LUMINOSITY VARIATIONS ALONG BUNCH TRAINS IN PEP-II*

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Abstract

In the spring of 2005 after a long shut-down, the luminosity of the B-Factory PEP-II decreased along the bunch trains by about 25-30%. There were many reasons studied which could have caused this performance degradation, like a bigger phase transient due to an additional RF station in the Low-Energy-Ring (LER), bad initial vacuum, electron cloud, chromaticity, steering, dispersion in cavities, beam optics, etc. The initial specific luminosity of 4.2 sloped down to 3.2 and even 2.8 for a long train (typical: 130 of 144), later in the run with higher currents and shorter trains (65 of 72) the numbers were more like 3.2 down to 2.6. Finally after steering the interaction region for an unrelated reason (overheated BPM buttons) and the consequential lower luminosity for two weeks, the luminosity slope problem was mysteriously gone. Several parameters got changed and there is still some discussion about which one finally fixed the problem. Among others, likely candidates are: the LER betatron function in x at the interaction point got reduced, making the LER x stronger, dispersion reduction in the cavities, and finding and fixing a partially shorted magnet.

HISTORY OF LUMINOSITY DROOPS ALONG BUNCH TRAINS

Besides the different luminosity for the first and last bunch in a train for a by-2 pattern, there was typically a luminosity drop along bunch trains over the years [1]. Initially that was due to an electron cloud built-up in the positron ring (LER), which increased the LER x-size. After winding many solenoids around nearly all chambers of the LER ring, the electron cloud was restricted to areas close to the walls, and the single beam x-size blow-up was fixed. But in collisions there were still luminosity drops. Their effect could be reduced by using short trains, which is believed to reduce the build-up of an electron cloud along the positron bunch train.

The effect that the beam size increases with its own current and only in colliding beam conditions disappeared finally in May of 2003 when we moved the LER x-tune from close to 2/3 (0.64) to just above the ½ integer (0.52) making the LER beam stronger. So there were three conditions necessary for a blow-up: electron cloud, beam-beam, and the tune just below a resonance, making the LER weak.

In the 2004 run we normally didn't see any or only a very small luminosity variation of 2% along the bunch trains. Sometimes when the machine was not tuned well, there could be luminosity droops of up to 10% [1]. Which beam dimension varied to account for these conditions was not determined, since they didn't last very long.

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So we were very surprised to see that this luminosity droop reappeared in the spring of 2005 and was very stubborn against any tuning efforts to reduce it. Figure 1 shows these droops of up to 40% in a bunch pattern with especially long trains in July 2005. The pattern consisted of 12 bunch trains, each with 120 bunches out of 144 places in the by2 pattern, so the gaps are 48 buckets long (or 100.8 ns). The eighth trains is longer, so there is only a 16 bucket gap, which was kept constant not to change BPM reading, which is done in the following train. The last train is also longer so that the abort gap had nearly the typical length with 50 buckets empty. Train # 9 (with the short gap before it) shows a faster fall and a very low luminosity, which nearly came to equilibrium.

