SLAC–PUB–9362
August 2002

Orbit Distortions and Bumps in the PEP-II LER Ring*

F.-J. Decker, Y. Cai, M. Sullivan, J.L. Turner, U. Wienands, SLAC, Stanford, CA 94309, USA

W. Kozanecki, DAPNIA-SPP, CEA-Saclay, Gif-s/-Yvette, France

Abstract

The PEP-II B-factory has already achieved twice the design daily-integrated luminosity. This is even more remarkable when looking at the beam orbits, especially in the low energy ring (LER). Orbit oscillations with an amplitude of 7 mm have grown over the years. Four attempts to steer them down resulted in a much lower luminosity and were therefore backed out. Finally, in August of 2001, the main part of the ring (5/6) could be steered flat, while keeping the sixth where the interaction region (IR) is located untouched. This resulted in a lower global dispersion and more luminosity. Since then the orbit is flat to 0.5 mm (slowly increasing to 2-3 mm), except in the IR where about four oscillations on each side of the interaction point reach peaks of 7-9 mm. This area is highly coupled by skew quadrupoles, which are compensating the effects of the BaBar solenoid field. The region also has strong sextupoles. In order to attack the remaining orbit excursions one at a time, an orbit bump program has been extended to handle coupled regions, by closing the oscillations in the other plane. Due to the big oscillations the beam is often close to the walls generating beam loss and reducing the lifetime. An interesting observation occurred a few times when the high-current LER beam was pulled away from the wall. The size of the LER or its tune appeared to have changed since the colliding beam started to blow up the high energy beam implying a decrease in the size of the LER beam. This was in a linear region so the effect has to come from unknown field errors, or more likely it is an effect of the high-current beam with its surrounding either electron cloud or wakefields.

Presented at 8th European Particle Accelerator Conference (EPAC 2002)

Paris, France, 3-7 Jun 2002

* Work supported by Department of Energy contract DE–AC03–76SF00515.

ORBIT DISTORTIONS AND BUMPS IN THE PEP-II LER RING*

F.-J. Decker, Y. Cai, M. Sullivan, J.L. Turner, U. Wienands, SLAC, Stanford, CA 94309, USA,
W. Kozanecki, DAPNIA-SPP, CEA-Saclay, Gif-s/-Yvette, France

Abstract

The PEP-II B-factory has already achieved twice the design daily-integrated luminosity. This is even more remarkable when looking at the beam orbits, especially in the low energy ring (LER). Orbit oscillations with an amplitude of 7 mm have grown over the years. Four attempts to steer them down resulted in a much lower luminosity and were therefore backed out. Finally, in August of 2001, the main part of the ring (5/6) could be steered flat, while keeping the sixth where the interaction region (IR) is located untouched. This resulted in a lower global dispersion and more luminosity. Since then the orbit is flat to 0.5 mm (slowly increasing to 2-3 mm), except in the IR where about four oscillations on each side of the interaction point reach peaks of 7-9 mm. This area is highly coupled by skew quadrupoles, which are compensating the effects of the BaBar solenoid field. The region also has strong sextupoles. In order to attack the remaining orbit excursions one at a time, an orbit bump program has been extended to handle coupled regions, by closing the oscillations in the other plane. Due to the big oscillations the beam is often close to the walls generating beam loss and reducing the lifetime. An interesting observation occurred a few times when the high-current LER beam was pulled away from the wall. The size of the LER or its tune appeared to have changed since the colliding beam started to blow up the high energy beam implying a decrease in the size of the LER beam. This was in a linear region so the effect has to come from unknown field errors, or more likely it is an effect of the high-current beam with its surrounding either electron cloud or wakefields.

1 INTRODUCTION

A typical LER orbit is shown in Fig. 1. The signal from a beam position monitor (BPM) is plotted versus *z*. The top two graphs show the *x* and *y* orbit, while the bottom (TMIT) shows the number of particles per bunch. The orbits have two distinct areas, which are clearly visible: The region PR02 around the interaction point has up to 9mm oscillations, which has given historically the best luminosity performance, and the rest of the ring was once (Aug 2001) steered flat and has since somewhat degraded.

