Performance of KEKB

Italy-Japan Symposium (16/Dec./1999)

KEK H. Fukuma

Overview of KEKB accelerator

Comissionig status

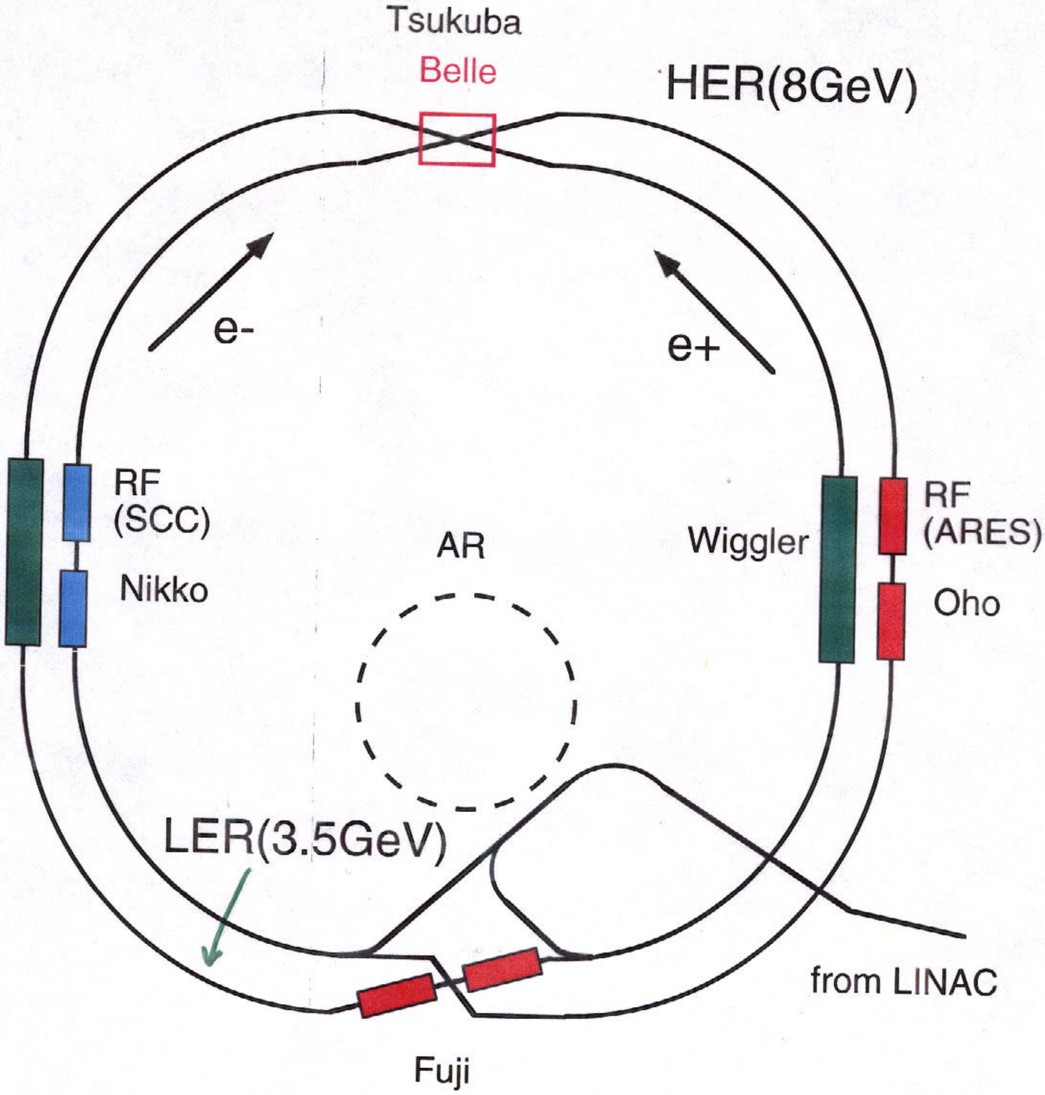
Overview of KEKB accelerator

KEKB (KEK B-Factory)

- 3.5 GeV positron x 8 GeV electron
- Design luminosity 1 x 10^{34} $cm^{-2}sec^{-1}$
("Factory")

Features

- Five year project (94 - 98)
- Built in TRISTAN tunnel
- Two ring, asymmetric collider
- Finite angle crossing of 2 x 11 mr at IP
- Noninterleaved chromaticity correction
- Specially designed RF cavity (ARES, SCC)


Tsukuba
Belle
HER(8GeV)
e-
e+
RF
(SCC)
Nikko
AR
Wiggler
RF
(ARES)
Oho
LER(3.5GeV)
from LINAC
Fuji

KEKB Ring

Main Parameters of KEKB

Ring	LER	HER	
Energy	3.5	8.0	GeV
Circumference	3016.26		m
Luminosity	1×10^{34}		$cm^{-2}s^{-1}$
Crossing angle	±11		mrad
Tune shifts(H/V)	0.039/0.052		
Beta function at IP (H/V)	0.33/0.01		m
Beam current	2.6	1.1	A
Natural bunch length	0.4		cm
Energy spread	7.1×10^{-4}	6.7×10^{-4}	
Bunch spacing	0.59		m
Particles/bunch	3.3×10^{10}	1.4×10^{10}	
Emittance(H/V)	$1.8 \times 10^{-8}/3.6 \times 10^{-10}$		m
Synchrotron tune	0.01-0.02		
Betatron tune(H/V)	45.52/45.08	47.52/43.08	
Momentum compaction	1×10^{-4} - 2×10^{-4}		
Energy loss/turn	0.81	3.5	MeV
RF voltage	5 - 10	10 - 20	MV
RF frequency	508.887		MHz
Harmonic number	5120		


N

RF system

•Requirement

High beam loading

->large stored enegy of cavities

Coupled bunch instability due to HOM

-> HOM-free cavities

• KEKB

ARES (normal conducting cavity)

Superconducting cavity

•Number of cavities

	t=0	8/Aug/99	final
LER (ARES)	12	16	20
HER (ARES)	6	10	12
(SCC)	4	4	8

Linac Upgrade

•Energy

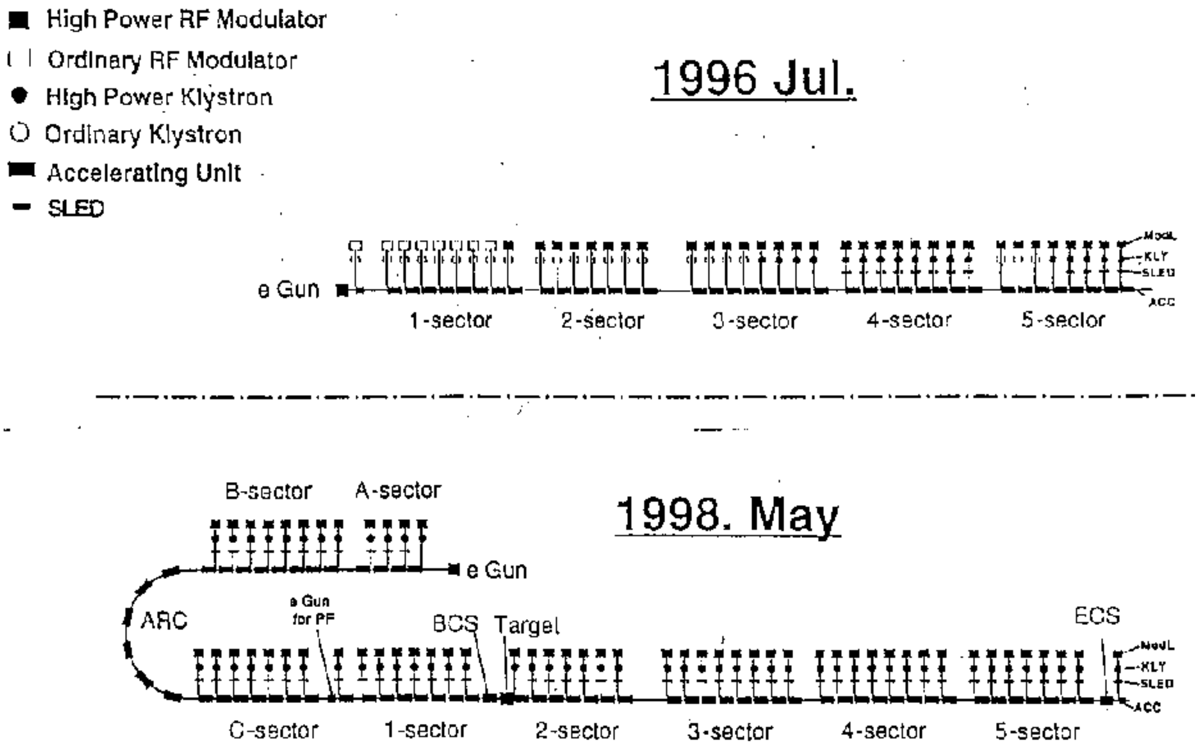
2.5 GeV to 8 GeV

-> "J- Linac"

