RECENT PROGRESS OF KEKB

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Abstract

We summarize the machine operation of KEKB during past one year focusing on progress for this period.

INTRODUCTION

In this reports, we summarize the machine operation of KEKB after the summer shutdown in 2006. A status report before this was written elsewhere [3]. During the winder shutdown in 2007, we installed a crab cavity in each ring. After the installation, KEKB has been devoted to a machine study on the crab crossing. Since reports on the experiment are written elsewhere [1][2], this report deals mainly with the machine operation before the crab installation.

Fig. 1 shows 6-year's history of the KEKB luminosity and beam currents. Table 1 shows latest machine parameters of KEKB compared with those before summer in 2006. In this report, we describe present performance and some recent progress at KEKB.

PERFORMANCE OF KEKB

By the end of 2006, the Belle detector accumulated an integrated luminosity of 710 fb^{-1}. In 2006, it accumulated 180.8 fb^{-1}. A new record of the peak luminosity of 1.712 $\times 10^{34}\mathrm{cm}^{-2}\mathrm{s}^{-1}$ was made in Nov. 2006. Causes of the luminosity increase is described in the next section. Fig. 2 shows a history of a weekly luminosity of KEKB. The weekly luminosity is increasing gradually. Fig. 3 shows a machine operation statistics. In FY. 2006, about 87% of the machine operation time was devoted to the physics run. This value is compared with 79% in FY. 2005, when we had a serious trouble with the Belle detector. Fig. 4 shows a machine trouble statistics in FY 2006. As is seen in the figure, troubles of the magnet system occupies a relatively big percentage. Main reasons of the magnet troubles are those with a cooling water system and a cryogenic system of superconducting quadruple magnets.

Table 1: KEKB Machine Parameters.

	June 2006		Nov. 2006		
	LER	HER	LER	HER	
Energy	3.5	8.0	3.5	8.0	GeV
Circumference	3016		3016		m
$\mathrm{I_{beam}}$	1616	1210	1662	1340	mA
# of bunches	1387		1387		
$\mathrm{I_{bunch}}$	1.16	0.871	1.20	0.965	mA
Ave. Spacing	2.1		2.1		m
Emittance	18	24	18	24	nm
β_x^*	59	56	59	56	cm
β_y^*	6.5	5.9	6.5	5.9	mm
Ver. Size@IP	1.7	1,7	1.9	1.9	μm
RF Voltege	8.0	15.0	8.0	15.0	MV
ν_x	.505	.511	.505	.509	
ν_y	.534	.568	.534	.565	
ξ_x	.106	.068	.117	.070	
ξ_y	.105	.060	.105	.056	
Lifetime	148	204	110	180	min.
Luminosity	16.52		17.12		/nb/s
Lum/day	1.232		1.232		/fb
Lum/7 days	7.81		7.81		/fb
Lum/30 days	30.21		30.21		/fb

RECENT PROGRESS

Before summer in 2006, the HER beam current was limited by troubles of standard-type bellows in arc sections [3]. We experienced frequent breaks with vacuum bellows at the level of 1350mA. The troubles occurred not with special type bellows but with regular type bellows in downstream of bending magnets. The bellows deformed in the horizontal direction when the beam current rapidly changes such as in beam aborts or during beam injections. The breaks of the bellows was induced by this tilt deformation and caused the beam current limitation at the level of 1350mA. During the summer shutdown in 2006, we made some countermeasures for this deformation which include installation of supports which prevent the deformation. In the autumn run 2006, we could increase the HER beam current up to 1400mA. This increase in the beam current was one of the causes of the increase of the peak luminosity.