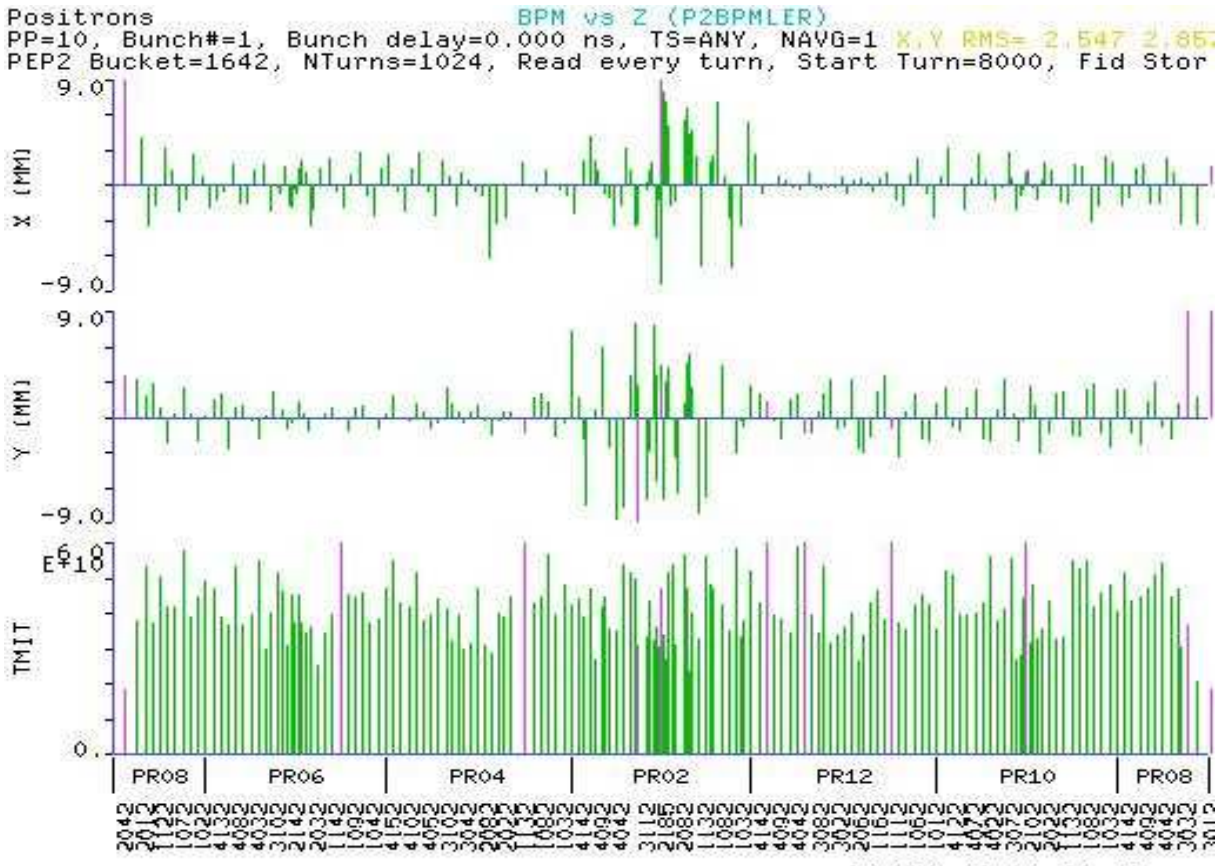

Figure 1: LER orbit showing the wild oscillation of 9 mm near the interaction point (PR02).

*Work supported by Department of Energy contract DE-AC03-76SF00515.

On top of that we see a –*x* bump in PR04, which puts the beam close to collimators and we have three (purple) excursions beyond the scale in PR08: +14 mm in *x* and two +10 mm bumps in *y*. They are in the injection region.

A problem can be hidden in these data, since a bad beam position monitor (BPM) cannot be easily detected in the 90° betatron lattice. This is made more difficult in the presence of strong sextupoles, which will change the focusing (*x*-offset) or coupling and dispersion (*y*-offset).

2 BPMS AND 90° LATTICE

The 90° betatron lattice in LER together with only BPMs in *x* at the focusing quadrupoles and in *y* at the defocusing quadrupoles is a main problem. There is no redundancy in the BPM system, one bad BPM e.g. with a loose cable can be responsible for a big offset after "steering" the beam flat to the BPMs.

A similar problem in *y* actually caused a problem. A corrector pair made a bump of about 8 mm although the BPM showed close to zero. This created such an angle in the arc that the synchrotron fan didn't hit the water-cooled absorber through the ±8 mm opening to the antechamber. This created a vacuum leak, which opened only up when the beam was present.

The "steering" mentioned above relies only on BPMs. There is also a procedure, which allows an SVD method to minimize corrector strengths at the same time. When this corrector minimization is not done we can afterwards look at the final corrector settings and calculate a "corrector orbit" by assuming no misalignments. This was done for a part of PR06 in Fig. 2.