• Positron yield

Increase of factor 20

-> e^- energy at e^+ production target : 0.2 to 3.7 GeV



Interaction region

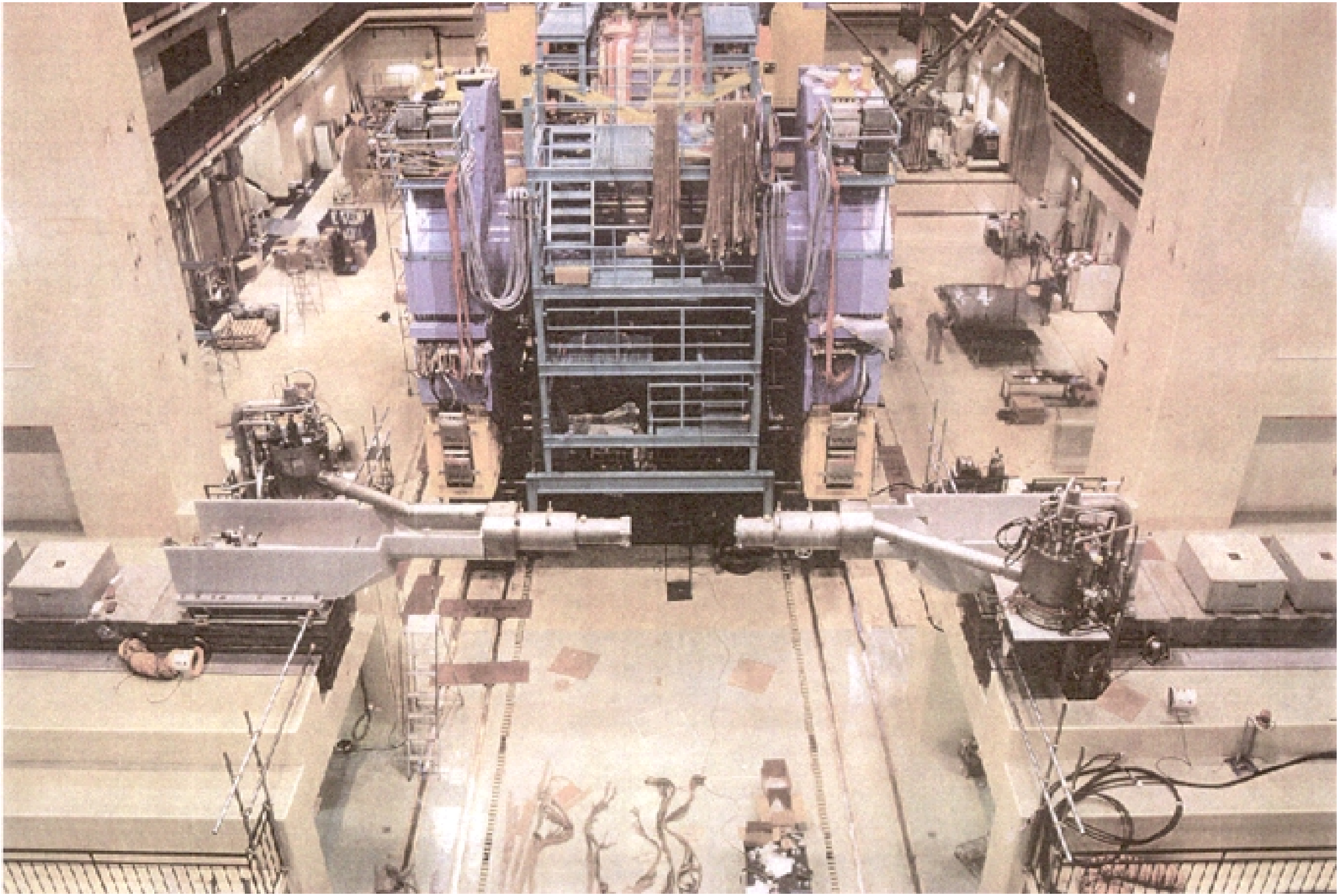
- Finite angle crossing of 2 x 11 mr at IP
  ->Simplify IR design

- Superconducting quadrupole magnets and anti-solenoids inside BELLE detector

- Special quadrupole magnets around IP

Vacuum

Copper duct was chosen for its ability to withstand a high peak heat load and to shield radiation from beam.



Commissioning status

The members of commissioning group (39)

K. Oide

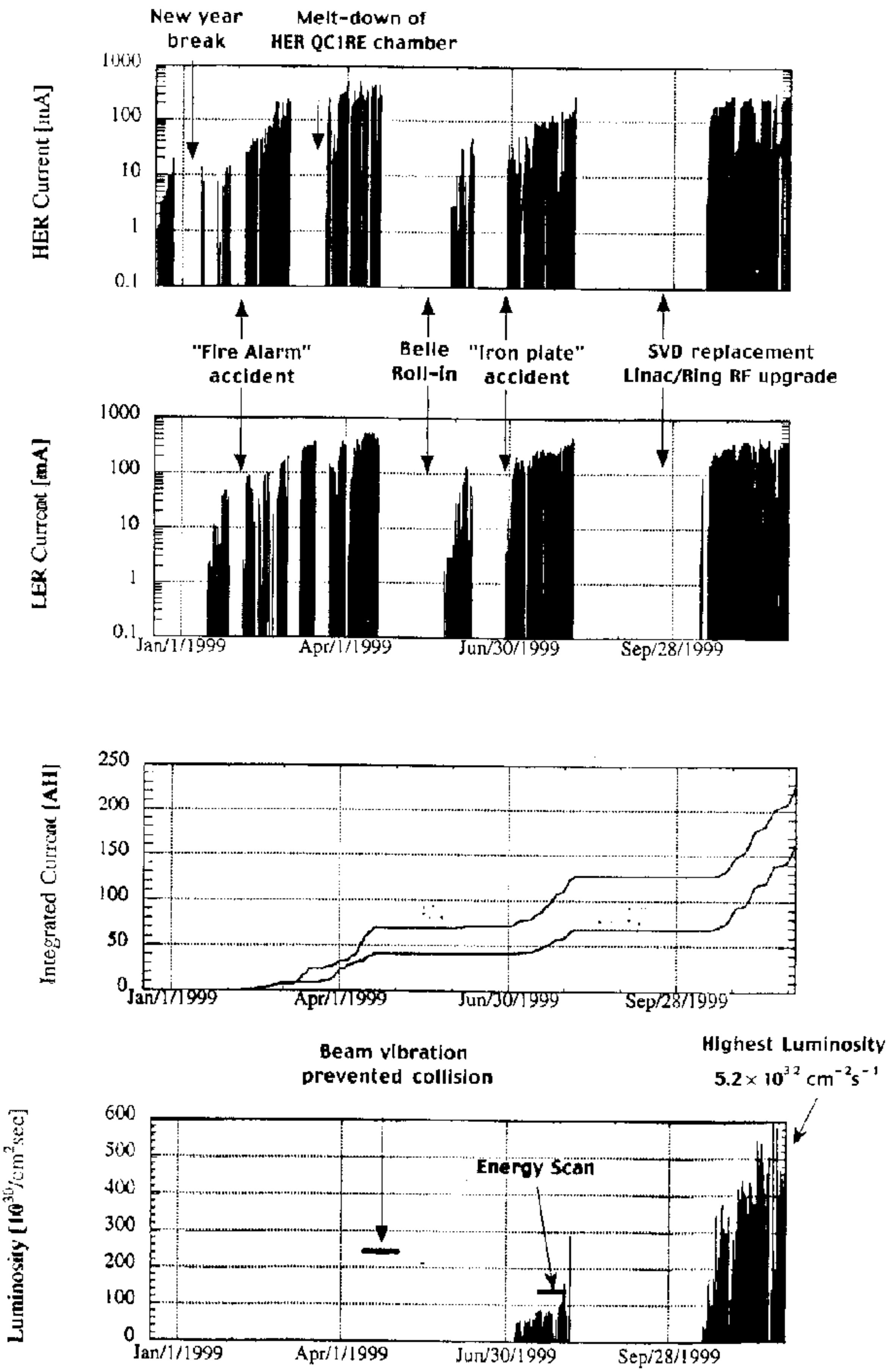
K. Akai, N. Akasaka, K. Bane, A. Enomoto, J. Flanagan, H. Fukuma, Y. Funakoshi, K. Furukawa, S. Hiramatsu, K. Hosoyama, T. Ieiri, N. Iida, T. Kamitani, S. Kato, M. Kikuchi, E. Kikutani, H. Koiso, T. Matsumoto, M. Msuzawa, S. Michizono, T. Mimashi, T. Nakamura, Y. Ogawa, K. Ohmi, Y. Ohnishi, S. Ohsawa, N. Ohuchi, K. Satoh, M. Suetake, Y. Suetsugu, T. Suwada, M. Tawada, M. Tejima, M. Tobiyama, N. Yamamoto, M. Yoshida, S. Yoshimoto, C. H. Yu

