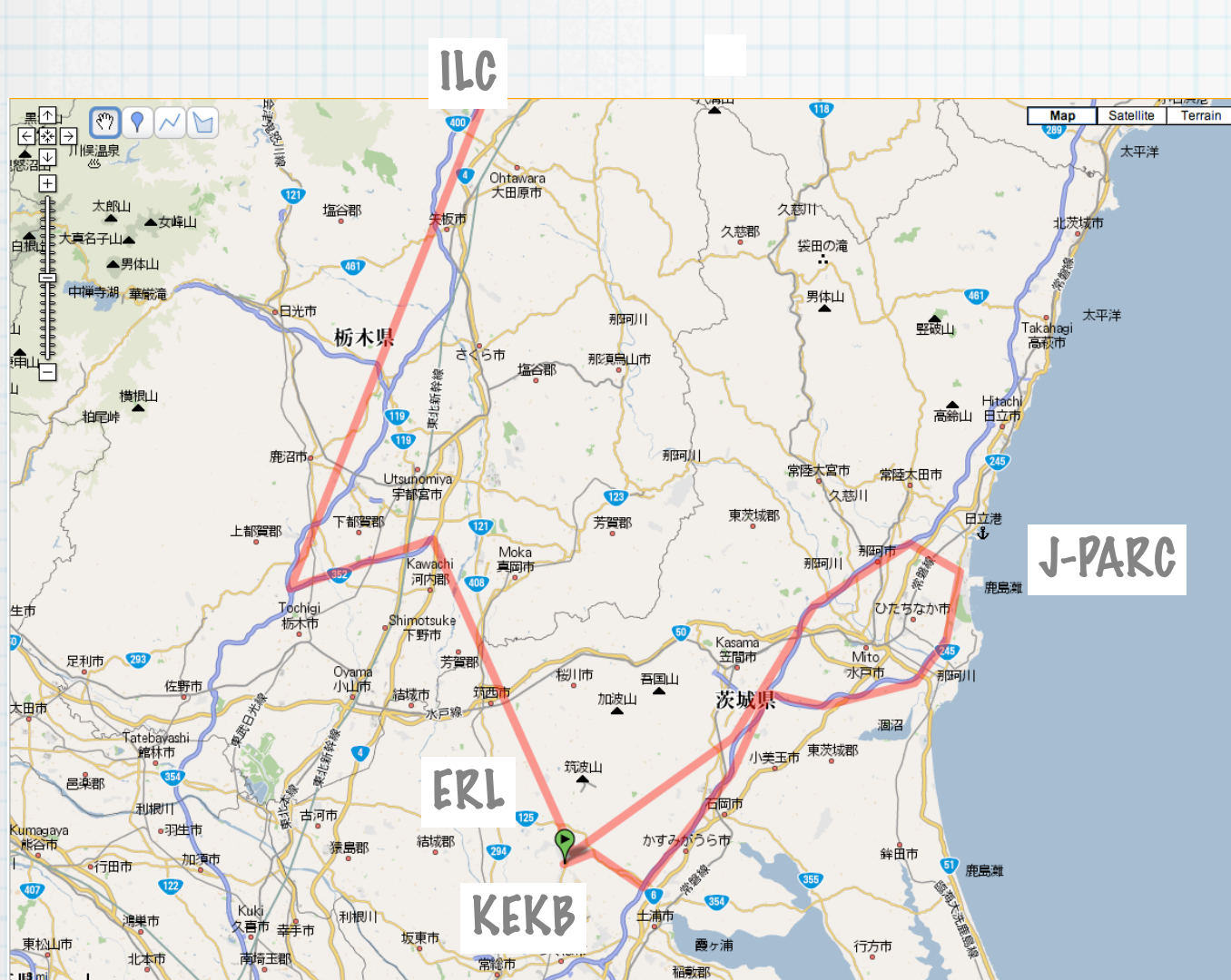


# KEKB Roadmap



K. Oide for the KEBB Accelerator Group

25 March 2008

IHEP, Protovino



Nikko

Mt. Tsukuba

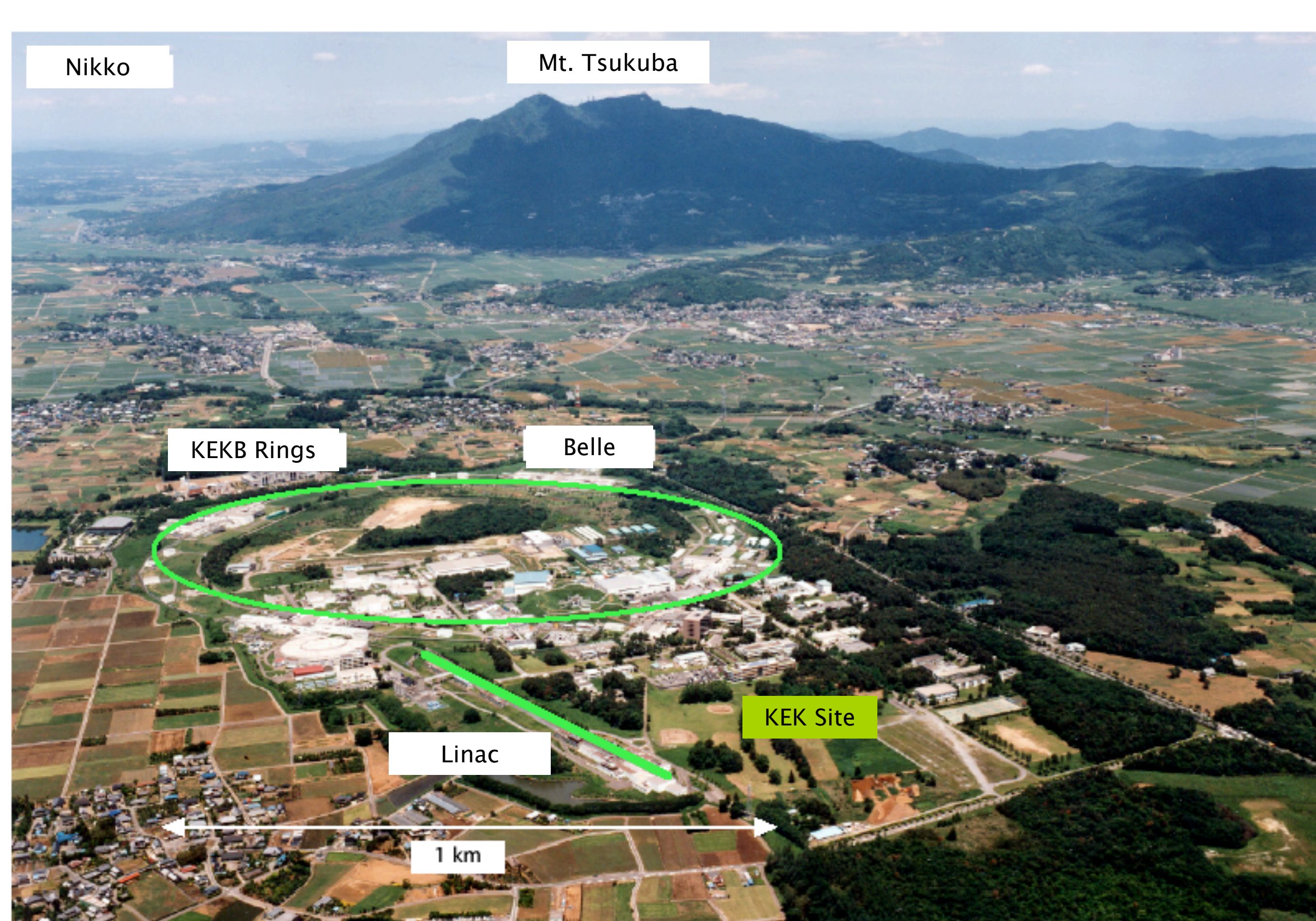
KEKB Rings

Belle

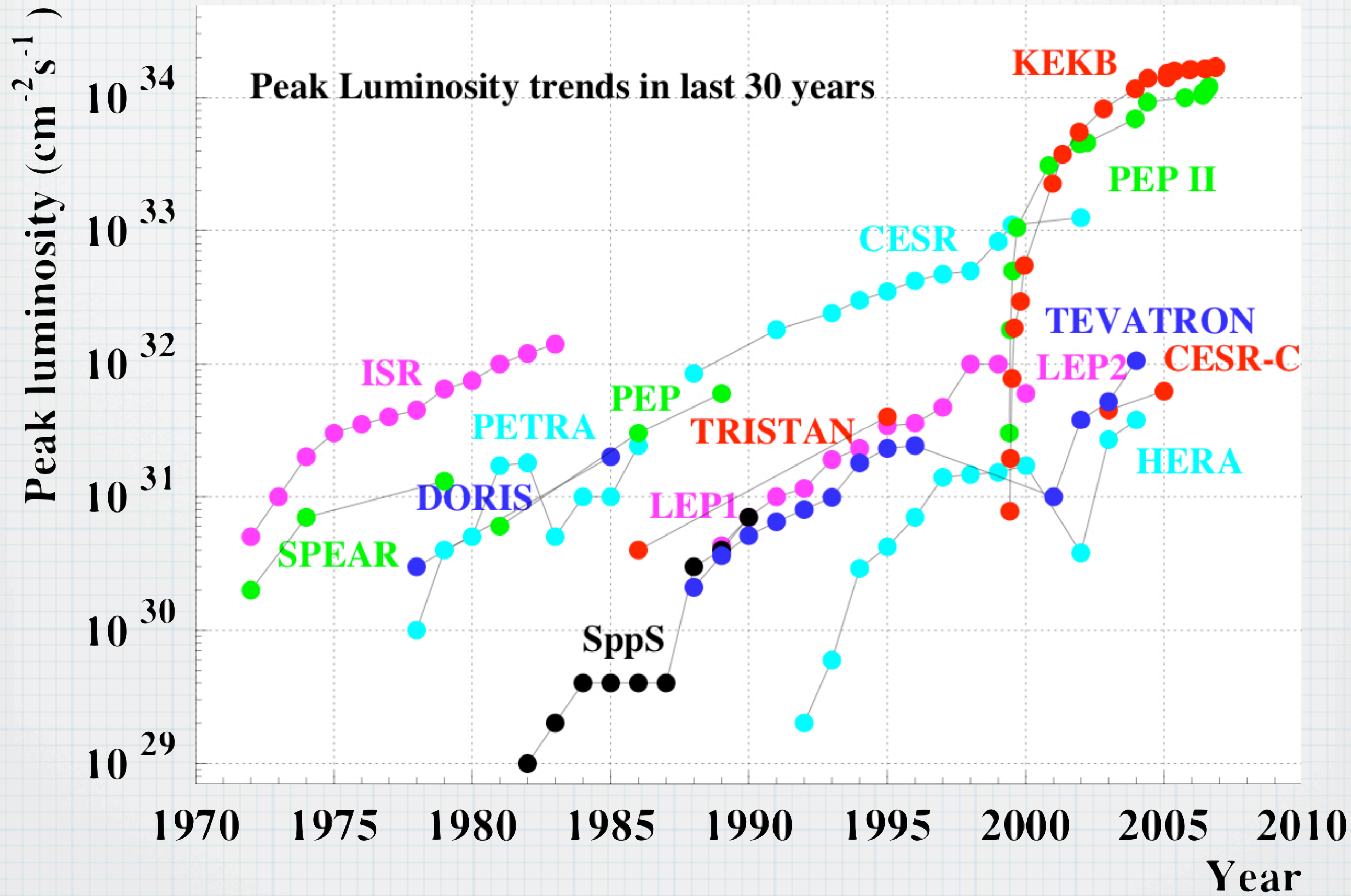
KEK Site

Linac

1 km









before Crab

# Luminosity of KEKB Oct. 1999 - Dec. 2006

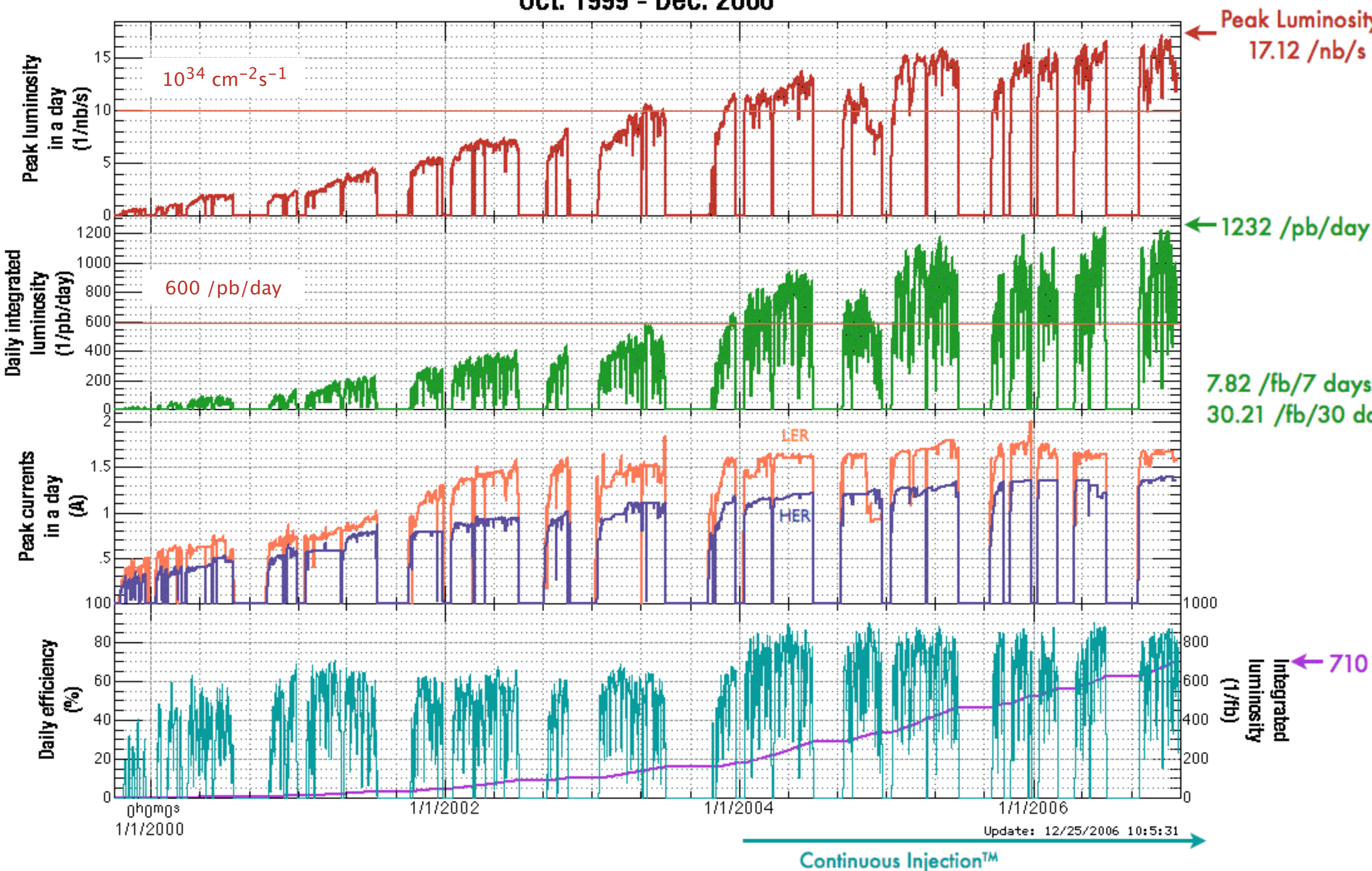




Table 1: Machine parameters of KEKB

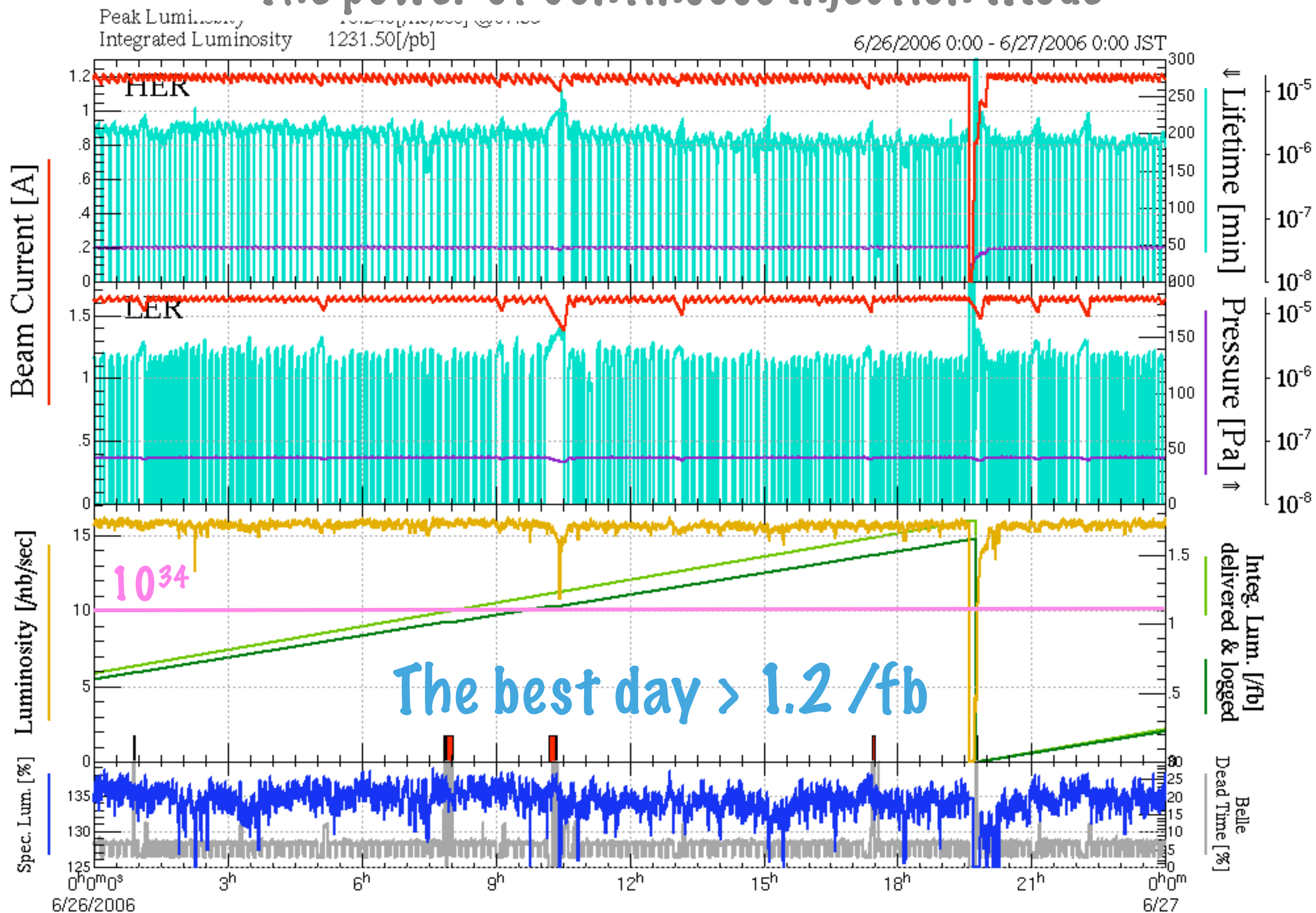
| Date                               | 11/15/2006 |       | Design     |      |               |
|------------------------------------|------------|-------|------------|------|---------------|
|                                    | LER        | HER   | LER        | HER  |               |
| Current                            | 1.65       | 1.33  | 2.6        | 1.1  | A             |
| Bunches/ring                       | 1389       |       | 5000       |      |               |
| Bunch current                      | 1.19       | 0.96  | 0.52       | 0.22 | mA            |
| Bunch spacing                      | 1.8–2.4    |       | 0.6        |      | m             |
| Emittance $\varepsilon_x$          | 18         | 24    | 18         | 18   | nm            |
| $\beta_x^*$                        | 59         | 56    | 33         | 33   | cm            |
| $\beta_y^*$                        | 0.65       | 0.59  | 1.0        | 1.0  | cm            |
| Hor. size @ IP                     | 103        | 116   | 77         | 77   | $\mu\text{m}$ |
| Ver. size @ IP                     | 1.9        | 1.9   | 1.9        | 1.9  | $\mu\text{m}$ |
| Beam-beam $\xi_x$                  | 0.115      | 0.075 | .039       | .039 |               |
| Beam-beam $\xi_y$                  | 0.101      | 0.056 | .052       | .052 |               |
| Bunch length                       | 7          | 6     | 4          | 4    | mm            |
| Luminosity                         | 17.12      |       | 10         |      | /nb/s         |
| $\int \text{Lum.}/\text{day}$      | 1232       |       | $\sim 600$ |      | /pb           |
| $\int \text{Lum.}/7 \text{ days}$  | 7.82       |       | —          |      | /fb           |
| $\int \text{Lum.}/30 \text{ days}$ | 30.21      |       | —          |      | /fb           |

70% higher than the design

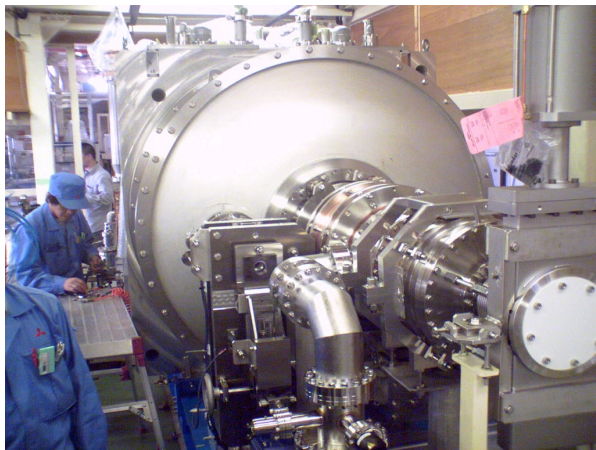
doubled the design



# The power of Continuous Injection Mode

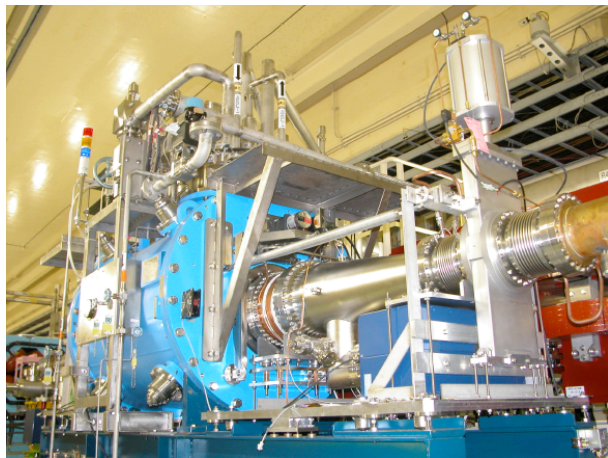




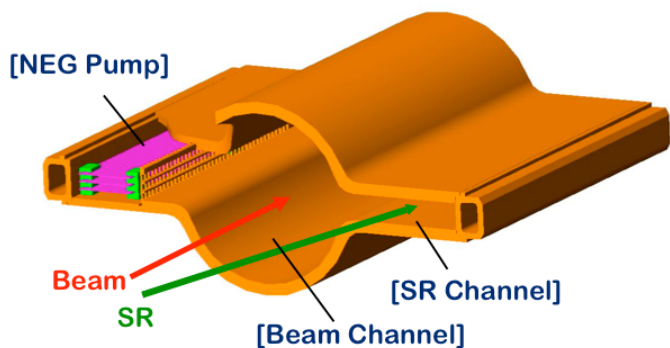


Crab cavities will be installed and tested with beam in 2006.

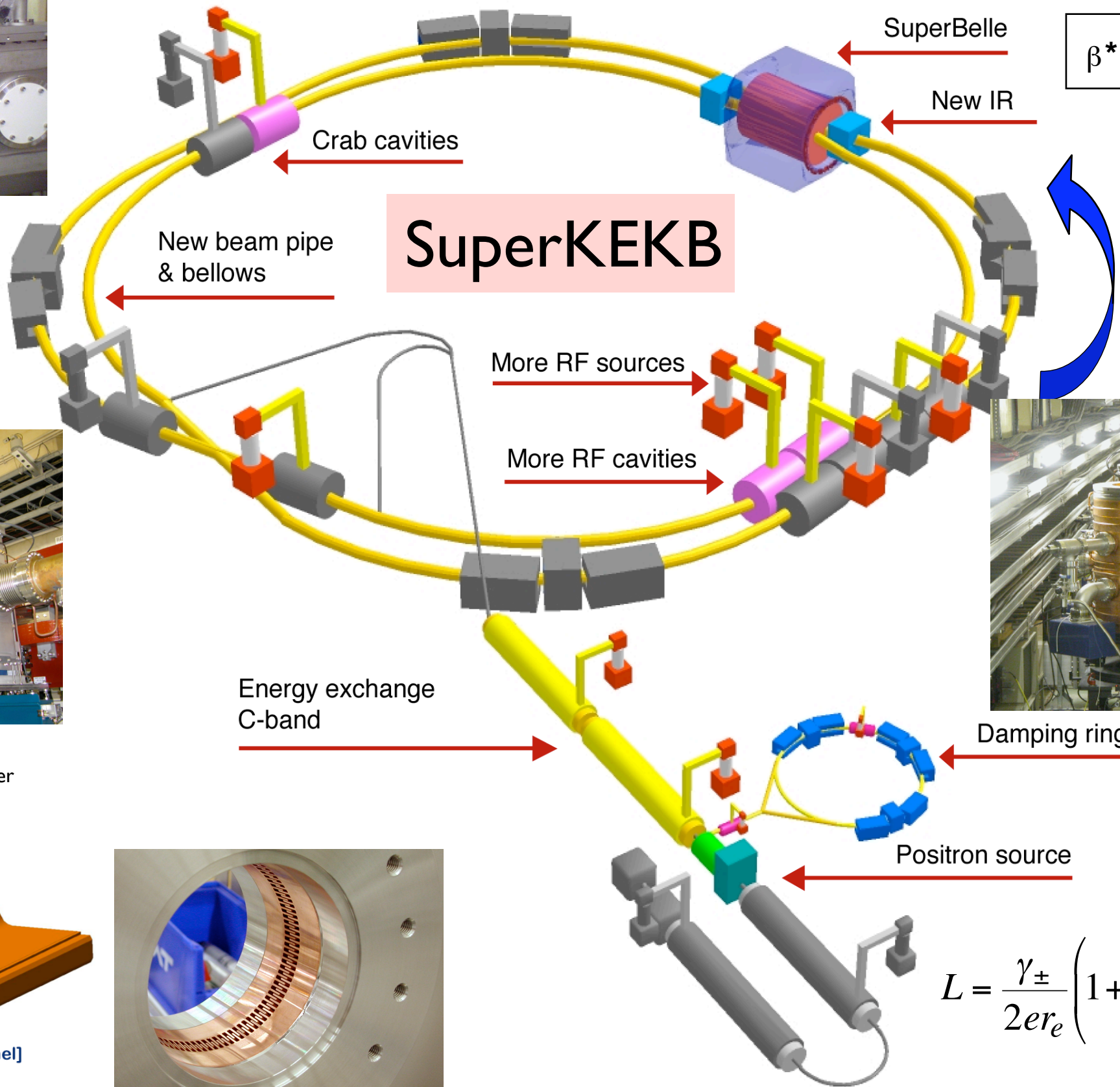
$e^+ 4.1 \text{ A}$



The superconducting cavities will be upgraded to absorb more higher-order mode power up to 50 kW.



The beam pipes and all vacuum components will be replaced with higher-current-proof design.



SuperBelle

New IR

$\beta_y^* = \sigma_z = 3 \text{ mm}$

$e^- 9.4 \text{ A}$



The state-of-art ARES copper cavities will be upgraded with higher energy storage ratio to support higher current.

$$L = \frac{\gamma_{\pm}}{2e r_e} \left( 1 + \frac{\sigma_y^*}{\sigma_x^*} \right) \frac{I_{\pm} \xi_{\pm y}}{\beta_y^*} \left( \frac{R_L}{R_y} \right)$$

will reach  $8 \times 10^{35} \text{ cm}^{-2}\text{s}^{-1}$ .