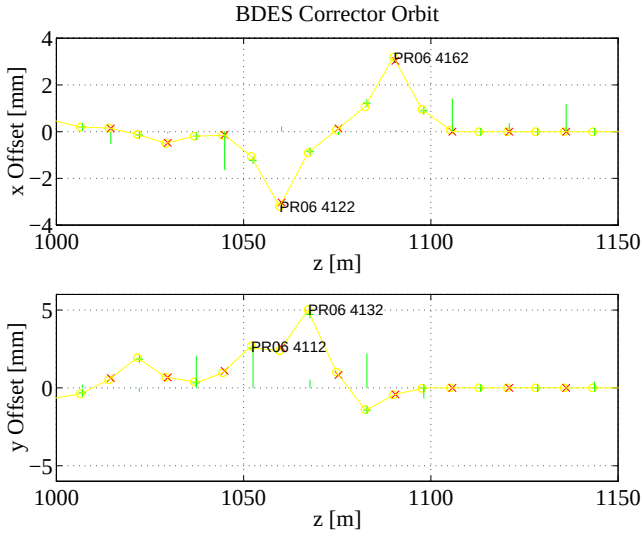

Figure 2: Orbits due to corrector strengths.

The corrector strengths (vertical lines in mT-m) generate nearly a 360° betatron oscillation in *x*. The beam comes from the right (!) and the first few correctors are ignored.

By zooming in at this region in Fig. 1 we find that the BPM 4122 shows actually a –3 mm offset from a fitted betatron oscillation consistent with Fig. 2, and that BPM 4162 reads close to zero but is most probably off by +3mm. In *y* an even bigger offset at 4132 of +5 mm is predicted. The kick of the corrector at 4092 (z = 1040 m) must either cancel a real kick or more probably a kick due to the sextupoles in that region.

3 STRONG SEXTUPOLES

The LER has very strong localized sextupoles, paired 180° apart. An offset of Δx = 3 mm at the strongest sextupole with a strength of $S \cdot l$ = –75 T/m gives a quad- or skew quadrupole (for Δy) field of $G \cdot l$ = 0.23 T, which is about 10% of the typical focusing strength. The same 3 mm offset in that additional focusing will create a kick like a corrector of $B \cdot l$ = 0.7 mT-m, resulting in a 1.5 mm oscillation. The following relations were used:

$$G = \Delta x \cdot S,$$

$$B = \Delta x \cdot G,$$

$$\theta\,[\text{rad}] = 0.3\, B \cdot l\,[\text{T-m}] / E\,[\text{GeV}]. \qquad (1)$$

Besides the kick, which can be measured by taking oscillation data and comparing them with the model, a symmetric offset in the sextupole pair will create a coupling wave, while anti-symmetric offsets make a dispersion wave. A single close bump of about 0.5 to 1.0 mm will reduce the luminosity by about 10%, which was experimentally found.

The main problem with these many lattice-changing effects is that the present ring setup is too far away from the model. A move closer to the ½ integer resonance in *x* to get more luminosity [1] is therefore more difficult since the ring is there about 7 times more sensitive to errors.

4 ORBIT BUMPS

Due to the strong coupling in the LER the usual online bump maker is not capable of making closed bumps if a skew quadrupole is inside the bump region.

4.1 Bump Maker

An existing MATLAB program was upgraded to four dimensions (BUMP_SVD4). It can use nearly any amount of correctors (up to three MICRO regions) and calculates with an SVD method the largest possible offset in one plan while in the other any oscillation gets closed. A knob file is created which specifies the maximum possible offset. Fig. 3 shows an example at the SK5L and SK6L region in PR02, where the coupled part is about 15% of the desired bump. The closing of the coupled part is done as close as possible to the skew quad, or an even bigger oscillation would be visible. Since it is database driven it can quickly create a closed bump for the current machine setup, eliminating lengthy closing procedures.