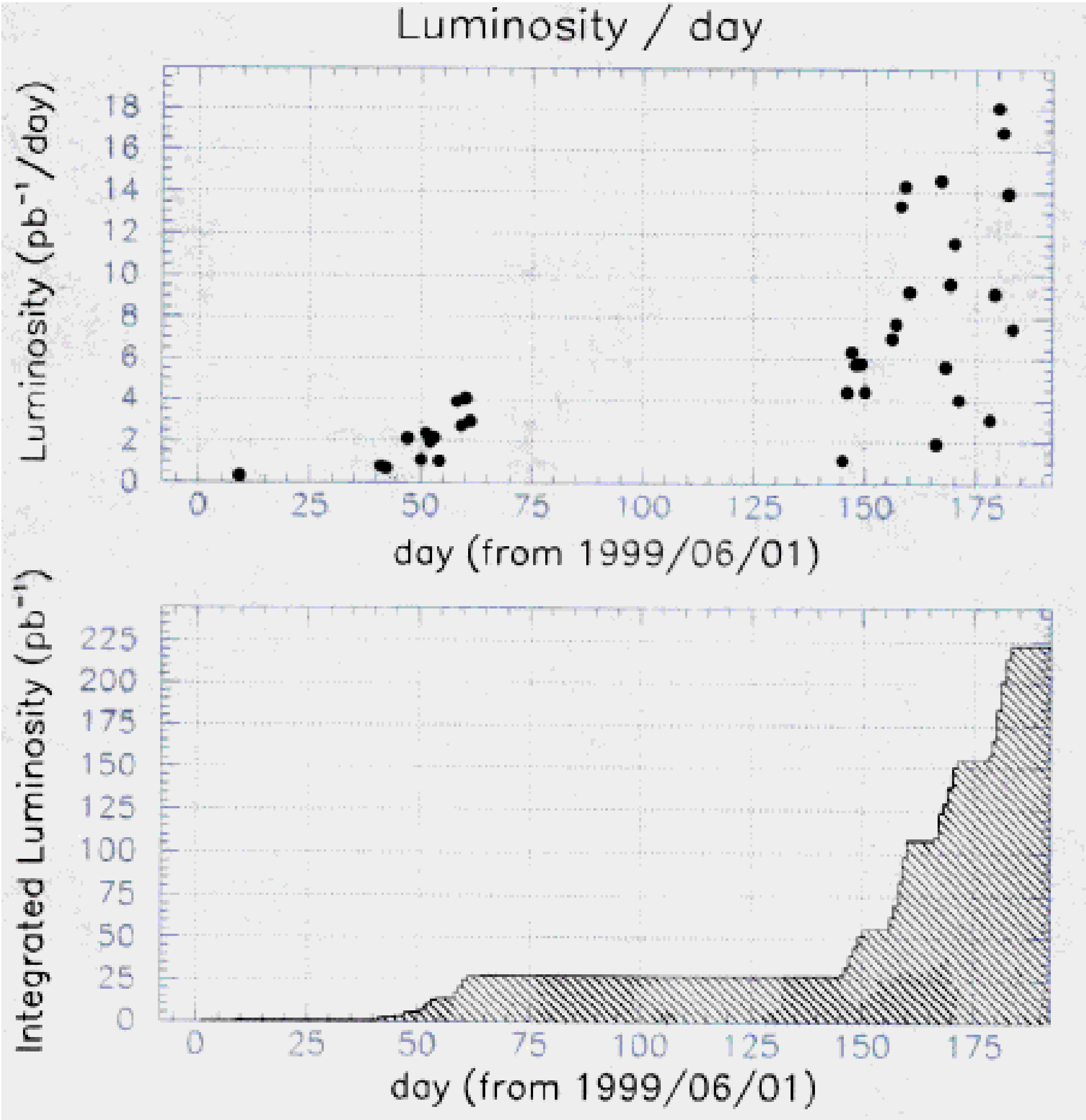
Collision performance

11/15/1999

	LER	HER	
Beam current	270(2600)	220(1100)	mA
Number of bunches	872(4600)	872(4600)	
Bunch current	0.30(0.52)	0.25(0.22)	mA
Bunch spacing	2.4(0.6)		m
Bunch trains	8		
Horizontal size at IP	140(140)		µm
Vertical size at IP	2.8(1.4)	2.2(1.4)	µm
Emittance ratio	4.0(1)	2.5(1)	%
β_x^*/β_y^*	100/1	100/1	cm
beam-beam parameters ξ_x/ξ_y	0.05/0.024 (0.05)	0.03/0.012 (0.05)	
Beam life	130@300mA	280@240mA	min.
Calculated Luminosity	5.7×10^{32}		$cm^{-2}sec^{-1}$
Measured Luminosity	5.2×10^{32}		$cm^{-2}sec^{-1}$

() : design values


New year break
Melt-down of HER QC1RE chamber
HER Current [mA]
"Fire Alarm" accident
Belle Roll-in
"Iron plate" accident
SVD replacement Linac/Ring RF upgrade
LER Current [mA]
Jan/1/1999
Apr/1/1999
Jun/30/1999
Sep/28/1999
Integrated Current [AH]
Beam vibration prevented collision
Highest Luminosity
5.2 × 10^32 cm^-2 s^-1
Energy Scan
Luminosity [10^30/cm^2sec]



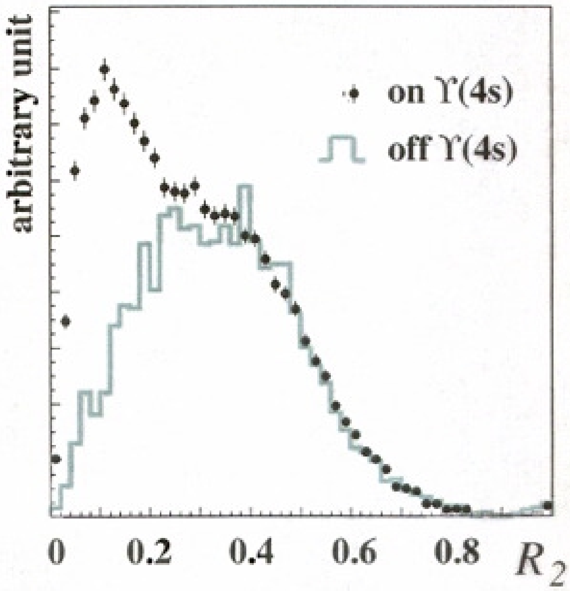
Luminosity / day
Luminosity (pb⁻¹/day)
18
16
14
12
10
8
6
4
2
0
0
25
50
75
100
125
150
175
day (from 1999/06/01)
Integrated Luminosity (pb⁻¹)
225
200
175
150
125
100
75
50
25
0
0
25
50
75
100
125
150
175
day (from 1999/06/01)

