KEKB PERFORMANCE

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Abstract

We summarize the machine operation of KEKB during past one year. Progress for this period, causes of present performance limitations and future prospects are described.

INTRODUCTION

The KEKB B-Factory is an electron-positron double ring collider working at KEK. Its peak luminosity surpassed $1 \times 10^{34}/\mathrm{cm}^2/\mathrm{sec}$ in May 2003 for the first time in the history of colliders. This peak luminosity is also the design value of KEKB. After this achievement, the KEKB luminosity has been still growing. In this reports, we summarize the machine operation of KEKB mainly after the summer-shutdown in 2003. A status report before this was written elsewhere [1]. Fig. 1 shows 5-year's history of the KEKB luminosity and beam currents. Table 1 shows present machine parameters of KEKB compared with those of about one year ago. As is seen in the table, there are no big changes in the machine parameters. Although the changes are small, we made significant progress in both the peak luminosity and the integrated one with continuous efforts. The peak luminosity increased by about 30%. On the other hand, the daily integrated luminosity increased by about 60%. The reason why the improvement in the integrated luminosity is much larger than the peak lies in adoption of so-called continuous injection scheme which we introduced at the beginning of this year (2004).

Table 1: KEKB Machine Parameters.

	June 2004		May 2003		
	LER	HER	LER	HER	
Energy	3.5	8.0	3.5	8.0	GeV
Circumference	3016		3016		m
I_{beam}	1650	1220	1500	1100	mA
# of bunches	1294		1284		
I_{bunch}	1.28	0.94	1.17	0.86	mA
Ave. Spacing	2.35		2.33		m
Emittance	18	24	18	24	nm
β_x^*	59	56	59	58	cm
β_y^*	5.2	6.5	5.8	7.0	mm
Ver. Size@IP	2.1	2.1	2.2	2.2	μm
RF Voltege	8.0	14.0	8.0	13.0	MV
ν_x	.505	.513	.507	.512	
ν_y	.535	.582	.546	.580	
ξ_x	.113	.072	.096	.065	
ξ_y	.074	.057	.069	.052	
Lifetime	152	178	127	256	min.
Luminosity	13.92		10.57		/nb/s
Lum/day	0.944		0.579		/fb
Lum/7 days	6.01		3.88		/fb
Lum/30 days	24.00		12.81		/fb

RECENT PROGRESS

Continuous Injection

In the conventional injection scheme, data taking by the physics detector (named Belle) was halted during the beam injection. After finishing the injection, Belle rose high voltage (HV) of each part of the detector and then started data taking. When the beam currents decreased to some values, Belle halted data taking and lowered HV for the next beam injection. The beam injection started after HV is lowered to some values. On the other hand, in the continuous injection scheme, data taking continues even during the beam injection. The continuous injection scheme has the following four advantages over the conventional scheme. 1) We can avoid the time loss of the beam injection and the up-and-down of HV. 2) The beam currents can be kept almost at the maximum value through the experiment. 3) We can optimize the machine tuning parameters at around the maximum beam currents as is explained in the next subsection. 4) We can operate the machine much more stably than the conventional scheme, since basically we need not change the machine parameters. By adopting the continuous injection scheme, an integrated luminosity per shift was increased by more than 20%.

In the continuous injection scheme, usually the beam is injected at 10 Hz (cf. 50Hz in the conventional scheme). After each beam injection, data taking is vetoed for 3.5 msec, which means that the dead time is 3.5% arisen from