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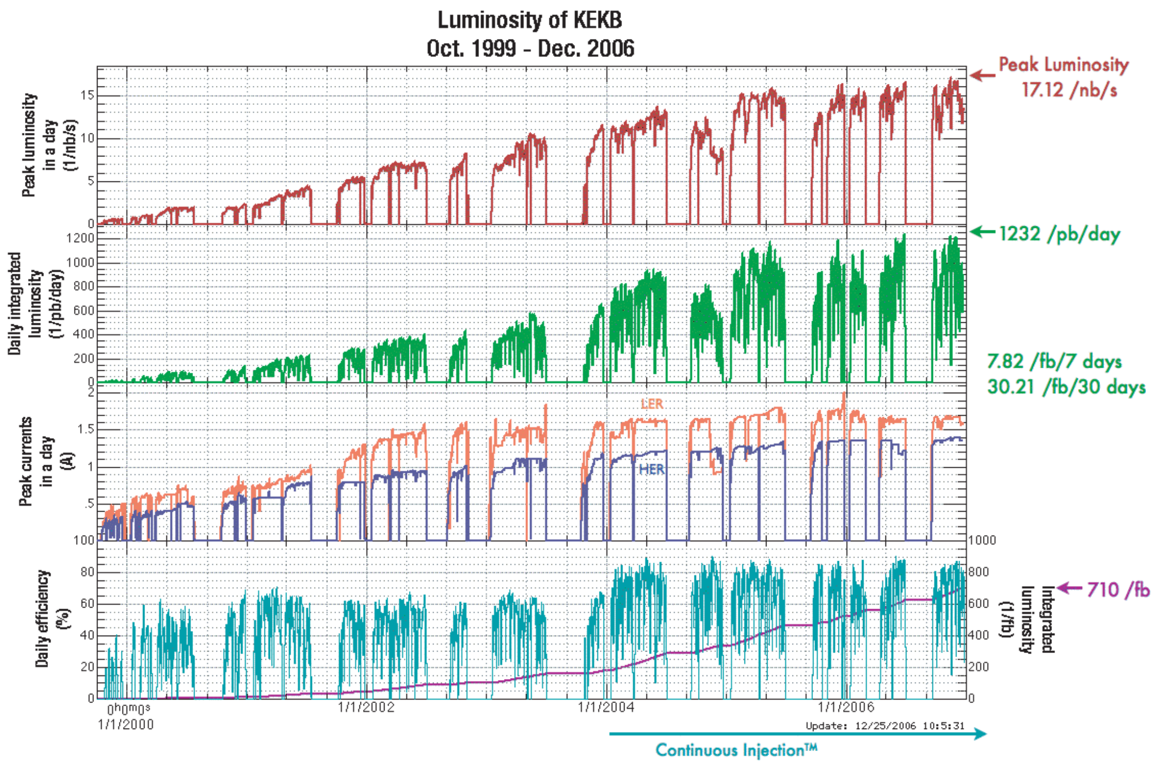

Figure 1: History of KEKB.

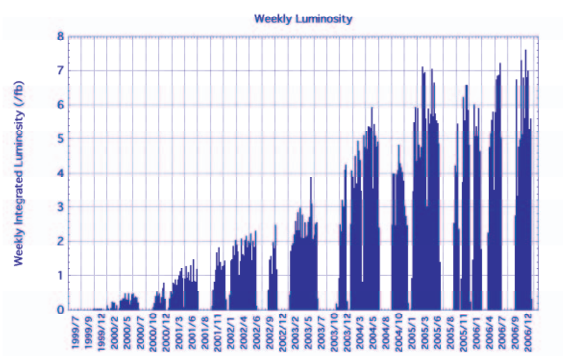

Figure 2: History of weekly luminosity.

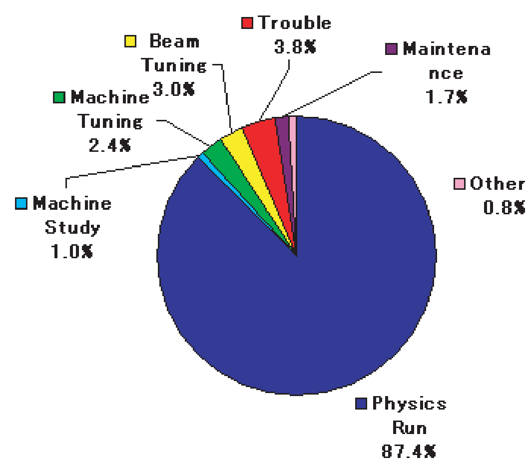

Figure 3: Machine operation statistics of KEKB in FY. 2006 (Apr. 2006 Dec. 2006).

Another point of the luminosity improvement was the change of the tune. As shown in Table 1, the horizontal tune of HER was slightly lowed in Nov. 2006 compared with before summer. Although this change was very small, its effect was remarkable for the luminosity. This change brought about 5% increase in the luminosity which is consistent with the prediction of beam-beam simulations. Fine tuning of the sextupole magnets enabled the change of the horizontal tune.

In KEKB, one of the most serious obstacles to a higher luminosity is the synchro-betatron resonance of $(2\nu_x+\nu_s = \mathrm{integer})$. With the ν_s of about -0.0225, the resonance condition is met at about $\nu_x = 0.51$. A higher luminosity is brought with the ν_x below this resonance. We have tried to operate the machine well below this resonance line. However, we gave up this trial due to intolerably short beam lifetime. With the strong resonance line, the beam lifetime is very short even well below the resonance line in the two-beam condition, maybe because some particles go across the resonance line due to the beam-beam tune shift.

