Negative Momentum Compaction at KEKB

H.Ikeda

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KEKB Lattice

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- RF wave-guide system
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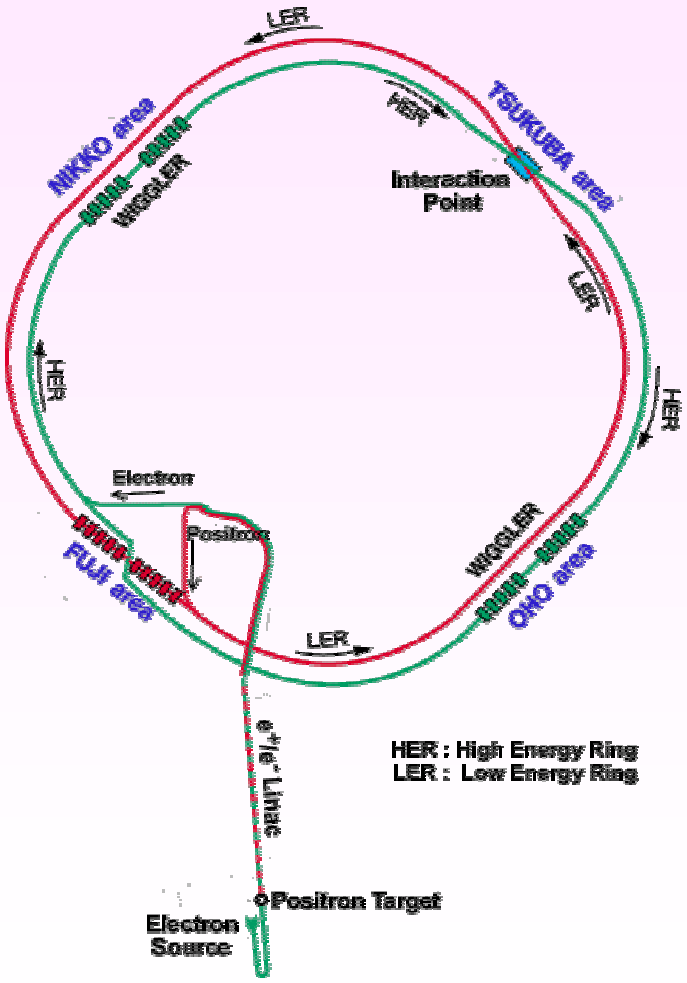
Summary

Introduction : KEKB Accelerator

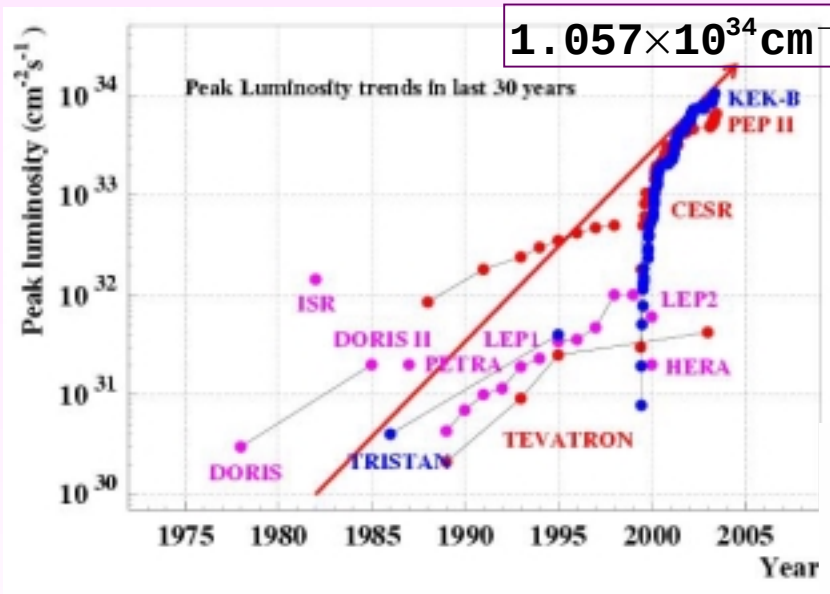


KEKB is a high luminosity machine.

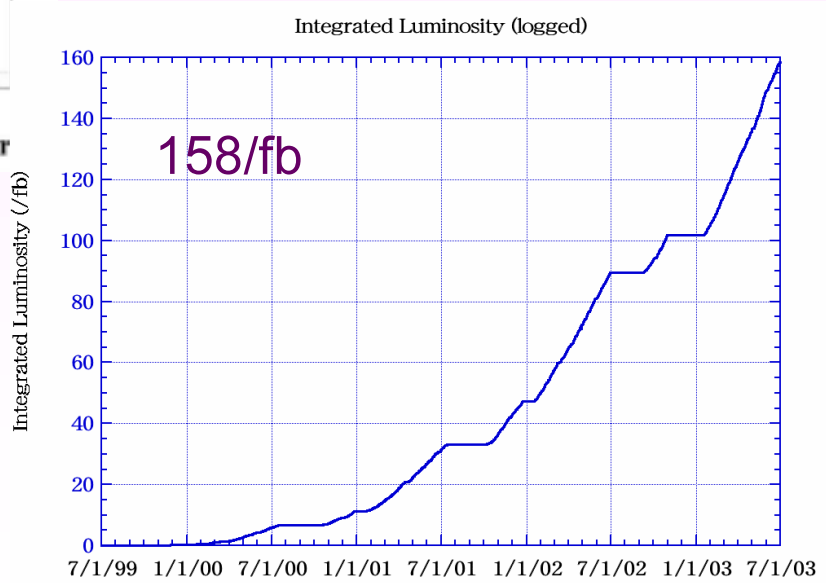
- Asymmetric energy e+e- (8GeV/3.5GeV) .
- High current (1.8A/1.1A).
- Crossing angle = ±11 mrad
- Circumference = 3016 m

Introduction : KEKB Accelerator

$1.057\times10^{34}\mathrm{cm}^{-2}\mathrm{s}^{-1}$



We have achieved the world's highest luminosity.



Introduction : KEKB Accelerator

Data	5/13/2003		Design		
Ring	LER	HER	LER	HER	
Current	1.38	1.05	2.6	1.1	A
Bunches	1265		5000		
Bunch Current	1.09	0.83	0.52	0.22	mA
Spacing	1.8 or2.4		0.6		m
Emittance εx	18	24	18	18	nm
εy/ εx	4.7	2.9	2	2	%
βx	59	58	33	33	cm
β y	0.58	0.70	1.0	1.0	cm
Hor.size @IP	103	118	80	80	μm
Ver.size @IP	2.2	2.2	1.9	1.9	μm
Beam-beamξx	.093	.068	.039	.039	
Beam-beamξy	.065	.051	.052	.052	
Luminosity	10.57		10		/nb/s
∫Lum/day	579		~ 600		/pb
∫Lum/7day s	3876				/pb
∫Lum/30days	12809				/pb

Introduction : KEKB Accelerator

In order to get higher luminosity, β_y^* was squeezed down below the design value and ξ_y of the LER was raised.

The bunch length is longer than design value and it may cause a luminosity reduction due to the hourglass effect.

