Status of SuperKEKB

Flavour in the era of the LHC
March 28, 2007

K. Oide (KEK)

1. Crab cavities
2. Beam commissioning of the crab crossing scheme
3. A few studies for SuperB
4. Low emittance/small beta option for SuperKEKB

Special thank to K. Akai, Y. Funakoshi, K. Hosoyama, H. Ikeda, H. Koiso, A. Morita, Y. Morita, K. Ohmi, Y. Ohnishi, M. Ono, P. Raimondi, Y. Yamamoto, and members of the KEKB group.

Crab Cavities

- Two cavities were successfully produced and assembled.
- Basically good performance in the horizontal tests.
- Installed successfully in both rings on schedule.
- Commissioning of the cavities has been basically successful, with and without beam.

HER

LER

Milestones of Crab Cavity at KEKB

K. Hosoyama

1994 Crab 1/3 Scale 1.5 GHz Model

1996 Crab Full Scale 500 MHz Model

2005

Jan. Start the Fabrication of 2 Crab Cavities

Dec. RF Test of Crab Cavity HER in Ver. Cryostat V_{kick} = 1.9 MV

2006

Jan. RF Test of Crab Cavity LER in Ver. Cryostat V_{kick} = 2.7 MV

Feb. Cool-down Test of Prototype Cryo-module

Feb. Start the Assembling of Cryo-module for Crab Cavity HER

Mar. Insertion Failure of Coaxial Coupler

Apr. Improved the Insertion Tool
Finished the Assembling Crab HER

May. Cool-down & High Power Test at Test Stand V_{kick} = 1.65 MV

July Dismantle the Cryo-module
Improved RF Contact of Coaxial Coupler and Bellows

Aug. Reassemble the Cryo-module

Sep. Cool-down and High Power Test of Crab HER at Test Stand V_{kick} = 1.8 MV

Oct. Assembling the Cryo-module for Crab LER

Nov. Cool-down and High Power Test of Crab LER at Test Stand V_{kick} = 1.93 MV

2007

Jan. 8,11 Installation of Crab Cavities for HER and LER into KEKB Ring

Jan.29,31 Start the Cool-down of Crab Cavities for HER and LER

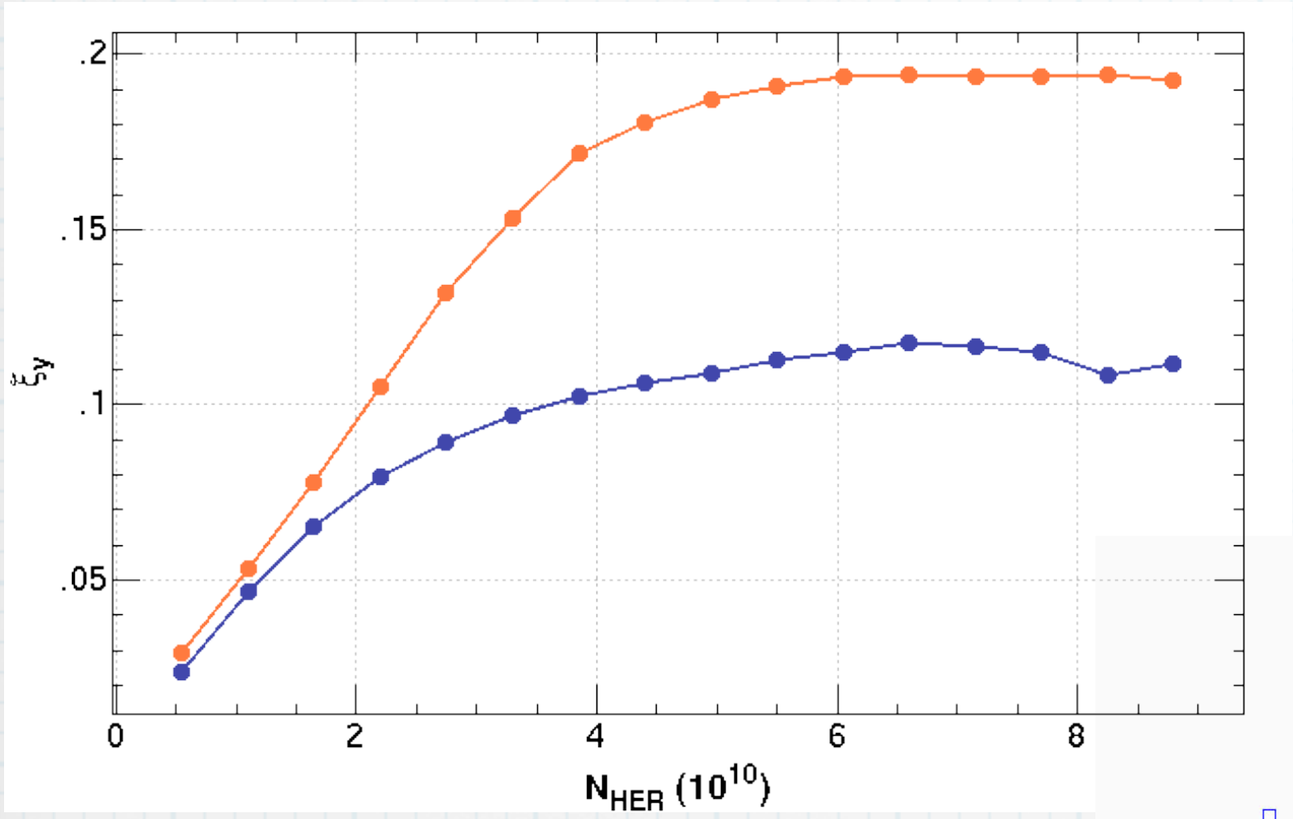
Feb. 9,10 Start of RF Aging V_{kick} = 1.7 and 1.43 MV for HER and LER

Feb. 19 First Crab Kick was observed by beam.

Crab Crossing has started @ KEKB!

- Crab crossing will boost the beam-beam parameter up to 0.2!

K. Ohmi



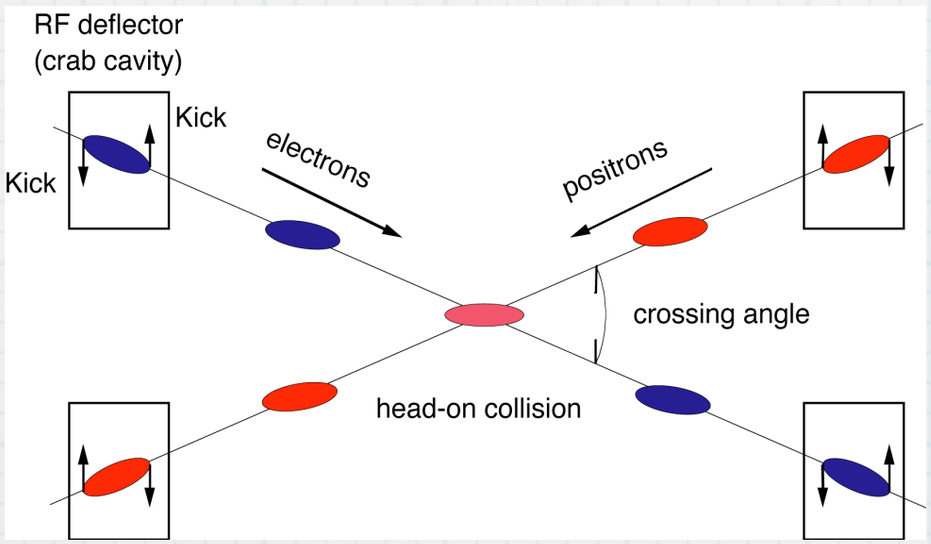
Head-on(crab)

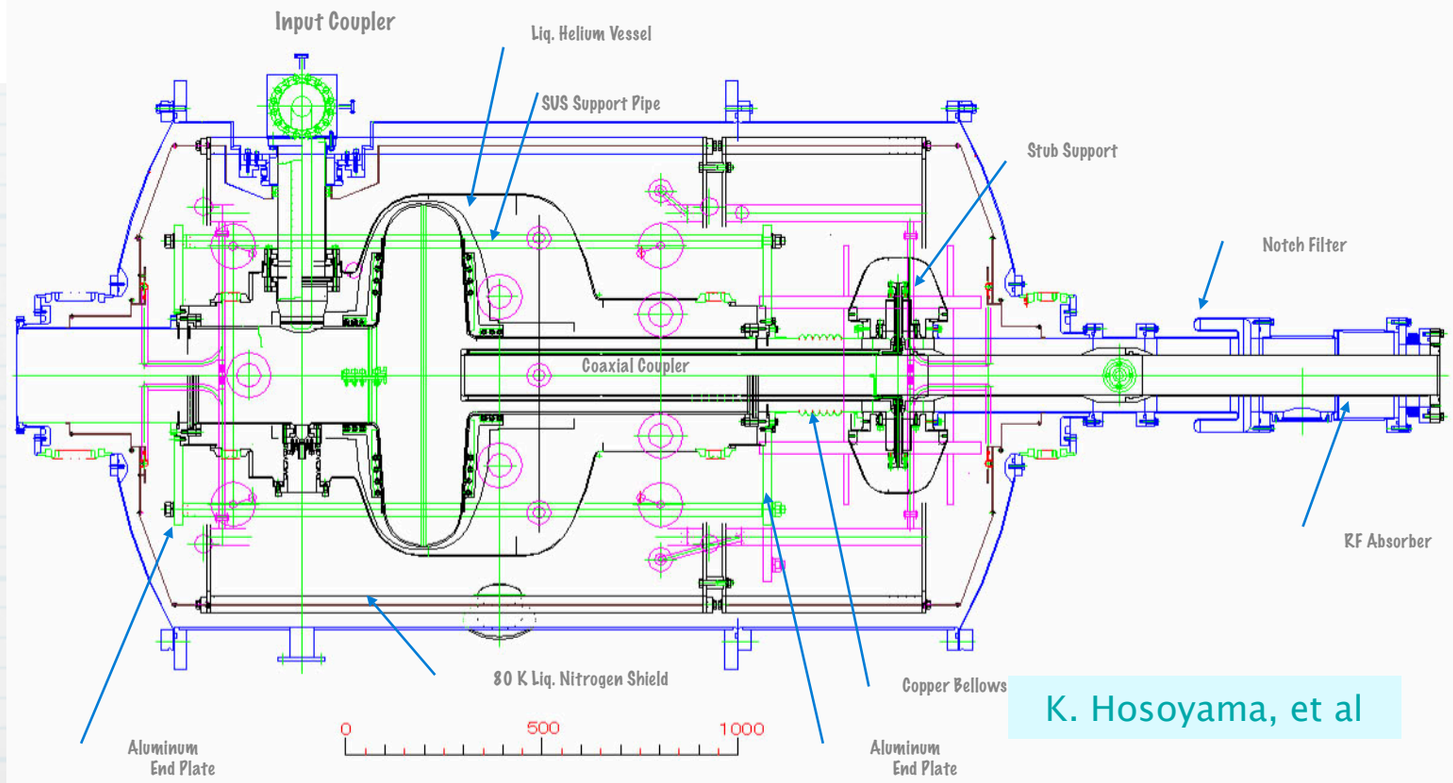
(Strong-strong simulation)

crossing angle 30 mrad

(at the optimum tune)

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



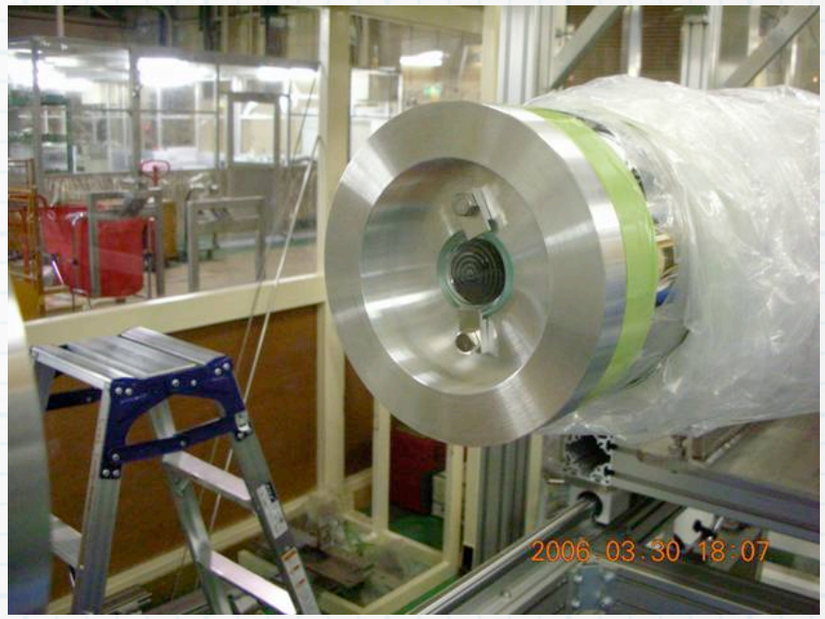


K. Hosoyama, et al

Alignment of Coaxial Coupler

K. Hosoyama

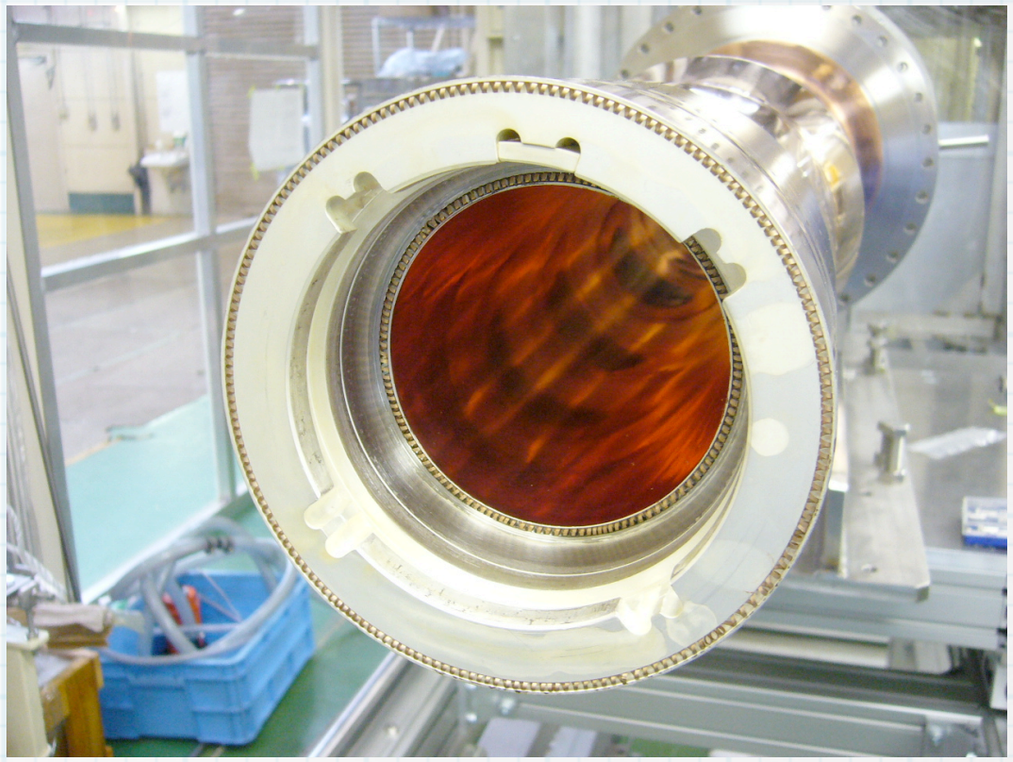
Determine the axis of the coaxial coupler
set in the cryostat by using a transit.

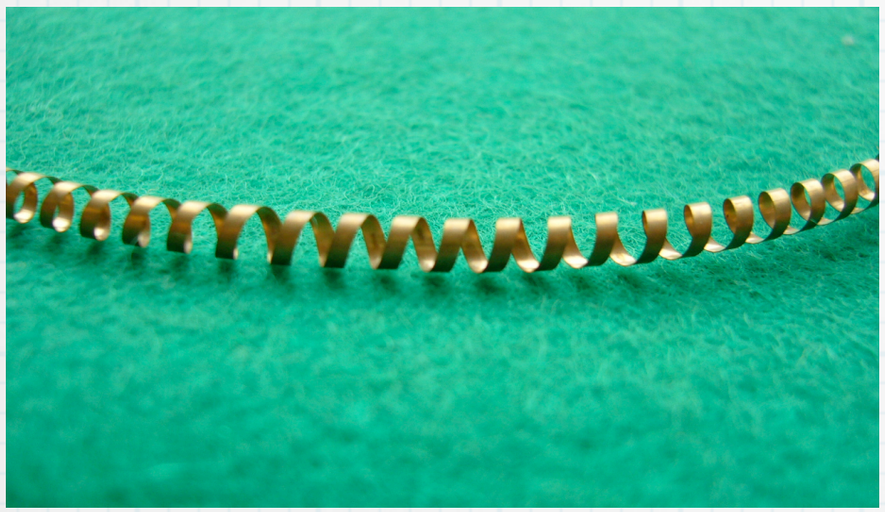


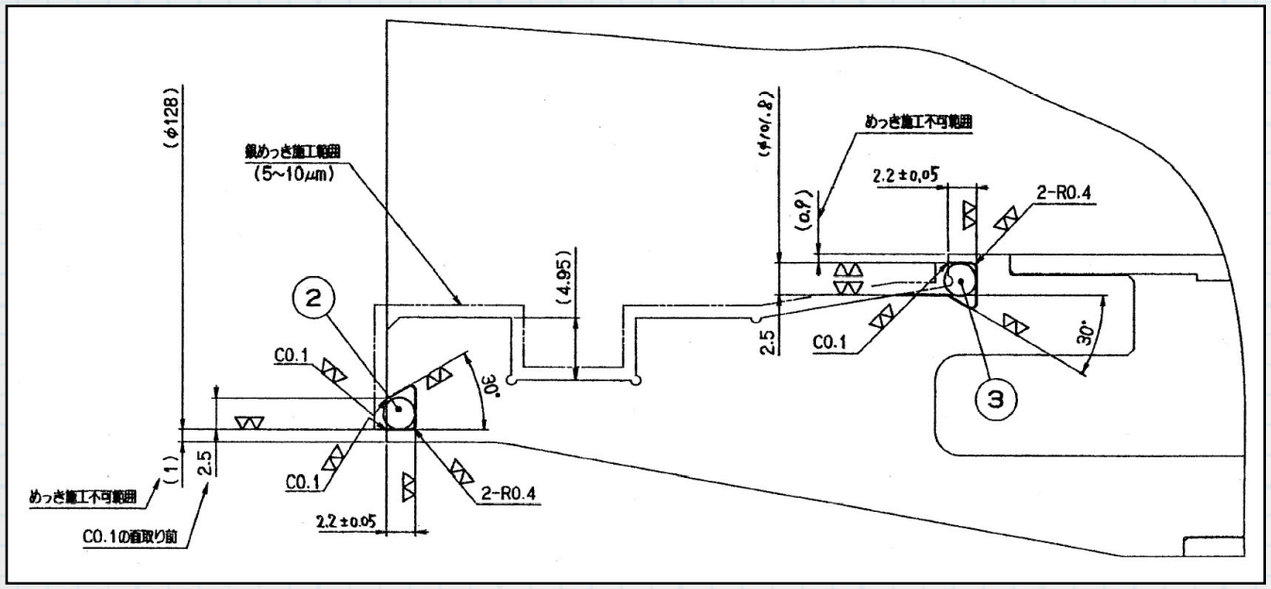
Align the axis of the coaxial coupler which will be connected to the coaxial coupler of cryostat side.

