IP ORBITAL FEEDBACK FOR COLLISION TUNING AT KEKB

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Abstract

KEKB is an asymmetric electron-positron collider with nominal energies of 8 GeV in the e- ring (HER) and 3.5 GeV in the e+ ring (LER). The relative orbit offset at the IP and crossing angle of the two beams are measured by beam-beam deflection scans[1]. Two sets of vertical and horizontal dipole correction magnets in the HER are used for the scans. These magnets are also used to maintain the collision as part of a feedback system. The luminosity is optimized by continuously correcting for the offset and crossing angle at the IP. The collision feedback system and its performance are discussed in this paper.

1 COLLISION FEEDBACK SYSTEM

1.1 Feedback parameters

The collision feedback system, called `iBump´, consists of 8 dipole correction magnets, 4 for horizontal and 4 for vertical correction. The magnets are located in the straight sections on the left and right side of the IP in the HER. These magnets are dedicated to the iBump feedback system and are used to create bumps at the IP to maintain collision. The feedback system only controls the HER orbit by monitoring the difference orbit between HER and LER. The global orbit feedback is taken care of by another task called `CCC´ (Continuous COD Correction). The beam position is monitored by the BPMs on the superconducting quadrupole magnet (QCS[2]). When the QCS BPMs in the HER are located at positions A and B and the LER BPMs at C and D, the beam positions at A and B are written as:

$$X_e^A = m_{11}^A x_e^* + m_{12}^A x_e^{'*a}$$
$$X_e^B = m_{11}^B x_e^* + m_{12}^B x_e^{'*b},$$

where M^A and M^B are the transfer matrices from the IP to A and the inverse transfer matrix of B to the IP. The subscripts e and p represent the e- and e+ beam, respectively. The superscripts a and b correspond to after and before the collision. Asterisks denote the values at the IP and primes indicate angles. The horizontal beam-beam kick that the e- beam receives is written as:

$$\Delta X_e^{'*} = X_e^{'*a} - X_e^{'*b} = \left(\frac{X_e^A - X_e^B}{m_{12}^A - m_{12}^B}\right) - \left(\frac{m_{11}^A - m_{11}^B}{m_{12}^A - m_{12}^B}\right) X_e^* .$$

Similarly, the e+ beam receives the following horizontal kick:

$$\Delta X_p^{'*} = X_p^{'*a} - X_p^{'*b} = \left(\frac{X_p^C - X_p^D}{m_{12}^C - m_{12}^D}\right) - \left(\frac{m_{11}^C - m_{11}^D}{m_{12}^C - m_{12}^D}\right) X_p^* .$$

Using the beam-beam kick above, we can define a new parameter, called the `canonical horizontal kick´ as:

$$\Delta X_{canonical}^{'*} \equiv \frac{\left(\frac{X_e^A}{m_{12}^A} - \frac{X_e^B}{m_{12}^B}\right)}{\left(\frac{m_{11}^A}{m_{12}^A} - \frac{m_{11}^B}{m_{12}^B}\right)} - \frac{\left(\frac{X_p^C}{m_{12}^C} - \frac{X_p^D}{m_{12}^D}\right)}{\left(\frac{m_{11}^C}{m_{12}^C} - \frac{m_{11}^D}{m_{12}^D}\right)} = F(X_e^* - X_p^*) .$$

The vertical canonical kick can be expressed similarly. The canonical parameters are functions of the difference of the two beam positions (offsets) and therefore good parameters to be used for a collision feedback. The canonical crossing angle between the two beams is defined similarly as:

$$\theta_{xcanonical} \equiv \frac{\left(\frac{X_e^A}{m_{12}^A} + \frac{X_e^B}{m_{12}^B}\right)}{\left(\frac{m_{11}^A}{m_{12}^A} + \frac{m_{11}^B}{m_{12}^B}\right)} - \frac{\left(\frac{X_p^C}{m_{12}^C} + \frac{X_p^D}{m_{12}^D}\right)}{\left(\frac{m_{11}^C}{m_{12}^C} + \frac{m_{11}^D}{m_{12}^D}\right)} .$$

The vertical canonical crossing angle is expressed similarly. The iBump feedback maintains the optimum collision condition by keeping the canonical kicks and crossing angles constant.

1.2 Feedback Method

The beam positions are monitored by the QCS BPMs. The coupling between the horizontal and vertical bumps by the iBump magnets are measured beforehand. The effect of a horizontal bump on the vertical orbit is non-negligible due to the coupling. The coupling effect from horizontal to vertical is taken care of by creating an extra vertical bump which cancels out the coupling effect. Fig.1 shows the effect of the horizontal bump on the vertical orbit before and after the cancellation. The calibration data were taken for the bump height range of +/- 200 μm, which is used for the nominal tuning. Once a good set of target values are found, they are relatively stable during fills and only adiabatic tuning is needed.