# Three factors to determine the luminosity:

Stored current:

1.7 / 1.4 A (e<sup>+</sup> / e<sup>-</sup> KEKB)

→ 9.4 / 4.1 A (SuperKEKB)

Beam-beam parameter:

0.059 (KEKB)

→ >0.24 (SuperKEKB)

Lorentz factor

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

Classical electron radius

Beam size ratio

Geometrical repipeion factors due to crossing angle and hour-glass effect

Luminosity:

$0.17 \times 10^{35} \text{ cm}^{-2} \text{ s}^{-1}$  (KEKB)

$8 \times 10^{35} \text{ cm}^{-2} \text{ s}^{-1}$  (SuperKEKB)

Vertical  $\beta$  at the IP:

6.5 / 5.9 mm (KEKB)

→ 3.0 / 3.0 mm (SuperKEKB)



# Costs & Effects

Preliminary

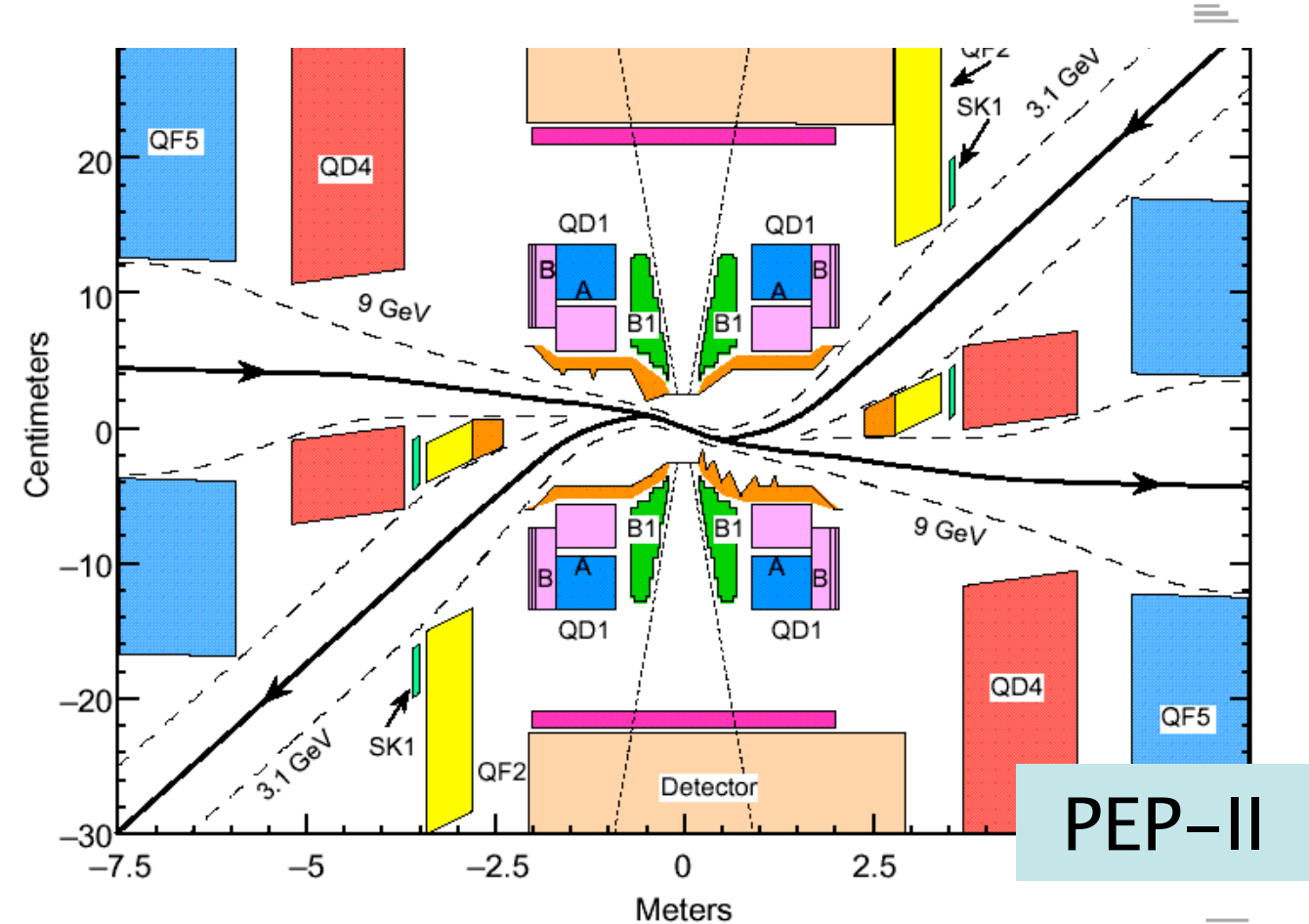
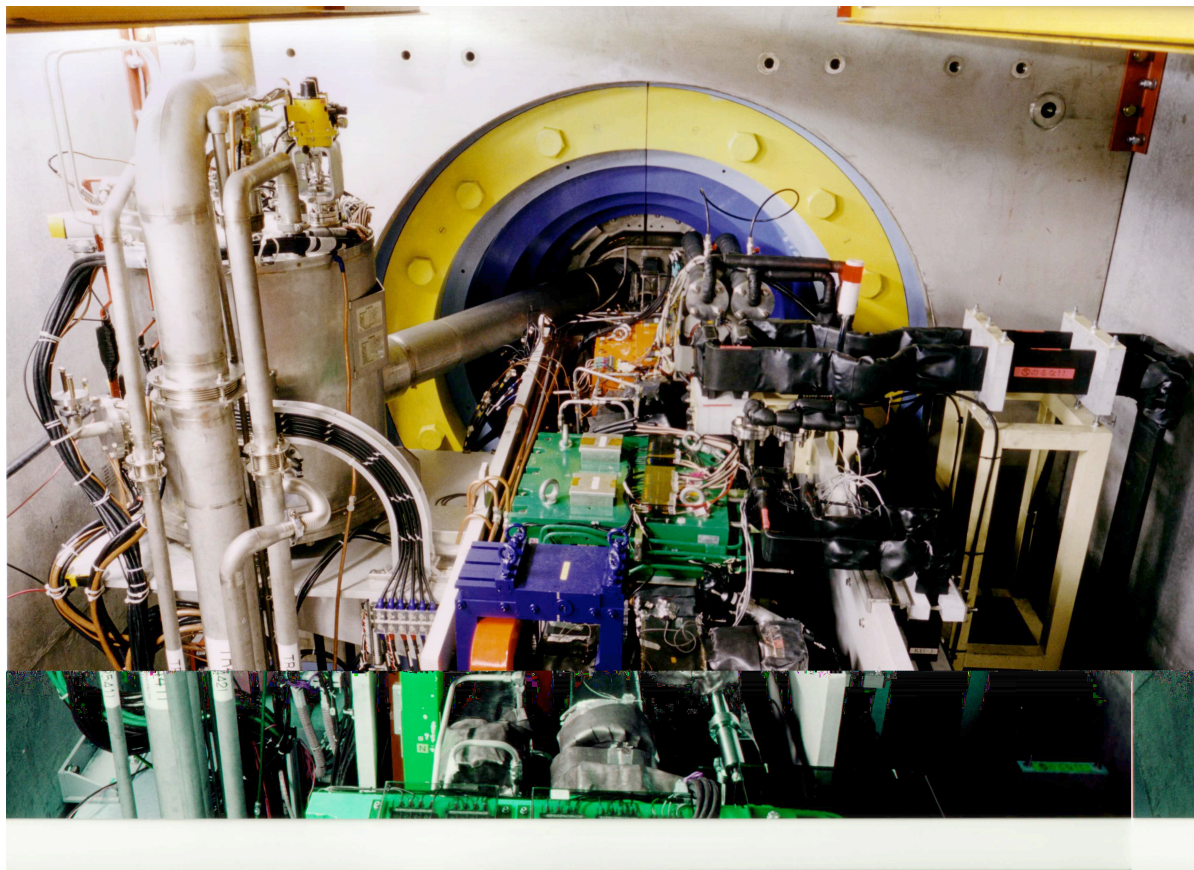
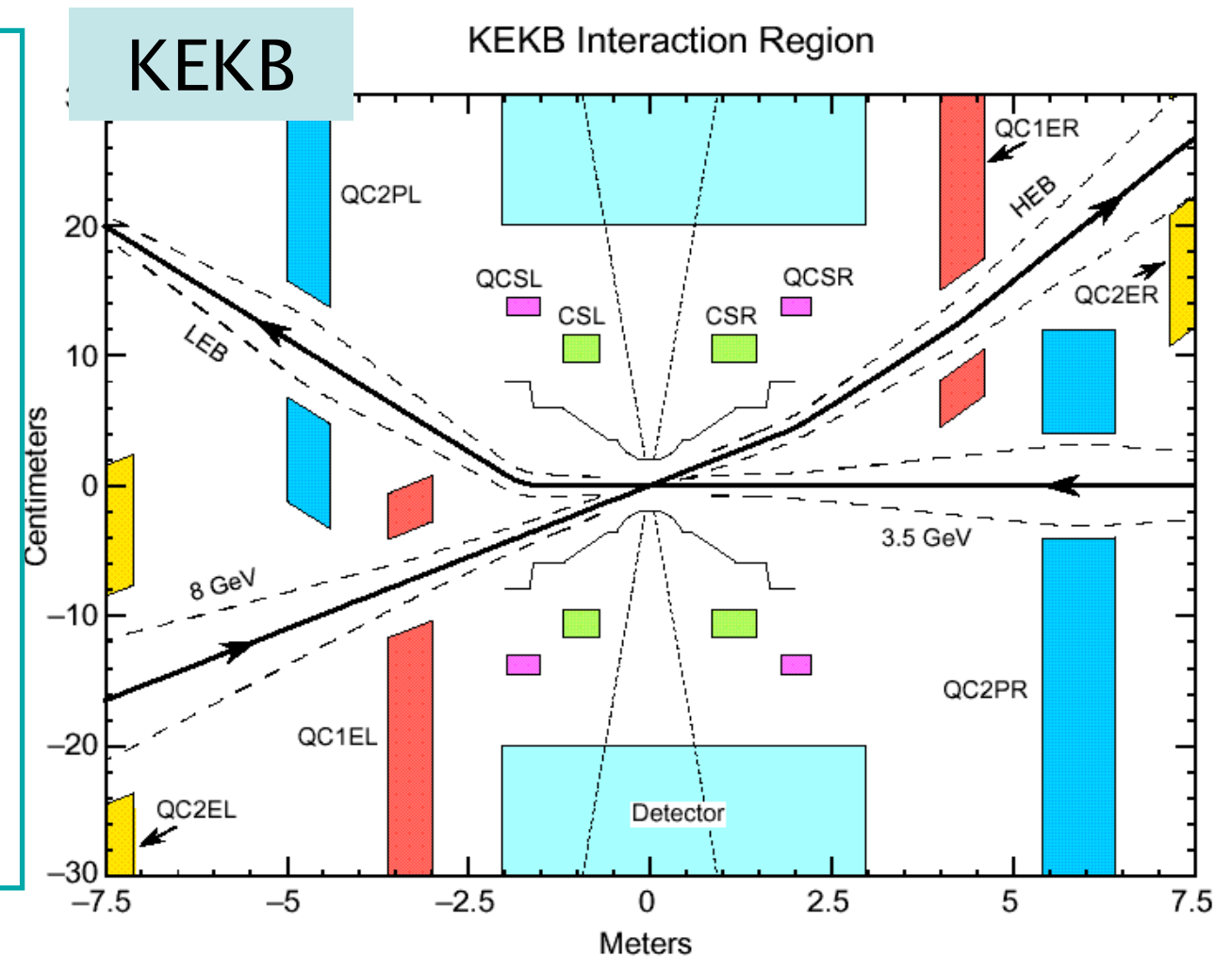
| Item                           | Object                                            | Oku-yen<br>= 1.0 M\$                 | Luminosity       |
|--------------------------------|---------------------------------------------------|--------------------------------------|------------------|
| New beam pipes                 | Enable high current<br>Reduce e-cloud             | 178<br>(incl. BPM,<br>magnets, etc.) | x1.5             |
| New IR                         | Small $\beta^*$                                   | 31                                   | x2               |
| e+ Damping<br>Ring             | Allow injection with small<br>increase e+ capture | 40 incl. linac<br>upgrade            | if not,<br>x0.75 |
| More RF and<br>cooling systems | High current                                      | 179<br>(incl. facilities)            | x3               |
| Crab Cavities                  | Higher beam-beam param.                           | 15                                   | x2 - x4          |

Items are interrelated.



KEKB has 22 mrad horizontal crossing angle at the IP:

- Easier beam separation
- Simpler design around the IP.
- Less number of components.
- Less synchrotron radiation.
- Less luminosity-dependent background.
- Space for compensation solenoid, etc.

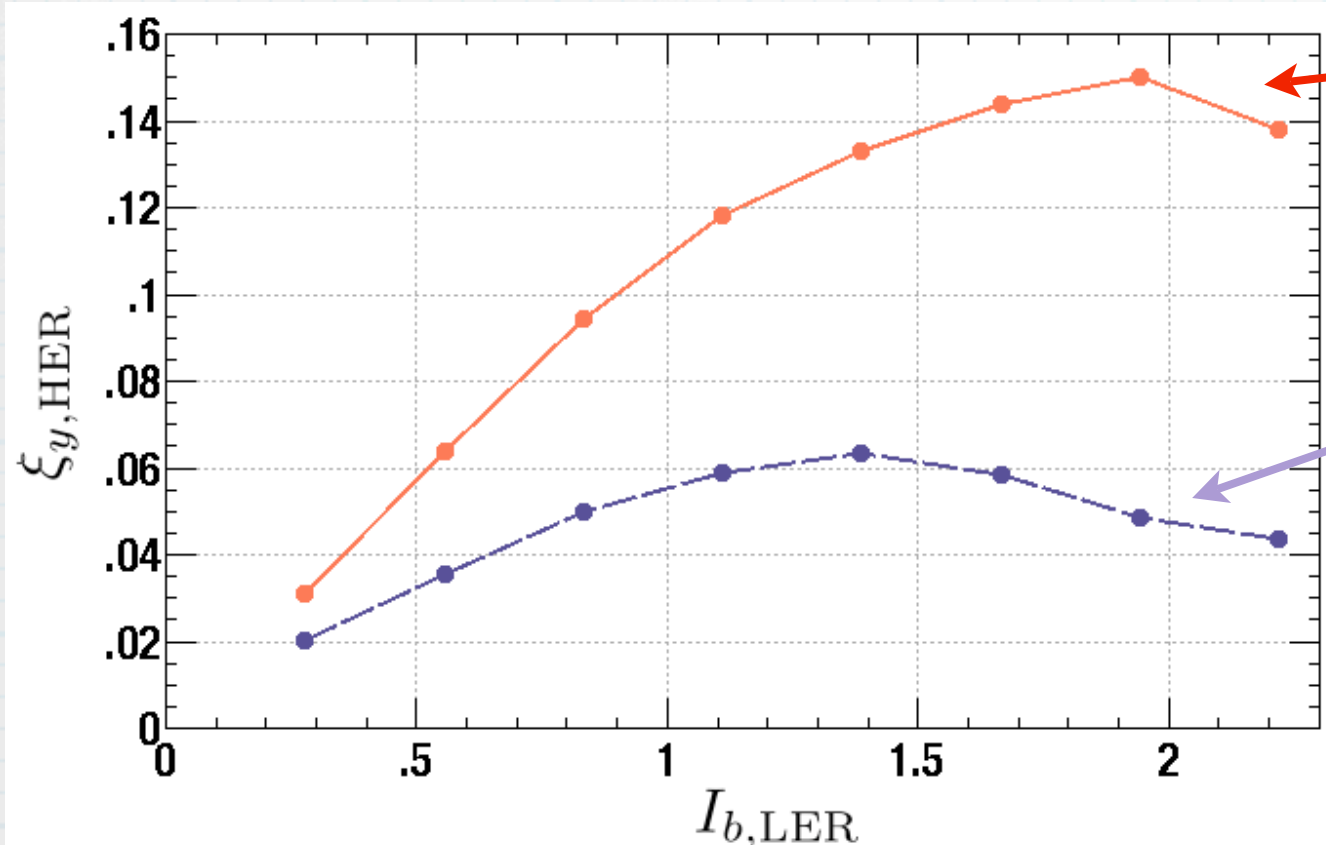




# Crab Crossing @ KEKB

- Crab Crossing can boost the beam-beam parameter higher than 0.15 !

K. Ohmi

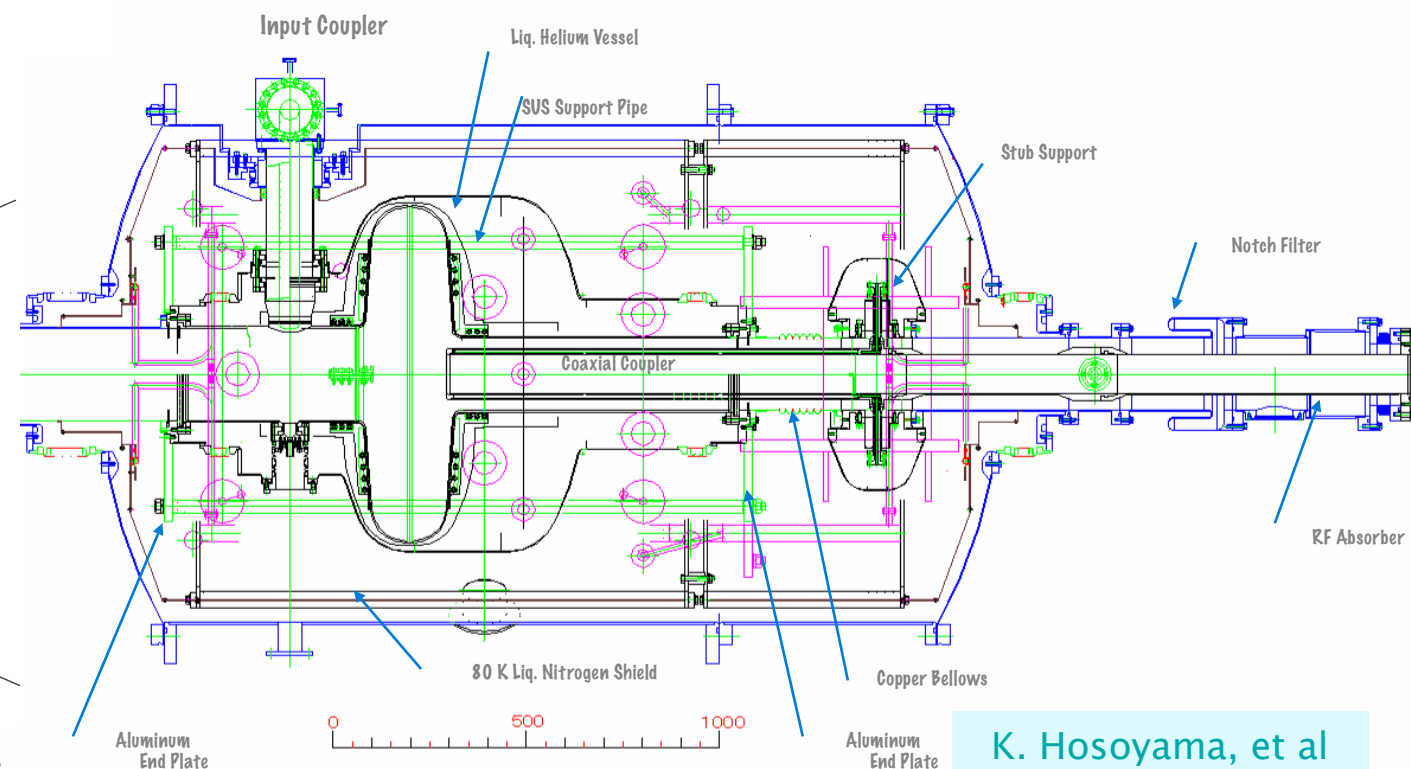
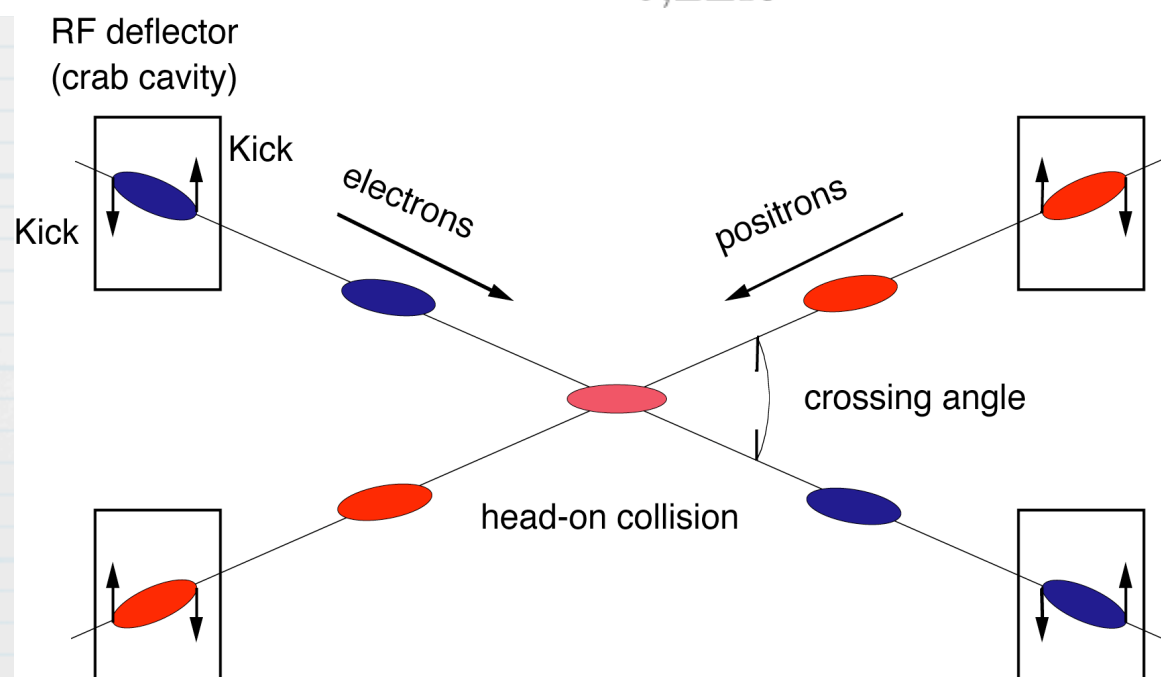


Head-on (crab)

(Strong-strong simulation)

Crossing angle 22 mrad

- Crab cavities were successfully produced and beam study has started in Feb. 2007.



First proposed by R. B. Palmer in 1988 for linear colliders.

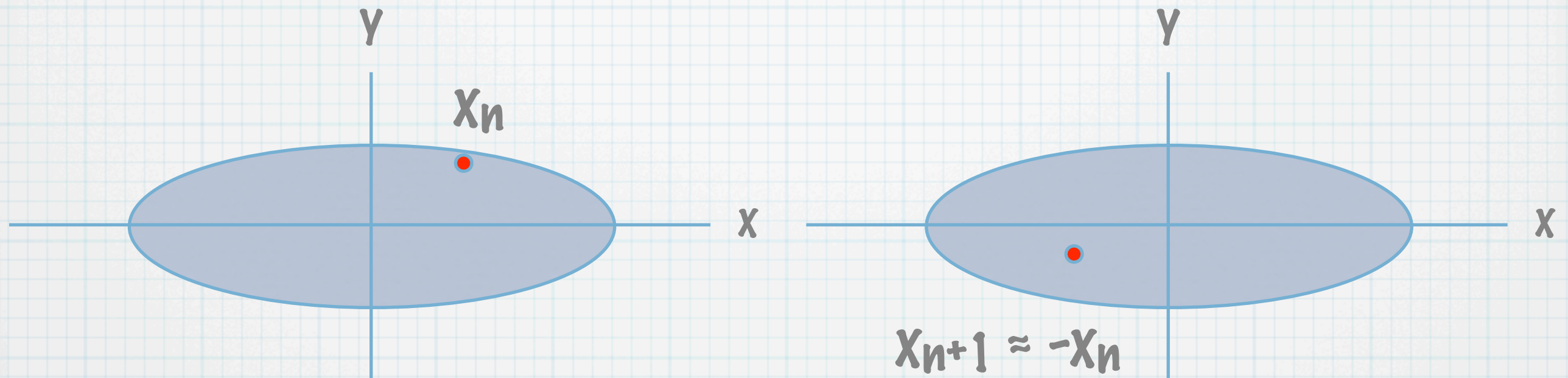
K. Hosoyama, et al



More gain than geometrical overlap is expected:

Head-on + hor. half integer tune

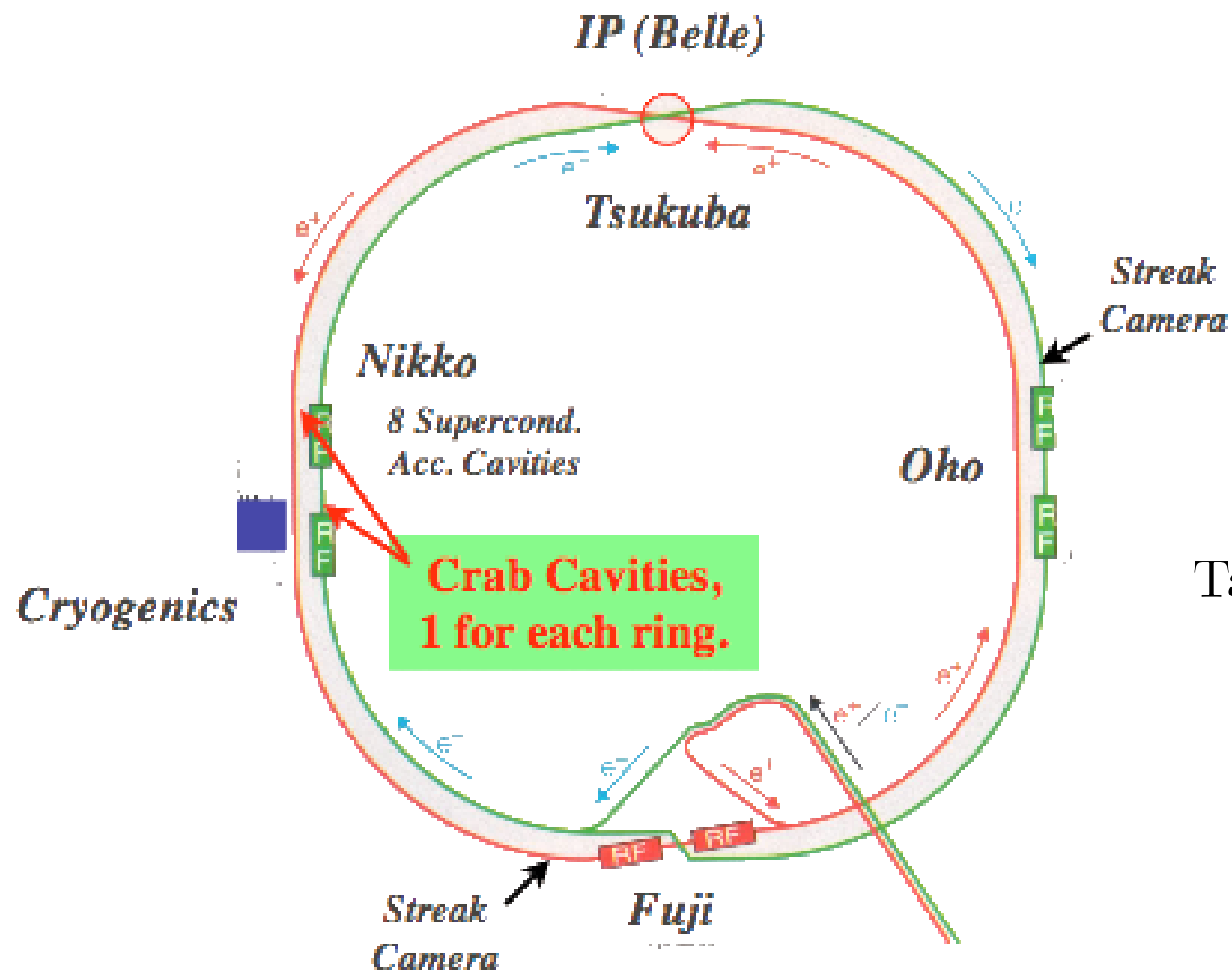
$\approx 1D$  + synchrotron motion



head-on: beam distribution is symmetric in x.

The beam-beam force becomes nearly independent on x  
at horizontal half integer and with head-on collision  
(Ohmi & Perevedentsev)

# Single Crab Cavity Scheme



- Beam tilts all around the ring.
- z-dependent horizontal closed orbit.
- tilt at the IP:

$$\frac{\theta_x}{2} = \frac{\sqrt{\beta_x^C \beta_x^*} \cos(\psi_x^C - \mu_x/2)}{2 \sin(\mu_x/2)} \frac{V_C \omega_{\text{rf}}}{Ec}$$

Table 1: Typical parameters for the crab crossing.

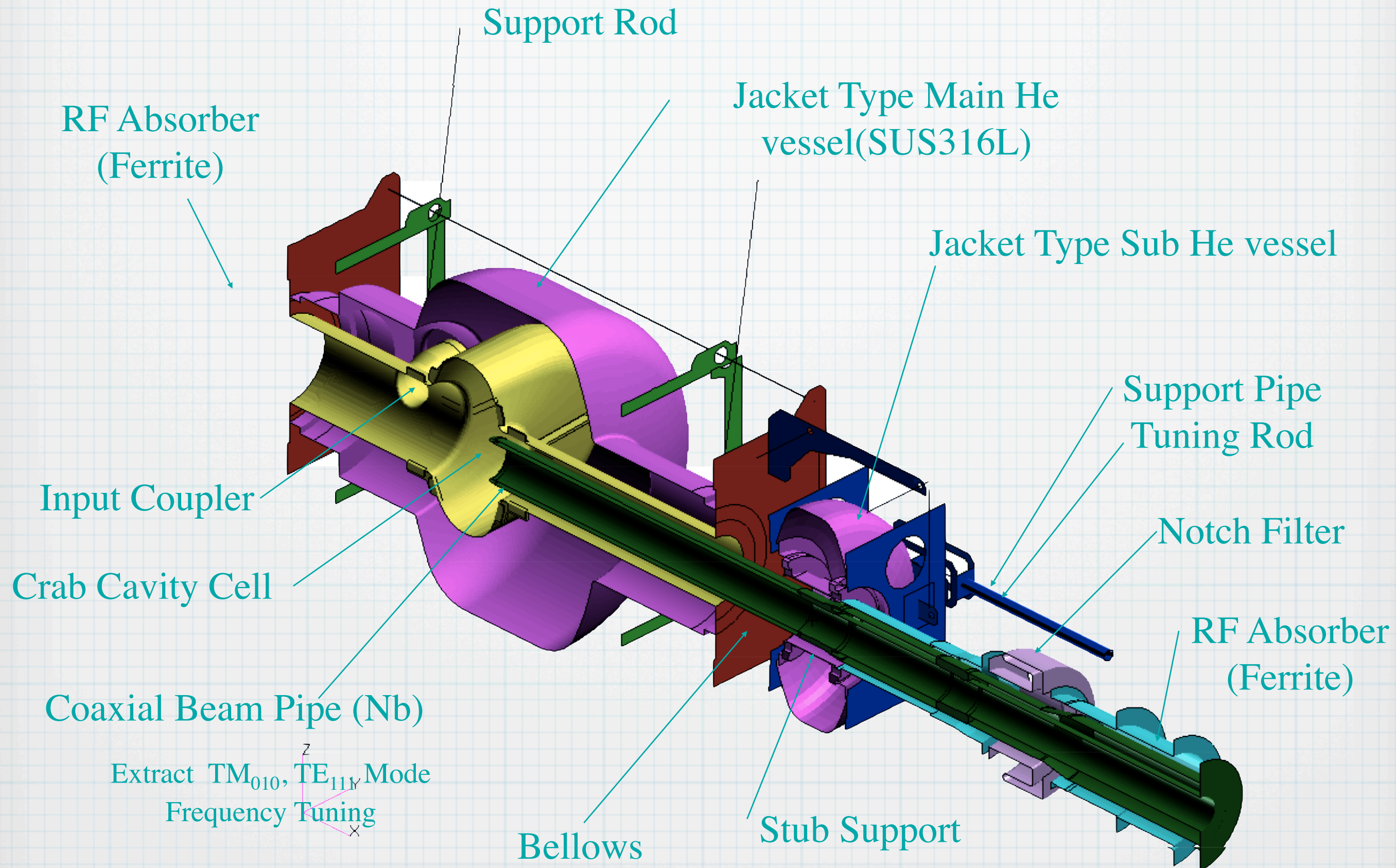
| Ring                      | LER         | HER         |      |
|---------------------------|-------------|-------------|------|
| $\theta_x$                | 22          |             | mrاد |
| $\beta_x^*$               | 80          | 80          | cm   |
| $\beta_x^C$               | 73          | 162         | m    |
| $\mu_x/2\pi$              | 0.505       | 0.511       |      |
| $\psi_x^C/2\pi$           | $\sim 0.25$ | $\sim 0.25$ |      |
| $V_C$                     | 0.95        | 1.45        | V    |
| $\omega_{\text{rf}}/2\pi$ | 509         |             | MHz  |

- \* 1 crab cavity per ring.
- \* saves the cost of the cavity and cryogenics.
- \* avoids synchrotron radiation hitting the cavity.