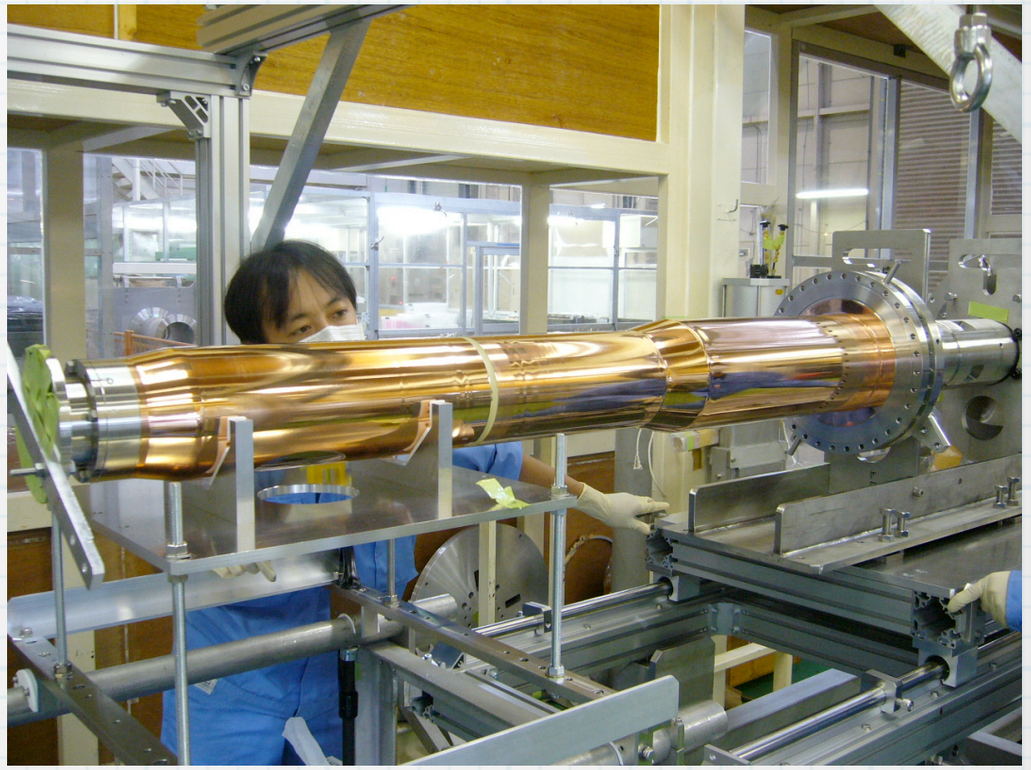
RF Contact for the Coax

Type: Spiral
Material: BeCu
Spring Constant: 14kg/φ94mm(0.5kg/cm)









K. Hosoyama

Move to a Test Stand for Cool-down & High Power Test

April 26, 2006 1st

Oct. 16, 2006 2nd

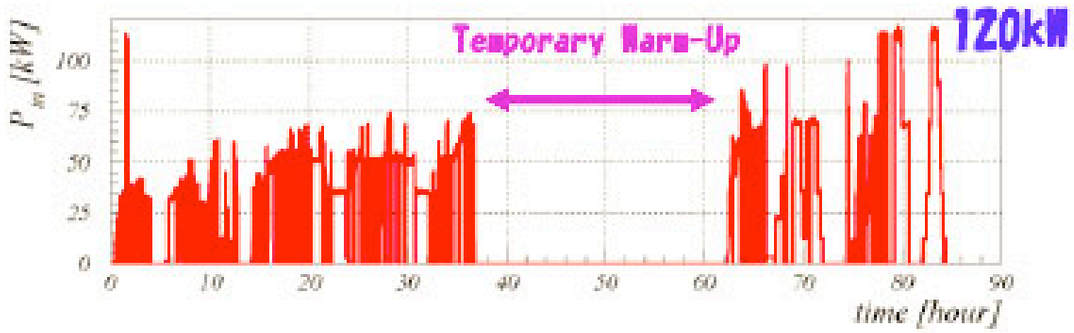
High Power Conditioning

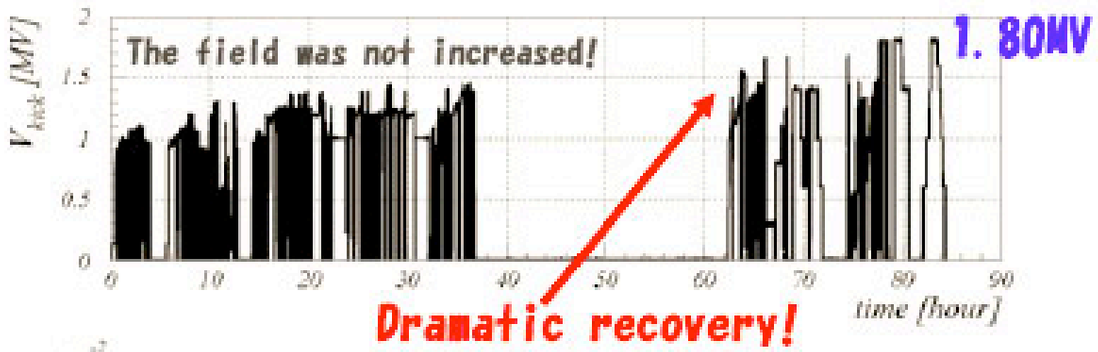
Y. Yamamoto

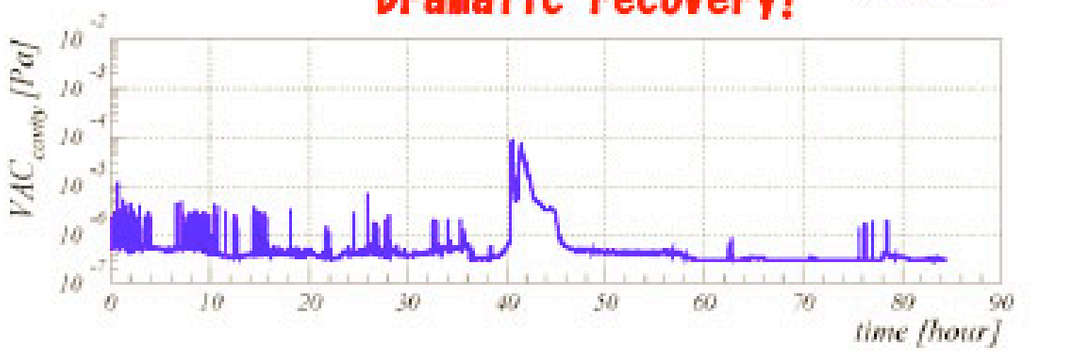
Both cavities were conditioned beyond the design voltage (1.4 MV).

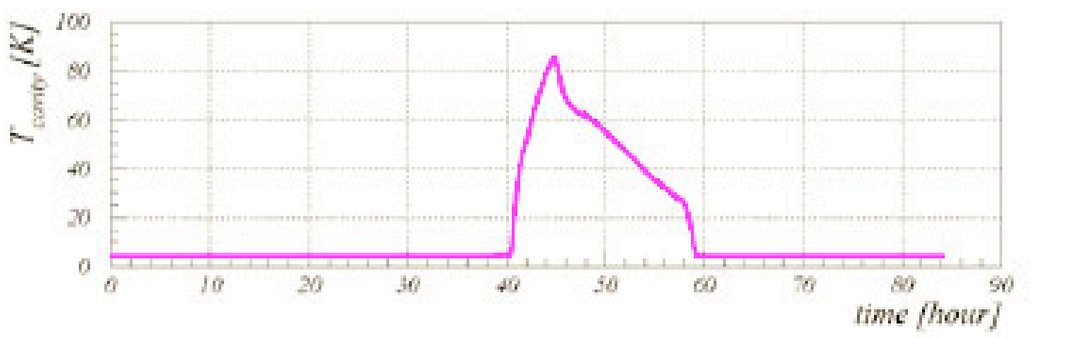
HER

Second Horizontal Test for HER Crab Cavity at 4K



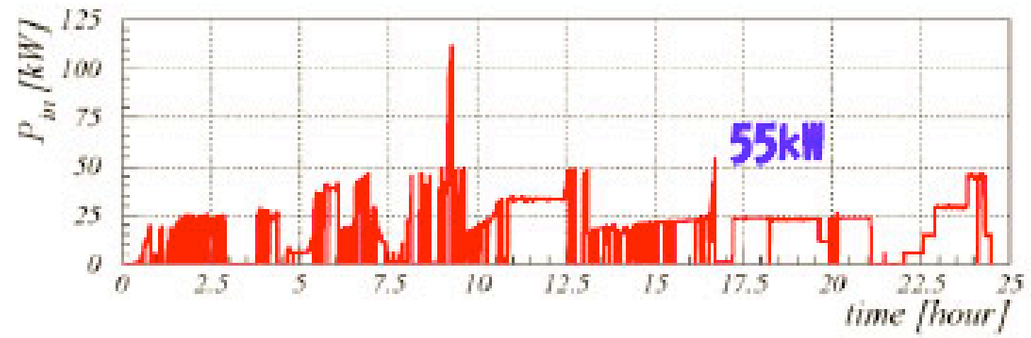


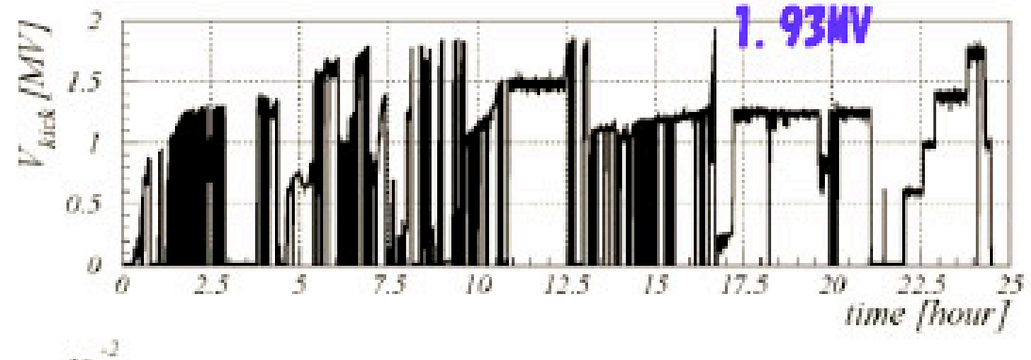


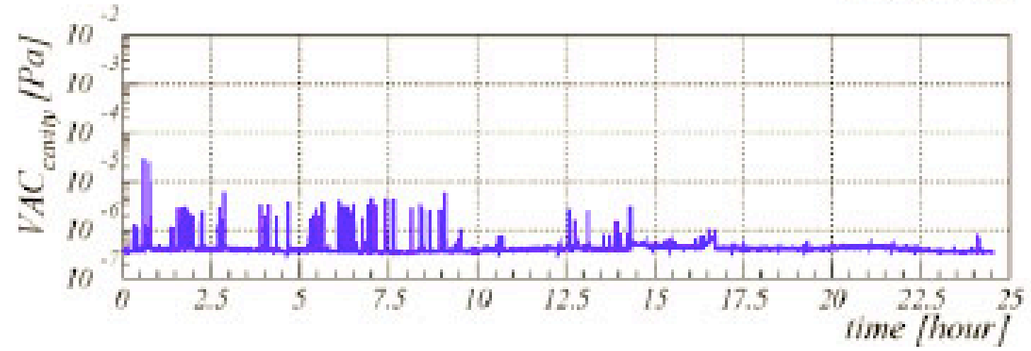


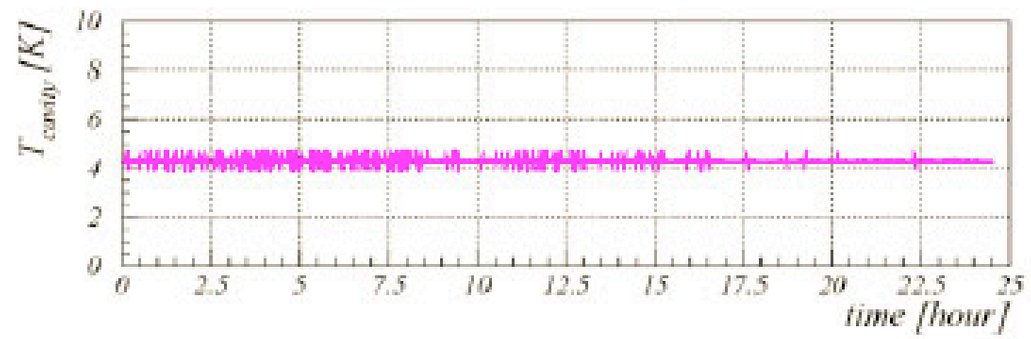
LER

Fisrt Horizontal Test for LER Crab Cavity at 4K





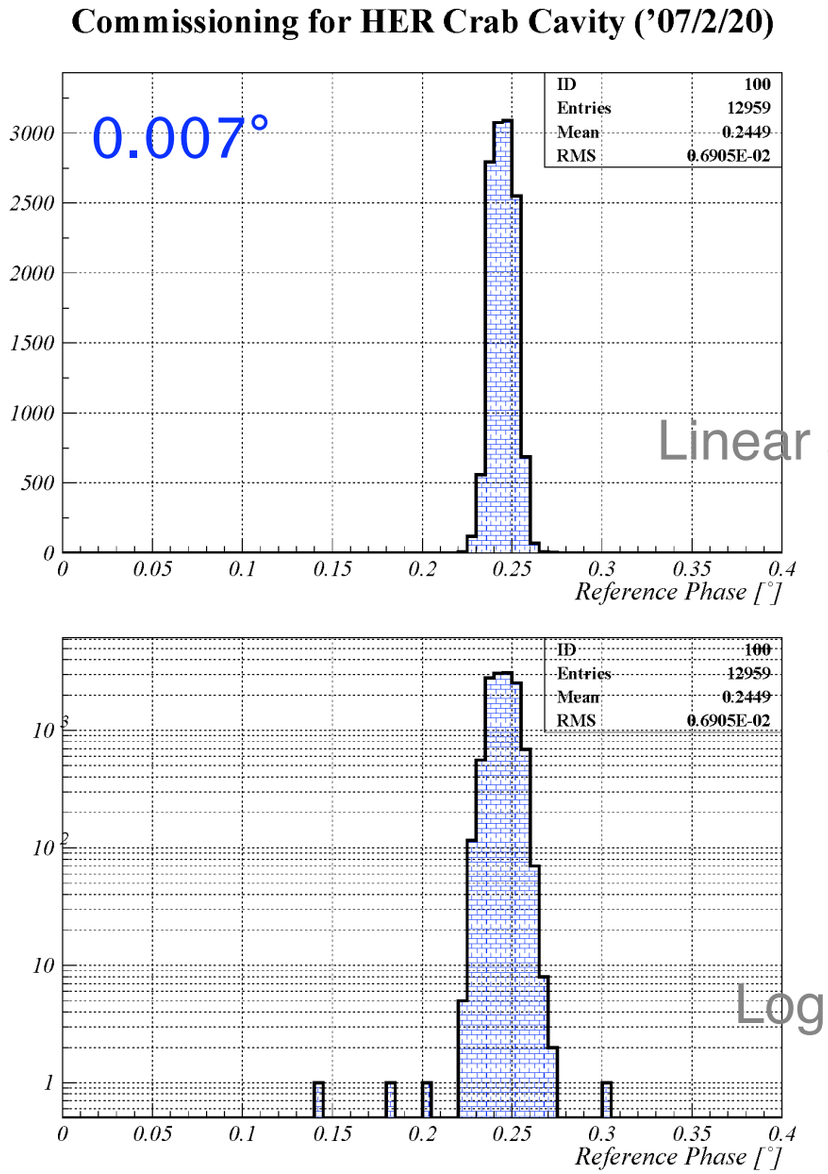




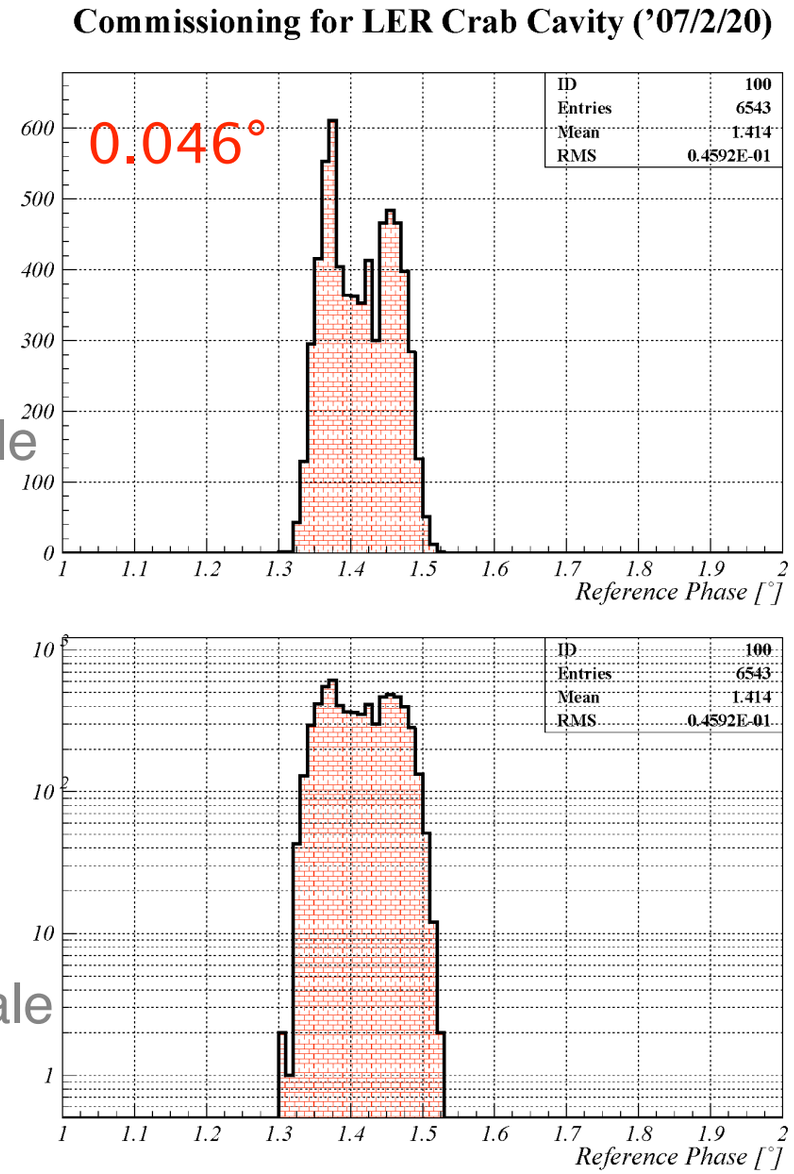
We decided the temporary warm-up of the HER Crab cavity again, as the field was not increased.

Phase stability (histogram of phase detector signal)

HER



LER



Distribution of cavity phase (with cavity rf feedback loops)

K. Akai

Crab Installation : How to

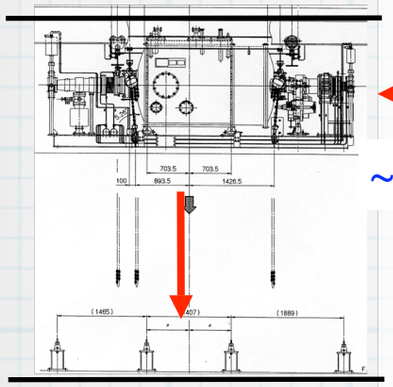
M. Ono

Nikko Exp. Hall

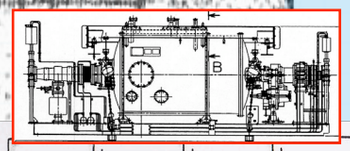
Crab ; LER; D11

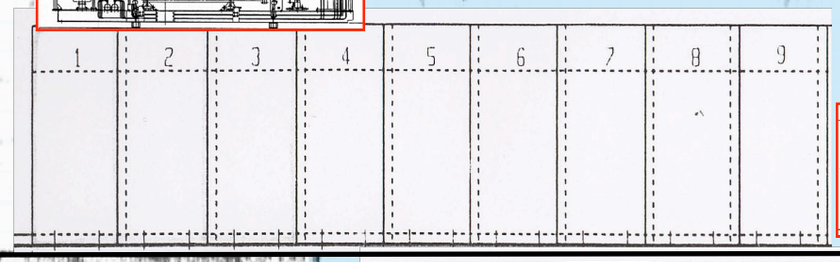
Set Crab to Carrier

Crab ; HER; D10

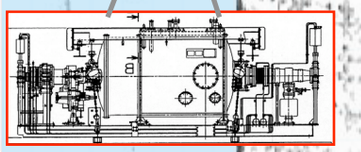


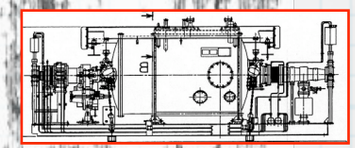
~60 m



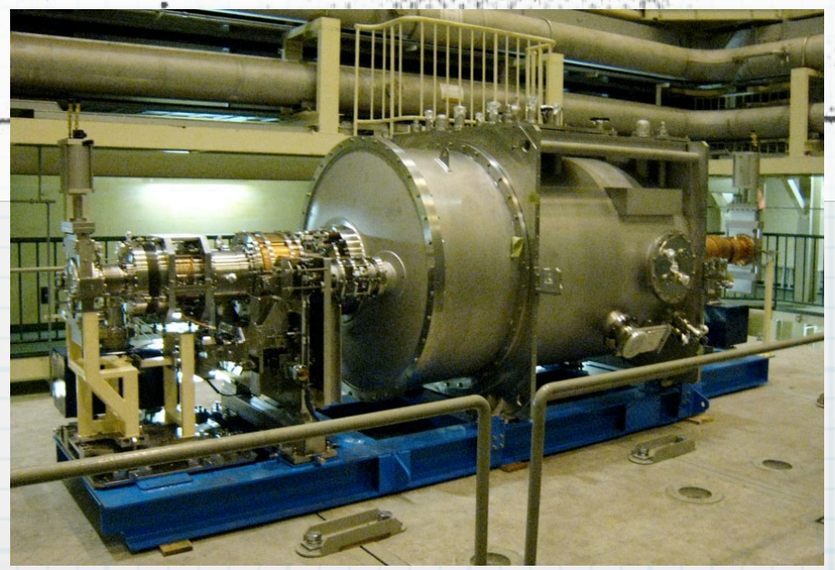


Set Crab to Tirroller





Removed 8 shield



Crab Cavities have been installed in the KEKB tunnel.
(1 cavity per ring.)

