Commissioning of the KEKB B-Factory

MAC2000
February 10, 2000

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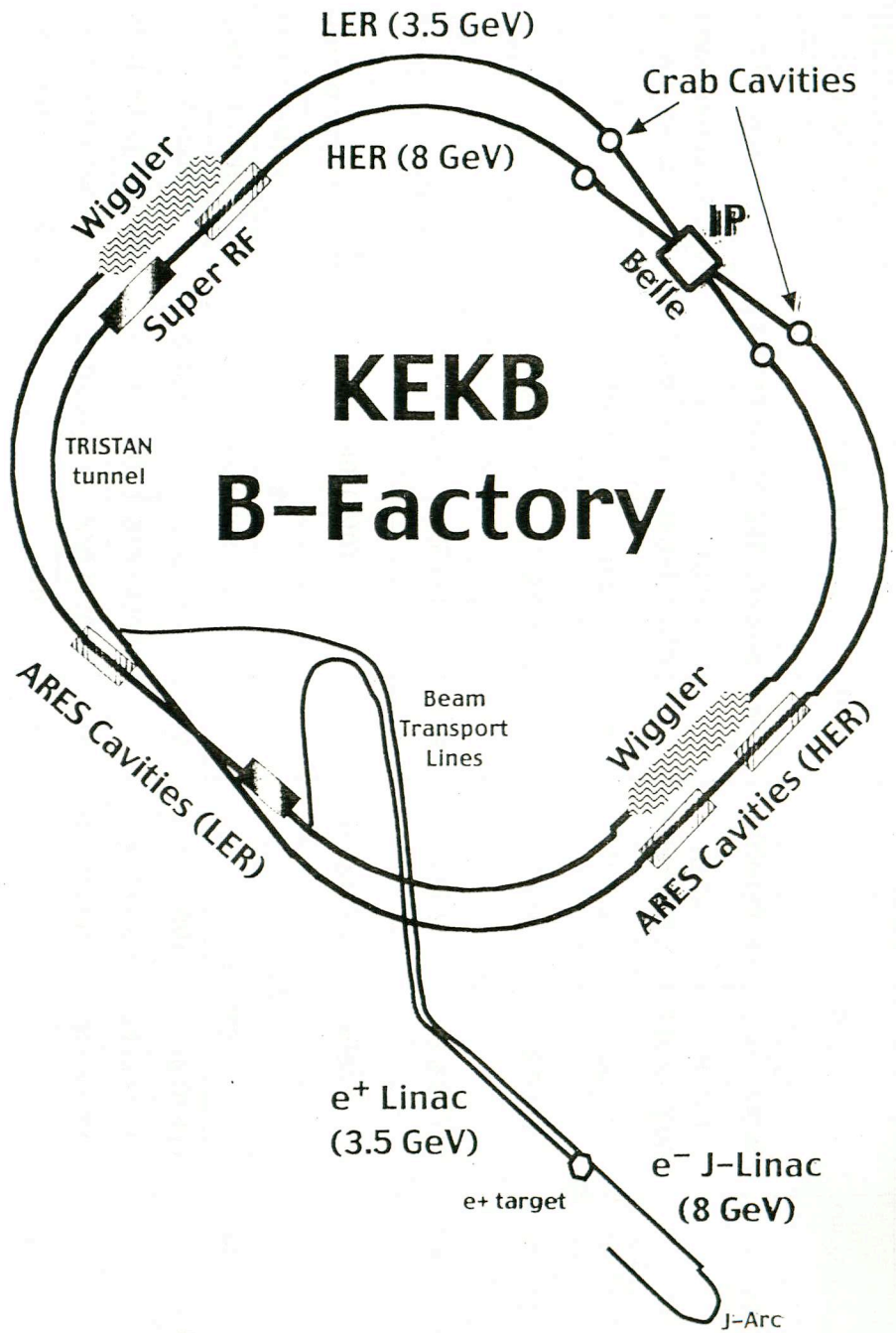
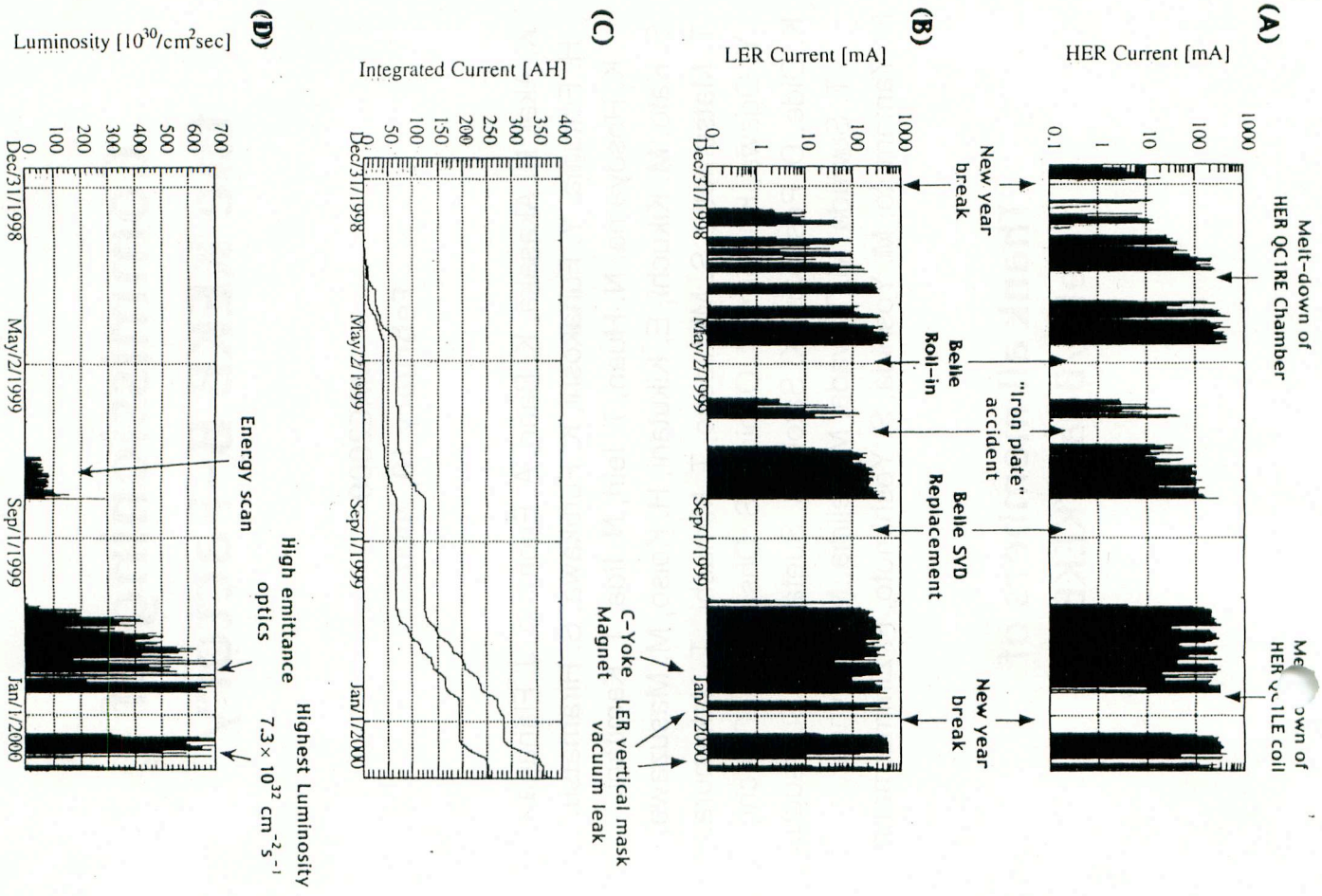
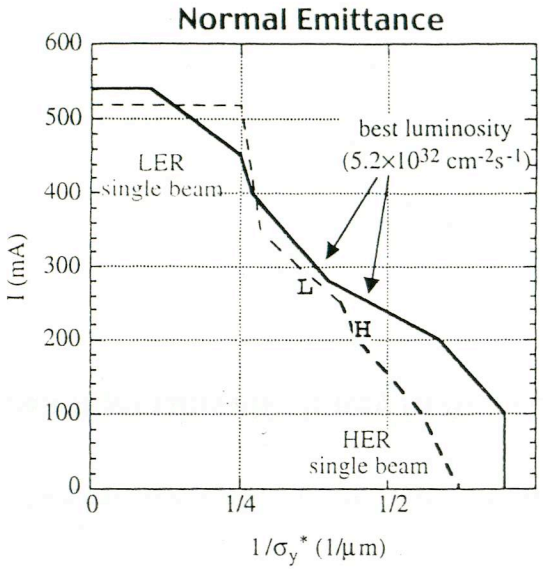
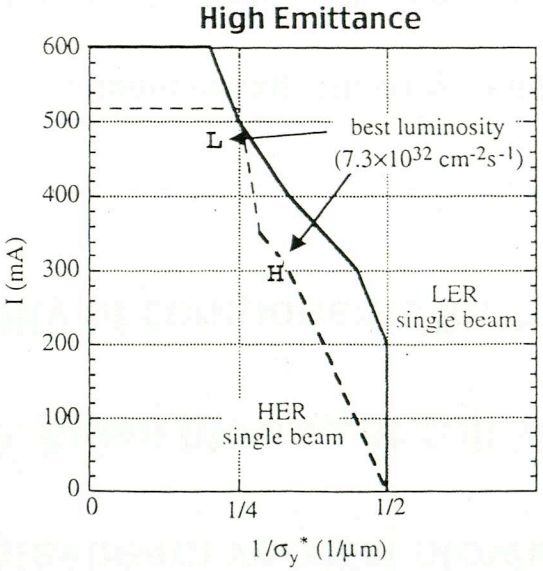
Thank all members of Belle/Beast/KEKB.