# Crab Cavity & Coaxial Coupler in Cryomodule

K. Hosoyama et al

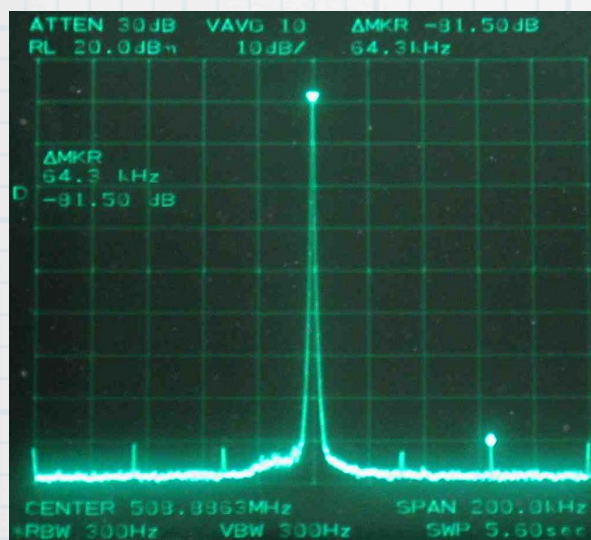




# Phase stability

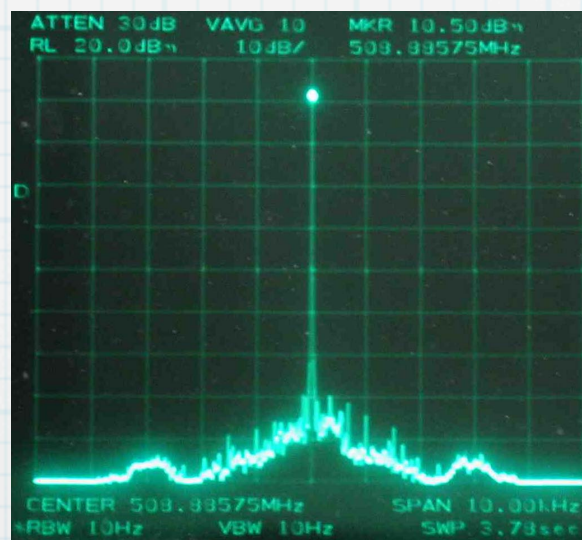
- \* Spectrum of pick up signal is consistent with phase detector data.
- \* Phase fluctuation faster than 1 kHz is less than  $\pm 0.01^\circ$ , and slow fluctuation from ten to several hundreds of hertz is about  $\pm 0.1^\circ$ .
- \* They are much less than the allowed phase error obtained from the beam-beam simulations for the crabbing beams in KEKB.

According to b-b simulation by Ohmi-san, allowed phase error for N-turn correlation is  $0.1 \times \sqrt{N}$  (degree).

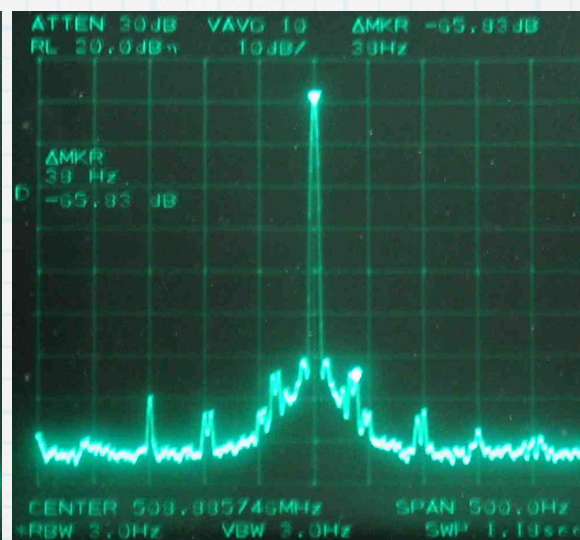


Span 200 kHz

Sideband peaks at 32kHz and 64kHz.



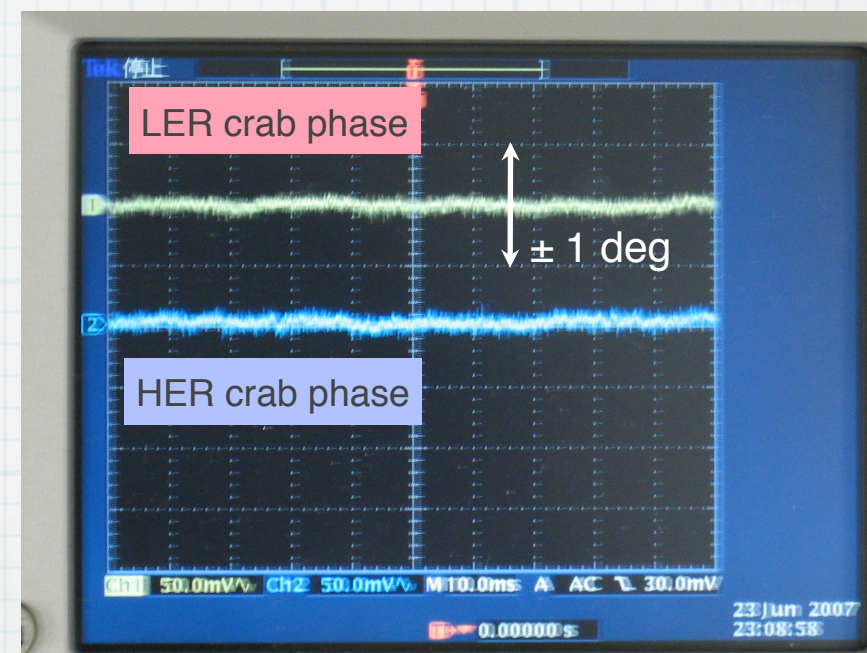
Span 10 kHz



Span 500 Hz

Sideband peaks at 32, 37, 46, 50, 100 Hz.

Spectrum around the crabbing mode measured at a pick up port of the LER crab cavity. Beam current was between 450 and 600 mA.

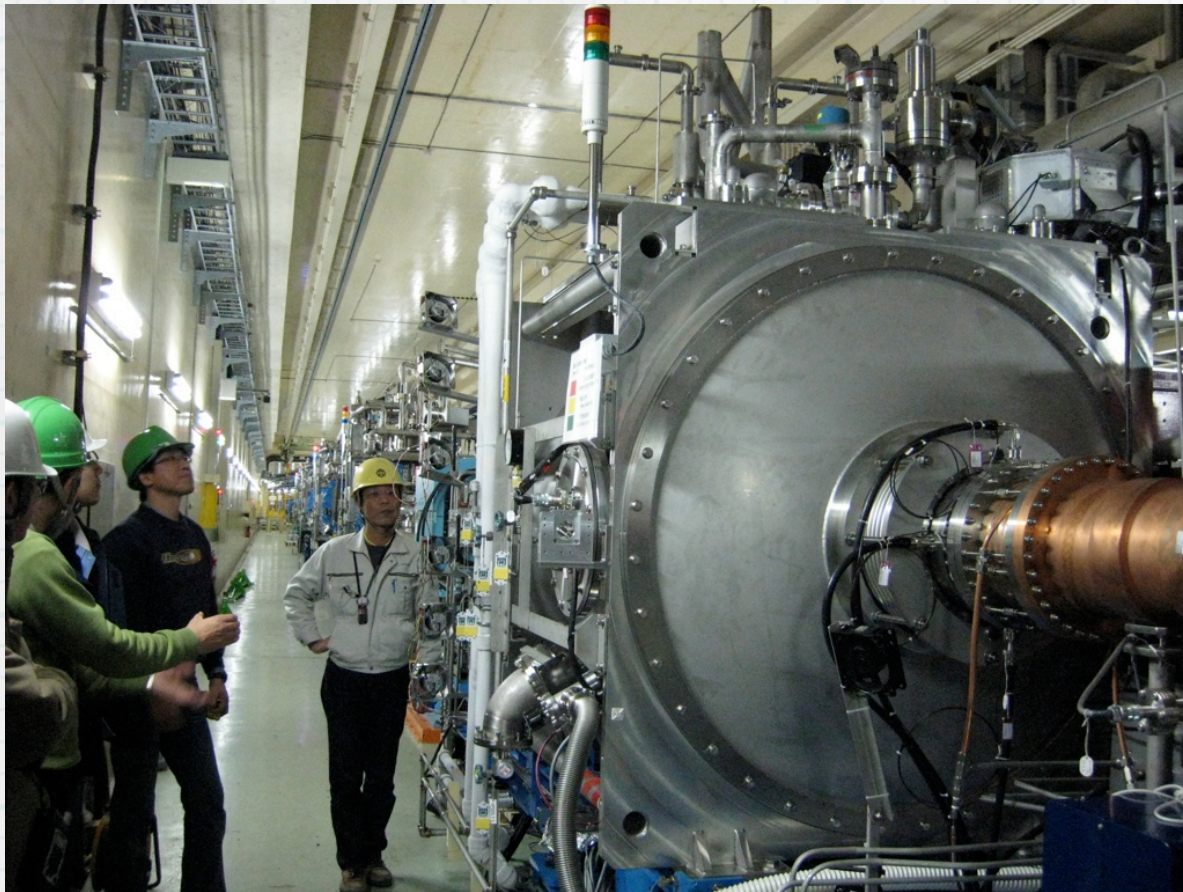


Phase detector signal. Beam current was 385mA (HER) and 600 mA (LER).

K. Akai



Finally two crab cavity was installed in KEKB,  
one for each ring in January 2007.



HER ( $e^-$ , 8 GeV)

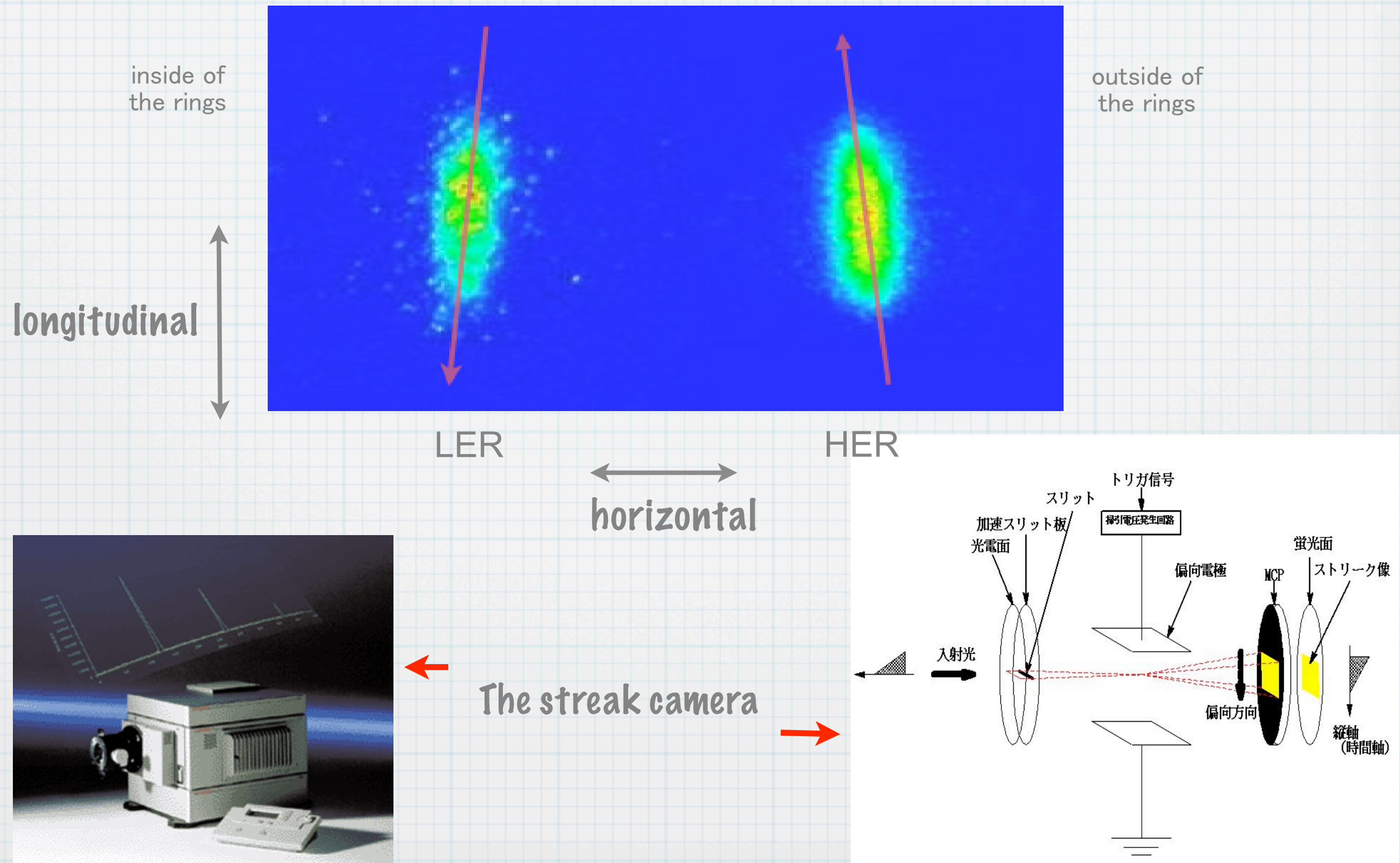


LER ( $e^+$ , 3.5 GeV)



# Beams has indeed tilted!

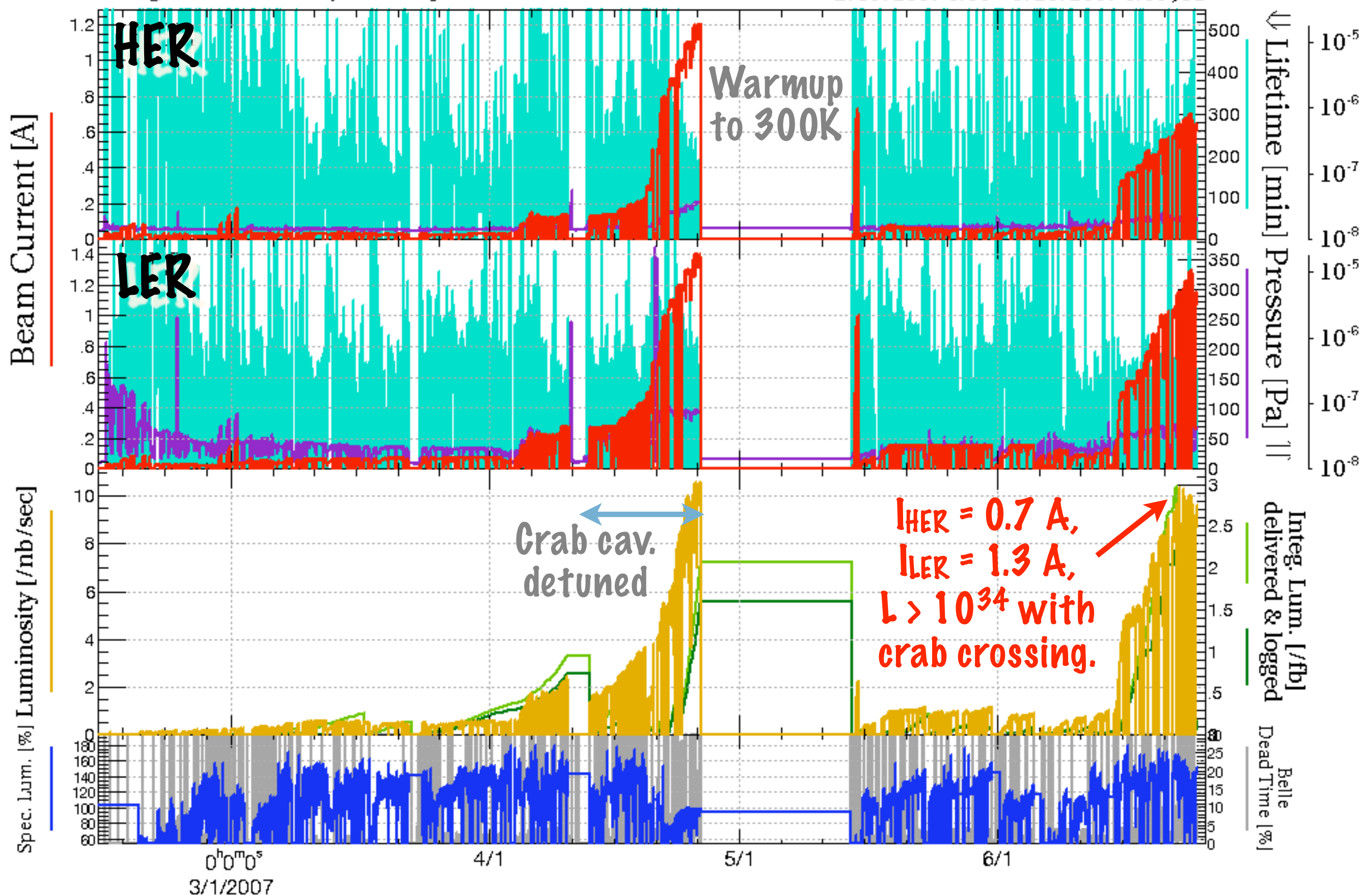
- Observation with Streak Cameras (H. Ikeda et al, FRPMN035)





Peak Luminosity 10.615[/nb/sec] @04/26 08:07  
Integrated Luminosity 723.70[/pb]

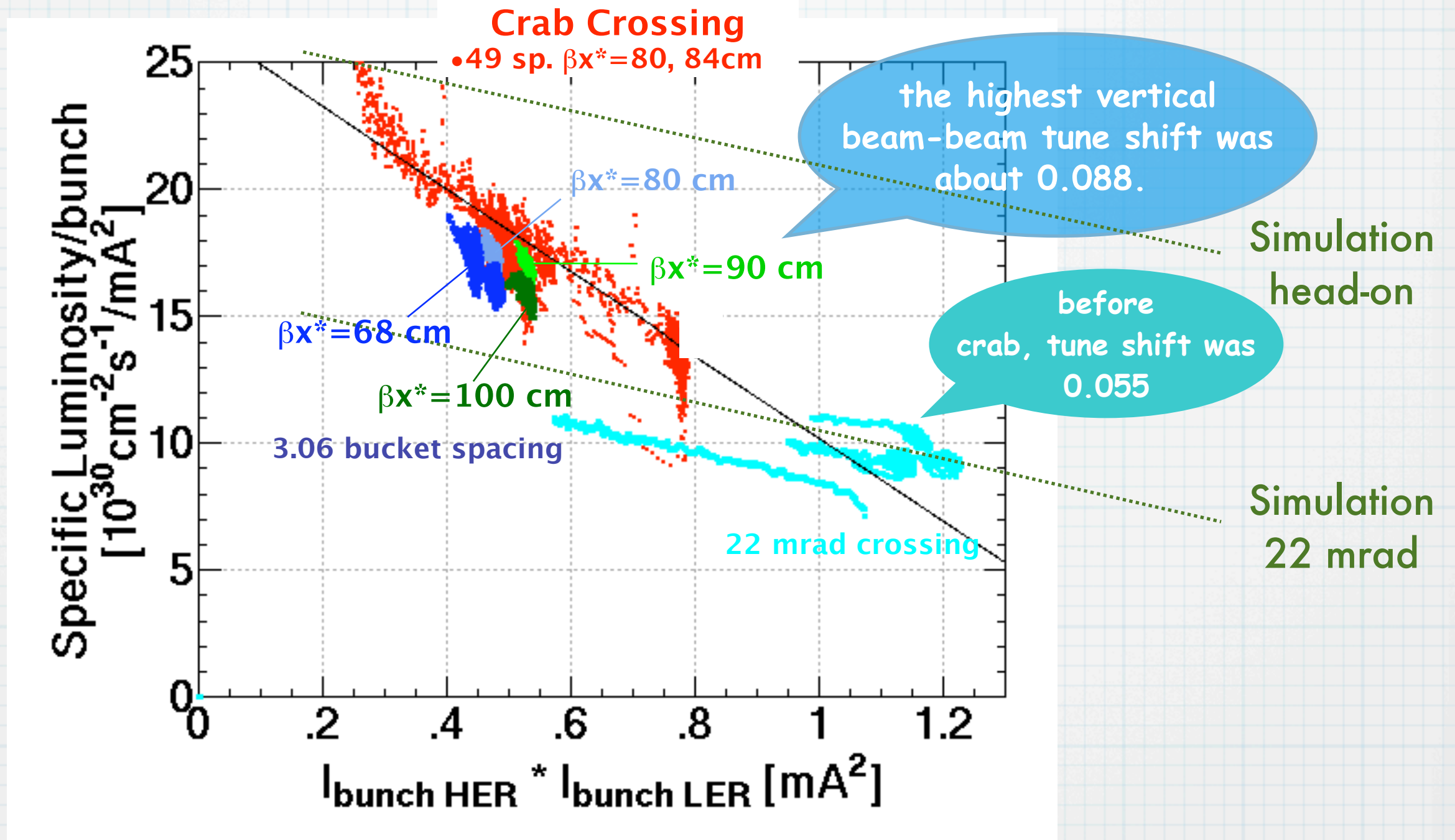
2/13/2007 0:00 - 6/26/2007 0:00 JST







# Specific Luminosity



- ★ A number of measurements indicate effective head-on collision.
- ★ The vertical tune shift became higher than 0.088. Before crab, it was 0.055.
- ★ The specific luminosity / bunch was improved more than the geometrical gain.
- ★ Need more time to achieve the goal (X2 specific luminosity).

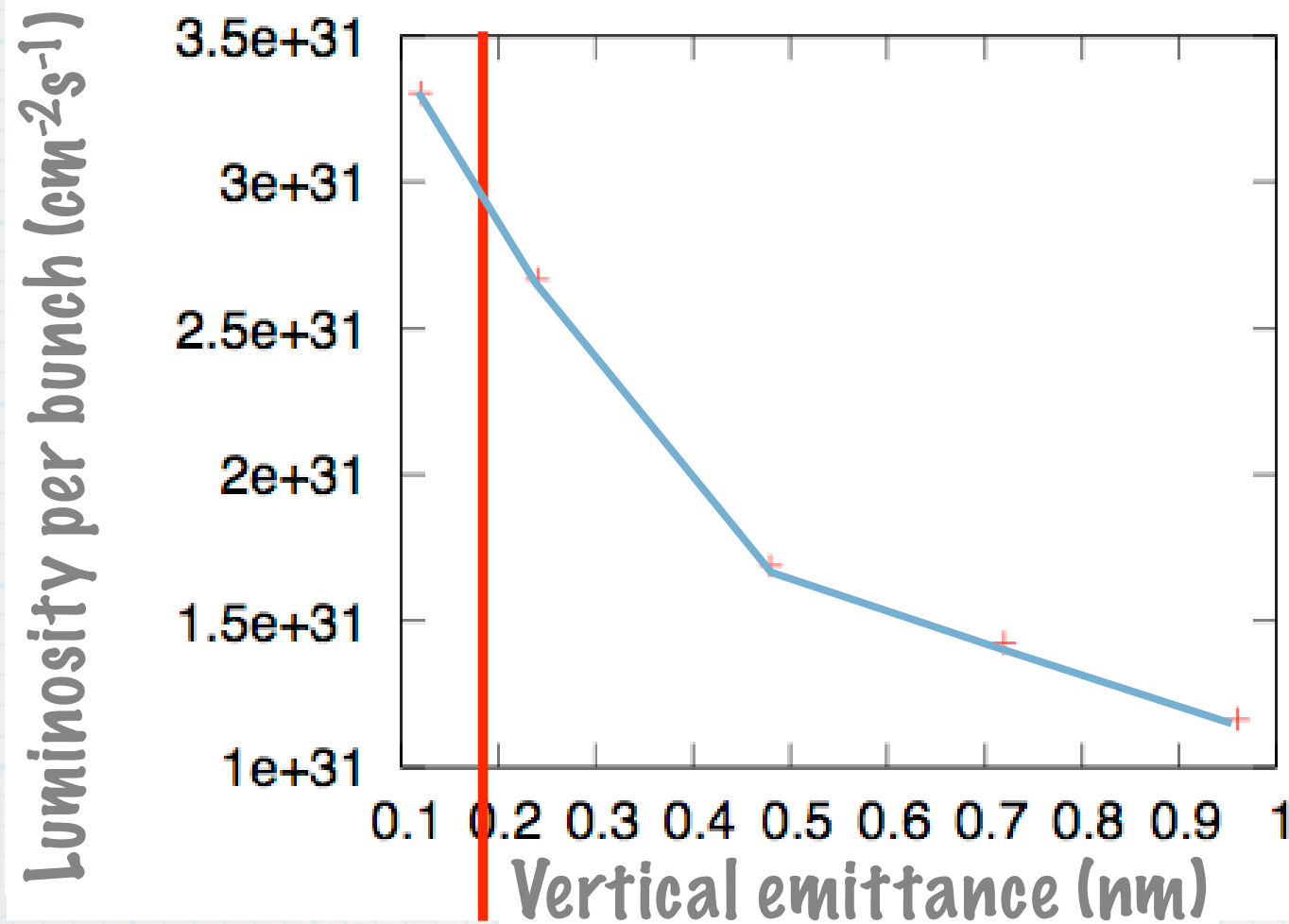
# Why the specific luminosity drops faster than expected?

## Speculations:

- \* The single beam vertical emittance may have to be sufficiently small
- \* Lifetime may be limited by the dynamic-  $\beta$  and dynamic emittance caused by beam-beam.
- \* Electron Cloud in the LER: Luminosity becomes better for longer bunch spacing.
- \* The SPOOABS nature in the optimum condition of the collision: Too many parameters.
- \* Synchrotron-betatron resonance near  $1/2$  integer.
- \* .. and more ..



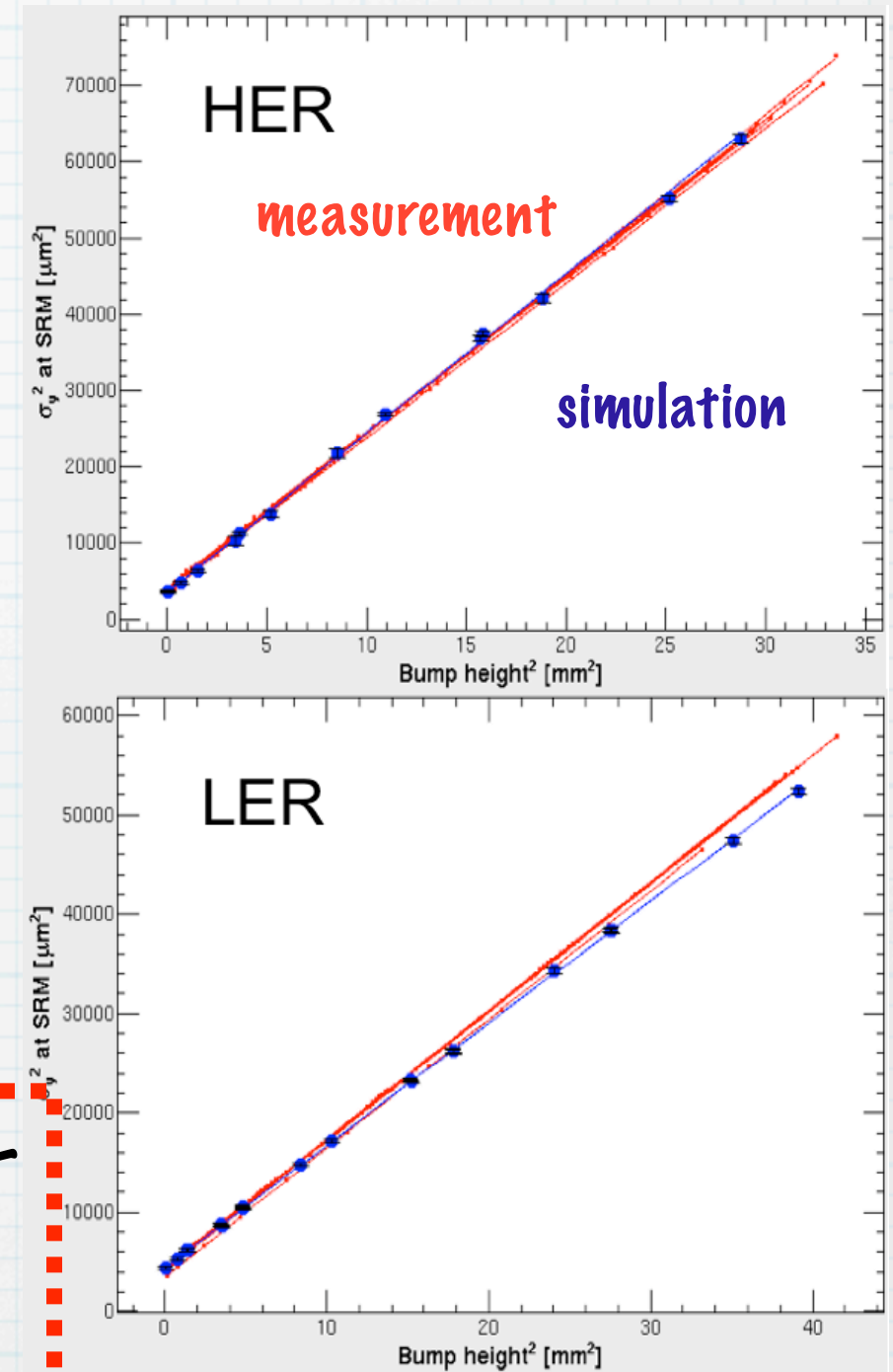
# Vertical emittance small enough?



K. Ohmi

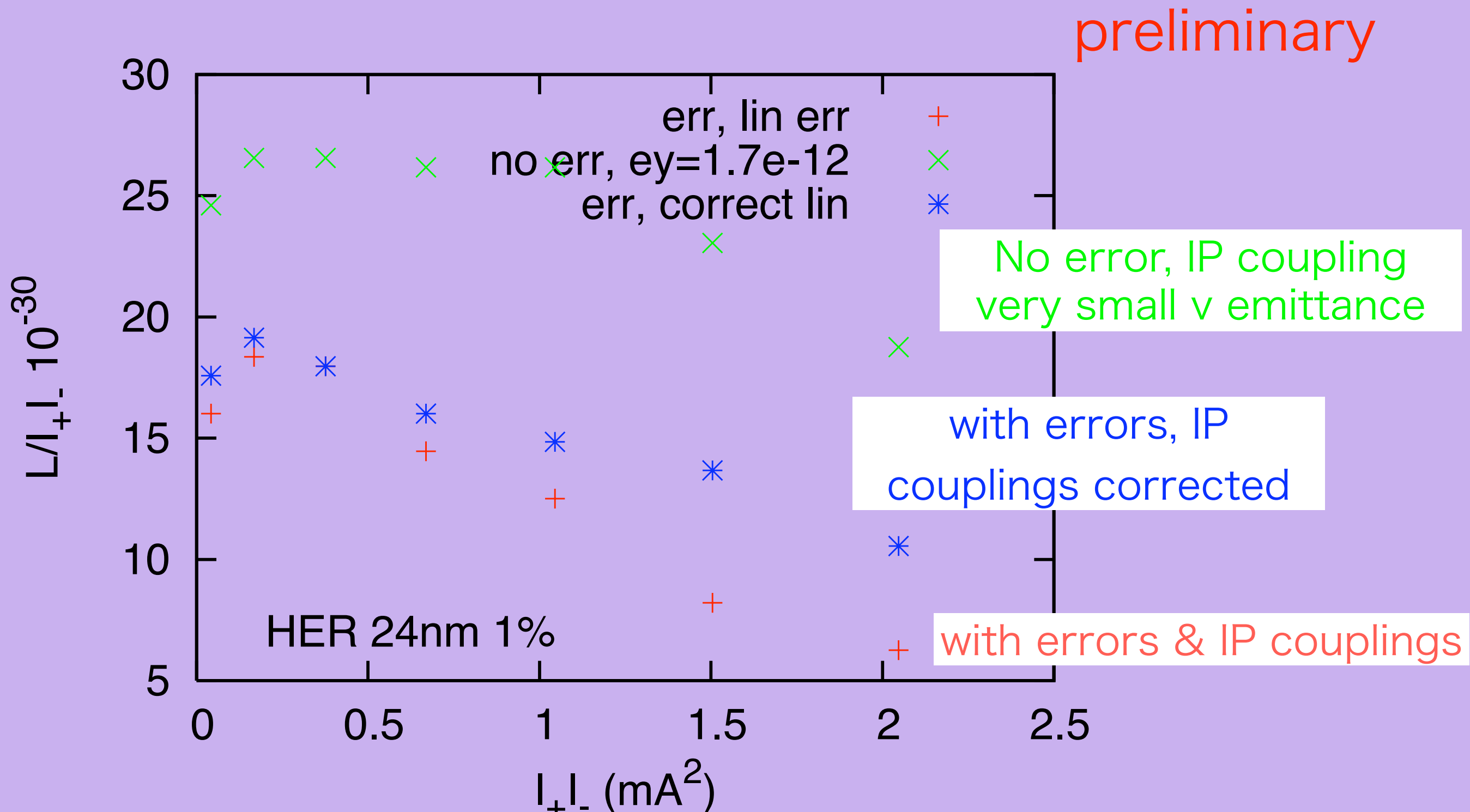
1%

- According to the simulation, the vertical single-beam emittance must be less than 1% to achieve the high luminosity(above).
- Recent calibration of the size monitor with "iSize" bump orbit shows the emittance ratio was 1.4%/1.2% for LER/HER (right).