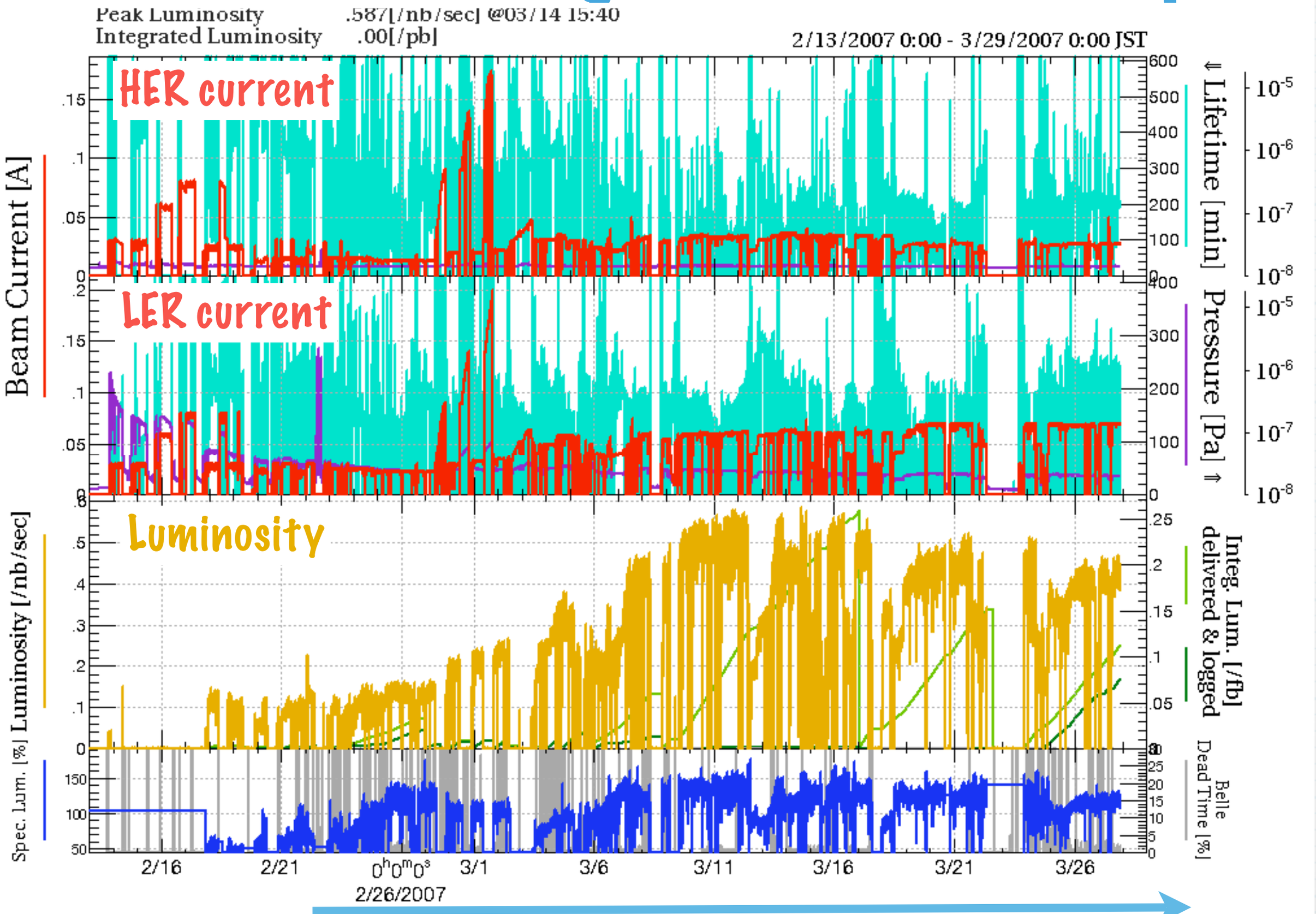
Electron Ring (HER, 8 GeV)

Positron Ring (LER, 3.5 GeV)

Crab Crossing

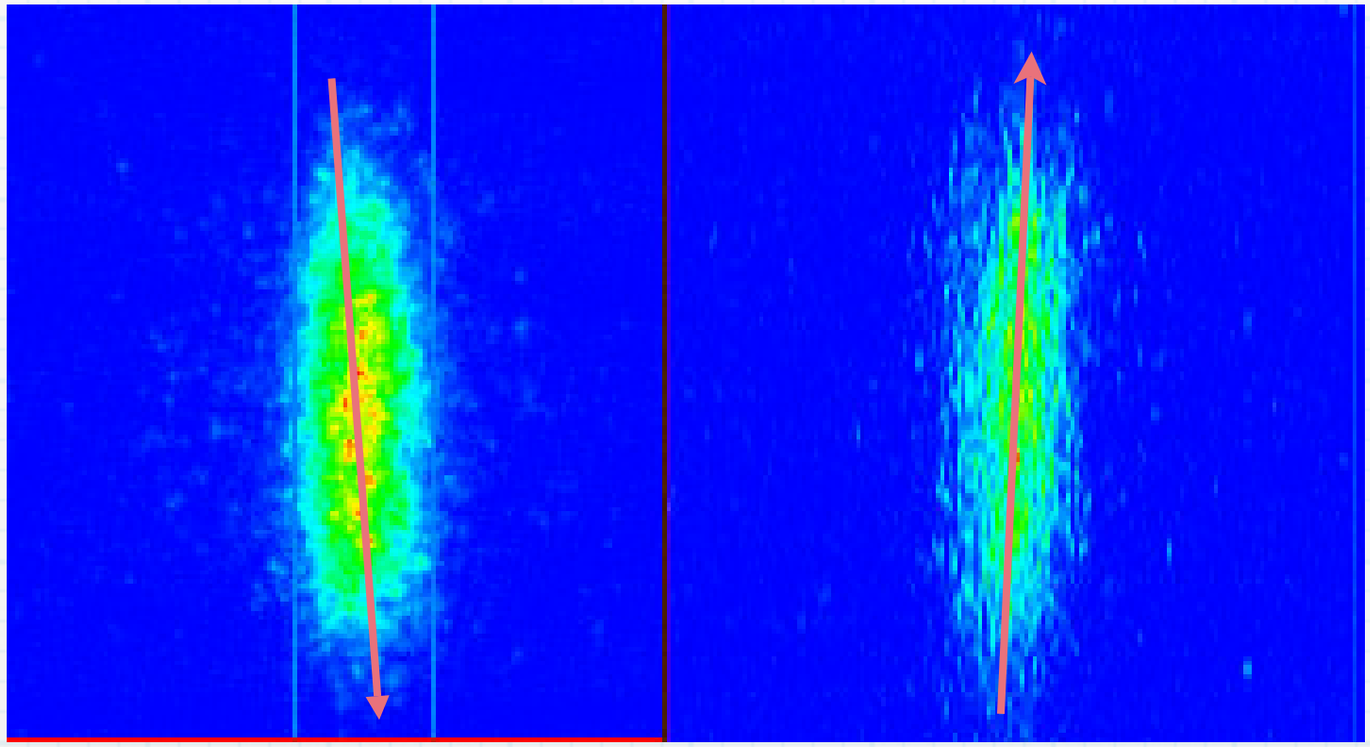
- A number of checks have confirmed the effective head-on collision:
  - streak camera
  - crab-phase scan
  - sign change and scan of crab voltage
  - horizontal beam-beam kick
  - vertical crabbing
- The highest vertical beam-beam tune-shift parameter is about 0.08 so far, which is a little higher than the geometrical gain due to head-on.
- Due to the low-current operation, the effect from electron cloud has been negligible.
- It is too early to say conclusion.

Crab Crossing Since February



Beams have indeed tilted!

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



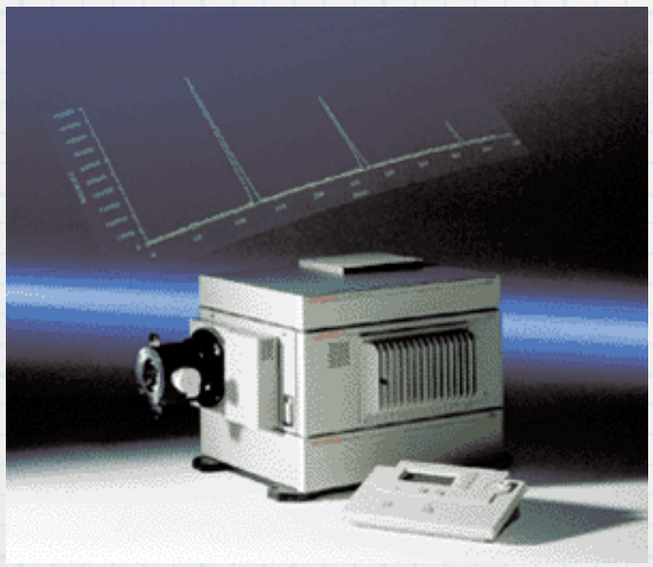
Longitudinal

Electron Ring

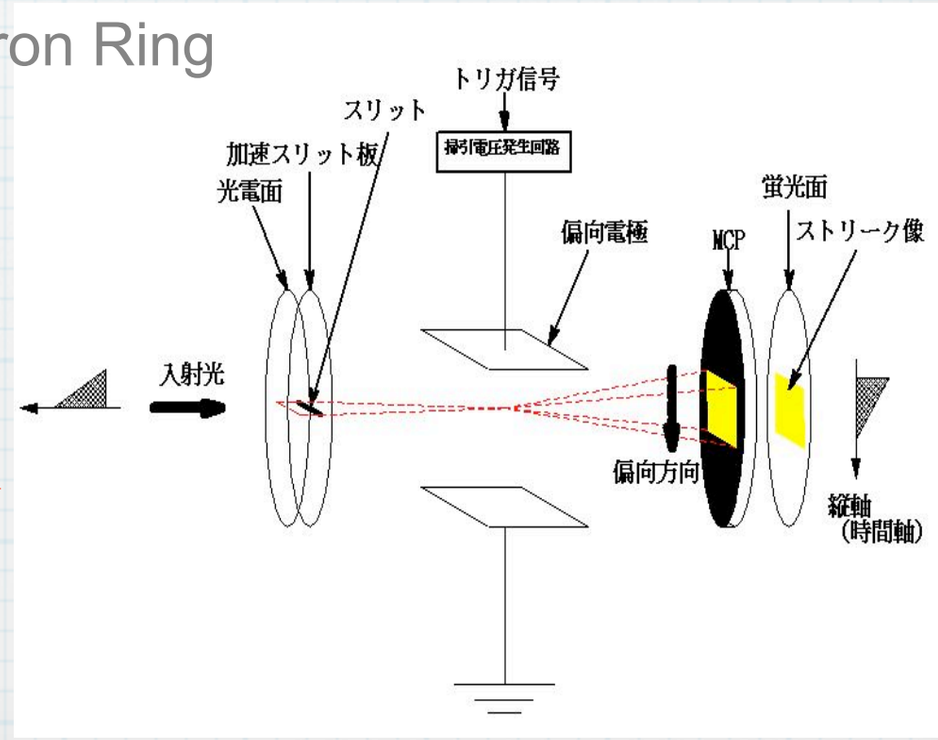
Positron Ring

outside ⟷ inside

Horizontal



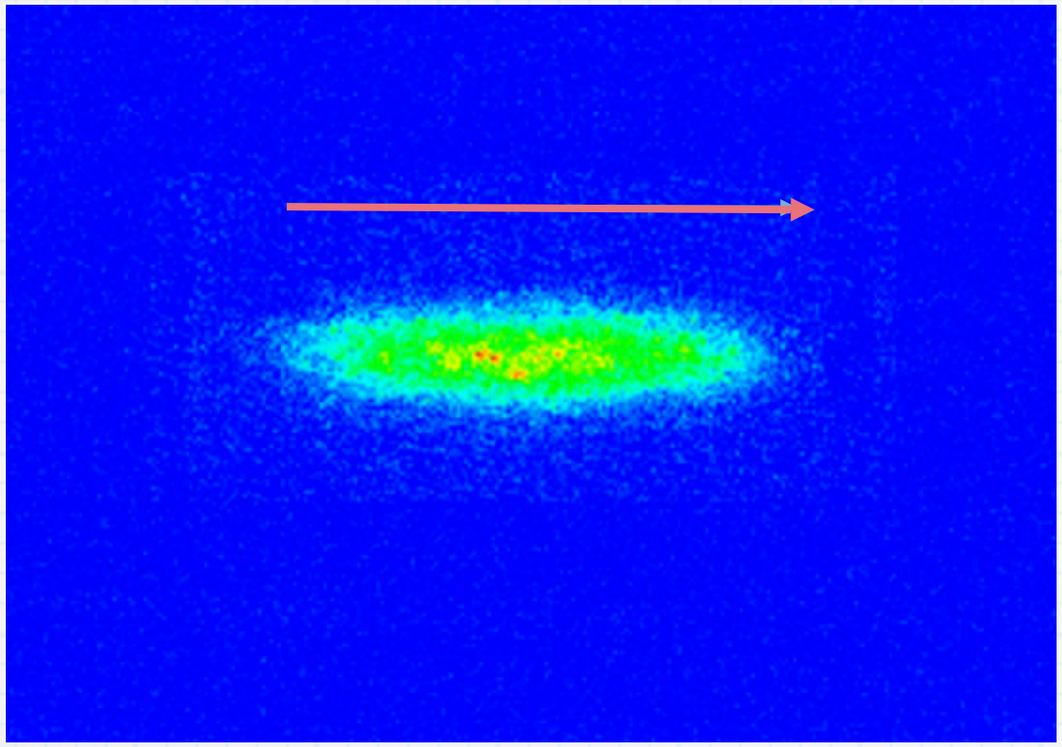
← Streak Camera ant its Schematic Diagram →