	Normal Emittance			High Emittance		
	LER	HER		LER	HER	
Horizontal Emittance	17	18	nm	30	30	nm
Beam current	270 (2600)	220 (1100)	mA	470 (2600)	300 (1100)	mA
Number of bunches	872 (4600)	872 (4600)		1042 (2700)	1042 (2700)	
Bunch current	0.30 (0.56)	0.25 (0.24)	mA	0.45 (0.96)	0.30 (0.41)	mA
Bunch spacing	2.4 (0.6)		m	2.4 (0.6)		m
Bunch trains	8			32		
Horizontal size at IP $\Sigma_x/\sqrt{2}$	140 (140)		μm	140? (170)	140? (170)	μm
Vertical size at IP σ_{y^*}	2.8 (1.4)	2.2 (1.4)	μm	5.0 (1.7)	3.5 (1.7)	μm
Emittance ratio $\varepsilon_y/\varepsilon_x$	4.0 (1)	2.5 (1)	%	13 (1)	6.3 (1)	%
β_{x^*}/β_{y^*}	100/1	100/1	cm	100/1	100/1	cm
beam-beam parameters ξ_{x^*}/ξ_{y^*}	0.039/0.030 (0.05)	0.021/0.012 (0.05)		0.044/0.021 (0.05)	0.028/0.0095 (0.05)	
Beam lifetime	130@300 mA	280@240mA	min.	100@450 mA	300@300mA	min.
Luminosity (calculated with parameters above)	5.1×10^{32}		$cm^{-2}s^{-1}$	5.7×10^{32}		$cm^{-2}s^{-1}$
Luminosity (CSI)	6.6×10^{32}		$cm^{-2}s^{-1}$	7.3×10^{32}		$cm^{-2}s^{-1}$


Normal Emittance
600
500
400
300
200
100
0
I (mA)
LER
single beam
best luminosity
(5.2×10^32 cm^-2s^-1)
L
H
HER
single beam
0
1/4
1/2
1/σy* (1/μm)