In the course of KEKB operation, it turned out that the synchro-betatron resonance of $(2\nu_x + \nu_s = \mathrm{integer})$ or $(2\nu_x + 2\nu_s = \mathrm{integer})$ affects the KEKB performance seriously. Nature of the resonance lines was studied in details during the machine study on the crab crossing this year. We found that the resonances affect (1) single-beam lifetime, (2) single-beam beam sizes (both in horizontal and ver-

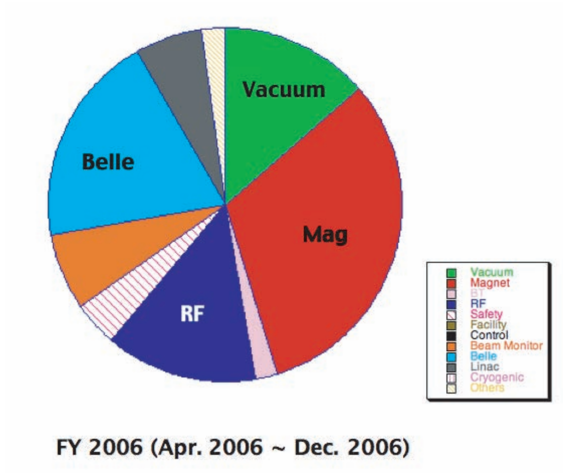

Figure 4: Machine trouble statistics of KEKB in FY. 2006 (Apr. 2006 Dec. 2006).

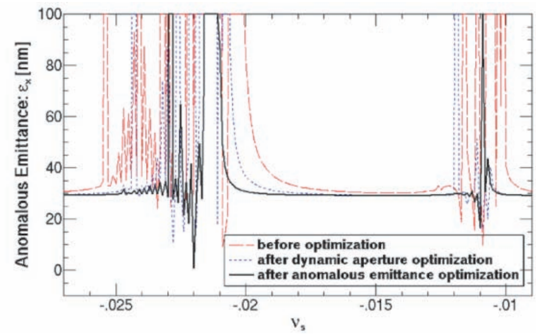

Figure 5: Optimization of anomalous horizontal emittance. $\nu_{\rm x}$ and $\nu_{\rm y}$ are 44.51053 and 41.5900, respectively. Two resonance lines of ($2\nu_{\rm x} + \nu_{\rm s} = {\rm integer}$) and ($2\nu_{\rm x} + 2\nu_{\rm s} = {\rm integer}$) are seen.

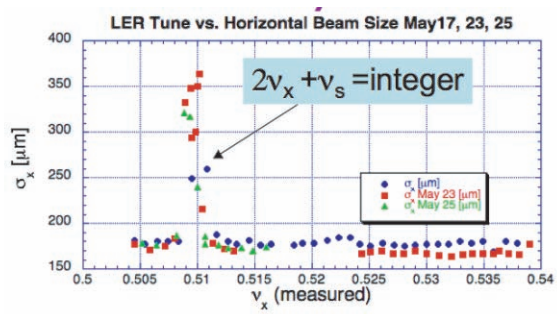

Figure 6: Measurement of the horizontal beam size in LER as function of the horizontal tune. Three different sets of sextupoles are tested.

tical directions), (3) two-beam lifetime and (4) two-beam beam sizes (both in horizontal and vertical directions) and the effects are beam current dependent. The effects lower the luminosity directly or indirectly through the beam-size blowup, the beam current limitation due to poor beam lifetime or smaller variable range of the tunes.

The strength of the resonance lines can be weaken by choosing properly a set of sextupole magnets. KEKB adopted the non-interleaved sextupole scheme to minimize non-linearily of the sextupoles. LER and HER have 54 pairs and 52 pairs of sexupoles, respectively. With so many degree of freedom in the number of the sextupoles, optimization of sextupole setting is not an easy task even with present computing power. Recently, we made a remarkable progress both in a method of evaluation of sextupole performance and the method of findings of sextuple setting in computers. The candidates of sextupole setting are found in computer. Usually dynamic aperture and an anomalous emittance growth [4] are optimized on the synchro-betatron resonance. Recently, in KEKB an efficient method of optimization has been developed by using Temperature Parallel Simulated Annealing (TPSA) method [5]. Fig. 4 shows a typical result of optimization.

The sextuple setting which gives good performance in computer does not necessarily bring good performance in the real machine. Usually we need to try many candidates to reach a good setting in the real machine. Recently, we found that the single-beam beam size and the beam lifetime is a good criterion for sextupole performance. A typical result of the beam size measurements is shown in Fig. 5. Most of candidates of the sextupole setting do not give satisfactory performance. When we change a linear optics, usually we need to try many candidates of settings until we finally obtain a sextupole setting with sufficient performance.

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