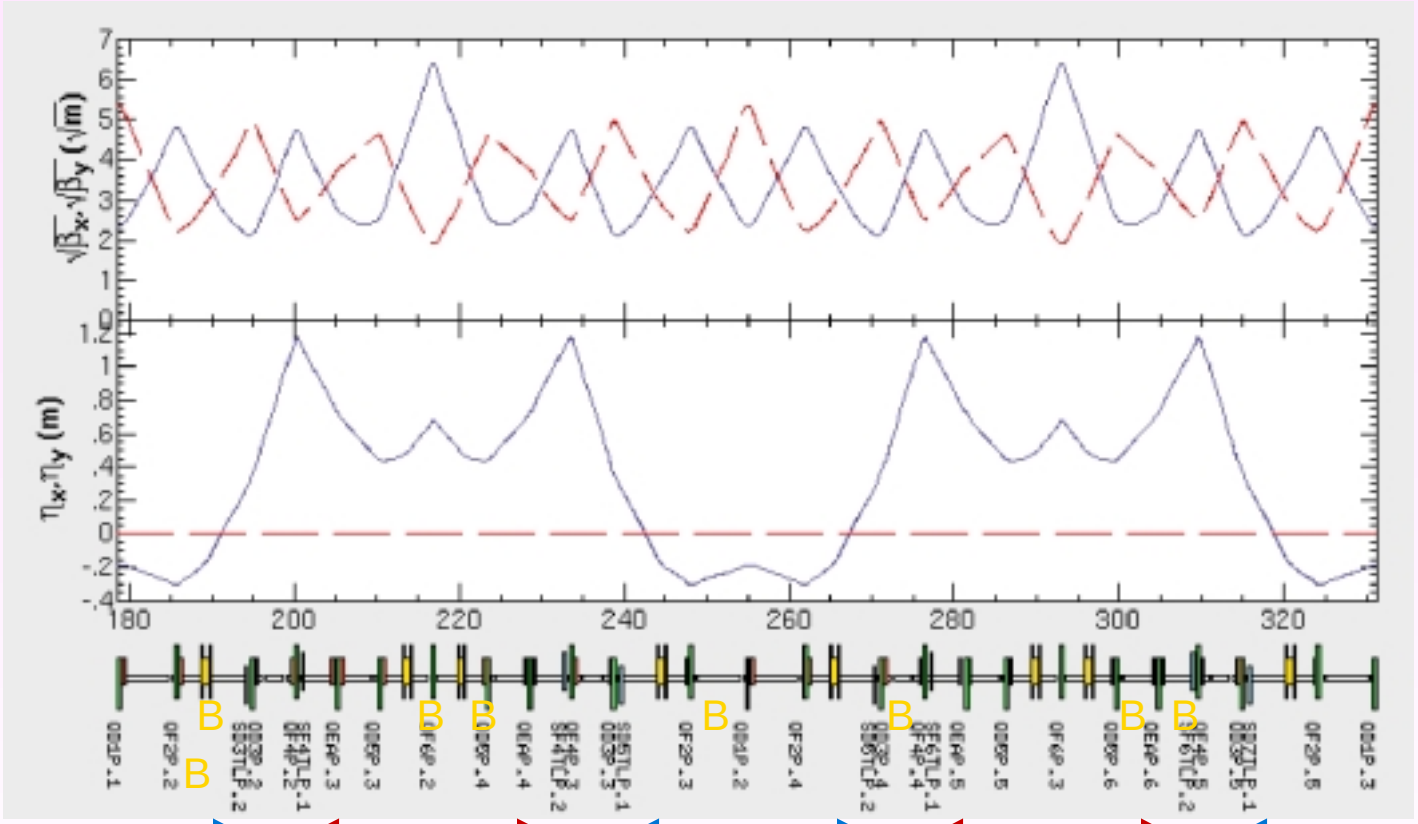
We tried negative momentum compaction optics in order to shorten the bunch length.

- Machine study : 2003/06/26
- Current : 5mA – 35mA
- Bunch current : 0.7mA - 1.17mA

The optics correction was done for the LER.

We measured the synchrotron tunes, beam phases and bunch lengths of both rings.

KEKB Lattice 2.5π Unit Cell



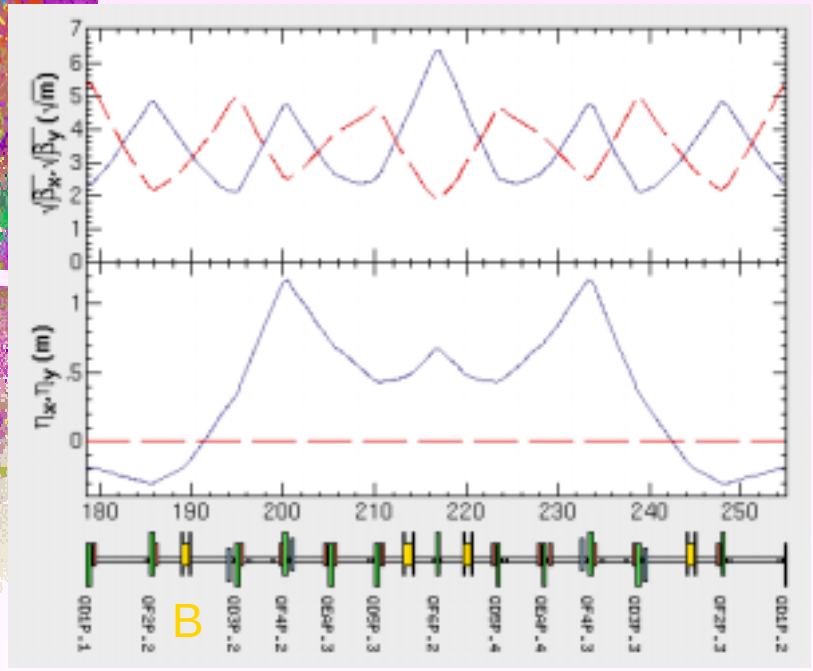
$$-I' \equiv \begin{pmatrix} -1 & 0 & 0 & 0 \\ * & -1 & 0 & 0 \\ 0 & 0 & -1 & 0 \\ 0 & 0 & * & -1 \end{pmatrix}$$

Chromaticity correction with non-interleaved sextupoles.

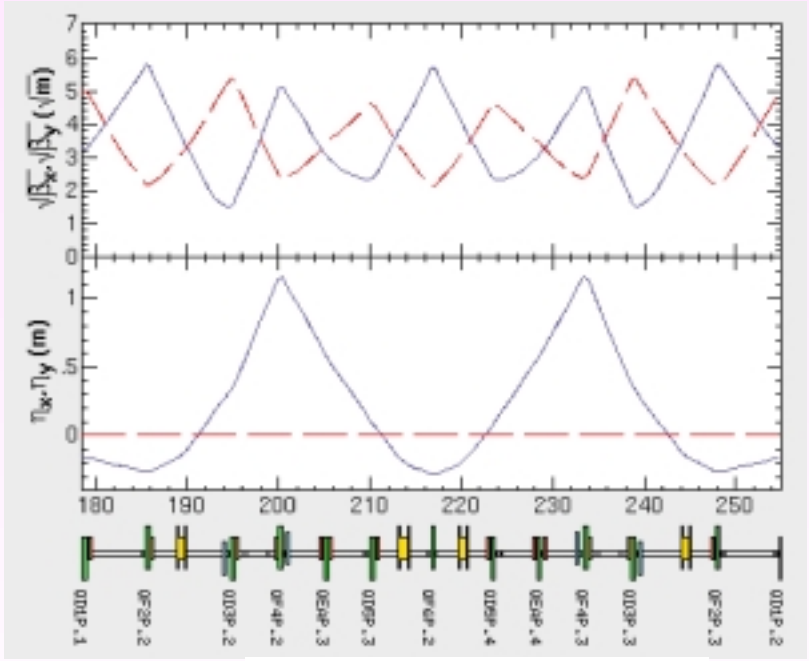
Horizontal emittance ε_x and momentum compaction factor α are independently adjustable.

