 (crab crossing)		mrad
Bean-beam	ξ_x	0.272		
	ξ_y	0.295		
Luminosity reduction	R_L	0.86		
Beam-beam	$R_{\xi x}$	0.98		
reduction	$R_{\xi y}$	1.11		

Boost factor

- Toy MC results considering Δt resolution and geometrical acceptance.
- Geometrical acceptance is assumed to be same as the current Belle detector at KEKB.

K. Hara (Nagoya Univ.)

– $J/\psi K^0$ tCPV

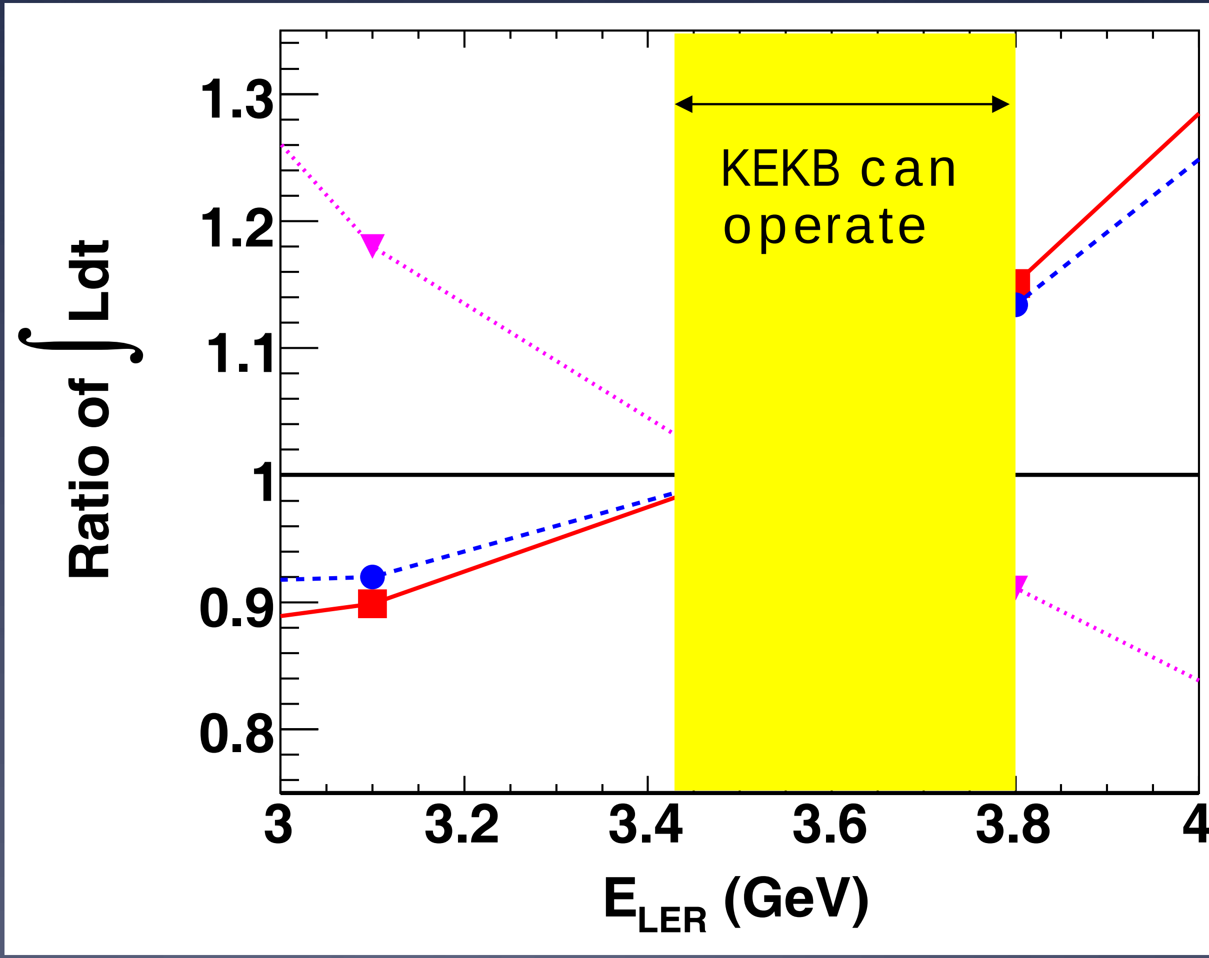
– ϕK^0 tCPV

– $B \rightarrow \tau\nu$ BR

worse

better

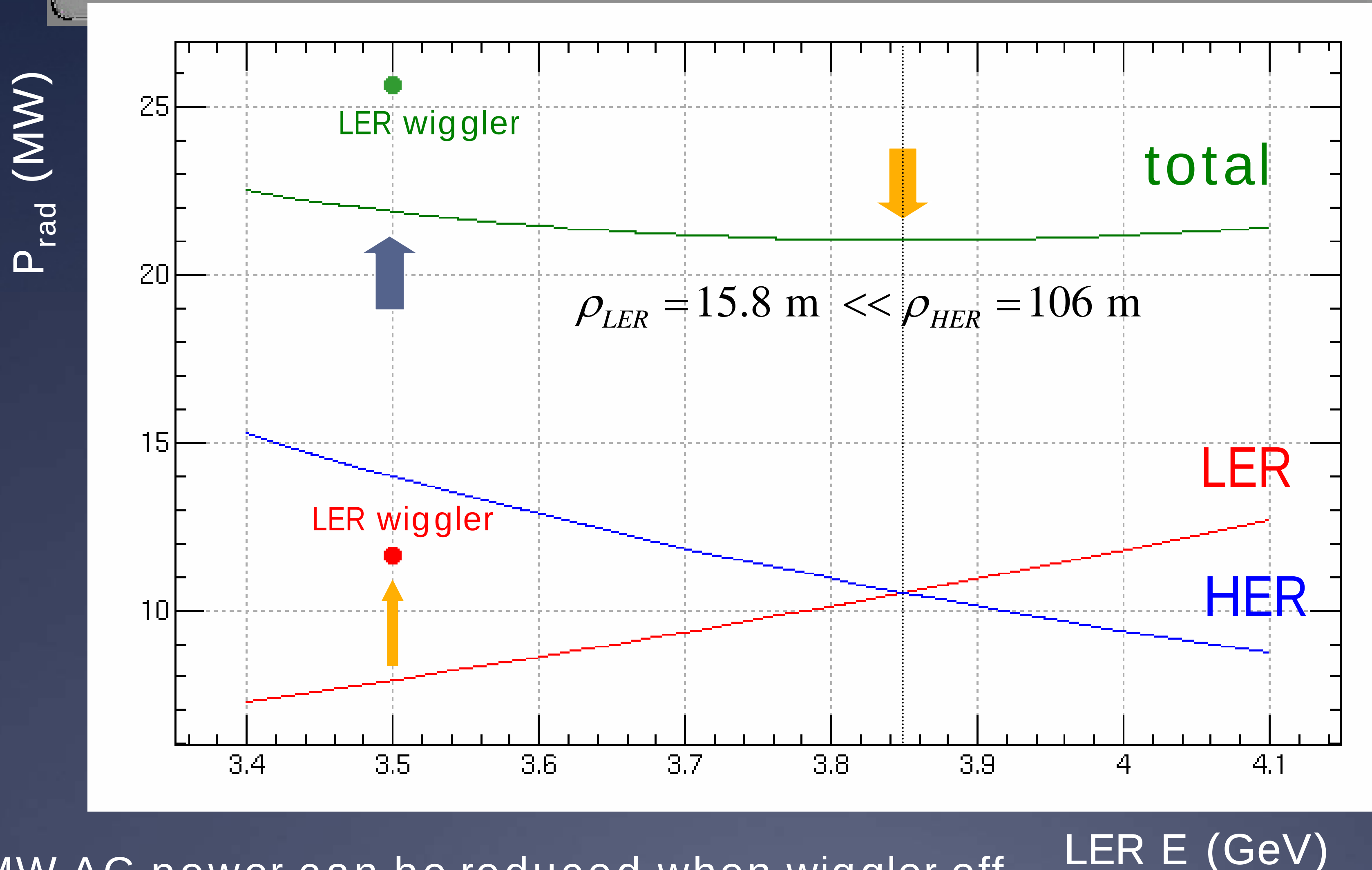
3.5x8 GeV is good choice.



Synchrotron radiation loss

$$m_{4S}^2 = 4E_{LER}E_{HER} \qquad E_{LER}I_{LER} = 3.5 \times 9.4 \text{ GeV A} \qquad \Rightarrow \qquad P_{rad} = U_0 I$$

$$L \propto E \cdot I \qquad E_{HER}I_{HER} = 8.0 \times 4.1 \text{ GeV A}$$



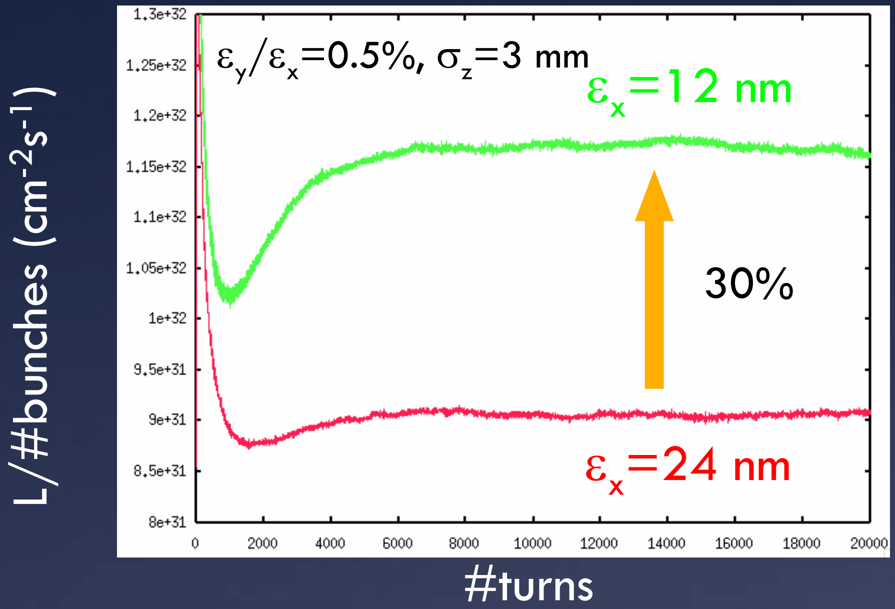
10 MW AC power can be reduced when wiggler off

Luminosity Estimation

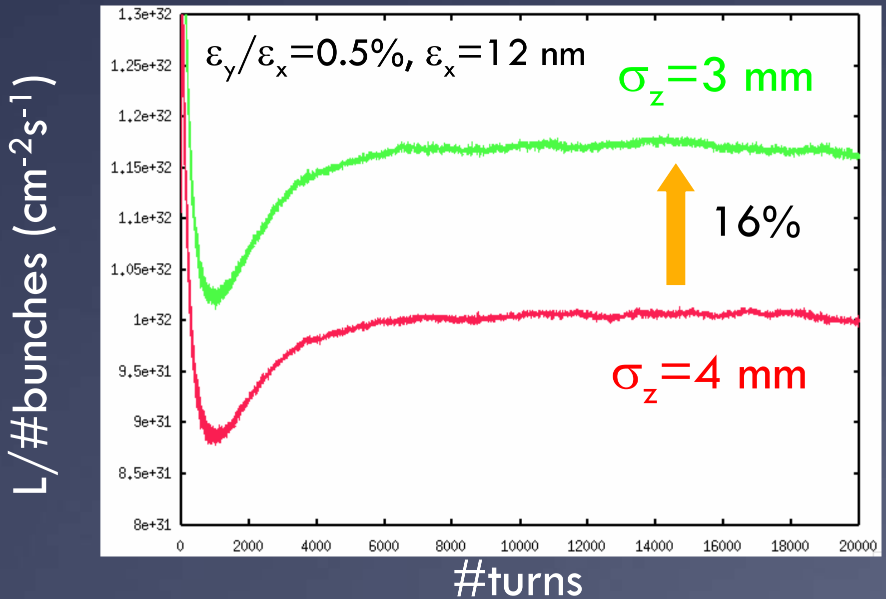
Beam-beam simulations

Beam-beam simulation (Strong-Strong)

K. Ohmi

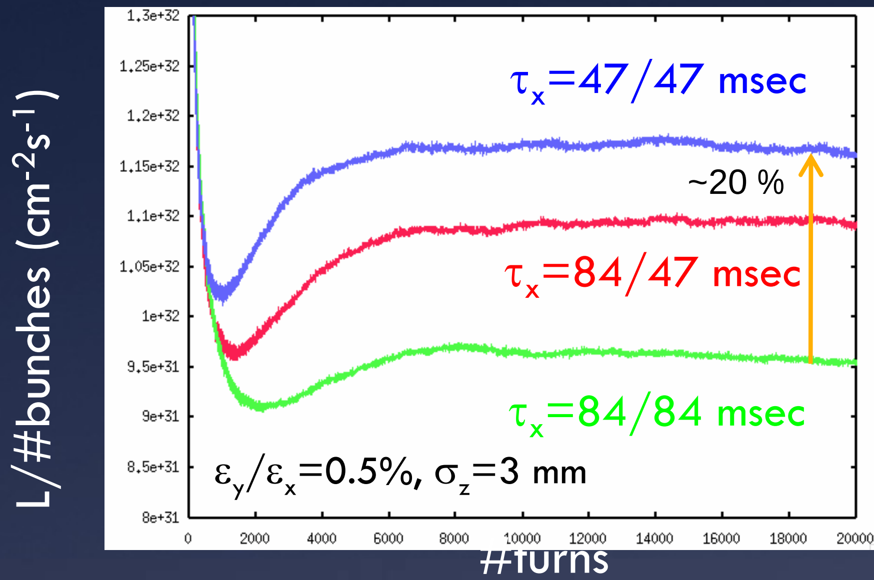


Lower emittance is preferable.