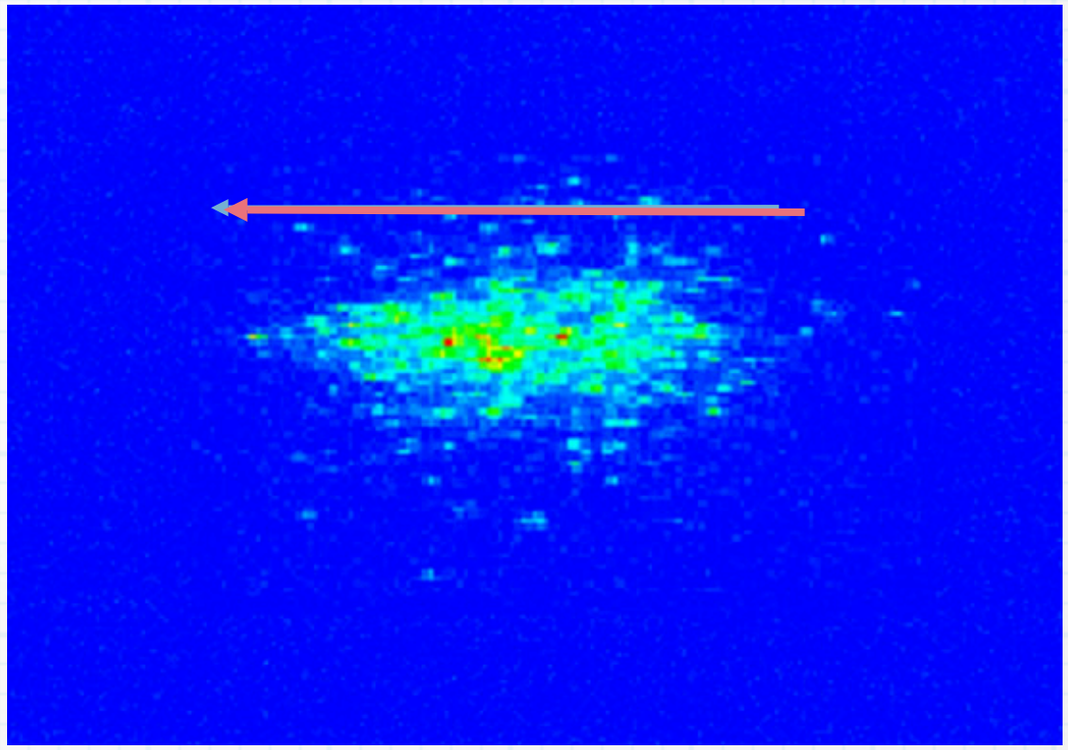


HER

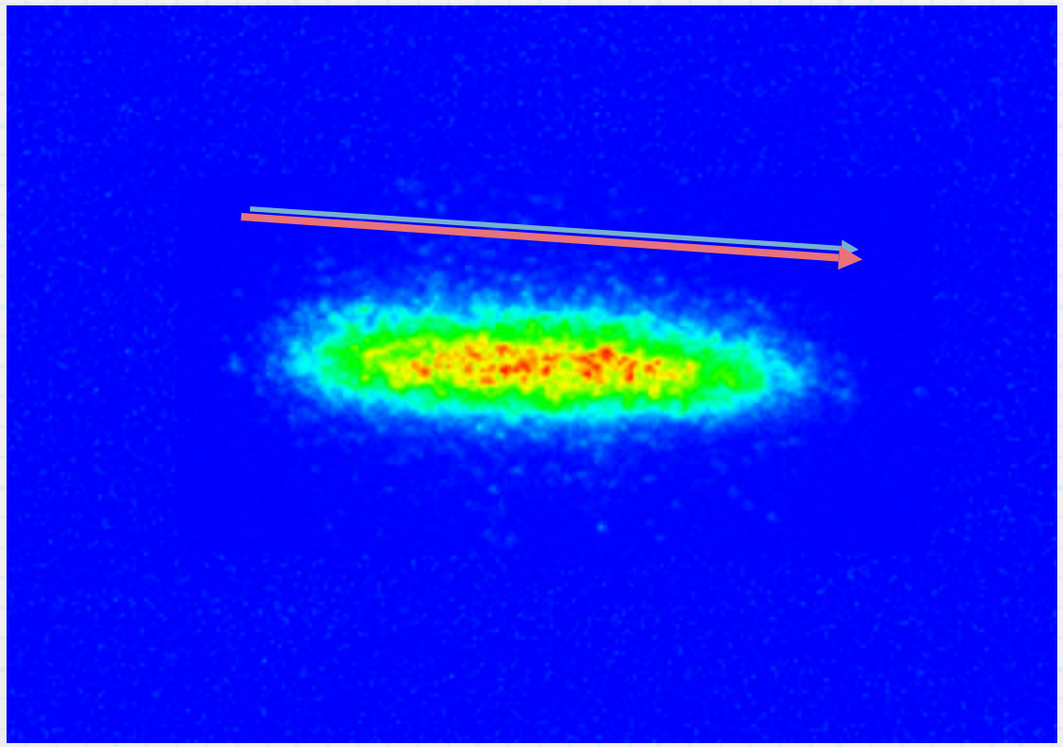
LER

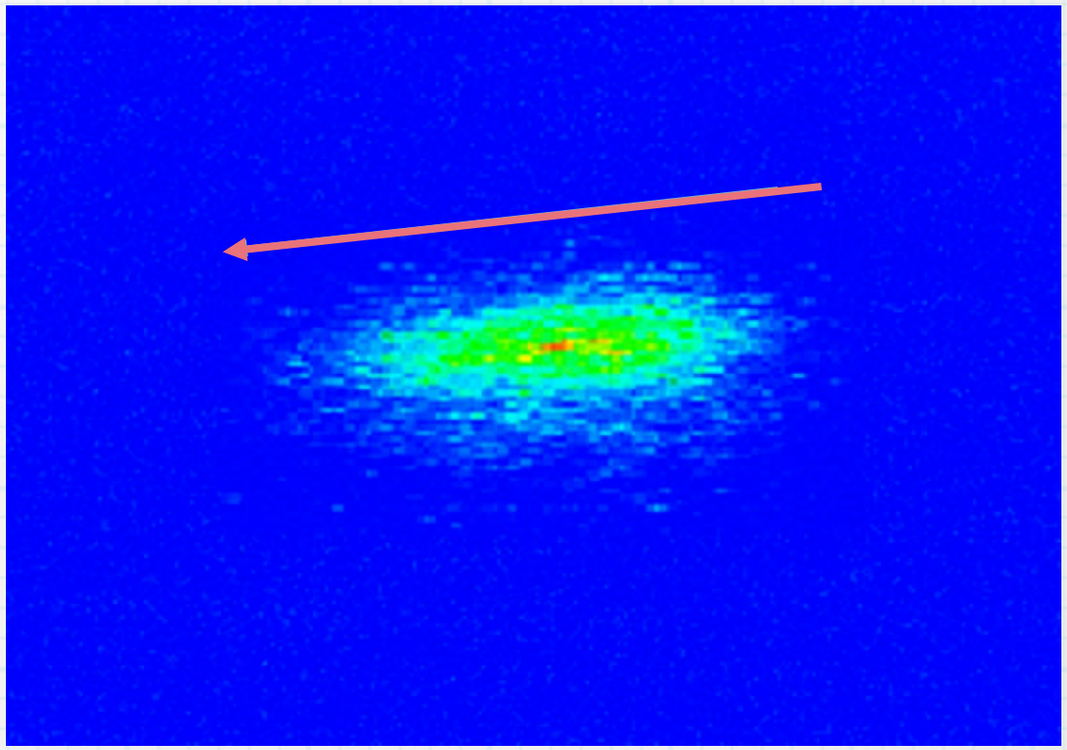
Crab OFF





Crab ON

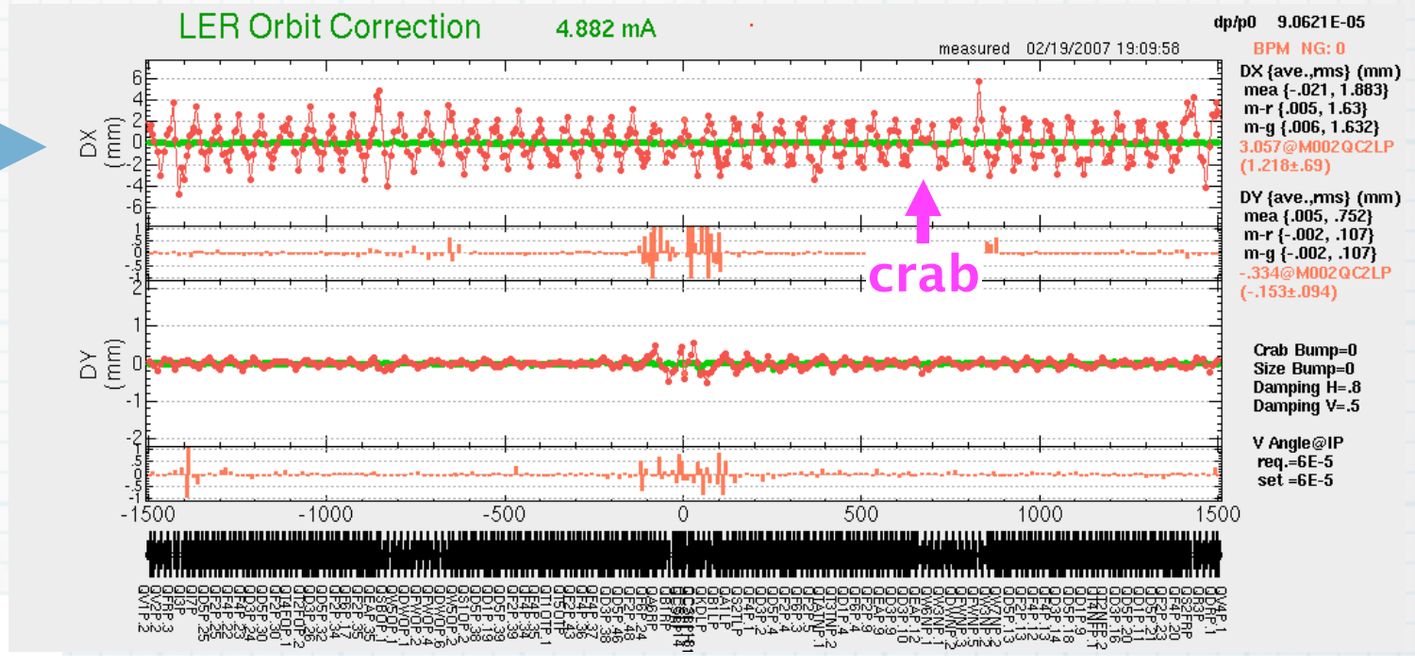


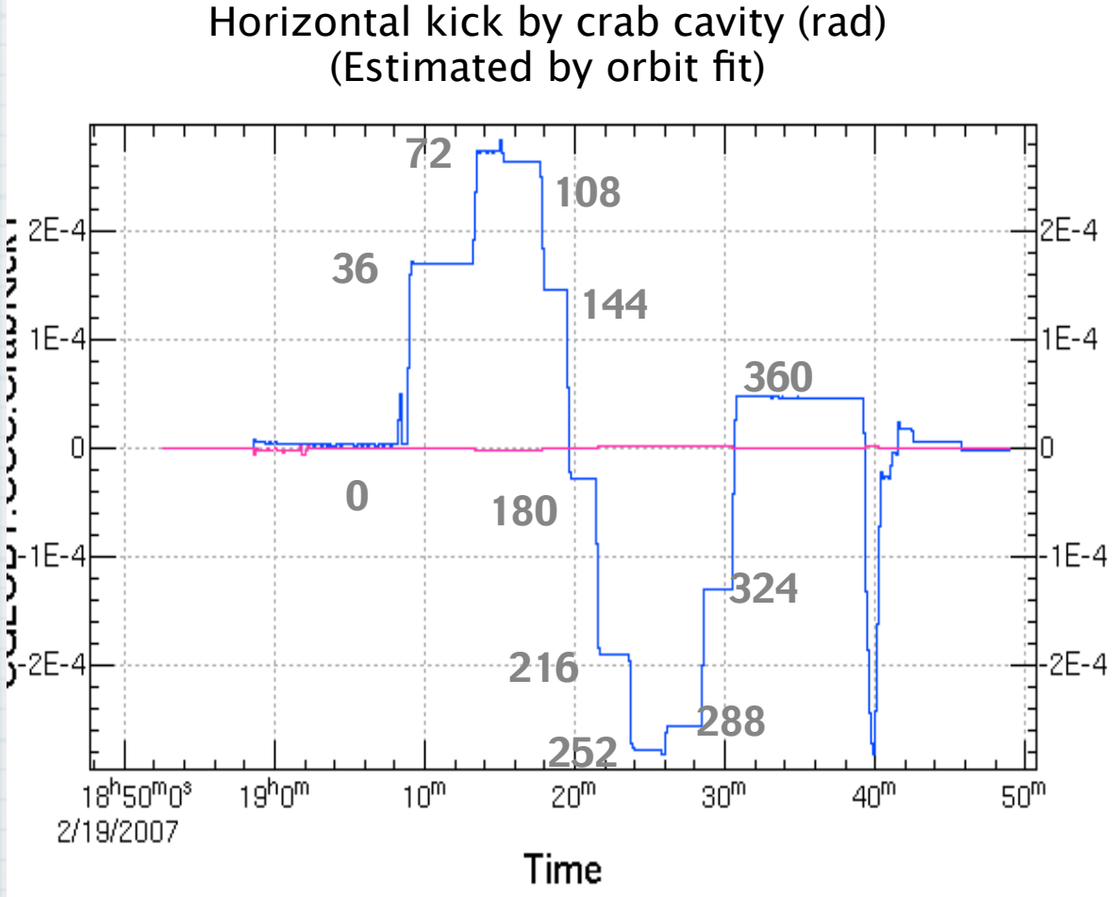


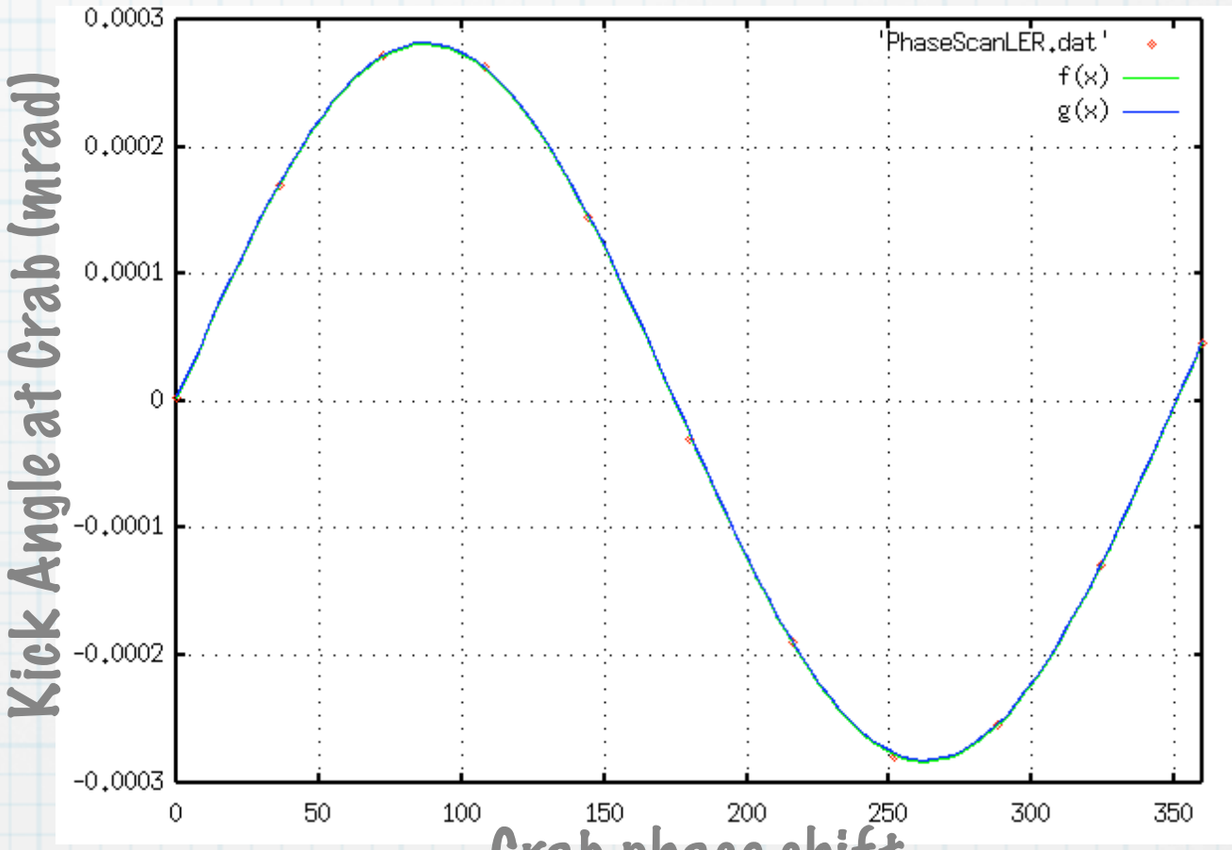
H. Ikeda

Crab Phase Scan (LER)

Horizontal orbit by crab kick







Phase 0：175 deg.

Vcrab set:1.0MV, estimated: 0.987MV

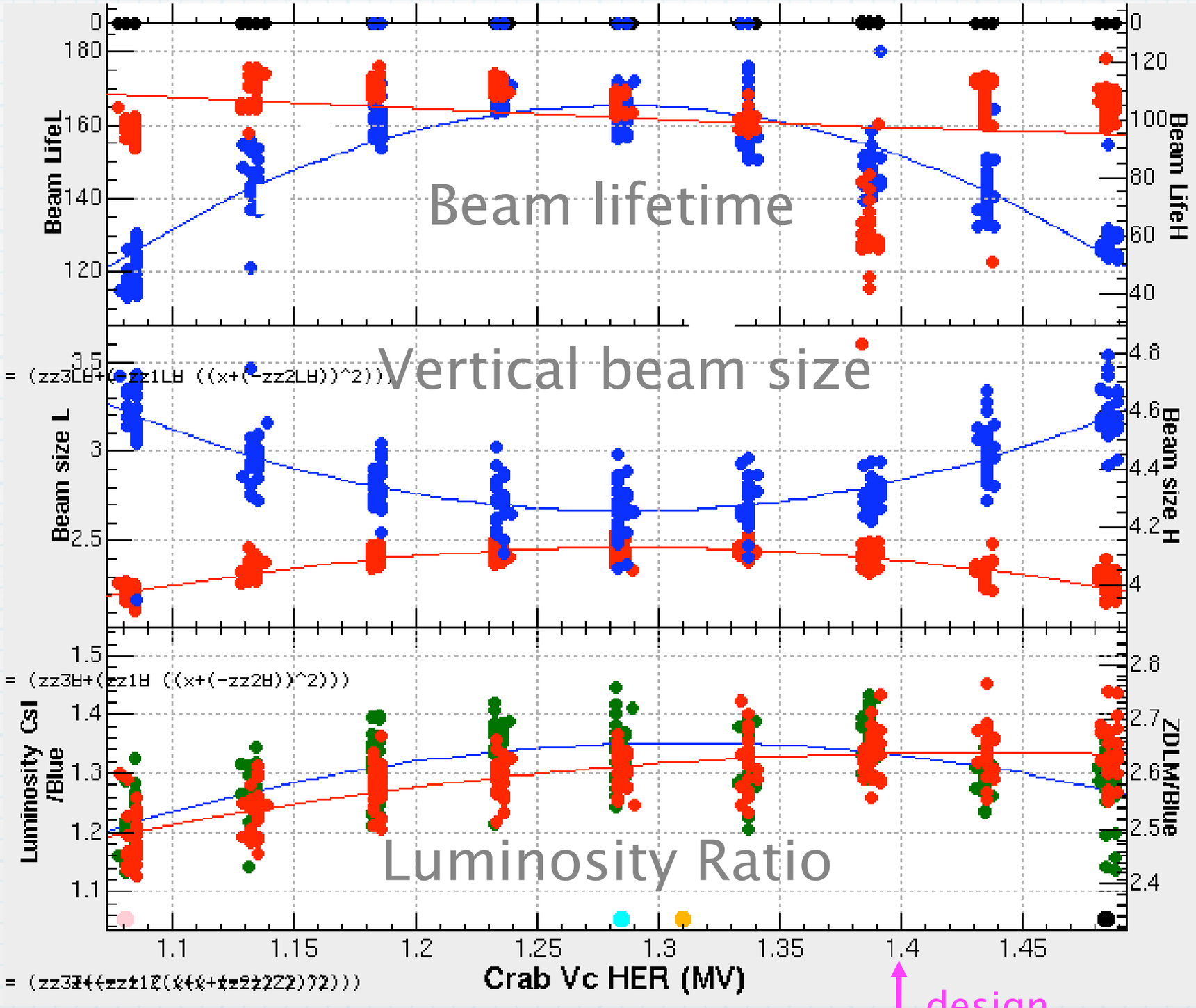
agree to each other very well

KCG Shift Report 2007_02_19_17

H. Koiso

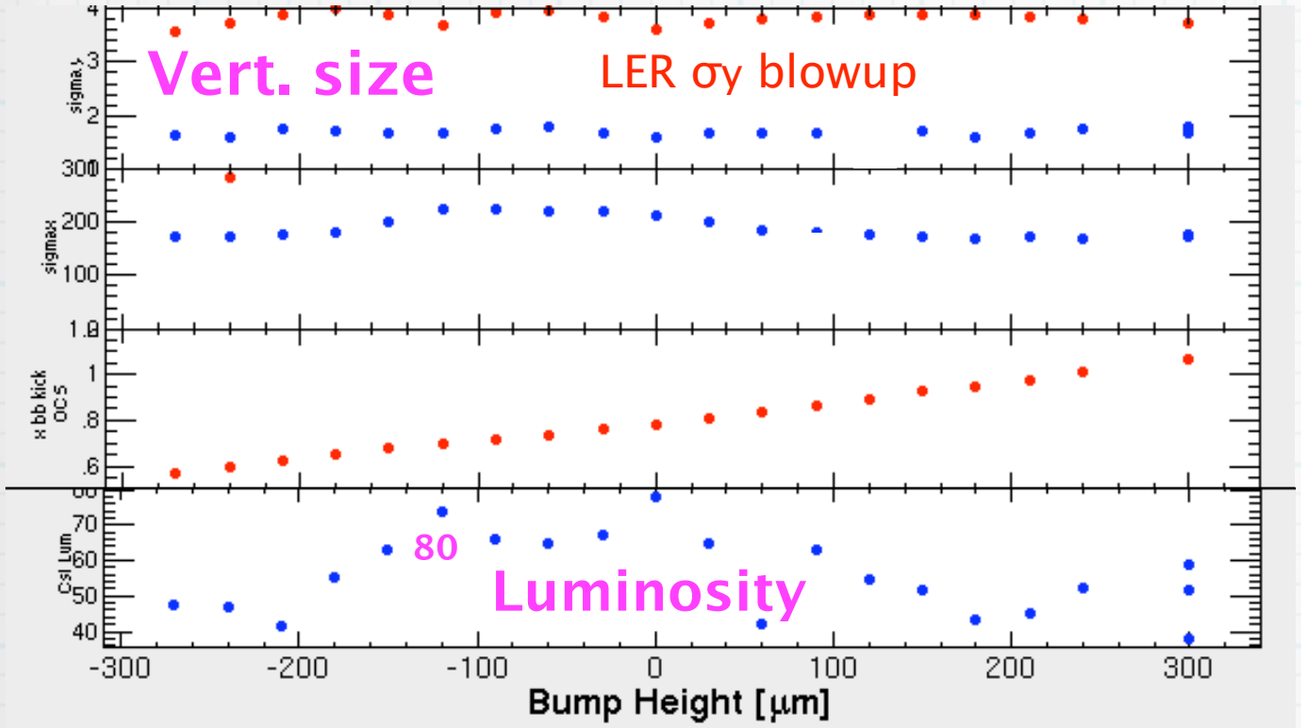
V_{crab} Scan (HER)