KEKB Lattice

LER *positive* & *negative* α cells



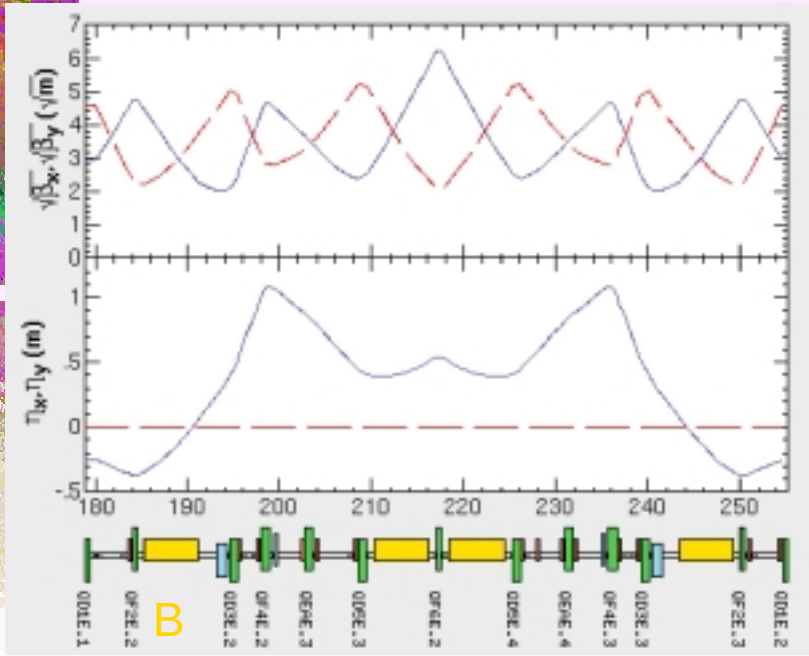
ε_x = 19 nm
α = 3.4E-4
σ_z = 4.7 mm



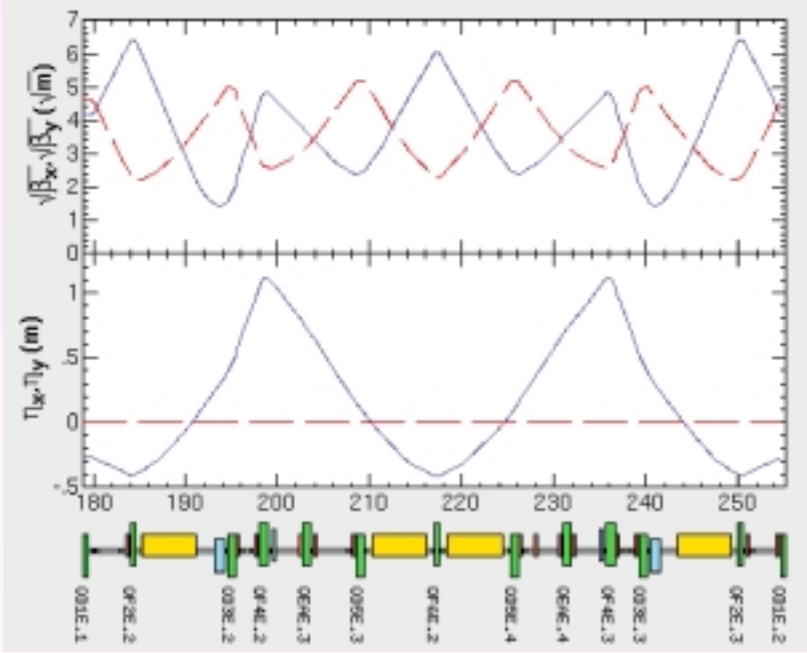
ε_x = 18 nm
α = -3.4E-4
σ_z = 4.6 mm

KEKB Lattice

HER *positive & negative* α cells



ε_x = 24 nm
α = 3.4E-4
σ_z = 5.2 mm



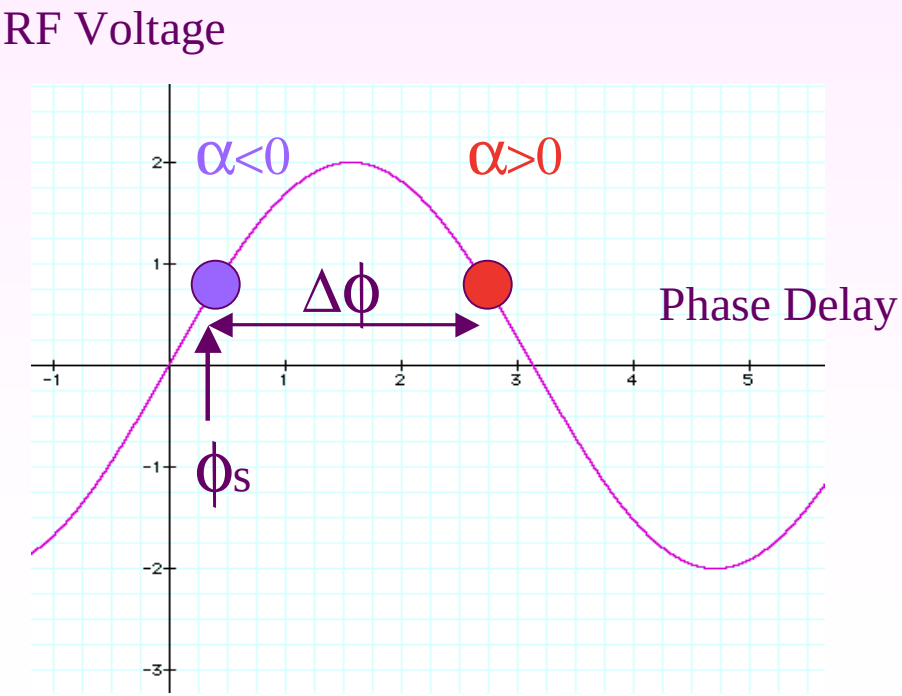
ε_x = 24 nm
α = -3.4E-4
σ_z = 5.4 mm

Machine parameters

	LER $\alpha>0$	LER $\alpha<0$	HER $\alpha>0$	HER $\alpha<0$
ε_x (nm)	18.8	17.8	2.41	2.40
α	3.41E-4	-3.41E-4	3.38E-4	-3.45E-4
σ_z (mm)	4.75 @8MV	4.58 @8MV	5.22 @13MV	5.44 @13MV
$\nu_{s\ set}$ ($\nu_{s\ measured}$)	0.0249	0.0248 (0.0247)	0.0208	0.0209 (0.0206)
ν_x/ν_y	45.508 /43.543	47.519 /43.560	44.509 /41.587	44.57 /41.60

Beam Phase Measurement

In switching to the negative momentum compaction lattice, the synchronous phase ϕ_s changes as shown in the figure below. ϕ_s was measured for negative and positive α.