N. Iida et al, TUPAN042

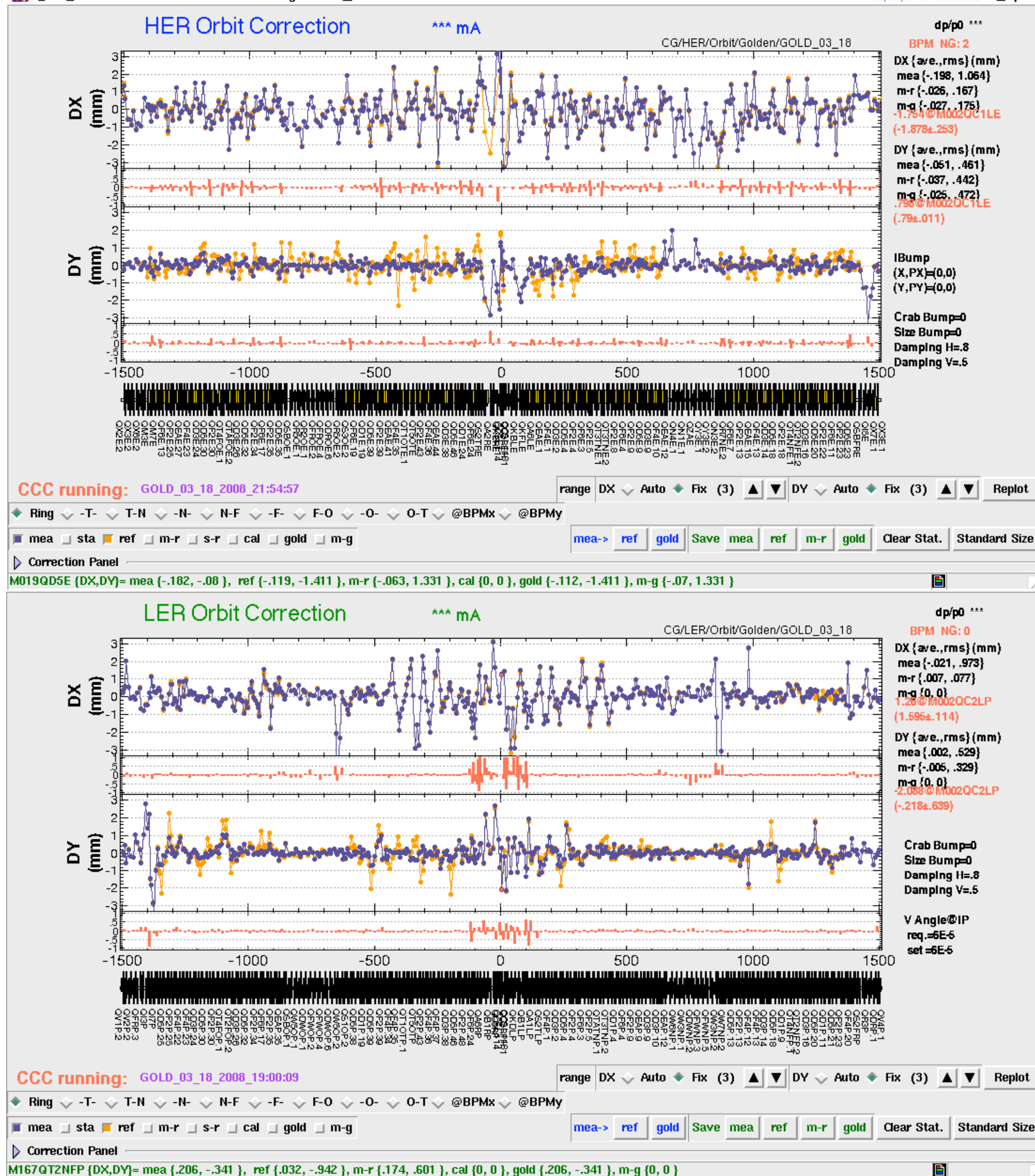
The legacy coupling & dispersion correction may not be sufficient to recover the luminosity



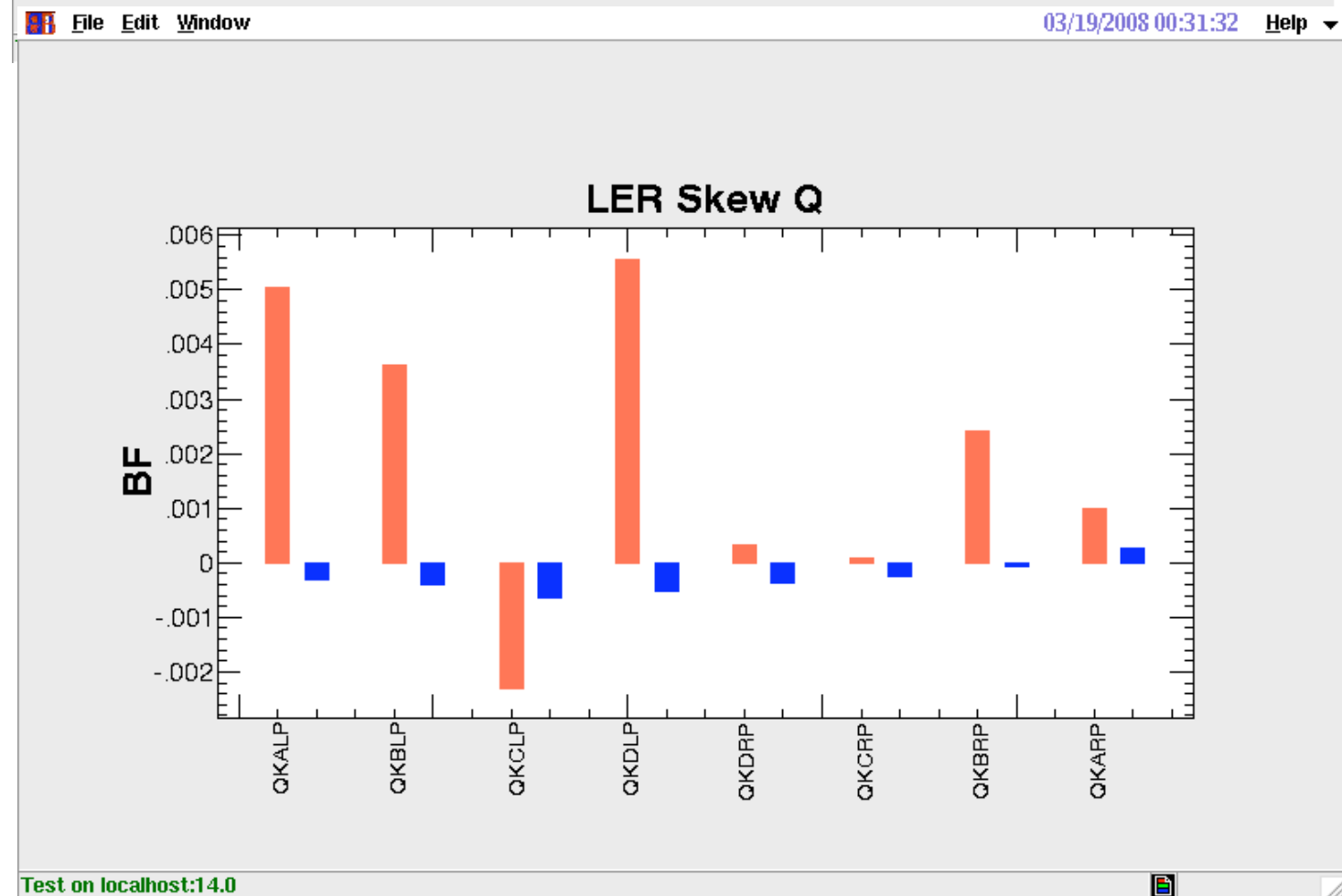
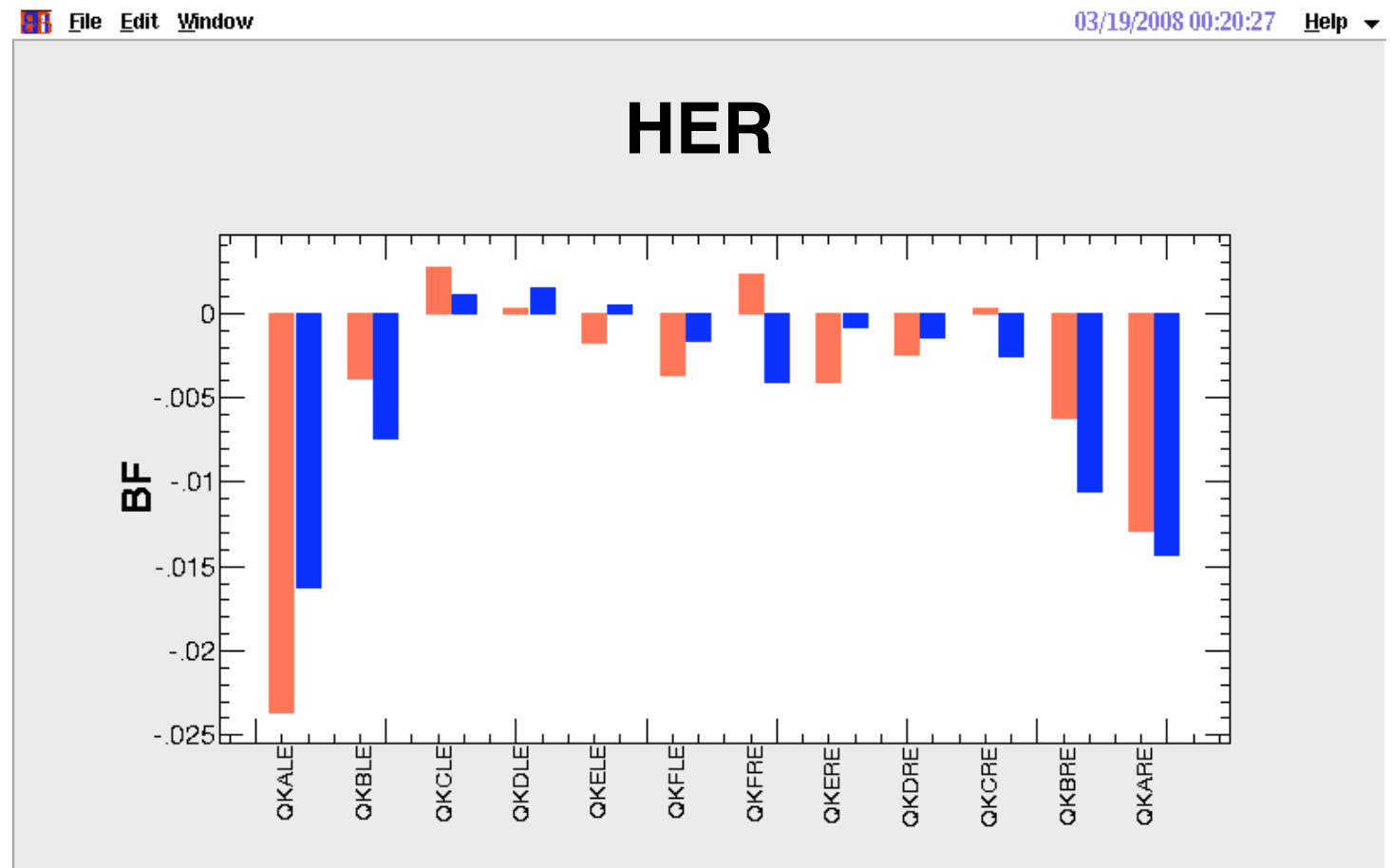


# new/old orbit

- skew quads closer to the model.
- flatten vertical orbit in the arcs.
- Include **BPM rolls** as variables of the xy coupling correction.

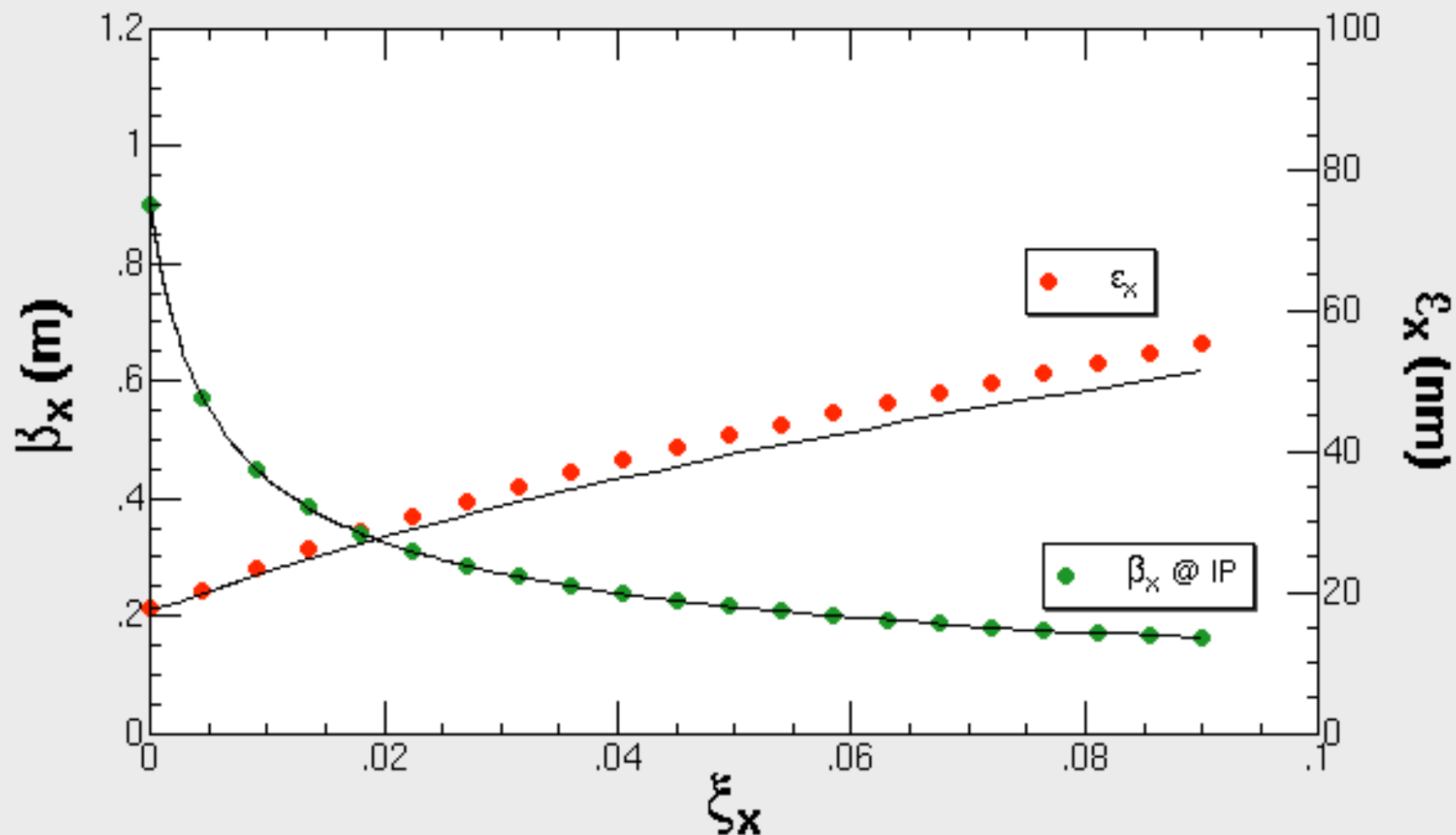


old/new skew  
quads





# LER dynamic- $\beta$ and emittance

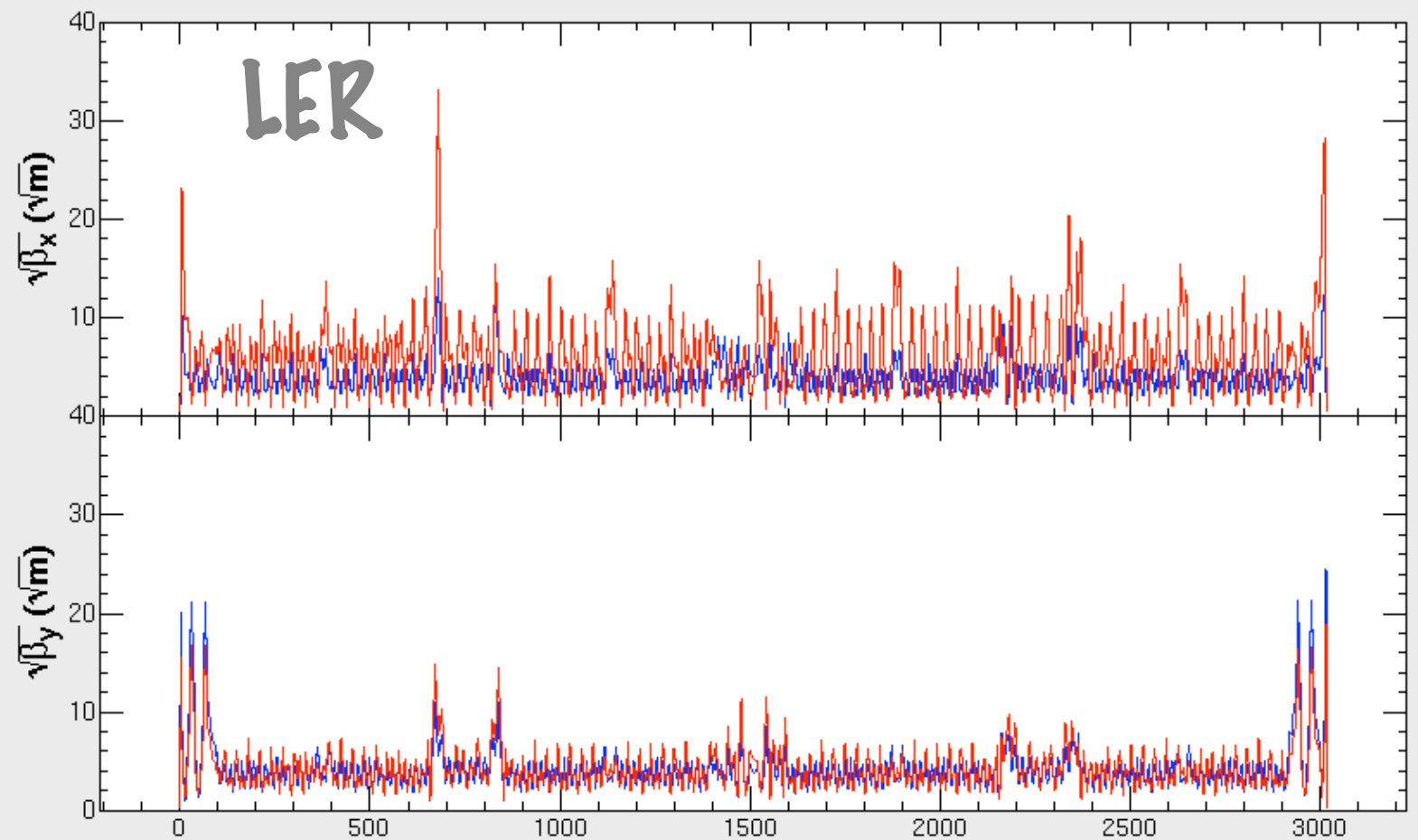


|                           |        |
|---------------------------|--------|
| LER                       |        |
| $\nu_x$                   | 45.506 |
| $\nu_y$                   | 43.57  |
| $\beta_x$ [m]             | .9     |
| $\beta_y$ [m]             | .0059  |
| $\epsilon_{x\text{ max}}$ | .09    |
| $\epsilon_{y\text{ max}}$ | .1     |

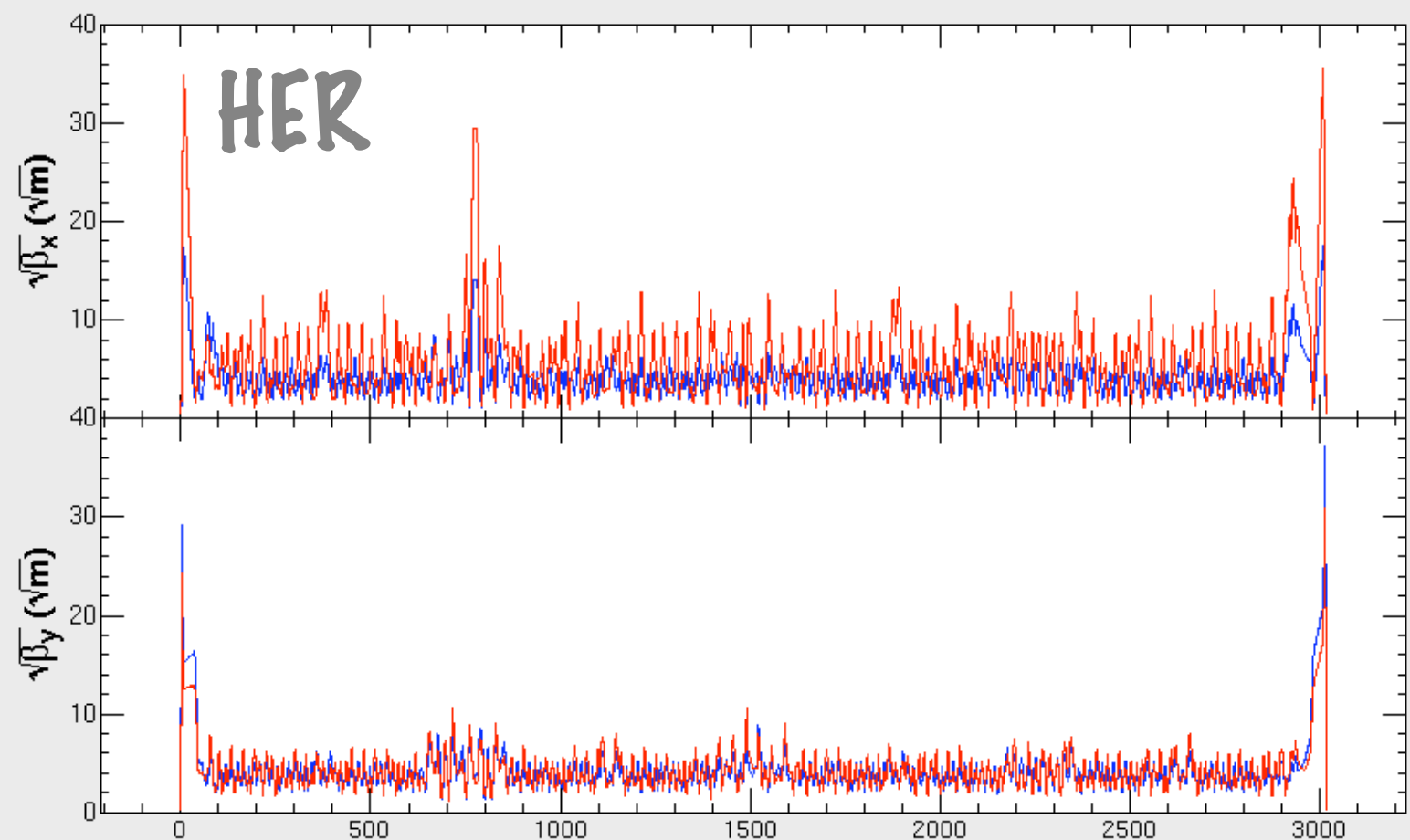
The focusing force of the beam-beam interaction not only squeezes the beam at the interaction point, but increases the emittance drastically.

Y. Funakoshi

Deformation of  $\beta$ -  
function all around  
the ring due to  
beam-beam effect  
("dynamic beta")



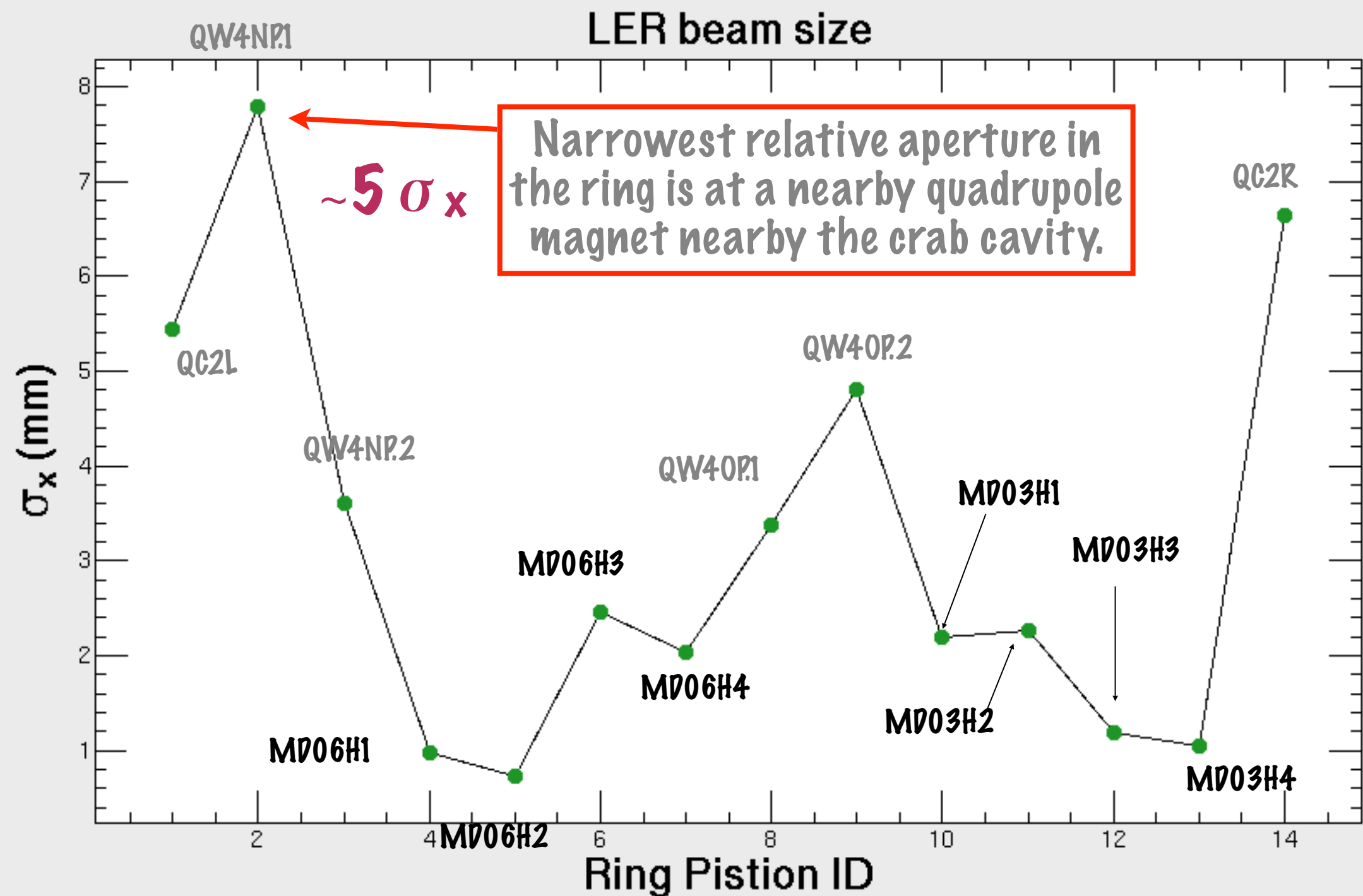
with/without beam-beam effects



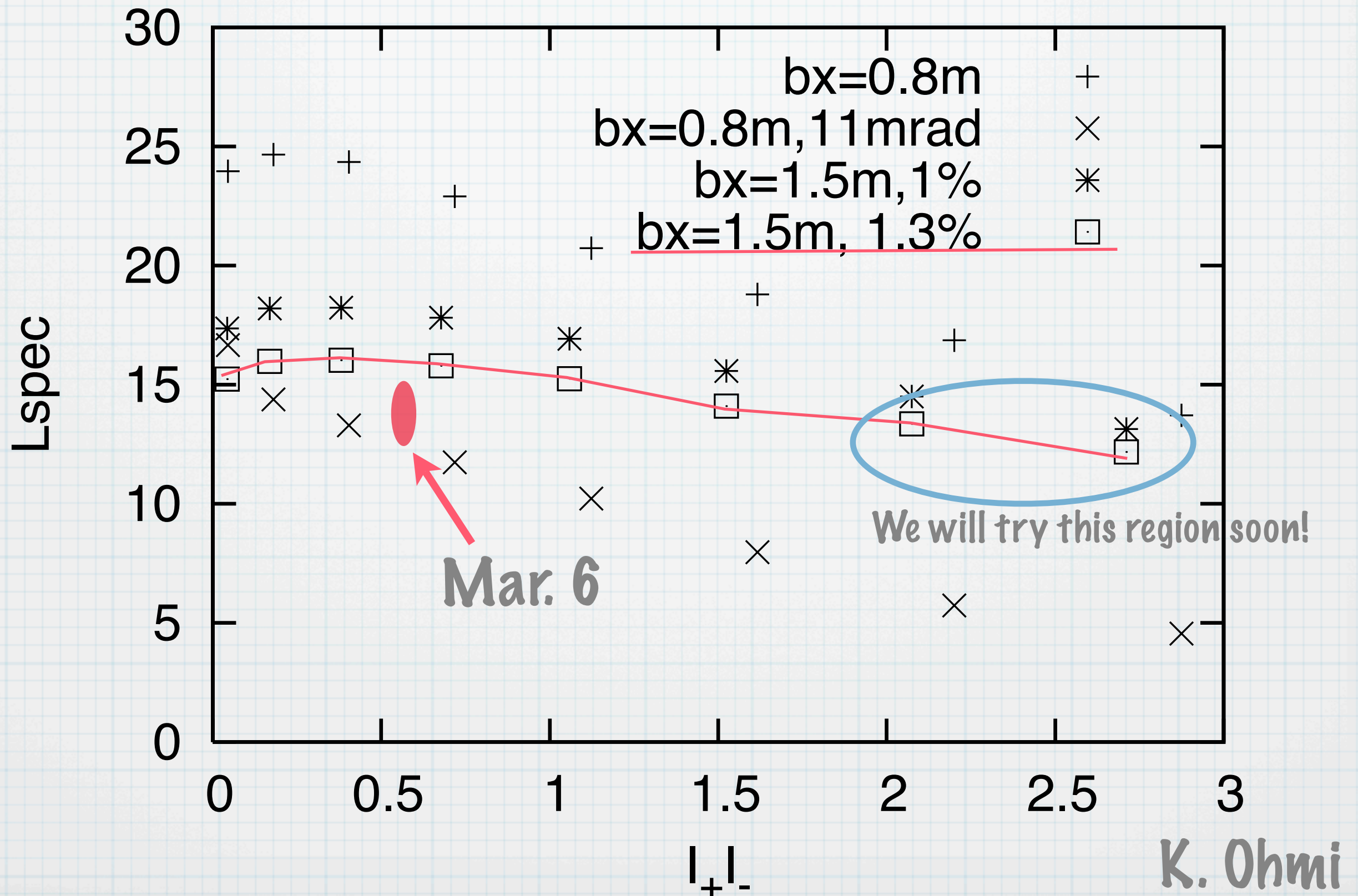
Y. Funakoshi



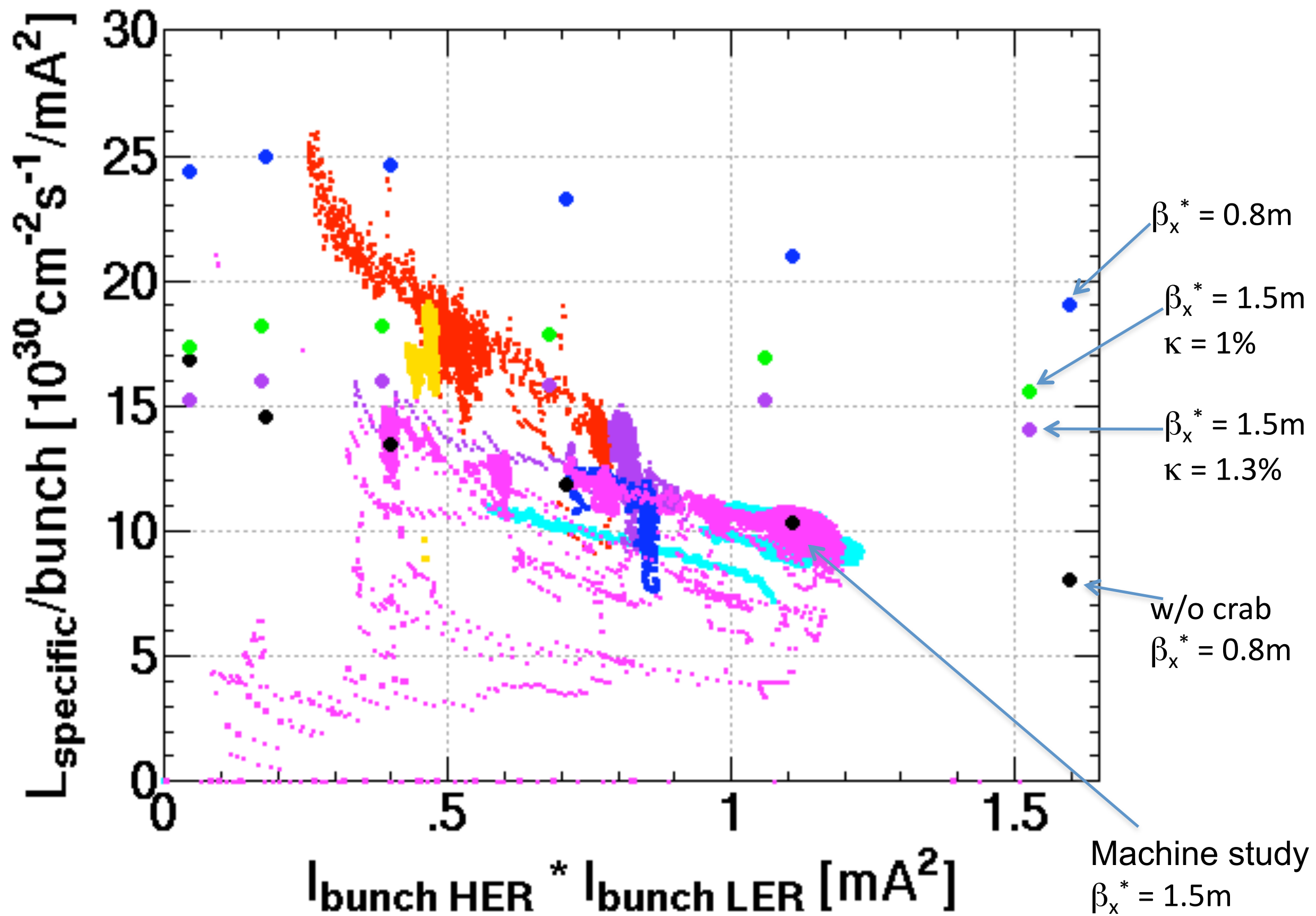
The lifetime may be limited by the dynamic beta effect.