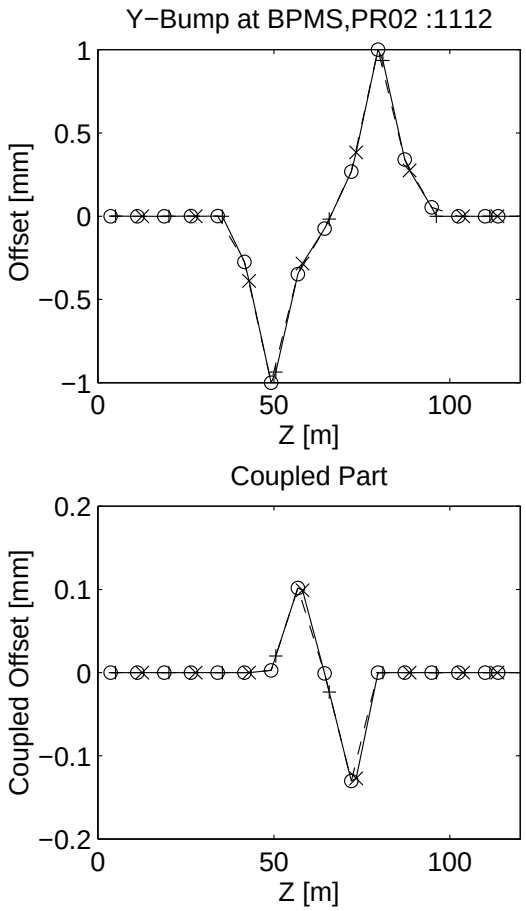

Figure 3: Dispersion bump closed in coupled region.

4.2 Lattice Diagnostic

If a bump is not closed it will indicate an error in the machine lattice, which is not accounted for. So far only a few bumps were not closed, one involved a "dual database" magnet (= bend + corrector at 3142 in PR02). This problem still has to be solved since it will also impact steering in this region.

Another more complicated bump in a region with many sextupoles (ARC 5) had many correctors (14 all together) and created a similar problem of not being closed by 40%. This means that a *y*-bump with a peak of 500 μm had about 200 μm leaking out (see Fig. 4). The fitted oscillation (black) gets extrapolated (yellow) and should fit on the other side if there is no additional unexplained kick. In this case there seems to be a kick near 1012 (or 1052) in PR06, which can also be quantified by fitting the whole region with a kick at that point, resulting in a kick value of 9 μrad. With equation 1 this corresponds to a field error of 0.087 mT-m. Assuming no problem with the corrector strengths themselves (they were moves up to 0.55 mT-m) an unexplained field error must be present. An offset of Δy = 0.5 mm would need additional focusing of $G \cdot l$ = 0.175 T, which might be created by an offset of Δx = 2.3 mm in the sextupole (-75 T/m). This is somewhat unlikely to be a local problem, since it is near a defocusing quadrupole (in *x*) and the *x* corrector pattern doesn't support it. The absolute orbit (Fig. 1) is of that order, but the 180° sextupole pairs should cancel that, implying a real misalignment.

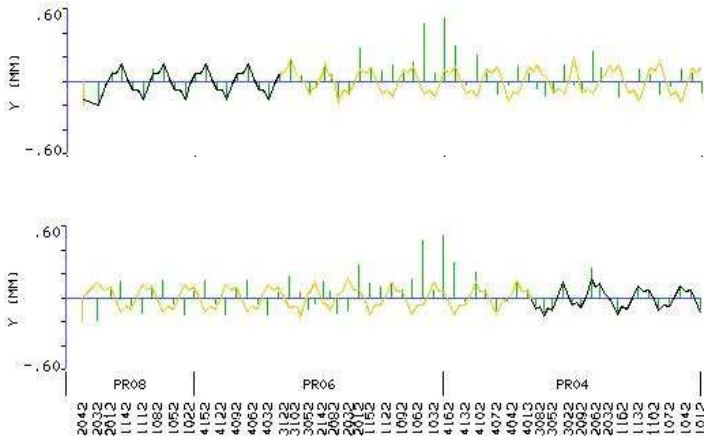

Figure 4: BPM data with *xy*-orbit fit.

5 BUMPS AT HIGH CURRENT

Its has been seen that very big bumps in *x* might affect the beam size of the LER. This was only observed at high current in colliding beam mode. In all cases we tried to reduce some unexpected beam loss in a area with no skew quads or sextupoles (PR06 and injection region PR08), so there should not have been any tune or coupling change involved. The problem was that it had a big effect on the other beam, the HER got blown up when the LER beam was removed from the wall. In two cases the HER lost bunches and in one the beam got actually aborted due to radiation in the detector from HER.

A possible explanation that is speculative argues that moving the orbit might change something, which has to do with electron cloud and/or wakefields. A special experiment was conducted but only at low current and with a single ring, no non-linear problems were found.

6 SUMMARY

The orbit in LER has a strong influence on the lattice due to strong sextupoles. Since there is only one BPM in each plan every 90°, broken BPMs can mislead the steering efforts and create lattice errors. This summer we will improve beam diagnostics by upgrading the BPMs near the sextupoles to 2-view BPMs. Looking at the corrector pattern or its corresponding orbit errors can be found and corrected by closed bumps.

7 REFERENCES

[1] J. Seeman et al., "Status and Future Plans for the PEP-II B-Factory," EPAC'02, Paris, June 2002.