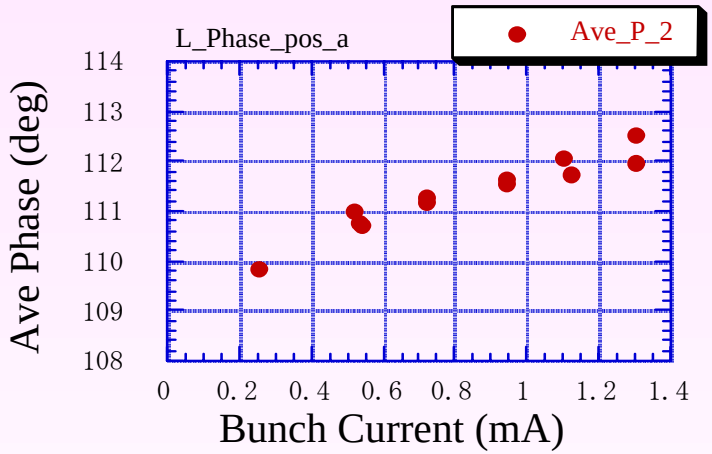


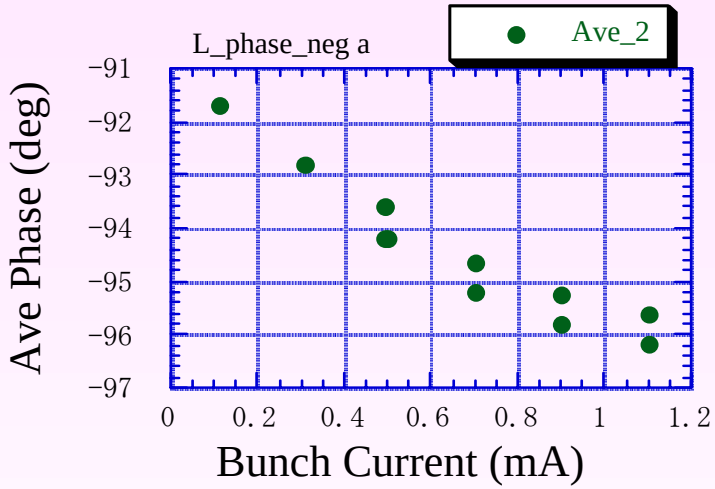
Beam Phase Measurement

$\alpha>0$

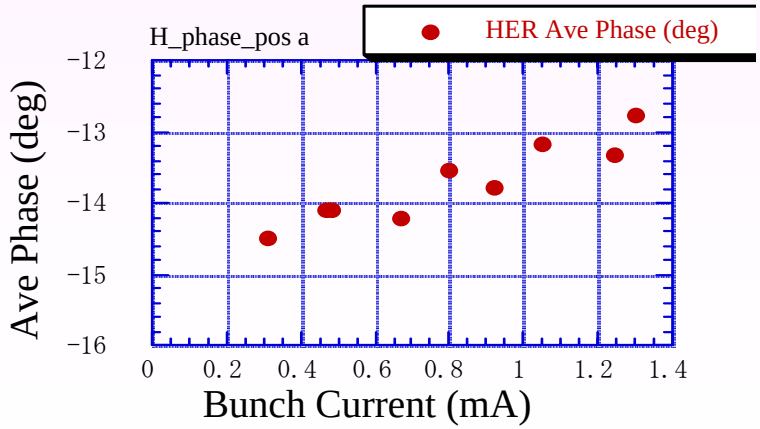
$\alpha<0$

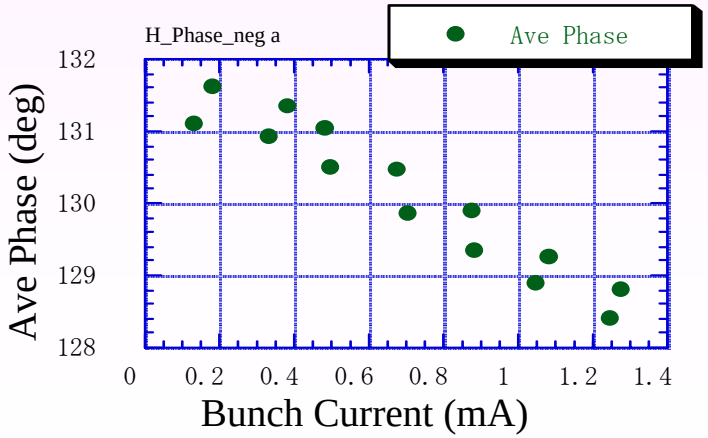
LER





HER





Phase change is consistent with expected value.

(T. Ieiri)

Bunch Length Measurement I : RMS bunch length monitor

- The frequency spectrum is defined by the Fourier transform of the bunch distribution, and an approximation is used.
- The bunch length is evaluated by detecting two frequency components of the bunch spectrum.
- The bunch signal is picked up by a button electrode installed on the beam pipe, and filtered by band pass filters tuned to two separate frequencies. The bunch length is calculated in an analog calculator unit.

(Resolution ~ +/- 0.2mm @4mm bunch length)

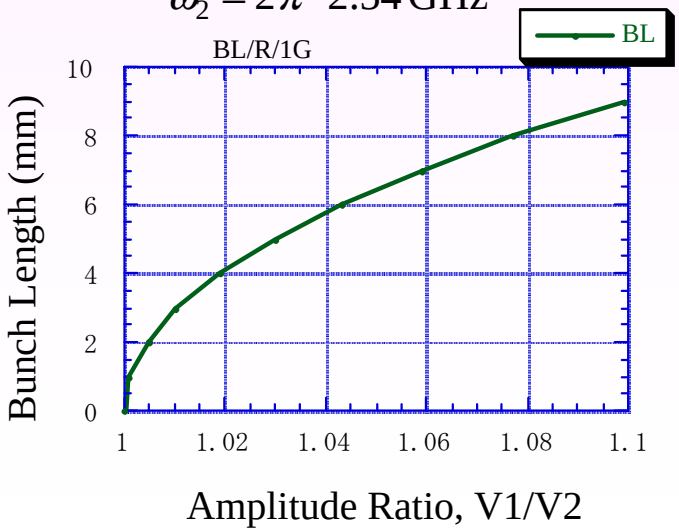
$$F(\omega) = \int_{-\infty}^{+\infty} f(t) e^{-j\omega t} dt$$

$$|F(\omega)| \approx I_0 (1 - \frac{1}{2} \langle t^2 \rangle \omega^2)$$

$$\sigma_l = c \sqrt{\frac{2}{(\omega_2^2 - \omega_1^2)} \ln(\frac{V_1}{V_2})}$$

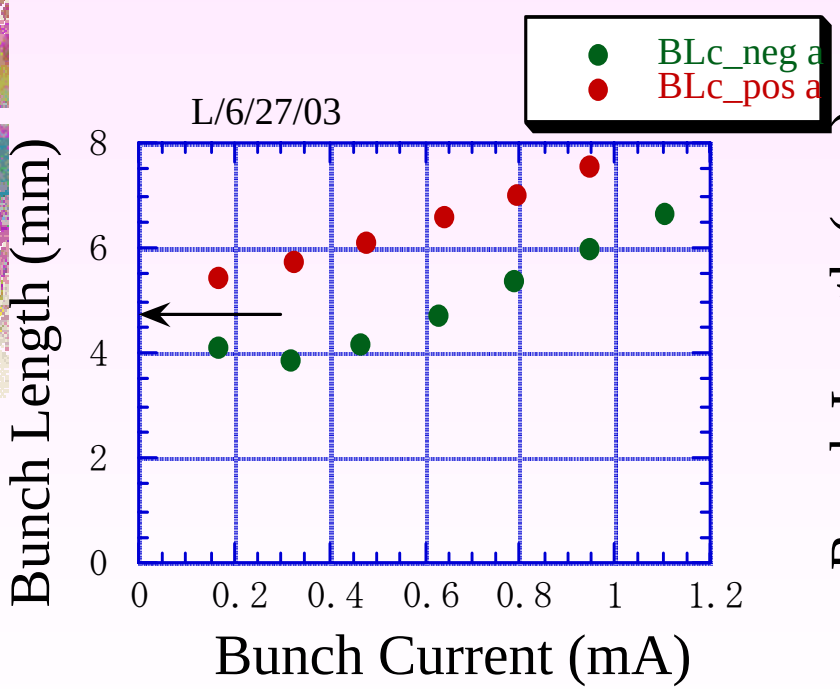
$$\omega_1 = 2\pi \cdot 1.02\,\mathrm{GHz}$$