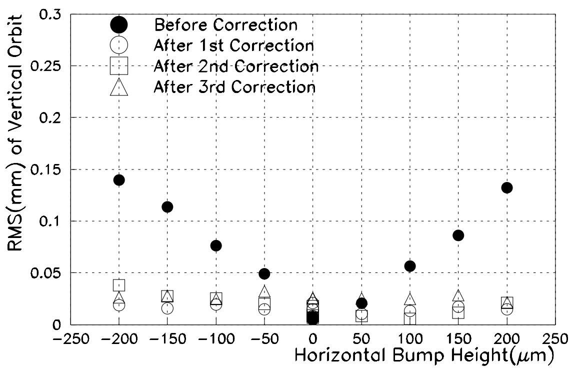

Figure 1: The calibration of the horizontal-vertical coupling from the iBump. After correction, the coupling effect is negligible.

The amount of feedback is determined by expressing a new parameter X_n expressed as a linear combination of the past NN data points. The coefficients C_k can be solved as long as N in the following equation is smaller than NN:

$$X_n = \sum_{k=1}^{N} C_k X_{n-k} \quad .$$

The number of coefficients and data points are chosen empirically to be 6 and 48, respectively. The current feedback speed is limited by the BPM readout time. The iBump feedback cycle times are 2 and 3 seconds for vertical and horizontal, nominally. The ranges of the bump heights are +/- 400 µm and +/- 150 µm for horizontal and vertical offsets, respectively, in order to protect the BELLE detector[3] from being irradiated.

2 FEEDBACK PERFORMANCE

2.1 Example

A luminosity trend graph for Fill 1677 (May 28, 2000) is shown in Figs.2-(a)-(e) as an example. The iBump feedback is usually turned on during injection. The horizontal feedback often gets disturbed during injection, probably due to a large orbital fluctuation caused by the horizontal kicker. The vertical beam size ratio between the two beams were found to be another important feedback parameter. The beam sizes are monitored by the SR monitor[4] and are used as an input for a size feedback routine called `iSize´[5]. The luminosity dip at 35 minutes from the e+ beam injection corresponds to a bad beam size ratio. The beam size is mainly controlled by a sine-like bump created at a sextupole magnet in the arc section in the HER. By creating dispersion, one can make the beam size larger. Since the e+ beam is more likely to blow-up[6], the iSize bump is usually created in the HER to maintain a desirable beam size ratio. Though the iBump and iSize feedbacks use different sets of dipole correction magnets, the bumps created by one feedback system often affect the global beam orbit and therefore the performance of the other feedback. The iBump angle bump creates dispersion, enlarging the beam size and affecting the iSize feedback at times. The coupling problems between the iSize and iBump feedback systems remain to be worked on.

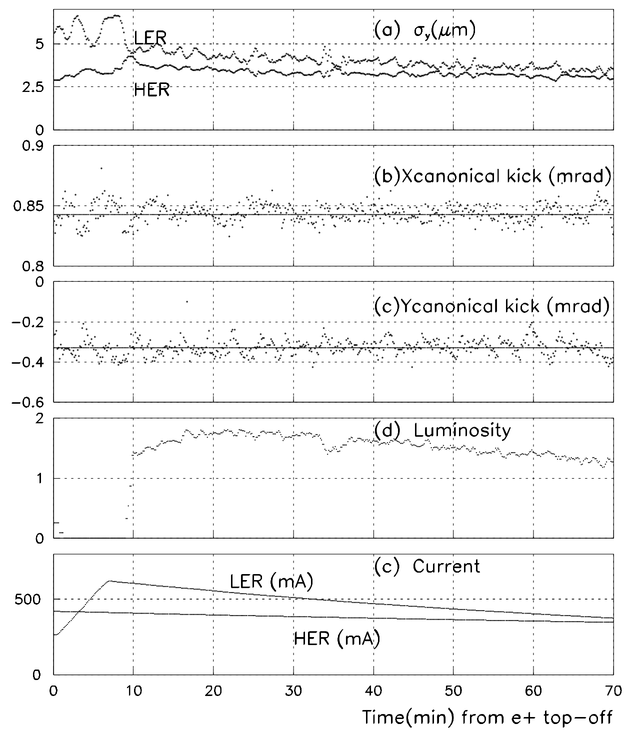

Figure 2: Fill 1677 trend graph, (a) HER and LER vertical beam sizes, (b) horizontal canonical kick and the target values, (c) vertical canonical kick and the target values, (d) Luminosity (×10E32/cm^2/s) and (e) HER/LER beam currents are plotted against time (minutes) measured from the beginning of positron top-off.

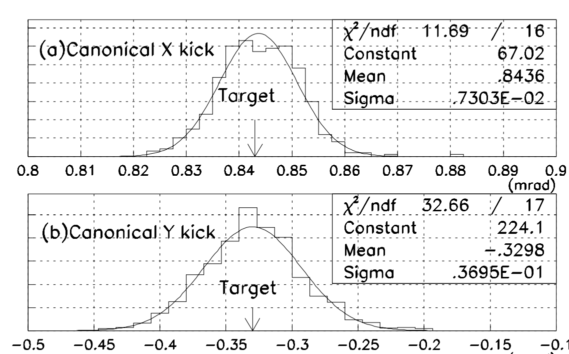

Figure 3: (a) The canonical horizontal kick distribution when the target value was 0.843 mrad; and (b) the canonical vertical kick distribution when the target value was -0.33 mrad during Fill 1677.