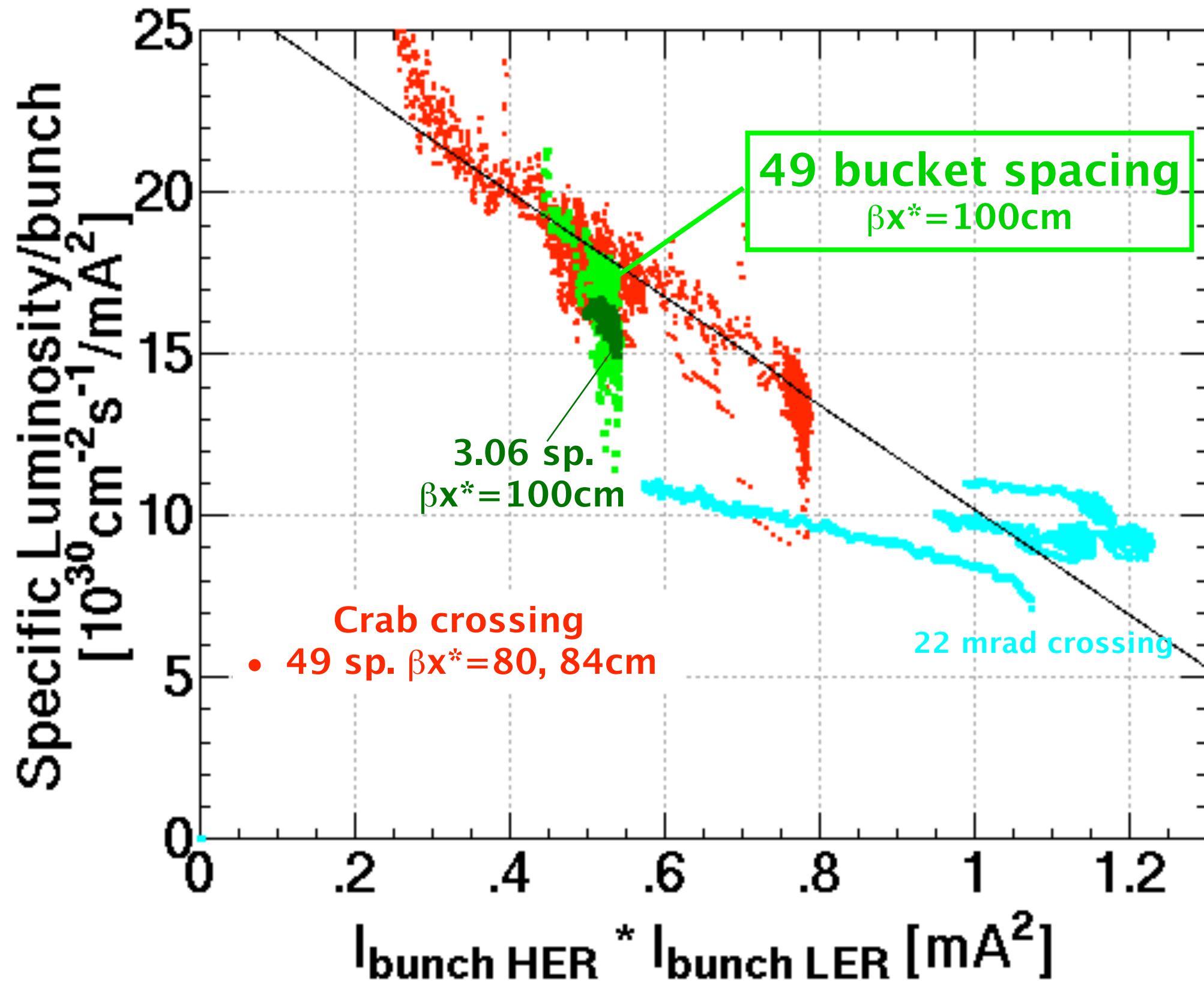
# Are we already close to simulation?







# Specific Luminosity becomes better for longer bucket spacing. Due to e-cloud?





# Too many tuning knobs?

Table 3: Tuning knobs for the crab crossing and their observables. Many depend only on the beam size  $\sigma_y$  at the synchrotron radiation monitor (SRM), besides the luminosity  $\mathcal{L}$ .

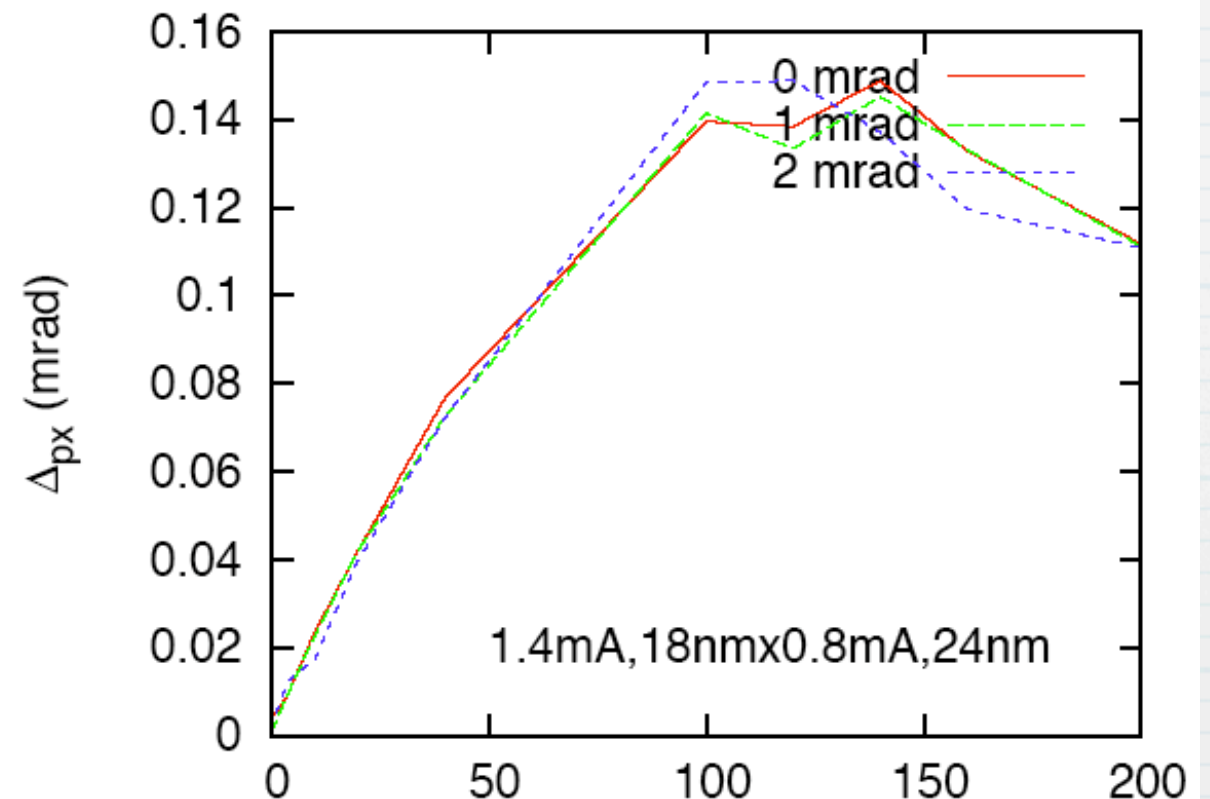
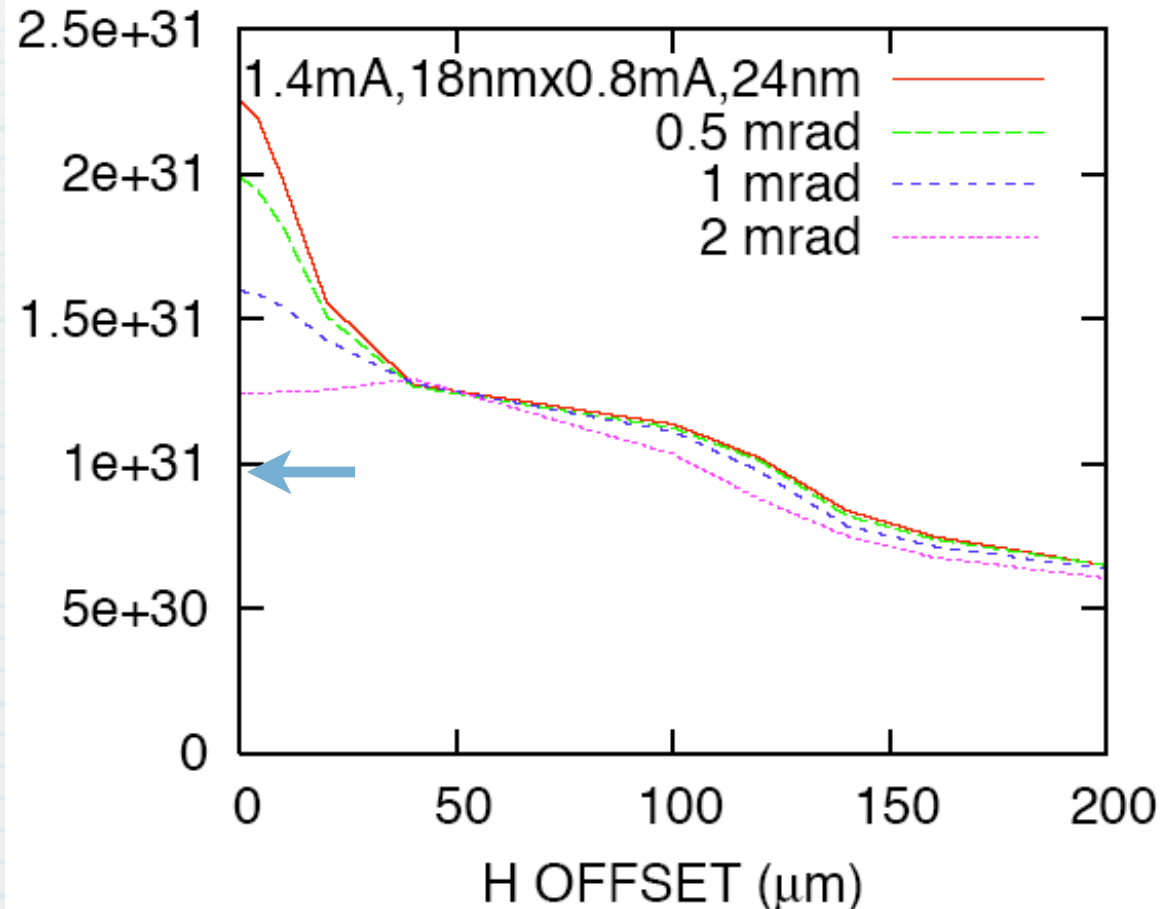
| Knob                                        | Observable                                             | frequency: every  |     |
|---------------------------------------------|--------------------------------------------------------|-------------------|-----|
| Relative beam offset IP                     | Beam-beam kick measured by BPMs around the IP          | 1 sec             | 2   |
| Relative beam angle IP                      | BPMs around the IP                                     | 1 sec             | 2   |
| Global closed orbit                         | All $\sim 450$ BPMs                                    | 15 sec            | -   |
| Beam offset at crab cavities[11]            | BPMs around the crab cavity                            | 1 sec             | 2   |
| Betatron tunes                              | tunes of non-colliding pilot bunches                   | $\sim 20$ sec     | 4   |
| Relative rf phase                           | center of gravity of the vertex                        | 10 min.           | 1   |
| Global couplig, dispersion, beta-beat       | orbit response to kicks & rf frequency                 | $\sim 14$ days    | -   |
| LER to HER crab voltage ratio               | response in the hor. beam-beam kick. vs. crab rf phase | $\sim 7$ days     | 1   |
| Rf phase of crab cavity                     | hor. kick vs. crab voltage response                    | $\sim 7$ days     | 2   |
| Vertical waist position                     | $\mathcal{L}$ and $\sigma_y$ at the SRM                | $\sim 1$ day      | 2   |
| Local x-y couplings and dispersions at IP   | $\mathcal{L}$ and $\sigma_y$ at the SRM                | $\sim 1$ day each | 16  |
| Sextupole settings                          | $\mathcal{L}$ and lifetime                             | $\sim 3$ days     | 106 |
| X-y coupling parameter at the crab cavities | $\mathcal{L}$ and $\sigma_y$ at the SRM                | $\sim 3$ days     | 4   |
| Crab kick voltage                           | $\mathcal{L}$ and $\sigma_y$ at the SRM                | $\sim 7$ days     | 2   |

- Many knobs are determined by scans only on the luminosity, beam sizes, and the lifetime.
- Scan is slow, each takes about 30 minutes.
- Question in the multi-dimensional nonlinear optimization.

# sharply-peaked-optimum-on-a-broad-shoulder (SPOOABS)

An example: the Horizontal Offset and the crossing angle at the IP  
beam-beam kick

- Luminosity



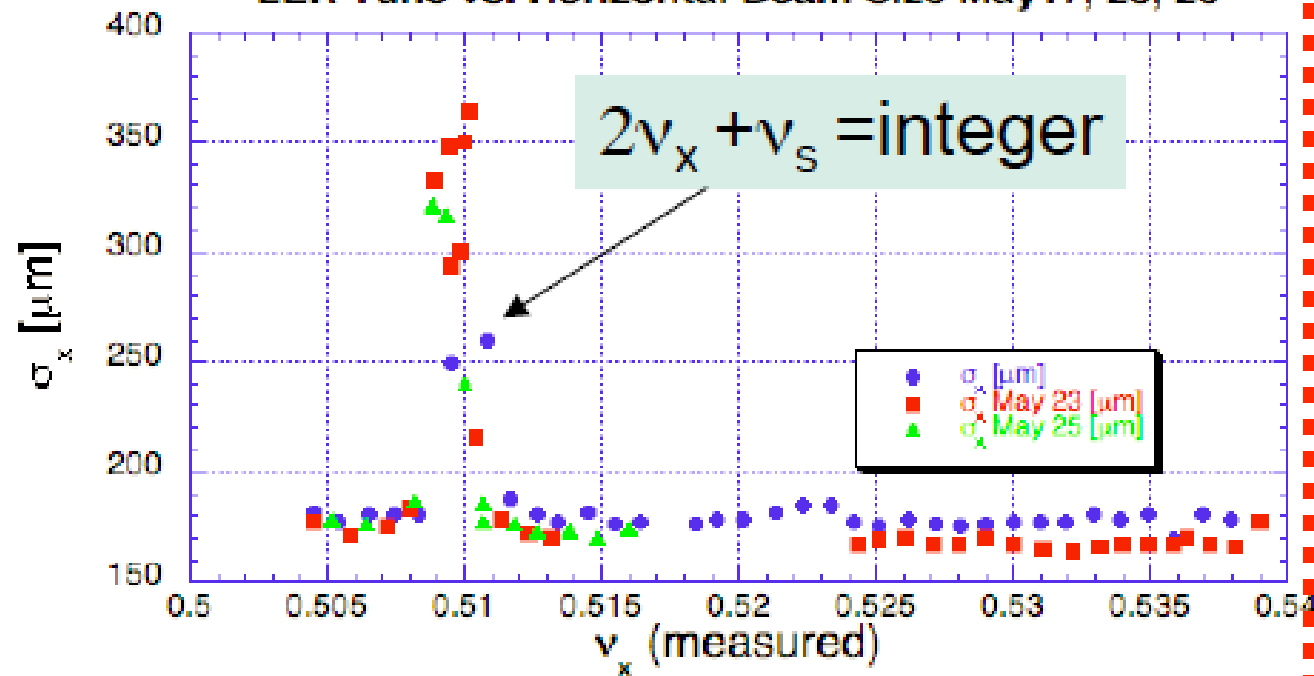
K. Ohmi

- Luminosity degrades by a small error in any one of the collision parameters. The horizontal offset of two beams and the crossing angle at the IP are such an example.
- Horizontal offset must be much less than  $25 \mu\text{m}$ , and the crossing angle less than 1.5 mrad to see the effect of crab crossing.
- There are more than 20 of such parameters. If one of them is largely off, the optima of other parameters cannot be found.



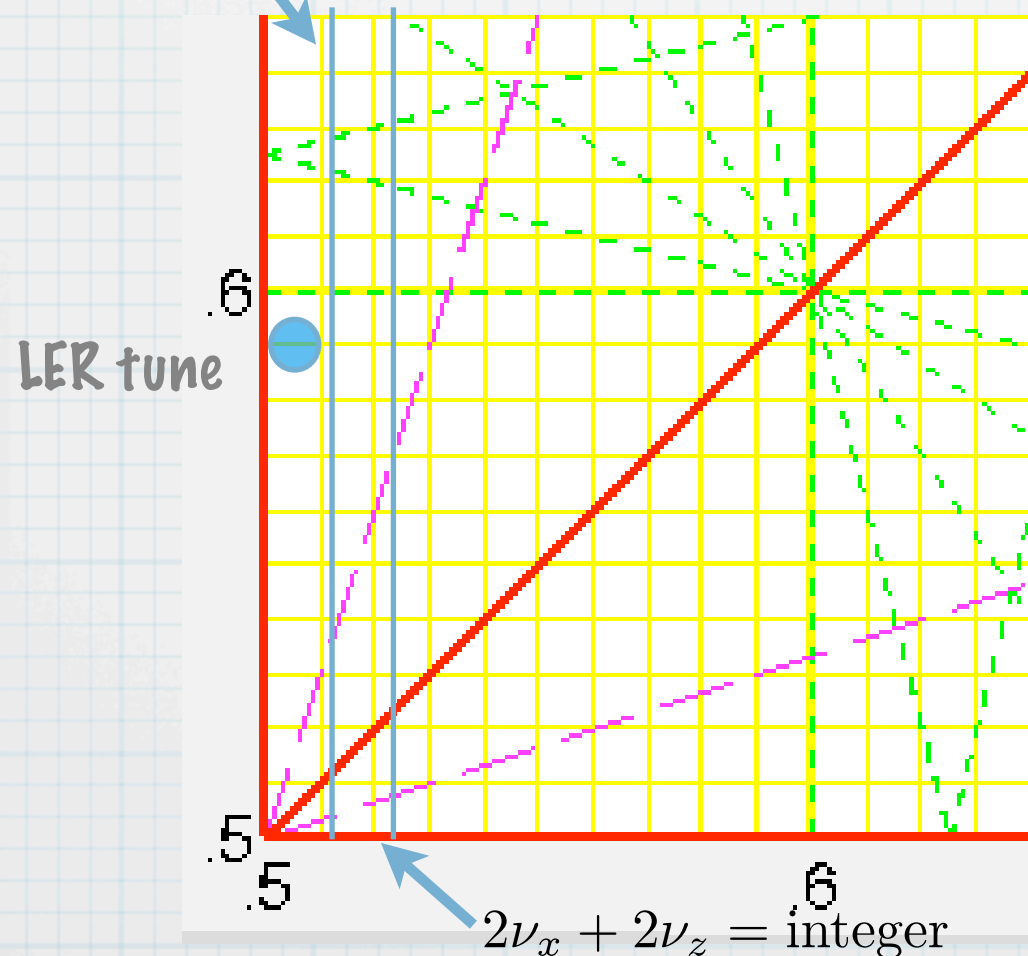
# Synchrotron-betatron resonance

LER Tune vs. Horizontal Beam Size May17, 23, 25

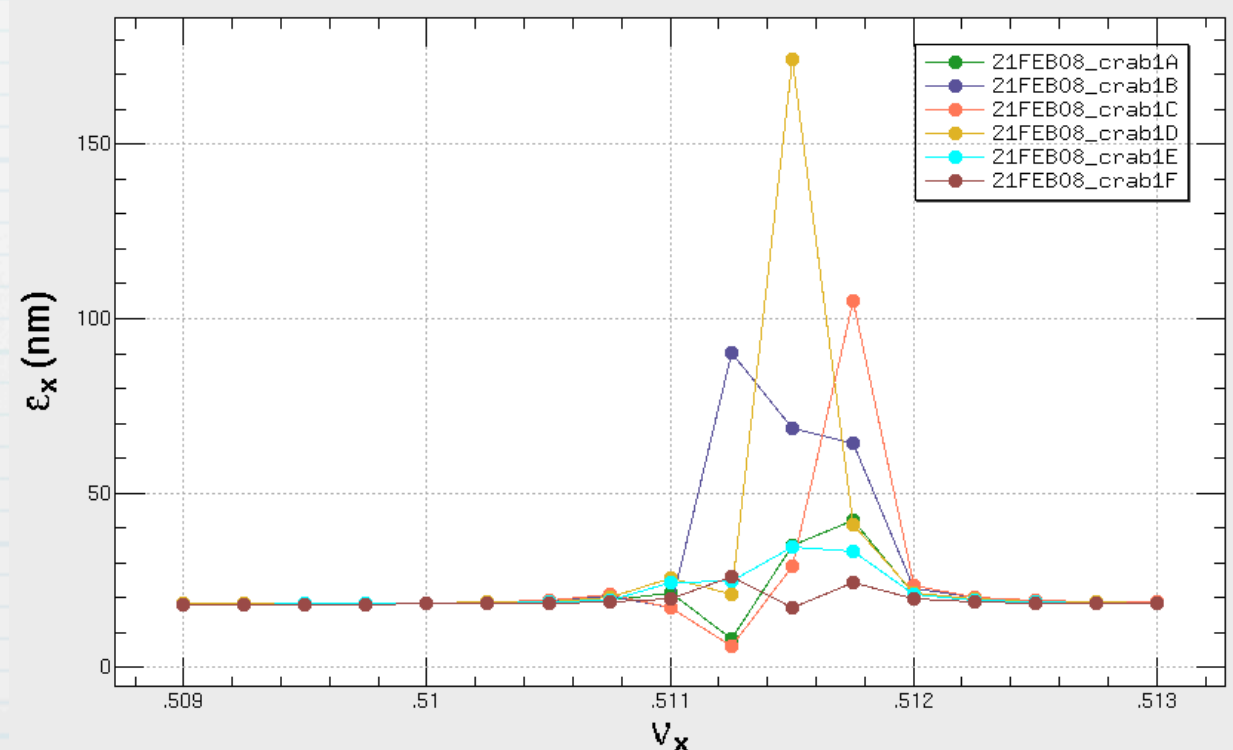


- The horizontal tune is set nearby the half integer resonance and its synchrotron sidebands.
- At the resonance, the single beam beam sizes blowup(left).
- This effect can be calculated by “anomalous emittance” effect.
- The blowup depends on the sextupole setting (below).

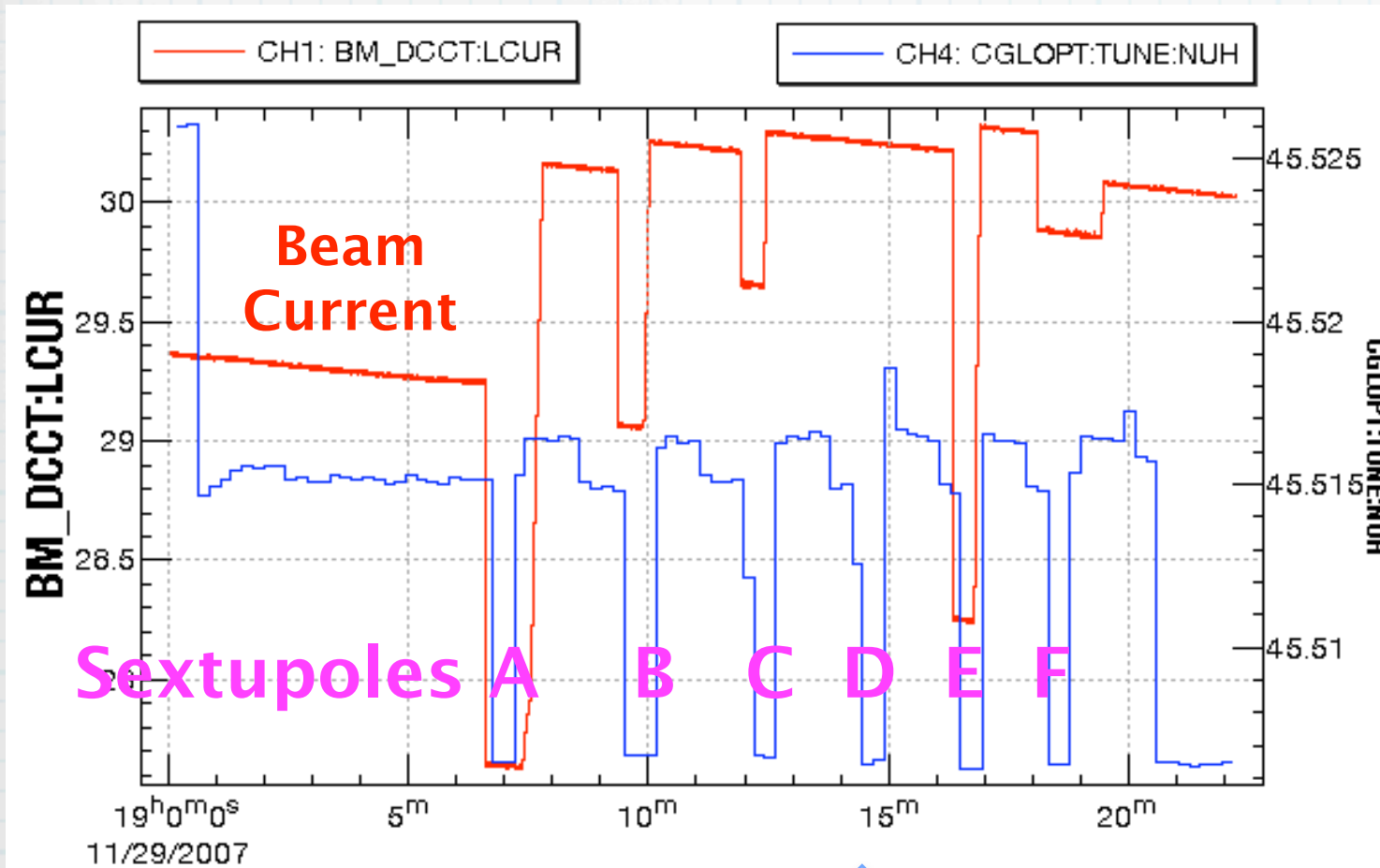
$$2\nu_x + \nu_z = \text{integer}$$



Anomalous Emittance,  $\nu_s = .0230$

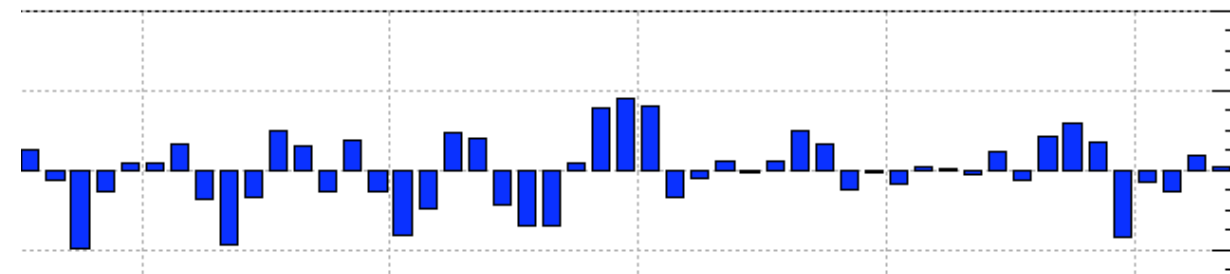


# Finding better sextupole setting: “bungee jump”

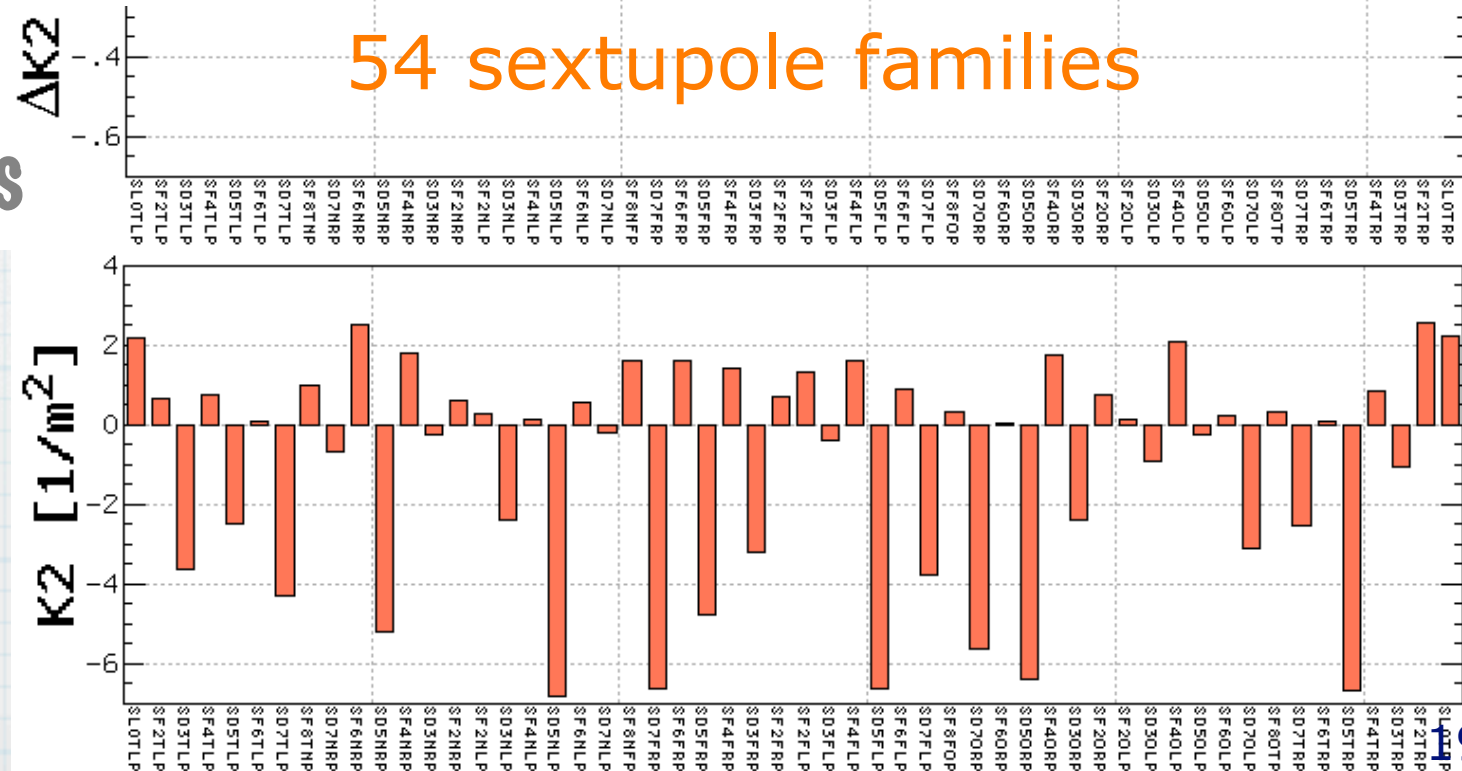


- We tested 5 different sextupole configurations.
- We checked beam loss by changing tune across the resonance.