Shorter bunch length is preferable.
If CSR is critical, 4 mm bunch length will be adopted (luminosity~16% low

Different damping time

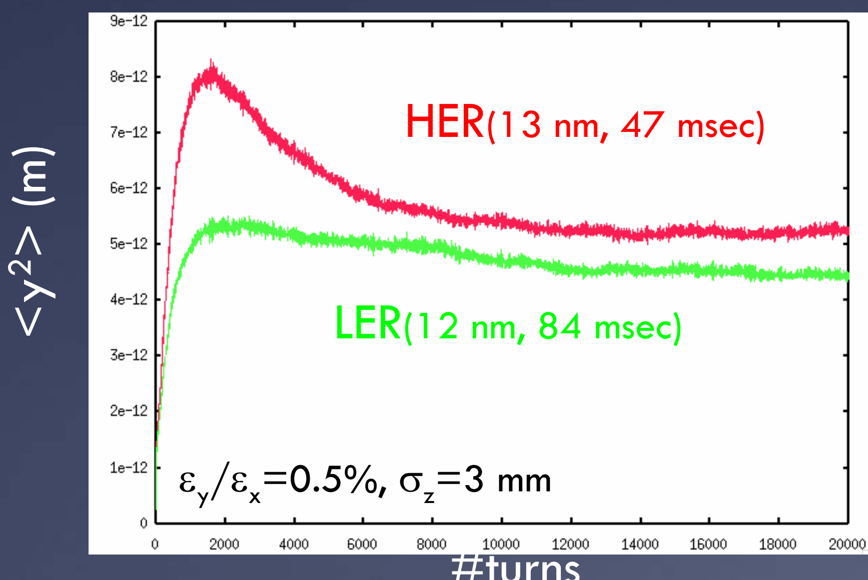


$$P_{rad} = U_0 I = \frac{2T_0 EI}{\tau_x} \propto \frac{L}{\tau_x}$$

Longer damping time with keeping luminosity can save money.... But, shorter damping time is preferable.

At high current, we will not use LER wiggler to save a power consumptio

LER : 47 to 84 msec



In the case of different damping time luminosity can be optimized by adjusting emittance.
(otherwise, one beam blowups, the other shrinks in the model.)

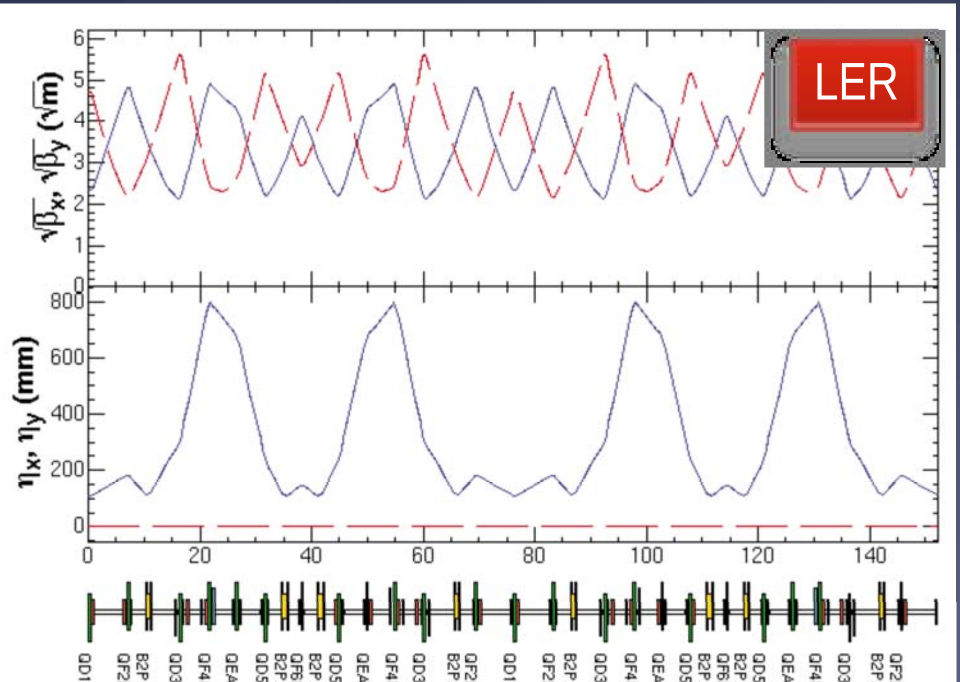
ε_x(LER)/ε_x(HER) = 12/13 nm, for instanc

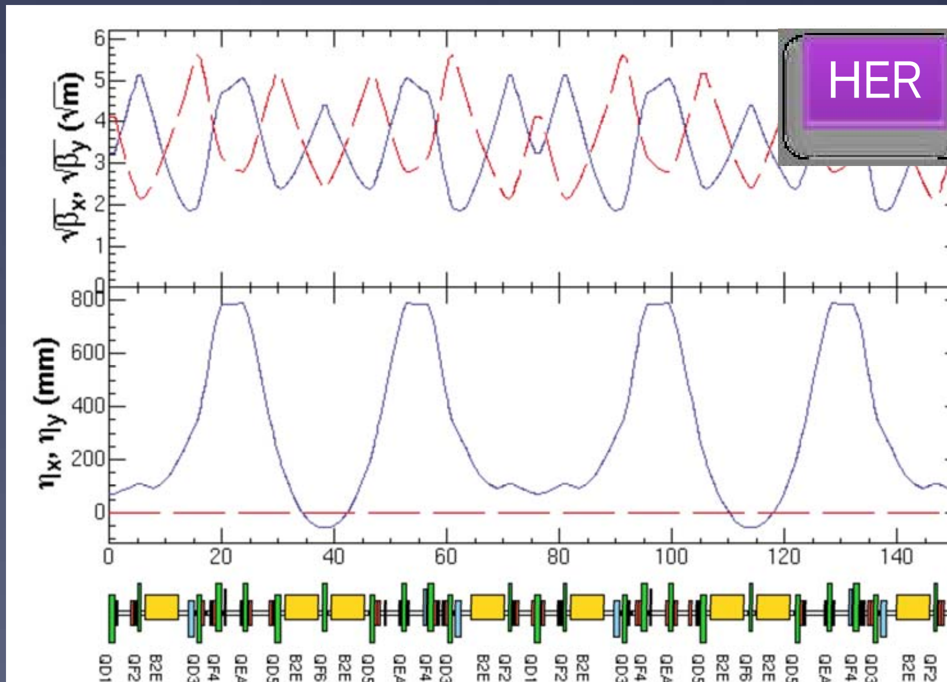
Optics

Arc lattice, Ground level of the tunnel, Dynamic aperture

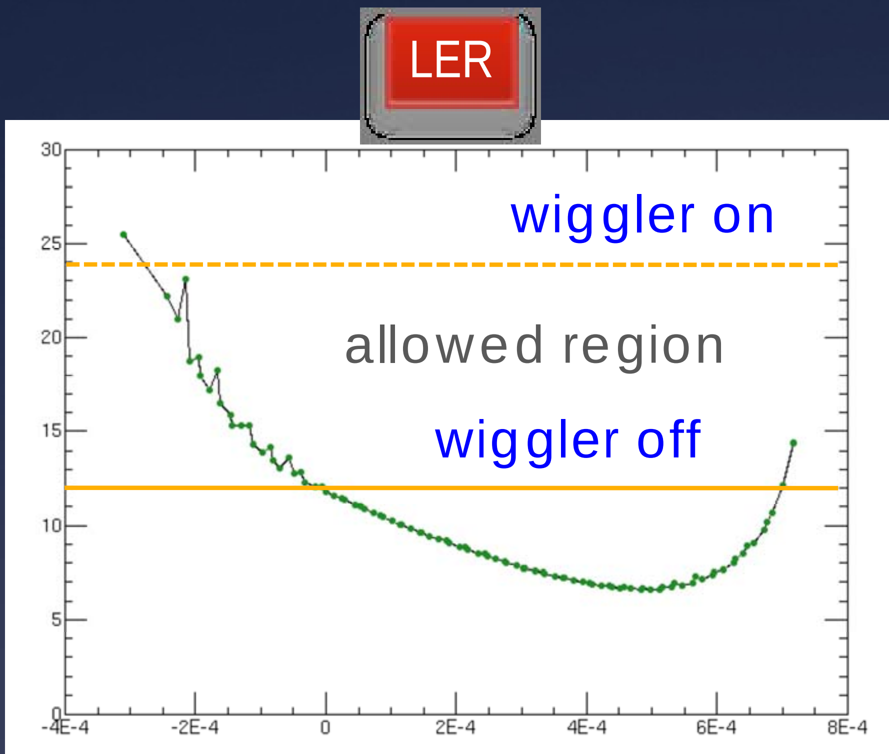
Lattice parameters

Lattice parameters	LER	HER	
Horizontal emittance	12	12	nm
Beta function at IP	200/3		mm
Bunch length	3		mm
RF voltage	12	17.4	MV
Momentum compaction	1.9×10^{-4}	1.4×10^{-4}	
Synchrotron tune	-0.0231	-0.0157	



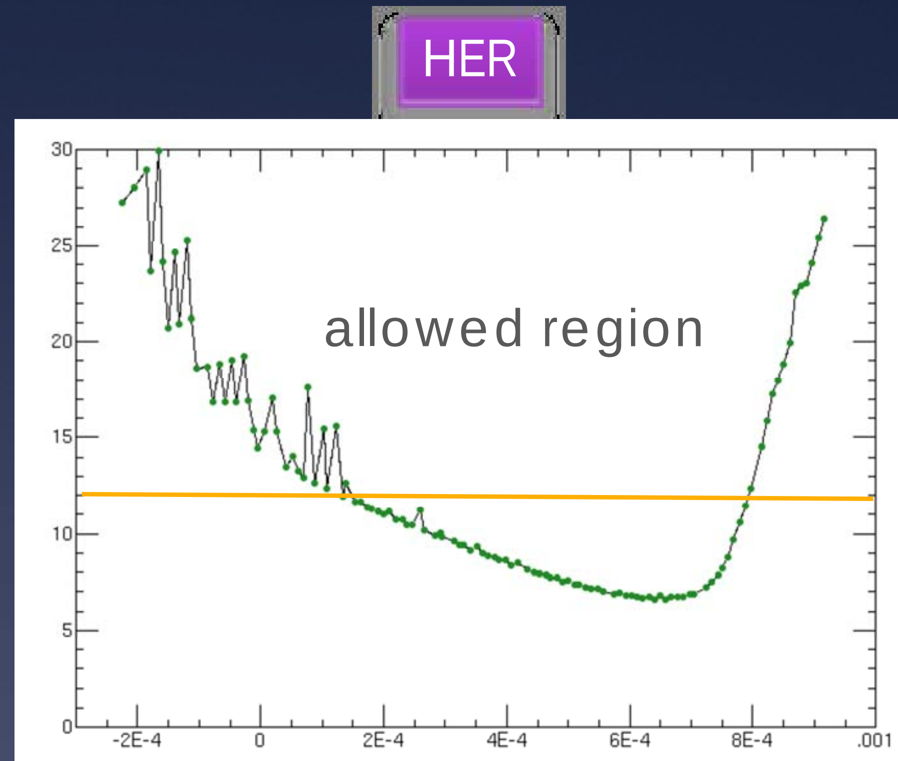


Flexibility of non-interleaved 2.5π arc cell



Momentum compaction

$0 < \alpha_p < 7 \times 10^{-4}$



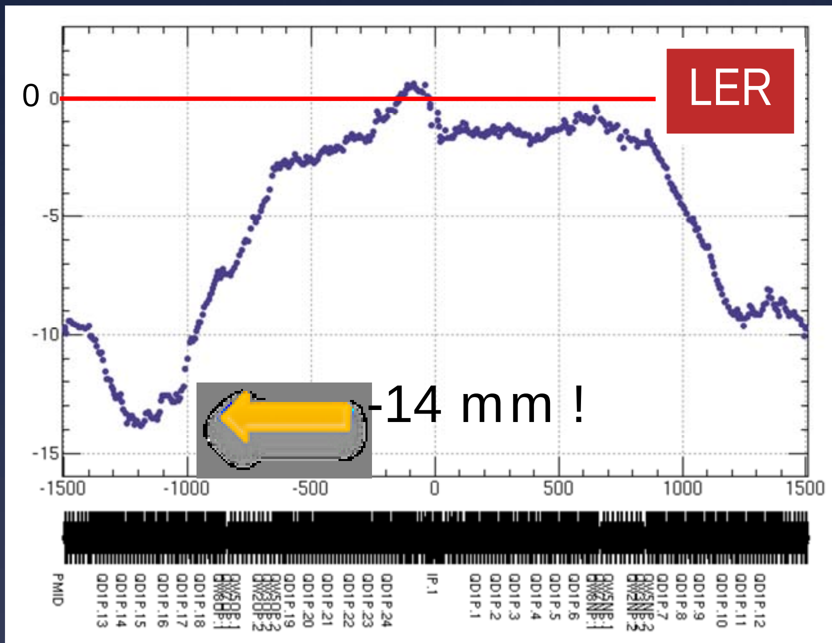
Momentum compaction

$1 \times 10^{-4} < \alpha_p < 8 \times 10^{-4}$

*Arc emittance is 24 nm in case LER wiggler is used.

