RECENT PROGRESS OF KEKB

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Abstract

The skew-sextupole magnets contributed to the luminosity improvement at KEKB. The luminosity gain by the crab cavities was measured as about 20% with the skew-sextupole magnets. The peak luminosity surpassed $2 \times 10^{34}\mathrm{cm}^{-2}\mathrm{s}^{-1}$ which is twice as high as the design value. The specific luminosity and the vertical beam-beam parameter are still much lower than the predictions by the beam-beam simulation with crab crossing. The total integrated luminosity accumulated by the Belle detector surpassed 1000 fb^{-1} which is one of the initial goals of KEKB/Belle.

INTRODUCTION

The KEKB B-Factory is the asymmetric electron positron collider working at KEK for more than ten years. Beam energies are 3.5 GeV for Low Energy Ring (LER e+) and 8 GeV for High Energy Ring (HER, e-). In this reports, we summarize recent progress of KEKB. Emphases are placed on effectiveness of skew-sextupole magnets and the crab cavities on the luminosity.

PERFORMANCE OF KEKB

Fig. 1 shows the 10-year history of the KEKB luminosity and beam currents. On November 29th 2009, the total integrated luminosity accumulated by the Belle detector reached 1000 fb^{-1}, which is one of the initial goals of KEKB/Belle. The crab cavities were installed in KEKB at the beginning of 2007. In 2009, the peak luminosity with the crab cavities exceeded that before installation of the cavities for the first time. The highest peak luminosity of $2.108 \times 10^{34}\mathrm{cm}^{-2}\mathrm{s}^{-1}$, which is higher than the double of the KEKB design luminosity, was achieved on June 17th. The machine parameters for the highest peak luminosity before and after installation of the crab cavities are shown in Table1. The recent improvement of the luminosity was brought by tuning with the skew-sextupole magnets and the increase of the HER beam current. The increase of the HER beam current became possible by solving the physical aperture problem around the crab cavity[1].

Table 1: Comparison of KEKB Machine Parameters before and after installation of crab cavities

	June 2009 with crab		**Nov. 2006** w/o crab		
	LER	HER	LER	HER	
Energy	3.5	8.0	3.5	8.0	GeV
Circumference	3016		3016		m
I_{beam}	1640	1190	1662	1340	mA
# of bunches	1585		1389		
I_{bunch}	1.03	0.75	1.19	0.965	mA
Ave. Spacing	1.84		2.10		m
Emittance	18	24	18	24	nm
β_x^*	120	120	59	56	cm
β_y^*	5.9	5.9	6.5	5.9	mm
Ver. Size@IP	0.94	0.94	1.8	1.8	μm
RF Voltege	8.0	13.0	8.0	15.0	MV
ν_x	.506	.511	.505	.509	
ν_y	.561	.585	.534	.565	
ξ_x	.127	.102	.117	.071	
ξ_y	.129	.090	.108	.057	
Lifetime	133	200	110	180	min.
Luminosity	21.08		17.60		/nb/s
Lum/day	1.479		1.232		/fb

CHROMATICITY OF X-Y COUPLING

It has been shown that the chromaticity of the x-y coupling at the interaction point (IP) could degrade the luminosity largely through the beam-beam interaction, if the residual chromatic coupling is large [3][4]. While even an ideal lattice has such a chromatic coupling, the alignment errors of the sextupole magnets could make a large chromatic coupling. It has been thought that this kind of chromatic couplings is one of the candidates that bring the serious luminosity degradation with crab crossing. We introduced tuning knobs to control them. We installed 14 pairs of skew-sextupole magnets (10 pairs for HER and 4 pairs for LER) in April 2009. The maximum strength of