Energy scan

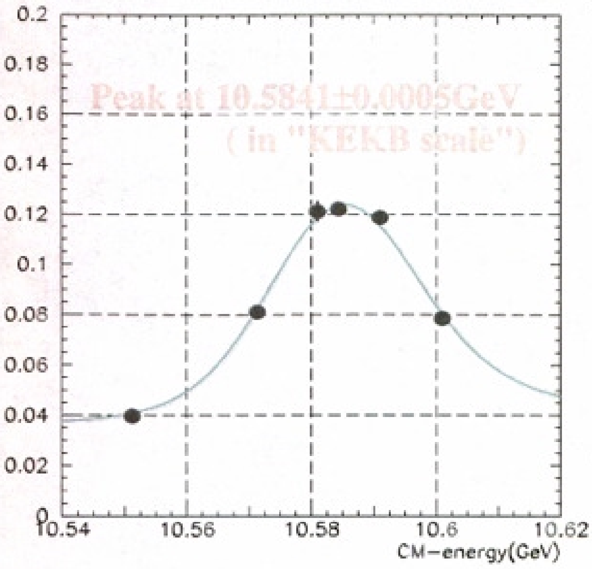
R_2 distribution

Fox-Wolfram moment ratio

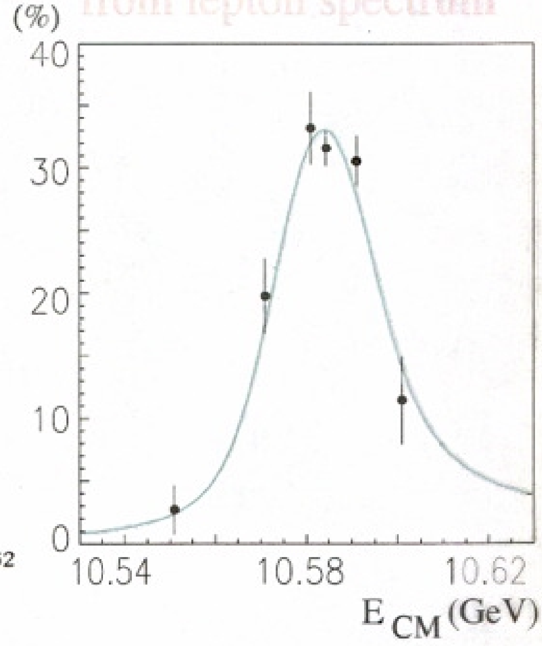
$$R_2 \equiv \frac{H_2}{H_0}$$



No. of events with $R_2 \leq 0.2$ / No. of Bhabha events



$B\bar{B}$ event rate from lepton spectrum



Optics

- Lattice

  ♦ Beta function at IP

  LER : β^*_x=1 m, β^*_y=0.01 m

  HER : β^*_x=1 m, β^*_y=0.01 m

  ♦ Chromaticity correction

  Noninterleaved 56-family correction

  Local correction in interaction region for LER

- Closed orbit

  ♦ Closed orbit is corrected by SVD or MICADO to less than 0.5 mm rms.

- Betatron tune

  ♦ Betatron tunes are determined by tune survey around predicted tunes based on the beam-beam simulation.

- Chromaticity
  - ♦ Chromaticity is set to high value to store high beam current.

- Optics correction (Beta function, dispersion, X-Y coupling)
  - ♦ Beta function, dispersion and X-Y coupling are well corrected.

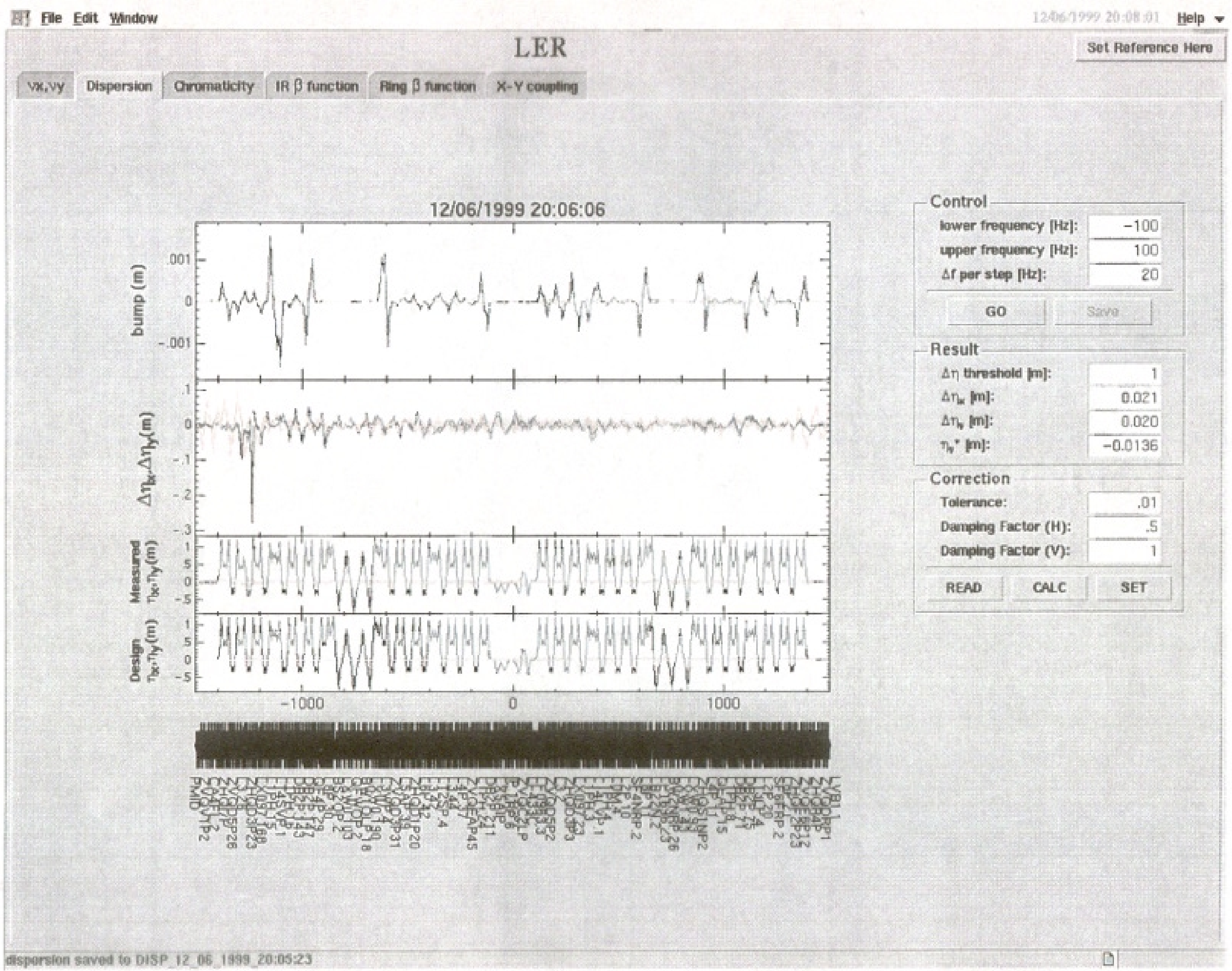
Beta function : $(\beta meas./\beta cal.)^{1/2} < 10$ %

Dispersion : $\Delta\eta < 20$ mm

X-Y coupling : leaked vertical orbit < 20 μm for 0.05mr horizontal kick

- Beam based measurement of BPM-offset
  - ♦ Almost all offset between magnetic center of quadrupole and BPM were measured by "Quad-BPM" method.

    After correcting offset error, vertical beamsize at low current in LER was reduced to 1 μm level.


File Edit Window
12/06/1999 20:08:01
Help
LER
Set Reference Here
vx,vy
Dispersion
Chromaticity
IR β function
Ring β function
X-Y coupling
12/06/1999 20:06:06
bump (m)
Measured
Design
-1000
0
1000
Control
lower frequency [Hz]:
-100
upper frequency [Hz]:
100
Δf per step [Hz]:
20
GO
Save
Result
Δη threshold [m]:
1
0.021
0.020
-0.0136
Correction
Tolerance:
.01
Damping Factor (H):
.5
Damping Factor (V):
1
READ
CALC
SET
dispersion saved to DISP_12_06_1999_20:05:23

Beam current

- Maximum storable beam current

  HER : 340 mA (8 trains, 4 bucket spacing)

  Limited by Belle background

  LER : 410 mA (8 trains, 4 bucket spacing)

  Limited by low injection rate accompanied with beam loss. In 2 trains current was reached 500 mA.