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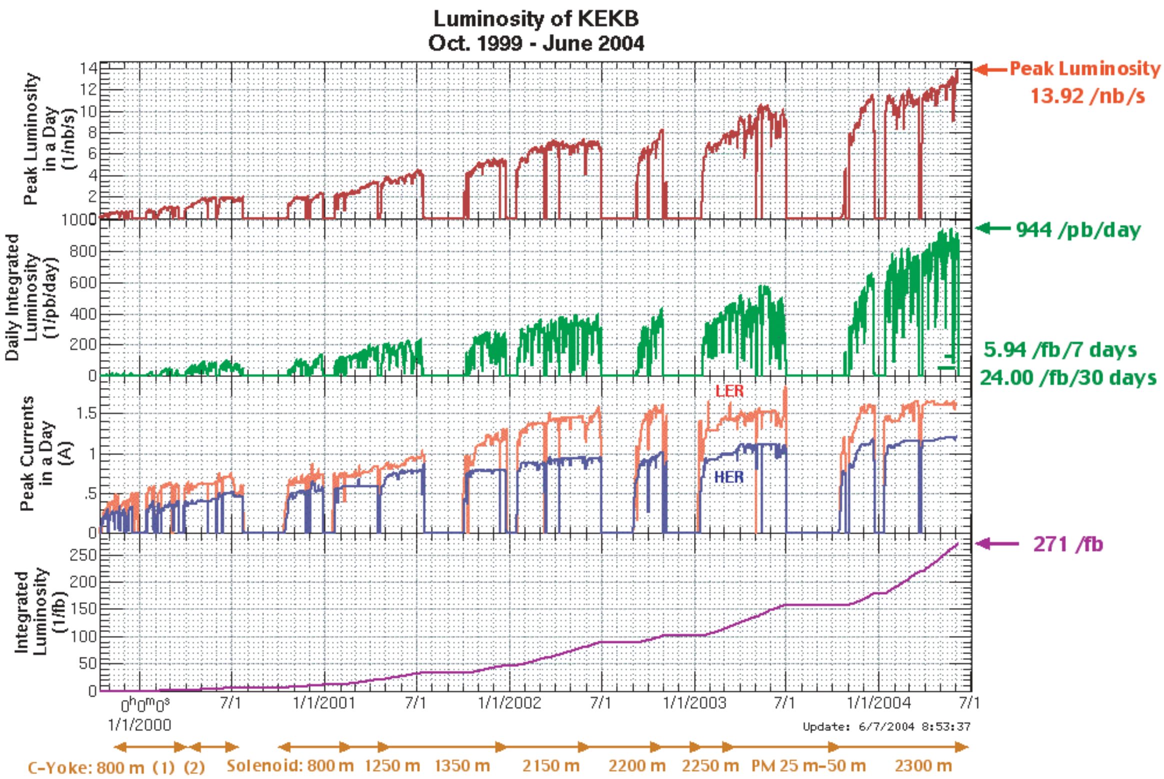

Figure 1: History of KEKB.

this veto. In the case of KEKB, the electron and positron beam can not be injected simultaneously. At present, the mode of the injector (electron or positron) is switched every 5 minutes. The continuous injection scheme was realized with preparations and trial-and-errors for more than one year. We had to rise above some serious problems such as malfunction of pre-amplifiers of the TOF detector and frequent DAQ (data acquisition) errors of Belle under a high beam background. To solve the problem with the pre-amplifiers, we adapted them so that they can accept a higher noise. The DAQ problems were overcome by upgrading the DAQ system during the summer shutdown in 2003. On the other hand, we also had to make efforts to decrease the detector beam background, which was done mainly by optimizing machine parameters.

Peak Luminosity

The improvement in the peak luminosity shown in Table 1 has been brought by both improvement in the specific luminosity and the increase of the beam currents. Fig. 2 shows a comparison of the specific luminosity of the present KEKB with that in May 2003. Two fills are shown in the figure, which gave the best luminosity so far of 13.92 /nb/s (red plot) and the best luminosity before summer in 2003 of 10.57 /nb/s (green plot). The fill of the red plot was a relatively long fill for about 7 hours due to the continuous injection. On the other hand, the fill of the green line was that for about one hour. From these plots and Table 1, we can see three causes of improvement in the peak luminosity . 1) The beam currents in both rings increased by about 10 %. 2) The specific luminosity increased by about 10 or 20 %. 3) The luminosity gets a peak at the highest beam currents in the present operation.

To increase the beam currents, the following three works were done during the summer shutdown in 2003. 1) Two more ARES cavities were installed in HER. 2) The IR vacuum chambers were replaced with new ones which realize more cooling power against heating by SR from the IR quadrupole magnets. 3) Several vacuum components which had troubles or would possibly restrict the beam currents were replaced with new versions (or simply removed from the rings), which include HER movable masks, bellows near IP, vacuum chambers of septum magnets in both rings, an ante-chamber for beam test in LER, a vacuum chamber of the synchrotron radiation (beam size) monitor in HER, beam stoppers in both rings and ceramic chambers of kicker magnets in HER. Since the vacuum works above, the HER beam current has been limited mainly by the RF power. The two new ARES cavities brought a higher HER current in autumn 2003 as shown in Fig. 1. At the beginning of 2004, one of superconducting cavities (SCC) in HER was removed from the ring due to vacuum leak. Although we had to decreased the HER beam current after this, the HER current has been increasing by increasing RF power for each SCC. On the other hand, the LER beam current is not limited by the RF power but by the luminosity itself, which means that the luminosity does not increase with a higher LER beam current than some value. We have not yet fully understood the reason for this. We suspect the effect of the electron cloud in LER and the beam-beam blowup of the HER beam.