H. Koiso

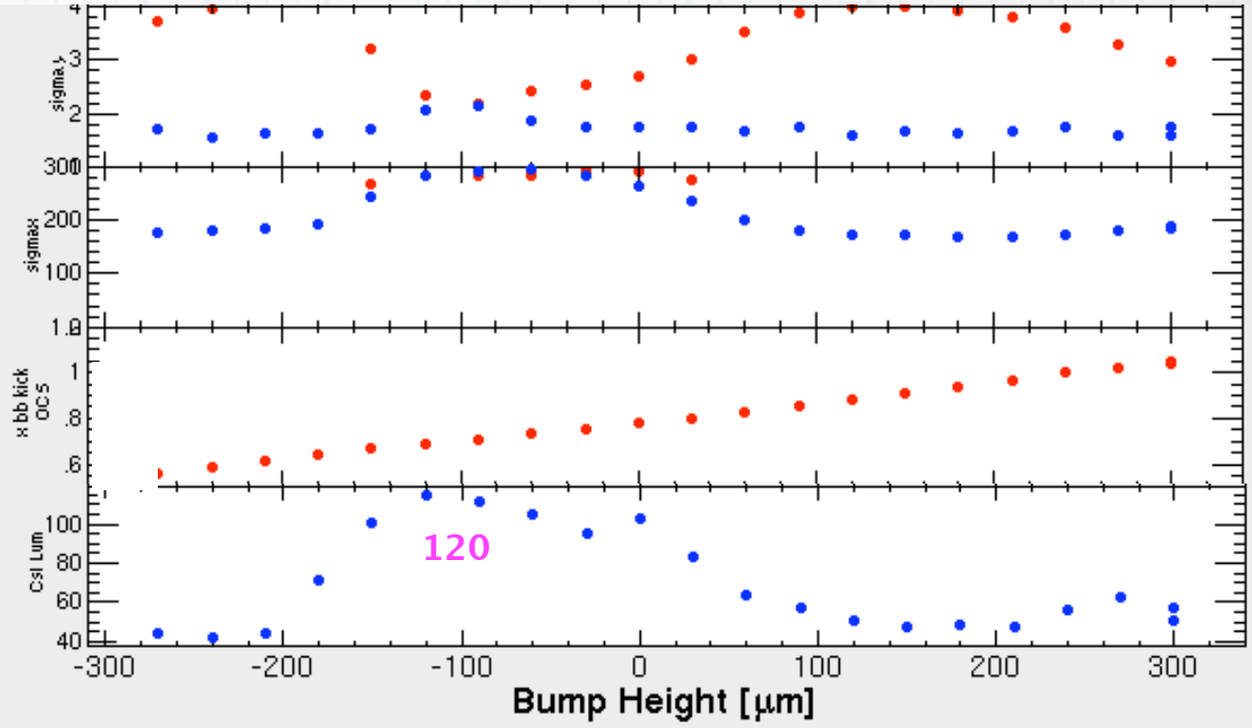


Sign Change in the Crab Angle

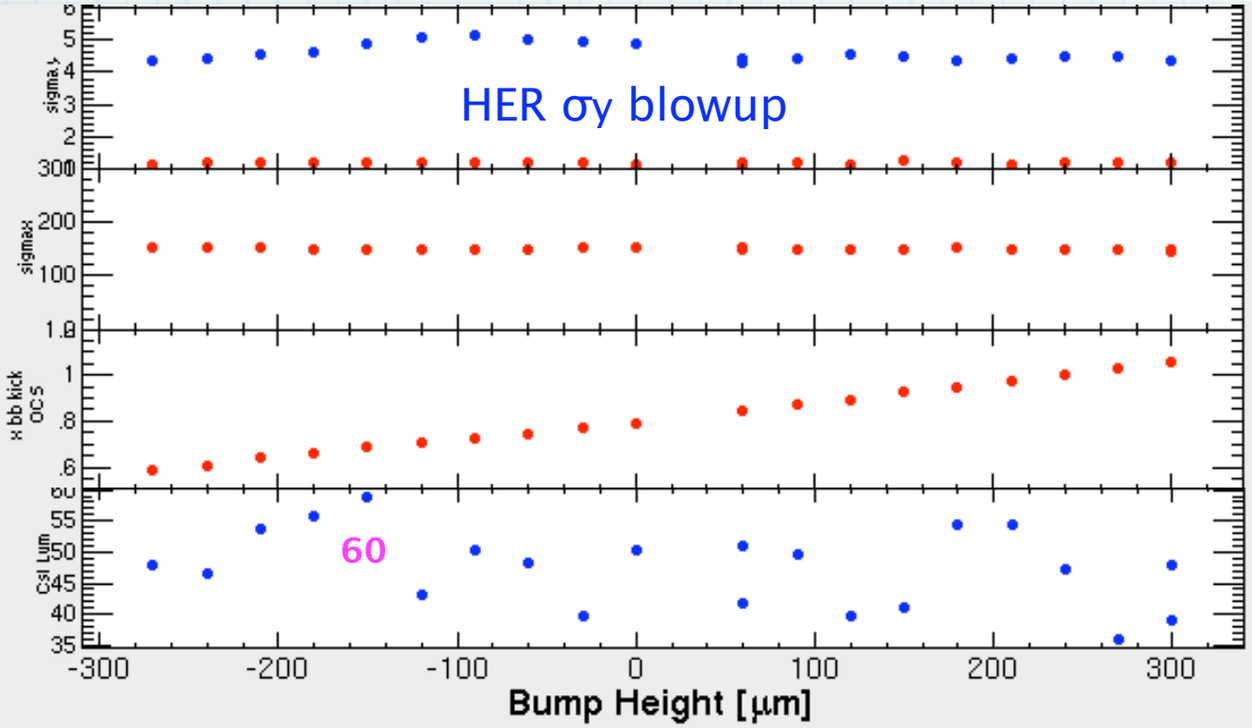
H. Koiso



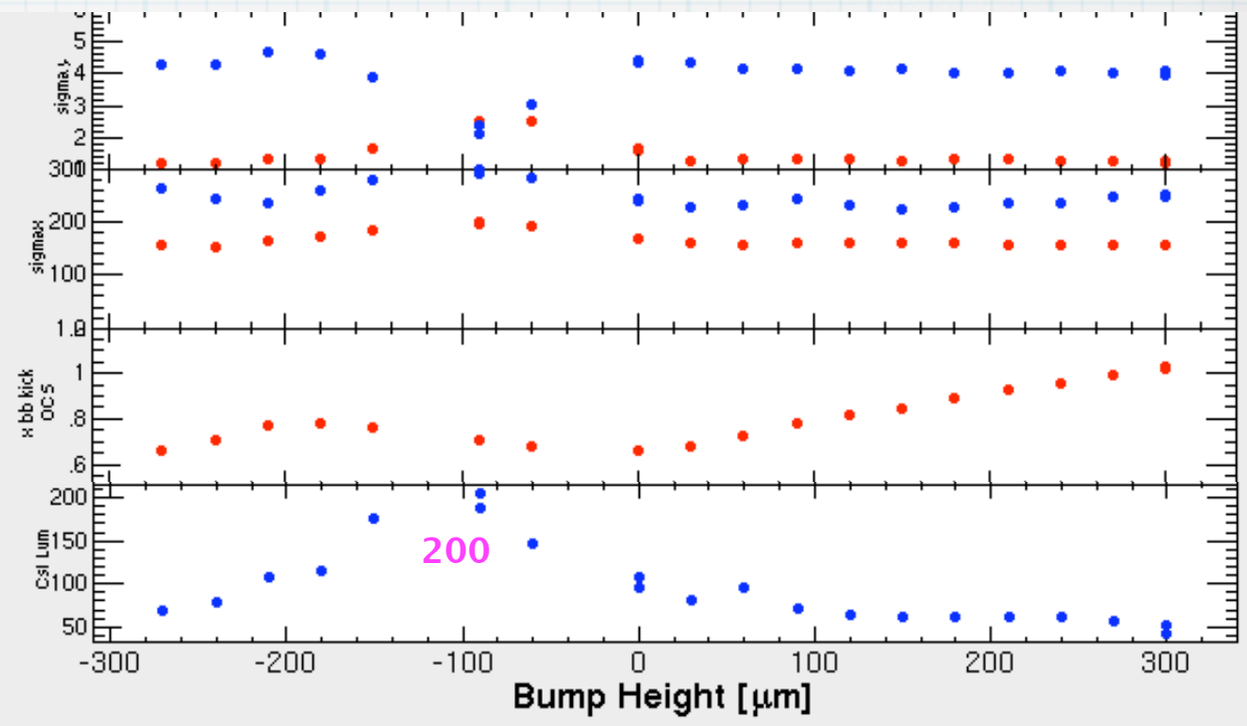
Reversed LER crab angle



Reversed LER & HER



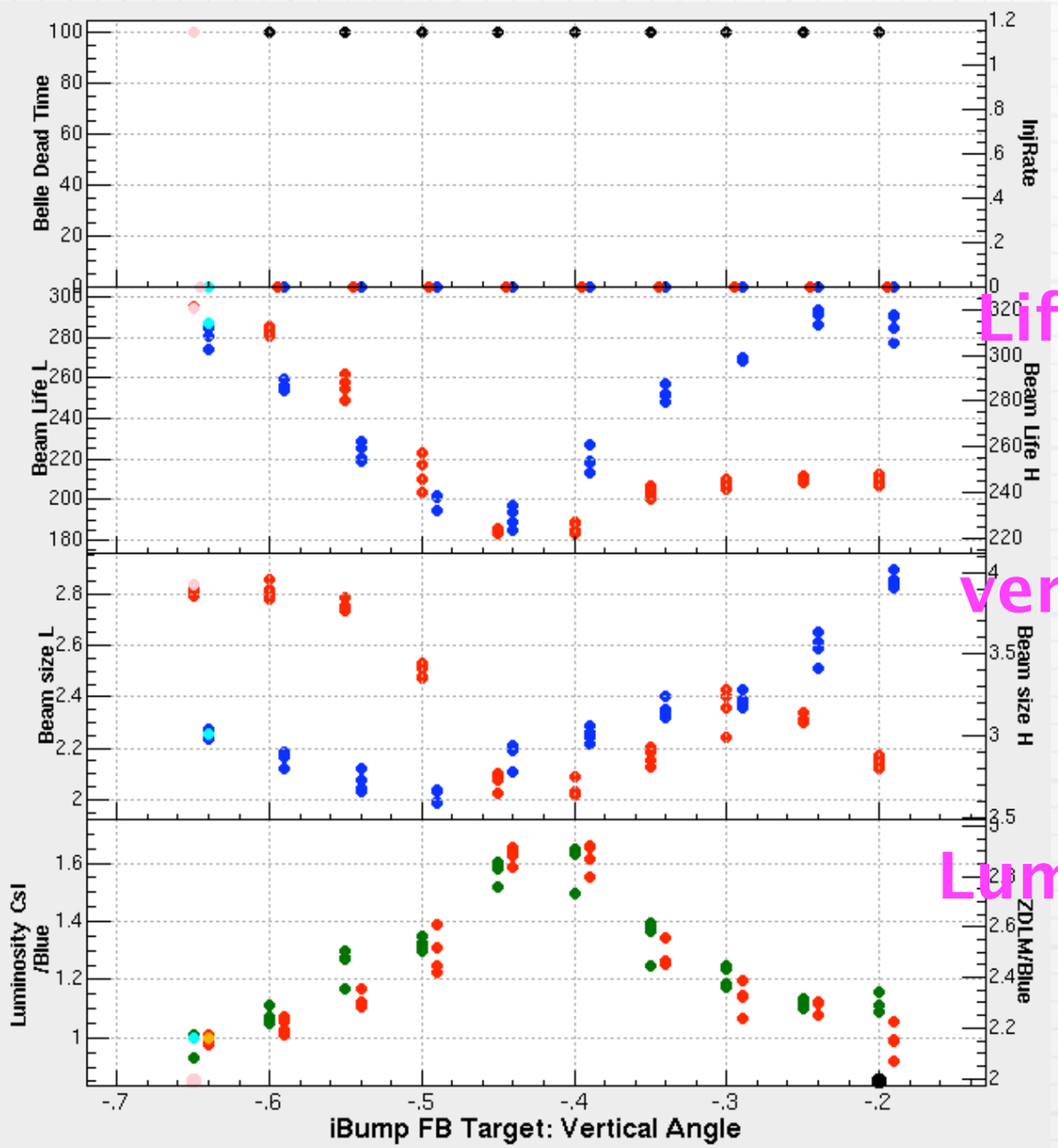
Reversed HER



Both correct

Vertical Crabbing ?

H. Koiso

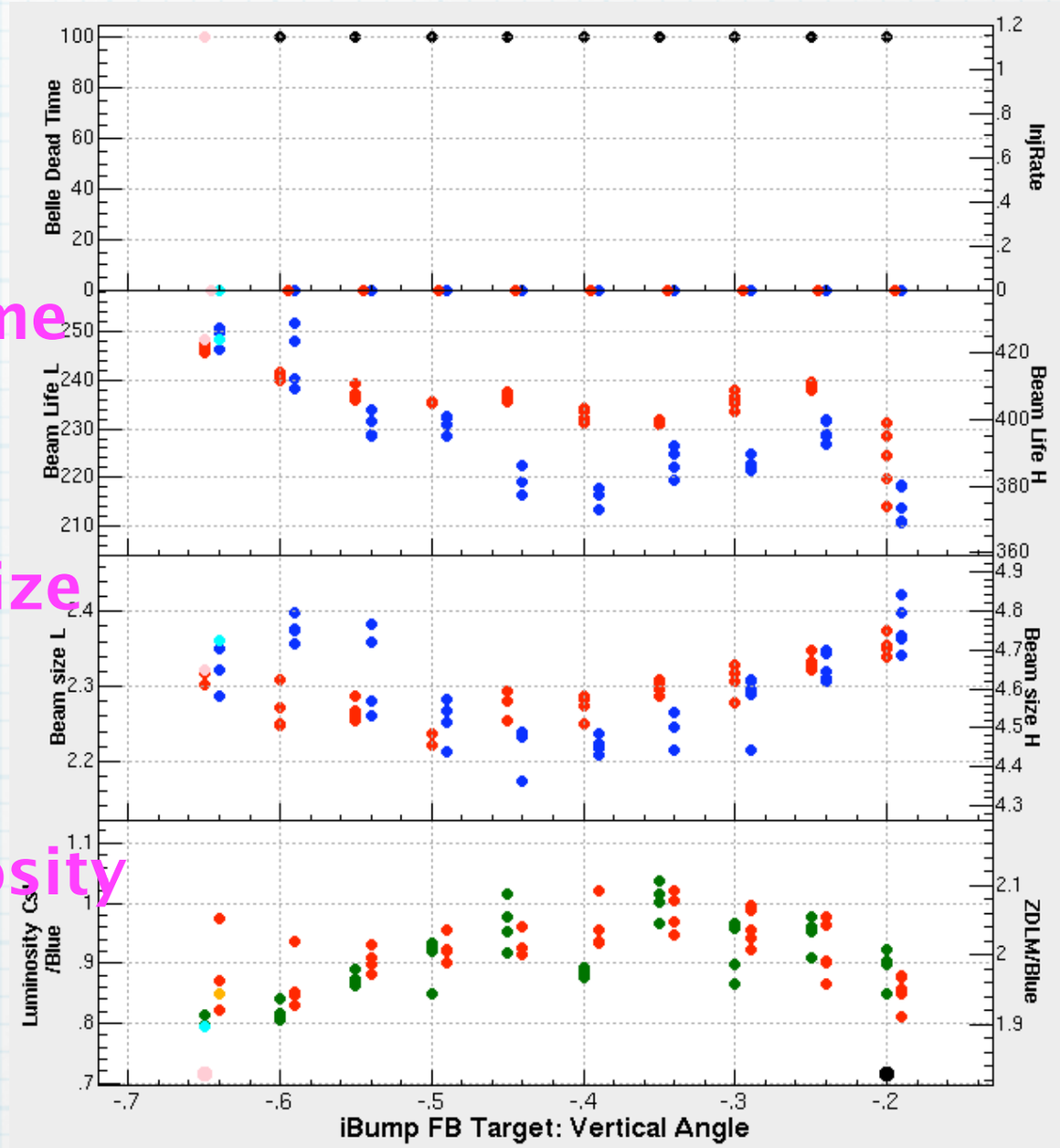


asymmetric

Lifetime

vert. size

Luminosity



more symmetric

Vertical size dependence on the vertical crossing angle should be symmetric around the vertical head-on collision.

How to find out the vertical head-on condition

H. Koiso

Adjust “R1” of one ring while fixing another to find the head-on condition.

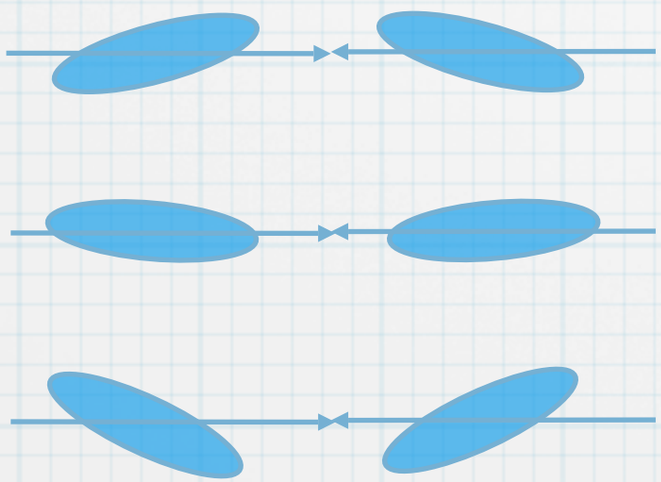
asymmetric

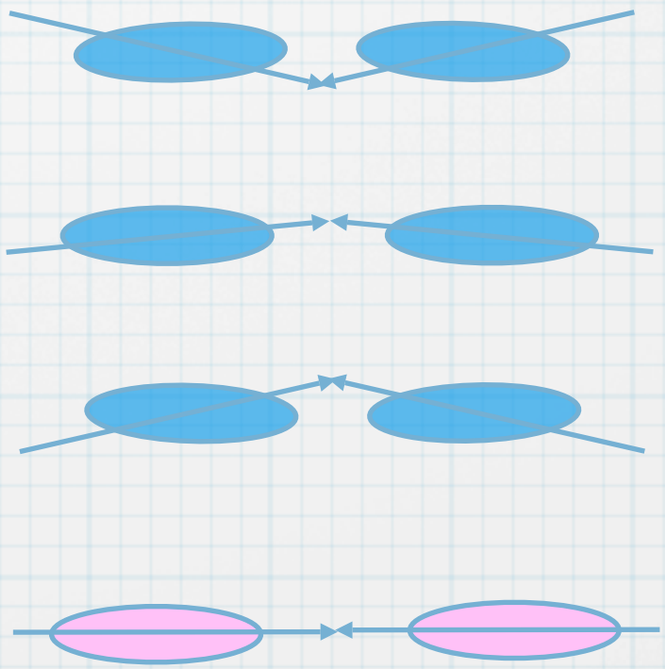
symmetric

Wrong choice of R1s

Right choice of R1s

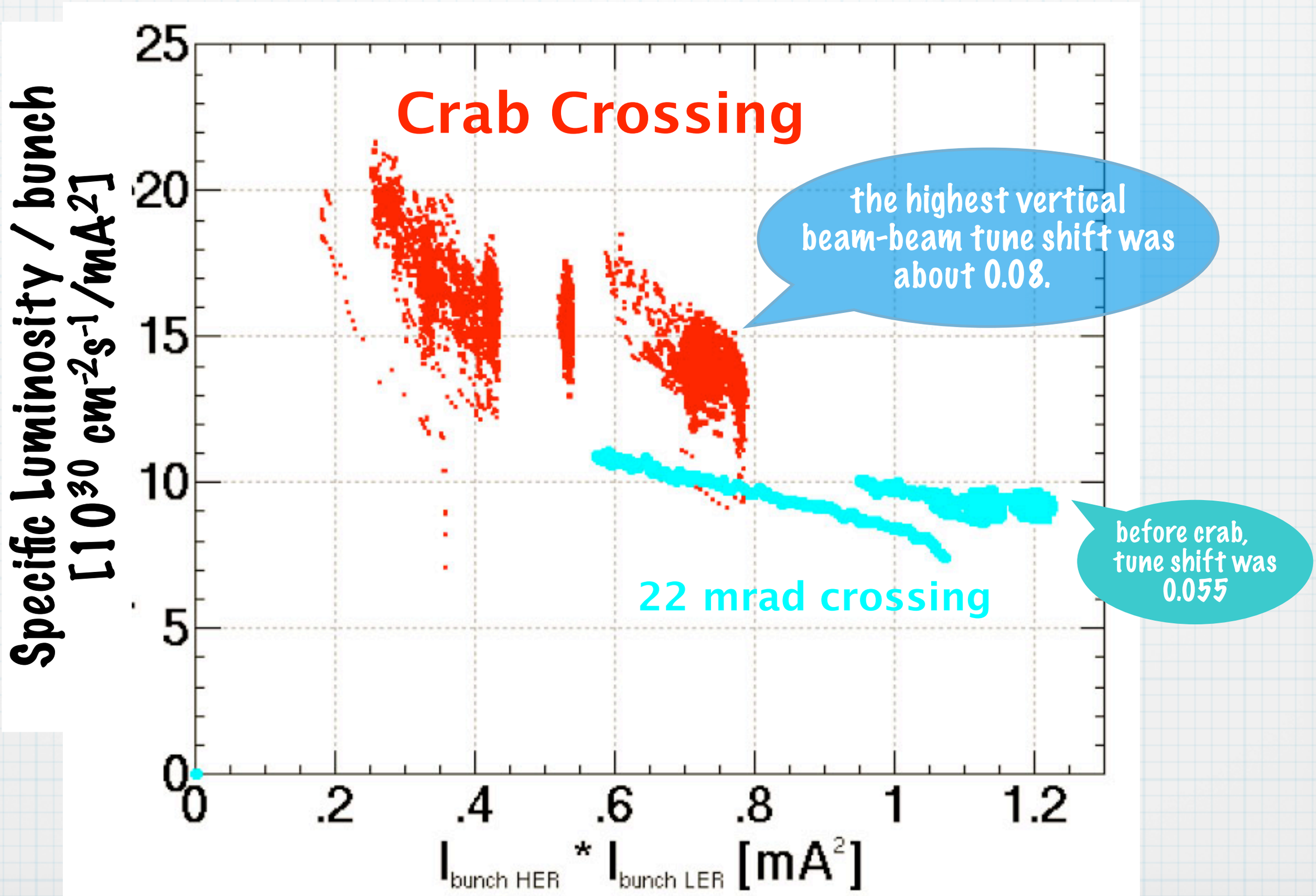
Vertical angle scan





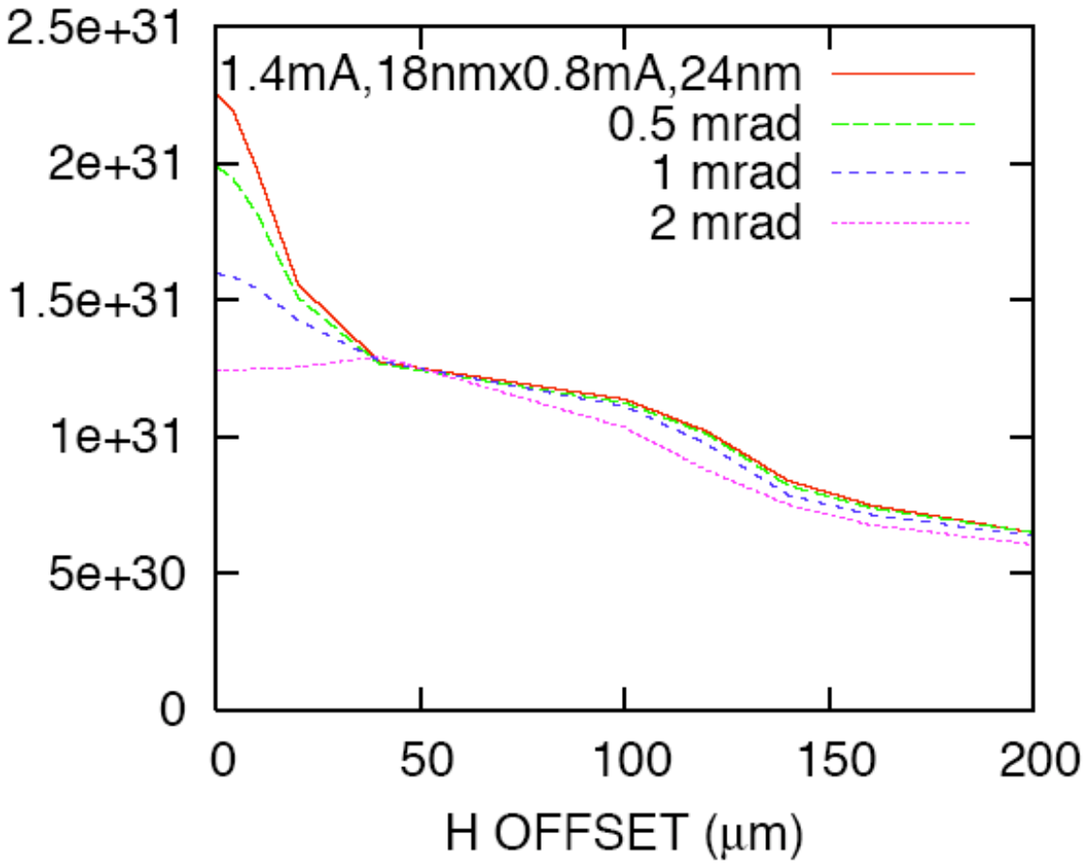
Specific Luminosity

H. Koiso

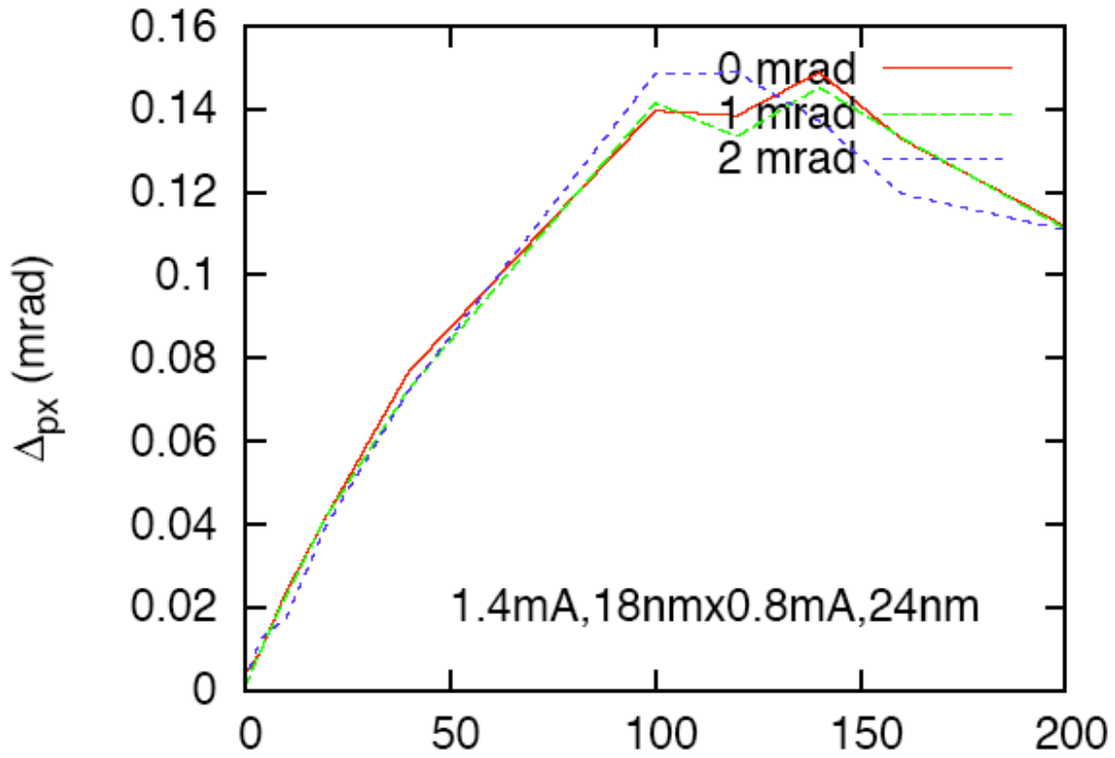


Sensitivity to the Horizontal Offset and the crossing angle at the IP

- Luminosity



beam-beam kick



K. Ohmi, 2007/3/5 report

- 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 examples.
- Horizontal offset must be much less than 40 μm to see the effect of crab crossing.
- There are more than 20 of such parameters. If one of them is off, the optima of other parameters cannot be found.