- Heating of mask

  Bunch spacing in LER is restricted to 4 buckets due to heating of mask. This prevents ,for example, 3 bucket spacing storage which is required to increase HER current.

- Transverse multi-bunch instability(TMBI)

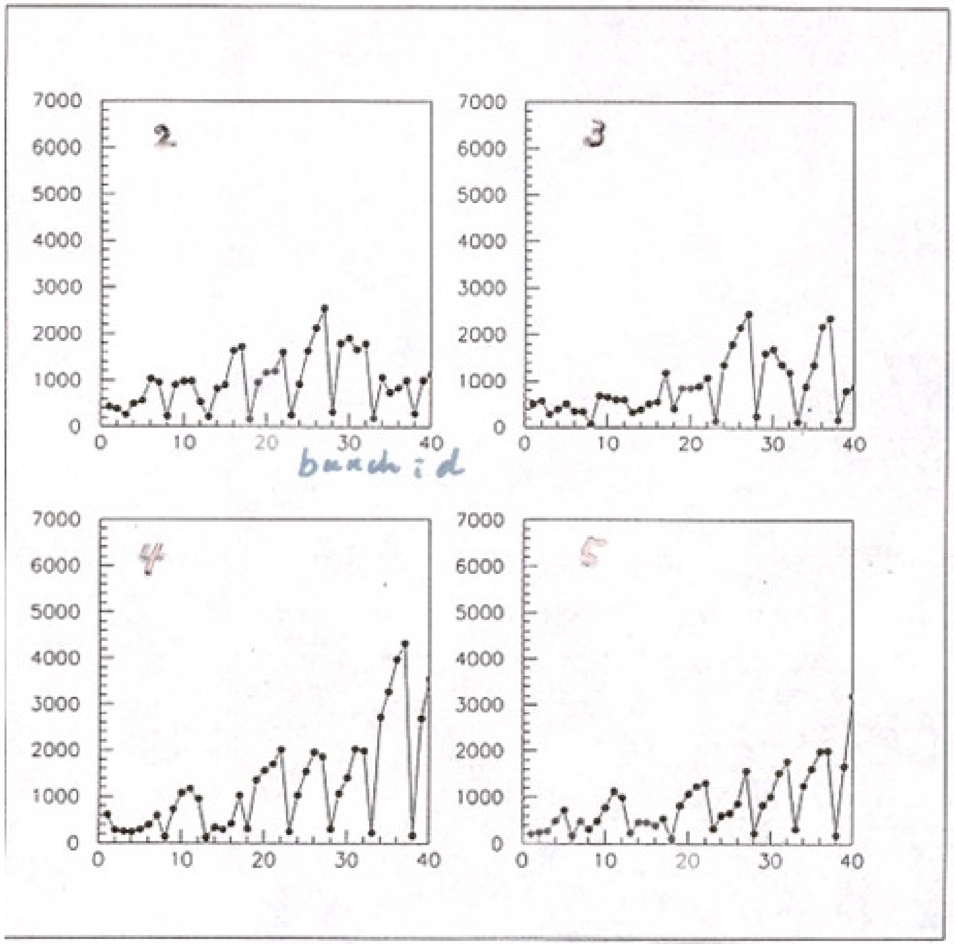
  1) HER

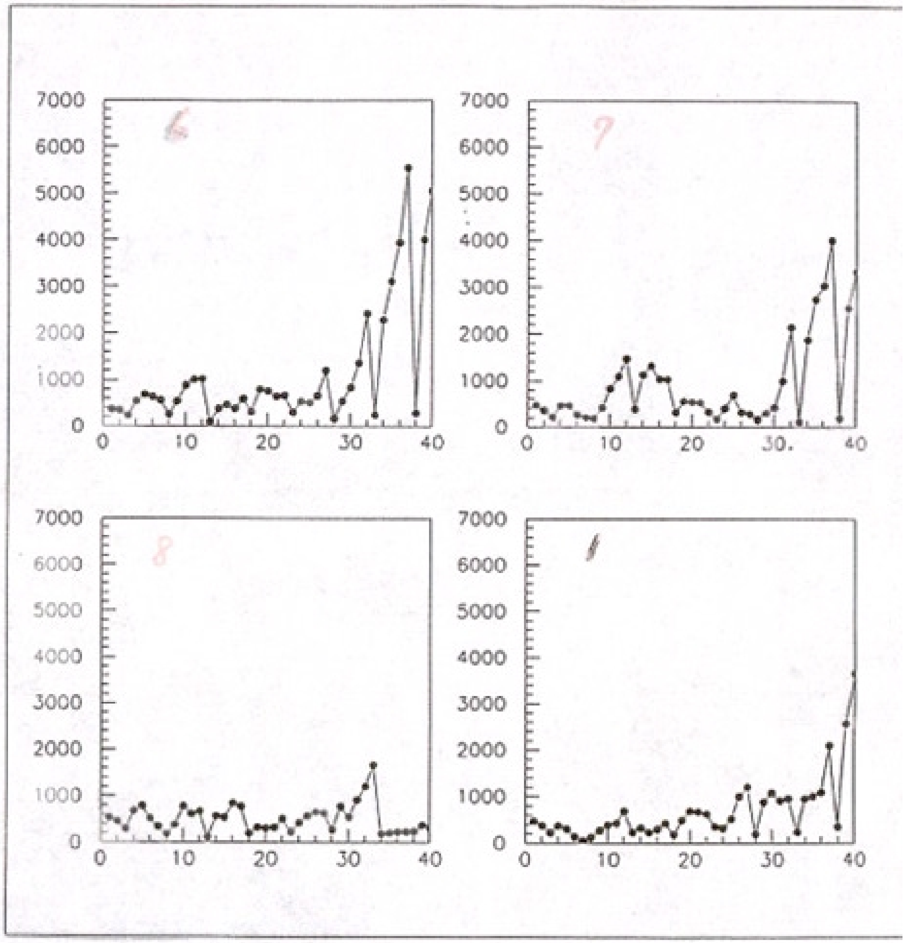
  - ♦ Both horizontal and vertical instability are observed.
  - ♦ Amplitude grows along the train in both planes.
  - ♦ Measurement suggests vertical instability is fast ion instability.

  2) LER

  - ♦ Both horizontal and vertical instability are observed.
  - ♦ Amplitude grows along the train in both planes.

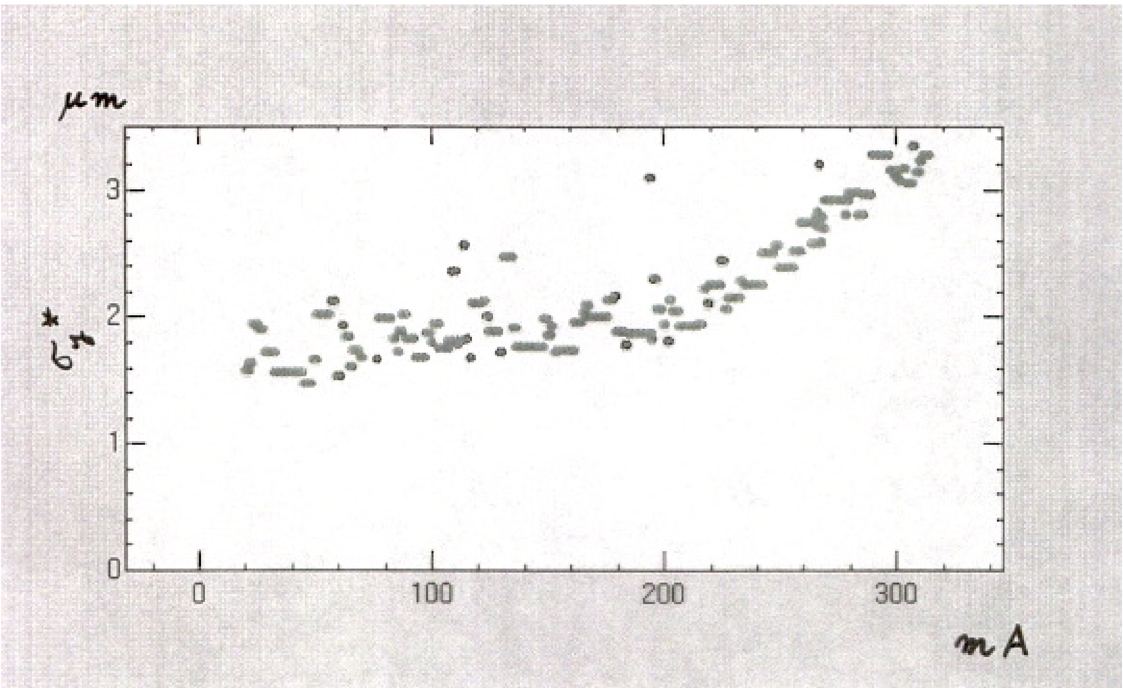
Amplitude 8/4014 61mA Hor. (HER)





FFT (1024 turn)

- Vertical beam size blowup in LER
    - ♦ Vertical beam size in LER blows up as beam current increases.
    - ♦ Blowup is multibunch effect.
    - ♦ A speculation that photoelectrons cause this blowup lead to installation of tiny permanent magnets on the vacuum chambers to sweep electrons. The beam study is in progress.