As for causes of improvement in the specific luminosity, we can list up the following four causes. The first is that we squeezed the vertical beta functions of both rings further. The second is fine tune survey particularly of the vertical tune of LER. The third are continuous efforts to improve methods of the optics and orbit corrections. The fourth is installation of more solenoid magnets for suppressing the effects of the electron cloud. During and after the summer shutdown in 2003, we installed 210 more solenoid coils and 50 permanent solenoid magnets.

As for the reason that the peak luminosity is obtained at the maximum beam currents at present unlike last year, we consider effectiveness of the continuous injection scheme. With this scheme, we can tune the machine with almost the same beam conditions. We experience that the beam orbits and the betatron tunes change as function of the beam currents even without any intentional changes, the mechanism of which we still have to investigate in future.

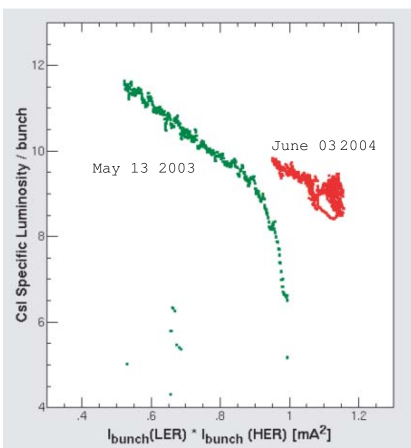

Figure 2: Progress of specific luminosity (in units of $10^{30}/\mathrm{cm}^2/\mathrm{s}/\mathrm{mA}^2$) in the past one year.

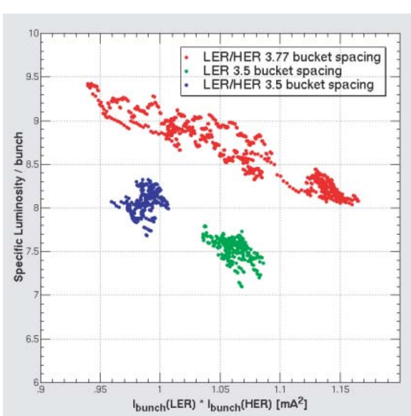

Figure 3: Reduction of specific luminosity with shorter bunch spacing.

Performance Limitations

One of the features of KEKB is that the number of bunches is much smaller than the design. In the design, the number of bunches was assumed to be around 5000 which means that every RF bucket is filled with particles (except for some abort gap). In the present KEKB, the specific luminosity tends to decrease when the number of bunches increases. This problem (bunch-spacing problem) imposes a performance limitation upon KEKB, since it is desirable to increase the number of bunches from the view point of avoiding hardware troubles due to HOM fields. The number of bunches is 1289 at the present KEKB. The fill pattern is a mixture of 3 and 4 RF bucket spacing and the averaged bunch spacing is 3.77 RF buckets (2.35m). To study the bunch-spacing problem, we made an experiment where 98 more bunches were added to both rings. They were placed in between 4 bucket spacing so that the averaged bunch spacing was 3.5 RF buckets. As is shown in Fig. 3, when we added 98 bunches, the specific luminosity decreased by about 5 % (from red dots to blue). We also tried to add the 98 bunches only in LER (positron ring). Also in this case, we observed a degradation of the specific luminosity by about the same amount shown in Fig. 3. On the other hand, in the case that we added the 98 bunches only in HER, we observed no significant degradation of the specific luminosity (not plotted in the figure). This suggests that the LER beam is responsible for the degradation. A beam size measurement using a streak camera showed that the added bunches and bunches followed just after those bunches in LER blow up[2]. A measurement using a bunch-by-bunch luminosity monitor showed that the specific luminosity per bunch corresponding to those bunches is degraded by about 30 %[3], which is consistent with the 5 % degradation of the total specific luminosity. As for causes of this, we suspect effects of the electron clouds and/or combined effects of the clouds and the beam-beam, although we need further study.

FUTURE PLANS

During the next summer shutdown, the SCC removed from HER will come back and input couplers of two ARES cavities which have now a problem will be replaced with an upgraded version. After these works, the HER beam current is expected to be raised by about 200mA. A crab cavity for the purpose of increasing the beam-beam parameters is scheduled to be installed in each ring in the end of 2005 or at the beginning of 2006. We have a long-term plan to increase the HER beam current up to 2A by 2007, although the budget for this has not been approved.

REFERENCES

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