High Emittance
600
500
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I (mA)
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best luminosity
(7.3×10^32 cm^-2s^-1)
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single beam
HER
single beam
0
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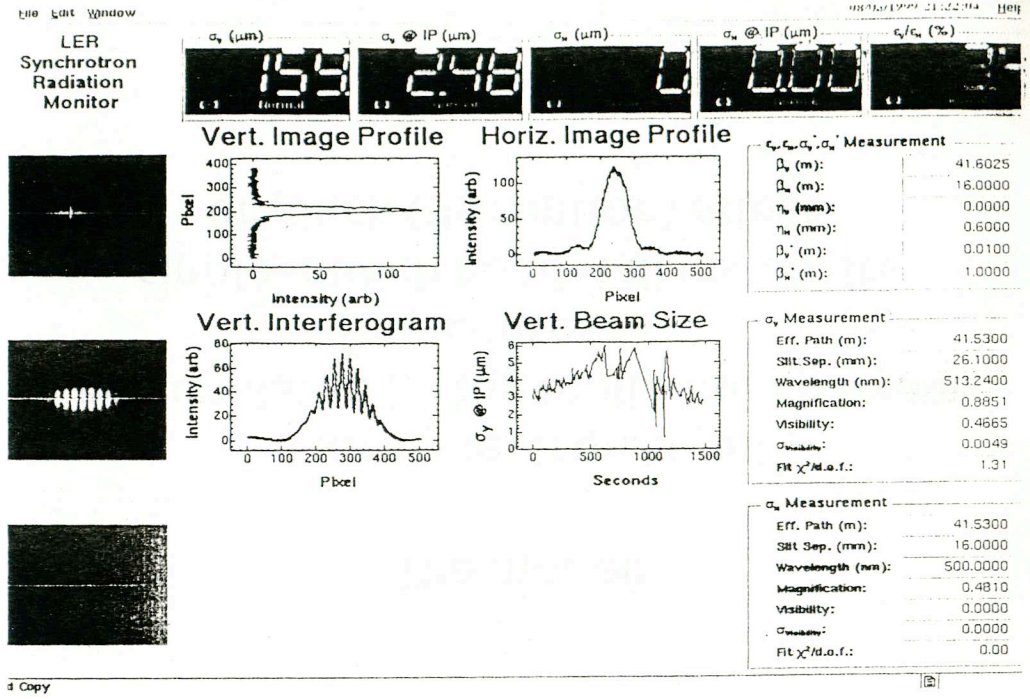
1/2
1/σy* (1/μm)


File Edit Window
LER
Synchrotron
Radiation
Monitor
Vert. Image Profile
Horiz. Image Profile
Vert. Interferogram
Vert. Beam Size
Pixel
Intensity (arb)
Seconds
Measurement
Eff. Path (m): 41.5300
Slit Sep. (mm): 26.1000
Wavelength (nm): 513.2400
Magnification: 0.8851
Visibility: 0.4665
Fit χ²/d.o.f.: 1.31
Eff. Path (m): 41.5300
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Wavelength (nm): 500.0000
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Visibility: 0.0000
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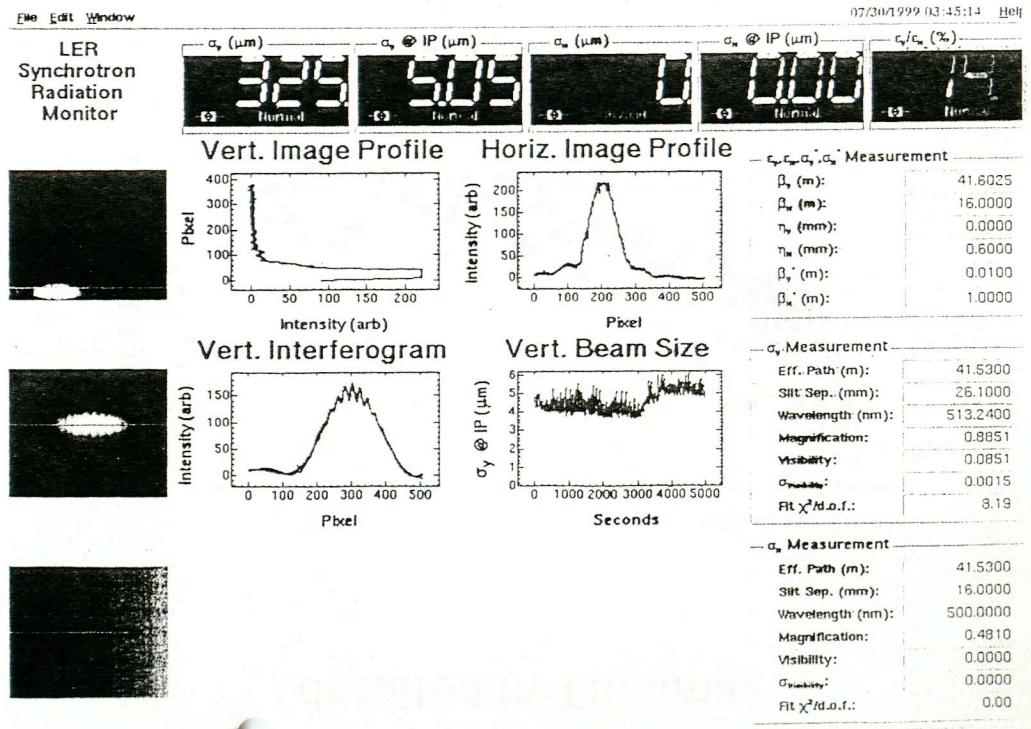
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LER
Synchrotron
Radiation
Monitor
Vert. Image Profile
Horiz. Image Profile
Vert. Interferogram
Vert. Beam Size
Pixel
Intensity (arb)
Seconds
Measurement
Eff. Path (m): 41.5300
Slit Sep. (mm): 26.1000
Wavelength (nm): 513.2400
Magnification: 0.8851
Visibility: 0.0851
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Wavelength (nm): 500.0000
Magnification: 0.4810
Visibility: 0.0000
Fit χ²/d.o.f.: 0.00
led LER Beam Profile Image

Issues to limit the luminosity

1. Single-beam vertical blowup in LER

2. Beam blowup at collision

3. Reliability of components for high current

4. Beam background for Belle

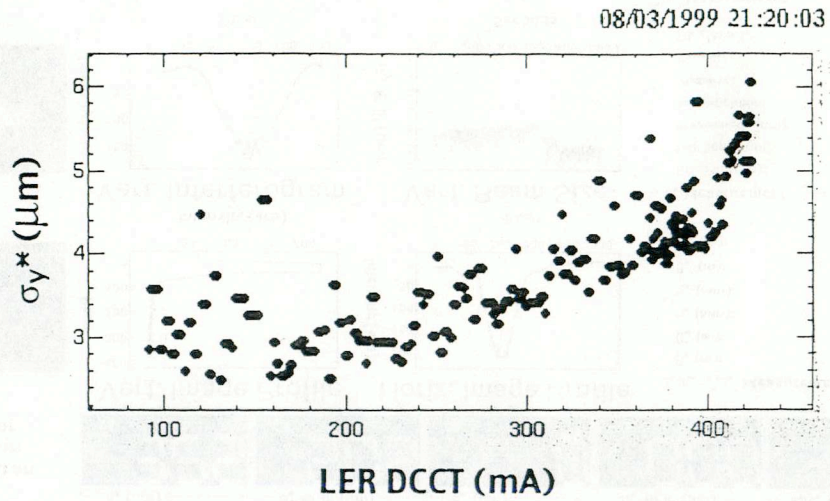
5. Other instabilities in LER and HER

6. Small momentum acceptance

7. Beam-optical errors (esp. in the IR)

8. Bad injection efficiency in HER (< 30%)

1. Single-beam vertical blowup in LER (detailed by Fukuma)



The model:

Photo-electron cloud
accumulated by the multi-bunch beam
causes
single-bunch head-tail instability
or pinch (disruption) effect.

