TRICKLE-CHARGE: A NEW OPERATIONAL MODE FOR PEP-II *

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Abstract

In regular top-up-and-coast operation, PEP-II average luminosity is about 70...75% of the peak luminosity due to detector ramp-down and ramp-up times plus the time it takes to top-up both beams. We recently commissioned a new operational mode where the Low Energy Ring is injected continuously without ramping down the detector. The benefits–increased luminosity lifetime and roughly half the number of top-ups per shift–were expected to give an increase in delivered luminosity of about 15% at the same peak luminosity; this was confirmed in test runs. In routine trickle operation, however, it appears that the increase in delivered luminosity is more than twice that due to an increase in availability credited to the more stable operating conditions during trickle operation. Further gains were made when continuous injection was extended to the high energy ring as well. In this paper we will present our operational experience as well as some of the diagnostics we use to monitor and maintain tuning of the machine in order to control injection background and protect the detector.

INTRODUCTION

Continuous injection (trickle-charge) was first established in the PEPII Low Energy Ring (LER) where the stored beam lifetime is lowest, and where injection backgrounds had been historically less of a problem than the High Energy Ring (HER). Large vertical beta functions outside the detector in the HER case combined with vertical injection necessitate better control of incoming beam parameters. In the LER, the large vertical beta functions occur in the detector closer to the interaction point such that sensitivity to incoming beam parameters is greatly reduced. Several factors contributed to the success of this trickle-charge endeavour.

- Background signals provided by the BaBar detector gated on actual injection pulses.
- Systematic improvements of the electron beam from the LINAC.
- Reduction of the distance of the injected beam from the closed orbit.
- Trajectory stabilization feedback.
- Both ring kicker systems were evaluated[1] and scheduled for upgrades.

Trickle-injection gain

The gain in delivered luminosity arises from the higher average luminosity as well as from not having to turn the detector off during injection periods. For LER trickle-charge injection, this gain was estimated to be about 15%. Early tests comparing two similar shifts, one in normal and one in trickle mode, confirmed this number, see Fig. 1. Luminosity life time almost doubled, reducing the number of top-ups during a shift commensurably. The actual gain during the first month of LER-trickle operation was closer to 35%, credited in part to increased reliability of the machine running at a fixed LER beam current. Adding trickle-charge to the HER gained another 12%, close to prediction, but no significant further reliability-gain was seen. In table 1 the different machine operating modes are compared.

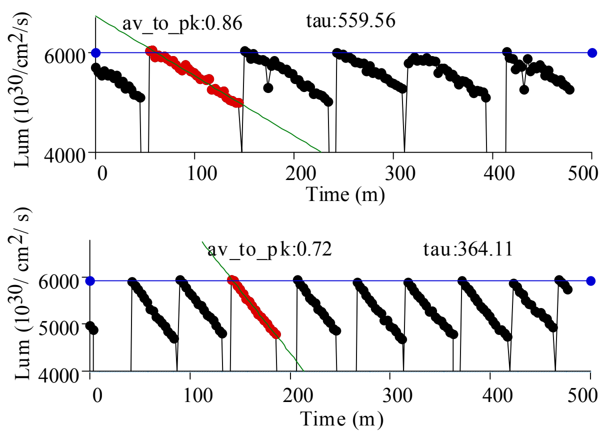

Figure 1. Luminosity for a shift in LER trickle mode (top), regular top-up mode (bottom).

Table 1. Operating Mode Summary

	Top-up	LER trickle	Both trickle
Lum. lifetime	364	560	N/a
Avg./peak ratio	72%	86%	99…100%
Top-ups/shift	10	6	n/a
Gain (expected)	0	15%	29%
Gain (delivery)	0	35%	50%

TRICKLE INJECTION DIAGNOSTICS

The primary concern for trickle-charge injection is to deliver sufficient current to keep up with stored beam losses while not delivering excessive radiation to the BaBar detector with all systems on and vulnerable. The regular BaBar background detectors are insufficient for trickle-charge tuning as they don't discriminate between stored and injected background. While the PEPII control system has some built in diagnostics for measuring injected beam parameters and beam losses, we developed a diagnostic based on EMC triggers gated on injection

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pulses[2]. These diagnostics have been the primary tools for the minimization of trickle injection related background.