$$\omega_2 = 2\pi \cdot 2.54\,\mathrm{GHz}$$

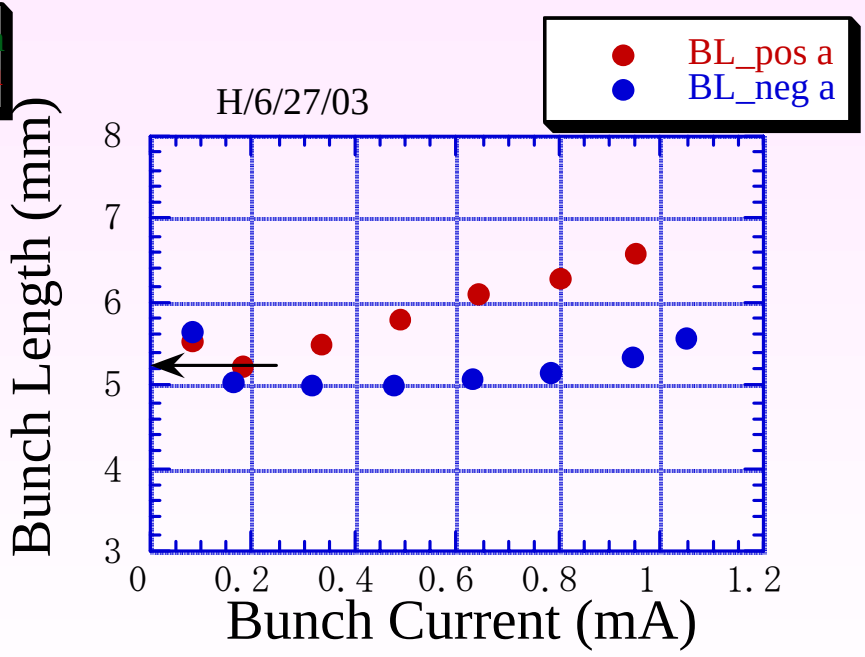


Bunch Length Measurement I : RMS bunch length monitor

LER



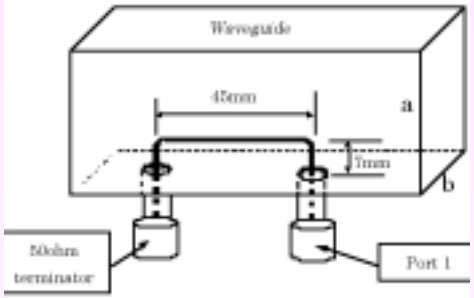
HER

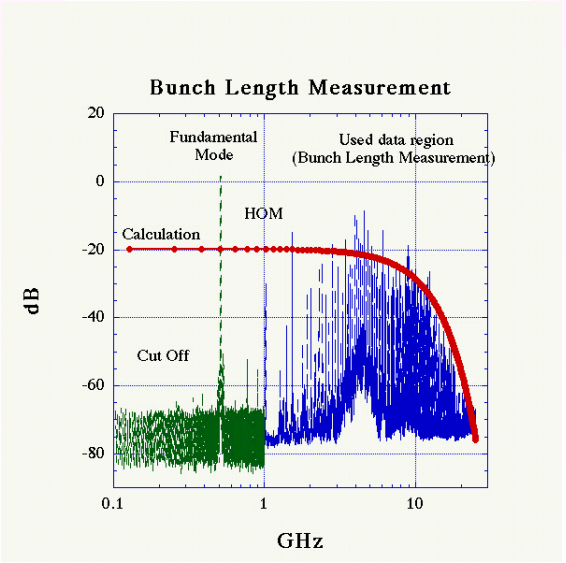


A normalization by the natural bunch length (σz) was done for the absolute value. (T. Ieiri)

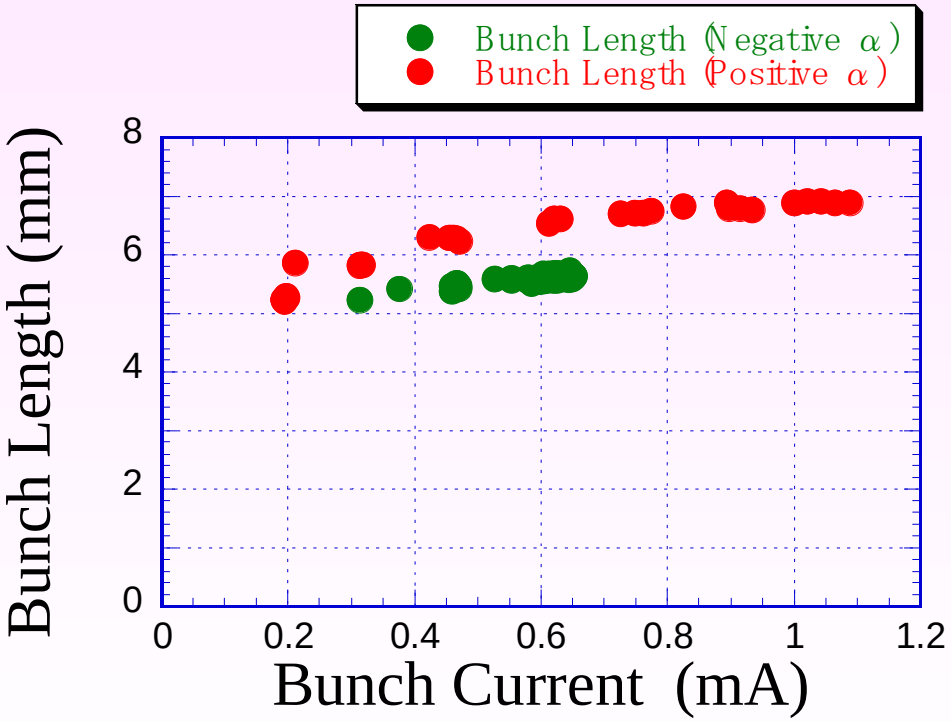
Bunch Length Measurement II : RF Wave-Guide System

The bunch length can be evaluated from a beam spectrum measurement of the beam-induced field in an RF cavity.
A wideband pickup is mounted on the wave-guide of the RF system.
Since the wavelengths of the field components above 5GeV are much smaller than the wave-guide, almost all of the components pass through the wave-guide and are detected by the pickup.
The spectrum of the pick-up signal is fitted by a Gaussian profile with the fitting parameters of the bunch length and the normalization factor.





Bunch Length Measurement II : RF Wave-Guide System



σz=4.3mm : Negative
σz=4.4mm : Positive

(T. Mimashi)

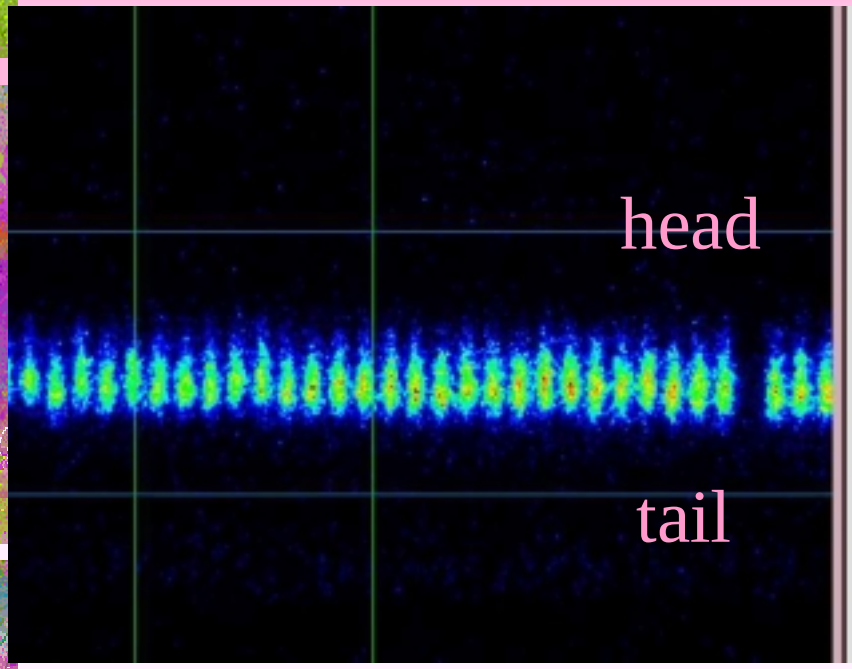
Bunch Length Measurement III : Streak Camera