Q: Do photo-electrons exist in LER?

A: Yes. They are detected by BPM currents and vacuum gauges at ion pumps.

Q: How about their density?

A: The measurement of bunch-by-bunch betatron tune tells the tune shift along a bunch train is about 0.01.

$$\Delta\nu \approx \frac{r_e}{2\gamma}\rho\beta_y L$$

gives $\rho \approx 10^{13}\ \mathrm{m}^{-3}$ with ($\beta_y = 10$ m, $L = 500$ m). This is close to the density to neutralize the positron beam:

$$\rho_{\mathrm{n}} = \frac{N_b}{s_b \pi a^2} = 2.1\times 10^{12}\ \mathrm{m}^{-3}$$

with ($N_b = 3.3\times 10^{10}$, $s_b = 2.4$ m, $a = 46$ mm).

Q: What kind of effects are conceivable for the photo-electron cloud with such density?

A: Single bunch head-tail instability is predicted by Zimmermann and Ohmi. It will results in a blowup of the vertical size. Also a pinch-effect in a bunch might be possible.

A photo-electron in a cloud is attracted by the positron bunch rapidly. The motion is rapid enough to make a few periods of oscillation within a passage of a bunch. The number of periods:

$$\nu = \frac{\omega\sigma_z}{c} \approx \sqrt{\frac{r_e N_b \sigma_z}{\sigma_x \sigma_y}} = 2.9$$

with ($\sigma_x = 10\sigma_y = 0.7$ mm, $\sigma_z = 4$ mm), or the oscillation frequency:

$$\omega/2\pi = 35\ \mathrm{GHz}.$$

Such a rapid oscillation of photo-electrons generates a short range transverse wake field to cause a head-tail instability.

Also this strong focusing increases the instantaneous density of photo-electrons to cause a pinch-effect on the positron.

(Further discussion will be given by Fukuma)

2. Beam-beam blowup (detailed by Funakoshi)

a) Parameters for collision is still under development. Not yet saturated.

b) Normal emittance vs. high emittance.

c) The single-beam blowup of LER worsens the blowup at collision.

d) Crab cavities.

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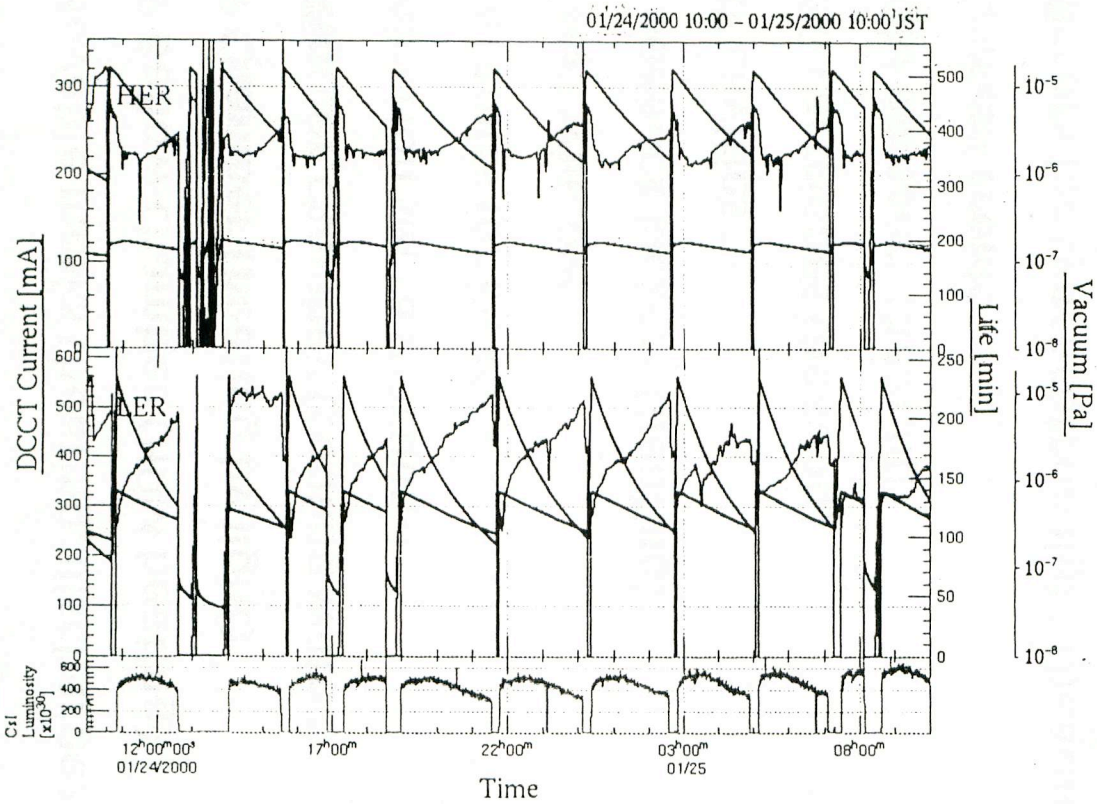

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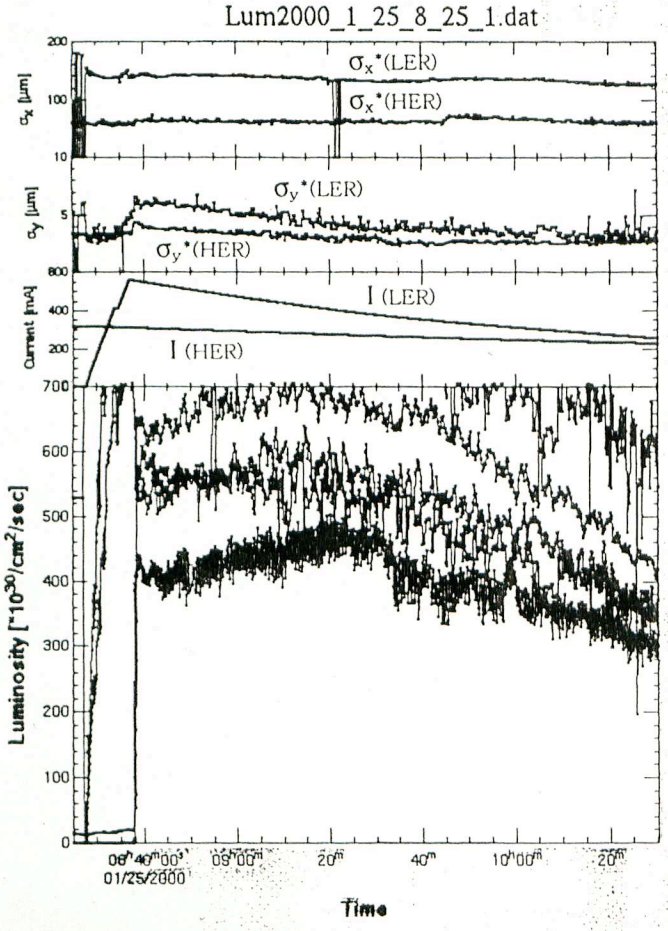
Luminosity History