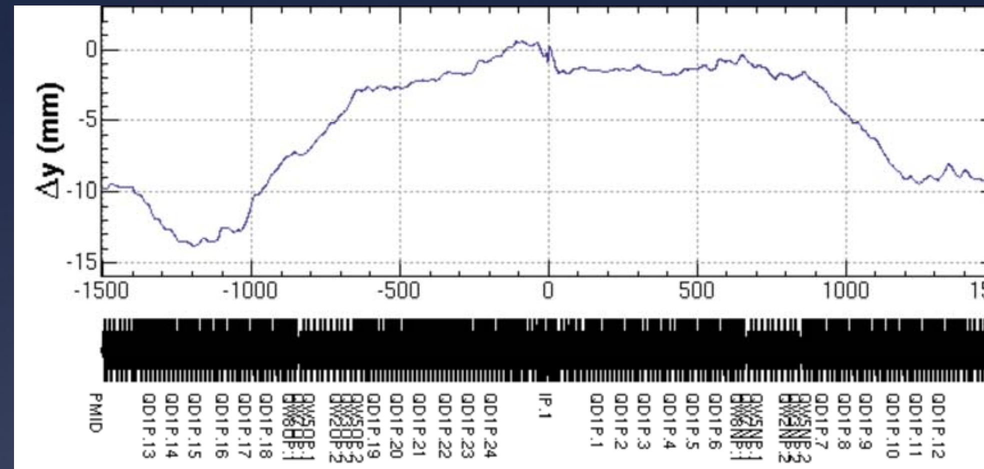
Beam line distortion (vertical)

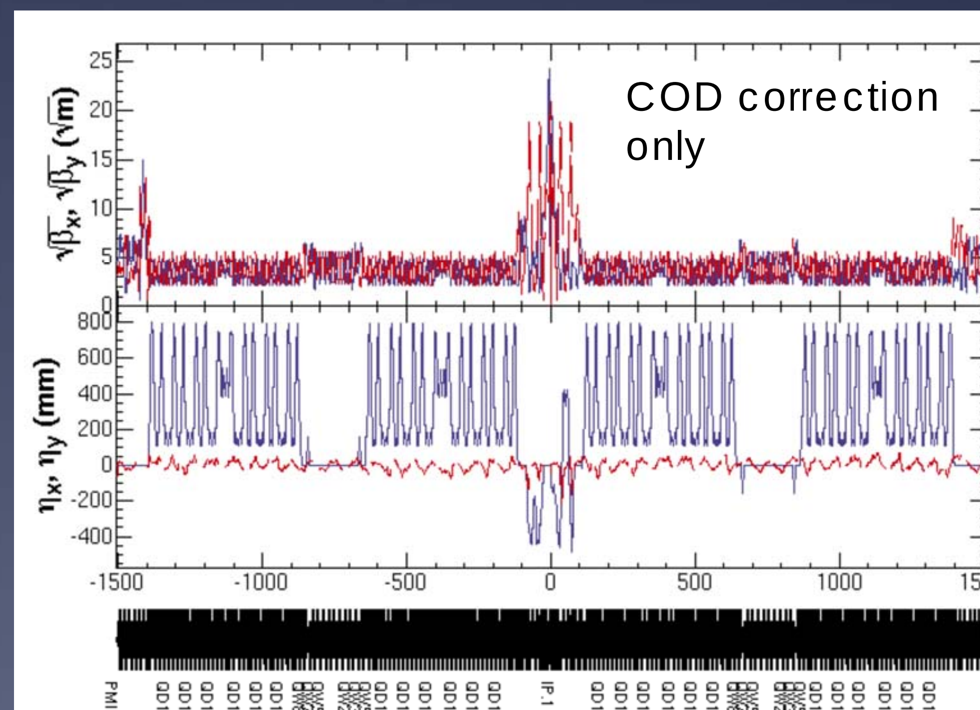
Measured ground level (quads.)



M. Masuzawa

Orbit correction (model)





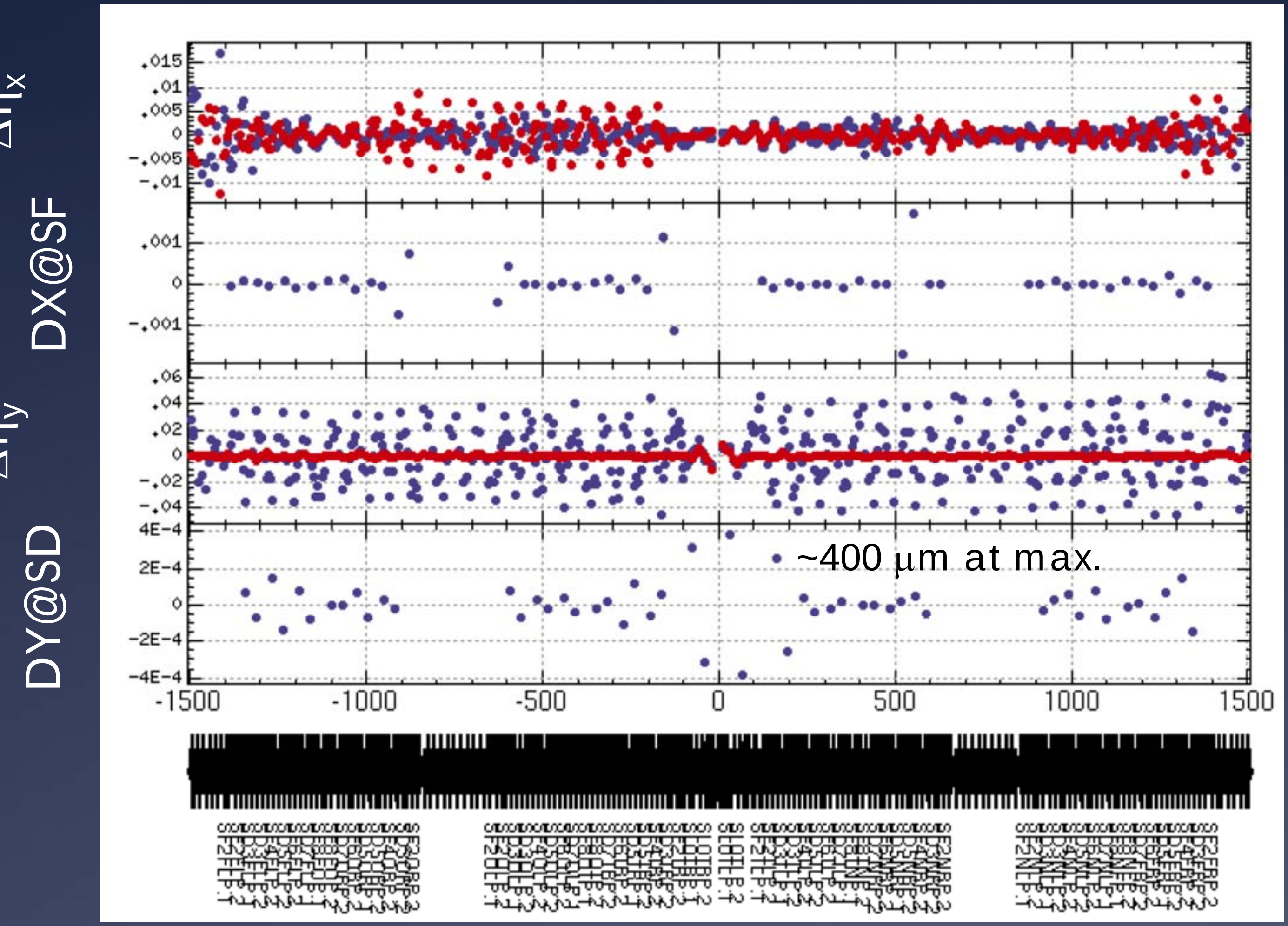
n the model, magnets have the
ertical offset measured at KEKB.

Coupling deteriorates to be 0.75 %
nly after the COD correction.

Dispersion correction recovers less
han 0.1% coupling

Dispersion correction

Sextupole offset is used to correct dispersions.



Sextupole offset is given by a magnet mover instead of a local bump. (or additional coils on the sextupole poles)

Local bump might be a problem of SR.

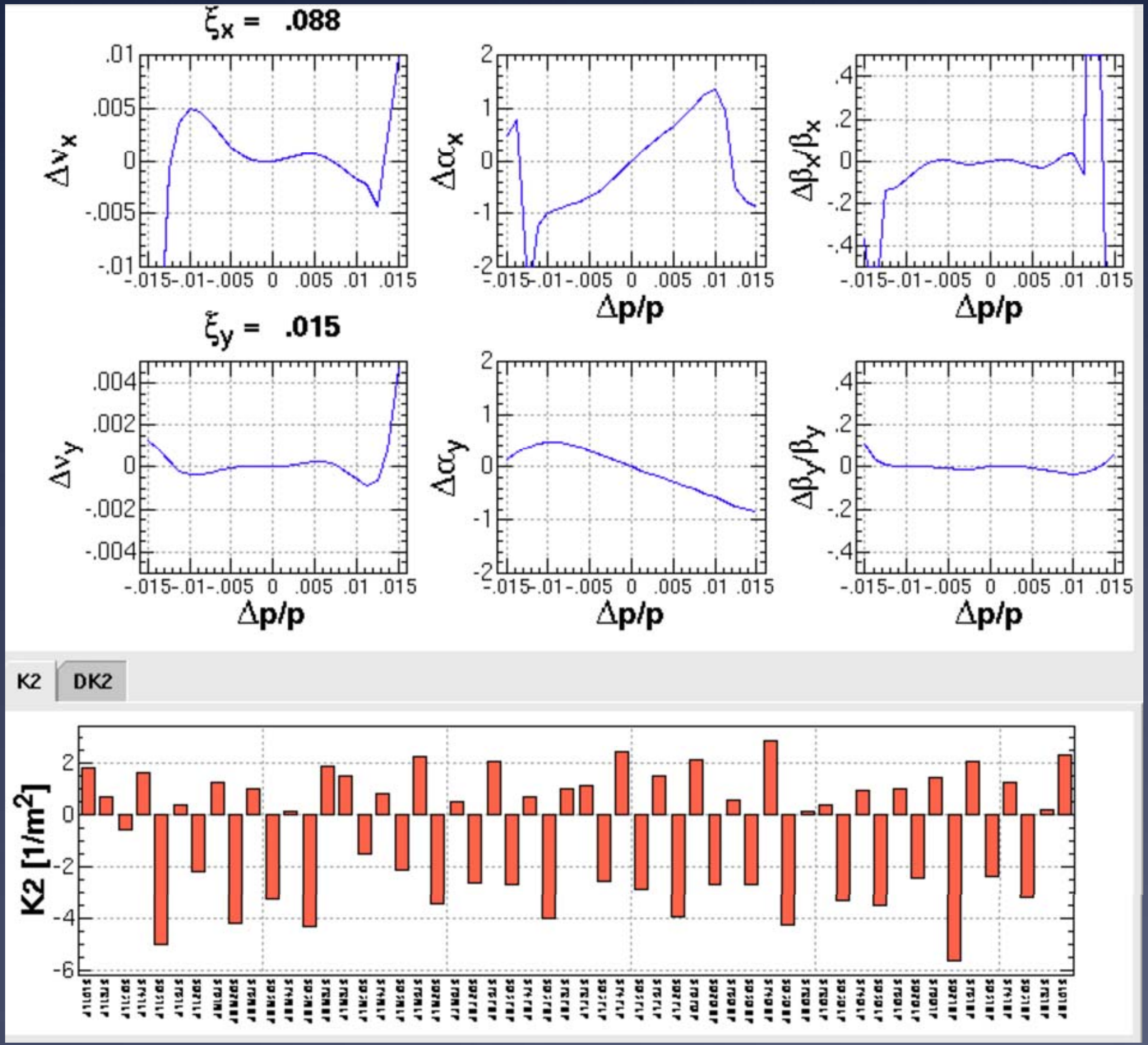
unit in m

blue: before dispersion correction

red: after dispersion correction (also xy, beta correction)

Chromaticity correction

LER

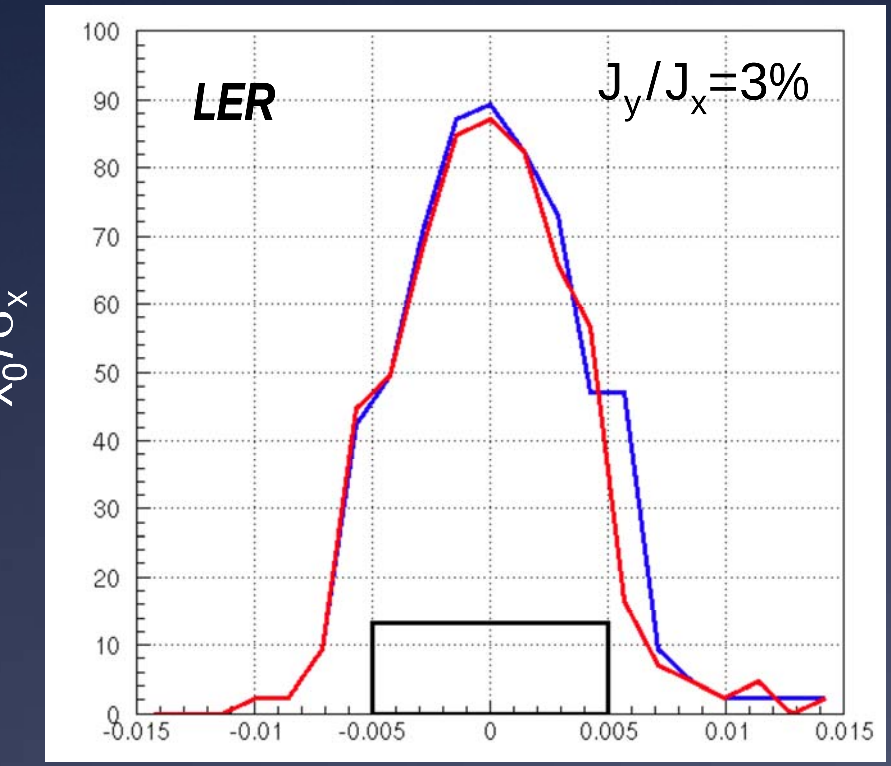


54 sextupole pairs in LER (52 in HER)

*Local chromaticity correction will be adopted to HER.