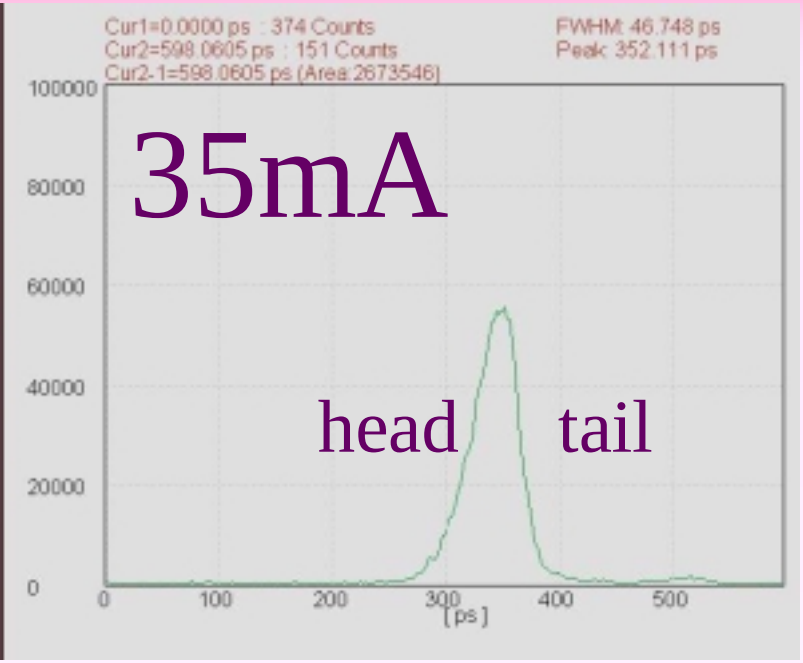
A beam monitor system using synchrotron radiation (SR) was constructed for KEKB.

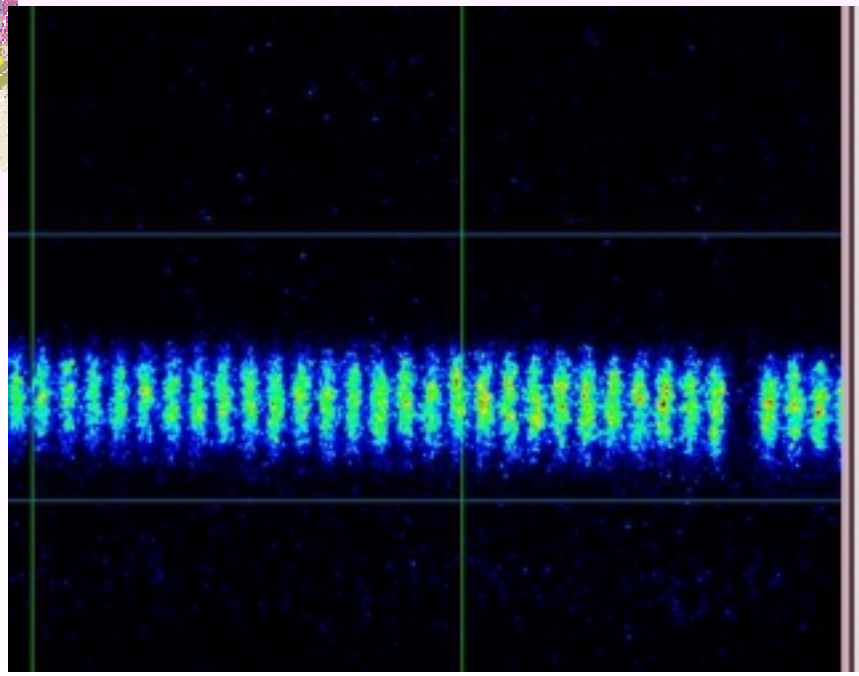
An SR beam is produced by a weak bending magnet and extracted by a mirror system. The beam is transferred to the monitor hut on ground by a 40m long optical path system.

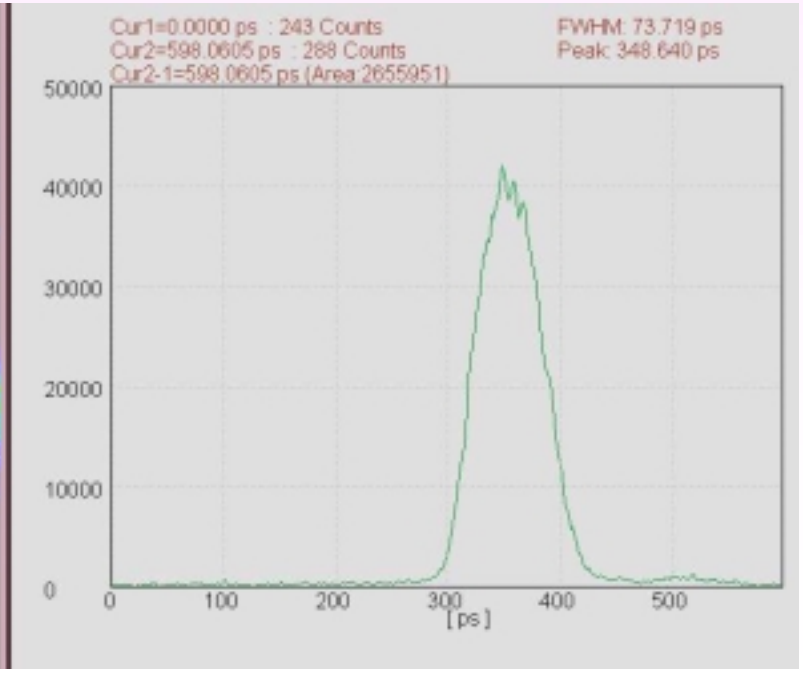
The streak camera is located in the hut, with a reflective optics system for higher light intensity.

The bunch-by-bunch shapes can be observed.

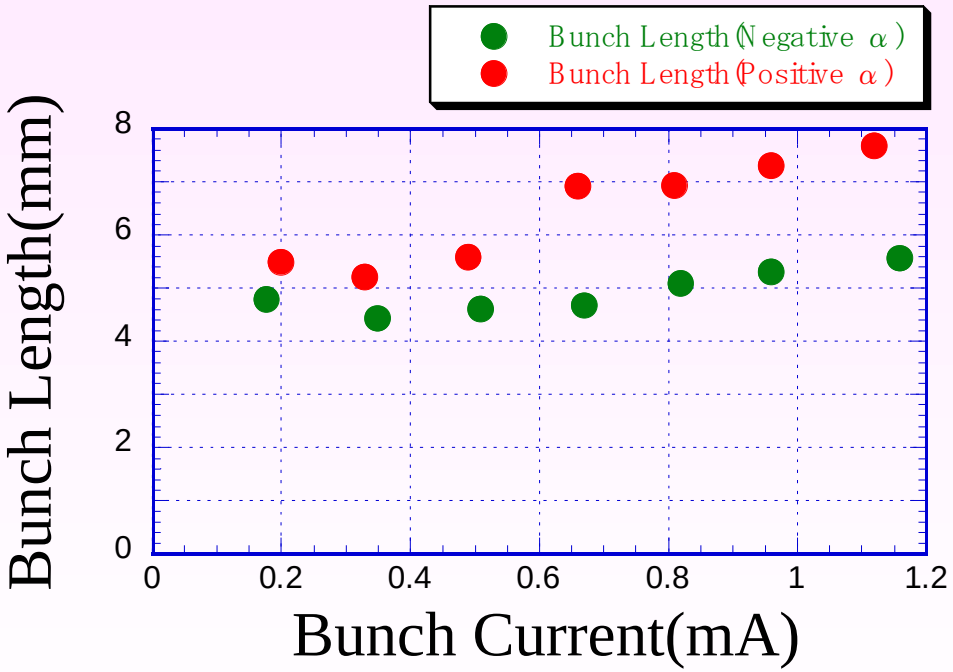

head
tail


Cur1=0.0000 ps : 374 Counts
Cur2=598.0605 ps : 151 Counts
Cur2-1=598.0605 ps (Area:2673546)
FWHM: 46.748 ps
Peak: 352.111 ps
35mA
head
tail
100000
80000
60000
40000
20000
0
0
100
200
300
400
500
[ps]