μm
σ_y^*
0
1
2
3
0
100
200
300
mA

Beam collision

- Collision tuning

To collide the beam, longitudinal, horizontal and vertical position of the beam should be adjusted.

1)Longitudinal position (Beam timing)

Adjust relative RF phase between LER and HER.

2)Horizontal scan

Observe beam-beam deflection by changing RF phase of LER

Adjust offset by an orbit bump at IP in LER.

3)Vertical scan

Observe beam-beam deflection by setting orbit bump with special steering magnets at IP

Adjust offset by orbit bump at IP in ~~L~~HER.

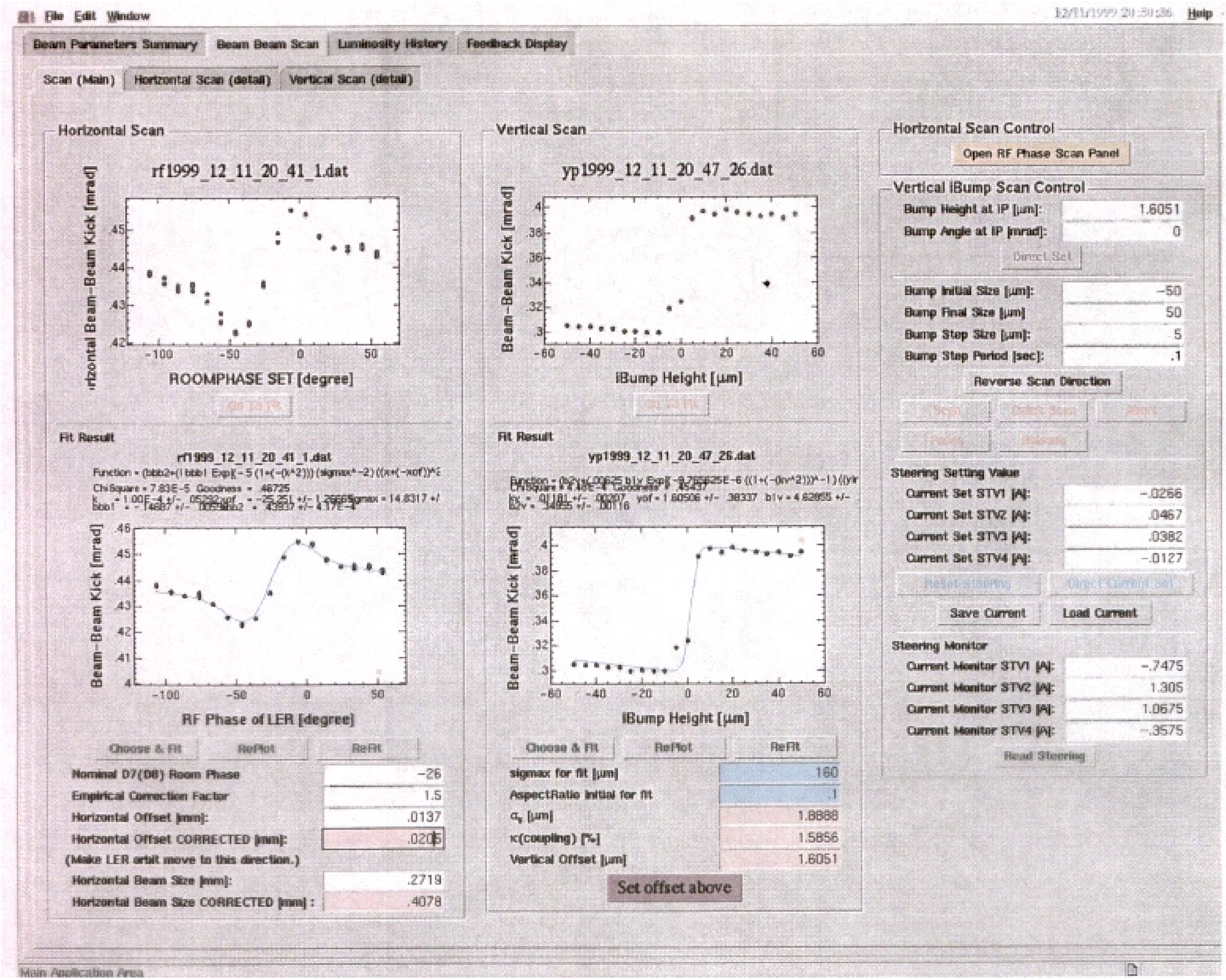
4)Waist scan

Beta waist is searched by changing beata at IP and observing luminosity and beam size.

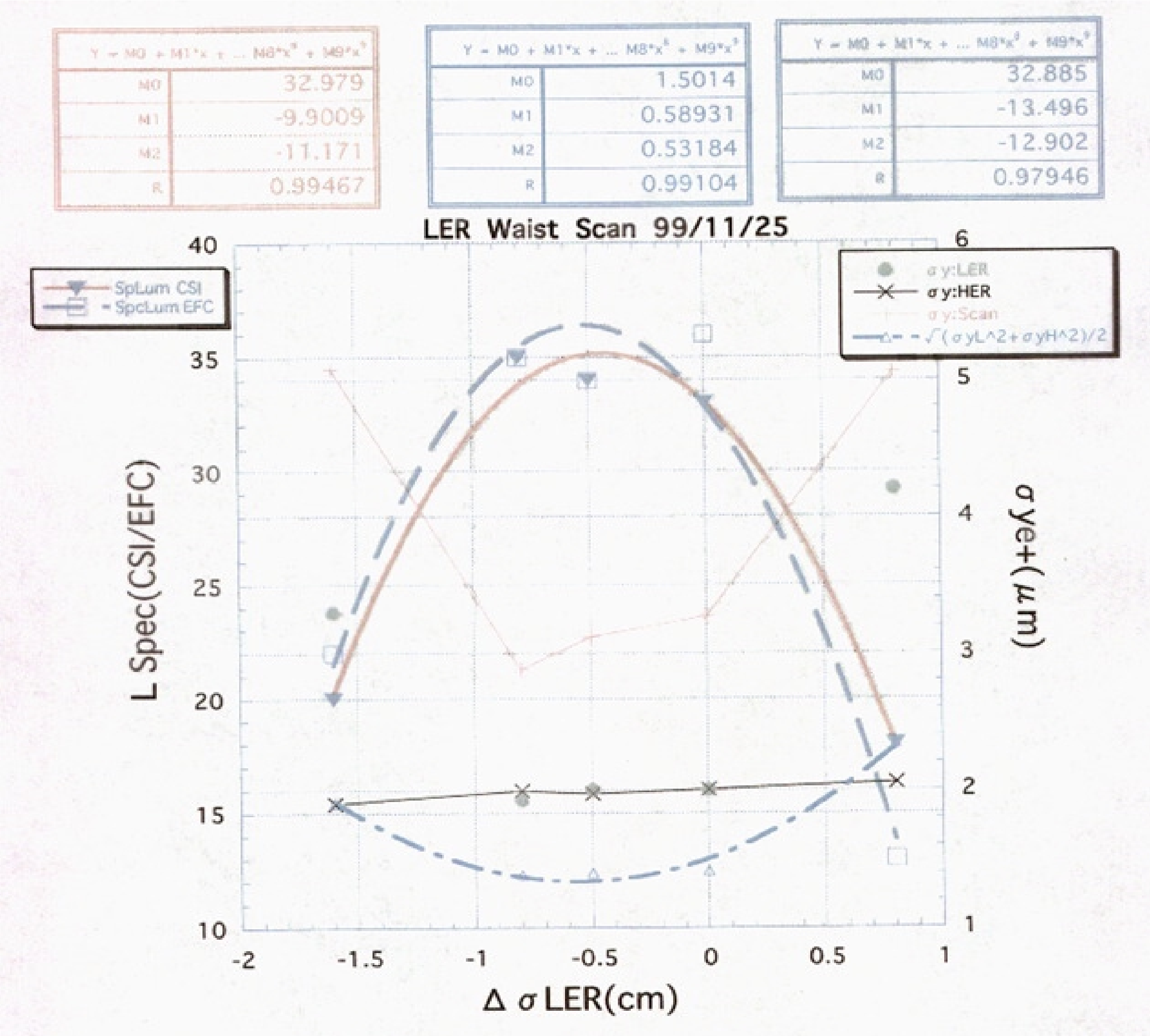
- Orbit feedback

  To maintain stable collision, an orbit feedback system is continuously working during collision in both planes.