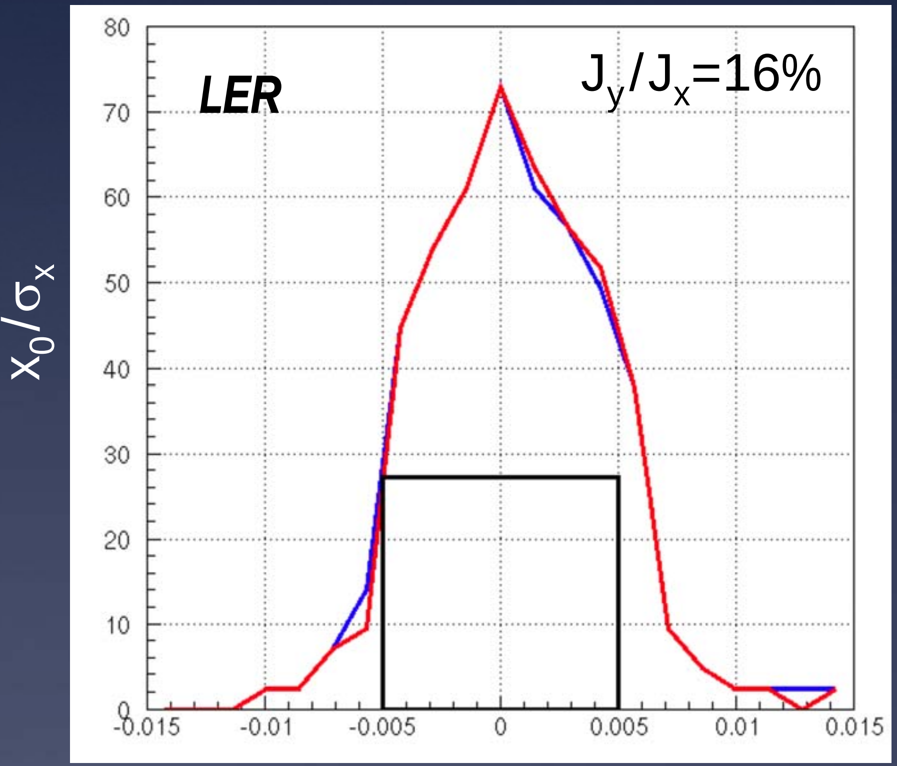
Injection aperture

with e^+ damping ring



$\Delta p/p_0$

w/o e^+ damping ring

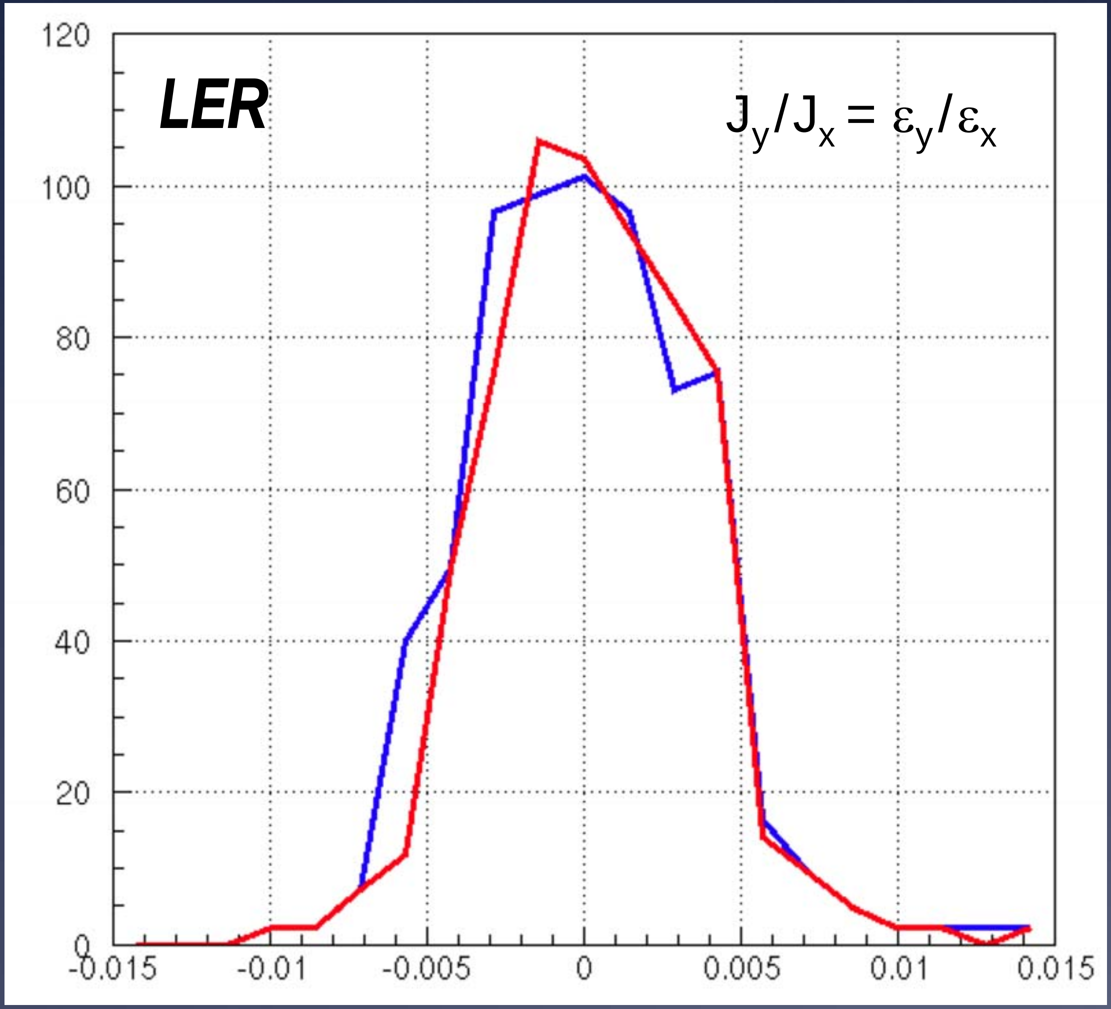


$\Delta p/p_0$

blue : no error

red : vertical orbit distortion with optics correction(xy, dispersion, beta)

Touschek lifetime



$\Delta p/p_0$

Touschek lifetime is estimate
by dynamic aperture.

$N = 1.17\text{x}10^{11}$ (9.4 A/5018)
$\varepsilon_y/\varepsilon_x = 0.5$ % (single beam)

$\tau = 17$ min.

(Dynamic effects & blowup:
$\varepsilon_y/\varepsilon_x = 0.46/63$ nm
Touschek lifetime becomes
longer... ~150 min)

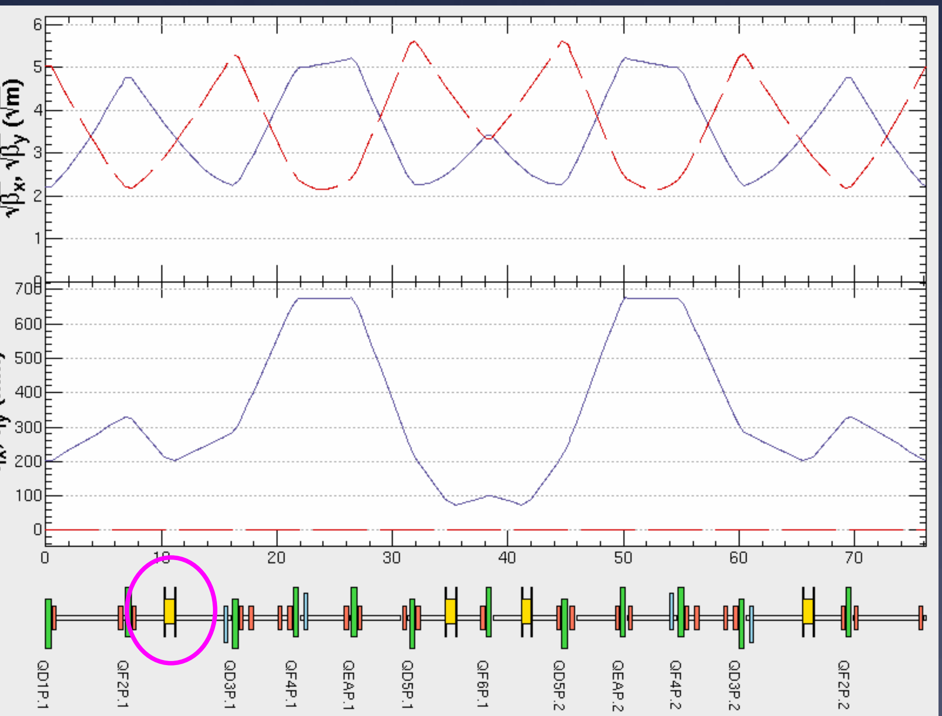
Luminosity lifetime: 81 min
(9.4 A, $5\text{x}10^{35}$ $cm^{-2}s^{-1}$)

blue : no error
red : vertical orbit distortion with optics correction

Further low emittance in LER

SuperB-like beam can be possible if bending magnets are replaced to a longer magnet.