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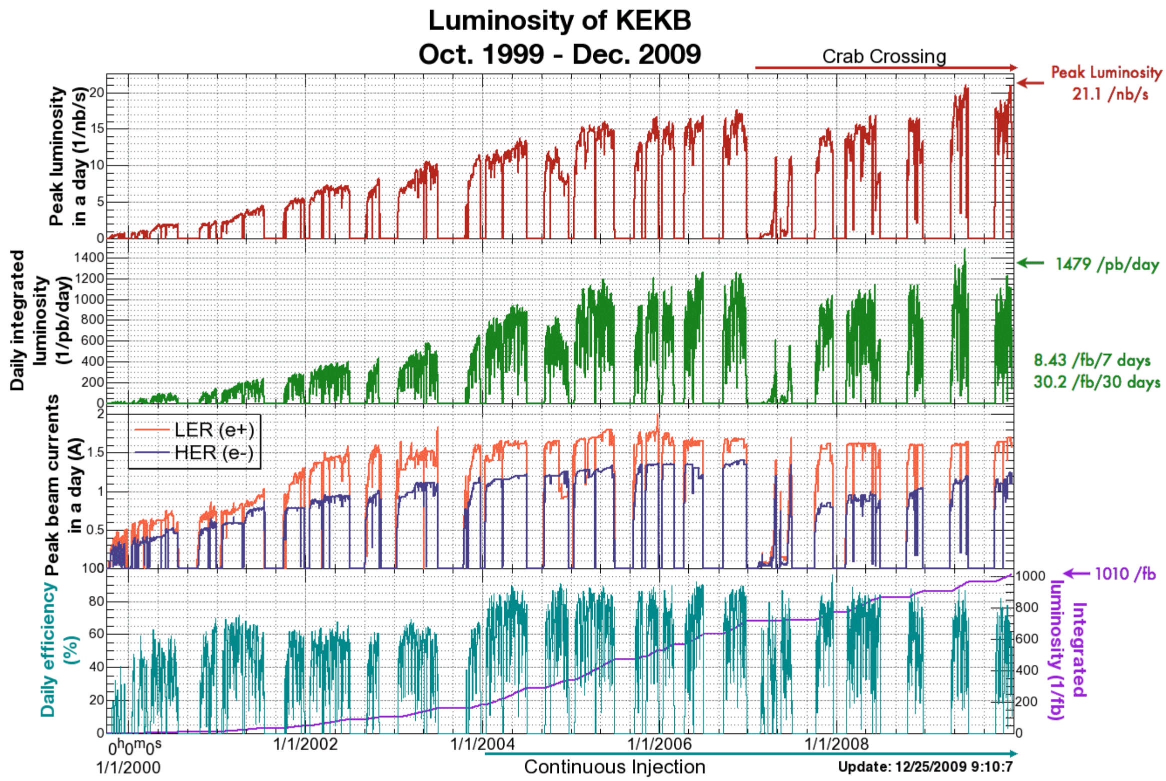

Figure 1: Ten-year history of KEKB.

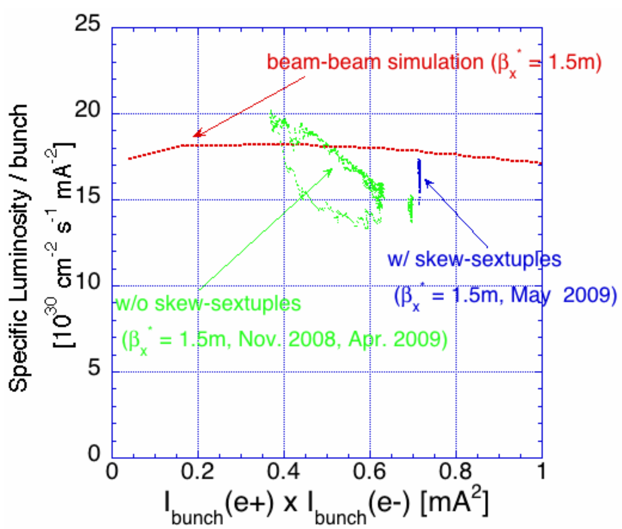

Figure 2: Comparison between specific luminosity with skew-sextupole tuning to that without tuning . Also shown is the prediction by the beam-beam simulation.

the magnets (bipolar) is $K_2 (\equiv B''L/B\rho) \sim 0.12\mathrm{m}^{-2}$ and $K_2 \sim 0.44\mathrm{m}^{-2}$ for HER and LER, respectively. In luminosity tuning, the chromaticity of the x-y coupling parameter at the IP was scanned one-by-one to maximize the luminosity. These scans are done as a part of the luminosity scans including other parameters such as the x-y coupling parameters at the IP and the dispersion functions at the IP. The luminosity gain with skew-sextupole tuning is about 15 %. The optimum settings of the skew-sextupole magnets are determined to maximize the luminosity. On the other hand, the chromaticity of the x-y coupling parameters at the IP has been directly measured by using the injection kicker magnets and the BPMs near the IP[2]. Fig.3 shows an example of the measurement of the chromatic x-y coupling at the IP. In the figure, a measurement of the chromaticity of 2 components of the R matrix of HER is shown. In the SAD code, the local x-y coupling parameters are expressed by the R matrix[5]. The R matrix is a 2×2 matrix and has 4 components. A usual transverse coordinate and a decoupled normal coordinate are connected by a 8×8 matrix in which 4 components of the R matrix are included. The red and blue dots in the figure show the data with and without tuning by using the skew-sextupole magnets, respectively. A remarkable thing in the figure is that the linear parts of the chromatic couplings became almost zero with tuning to maximize the luminosity. This confirmed that the luminosity improvement with skew-sextupole tuning was actually brought by vanishing the chromatic x-y coupling at the IP. The dotted lines in the figure show the chromatic x-y coupling with the model (ideal) optics. There is a large difference between the dotted line and the blue data. This indicates that the machine errors are also important for the chromatic x-y coupling at the IP. Effectiveness of skew-sextupole tuning was also studied in case that the crab cavities are off. The result is show in Fig. 4. As is show in the figure, skew-sextupole tuning is also effective with the crab cavities off.