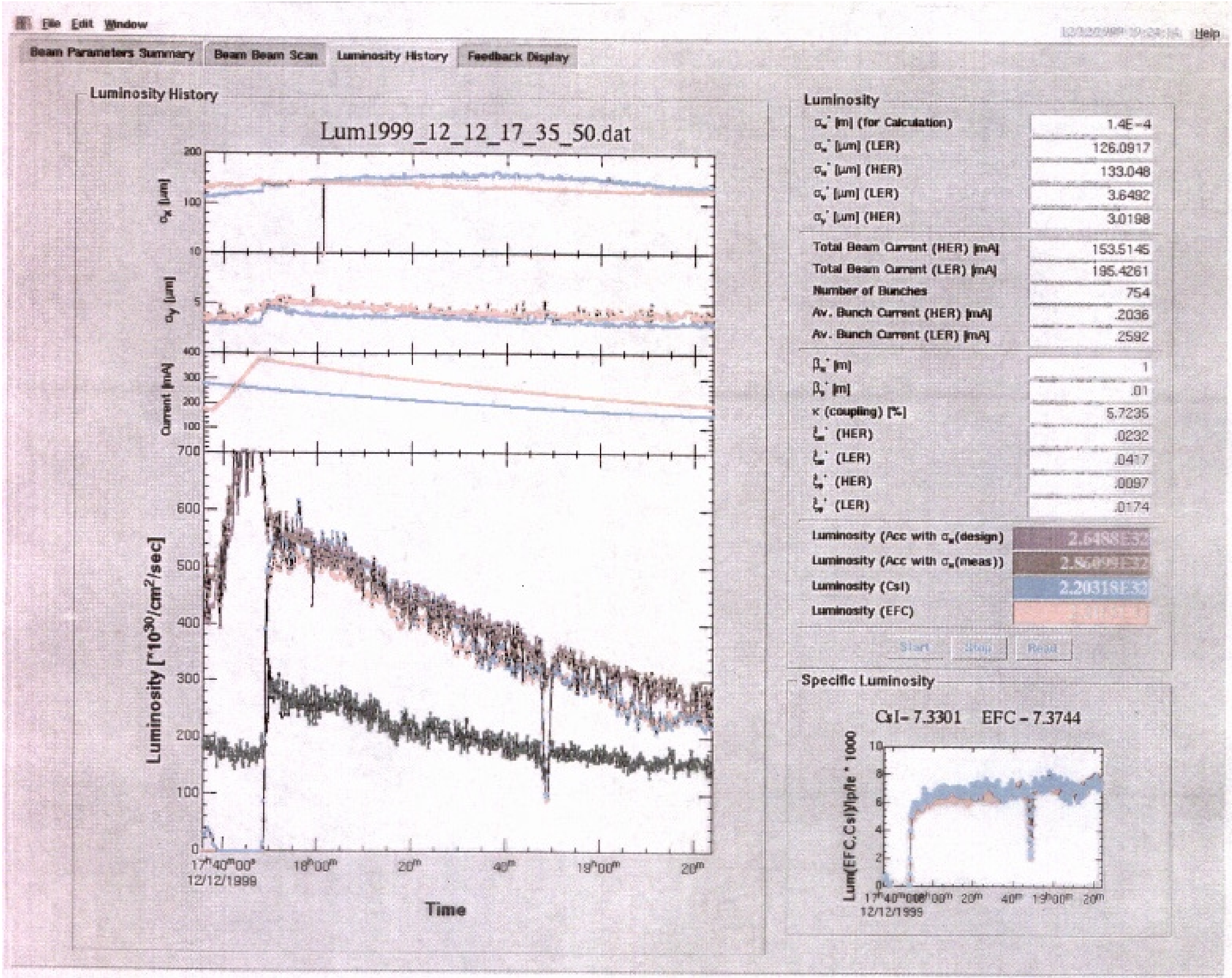
- Vertical beam blowup at collision
  - ♦Blowup of vertical beam size is observed at collision.
  - ♦Beam-beam simulation by K. Ohmi suggests that X-Y coupling can produce blowup.
  - ♦An attempt to measure coupling matrix is in progress.



File Edit Window
Help
Beam Parameters Summary
Beam Beam Scan
Luminosity History
Feedback Display
Scan (Main)
Horizontal Scan (detail)
Vertical Scan (detail)
Horizontal Scan
rf1999_12_11_20_41_1.dat
ROOMPHASE SET [degree]
Fit Result
rf1999_12_11_20_41_1.dat
Beam-Beam Kick [mrad]
RF Phase of LER [degree]
Choose & Fit
RePlot
ReFit
Nominal D7(D8) Room Phase
-26
Empirical Correction Factor
1.5
Horizontal Offset [mm]:
.0137
Horizontal Offset CORRECTED [mm]:
(Make LER orbit move to this direction.)
Horizontal Beam Size [mm]:
.2719
Horizontal Beam Size CORRECTED [mm] :
.4078
Vertical Scan
yp1999_12_11_20_47_26.dat
Beam-Beam Kick [mrad]
iBump Height [μm]
Fit Result
yp1999_12_11_20_47_26.dat
iBump Height [μm]
Choose & Fit
RePlot
ReFit
sigmax for fit [μm]
160
AspectRatio Initial for fit
.1
1.8888
κ(coupling) [%]
1.5856
Vertical Offset [μm]
1.6051
Set offset above
Horizontal Scan Control
Open RF Phase Scan Panel
Vertical iBump Scan Control
Bump Height at IP [μm]:
1.6051
Bump Angle at IP [mrad]:
0
Bump Initial Size [μm]:
-50
Bump Final Size [μm]
50
Bump Step Size [μm]:
5
Bump Step Period [sec]:
.1
Reverse Scan Direction
Steering Setting Value
Current Set STV1 [A]:
-.0266
Current Set STV2 [A]:
.0467
Current Set STV3 [A]:
.0382
Current Set STV4 [A]:
-.0127
Save Current
Load Current
Steering Monitor
Current Monitor STV1 [A]:
-.7475
Current Monitor STV2 [A]:
1.305
Current Monitor STV3 [A]:
1.0675
Current Monitor STV4 [A]:
-.3575
Read Steering



Y = M0 + M1*x + ... M8*x^8 + M9*x^9
M0 32.979
M1 -9.9009
M2 -11.171
R 0.99467
Y = M0 + M1*x + ... M8*x^8 + M9*x^9
M0 1.5014
M1 0.58931
M2 0.53184
R 0.99104
Y = M0 + M1*x + ... M8*x^8 + M9*x^9
M0 32.885
M1 -13.496
M2 -12.902
R 0.97946
LER Waist Scan 99/11/25
SpLum CSI
SpcLum EFC
σ y:LER
σ y:HER
σ y:Scan
√(σ yL^2+σ yH^2)/2
L Spec(CSI/EFC)
σ ye+(μ m)
Δ σ LER(cm)
40
35
30
25
20
15
10
6
5
4
3
2
1
-2
-1.5
-1
-0.5
0
0.5
1



File Edit Window
Help
Beam Parameters Summary
Beam Beam Scan
Luminosity History
Feedback Display
Luminosity History
Lum1999_12_12_17_35_50.dat
σx [μm]
σy [μm]
Current [mA]
Luminosity [*10^30/cm^2/sec]
17h40m00s 12/12/1999
18h00m
20m
40m
19h00m
20m
Time
Luminosity
σx* [m] (for Calculation) 1.4E-4
σx* [μm] (LER) 126.0817
σx* [μm] (HER) 133.048
σy* [μm] (LER) 3.6482
σy* [μm] (HER) 3.0198
Total Beam Current (HER) [mA] 153.5145
Total Beam Current (LER) [mA] 195.4261
Number of Bunches 754
Av. Bunch Current (HER) [mA] .2036
Av. Bunch Current (LER) [mA] .2592
βx* [m] 1
βy* [m] .01
κ (coupling) [%] 5.7235
ξx* (HER) .0232
ξx* (LER) .0417
ξy* (HER) .0097
ξy* (LER) .0174
Luminosity (Acc with σx(design))
Luminosity (Acc with σx(meas))
Luminosity (CsI) 2.20318E32
Luminosity (EFC)
Start
Stop
Read
Specific Luminosity
CsI - 7.3301 EFC - 7.3744
Lum(EFC,CsI)/Ip/Ie * 1000

Orbit drift and orbit vibration

•Orbit drift

Orbit drift is a problem in KEKB because it affects to vertical emittance, stable beam collision, damping time of bunch feedback and lattice diagnostics.