LER cell

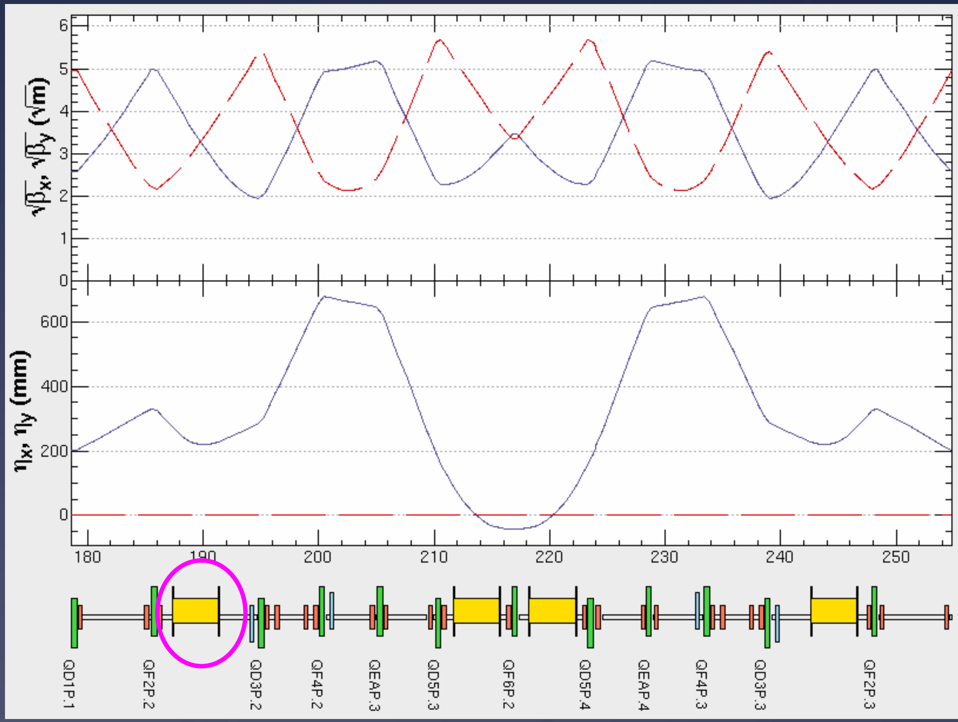


L bend = 0.9 m

ε_x: 6.8 nm

α: 4.15E-4

LER cell



L bend = 4.0 m

ε_x: 2.2 nm

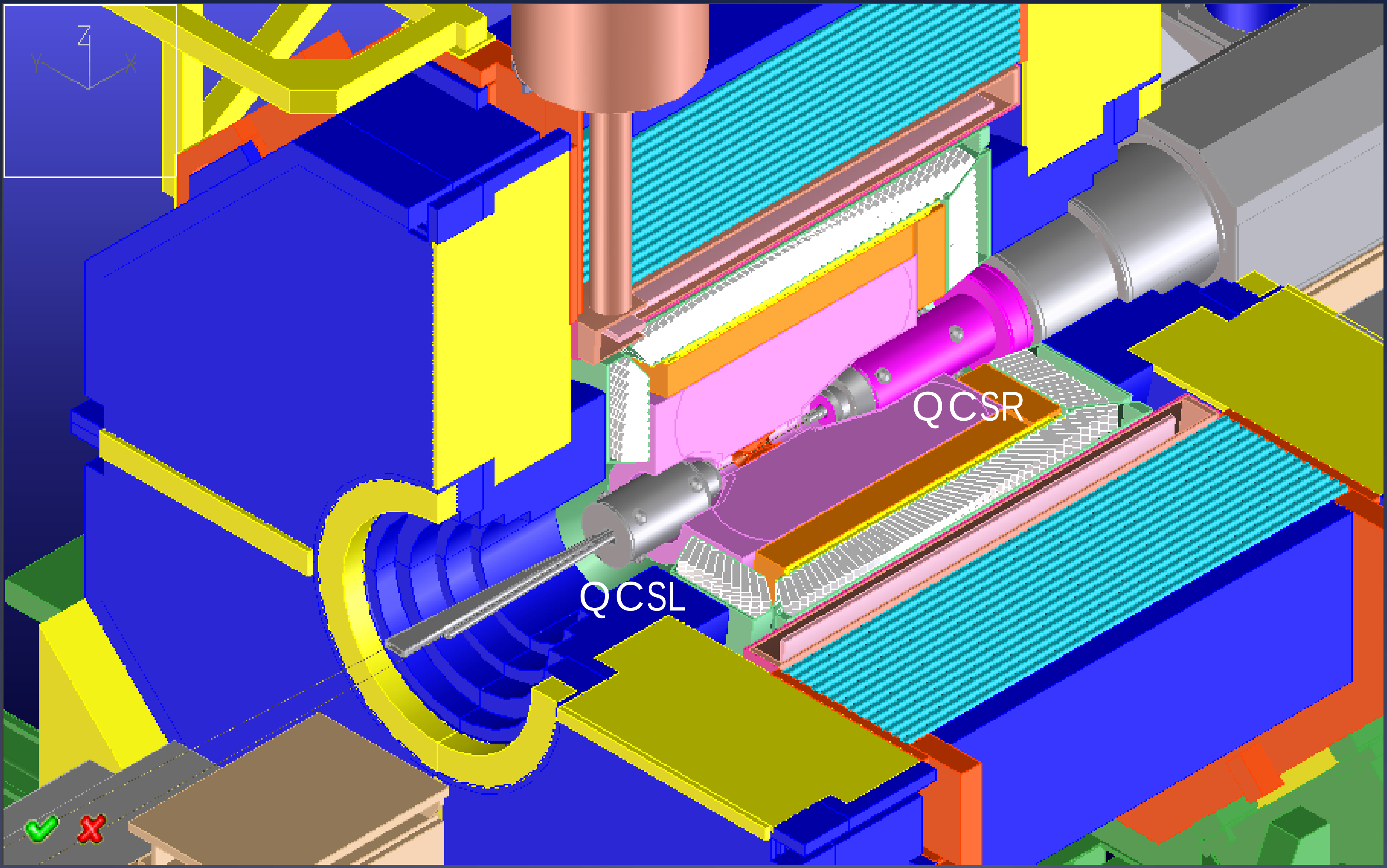
α: 3.52E-4

H. Koiso

Interaction Region

IR Quadrupole magnets, Aperture, SR fan

QCS and IP

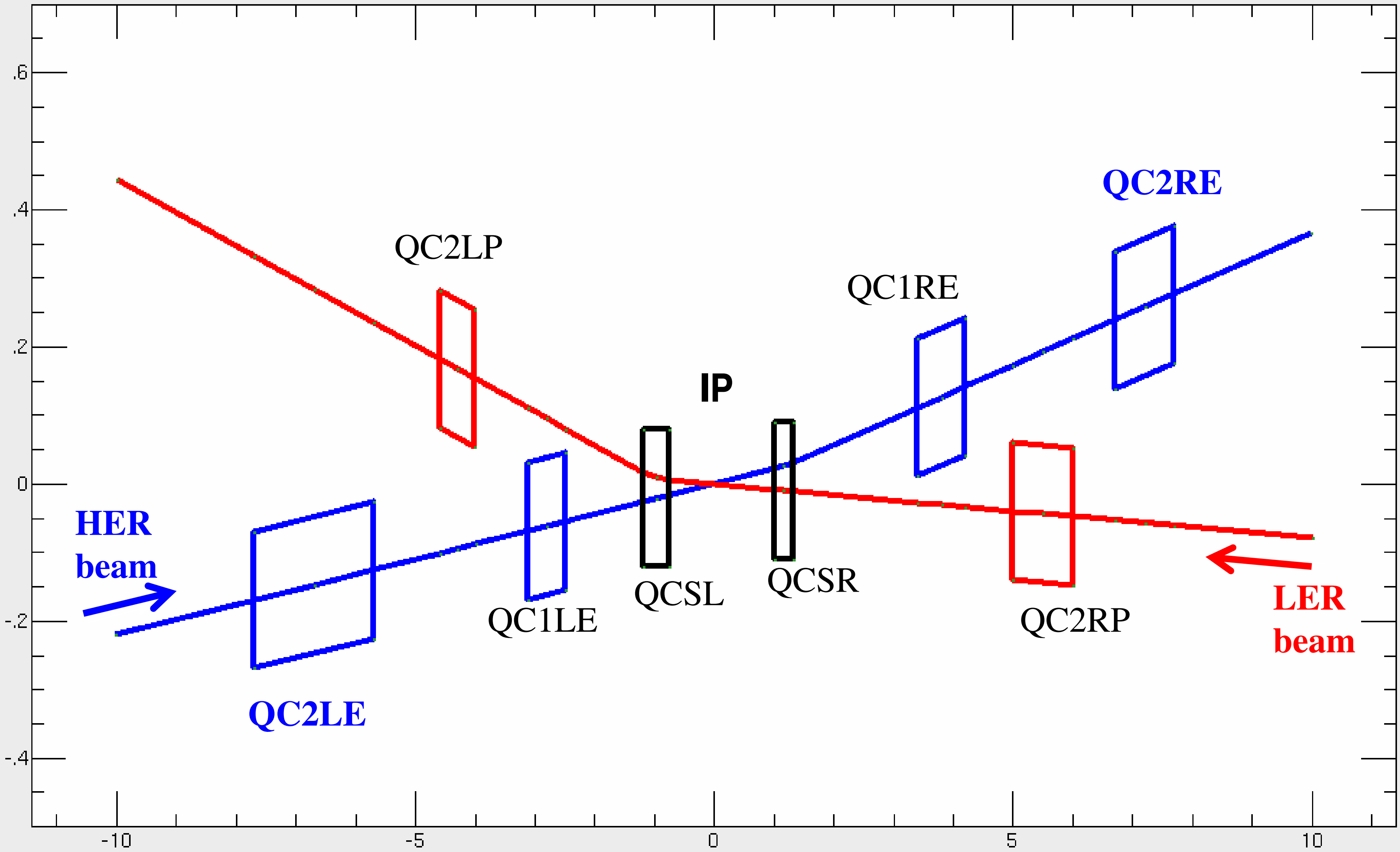


N. Ohuchi

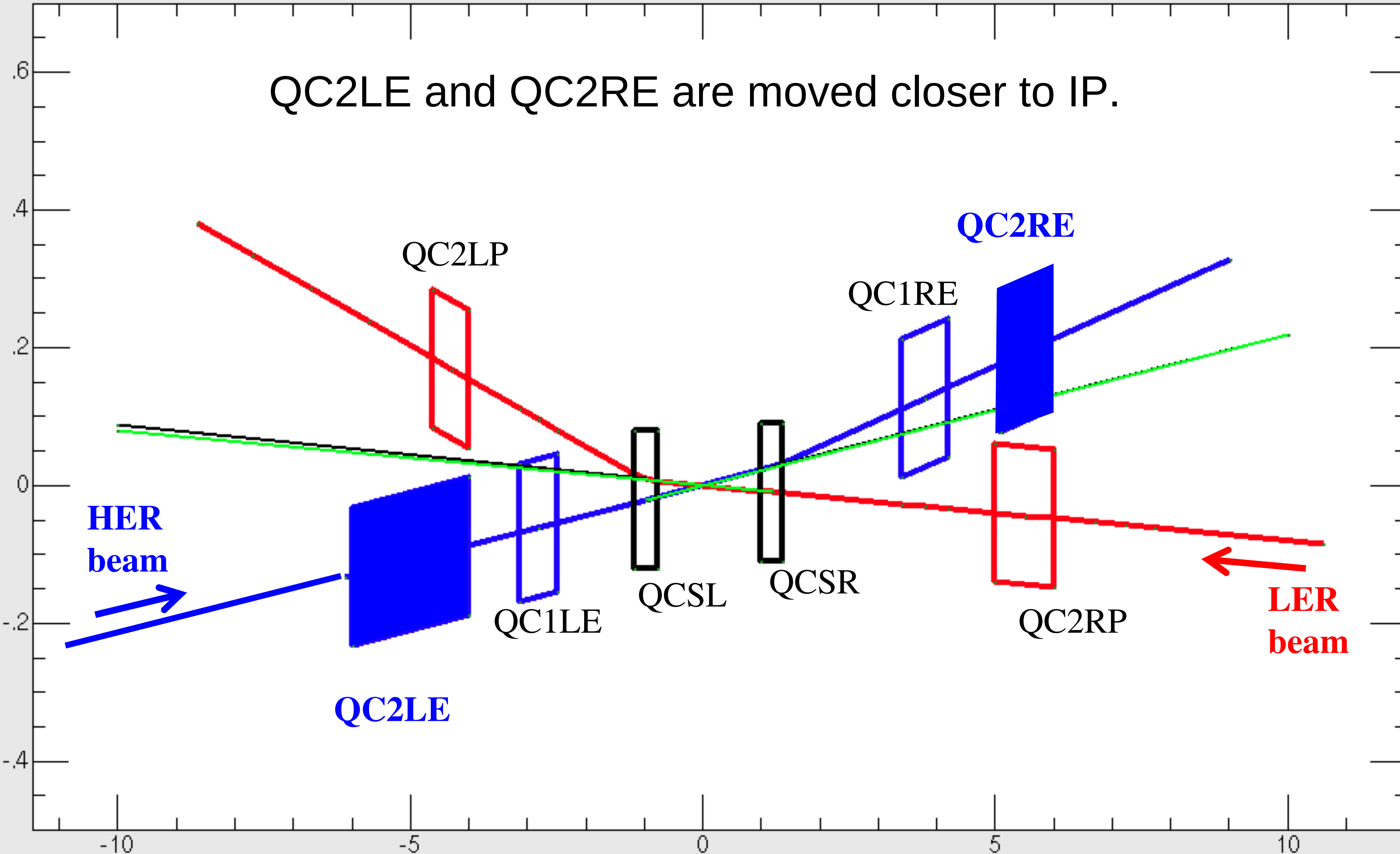
L(IP-QCSL) = 70 cm
L(IP-QCSR) = 90 cm

QCS + compensation solenoids in the cryostat

IR magnet layout (old)

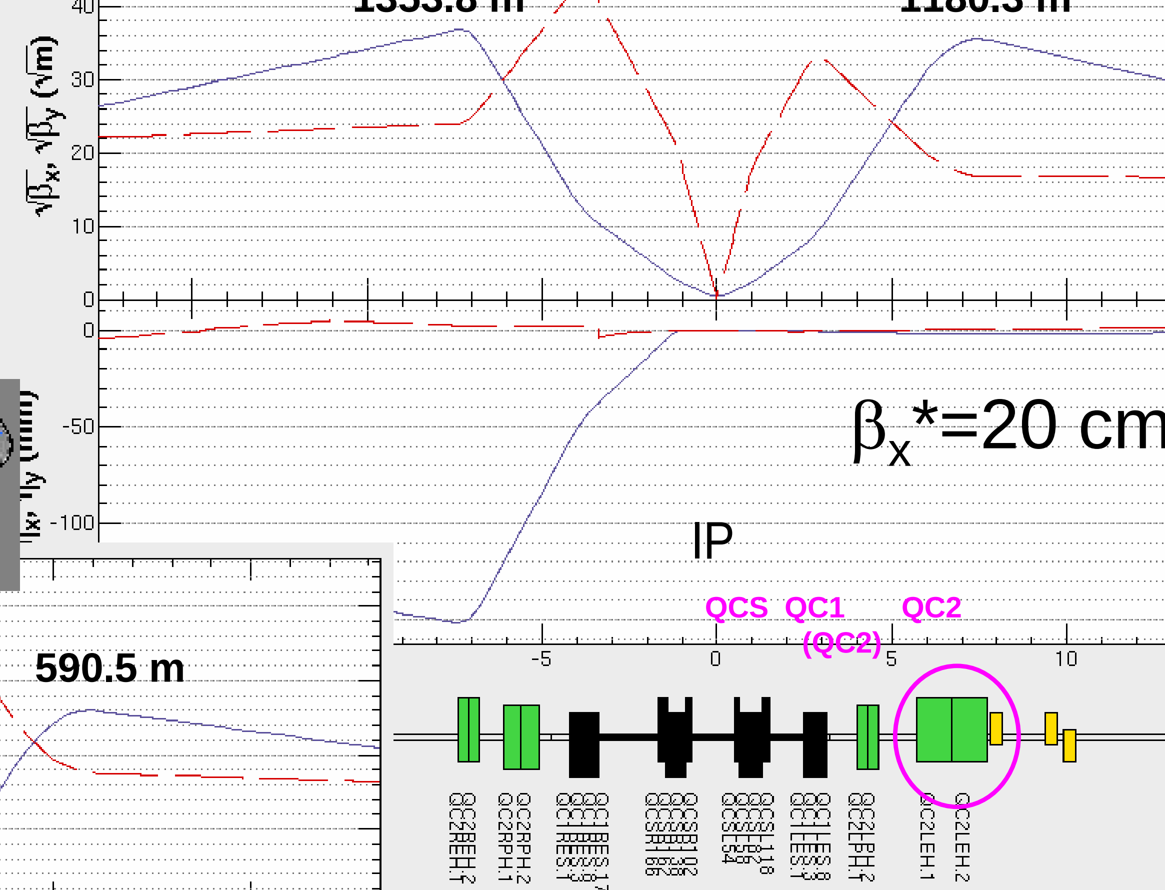


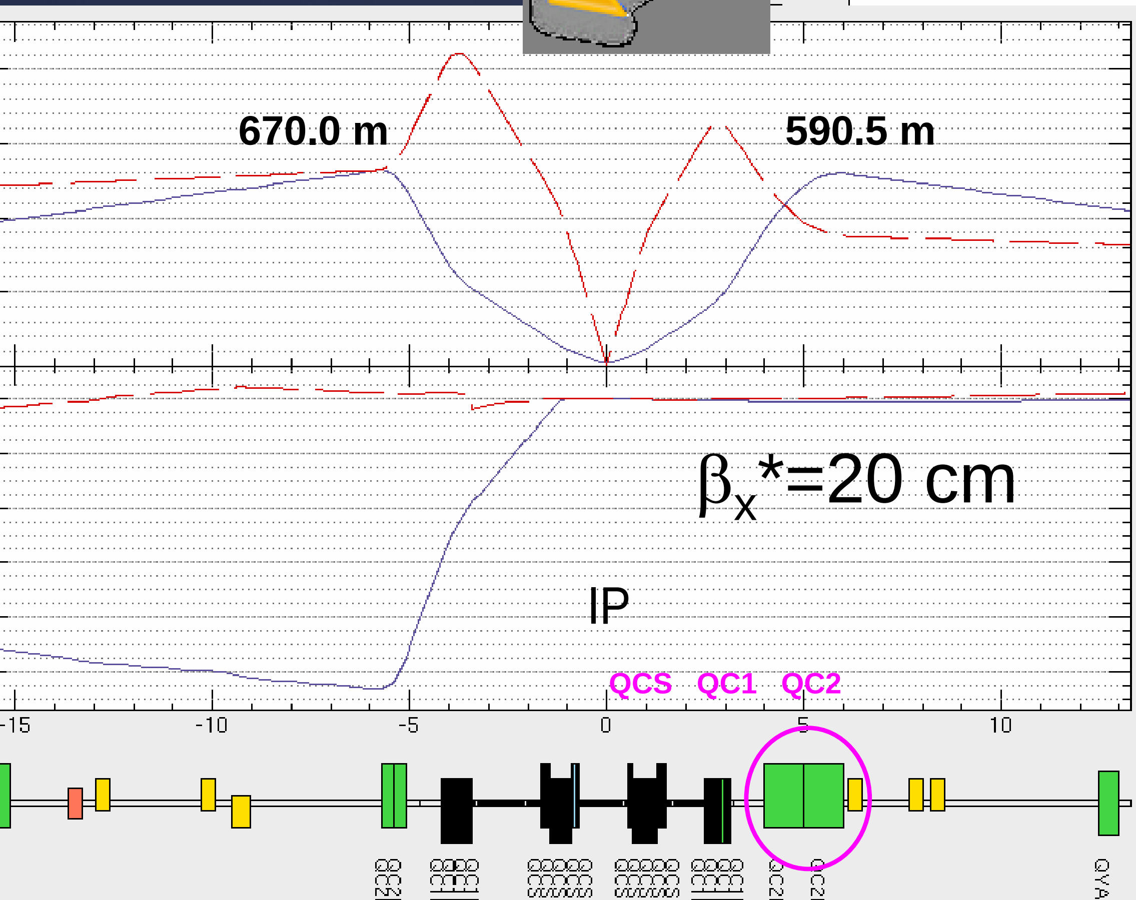
IR magnet layout (new)



HER QC2 is moved closer to IP.