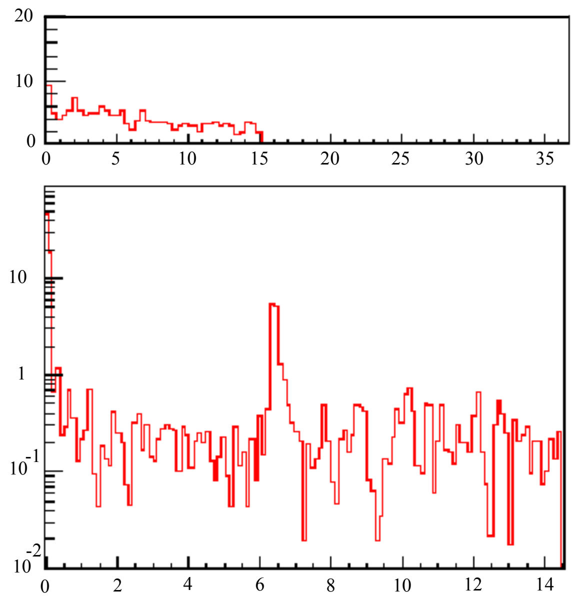

Figure 2. Top: BaBar background signal from HER injection to 15ms. Bottom: PSD of that signal versus frequency.

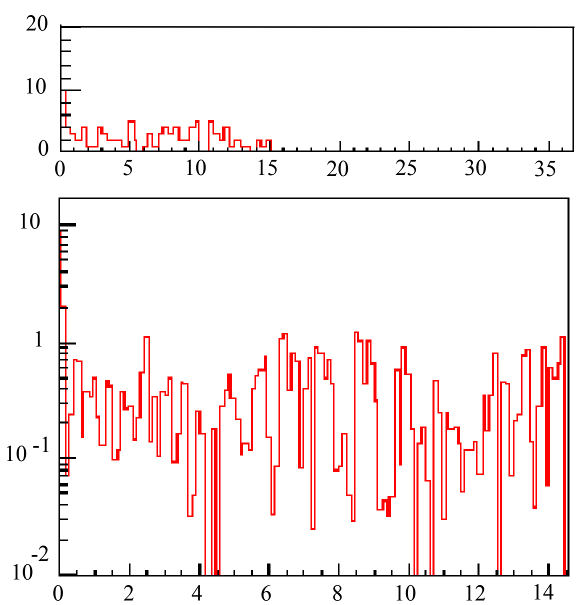

Figure 3. Same as in figure 2, only after the energy of the injected beam has been corrected.

Figure 2 shows the gated trigger rate against time after injection and its FFT. The peak at 6 kHz indicates synchrotron related losses caused by energy or phase offset of the injected beam. In figure 3 this has been corrected. These BaBar generated plots are continuously updating at one Hz in the control room.

In Gating the BaBar diagnostics from the EMC, from added cesium iodide detectors, and other sources we can correlate BaBar "On" system background with other detectors in order to tune with BaBar "Off" if necessary.

In figure 4 a cesium iodide detector and EMC background at injection are plotted against bunch positioin in the mini-trains in the HER ring. Lower is more background on these plots, so the ends of the mini-trains cause somewhat more injection related backgrounds than other buckets. Injection backgrounds in the HER were seen early on to depend strongly on the LER current indicating the significance of beam-beam forces. It was also seen that injection rate and background depend on the bunch being filled. This is presumably due to some buckets only having a single parasitic crossing rather than crossing on both sides of the interaction point. This condition was rapidly addressed with a small change in the horizontal tune.

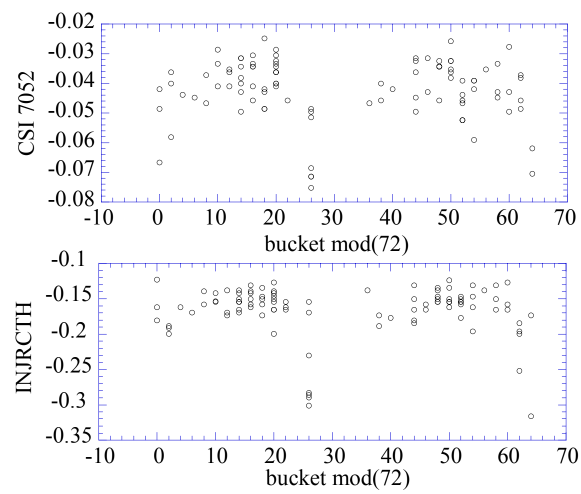

Figure 4. Top is a cesium iodide detector versus "mini-train" bunch number. Below is EMC background.

JITTER SOURCE REDUCTION

In commissioning HER trickle-charge, the most severe issue was high background injection pulses ("fliers"). Linking BaBar's signals into the PEPII control system, we are then able to correlate incoming beam parameters with such fliers.

The injected beam energy, phase (timing), transverse position are measured and stabilized by feedbacks. Nonetheless, jitter from faulty hardware or mis-set parameters is still possible.

Source intensity jitter, which can cause parameter changes of the injected beam has been reduced by progressive tuning, then hardware repair. In figure 5 the beneficial effect of tuning and repair is clearly visible.