Difference between “A” and “D”



54 sextupole families



No beam loss with “D” sexts

Jumped from  $\nu_x=0.516$  to 0.506.  
 $\nu_x=.512$  is the resonance  
 $2\nu_x+\nu_z=\text{integer}$



# Three factors to determine the luminosity:

Stored current:

1.7 / 1.4 A (e<sup>+</sup> / e<sup>-</sup> KEKB)

→ 9.4 / 4.1 A (SuperKEKB)

Beam-beam parameter:

0.059 (KEKB)

→ >0.24 (SuperKEKB)

Lorentz factor

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

Classical electron radius

Beam size ratio

Geometrical repipeion factors due to crossing angle and hour-glass effect

Luminosity:

$0.17 \times 10^{35} \text{ cm}^{-2} \text{ s}^{-1}$  (KEKB)

$8 \times 10^{35} \text{ cm}^{-2} \text{ s}^{-1}$  (SuperKEKB)

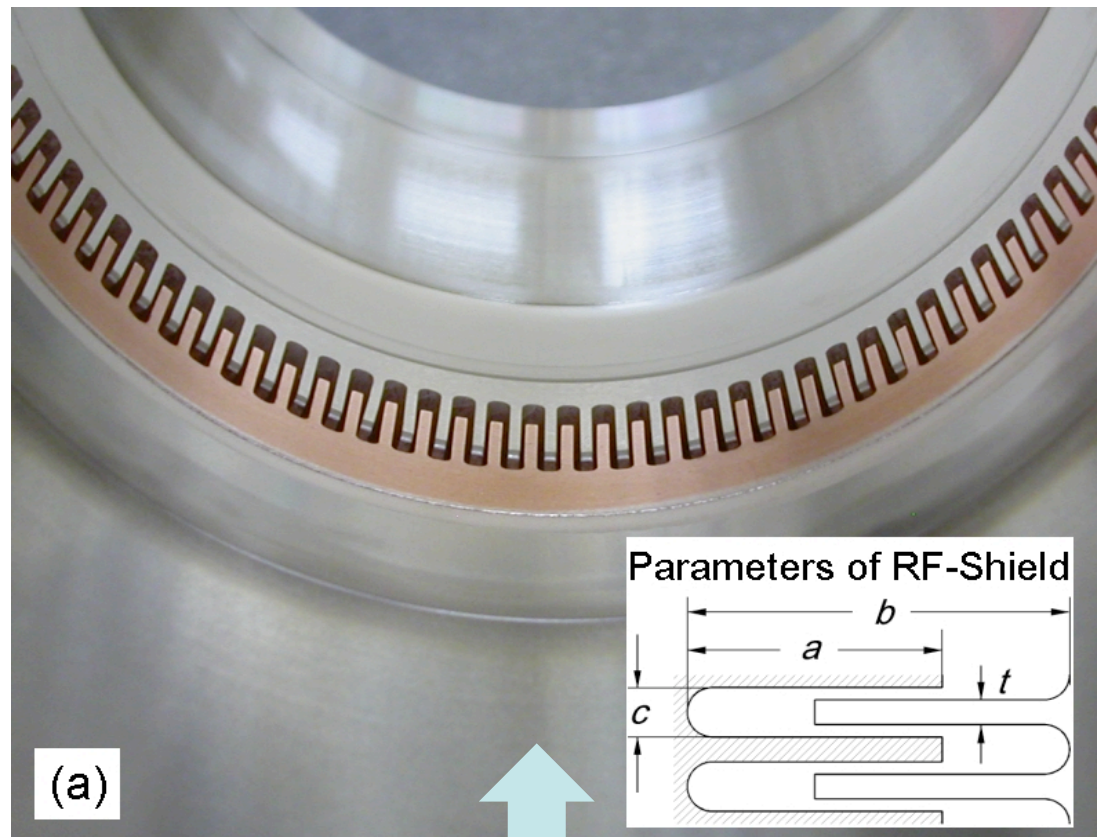
Vertical  $\beta$  at the IP:

6.5 / 5.9 mm (KEKB)

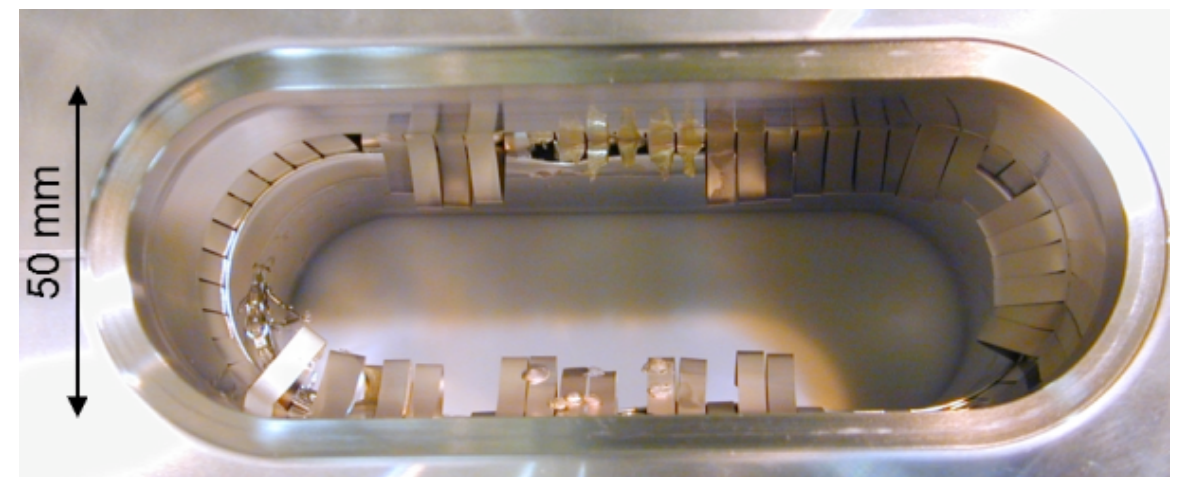
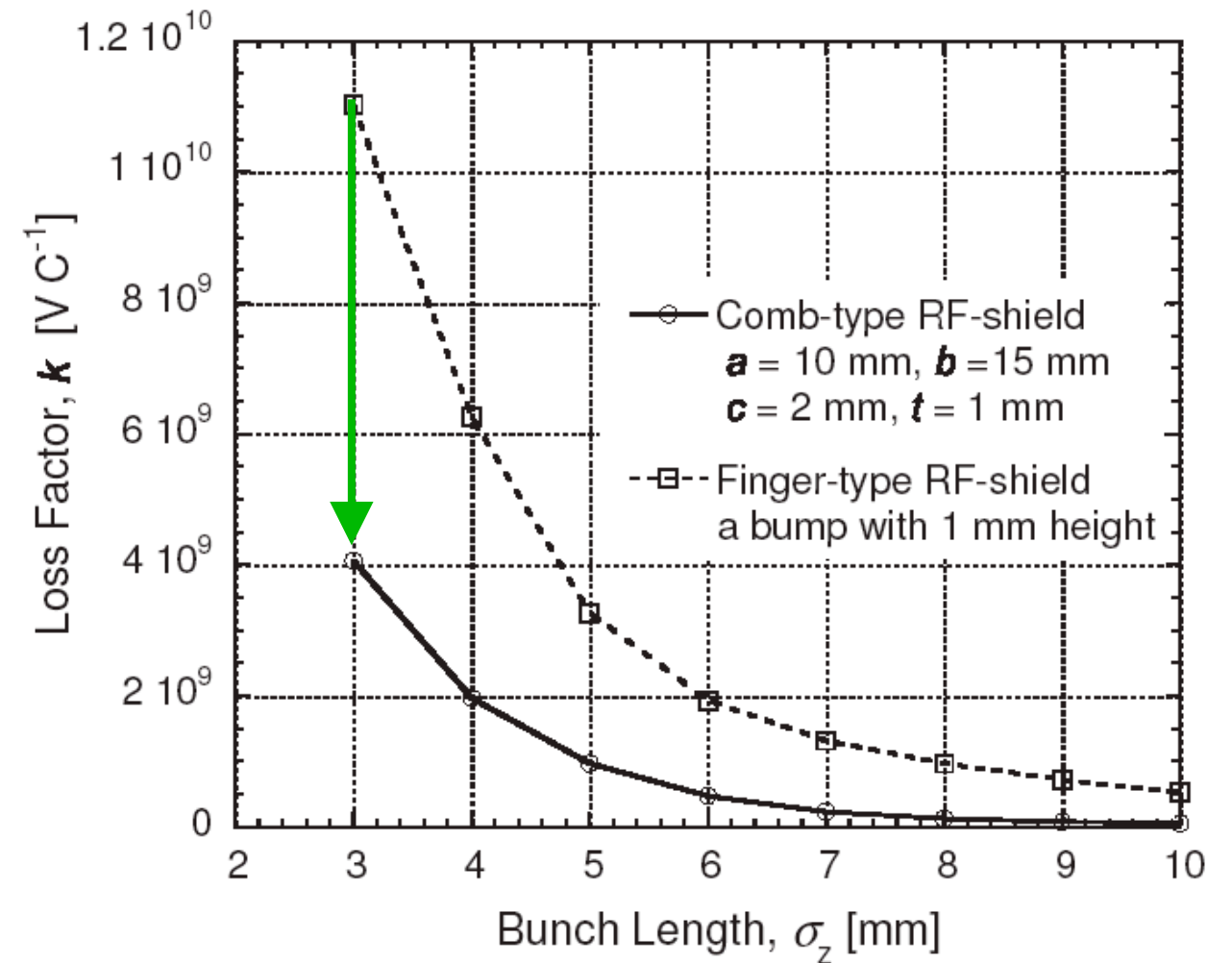
→ 3.0 / 3.0 mm (SuperKEKB)

# Vacuum components:

## Bellows chamber with comb type RF-shield



- High thermal strength
- Low impedance
- No sliding contact on the surface facing the beam



Comb-type bellows were installed in the LER (2004).

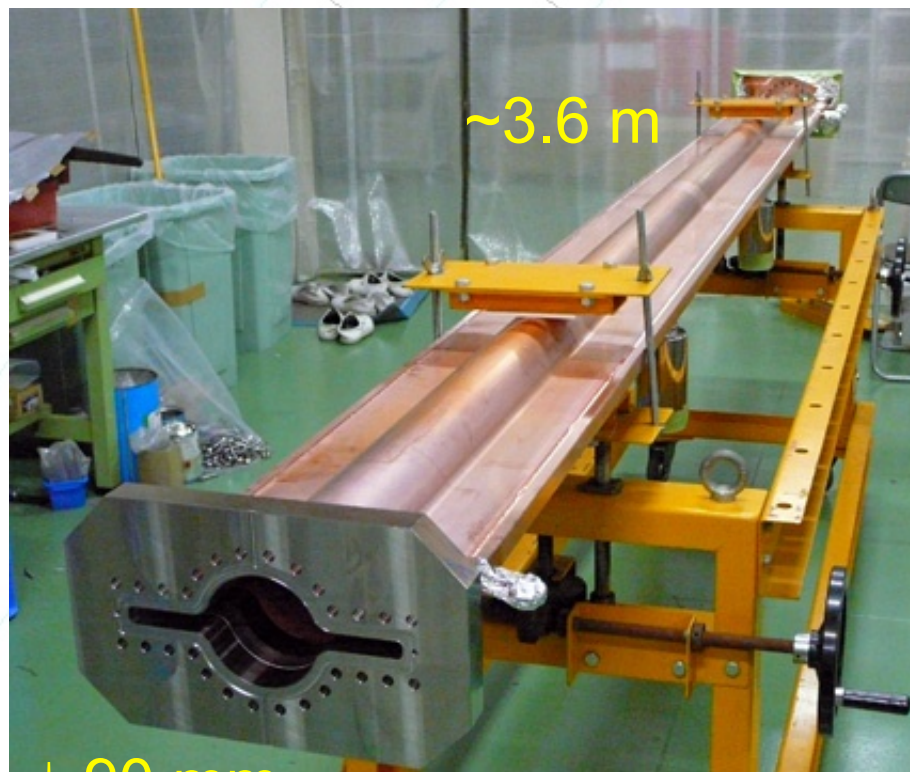


# Beam pipe with antechamber Manufacturing

- Cold drawn copper pipe, and welded by EB.
- MO-type flange (stain-less steel).
- BPM electrode was connected by ICF flange.
- No mapping before installation;  
Gain mapping will be done by BBA

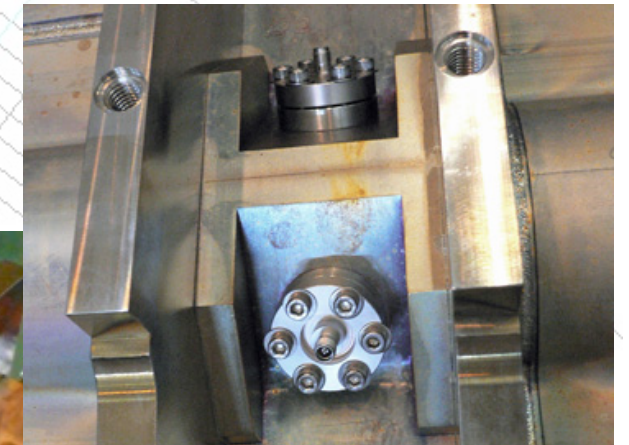
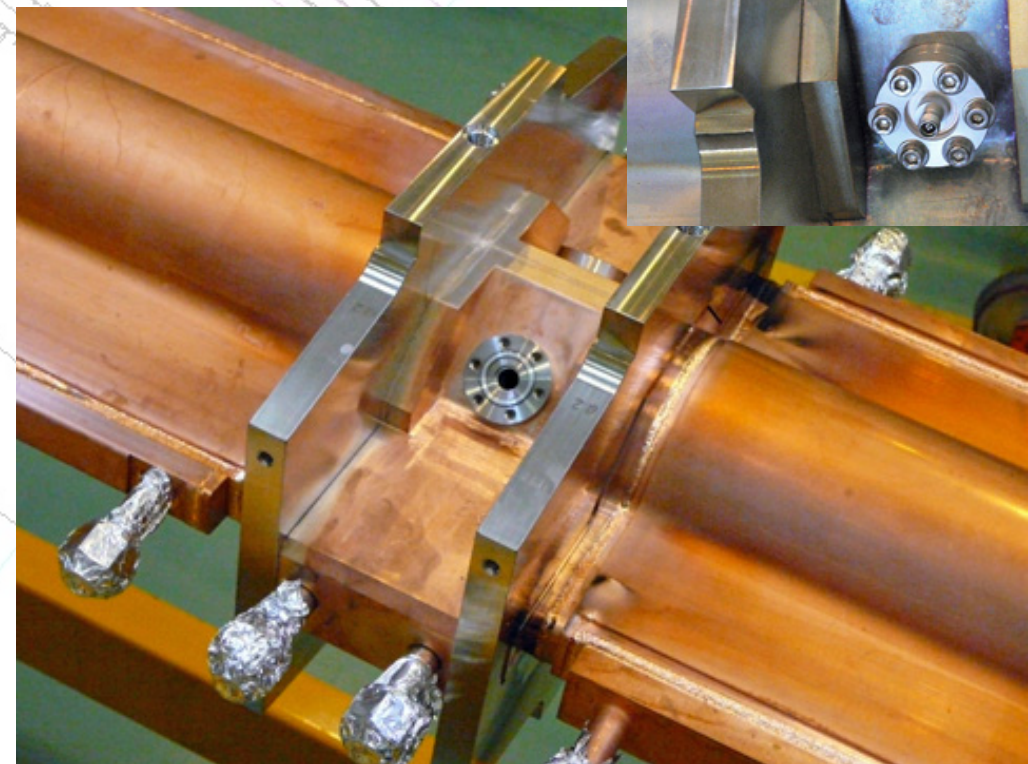
BPM

Straight pipe



$\phi$  90 mm

Q-pipe



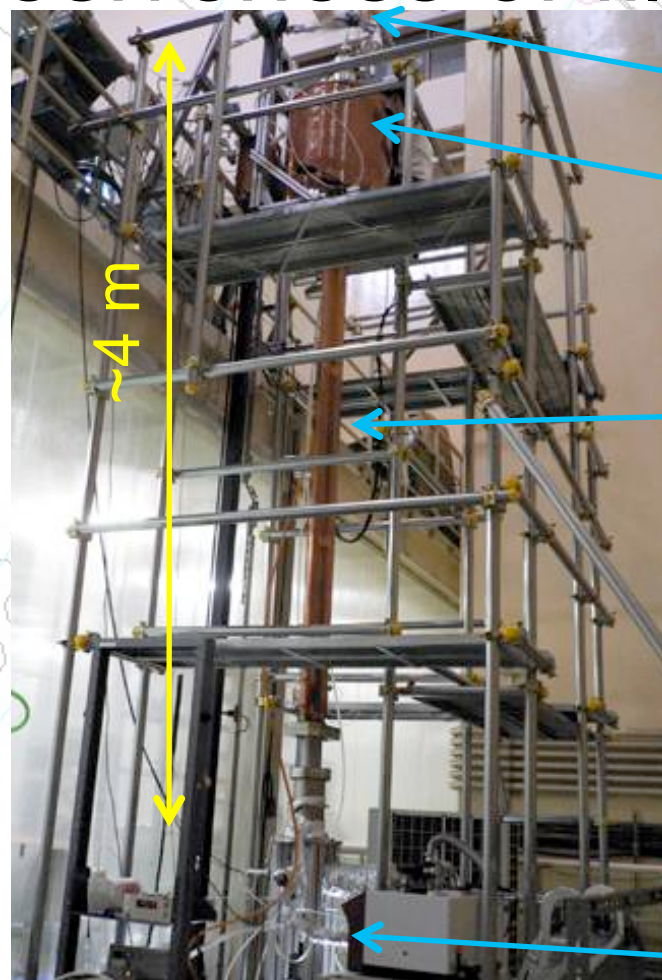
Y. Suetsugu



# Beam pipe with antechamber

## TiN coating

- TiN was coated in KEK (K. Shibata et al.)
- Coating system available for  $\sim 4$  m pipe was set up.
- Thickness is  $\sim 200$  nm, which is determined from adhesiveness of film and  $\delta_{\max}$  ( $\sim 0.84$ ).

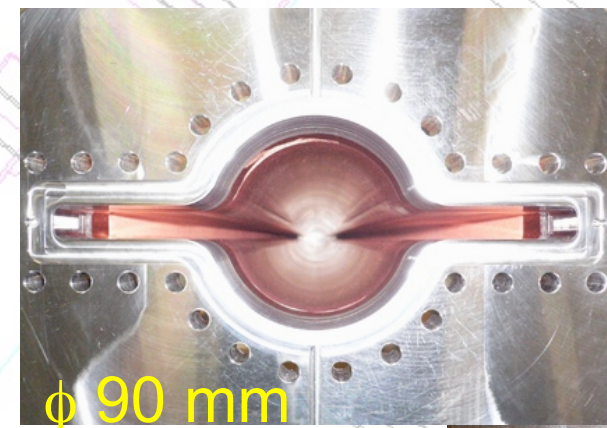


Gas inlet

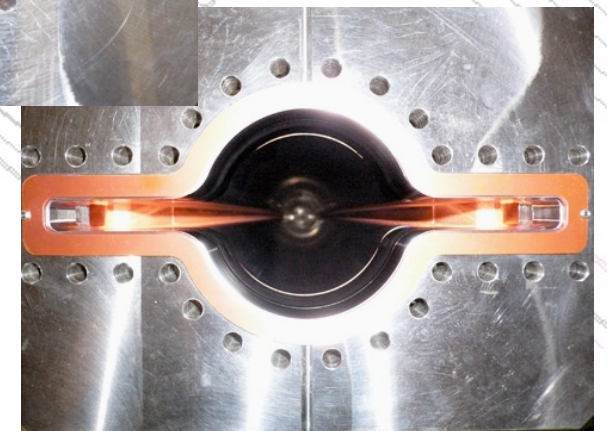
Solenoid

Pipe

Pumping system



Coated at only beam channel part



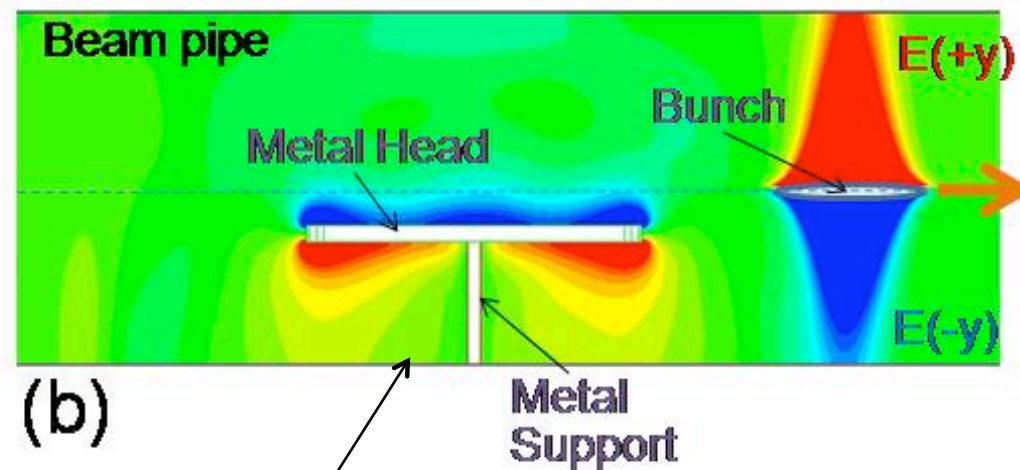
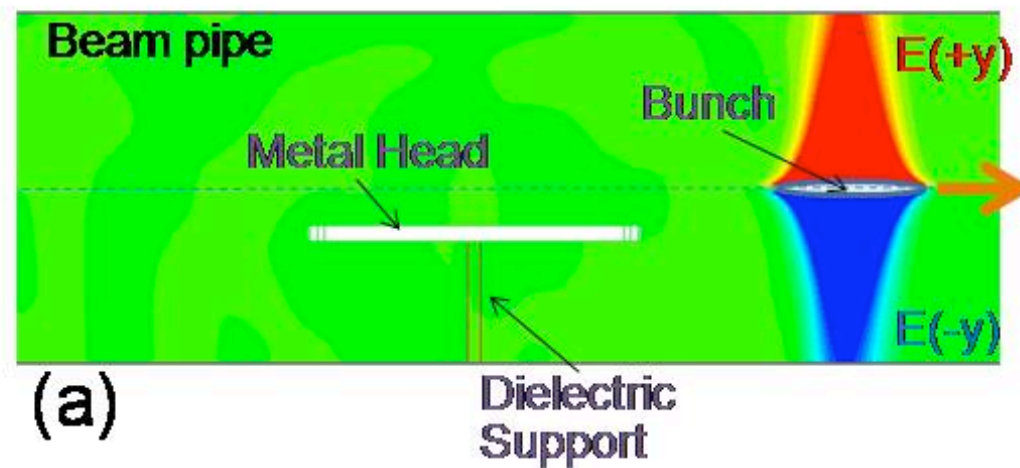
Y. Suetsugu



# Movable Mask Ver.6

## Concept

- Proposal : Metal head supported by dielectric material



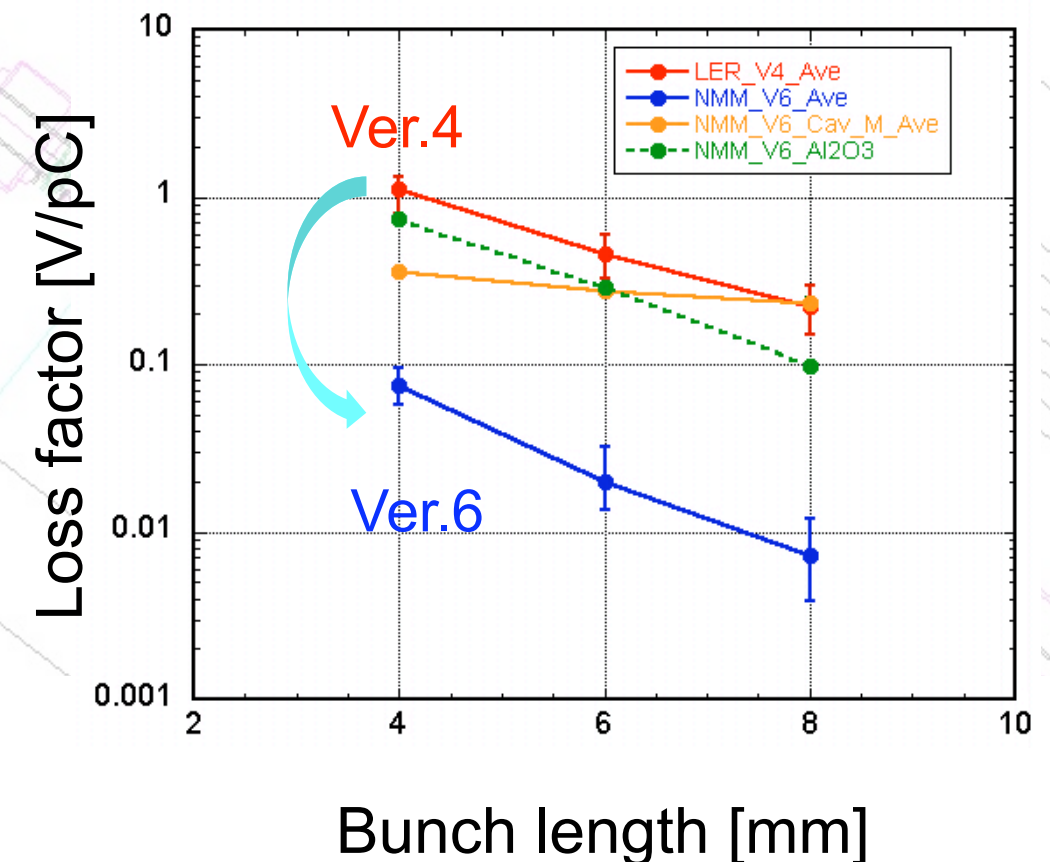
Trapped mode

- Little interference with beam



Small

Loss factor

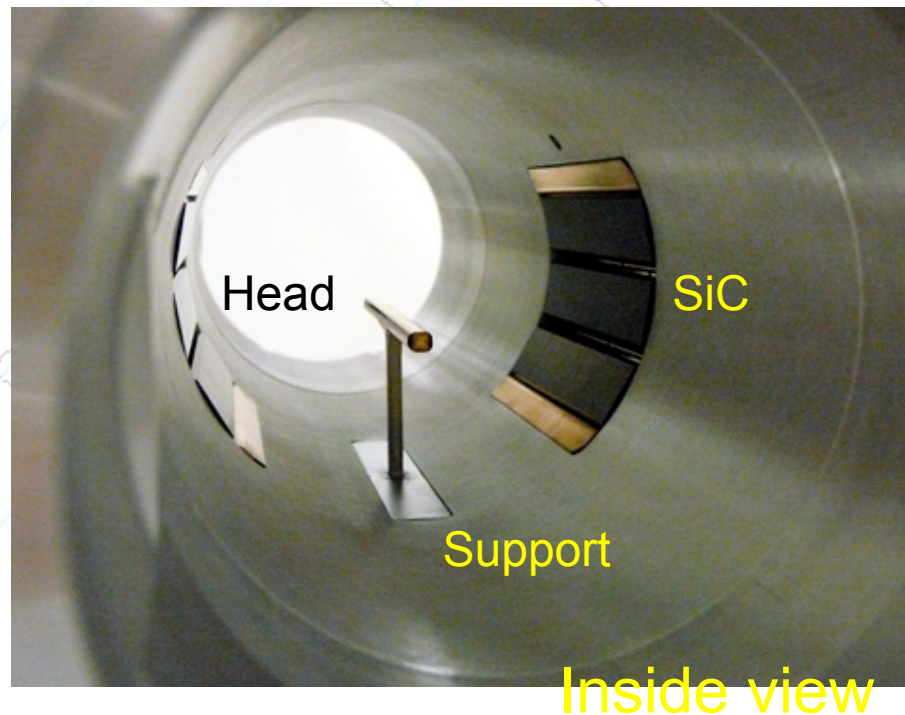


# Movable Mask Ver.6

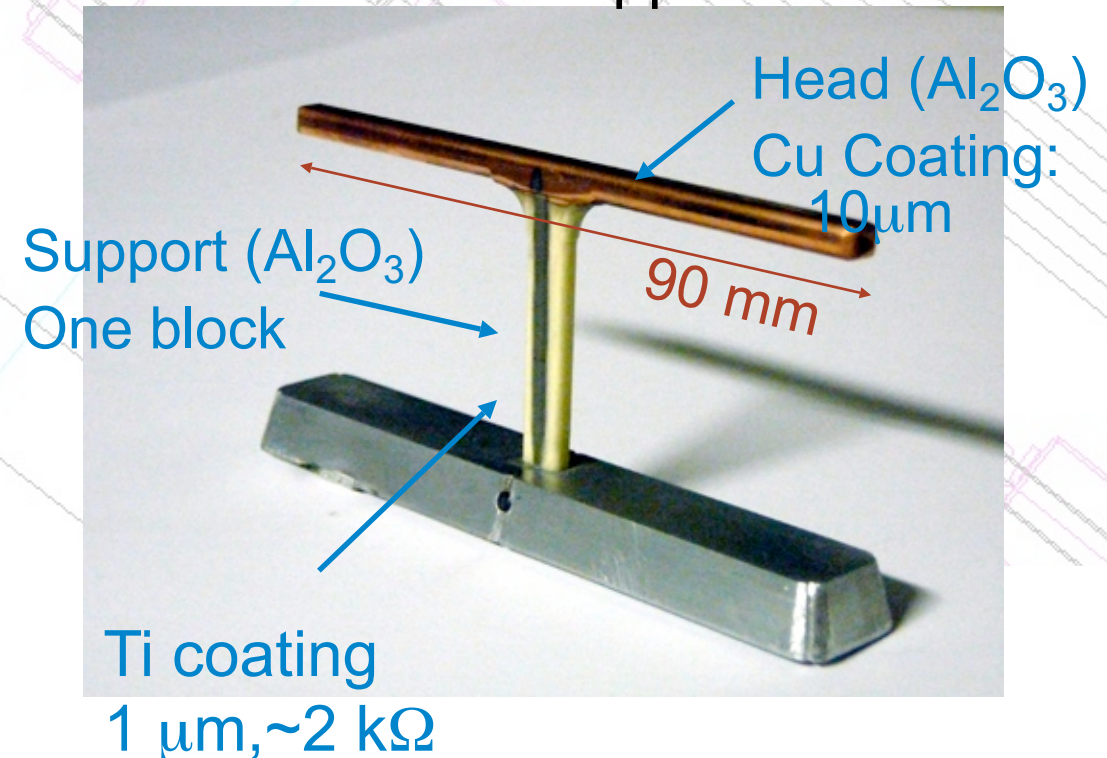
## The first test model (Ver. 6.0)

- In 2006, Ver.6.0 was manufactured.
- Head:  $\text{Al}_2\text{O}_3$  Coated with copper
- Support:  $\text{Al}_2\text{O}_3$  (Ti coating at one side)
  - Head and support was shaped as a unit.
- HOM absorber: SiC (Inside of chamber)
- Installed into LER for proof of concept.