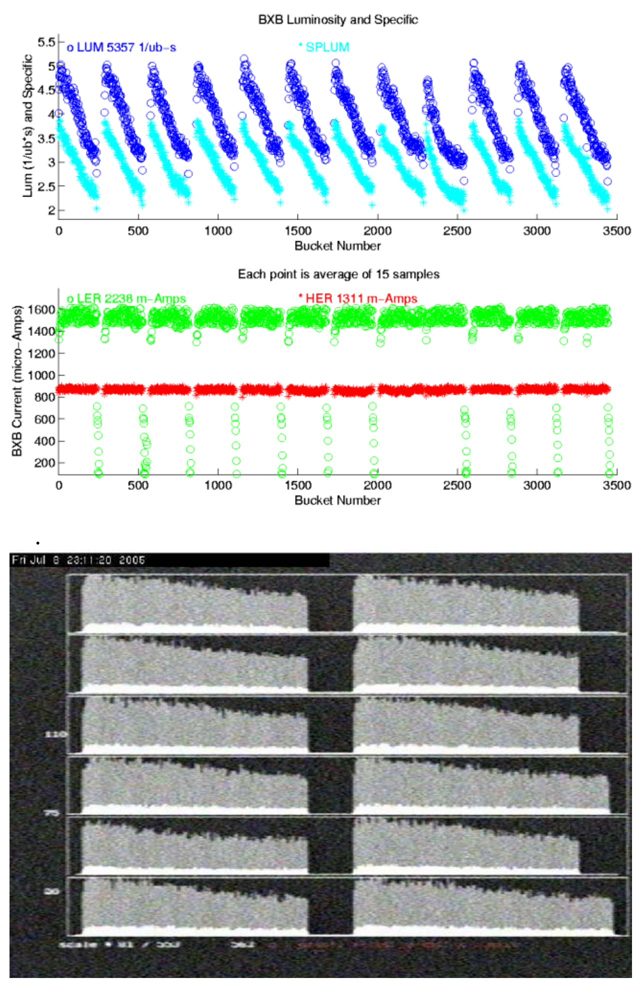

Figure 1: Luminosity and beam currents are plotted versus bucket number for all bunches. The specific luminosity (light blue) drops from 3.8 to 2.3 over the 120 bunch long trains. The bottom part of the figure shows all bunches in six rows spread out so the relative size of the gaps is better visible.

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HISTORY IN AUGUST 2005

To get a higher luminosity we were normally not running long trains of 120 bunches out of 144, but 60 out of 72 or mostly even 30 out of 36. Due to the shorter trains the luminosity drop is more like 10% instead of 40%. This makes it much more difficult to pinpoint the exact date and cause of the elimination of the luminosity droop, especially when it starts to disappear and reappear over time. The following gives a summary of events from the logbook in 2005, the specific luminosity (L_sp) showed certain droops and events are indicated in different PEP-II regions, like PR02:

1-Aug: bad droop, L_sp: 3.4 →3.0 (Fig. 2)
2-Aug: steered PR02, lower luminosity, LER stronger
5-Aug: droop: L_sp: 3.2 →2.8
6-Aug: bad quadrupole (QF) in PR06 found and fixed
7-Aug: eta_y steered in PR04 (cavity region)
8-Aug: droop L_sp: 3.2 → 2.8
9-Aug: measured big LER beta beat being about 4
10-Aug: flat and high: L_sp: 3.2 (Fig. 3 top),
10-Aug: LER x-ray spot size reduction in x
11-Aug: beta beat knob (MIA)
13-Aug: droop: L_sp: 3.2→2.9 (Fig. 3 bottom)
14-Aug: flat: L_sp: 3.2
16-Aug: 8.2E33 T31 →T32 of T36, beta beat bump
19-Aug: last mentioned luminosity droop,
19-Aug: combined LER eta_x bump knobs (R1,R3)
21-Aug: more beta beat bumps L_sp up