The feedback stability is examined for this fill, where the target values were not changed. Figs.3-(a) and (b) show the horizontal and vertical canonical angle spread.

The horizontal and vertical kick spreads can be compared to the beam size. From the expressions for the canonical kicks and using the beam-beam parameters ξ_x and ξ_y calculated from the luminosity, one can translate the canonical parameters into the beam-beam kicks using the fact that the kick $\Delta X'$ is proportional to the offset ΔX and the coefficient k is written as $k=2\pi\xi/\beta^*$. The average beam-beam parameters for Fill 1677 are obtained to be ξ_x(HER)=0.0221, ξ_x(LER)=0.0364, ξ_y(HER)=0.0178 and ξ_y(LER)=0.0321, where β_x=70 cm and β_y=7 mm. From those beam-beam parameters and the transfer matrices, the collision fluctuations of the horizontal and vertical offsets for Fill 1677 become ~5 μm and ~0.3 μm, respectively. Therefore the target collision condition is maintained to within ~15 μm horizontally and ~1 μm vertically, peak-to-peak. The horizontal beam size did not change as much as the vertical beam size through the fill. The horizontal beam sizes are typically ~120 μm for both HER and LER. The iBump feedback keeps the collision fluctuations below the level of the beam sizes. The angles between the beams are also kept constant by iBump in order to achieve a stable collision. Figs.4-(a) and (b) show the canonical crossing angle fluctuations during a fill. If we assume that the offset between the two beams is kept small by the feedback, the canonical angle fluctuation also can be evaluated. The typical horizontal and vertical beam crossing angle fluctuations are estimated to be ~15 μrad and ~40 μrad, respectively.

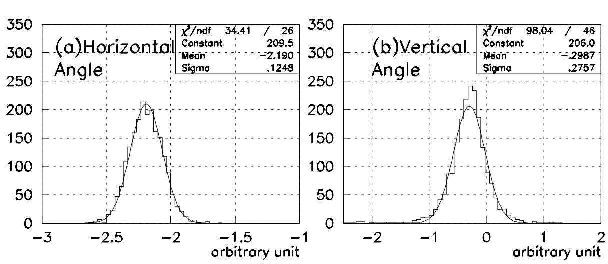

Figure 4-(a) and (b): The canonical crossing angles between the two beams during a fill.

Fig.5 shows the iBump feedback parameters and the luminosity for Fill 1980. The feedback for the vertical canonical kick was intentionally turned off at ~4 minutes past midnight in order to see the effect of the feedback. The canonical kick started drifting away from the target value, as much as ~3 times the previous peak-to-peak fluctuation, resulting in the dip in the luminosity plot. The luminosity recovered when the feedback was turned back on.

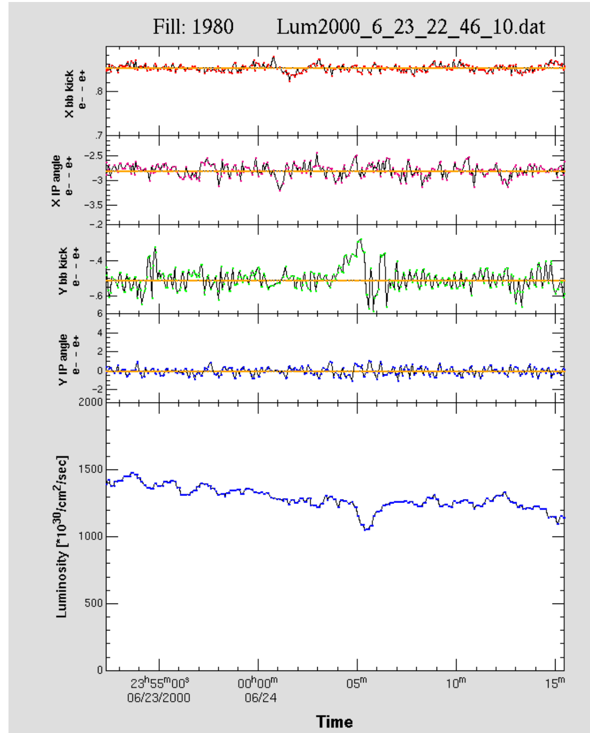

Figure 5: Top four plots correspond to the canonical horizontal kick, horizontal crossing angle, vertical kick and vertical crossing angle, respectively for Fill 1980. Luminosity($\times$10E32/cm^2/s) is plotted at the bottom.

3 SUMMARY

The iBump feedback has resulted in a stable collision for KEKB. The collision fluctuations are smaller than the beam sizes both horizontally and vertically. The angle bump creates dispersion and affects the iSize feedback. The coupling problem remains to be solved.

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