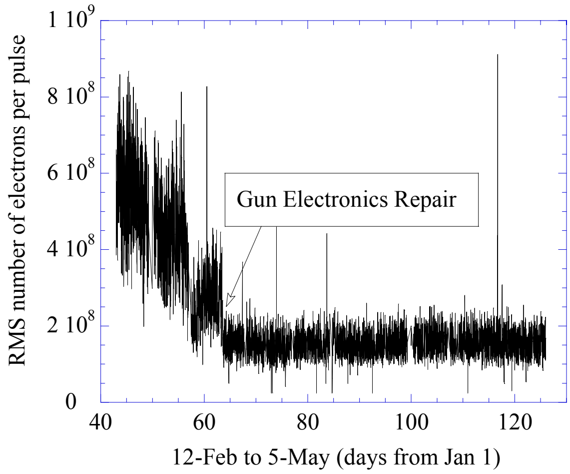

Figure 5. Intensity jitter versus day.

In figure 6, timing jitter out of the damping ring is seen as energy jitter in the bunch compressor. This timing jitter will cause changes in the six dimensional beam distribution. The reduction of this timing jitter was accomplished by empirical adjustments of the electron damping ring RF system.

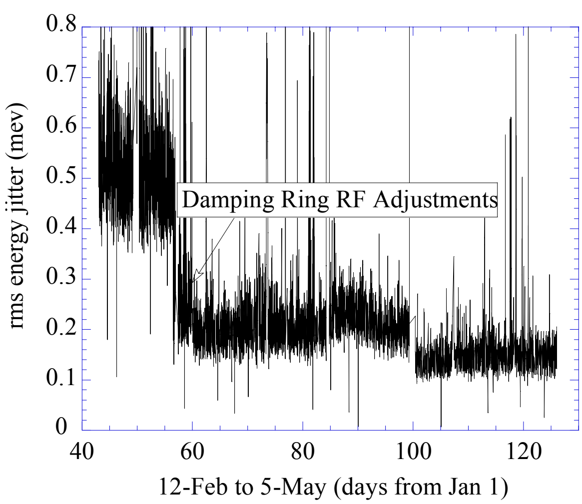

Figure 6. Energy in MeV is indicative of beam phase jitter (time jitter) out of the electron damping ring.

INJECTOR TRAJECTORY STABILIZATION

The injecting beams for both rings show trajectory drifts over the time scale of hours or longer. Stabilizing the incoming beams very near the PEPII rings has been successful in the case of positron injection into the LER. Figure 7 shows the stabilizing effect of the feedback on the vertical trajectory. A similar feedback is planned for the electrons.

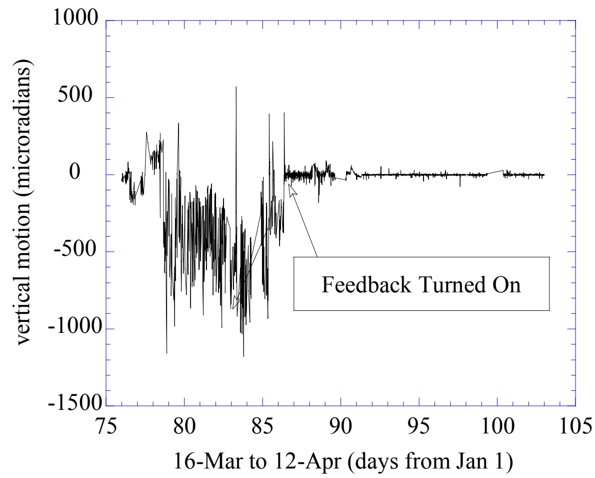

Figure 7. Signal from trajectory stabilization feedback.

SUMMARY

Key to the success (see figure 8) of trickle-charge has been the diagnostics provided by BaBar, the tuning down different sources of jitter, new stabilization feedbacks, and moving the stored beams closer to the septum[1].

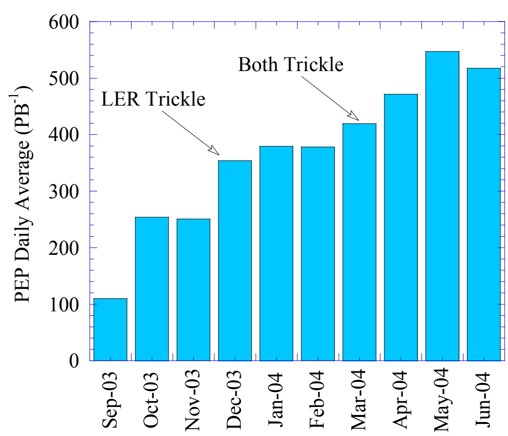

Figure 8. Daily Avg. Luminosity increase with trickle

ACKNOWLEDGEMENTS

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REFERENCES

[1] F. J. Decker et. al, "Diagnosing the PEPII Injection System" EPAC'04, Lucerne, July 2004.
[2] F. J. Decker et. al, "Injection Related Background due to the Transverse Feedback" PAC'03, Portland, OR, USA, May 2003.