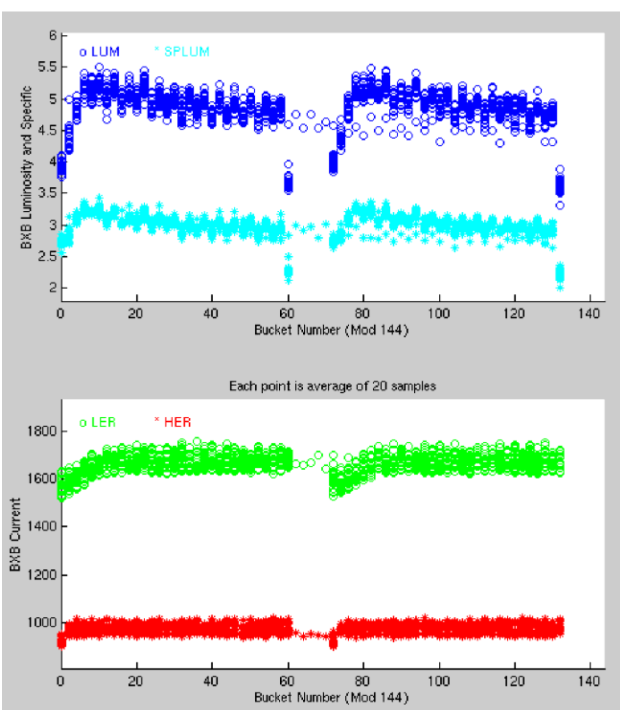

Figure 2: Luminosity versus bucket number modulo 144. Early August 2005 still showed a 12% luminosity drop over short bunch trains of only 30 bunches. The first 5 bunches of each train have reduced currents in the LER.

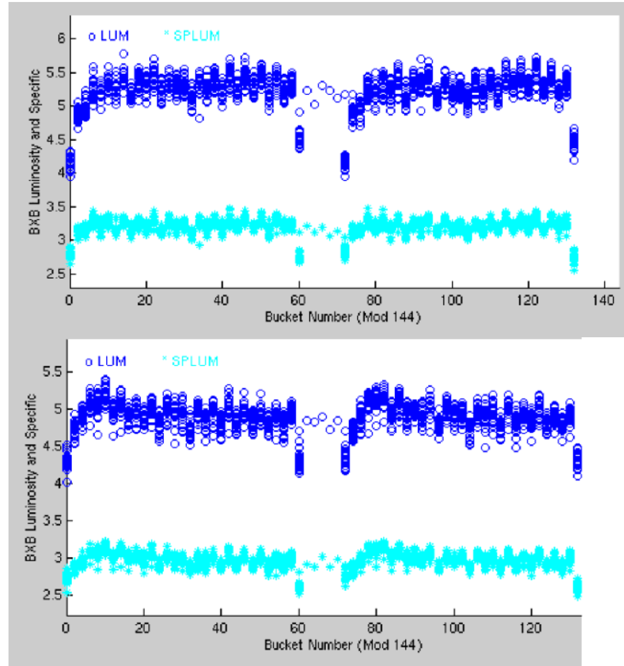

Figure 3: Luminosity versus bucket number modulo 144. The top shows the first flat luminosity at reasonable high luminosity on 10-Aug-2005. The bottom shows the more typical droop of about 10% at that time (13-Aug).

POSSIBLE EXPLANATIONS

There are at least as many different explanations as people involved with PEP-II during August 2005.

LER Parameters in X

One possible explanation goes in the following way and involves the LER beam-beam strengths in x. On August 2nd during the PR02 steering of the LER we implemented a solution of the quadrupoles (QFCX1s) near the interaction point (IP), which lowered the beat-x at the IP, see Fig. 4. This made the LER in principle stronger in x to give it a fighting chance against beam-beam and electron cloud.

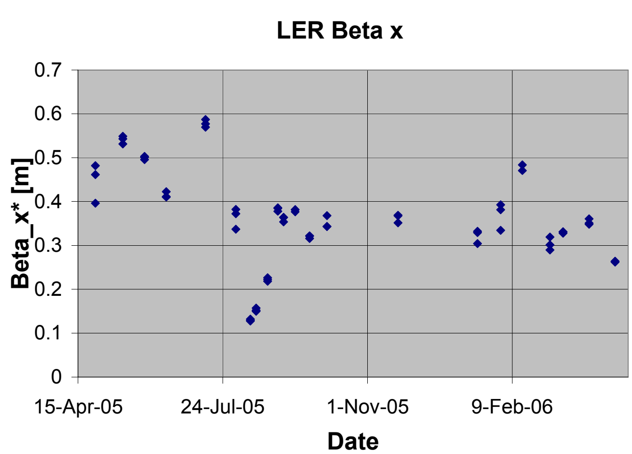

Figure 4: LER IP beta_x function versus time. The first reduction to below 0.4 m happened with the IP steering on 2-Aug-2005.