Inside view of mask chamber



Mask head and support of Ver.6.0



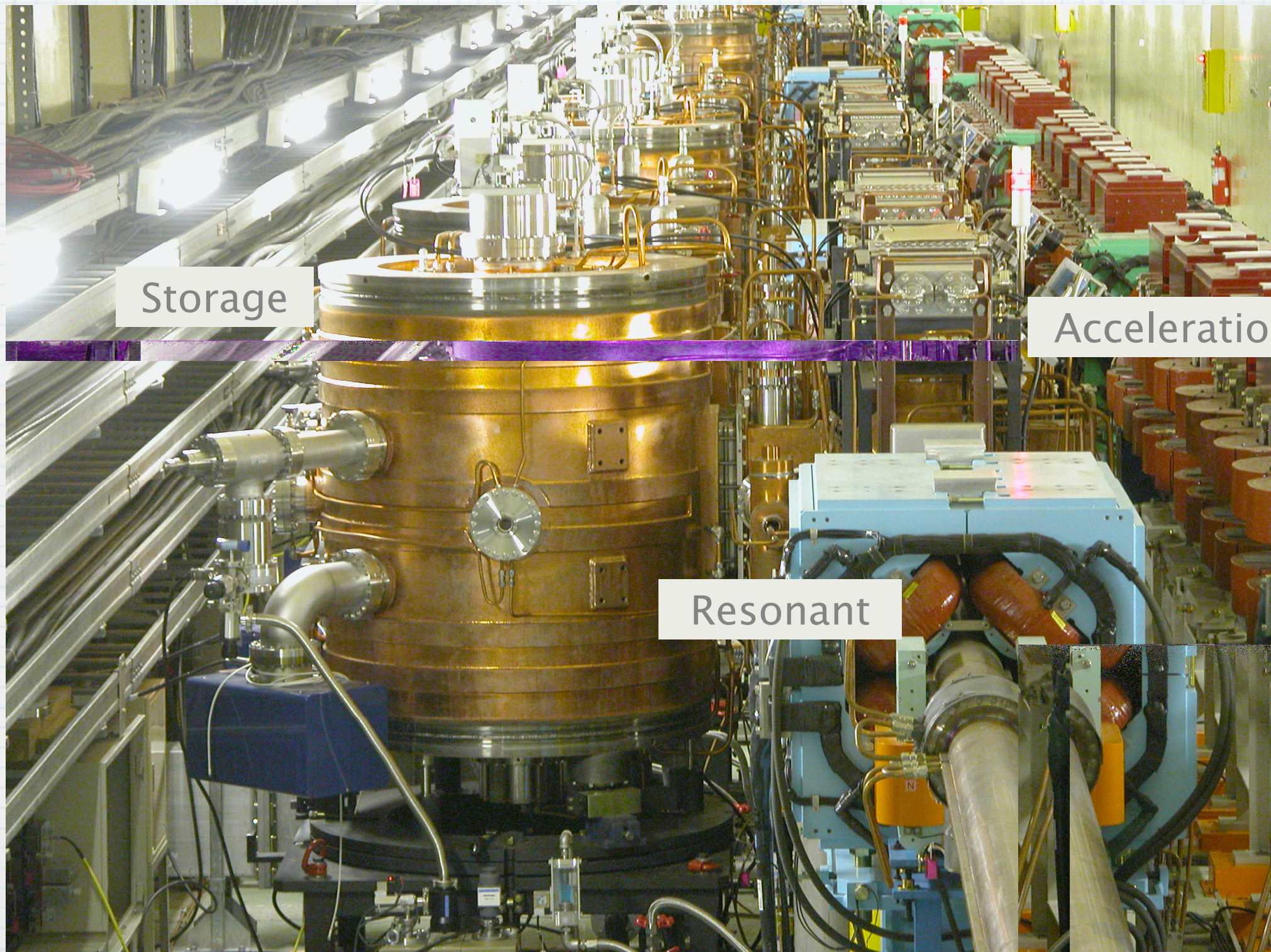


# The ARES Cavity

Accelerator Resonantly-coupled Energy Storage

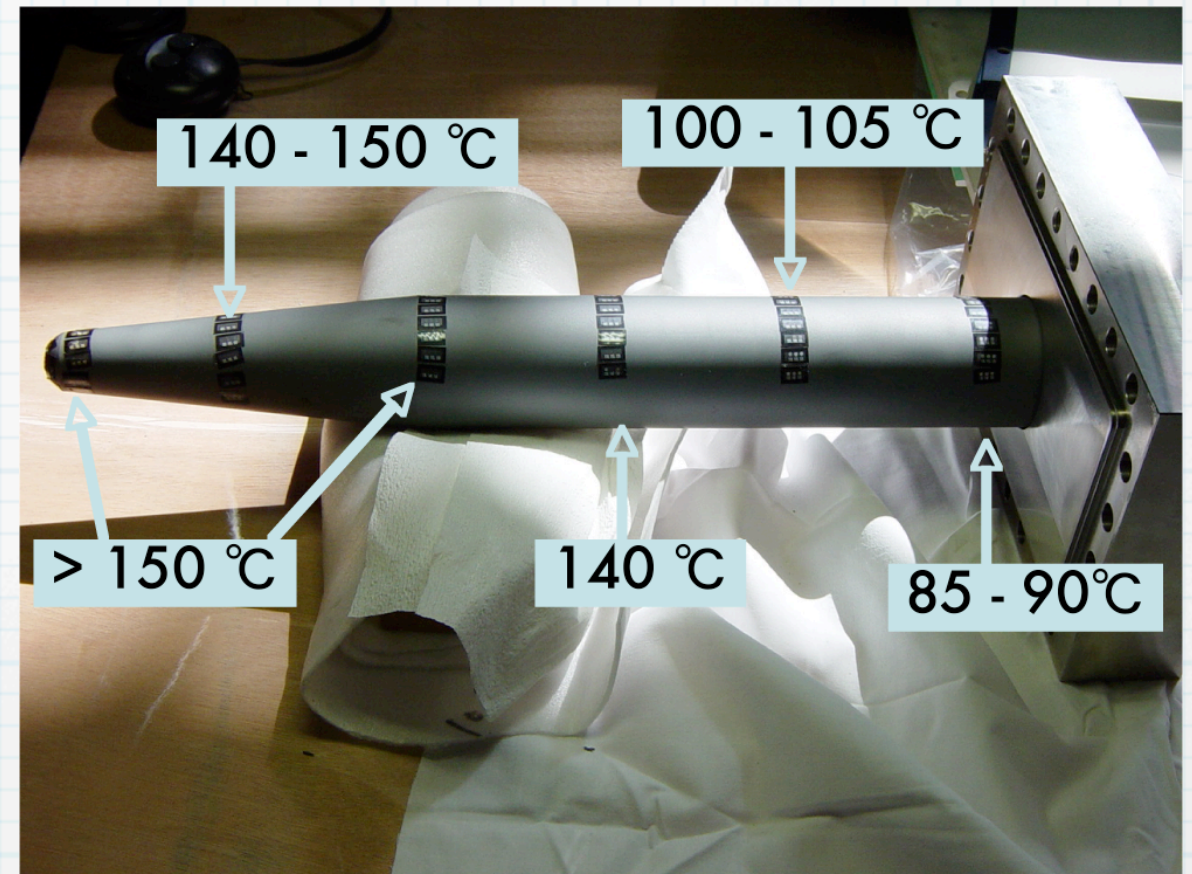
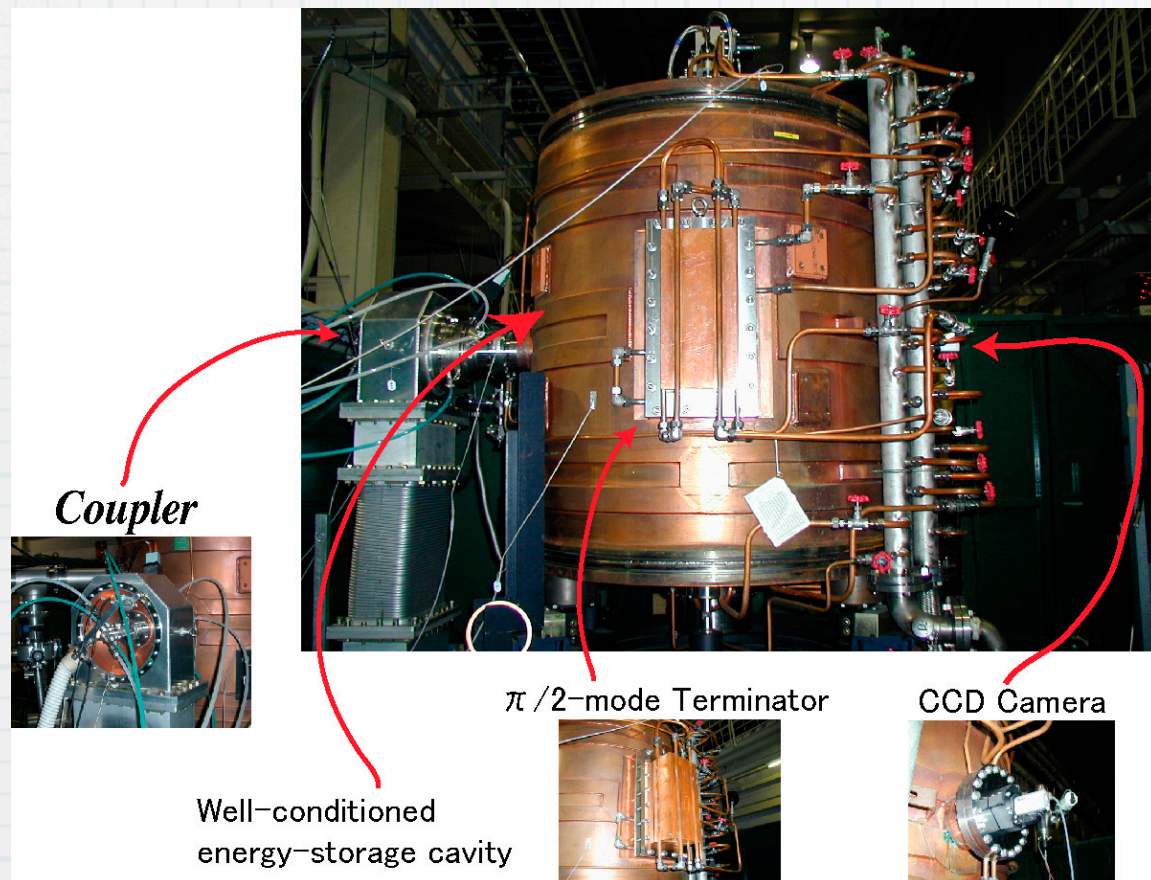
T. Kageyama, et al

- \* Passive stabilization with huge stored energy.
- \* Eliminate unnecessary modes by coupling of 3 cavities.
- \* Higher order mode dampers and absorbers.
- \* No need for longitudinal bunch-by-bunch feedback.
- \* No transverse instability arises from the cavities.





# High power RF R&D



- \* Upgrade of ARES with higher energy storage ratio. (left)
- \* High power rf input couplers.
- \* SiC dummy load with higher power capability (right).

Y. Takeuchi, T. Kageyama, et al

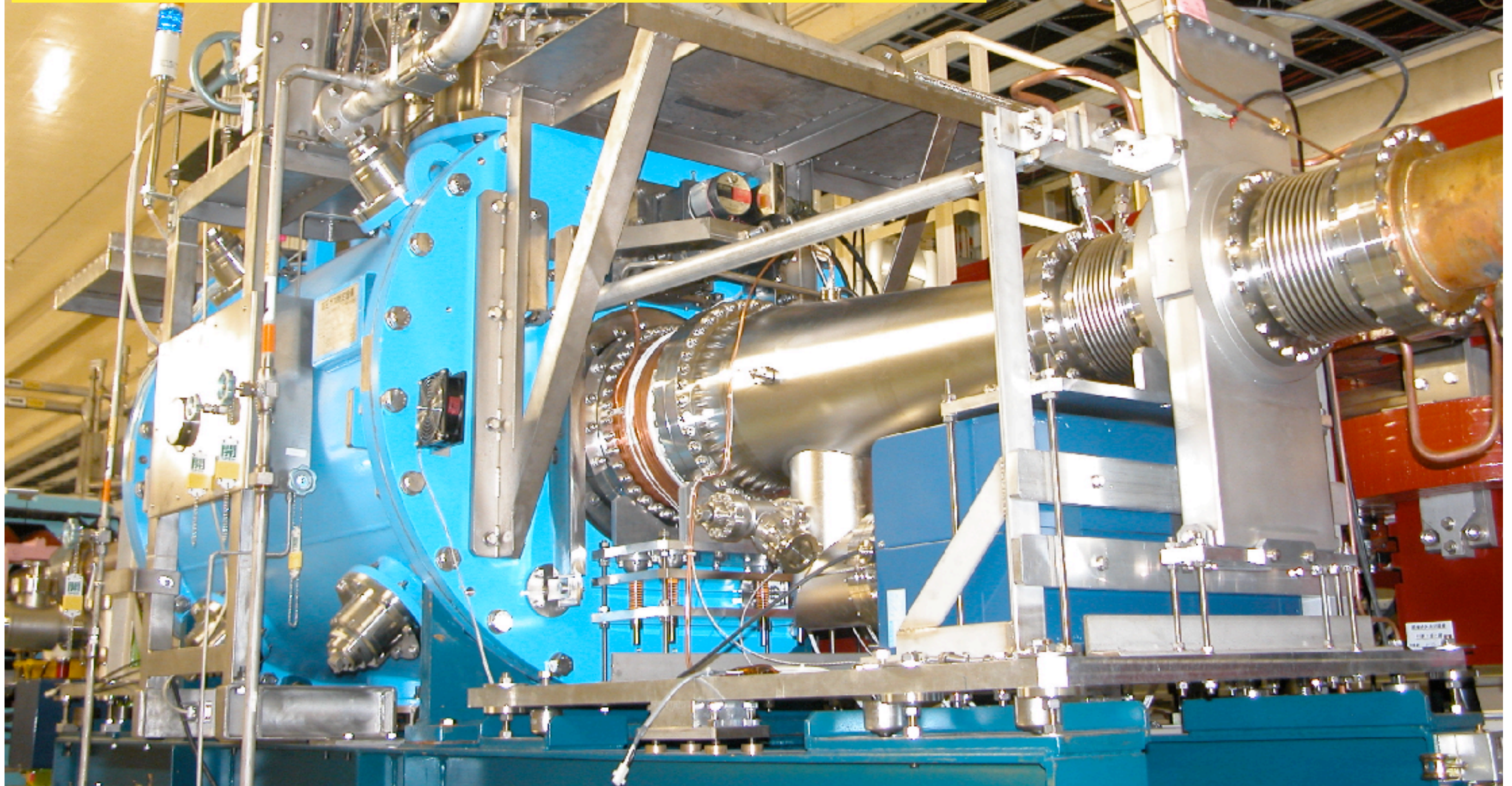


# Superconducting Cavity

SuperKEKB challenges:

The expected power load to the HOM absorber is 50 kW/cavity at 4.1 A, (even) with a larger beam pipe of 220 mm $\phi$ .

HOM damper upgrade may be needed.

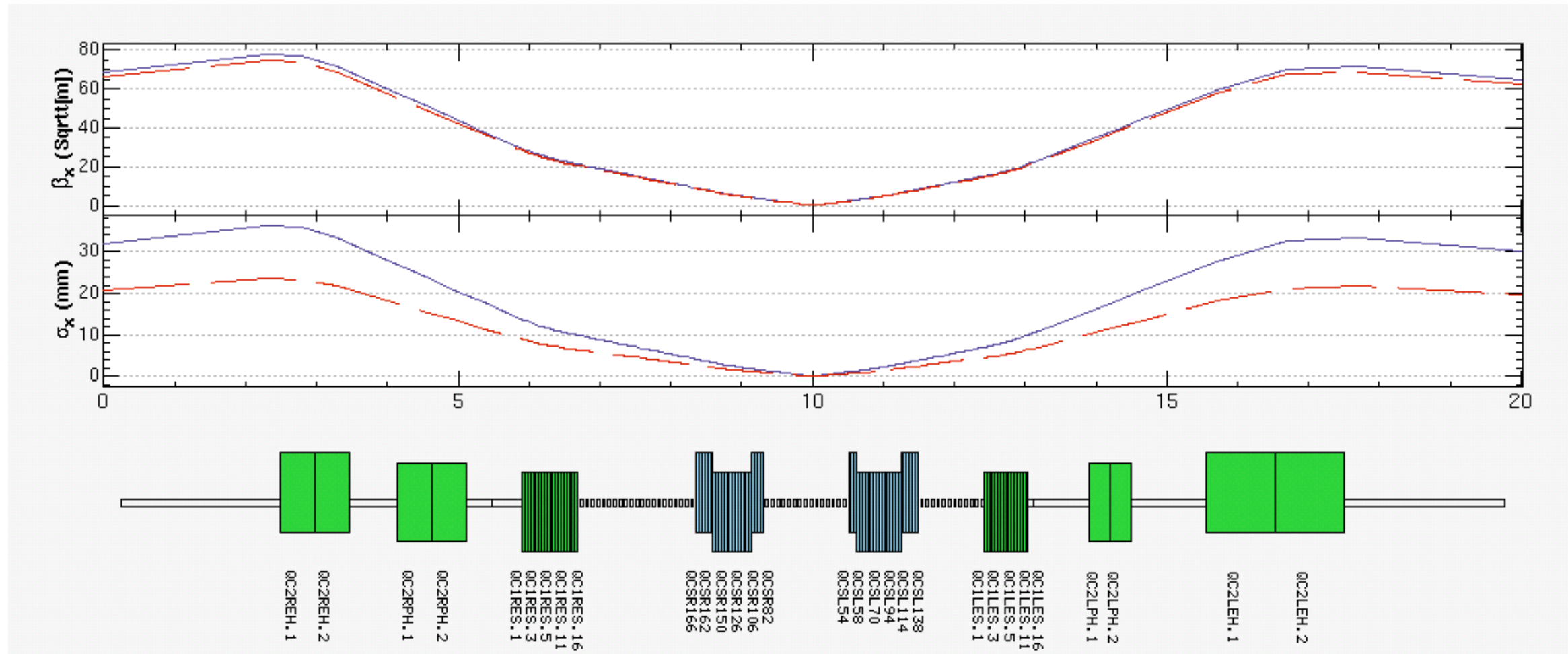




# HER IR

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

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



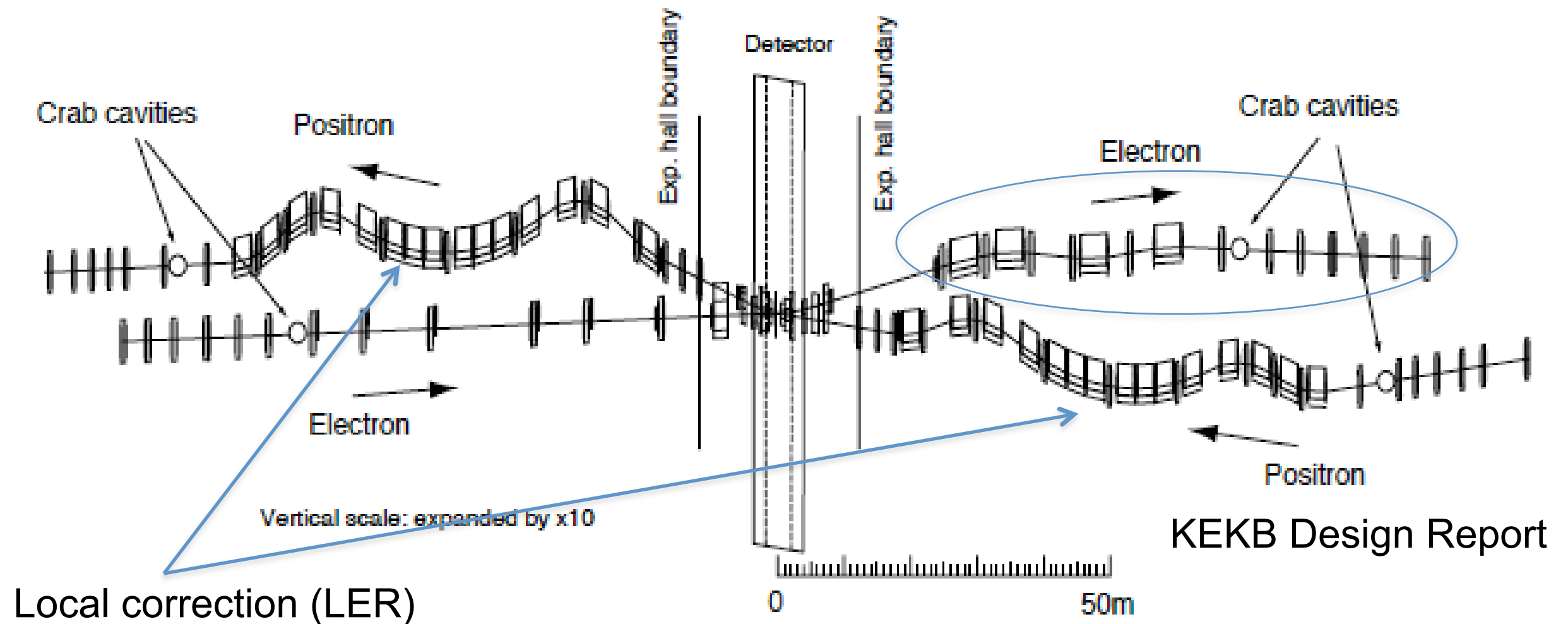
The dynamic beta and dynamic emittance effects enlarge beam sizes at IR magnets drastically.

This physical aperture issue seems serious.

IR design work is still going on to overcome this issue.



# Local chromaticity correction



## Effects of local correction

- widen dynamic aperture
- weaken synchro-betatron resonance

KEKB:

local correction only in LER

KEKB upgrade:

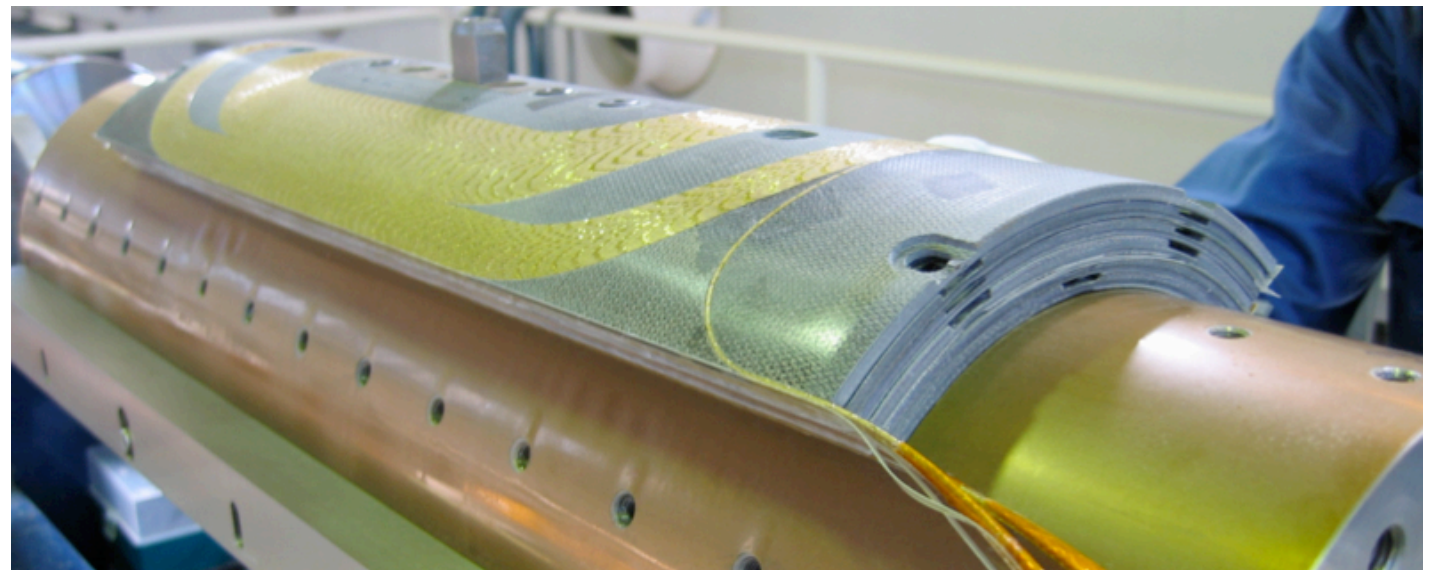
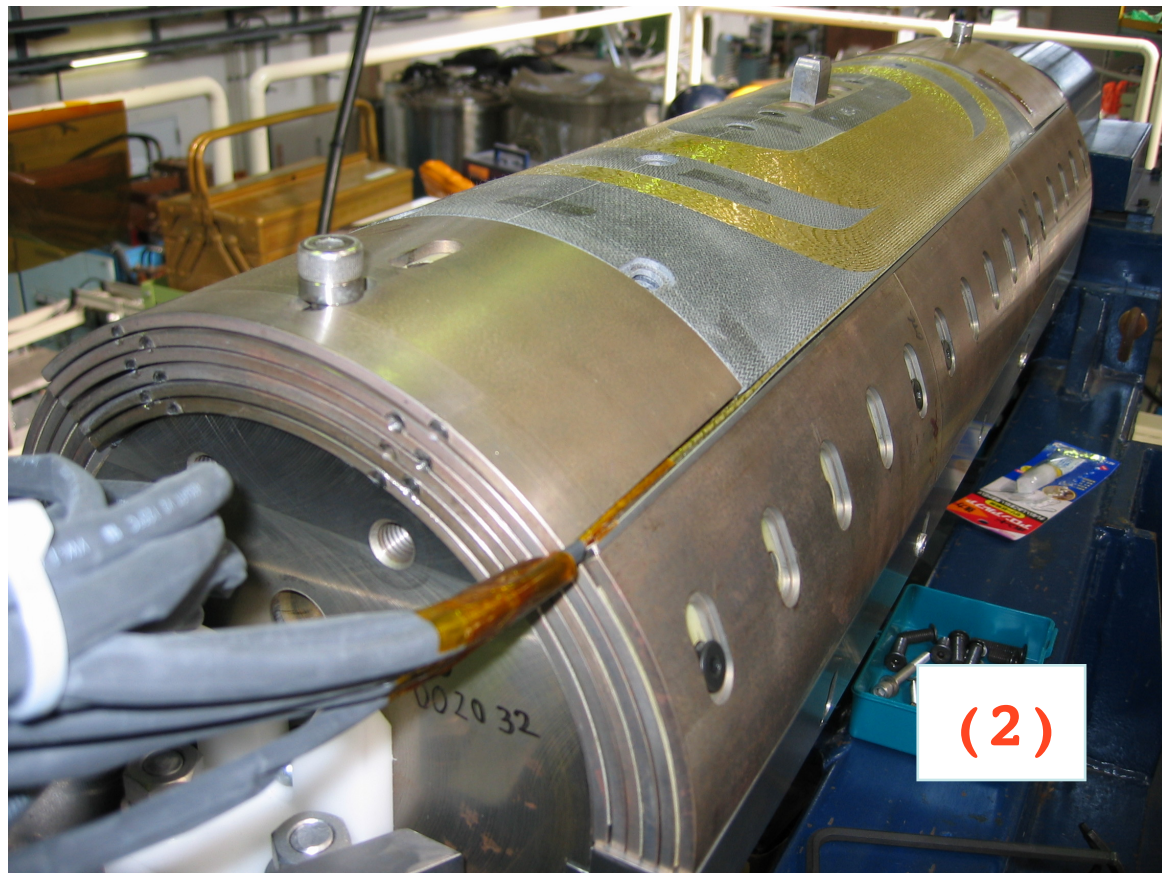
local correction also in downstream  
of HER