Dynamic Aperture with Crab Waist Scheme

* Beam-beam simulation by K. Ohmi has shown that the crab waist scheme will boost the luminosity of present KEKB, as well as the crab cavity.
* Lattice design was tried by H. Koiso and A. Morita.
* As the result, drastic degradation of the dynamic aperture was found. No good solution has been obtained.

Crab waist Oho-Nikko Version

H. Koiso

File Edit Settings Window 12/27/2006 09:44:14 Help

KEKB LER Optics: 2006/12/26DEC06G Convergence = .00000

ν_x = 45.50600 ν_y = 43.54000
β_x^* = .59000 m β_y^* = .00650 m

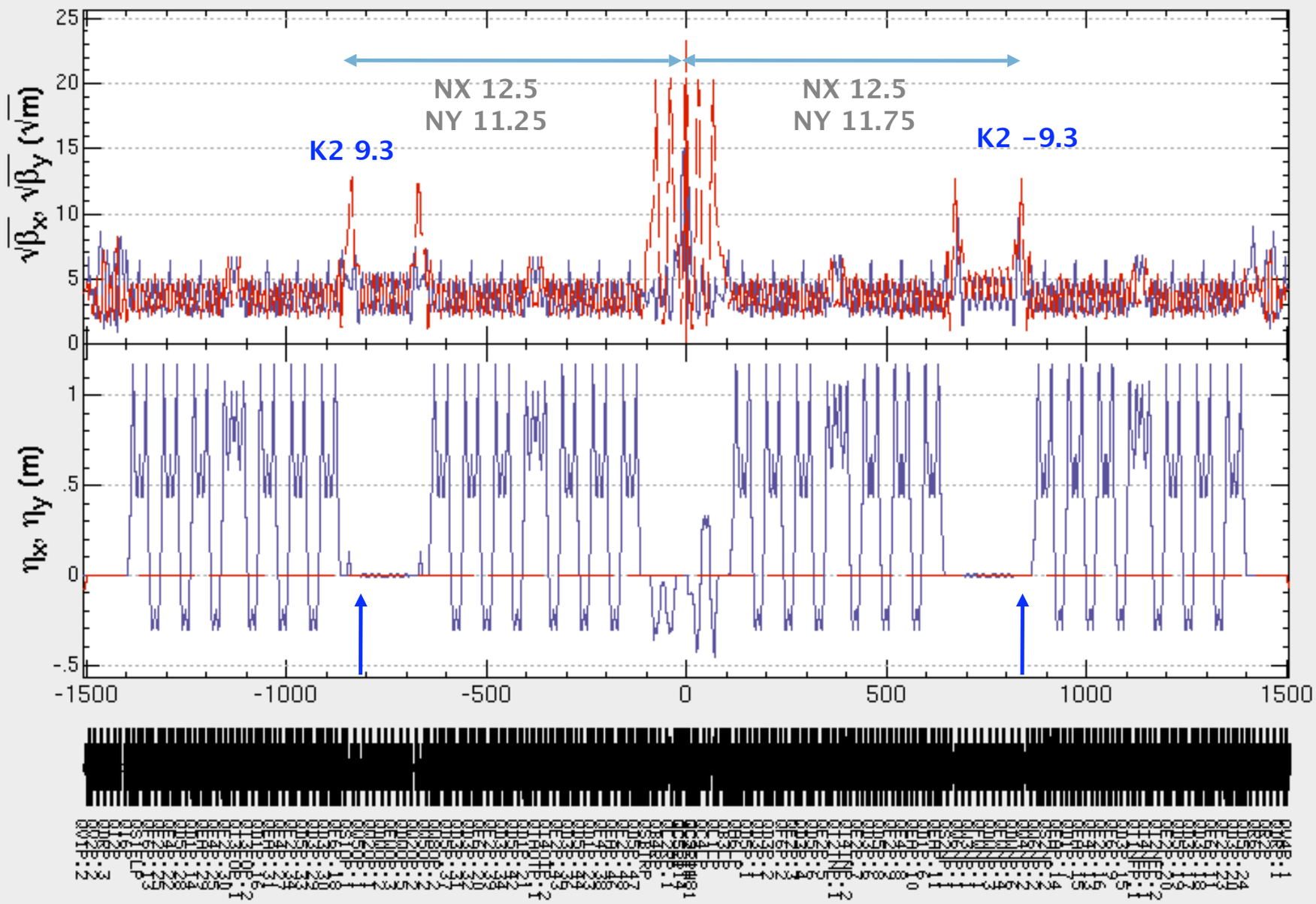
Ring | Tune Adjust | IR | Normal Cell | WigglerN | WigglerO | Chromaticity | Dynamic Aperture | Poincare Map | Magnet

Display All Ring

ε_x (m)	1.513894E-8
ε_y (m)	1.69073E-12
ε_z (m)	3.029441E-6
α	3.172496E-4
σ_z (mm)	4.16831
$\delta p/p_0$	7.267928E-4
U_0 (MV)	1.636932
$\delta V/p_0$	.028333
C (m)	3016.242600
Δs (m)	-.021358
f (Hz)	508890559.63
Δf (Hz)	-3603.462408
ν_s	-.0264
Crabing$_{IP}$ (mrad)	.0000

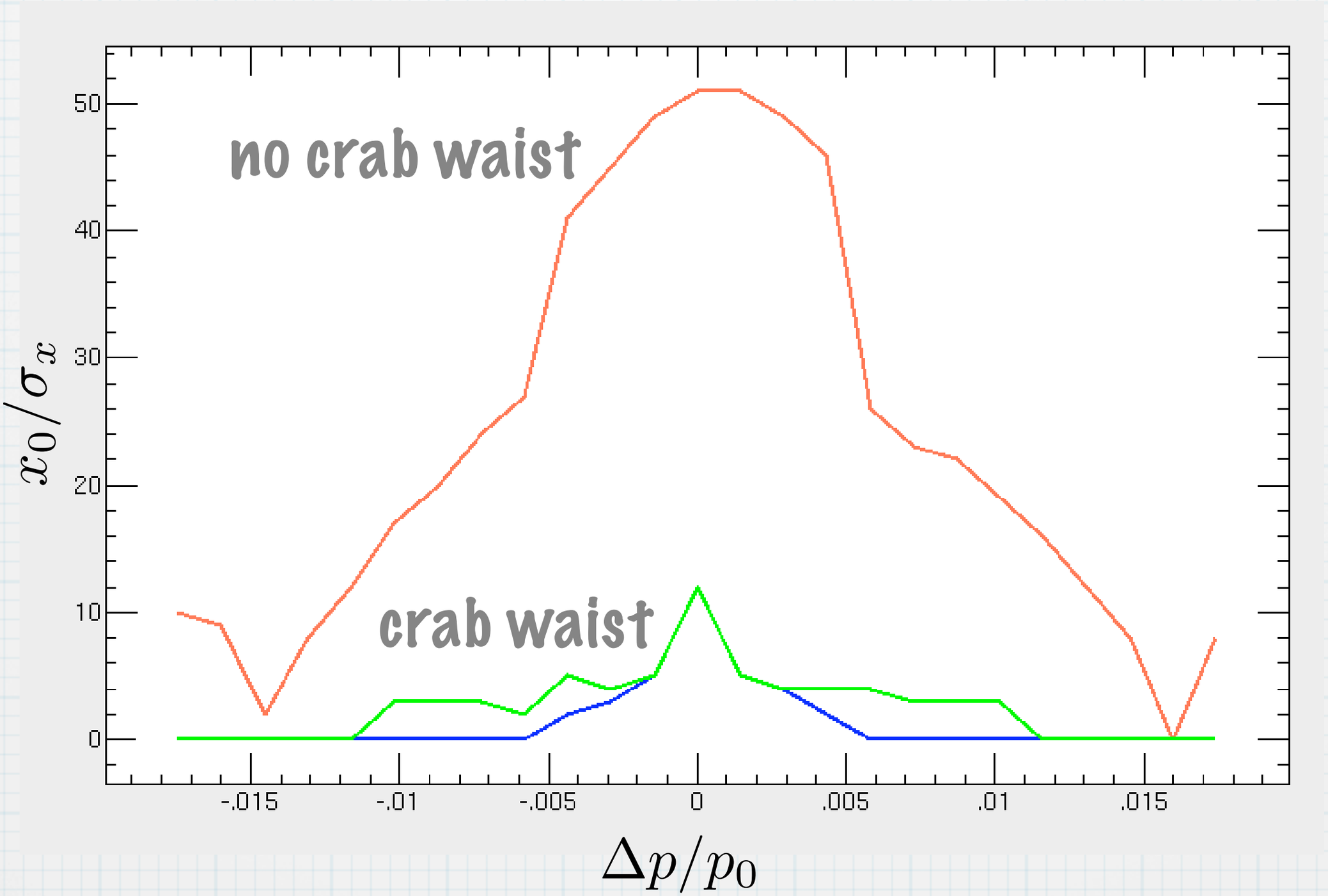
$\Delta f'$ (Hz)	.0	.0
V_c (MV)	9.60000	9.60000
V_{crab} (MV)	.00000	.00000
ϕ_{crab} (deg)	.000	.000

Calculate emittance



Crab waist Oho-Nikko Version

H. Koiso

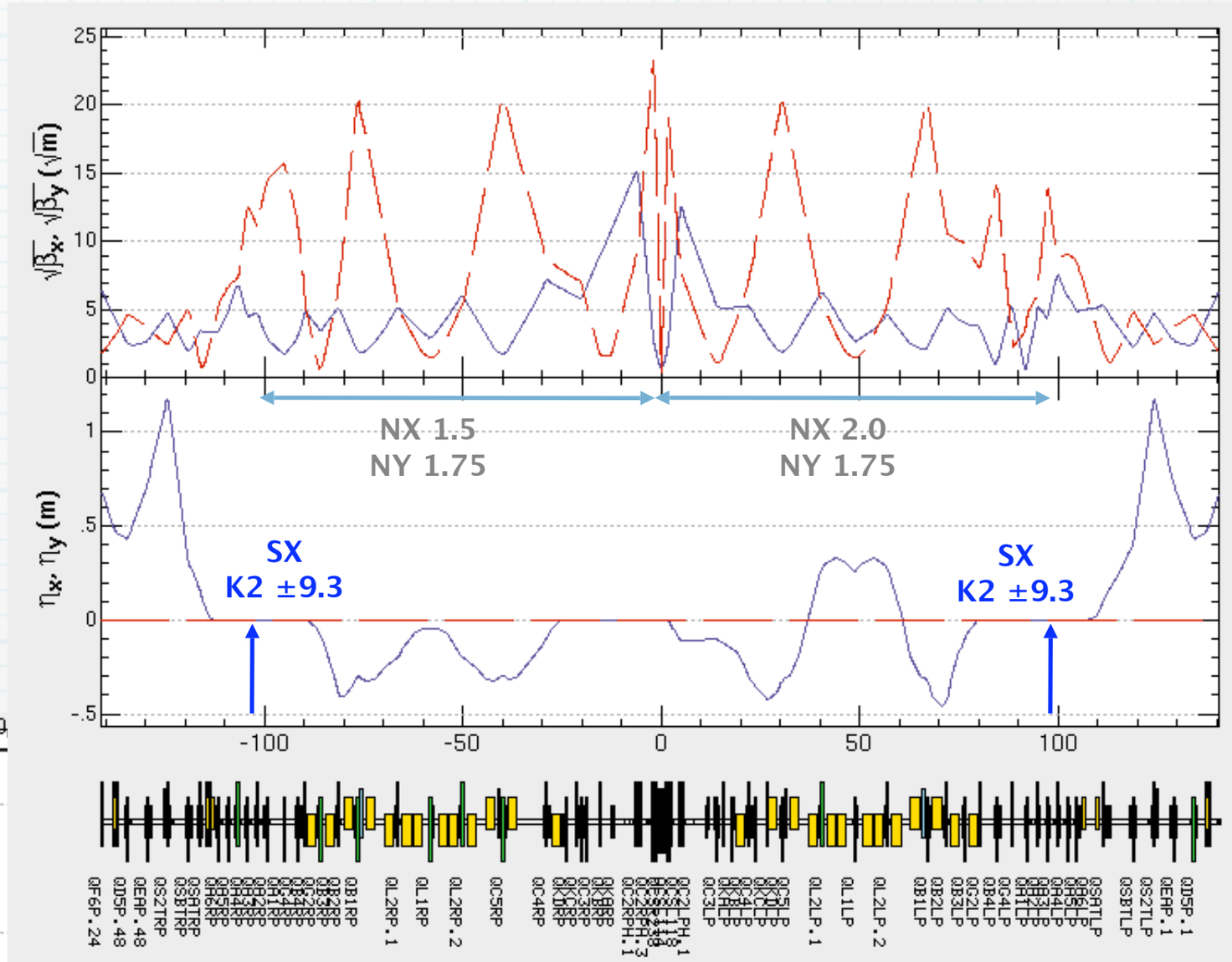


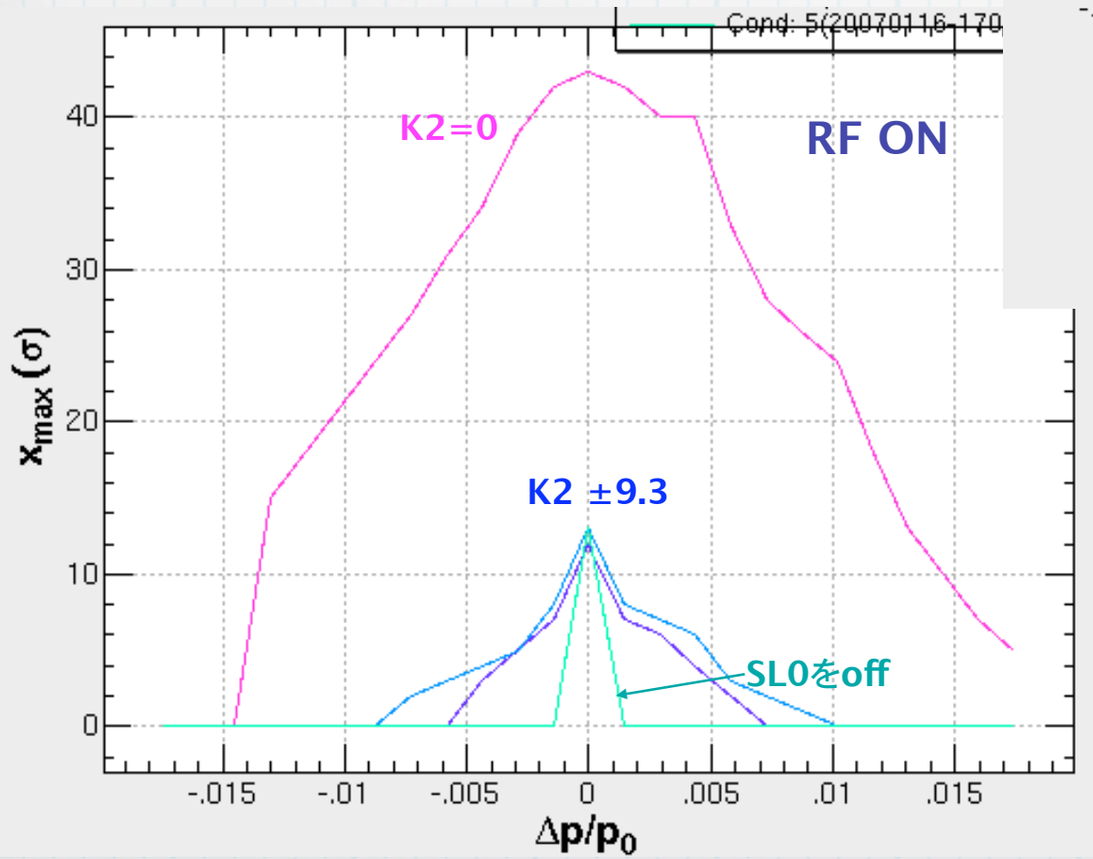
The dynamic aperture was drastically reduced by Crab Waist sextupoles.

Crab waist Tsukuba Version 1

H. Koiso

- Put crab waist sextupoles closer to the IP.
- **-I' transformer between sexts.**
- **BX/BY=21/150 @ SCWTR/L**
- Dynamic aperture again drastically reduced.