New





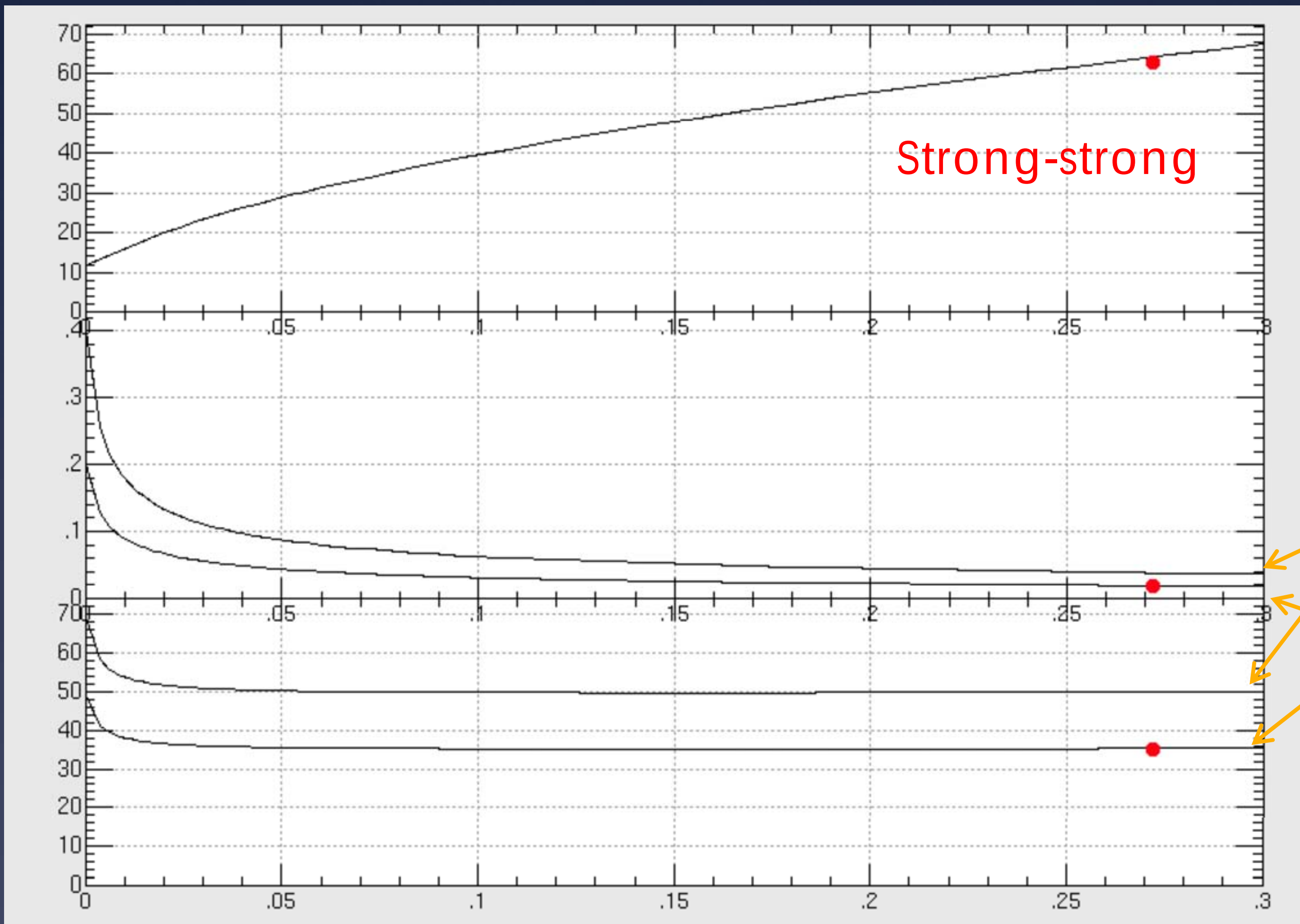
Horizontal beta function can be suppressed.

New QC2 can relax constrain

Aperture on quadrupoles should be kept 5 σ_x → OK?.

Dynamic beta and emittance

ν_{x0} =0.505

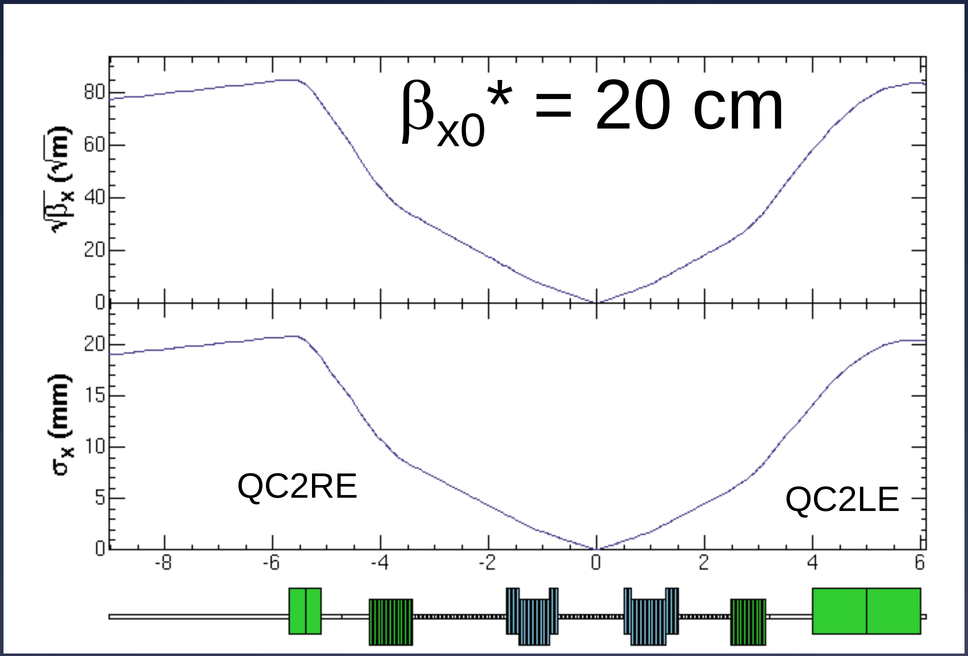


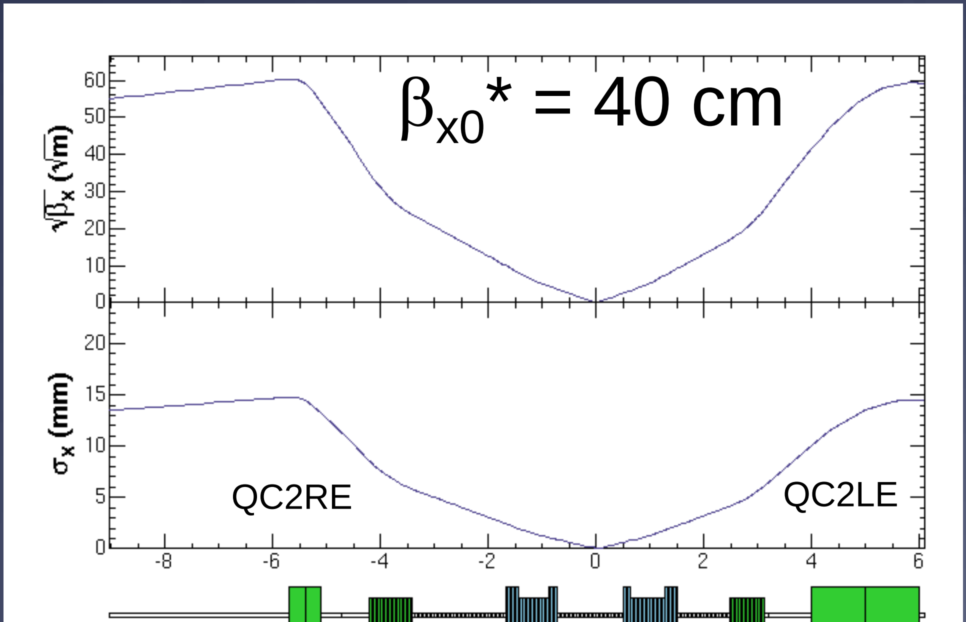
β_{x0}^* = 40 cm

β_{x0}^* = 20 cm

ξ_x

Beam size at IR quadrupoles

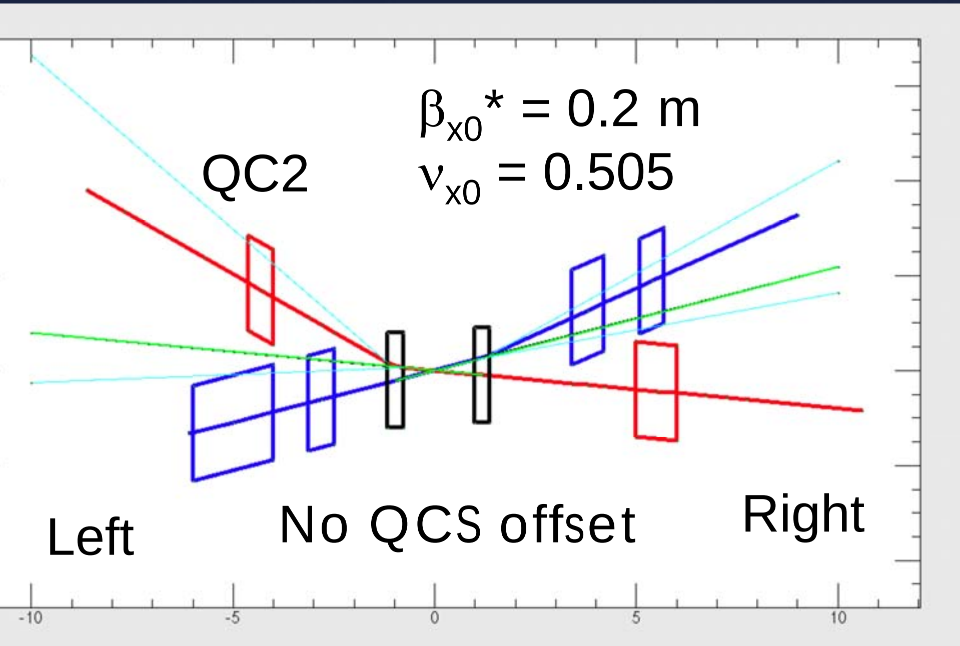




Dynamic beta and dynamic emittance are included to estimate beam size.
(ν_{x0} = .505 ξ_x = 0.27)

$5\sigma_x$ aperture at QC2:
100 mm for β_{x0}^*=20 cm,
75 mm for β_{x0}^*=40 cm

SR fan with $3\sigma_x$ beam size



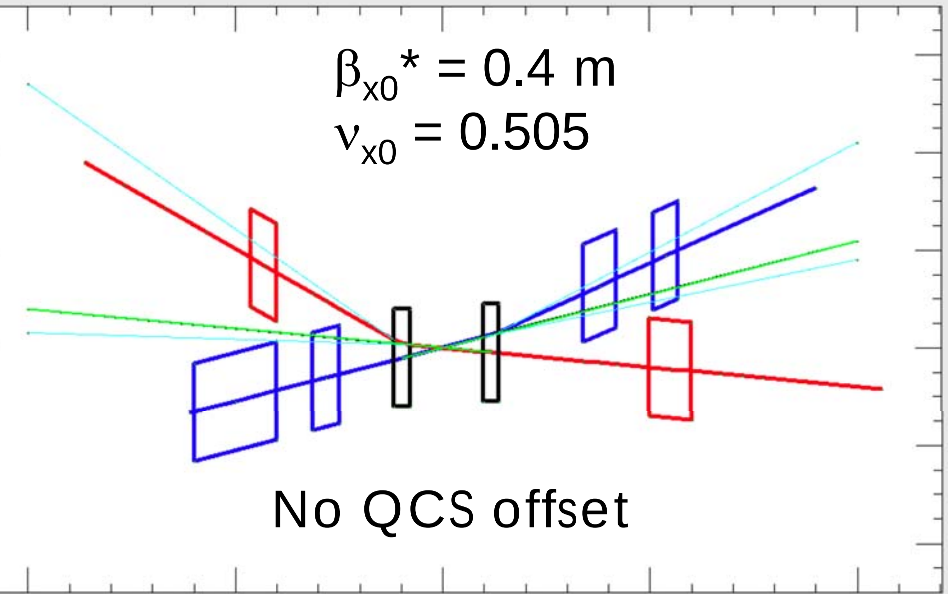
Spread of SR fan is large in QC2(L).

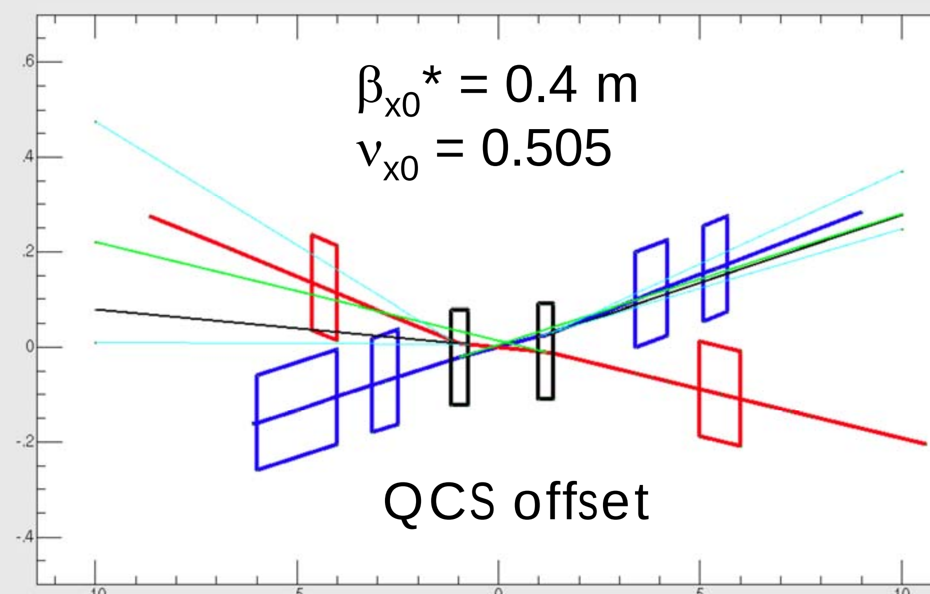
QCS offset can make SR fan small.

→Two beams separation becomes sma

→SR at IP is OK ?