Luminosity

σ_x^* [m] (for Calculation)	1.7E-4
σ_x^* [μm] (LER)	126.9368
σ_x^* [μm] (HER)	59.9255
σ_y^* [μm] (LER)	3.6336
σ_y^* [μm] (HER)	2.804
Total Beam Current (HER) [mA]	228.1309
Total Beam Current (LER) [mA]	255.2211
Number of Bunches	1041
Av. Bunch Current (HER) [mA]	.2191
Av. Bunch Current (LER) [mA]	.2452
β_x^* [m]	1
β_y^* [m]	.01
κ (coupling) [%]	3.6446
ξ_x^* (HER)	.015
ξ_x^* (LER)	.0306
ξ_y^* (HER)	.0078
ξ_y^* (LER)	.016
Luminosity (Acc with σ_x(design))	3.16258E32
Luminosity (Acc with σ_x(meas))	5.41655E32
Luminosity (Csf)	3.71283E32
Luminosity (EFC) (EFC)	4.18009E32

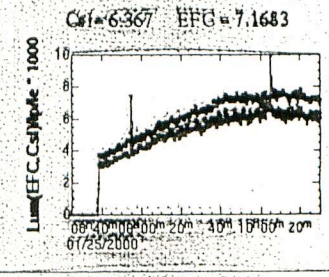
Luminosity (EFC)

Luminosity/1.14 (CSI)

Start Stop Read

Specific Luminosity

Csf = 6.367 EFC = 7.1683



3. Reliability of components for high current

a) Movable masks (heating, discharge)

b) IP Bellow chamber (HOM heating)

c) IP Chamber (heating by light)

d) Wiggler chamber (cooling water)

d) Injection septa (vacuum)

e) Ceramics for kickers

f) Abort window

g) Feedback kickers (heating)

h) RF cavities

i) NEG cartridges (heating)

j) HOM dampers (heating)

k) Current troids

l) Mirrors for synchrotron light (heating)

m)

COMMISSIONING OF THE KEKB B–FACTORY

K. Akai, N. Akasaka, K. Bane*, A. Enomoto, J. Flanagan, H. Fukuma, Y. Funakoshi, K. Furukawa, J. Haba, S. Hiramatsu, K. Hosoyama, N. Huang†, T. Ieiri, N. Iida, T. Kamitani, S. Kato, M. Kikuchi, E. Kikutani, H. Koiso, M. Masuzawa, T. Matsumoto, S. Michizono, T. Mimashi, T. Nakamura, Y. Ogawa, K. Ohmi, Y. Ohnishi, S. Ohsawa, N. Ohuchi, K. Oide, D. Pestrikov‡, K. Satoh, M. Suetake, Y. Suetsugu, T. Suwada, M. Tawada, M. Tejima, M. Tobiyama, S. Uno, N. Yamamoto, M. Yoshida, S. Yoshimoto, F. Zimmermann§, KEK, Oho, Tsukuba, Ibaraki 305-0801, Japan

Abstract

The commissioning of the KEKB B–Factory storage rings started on Dec. 1, 1998. This article briefly describes the progress after the installation of the Belle detector (May 1999) until the end of 1999. The commissioning before Belle has been reported in the PAC99 paper[2].

1 BRIEF HISTORY OF THE COMMISSIONING AFTER BELLE

The KEKB B–Factory[1] consists of two storage rings, the LER (3.5 GeV, e^+) and the HER (8 GeV, e^-), the injector Linac, and the beam-transport (BT) system. Before the Belle installation, collisions were successfully tried a few times, but a disturbance in the orbit due to the leakage fields of the KEK Proton Synchrotron prevented collision with high luminosity.

Figure 1 shows the history of the stored currents, the integrated currents, and the luminosity measured by the Belle CSI detector since Dec. 1998 through 1999. This figure also shows several breaks, the scheduled ones (for the new-year holidays, the installation of Belle, the upgrades of RF) and accidental shutdowns. The total length of breaks was about 6 months out of a year. So far, both rings have achieved stored currents more than 0.5 A, which corresponds to 20% (50%) of the design goal of the LER (HER). There were several reasons as described later to limit the maximum currents in the both rings up to the end of 1999.

After the installation of Belle, the machine was commissioned with the solenoid field at the interaction point(IP) for a few weeks. The problem of the orbit vibration had been basically solved. Then in mid June, we had a very unusual accident: an iron plate carelessly left around the superconducting quadrupole magnet (QCS) was attracted by the magnetic field. Then it hit a beam position monitor close to the IP, resulted in a vacuum leak and a shutdown for about 3 weeks.

The real collision thus did not start until July 1999. In July, though the luminosity was low ($1 \sim 2 \times 10^{32}\mathrm{cm}^{-2}\mathrm{s}^{-1}$), an energy scan was successfully done to determine the $\Upsilon(4S)$ resonance. The highest luminosity