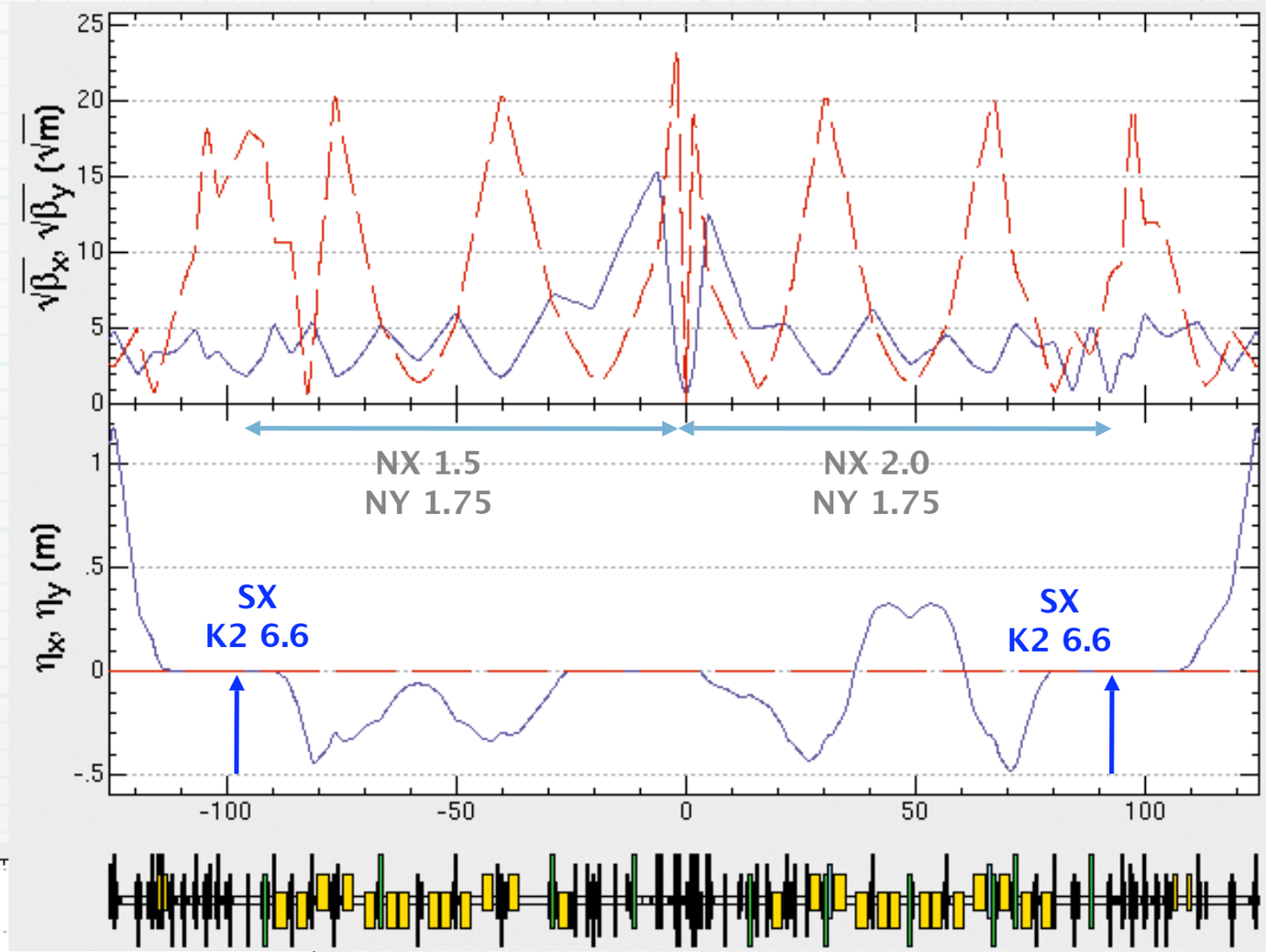


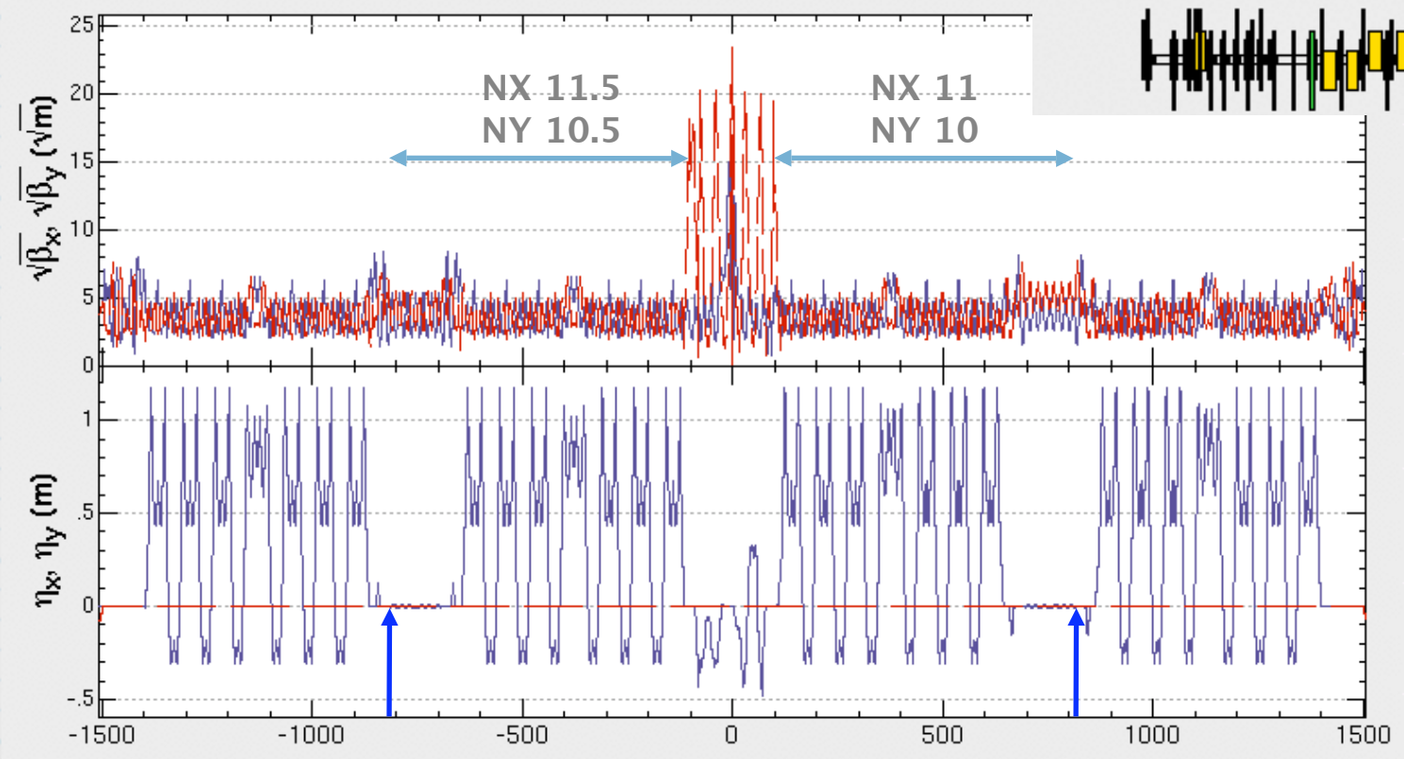


Crab waist Tsukuba Version 2

H. Koiso

- Two sexts close to the IP.
- **Put 2 sexts to cancel x^3 term.**
- **BX/BY=10/300 @ SCWTR/L**
- **BX/BY=60/15 @ SCWN/O**
- Remove solenoids, nonlinearities in quads.
- **Zero thickness sexts.**



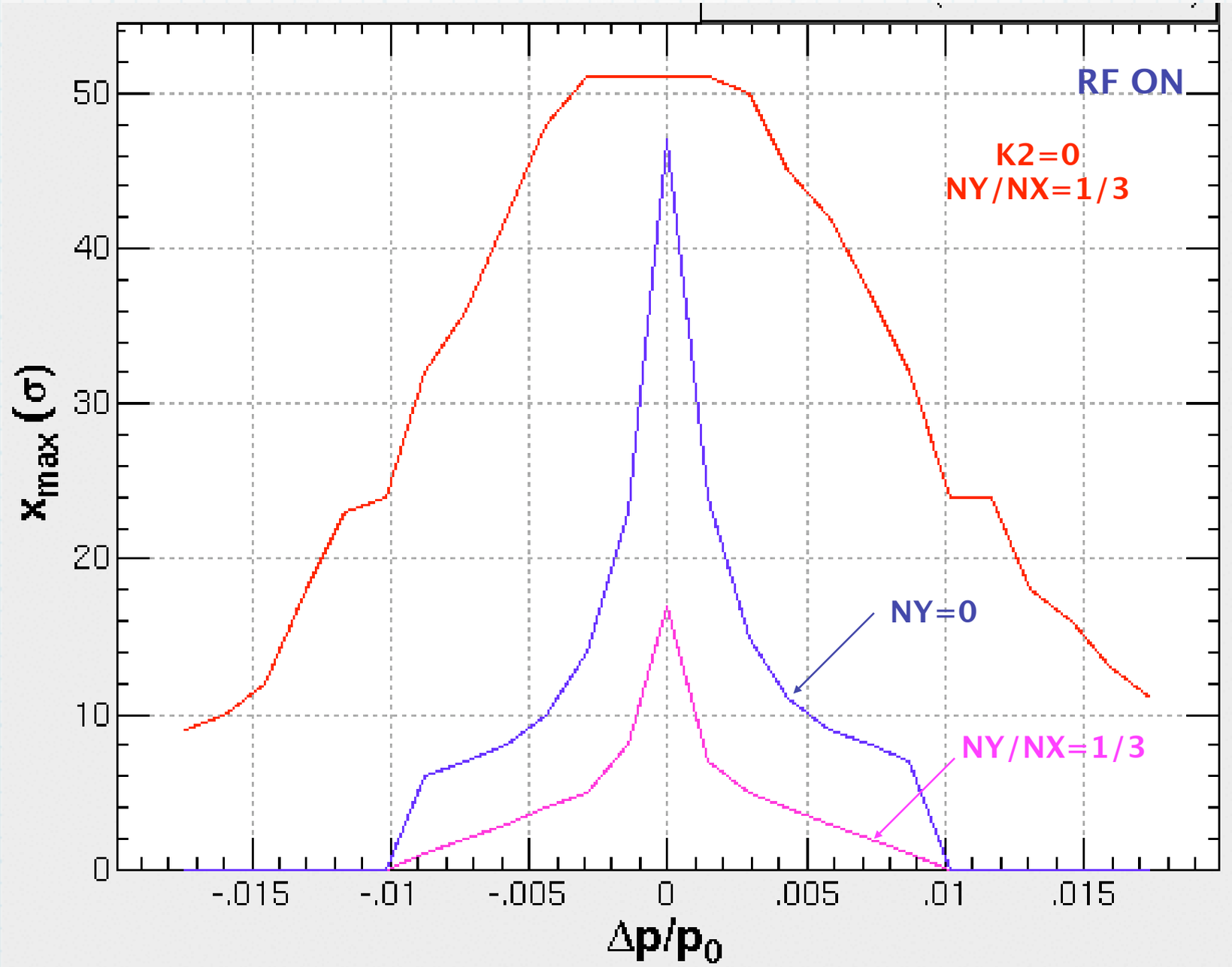


筑波6極間は-I'

SCWTR/L: K2=+6.6
SCWN : K2=-.449
SCWO : K2=+.449

Crab waist Tsukuba Version 2

H. Koiso

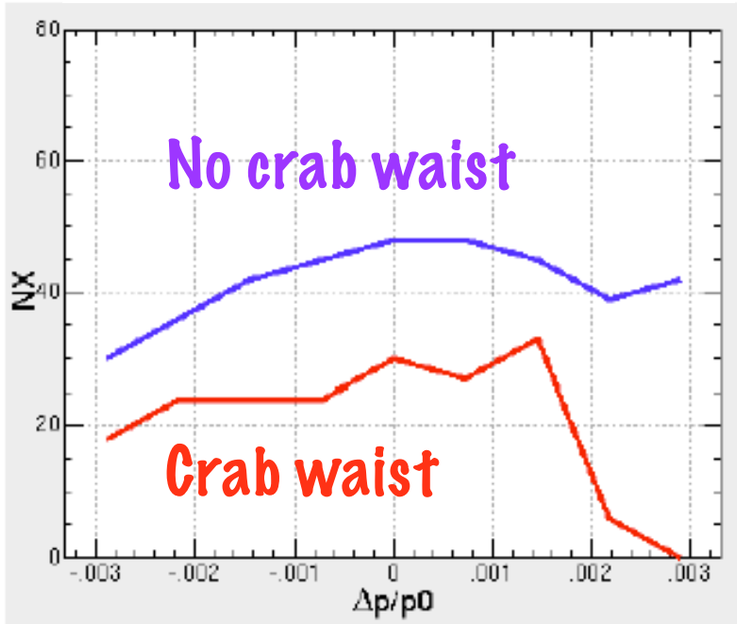
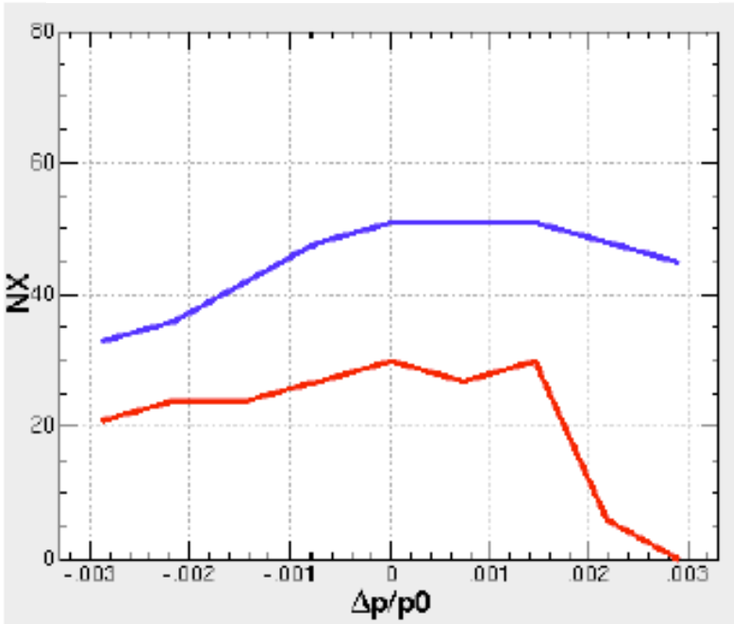
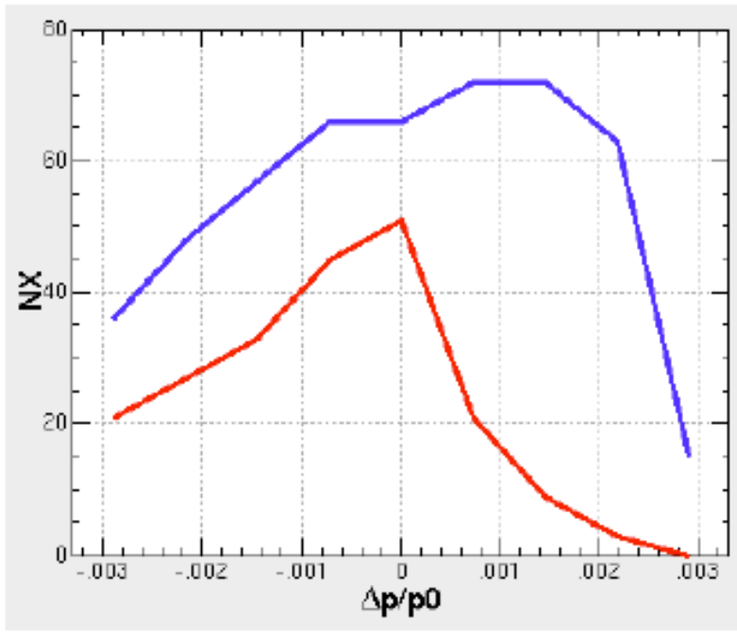
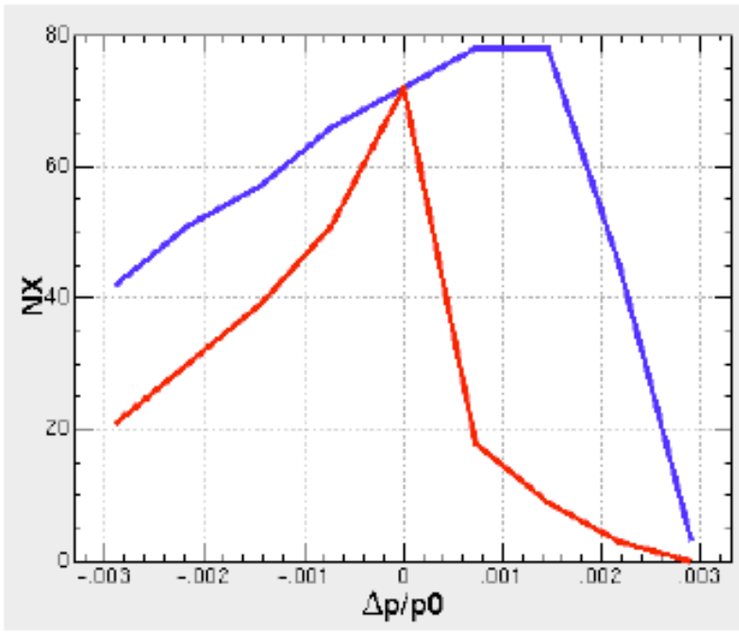


The on-momentum aperture recovered if y0 = 0.

Optics: 27JAN07C solenoid skewQ なし
SCWTR/L: Bx/βy = 10/300 m |K2|=6.6
SCWN/O : Bx/βy = 60/15 m |K2|=0.449

Crab waist Simple IP

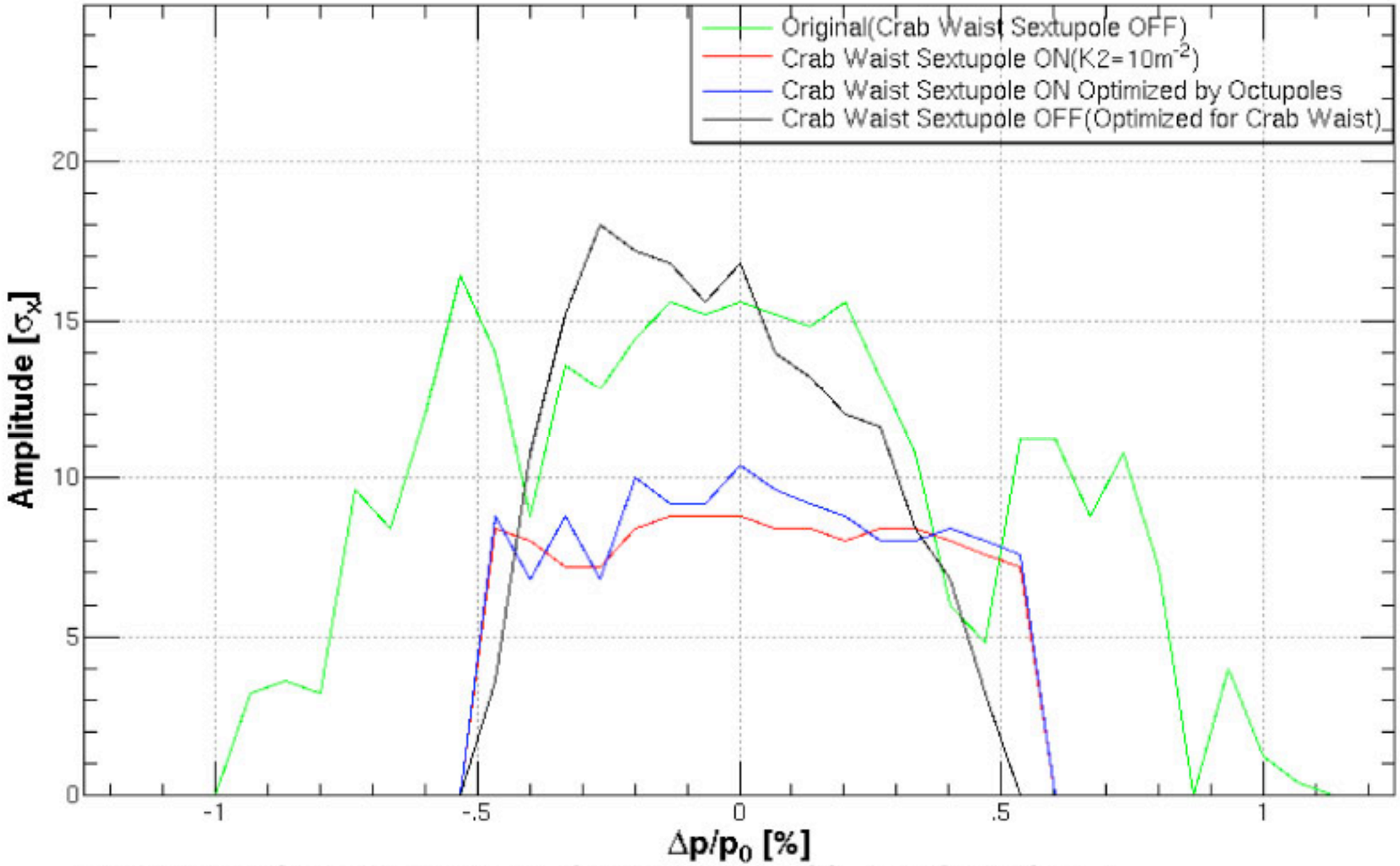
H. Koiso

	With kinematical term	Without kinematical term
With fringe		
Without fringe		

The dynamic aperture was recovered when both the fringe field of the IR quadrupoles and the kinamatical temr was turned off.