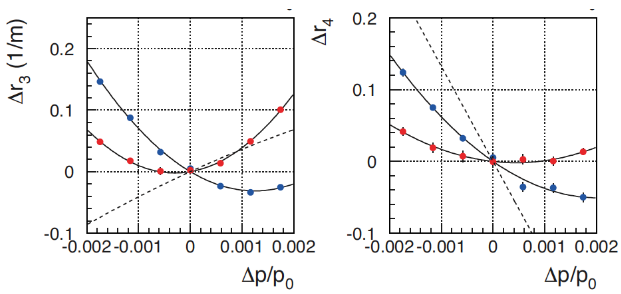

Figure 3: An example of measurements of chromatic x-y coupling at the IP in HER.

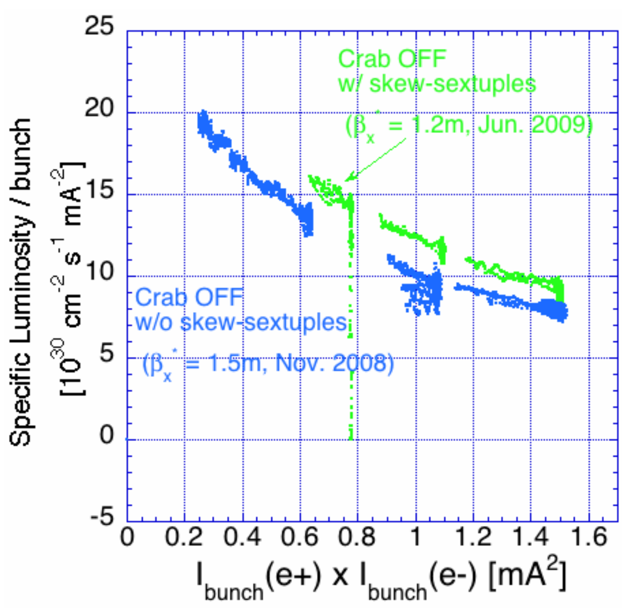

Figure 4: Effect of skew-sextupole tuning with the crab cavities off.

PERFORMANCE WITH CRAB CAVITIES

Since installation of the crab cavities at the beginning of 2007, we have been trying to increase the luminosity. The introduction of the skew-sextupole magnets is a part of these efforts. To study on effectiveness of the crab cavities, we measured the specific luminosity with the crab cavities on and off. In both cases, skew-sextupole tuning was done to maximize the luminosity. The results are shown in Fig. 5. The luminosity gain by the crab cavities is about 20%. This value is almost the same as that before installation of the skew-sextupole magnets. Since the luminosity degradation due to the geometrical loss which originates from the crossing angle is about 11 %, the crab cavities did work to increase the luminosity. However, so far the luminosity gain by the crab cavities is much lower than the initial expectation. In Fig. 5, the results of the beam-beam simulations are also shown. The simulation results depend strongly on the horizontal beta functions at the IP. Even with the improvement by the skew-sextupoles, there is still a large discrepancy between the specific luminosity achieved and the simulation. As for the vertical beam-beam parameter (ξ_y), the highest value of HER with the crab cavities is about 0.09. Although the skew-sextupoles increased ξ_y from ~ 0.08 to ~ 0.09, this value is still much lower than 0.15 which is the prediction by the beam-beam simulation. We have not yet understood the causes for this discrepancy. A possible cause is the machine errors. The x-y couplings or the dispersions at the IP could degrade the luminosity. Although these errors can be compensated by using the tuning knobs, such large tuning knobs bring side effects and degrade the luminosity. Therefore, if the machine errors such as mis-modeling of the detector solenoid and the compensation solenoids are large, the luminosity predicted by the simulation can not be achieved by using usual tuning knobs.

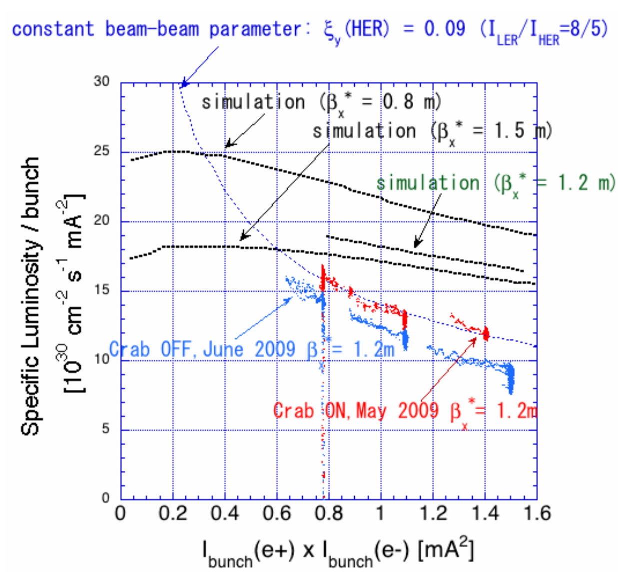

Figure 5: Comparison of specific luminosity with and without the crab cavities.

KEKB OPERATION IN FY 2010

The KEKB operation was resumed on May 13th 2010. The total integrated luminosity is 1022fb^{-1} as of May 26th. The operation will continue until the end of June. After this, the KEKB operation will be terminated and we plan to start works for the upgrade toward SuperKEKB.

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