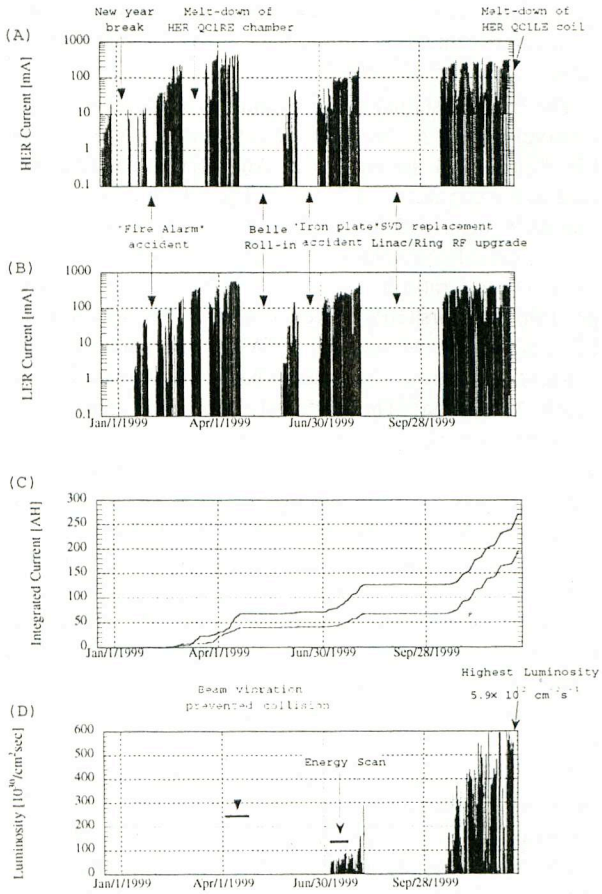


Figure 1: The stored beam currents, in log scale, during the commissioning are shown in HER (A) and LER (B), respectively. Several significant events are also shown. (C) The integrated beam current. (D) The luminosity observed by the CSI detector of Belle.

recorded in that period was $2.9 \times 10^{32}\mathrm{cm}^{-2}\mathrm{s}^{-1}$, with a correction in the skew windings in QCS (N. Ohuchi, H. Koiso), and a choice of transverse tunes. Systematic beam-optical corrections were started during this period to reduce the vertical beam size for single beams[4]. A set of special magnets (iBump) was also applied to maintain the collision[5], together with a continuous orbit correction (CCC) system (H. Koiso). The synchrotron light interferrometer[3] determined the vertical beam size of each beam, which was

* visiting from SLAC, U.S.A.
† visiting from IHEP, China.
‡ visiting from BINP, Russia.
§ visiting from CERN, Switzerland

nearly consistent with the luminosity taken by Belle. Also the wigglers were turned on in LER to equalize the damping time of the two rings.

Then we have to mention the next tragedy happened in July: the SVD detector of Belle was heavily damaged by the synchrotron light with 1–3 keV produced by the steering magnets upstream from the IP in HER[6]. Those magnets were excited to tune the background of Belle, but unnecessarily maintained at high strength for significant period without notice. Belle must replace it during the shutdown in August, as well as other reformation of the vacuum chambers/shields/monitors to improve the background. Actually these improvements in August have been very successful so far up to the end of 1999.

The fall run started at the beginning of October, with a relatively quick recovery of the luminosity. As shown in Fig. 1, the peak luminosity in August was easily recovered in the beginning of October. Then the luminosity was gradually increased in October through November. The global optical corrections were quite successful to achieve the emittance ratio less than 1%. Offsets of every beam position monitors (BPMs) were determined by quadrupole-BPM scans (M. Masuzawa, N. Akasaka), which is independently confirmed by a beam-based BPM mapping (K. Satoh, M. Tejima). The luminosity was tuned up by waist-scans for both rings, iBump feedbacks for both horizontal and vertical planes, tune surveys, tuning of vertical crossing angle and the x-y coupling knobs at the IP, etc. (Y. Funakoshi, M. Masuzawa, M. Tawada, J. Flanagan, N. Akasaka, *el al*). The interferrometer was then extended to the horizontal plane (J. Flanagan, T. Mitsuhashi), giving a better agreement with the Belle luminosity. Thanks to the flexible bucket-selection system with a bunch-current equalizer (E. Kikutani, M. Tobiyama, M. Suetake, T. Urano, N. Akasaka)[8], any bunch pattern could be generated and tested.

Until the end of November the collision was done with the normal emittance around 18 nm, giving the highest luminosity $5.2 \times 10^{32}\mathrm{cm}^{-2}\mathrm{s}^{-1}$. Then since it looked difficult to increase the number of bunches more than about 900 bunches/ring, we switched to a high-emittance (30 nm, from the normal emittance 18 nm) optics in both rings in December (H. Koiso). The luminosity with the high-emittance optics recorded $5.9 \times 10^{32}\mathrm{cm}^{-2}\mathrm{s}^{-1}$ so far, and is still improving.

The fractional parts of the transverse tunes have been chosen around $(0.52, 0.12)$ for both rings, which gave the best luminosity in the simulation in the Design Report. Tunes of each ring were optimized around the region individually looking at the luminosity. As a result, tunes of the two rings differed by about $0.02 - 0.05$. Since it takes a long time to develop the best condition for a given region in the 4-dimensional tune space, possibilities of other tunes will never exhaust. The same is true for other parameters such as $\beta^*_{x,y}$.

The last accident in 1999, the melt-down of a coil of one of the special quadrupole magnets in HER around the IP, happened on Dec. 16. This magnet, QC1LE, has conductors with very high current density, being potentially vulnerable at stagnancy or vapor lock of the cooling water. The fix will be complete and the machine will restart on Jan. 11, 2000.

Throughout this period of commissioning, the most parts of the machine, including the Linac, BT, injection, RF(ARES copper cavities[9] and the superconducting cavities[10]), iron and superconducting magnets, vacuum, control, timing, abort, civil engineering, and the safety systems basically worked as designed. Switching the Linac for the four beams (KEKB e^+, KEKB e^-, the Photon Factory, PF-AR) has been successful so far with a minimum loss time (A. Enomoto, H. Kobayashi, K. Furukawa *et al*).

2 LUMINOSITY PERFORMANCE

Table 1: Parameters of the collision in 1999, those gave the highest peak luminosities. Beam sizes are obtained by the synchrotron-light interferrometer. The accelerator luminosity/beam-beam parameters include the geometric reduction factors due to the crossing angle and the hour-glass effect. (A) The normal emittance and (B) the high emittance optics.