Dynamic Aperture of HER Model Optics

A. Morita



- Tracking Condition: XY-Coupling 10%, RFSW OFF
- K2 and K3 parameters are optimized by TPSA/AN

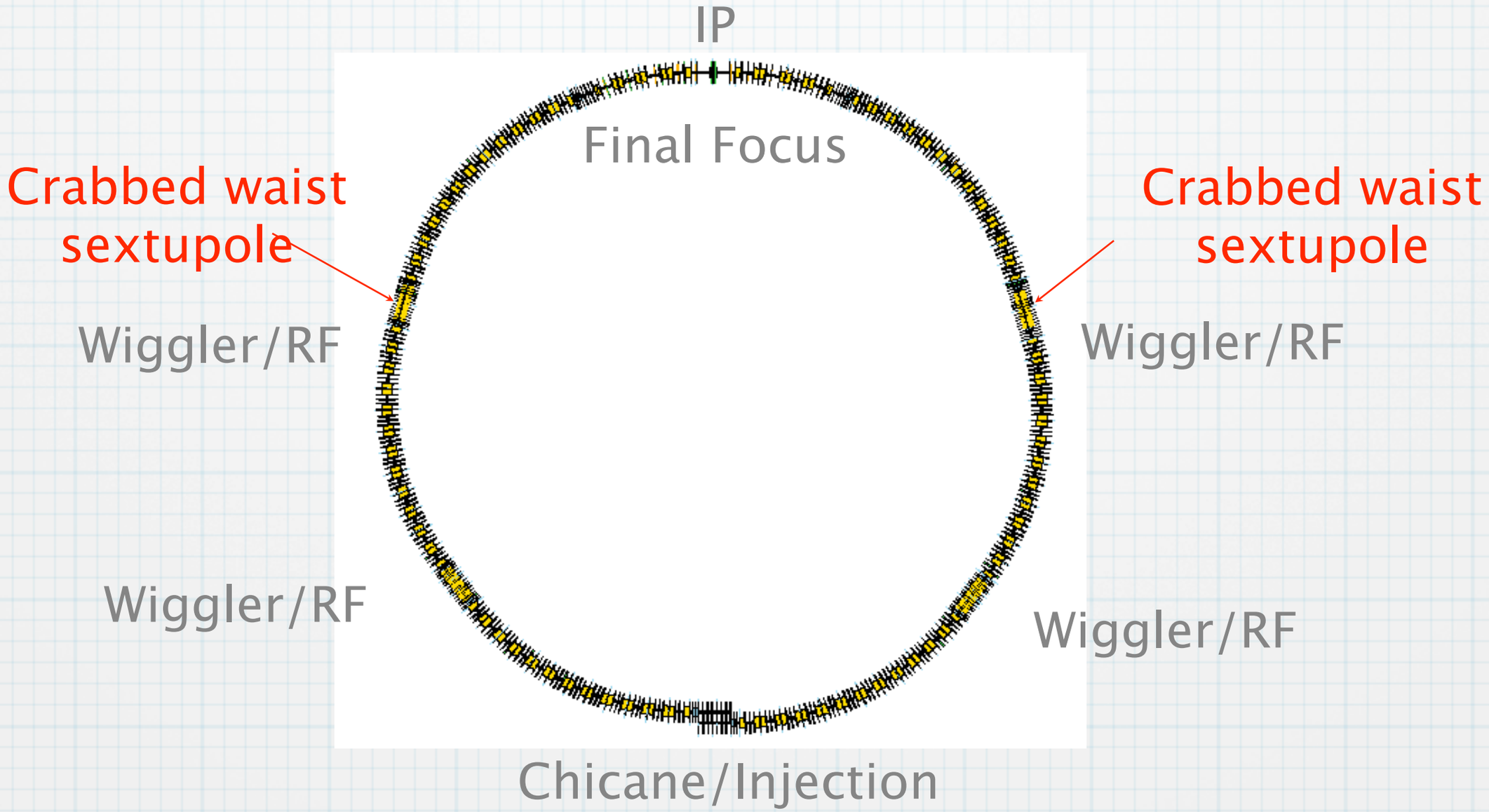
Enlargement of dynamic aperture was tried by introducing many octupole magets, but not yet very successful.

Dynamic Aperture with Crab Waist Scheme (2)

* Y. Ohnishi has made a semi-complete lattice design for Super B (tiny emittance & tiny beta).
* Again the dynamic aperture was drastically reduced by the crab waist sextupoles.

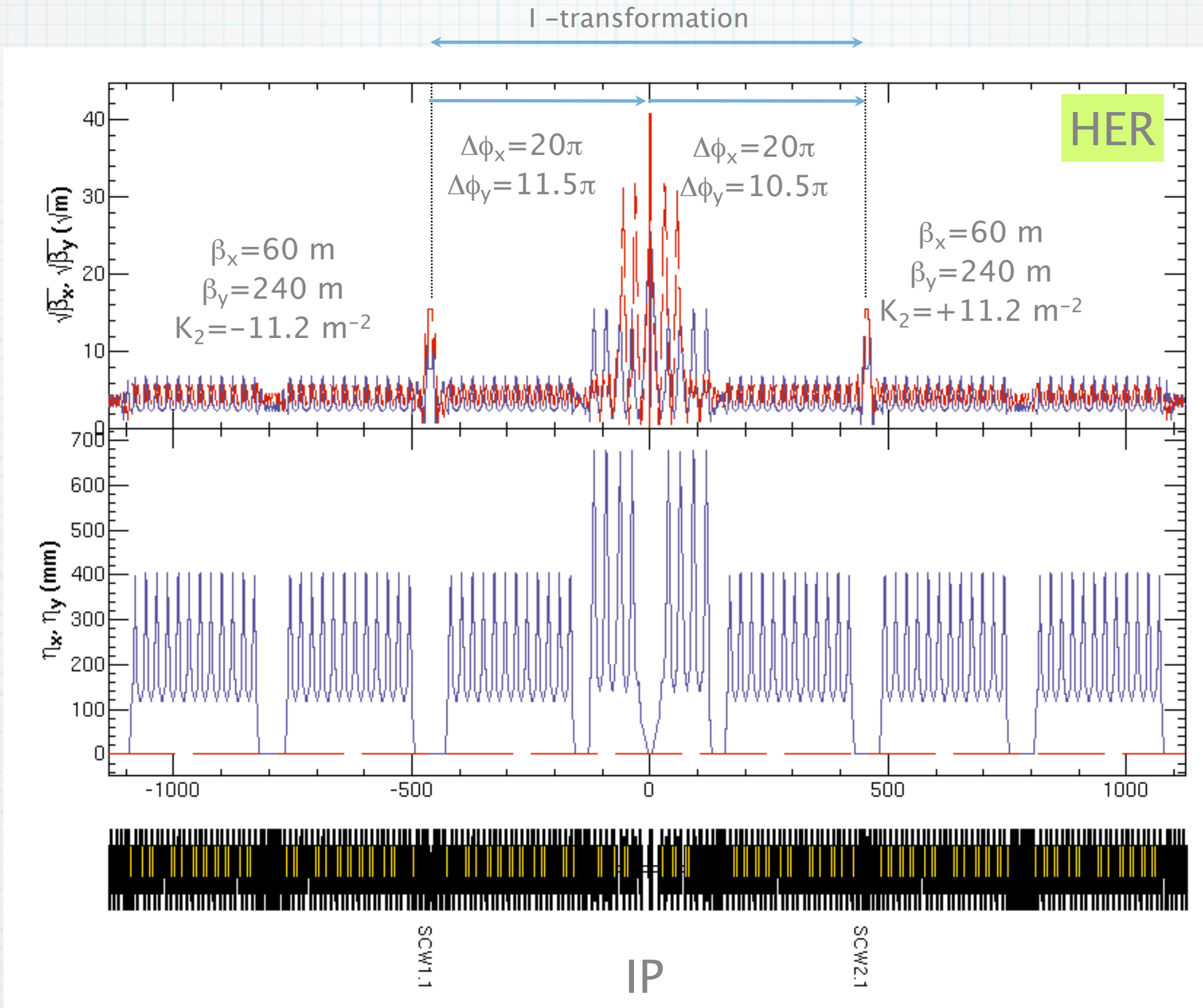
Layout of the SuperB Ring

Circumference ~2.3 km



Y. Ohnishi

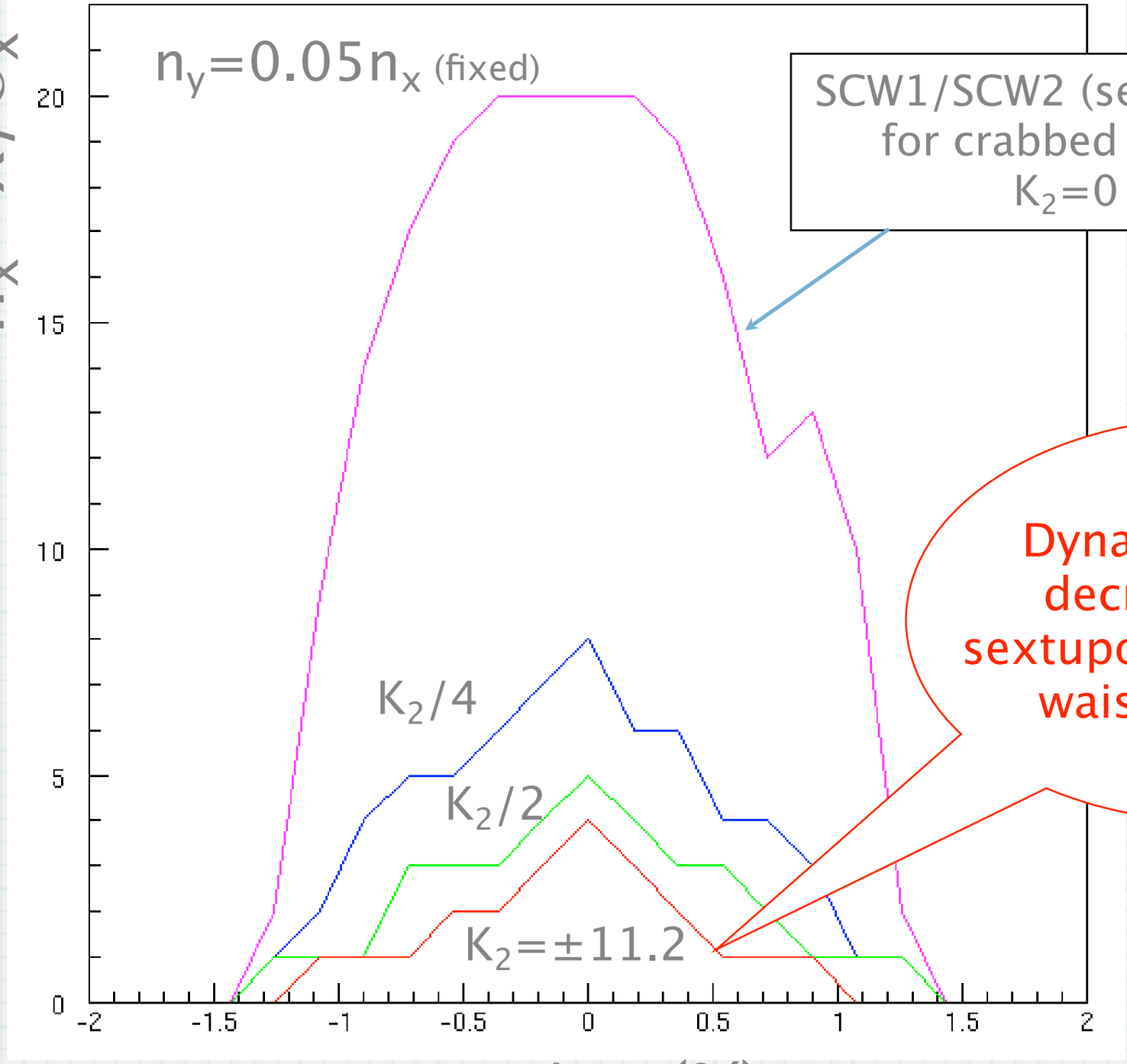
SuperB Lattice with Crabbed Waist



Y. Ohnishi

Dynamic Aperture

HER



SCW1/SCW2 (sextupoles for crabbed waist)
$K_2=0$ $\tau_{Touschek}$=16 min

$N_p = 2.94\times10^{10}$
$\varepsilon_y/\varepsilon_x$ = 0.25 %

$\Delta\nu_x$= 49.56
$\Delta\nu_y$= 24.60

Dynamic aperture decreases when sextupoles for crabbed waist turned on.

Synchrotron radiation: ON
Quantum excitation: OFF
1 damping time

Y. Ohnishi

Tiny Emittance & tiny β Option for SuperKEKB

* Although the crab waist may not have a solution of the lattice, it is not essential for SuperB to achieve 10^{36} (P. Raimondi).

* The tiny emittance & tiny β scheme of SuperB may have difficulties in injection, lifetime, stability, etc., but it is not easy to prove them against SuperB people.

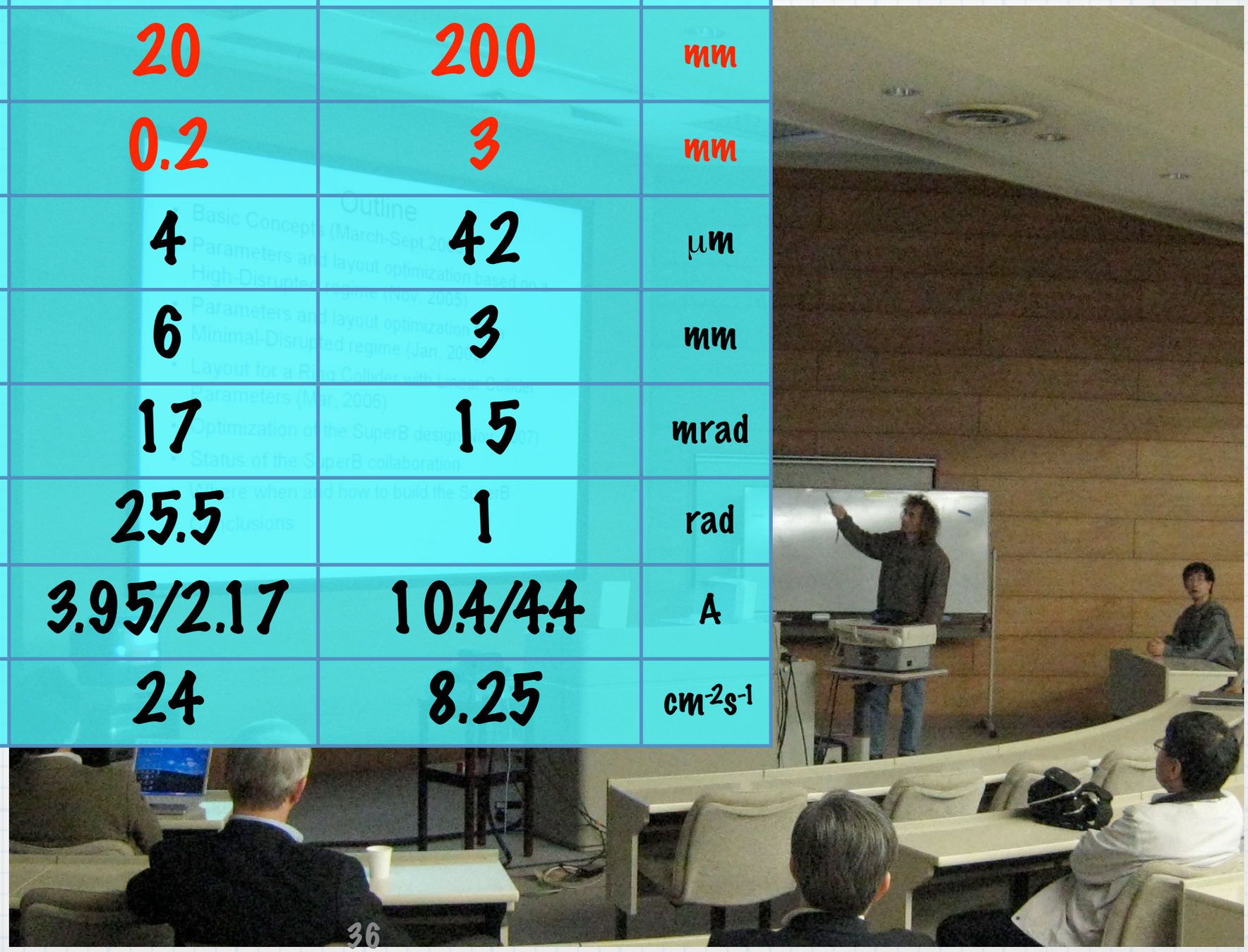
* Having the tiny emittance & tiny β option for SuperKEKB will bring more robustness in the operability of the machine.

* By pursuing such an option may clarify issues which are common for both SuperB and SuperKEKB.

* We do not abandon the present high emittance & high current version, but make the lattice and the IP adjustable to both schemes.

Comparison of Machine Parameters

		SuperB (Upgrade)	SuperKEKB (2006)	
Emittance	ε_x	0.8	9	nm
Horizontal beta	β_x^*	20	200	mm
Vertical beta	β_y^*	0.2	3	mm
Horizontal beam size	σ_x^*	4	42	μm
Bunch length	σ_z	6	3	mm
Half crossing angle	ϕ_x	17	15	mrad
Piwinski angle	φ	25.5	1	rad
Current(LER/HER)	I_b	3.95/2.17	10.4/4.4	A
Luminosity ($\times 10^{35}$)	L	24	8.25	$cm^{-2}s^{-1}$



Summary

* The crab cavities were successfully produced and have been operated at KEKB with beam. No serious problem has been found up to now, at least at low current.

* The crab crossing was done first at KEKB. An effective head-on collision was basically achieved. High gain in the luminosity needs more time for tuning and development of method.

* The crab waist scheme may have difficulties in dynamic aperture due to the sextupoles.

* SuperKEKB will pursue a solution of adjustability to a tiny emittance & tiny β option comparable to SuperB.

JAHEP's statement

- On Oct. 25, 2006, The Japan Association of High Energy Physicists (JAHEP) unanimously approved Prospects for Elementary Particle Physics saying:

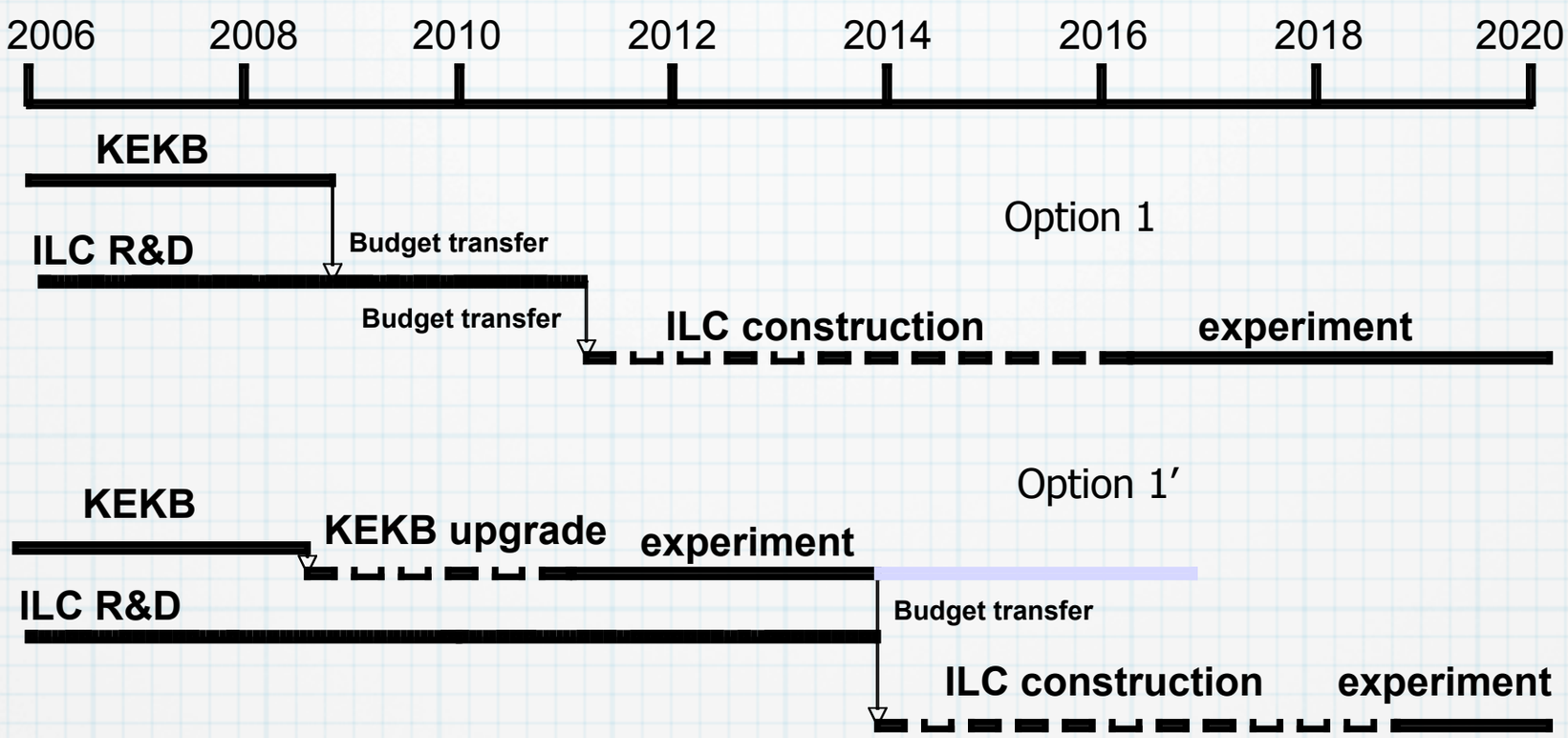
We, the Japanese HEP community, recognize that physics at the energy frontier is of primary importance. With this understanding, we give the highest priority to the realization of the ILC. Before the ILC experiment commences, we will also promote flavor physics that is complementary to physics at the energy frontier. We should pursue the above two goals as a single master plan.

Japan is now taking the lead in a wide range of accelerator technologies that are essential to carry out the ILC and flavor experiments. To realize the ILC, we have to facilitate industrialization of state-of-the-art accelerator technologies and boost accelerator R&D for the ILC. For this purpose, we will unify the existing accelerator R&D activities for both the energy frontier and the flavor physics projects.

In Japan, the K2K experiment, which was the first long-baseline neutrino experiment in the world, was carried out successfully while the KEK B factory has been constantly improving world luminosity records. Furthermore, J-PARC construction will be completed soon. Based on these achievements, we will endeavor to make neutrino and kaon experiments at J-PARC successful, and promote an upgrade of the B factory to achieve a significant breakthrough in luminosity in order to explore new physics that emerges in the phenomena of b, c and τ decays.

- Since then, no official response has been made by the Management of KEK.
- No budget request to the government for any new projects will be possible before the completion of J-PARC (JFY2009).

Options in KEK's HEP program



* KEK will announce in this summer that R&D for SuperKEKB is an official program of the lab.

* Following this announcement, Belle will call for participation in the detector design effort. The new collaboration at SuperKEKB is not just an extension of the present Belle, but is open to the international flavor physics community.