Cur1=0.0000 ps : 243 Counts
Cur2=598.0605 ps : 288 Counts
Cur2-1=598.0605 ps (Area:2655951)
FWHM: 73.719 ps
Peak: 348.640 ps
50000
40000
30000
20000
10000
0
0
100
200
300
400
500
[ps]

Bunch Length Measurement III : Streak Camera

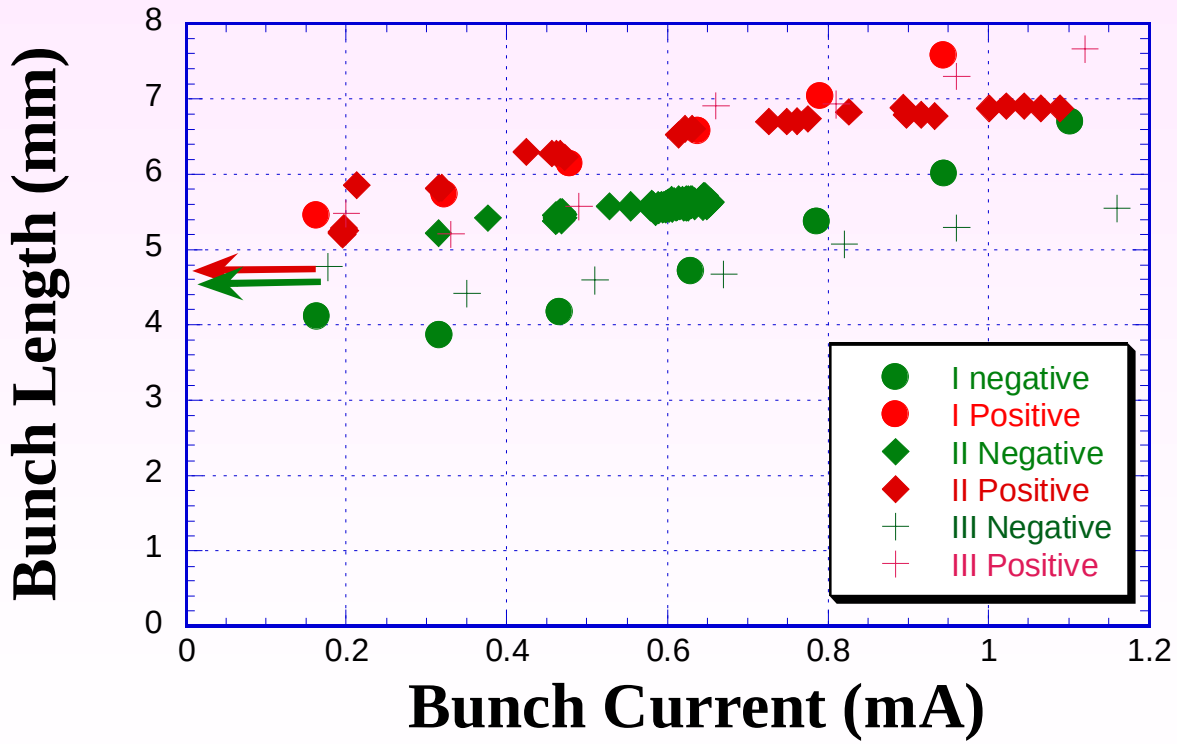


The average over all bunch lengths is plotted (FWHM/2.354).

σz=4.8mm : Negative
σz=4.6mm : Positive

(H. Ikeda)

Bunch Length Measurement : Comparison of 3 Methods



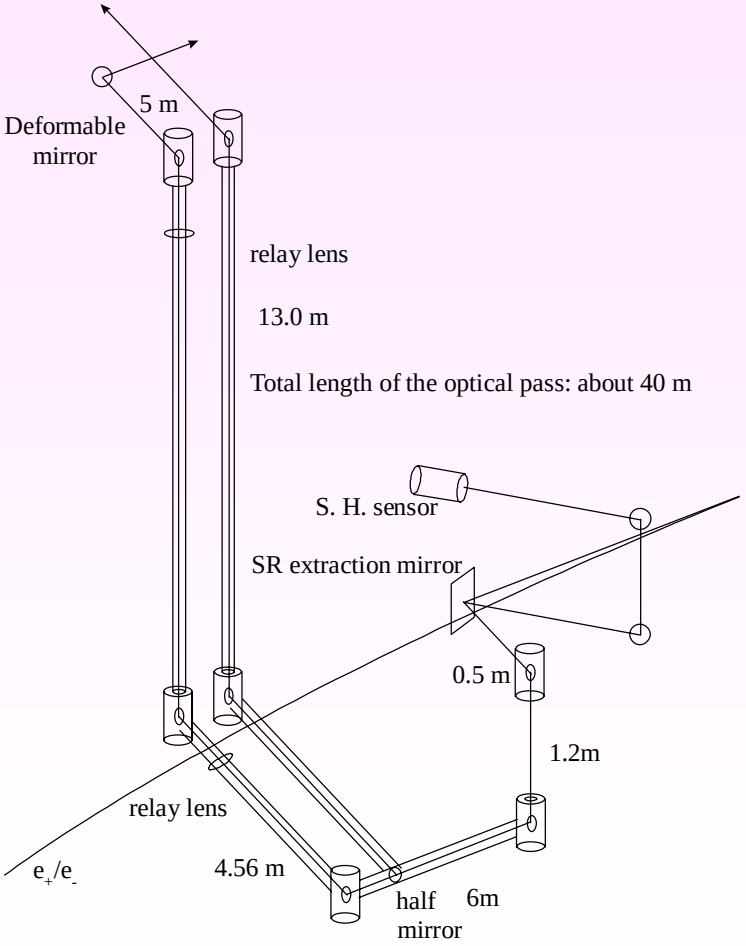
Summary

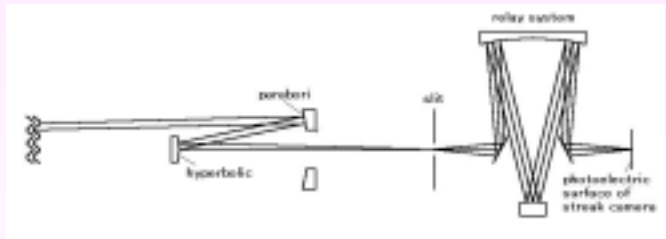
The horizontal emittance and momentum compaction factor α are independently adjustable at KEKB. We tested negative momentum compaction optics in order to shorten the bunch length.