# Construction of QCS R&D Magnet

## (2-4) 12 Cured Coils and curing 6 layer coils all at once

N. Ohuchi

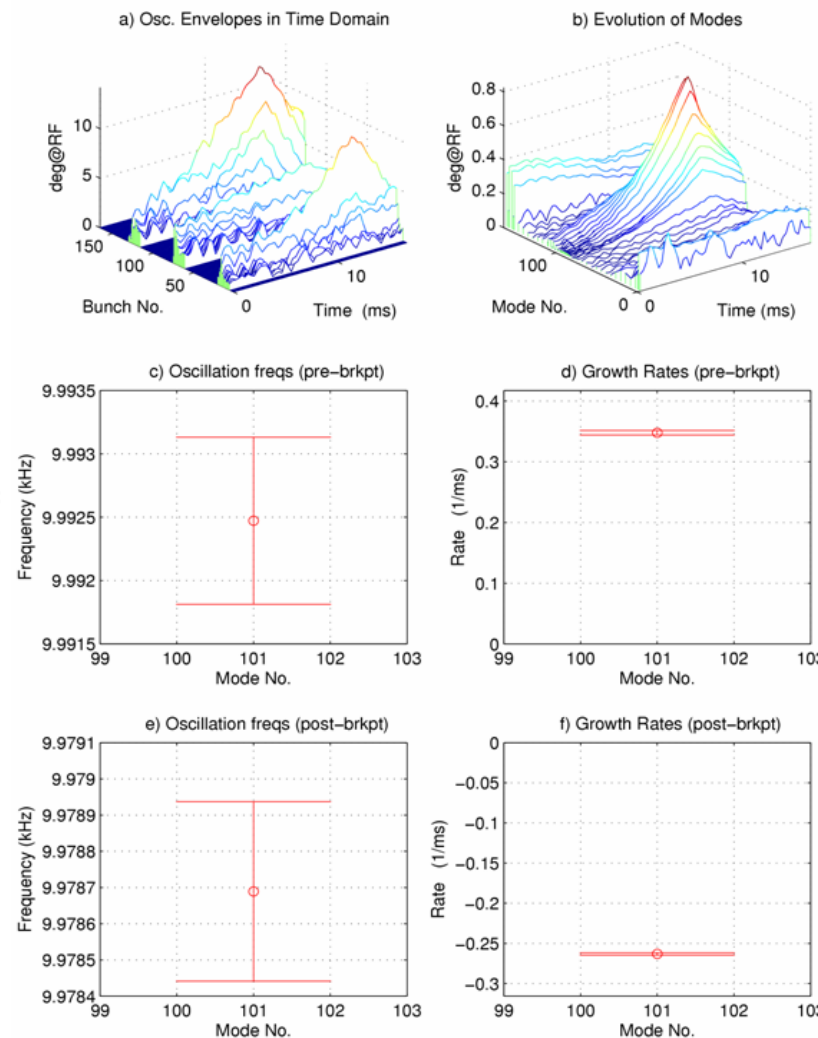
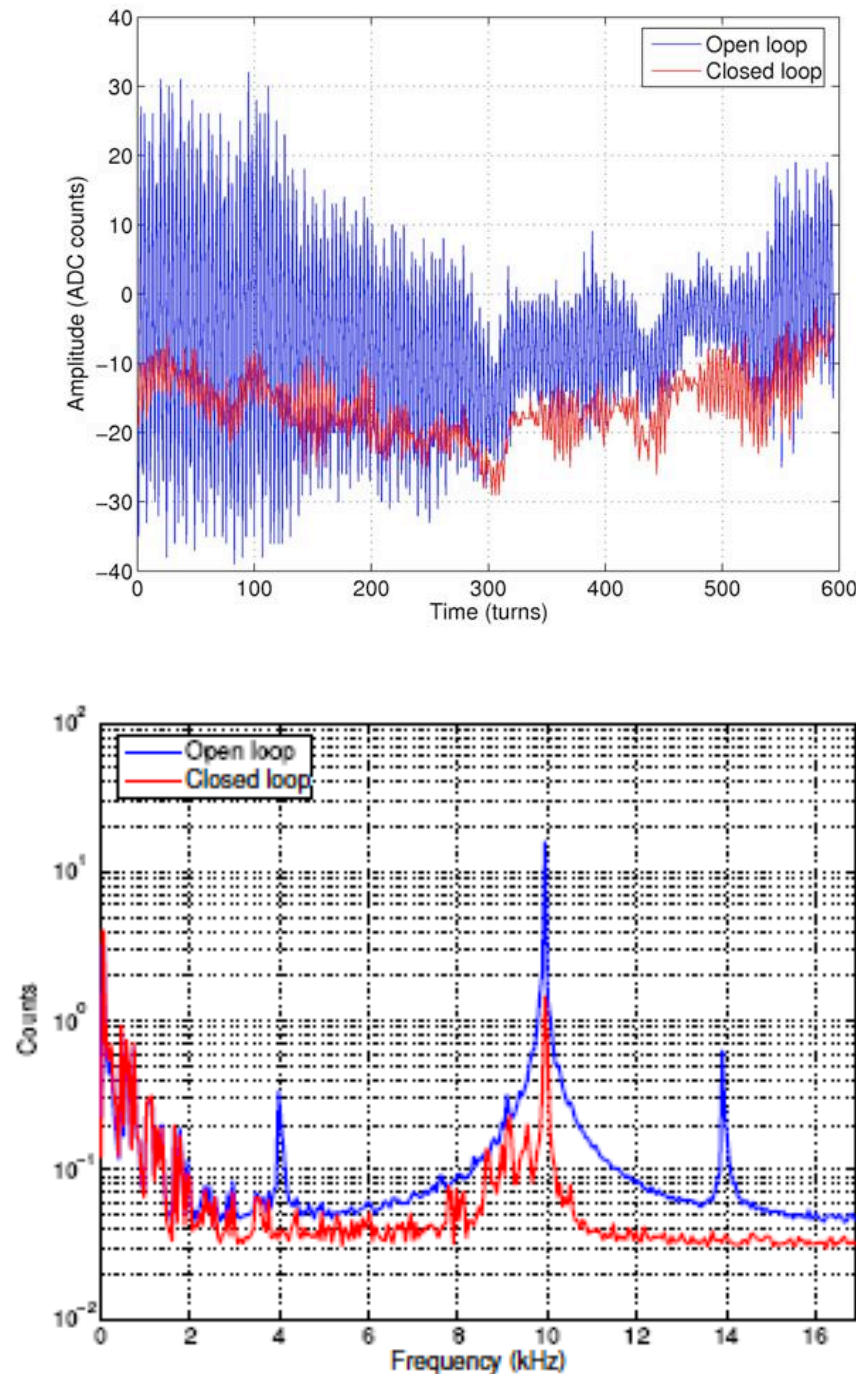


- (1) 12 cured double pan-cake coils.
- (2) Curing process of 6 layer coils. This process is necessary for improving the field quality in the magnet straight section (magnet body).





A prototype of the new bunch-by-bunch feedback system (G-board / Gproto) was tested at KEKB and ATF. The results were quite successful.



ATF DR:nov1505/131237: Io= 28.9984mA, Dsmp= 64, ShifGain= 4, Nbun= 165,  
At Fs: G1= 5.9866, G2= 0, Ph1= -123.9911, Ph2= 0, Brkpt= 420, Calib= 2.2253.

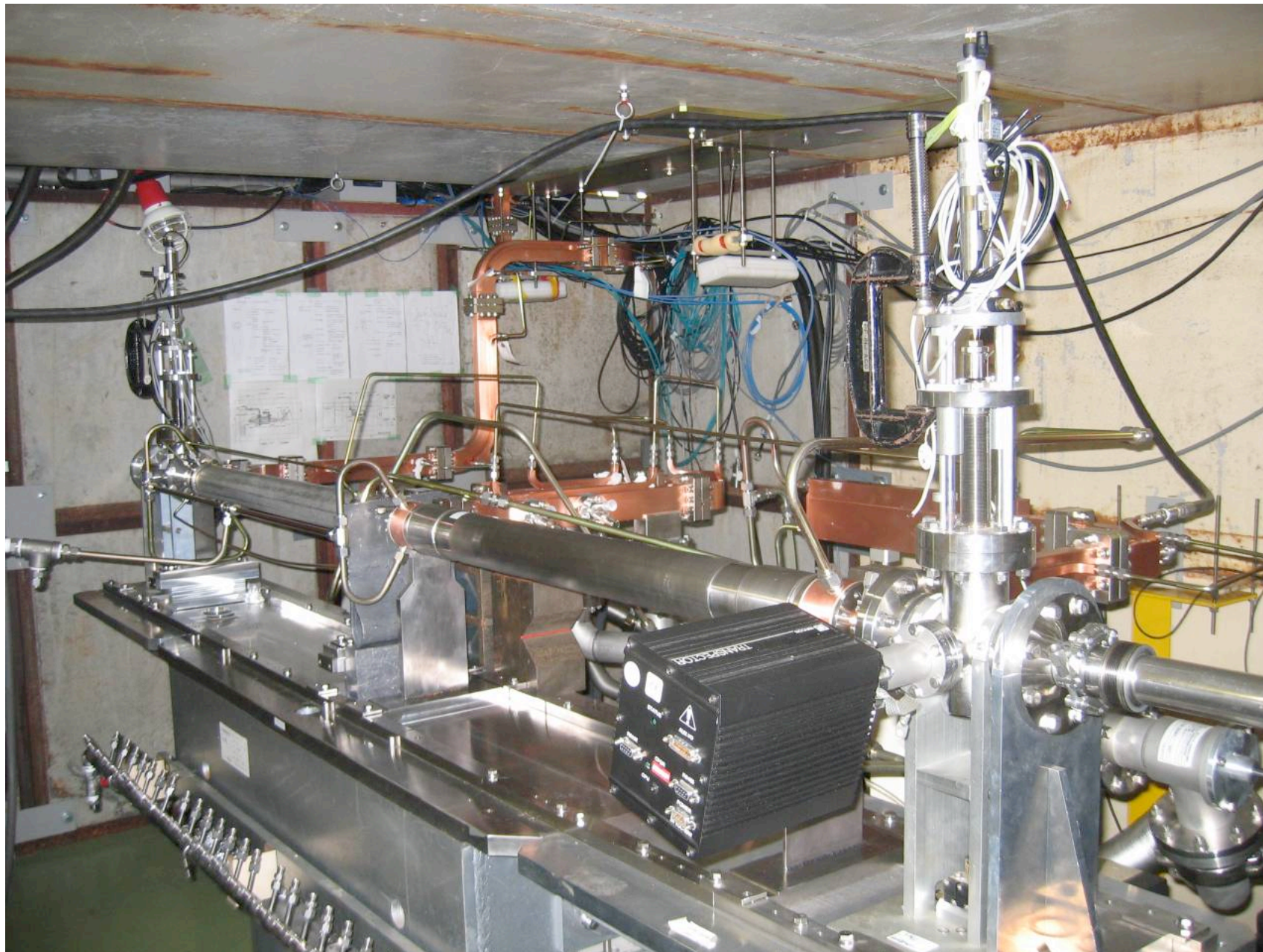
- Even in single-bunch mode, we observed a strong longitudinal instability at the ATF.
- In multi-bunch mode, we observed a strong CBI.
- Successfully damped the longitudinal CBI with the BxB feedback system using Gproto down to 1/10.
- Successfully analyzed strongest coupled-bunch mode. ( $218+n*357$  MHz)
- For practical use, it will be necessary to build and install a good feedback kicker.

M. Tobiyama



- C-band linac: completed a single section in the linac with 4 structures.
- Performance was satisfactory with the beam.

T. Kamitani, et al





# C-Band Klystrons

Prototype C-band structure installed and tested at linac using actual beam (2003). Measured field gradient of 41 MV at 43 MW agrees with expectation.

| Parameters                 | S-band        | C-band         |               | Unit          |
|----------------------------|---------------|----------------|---------------|---------------|
|                            | KEKB          | 1-st prototype | 2m-structure  |               |
| total length               | 2.072         | 1.082          | 2.0           | m             |
| number of regular cells    | 54            | 54             | 108           |               |
| regular cell length (d)    | 35.0          | 17.5           | 17.5          | mm            |
| disk thickness (t)         | 5.0           | 2.5            | 2.5           | mm            |
| disk iris diameter (2a)    | 24.95 - 20.90 | 12.48 - 10.45  | 14.03 - 10.54 | mm            |
| cavity diameter (2b)       | 83.0 - 82.0   | 41.5 - 41.0    | 42.0 - 41.0   | mm            |
| group velocity ( $v_g/c$ ) | 1.4           | 1.9 - 1.0      | 2.8 - 1.0     | %             |
| shunt impedance            | 57            | 75 - 85        | 67 - 85       | M $\Omega$ /m |
| Q factor                   | 13700         | 9690           | 9700          |               |
| RF power in cells          | 30 - 15       | 34 - 15        | 59 - 15       |               |
| Field gradient             | 21            | 41.2 - 39.0    | 42.5 - 38.1   |               |
| Filling time               | 462           | 234            | 376           |               |
| Attenuation constant       | 0.302         | 0.434          | 0.696         |               |

Table 11.3: Accelerating section characteristics

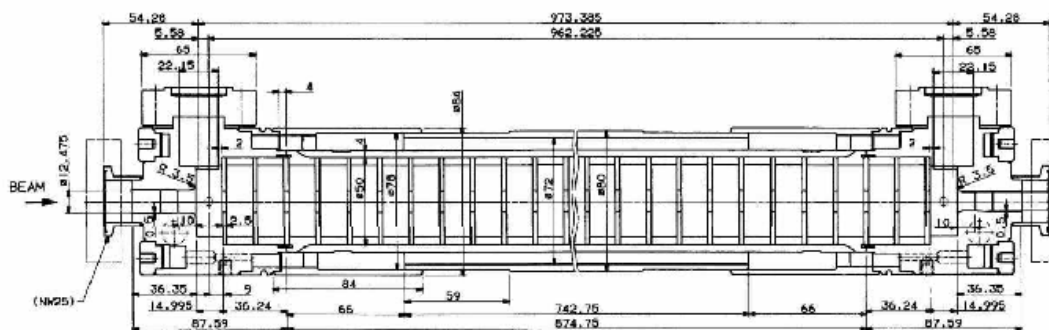
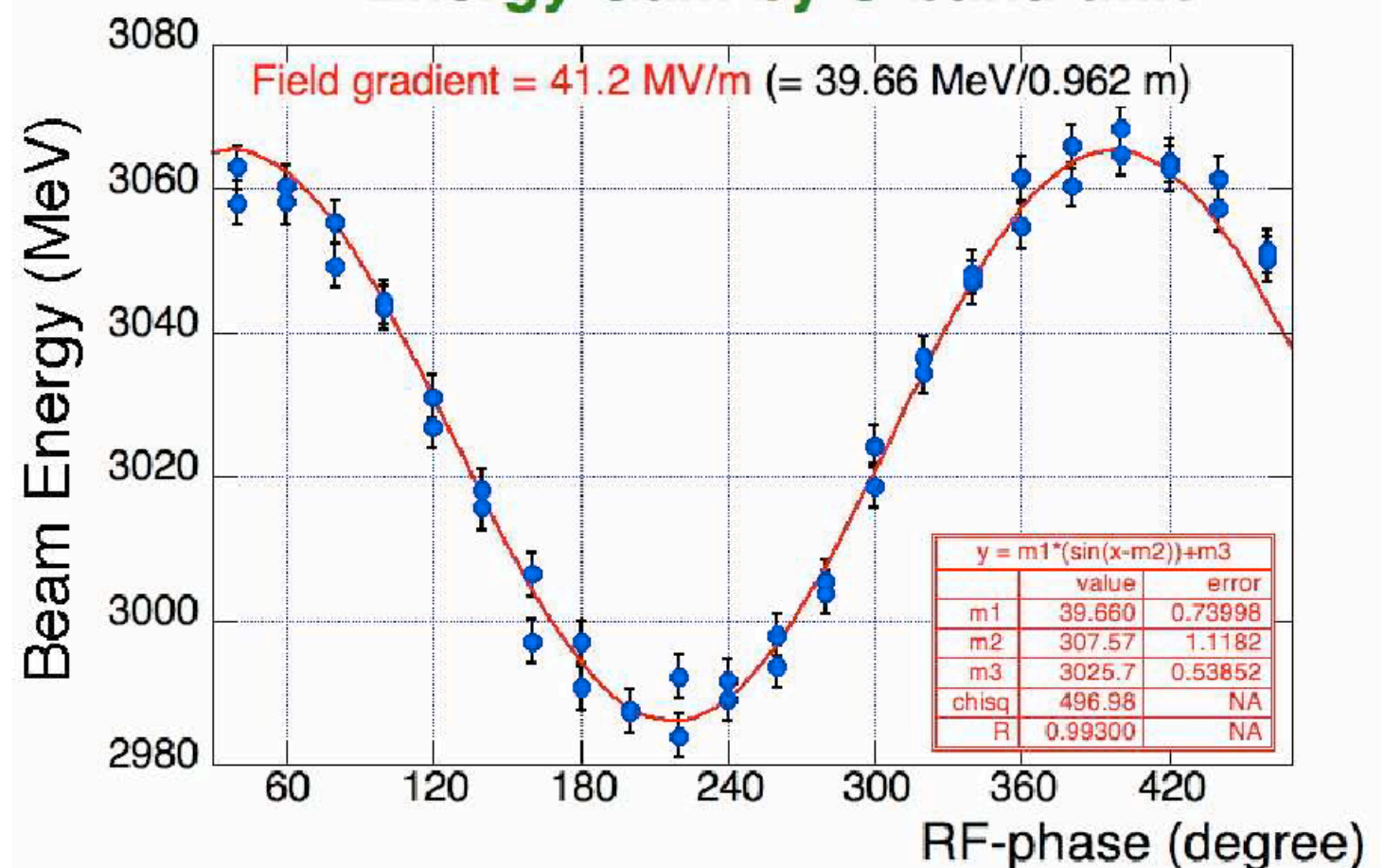


Figure 11.7: C-band 1m-long accelerating section (1st prototype)

## Energy Gain by C-band unit



T. Kamitani, et al

# Damping Ring

- \* Positron emittance needs to be damped, to pass reduced aperture of C-Band section and to meet IR dynamic aperture restrictions.
  - \* Electron DR may be considered later to reduce injection backgrounds in physics detector, but for now only positron DR considered.
- \* Damping ring located downstream of positron target, before C-Band accelerating section.

M. Kikuchi



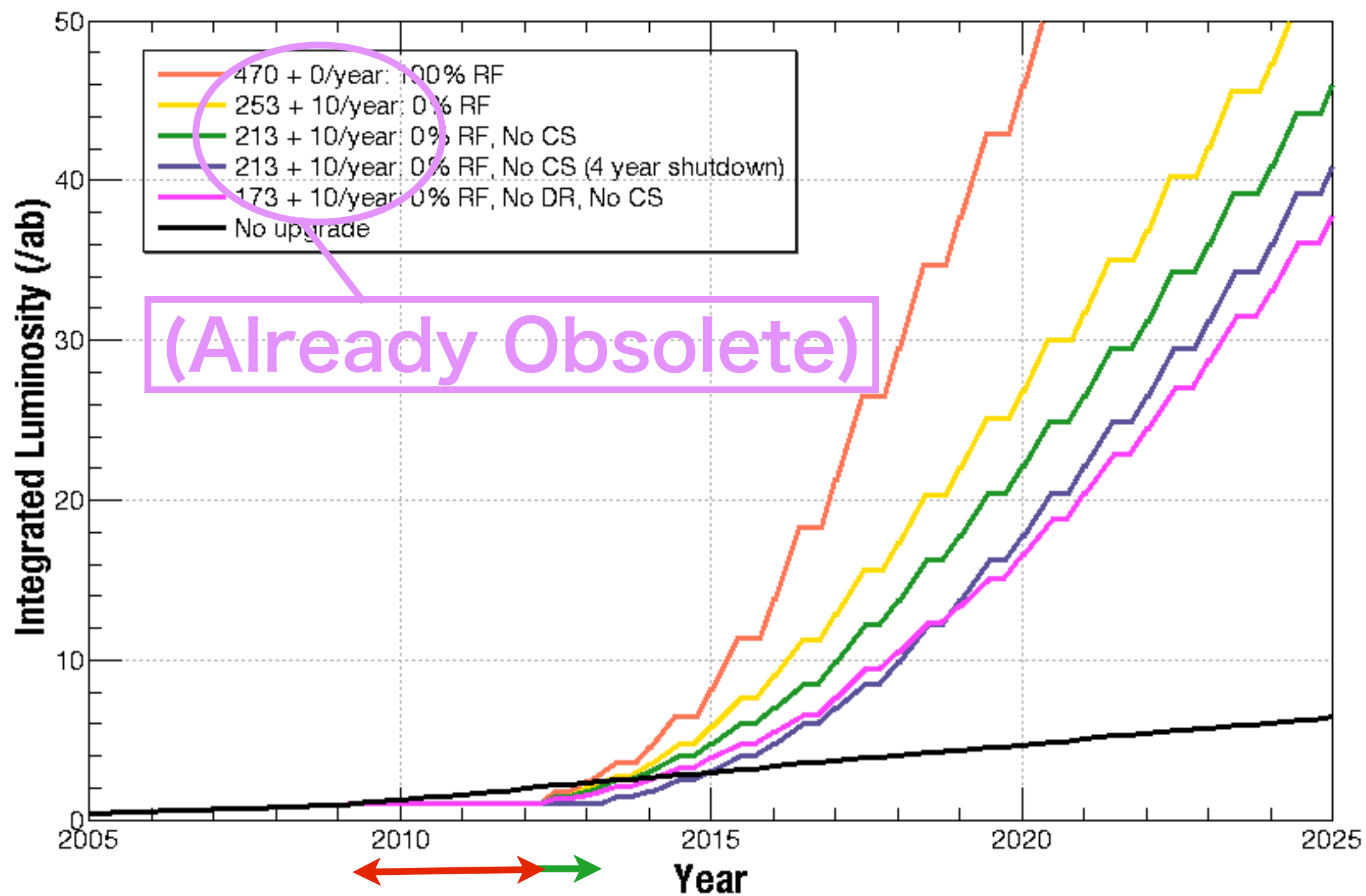


# Cost Estimation

Preliminary

(in Oku-yen = 1.0 M\$)

|                                            | Old estimation<br>Full Spec SuperKEKB | Construction<br>(for 3 years) | Upgrade during<br>operation | Total  |
|--------------------------------------------|---------------------------------------|-------------------------------|-----------------------------|--------|
| Vacuum                                     | 116.86                                | 139.36                        | 0                           | 139.36 |
| RF                                         | 115.873                               | 16.45                         | 84.25                       | 100.7  |
| Infrastructure                             | 84.3                                  | 3                             | 75.2                        | 78.2   |
| Magnet                                     | 16.7008                               | 31.9                          | 0                           | 31.9   |
| Crab                                       | 17                                    | 5                             | 10                          | 15     |
| Beam monitor                               | 174684                                | 17.7                          | 4.5                         | 22.2   |
| Injector                                   | 58                                    | 10                            | 53.7                        | 63.7   |
| Damping Ring<br>(other than RF<br>monitor) | 16.8                                  | 0                             | 21.26                       | 21.26  |
| Control                                    | 9.4                                   | 2                             | 7.4                         | 9.4    |
| IR                                         | 8                                     | 14.7                          | 0                           | 14.7   |
| Beam transport                             | 2.5                                   | 2.5                           | 0                           | 2.5    |
| Total                                      | 462.9022                              | 242.61                        | 256.31                      | 498.92 |

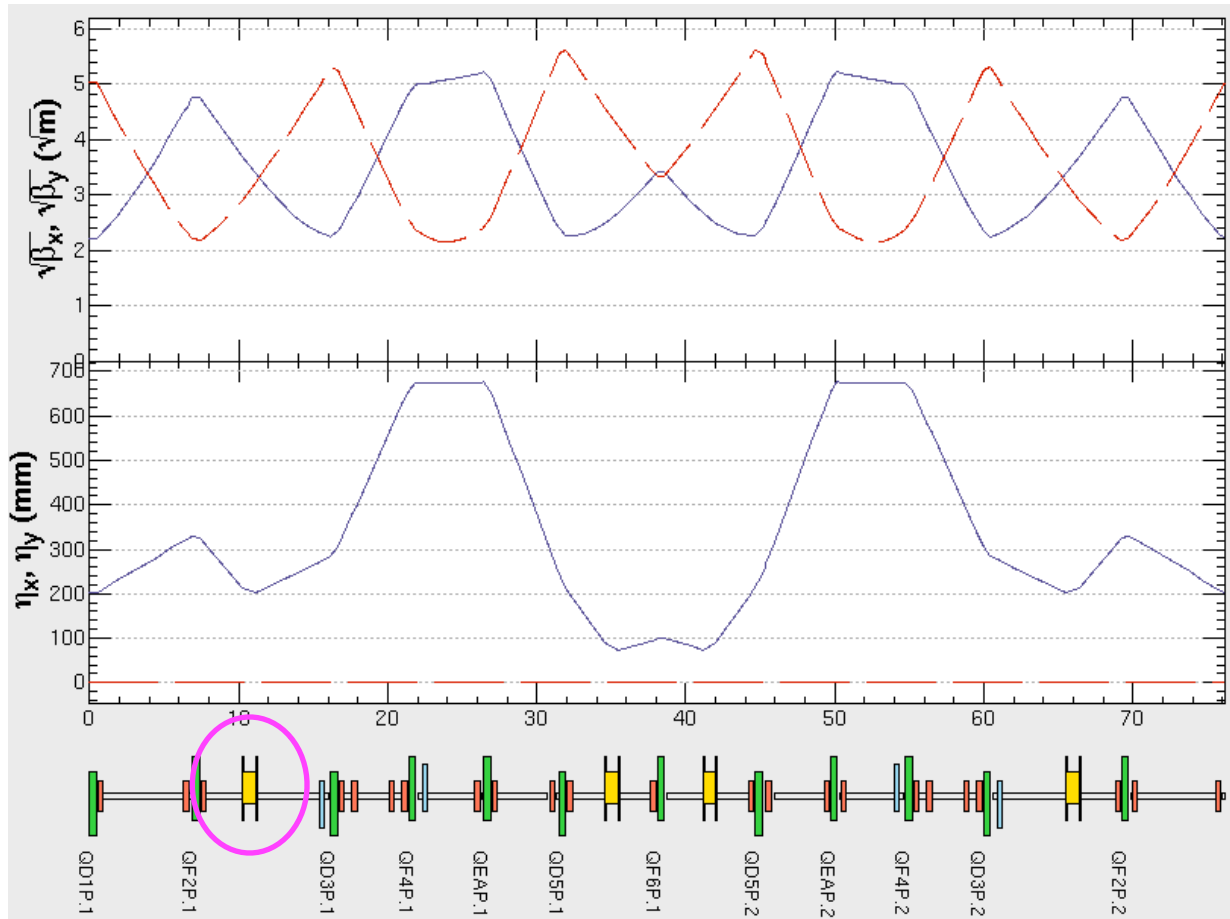




# Compatibility with Italian option

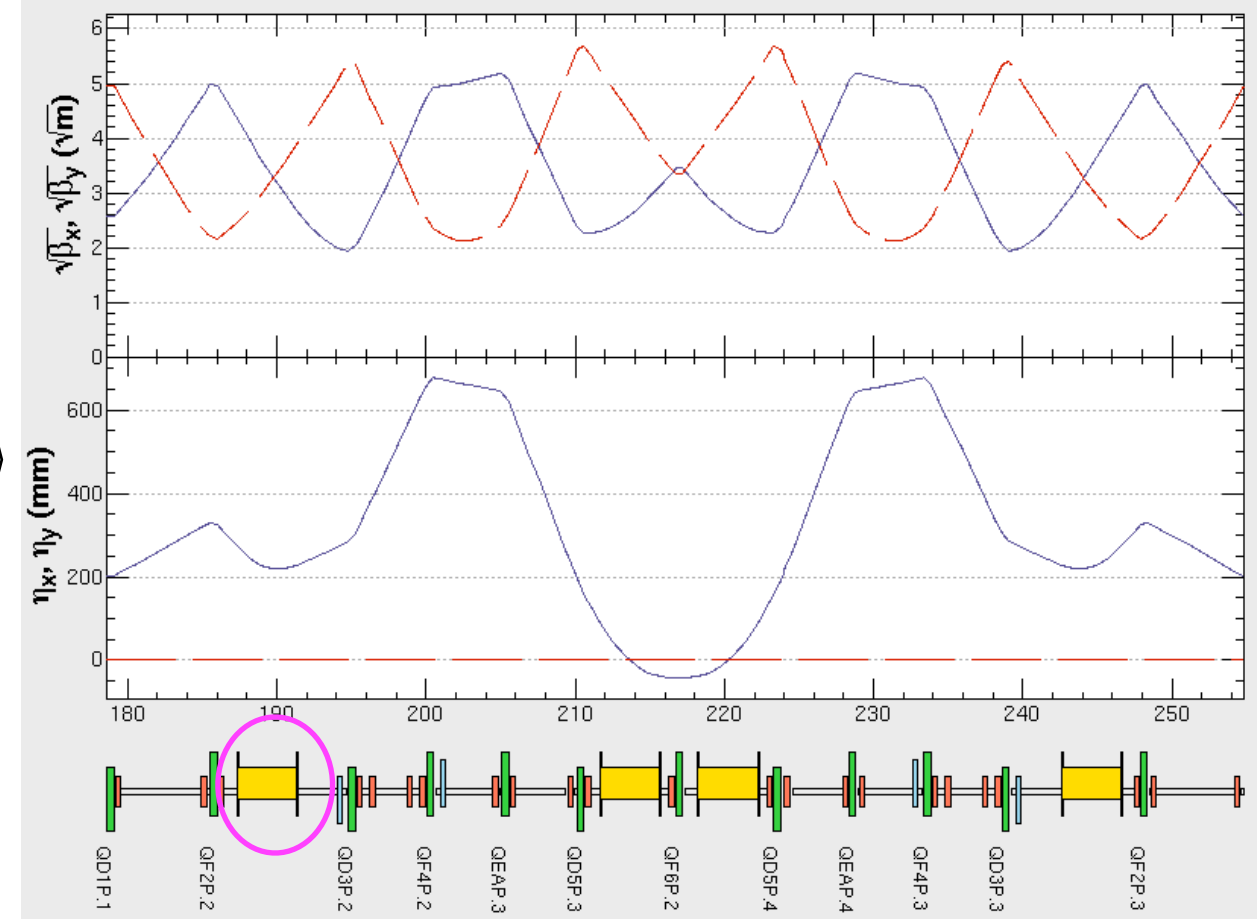
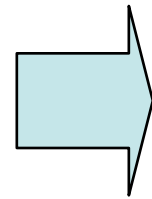
# LER arc cell

# Preliminary



**L bend = 0.9 m**

$$\epsilon_x = 6.8 \text{ nm}$$



**L bend = 4.0 m**

$$\epsilon_x = 2.2 \text{ nm}$$

- The arc cell lattice of the KEKB LER (left) can be modified to the low-emittance version (right), by weakening the magnetic field of the dipoles.
- No need for changing other components, beam pipes, geometry.
- The interaction region must be rebuilt.
- The HER's emittance is not reduced, but unequal emittance may be OK. H.

H. Koiso