(A)	LER	HER	
Hor. emittance	17	18	nm
Beam current	270	220	mA
Bunches	872		
Bunch current	0.31	0.25	mA
Bunch spacing	2.4		m
Bunch trains	8		
σ^*_x/σ^*_y	140/2.8	140/2.2	μm
Emittance ratio	4.0	2.5	%
β^*_x/β^*_y	100/1	100/1	cm
Beam-beam params ξ^*_x/ξ^*_y	0.039/0.030	0.021/0.012	
Lifetime	130@300	280@240	min.@mA
Luminosities:			
by above params	5.1×10^{32}		$\mathrm{cm}^{-2}\mathrm{s}^{-1}$
Belle CSI	5.2×10^{32}		$\mathrm{cm}^{-2}\mathrm{s}^{-1}$

(B)	LER	HER	
Hor. emittance	30	30	nm
Beam current	430	270	mA
Bunches	841		
Bunch current	0.51	0.32	mA
Bunch spacing	2.4		m
Bunch trains	32–64		
σ^*_x/σ^*_y	170/4.6	140/3.6	μm
Emittance ratio	7.3	4.5	%
β^*_x/β^*_y	100/1	100/1	cm
Beam-beam params ξ^*_x/ξ^*_y	0.049/0.023	0.023/0.010	
Lifetime	100@450	250@300	min.@mA
Luminosities:			
by above params	5.7×10^{32}		$\mathrm{cm}^{-2}\mathrm{s}^{-1}$
Belle CSI	5.9×10^{32}		$\mathrm{cm}^{-2}\mathrm{s}^{-1}$

Table 1 lists beam parameters at collision when the luminosity recorded the best during the run in fall 1999, for the normal (A) and the high (B) emittance optics. Note that the each parameter may have better values individually than in this table during the run. It is seen that the luminosities estimated from the beam currents and the sizes are well consistent with those actually measured by the Belle CSI detector. The beam size are obtained by the synchrotron-light interferrometer, assuming the magnification between the light observation point and the IP given by the model optics. No dynamic-beta/dynamic-emittance effects are taken into account.

As shown in this table, the major problem in the luminosity of KEKB is the low luminosity/beam current ratio, or small vertical beam-beam tune-shift parameter $\xi_y \sim 0.01$. During this period, we have experienced heavy vertical blowups at the collision. In the case of the normal emittance optics, the blowup was occurred mainly in LER. On the other hand, HER beam looked weaker than LER for the high emittance optics. The blowup occurred in one beam, in both beams, or flip-flopped during a fill, depending on unknown conditions. A good condition with small blowup was not very reproducible, even with maintaining the intensities, orbits, tunes unchanged. The blowup might have been very sensitive to the small deviation in collision offsets. In some cases the luminosity was improved by a small change in the vertical tune by 0.002. The blowup sometimes affected the beam lifetime, when the masks were set narrow in particular.

It is too early to conclude the reasons of the heavy blowup at this moment, but several candidates have been considered and possible cures are under development. (1) The residual x-y-z coupling at the IP. Strong-strong simulations by K. Ohmi showed reduction of luminosity down to 1/3, when there are residual x-y couplings at the IP, together with the horizontal crossing angle. The local x-y coupling at the IP is going to be measured using nearby single-pass BPMs (OctoPos). The negative effects of the horizontal crossing angle will be eventually cured by the crab cavities in future. (2) Small deviation in parameters such as waists. The detectors for the luminosity were neither fast nor accurate enough to find the optimum conditions such as waist or the vertical crossing angle in a limited tuning period. With inaccurate monitors, tuning more knobs results in worse luminosity. (3) Small imbalance in beam sizes of two beams. As the single-beam sizes are suffered from the beam instabilities, it is hard to equalize the sizes of the two beams.

The peak luminosity was just one of many factors to determine the integrated luminosity actually taken by Belle. Beam lifetime, trip/burst/abort of Belle, injection rate/efficiency have been also important among them.

3 PROBLEMS

Besides the beam-beam blowup, there are a number of issues to limit the present luminosity of KEKB.

3.1 *Single-beam blowup in LER*

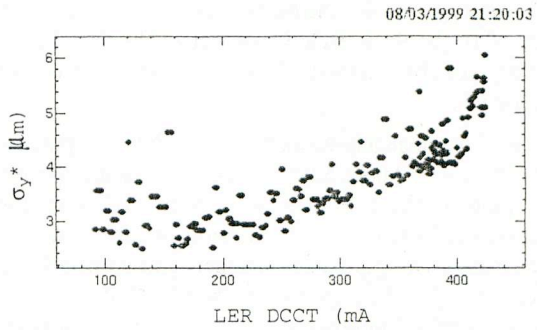


Figure 2: A typical single-beam blowup of the vertical beam size in LER.

As shown in Fig. 2, the vertical beam size of LER blows up as current increases. It is characterized as[7]

- A multi-bunch effect.
- The threshold intensity is determined roughly by (bunch current)/(bunch spacing).
- The effect is confined in a train, if the separation between trains is sufficiently long (longer than about 100 buckets, 60 m).
- The blowup becomes weaker for a train shorter than about 80 buckets.
- No dipole oscillation has been observed when the vertical chromaticity is high (5 to 8). When the chromaticity is as small as 2, a vertical dipole oscillation is excited, but the relationship between the dipole oscillation and the blowup is not known. The blowup does not change much for the chromaticity between 5 and 8.
- Almost independent on betatron tunes.
- The beam size after blowup does not depend on the zero current beam size. When the initial size is high, the threshold becomes high.
- Does not depend on the position of the vertical masks.
- Does not depend on the vacuum pressure in the arc.
- Does not depend on the excitation of the wigglers.
- No aging effect has been seen so far.

So far the photo-electrons generated in the arcs by the synchrotron radiation have been suspected as the cause of this phenomenon. Actually photo-electron currents were observed at ion pumps downstream of bending magnets in the arc (S. Kato, Y. Suetsugu). Also a current has been observed in BPM electrodes applying a DC bias voltage (M. Tejima, S. Hiramatsu). Though the existence of the photo-electron is confirmed, its density, energy, or distribution, etc. have not been exactly determined. A possible indication was a change in the vertical betatron tune along a long train (T. Ieiri), by about 0.01 for 120 bunches with 4 bucket spacing, which is consistent with a simulation (F. Zimmermann, K. Ohmi). So far the most probable mechanism of the blowup is a head-tail or a beam breakup instabilities

caused by the photo-electron cloud which works as a media of a transverse wake function (F. Zimmermann, K. Ohmi). This model explains the blowup as a single-bunch dynamics, while the electron cloud is generated by the multi-bunch effect. No observation to deny this hypothesis has not been made yet.

In November, a brute method was applied hoping to cure this blowup. About 5,000 so-called "C-Yoke" permanent magnets (S. Olsen, F. Takasaki, S. Kato *et al*) were attached all around LER, outside the vacuum chamber. The C-Yoke consists of two permanent magnets and an iron C-shaped yoke. They are attached in every 10 cm of the LER drift space within 7 m downstream from bending magnets. It was not possible to attach them in 6 hours without the help of the Belle people. A C-Yoke produces a vertical magnetic field of 200 and 40 Gauss at the chamber wall and the beam, respectively. It was expected that the photo-electron generated by the primary photon was well suppressed by those C-Yokes. The polarity of the magnets were reversed in every 20 cm to reduce the effects on the beam.