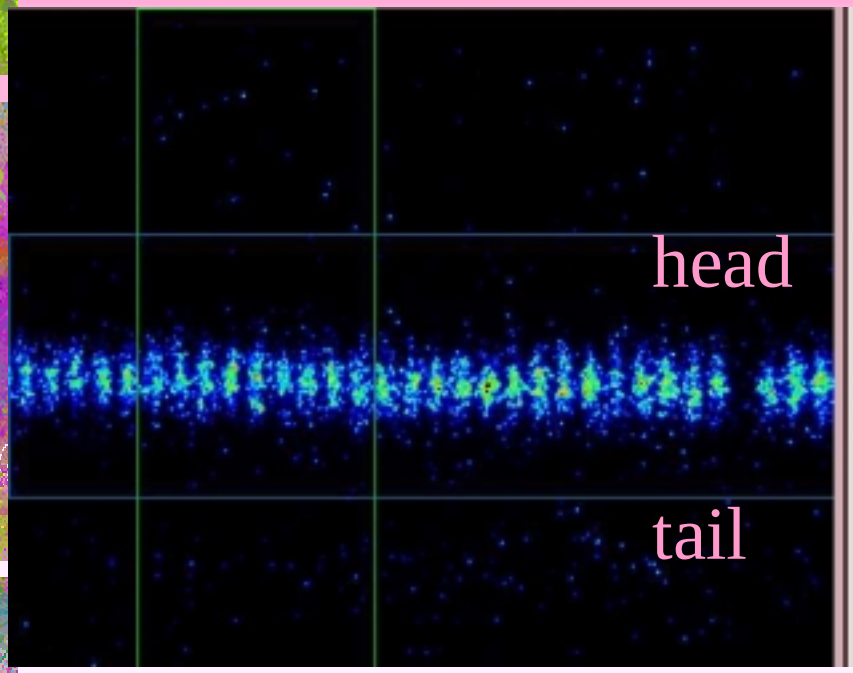
•Synchrotron tune vs is consistent with the calculated value.
•Beam phases are changed between negative and positive α as expected.
•Lattice setting of negative compaction factor was successfully done.

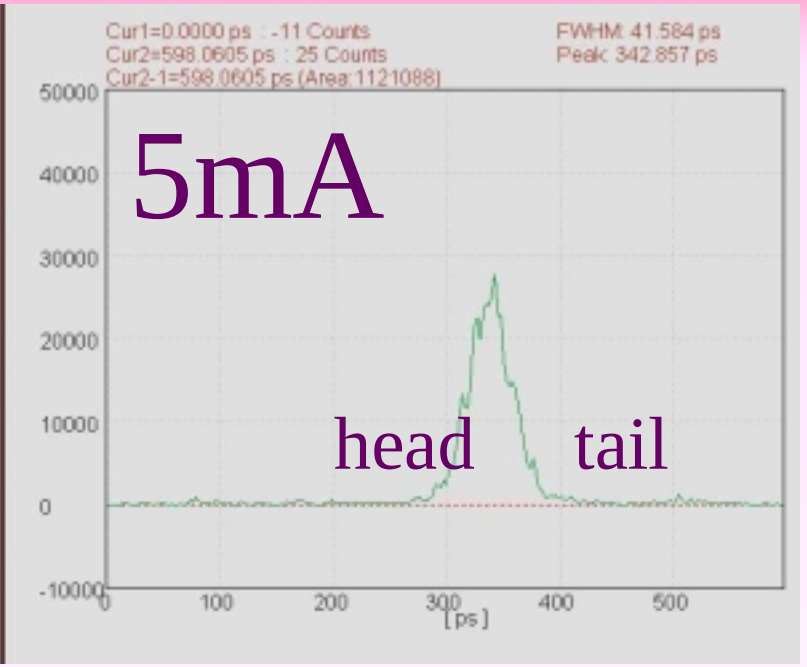
•Three methods were used to measure the bunch length for the LER and all of the results showed beam shortening at negative compaction.
•Bunch lengthening was reduced.

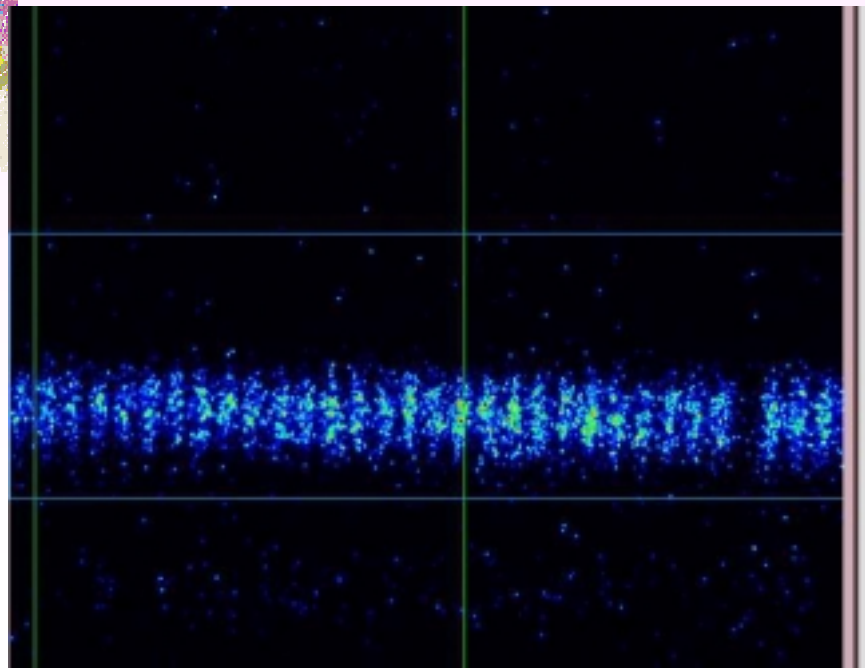
Bunch Length Measurement III : Streak Camera

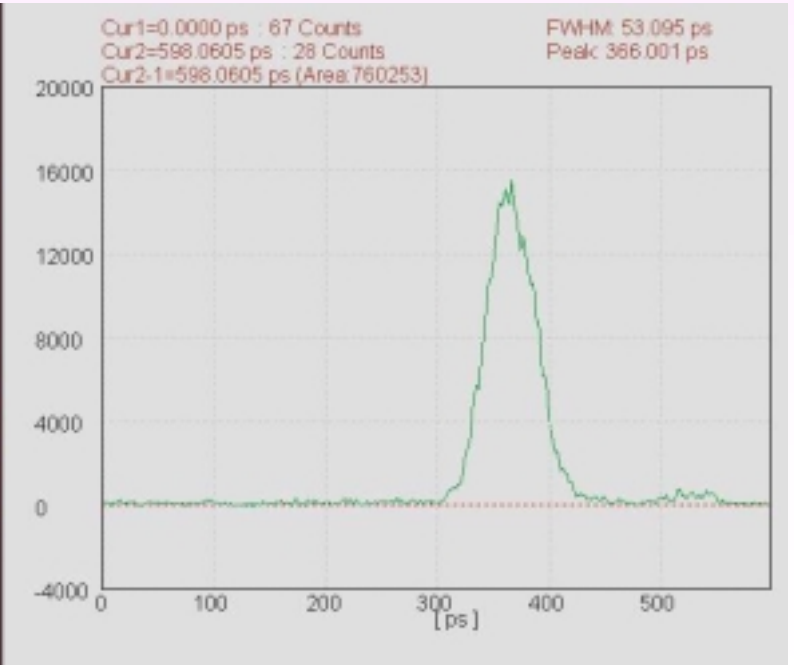





head
tail


Cur1=0.0000 ps : -11 Counts
Cur2=598.0605 ps : 25 Counts
Cur2-1=598.0605 ps (Area:1121088)
FWHM: 41.584 ps
Peak: 342.857 ps
5mA
head
tail
50000
40000
30000
20000
10000
0
-10000
0
100
200
300
400
500
[ps]




Cur1=0.0000 ps : 67 Counts
Cur2=598.0605 ps : 28 Counts
Cur2-1=598.0605 ps (Area:760253)
FWHM: 53.095 ps
Peak: 366.001 ps
20000
16000
12000
8000
4000
0
-4000
0
100
200
300
400
500
[ps]