Y. Funakoshi





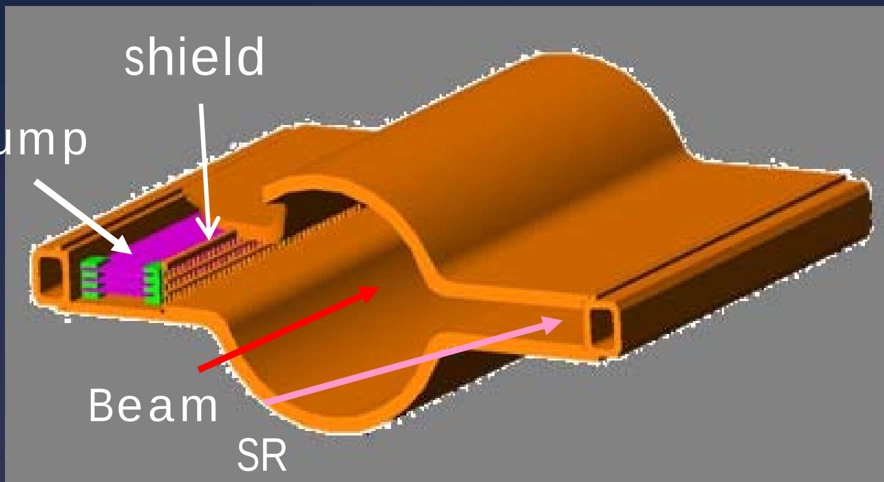
Vacuum System

Beam pipe, Bellows,

TiN coating, …

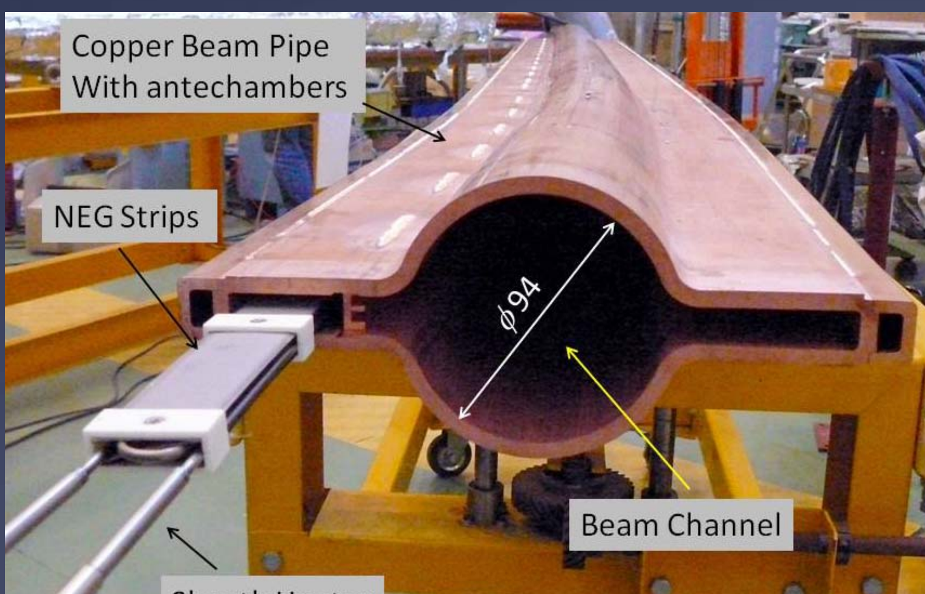
Beam pipe

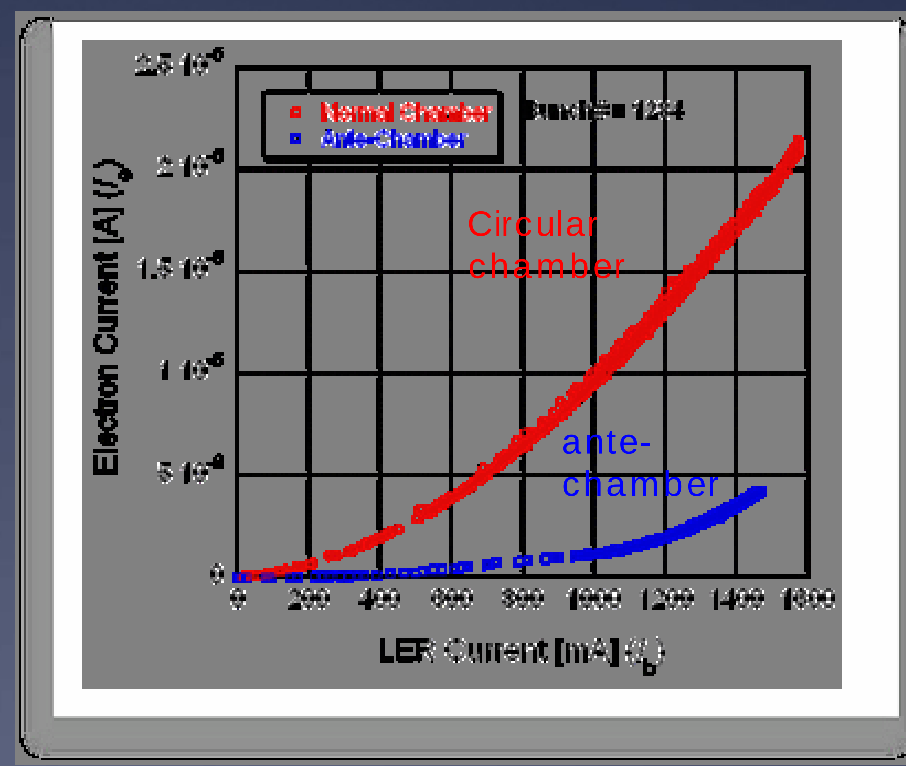
* Copper beam pipe with ante-chamber for arc section



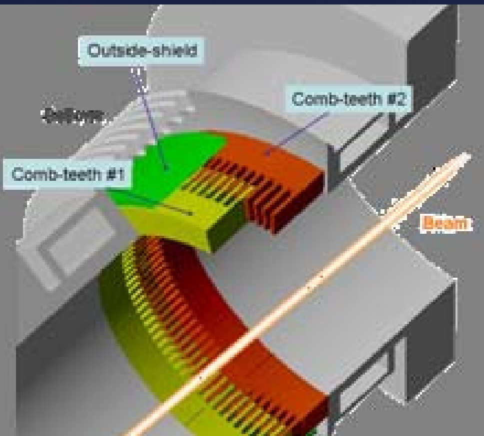
Low SR power density
Low photoelectrons around beam
Low beam impedance
Expensive

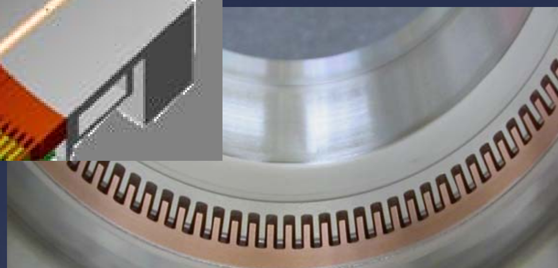
Y. Suetsugu





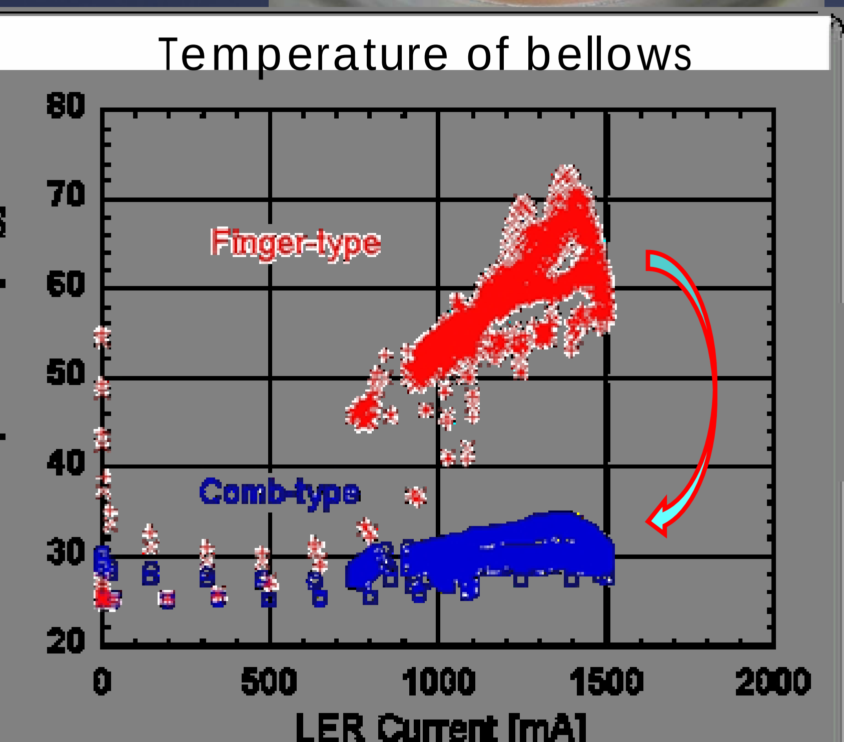
Bellows with RF shield





Comb-type
RF-shield

- Low beam impedance
- High thermal strength
- Applicable to a complex shap
  (ante-chambers,....)
- Less flexibility



The feasibility has been proved at KEKB.

Y. Suetsugu

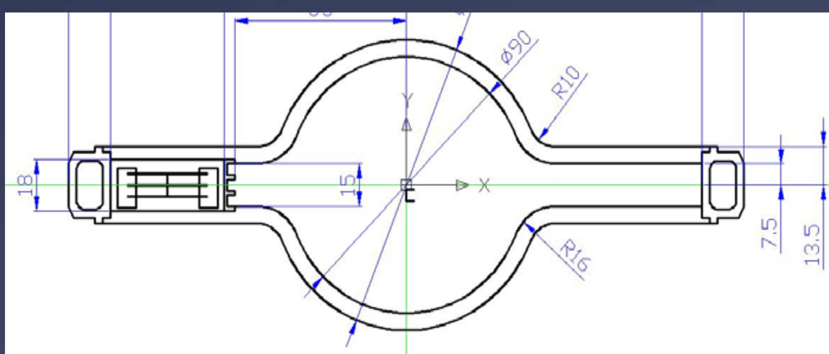
Coherent synchrotron radiation

- Optimization of beam pipe shape

Larger aperture ← ---- → Smaller aperture

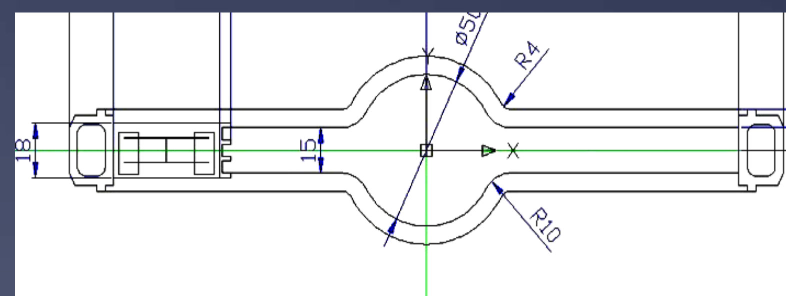
Larger aperture	Smaller aperture
Low impedance (ex, resistive wall) Effective pumping	Cure for CSR [Low cost?]

(ϕ90)



?

(ϕ50)



- We still continue CSR calculation. If the small aperture is not available, we will choose longer bunch(4 mm).

Crab cavity

Global crab crossing (similar to KEKB)

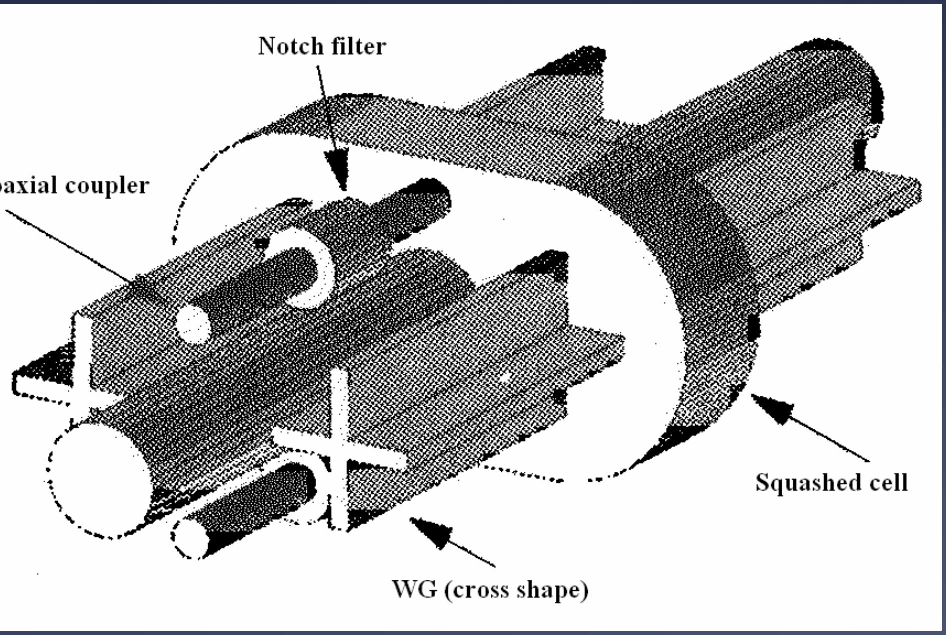
New crab cavity

PAC2005

K. Akai et a

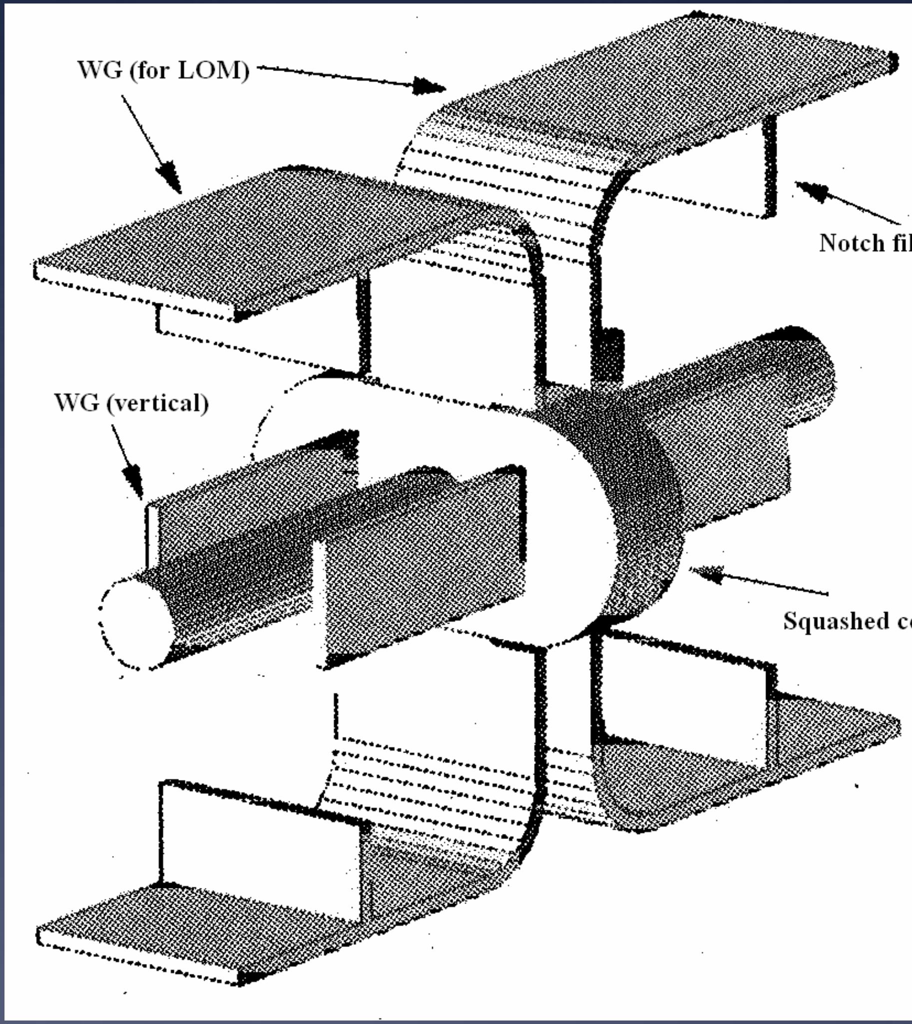
Sufficient mode damping
Reduction of HOM power

(1) Coaxial type



LOM damping: Coaxial coupler

(2) Wave guide type



LOM damping: Wave guide

Summary

5x10^{35} cm^{-2}s^{-1} is a target luminosity for KEKB upgrade (High current scheme).