Though the effect of the C-Yoke on the blowup was not visible at least for a long train, there were changes in vertical sizes in leading 10–20 bunches at the head of a train, which was detected by a fast gated camera(T. Mitsuhashi, J. Flanagan, H. Fukuma). Anyway the fact that the suppression of the blowup by the C-Yoke was not drastic suggests that the effect due to the reflected light might be significant, if the blowup comes from photo-electrons. A modification of the vacuum chamber to suppress the reflection is now under planning.

Actually, the C-Yoke was the second version of the trial of the attached magnets; the first version was a single line of alternating permanent magnets. Though the first version suppressed the blowup for a bunch-spacing longer than 16 buckets, it also introduced a strange instability around 20 mA for the spacing less than 4 buckets. The positive effects were weaker than the C-Yoke, and the negative effect was suspected to be due to the horizontal component of the magnetic field.

3.2 *HER instability*

HER beam also blows up as current increases. Its behavior is quite different from LER's. Many strong indications for a fast-ion instability (FII) have been observed with the bunch-oscillation recorder (BOR) (M. Tobiyama, E. Kikutani, H. Fukuma, Y. Ohnishi)[11]. Depending on the conditions such as dispersion, chromaticity, x-y coupling, etc., the single-beam beam size of HER also increases as current. As shown in Fig. 3, this increase in HER starts at zero current, and does not show any threshold. In different conditions the increase becomes much less, but the critical factors to suppress the increase have not been identified yet. The detail of this increase will be studied in early 2000.

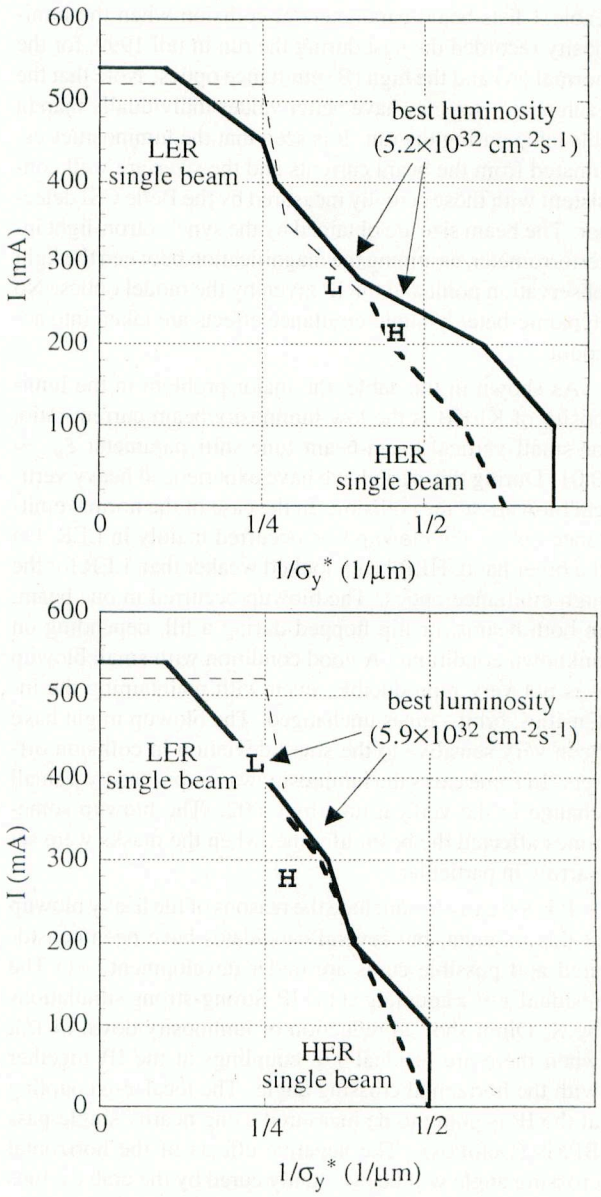


Figure 3: Inverse of the single-beam vertical beam sizes against the stored current are plotted for LER (solid) and HER (dashed). (A) The normal emittance and (B) the high emittance. The beam sizes are measured by the interferrometer, then scaled to the IP, assuming the model optics. The markers L and H denote the parameters at collision listed in Table 1. In the case A(B), LER(HER) beam blows up at the collision, while the HER(LER) beam size at collision keeps the single-beam beam size.

3.3 *Heatings*

As beam current increases, the heating by synchrotron light or higher-order modes becomes serious. Components such as

- Vertical masks in LER
- IR chamber, downstream from IP in HER
- Structures around the feedback system

needed special care/reformation to store the beam current higher than 500 mA. Vertical masks with new designs will be installed in early 2000 (Y. Suetsugu *et al*).

3.4 *Trip/Burst/Abort*

During a physics run, trips of Belle randomly occurs due to HER beam current. Sometimes a big trip associates a decrease of the lifetime, and a very big one triggers the abort kicker via either the background detector of Belle or the beam loss monitor around the ring. Dust traps are suspected as the cause, since it is only for HER, and the finger contact of the vertical movable mask has been suspected as the source. The frequency and the magnitude of the trips depend on the beam size, the orbit, and the residual beam oscillation.

3.5 *Orbit vibration and drift*

The vibration due to the Proton Synchrotron was cured by magnetic shields and compensation steering magnets (K. Hosoyama, A. Kabe, Y. Morita, H. Nakai, T. Mimashi, N. Akasaka, *et al*). Then a vertical vibration at 10 Hz with an amplitude of 0.5 μm at the IP was the next large vibration, whose source has not been identified. A slow orbit drift is still a potential problem to degrade the collision performance, even with the continuous orbit correction (CCC). The CCC system corrects the orbit in every 20 seconds with the help of the synchronized magnet setting system (T. Nakamura, T. Naito, M. Yoshida). Such a slow drift also disturbs the measurements for the lattice diagnostics.

3.6 *Injection rate*

The injection rate reached 1.3 mA/s for both beams, but the question is to maintain the best condition. For this purpose, beam dumps were newly installed in the BT line to diagnose/tune the injecting beam during a physics run of the rings (M. Kikuchi *et al*). The wire scanners (N. Iida, Y. Funakoshi, T. Suwada), the orbit correction system (T. Kamitani, Y. Ohnishi), and the feedback system in Linac and BT (K. Furukawa, Y. Ohnishi) will be fully utilized.

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