♦ Vertical orbit drift

Long term drift : 1 mm/12hr

Short term drift : 0.1mm/10 min

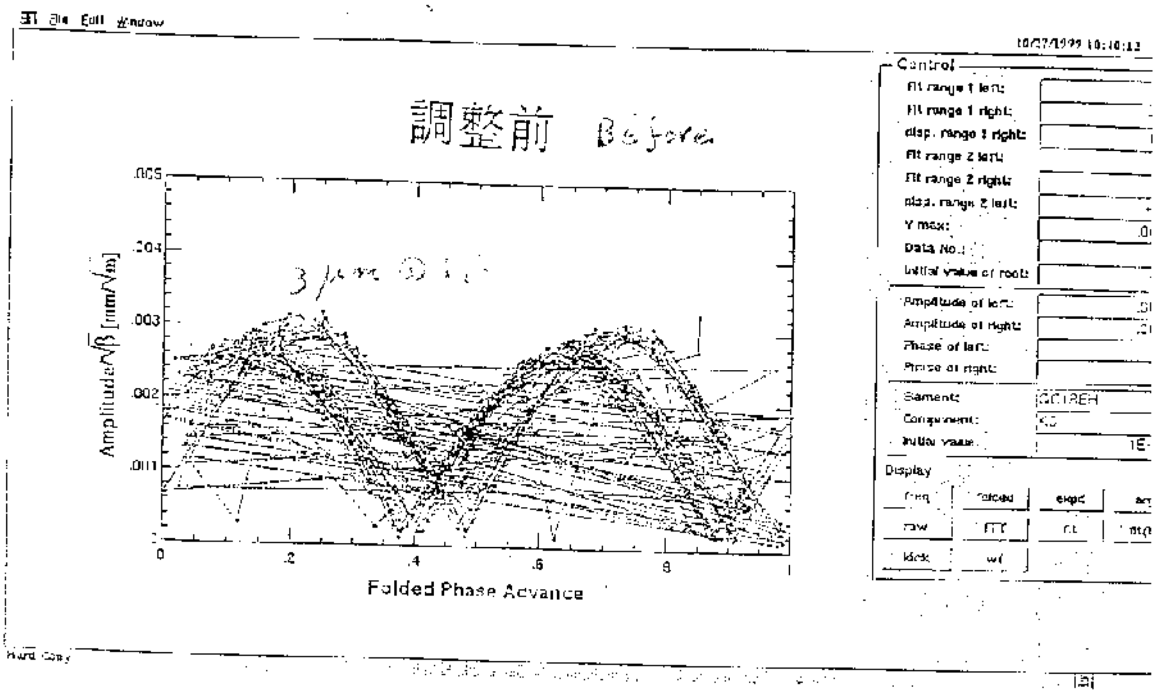
♦ Vertical orbit drifts of LER and HER are strongly correlated each other.

-> Sources of drifts are around IR.

♦ Long term vertical orbit drifts seem to be correlated with temperature around IP.

♦ To maintain stable orbit, closed orbit is continuously corrected every 40 sec.

- Orbit vibration
  - ♦It is found that orbit is vibrated at repetition rate (0.4Hz) of 12 GeV proton synchrotron (PS).
  - ♦Power converter of PS is located on the KEKB tunnel.
    Magnetic field from the monitor-magnet and power cables which is about 25 mG at KEKB tunnel affects to the orbit.
  - ♦To reduce the vibration,
    1) magnetic shields are installed near the monitor-magnet and around power cables,
    2) active feedback system with coils is introduced .


File Edit Window
調整前 Before
Amplitude/√β [mm/√m]
Folded Phase Advance
Control
Fit range 1 left:
Fit range 1 right:
disp. range 1 right:
Fit range 2 left:
Fit range 2 right:
disp. range 2 left:
Y max:
Data No.:
Initial value of root:
Amplitude of left:
Amplitude of right:
Phase of left:
Phase of right:
Element:
Component:
Initial value:
Display
freq
folded
expd
raw
FFT
kick
wf
Hard Copy

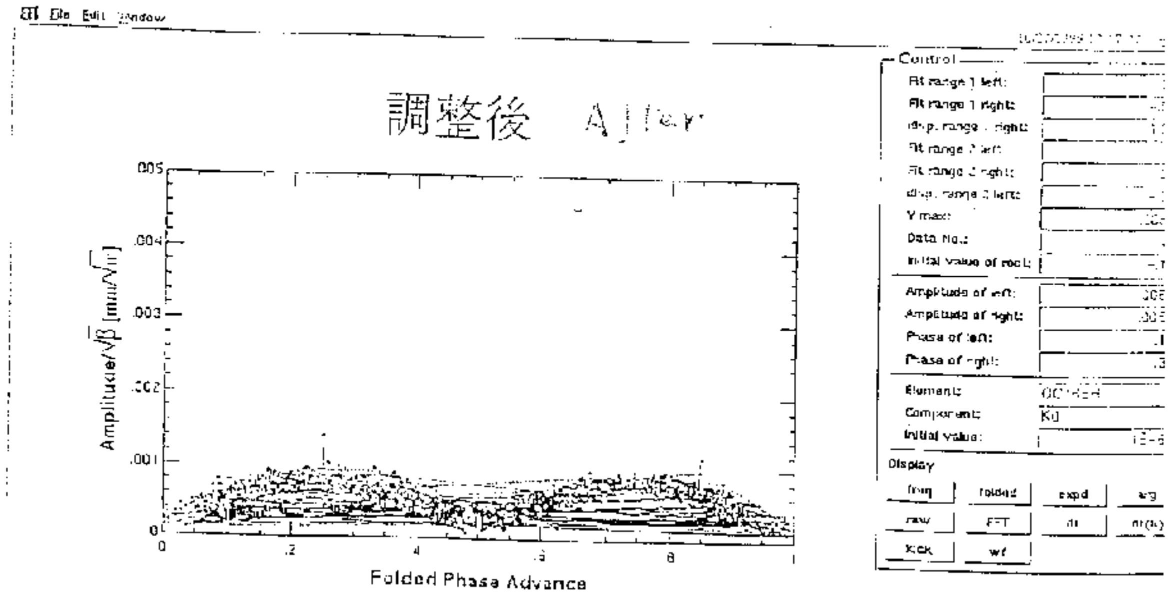

File Edit Window
調整後 After
Amplitude/√β [mm/√m]
Folded Phase Advance
Control
Fit range 1 left:
Fit range 1 right:
Y max:
Data No.:
Initial value of root:
Amplitude of left:
Amplitude of right:
Phase of left:
Phase of right:
Element:
Component:
Initial value:
Display
freq
folded
expd
raw
FFT
kick
wf

図２０

Belle background

- Soft photons (about 5 keV) from HER correction magnets near IP damaged Silicon Vertex Detectors.

  Software was modified to limit the strength of correctors.

- Reflected photons (about 30 keV) from the vacuum chamber near IP were another source of background.

  In this summer a vacuum chamber was replaced from Al to Cu to prevent reflected photons.

Reduction of background in autumn run,

SVD : factor 100

CDC : factor 10

- Now, spent particles are dominant source of background.

Schedule

KEKB will be operated to July 2000 almost without a break.