ε_x=12 nm optics can be feasible (ε_x~2 nm if bends are replaced).

Design of the vacuum system is almost completed except for the IR chamber. CSR evaluation not yet.

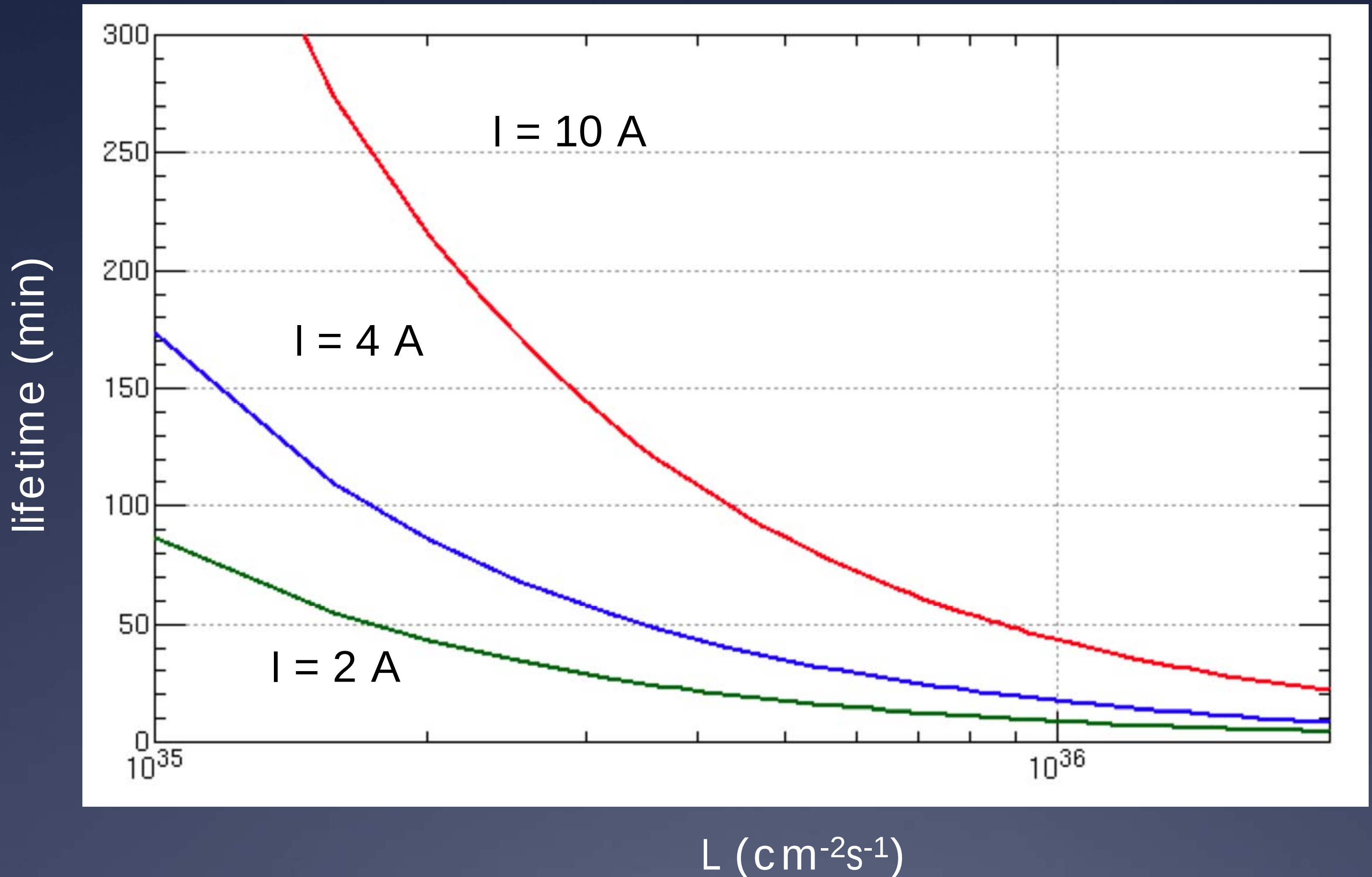
In IR design, there are still things to be fixed, especially, cure of SR fan, beam pipes.

Backup Slides

for KEKB upgrade

Luminosity lifetime

$\sigma_{\text{rad Bhabha}} = 2.4\text{x}10^{-25}\ \text{cm}^2$



Definition of xy-coupling parameters and dispersion functions

In the normal coordinate
(no xy-coupling space)

In the the physical coordinate
(real space)

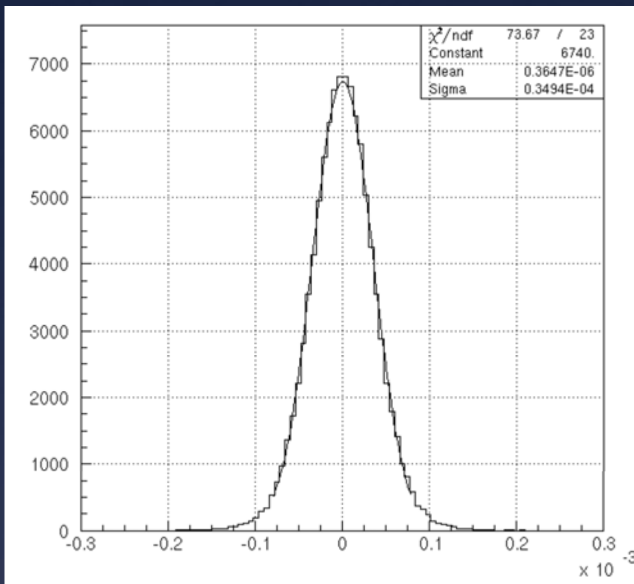
$$\begin{pmatrix} X \\ p_X \\ Y \\ p_Y \end{pmatrix} + \begin{pmatrix} \eta_X \\ \eta'_X \\ \eta_Y \\ \eta'_Y \end{pmatrix} \delta = \begin{pmatrix} \mu & 0 & -R_4 & R_2 \\ 0 & \mu & R_3 & -R_1 \\ R_1 & R_2 & \mu & 0 \\ R_3 & R_4 & 0 & \mu \end{pmatrix} \begin{pmatrix} x \\ p_x \\ y \\ p_y \end{pmatrix}$$

$\mu^2+(R_1R_4-R_2R_3)=1$

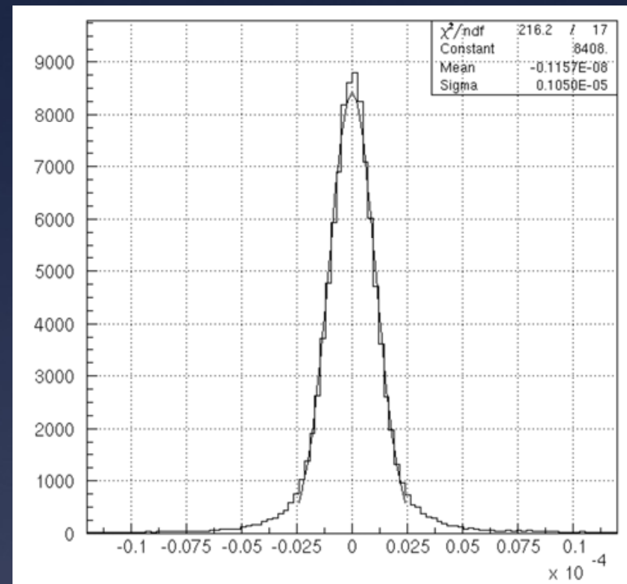
$\delta = \Delta p/p.$

$$\begin{pmatrix} \eta_X \\ \eta'_X \\ \eta_Y \\ \eta'_Y \end{pmatrix} = \begin{pmatrix} \mu & 0 & -R_4 & R_2 \\ 0 & \mu & R_3 & -R_1 \\ R_1 & R_2 & \mu & 0 \\ R_3 & R_4 & 0 & \mu \end{pmatrix} \begin{pmatrix} \eta_x \\ \eta'_x \\ \eta_y \\ \eta'_y \end{pmatrix}$$

Beam-beam simulation (LER)



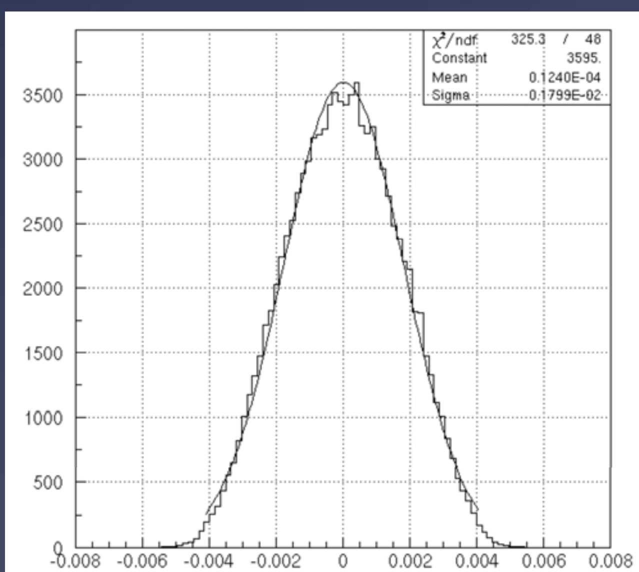
x (m)

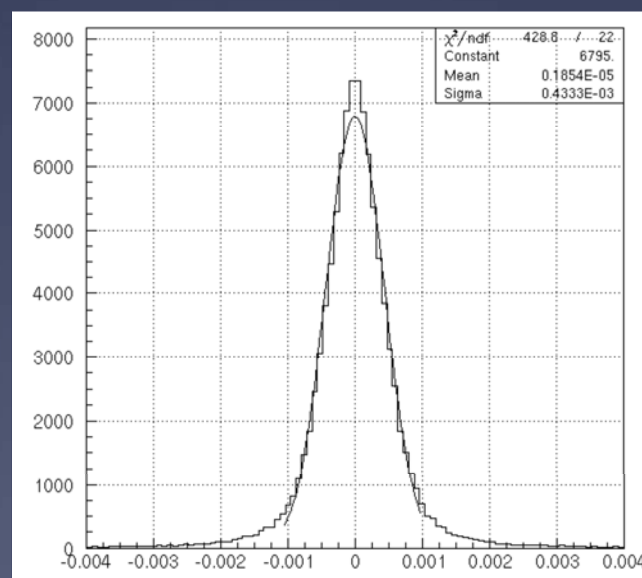


y (m)

Beam profile at IP

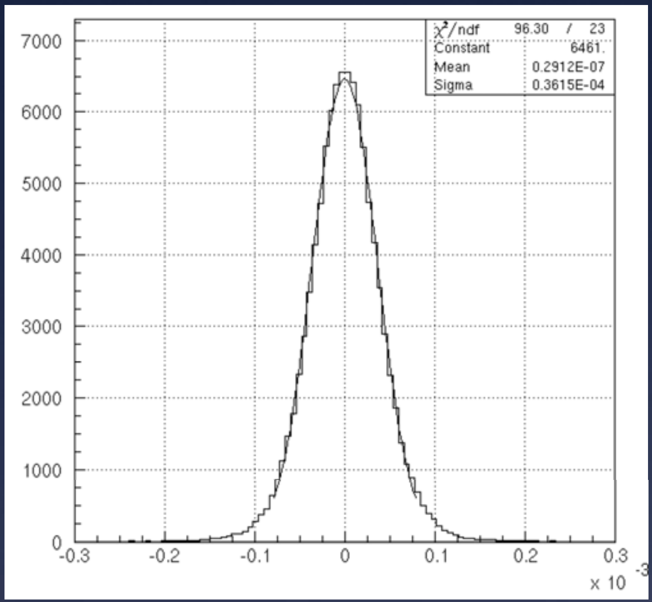
$\varepsilon_x = 63$ nm
$\beta_x = 19.4$ mm
$\varepsilon_y = 455$ pm
$\beta_y = 2.4$ mm



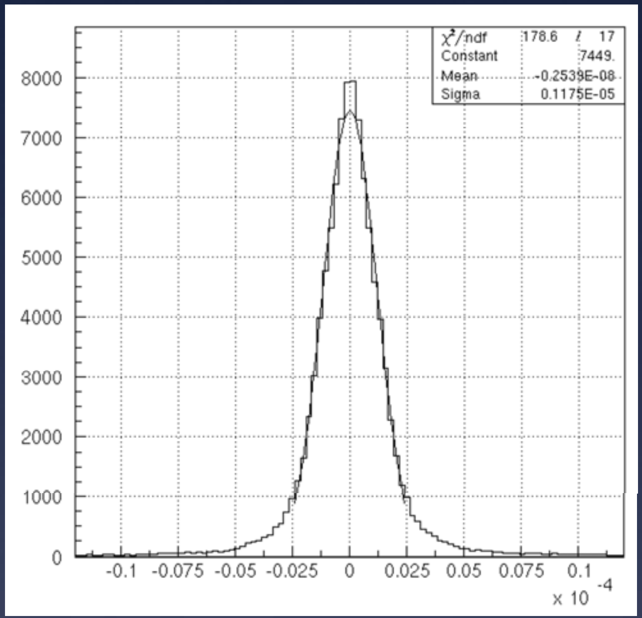


Beam-beam simulation (HER)

Beam profile at I



x (m)



y (m)