Due to a created / developed beta beat or dispersion wave the beam emittance seems to have risen. This is visible in Fig. 5 showing the two synchrotron light sizes in x at n*180+90 deg (LS) and at n*180+0 deg (LX) away from the IP, so their product gives an estimate of the relative beam emittance. On 6-Aug a partly shorted QF quadrupole (10% or 30% of one quadrant) got fixed. This increased the size at 90 deg even further, which normally results in a smaller IP size.

A small hint, that the luminosity droop is caused by the LER x size, is also visible in Fig. 6, where the synchrotron light spot size in x at the 90 deg point shows some weak dependence over the trains. The decrease at 90 deg should have an increase at 0 deg (IP phase), if the effect is purely by dynamic beta. This was confirmed with a clever time resolving method analyzing the luminous region with the BaBar detector measuring a 3-4% increase along 60 bunch long trains [2, 3, 4]. Comparing these 5% effects with the observed 24% droop for 60 bunch trains (12% for 30 bunch trains, and 40% for 120 bunch trains), it seems like there might be other effects.

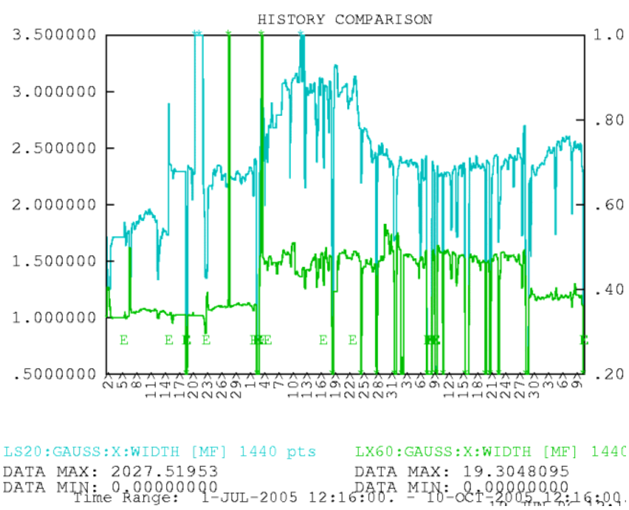

Figure 5: LER spot size in mm versus time (1-Jul to 10 Oct-2005). On 2-Aug both sizes (LS = x_90deg and LX = x_0deg) show a blow-up.

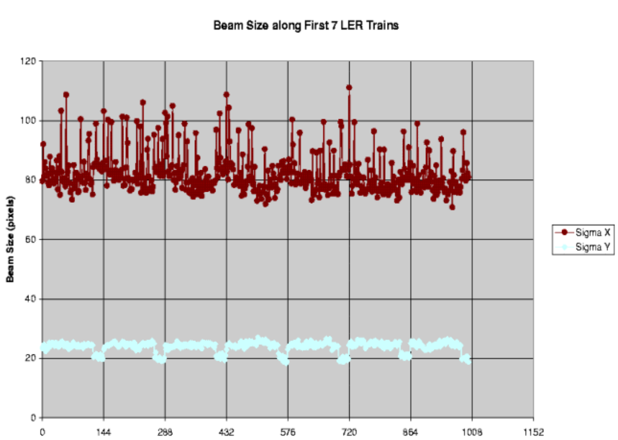

Figure 6: LER beam size for the first 7 trains at the 90 deg away from the IP point. The x size (top) shows a small (5%) decrease along the trains.

LER Parameters in Y

The LER size in y is tricky to measure, especially in a time resolved manner. The synchrotron light at the 90 deg point in x has a hard time to see any "y size" at all, since the vertical size there is dominated from mode 1 (mainly x'). The resolution of the vertex detector of BaBar is not good enough, and synchrotron x-ray size monitor (Fig. 7) doesn't have the possibility to time resolve it (yet). So there is a chance that the dispersion steering in the cavity region had some influence on the luminosity slope. This would mean the root problem might not be beam-beam and electron cloud in x, but the longitudinal phase transient and dispersion in y in RF cavities.

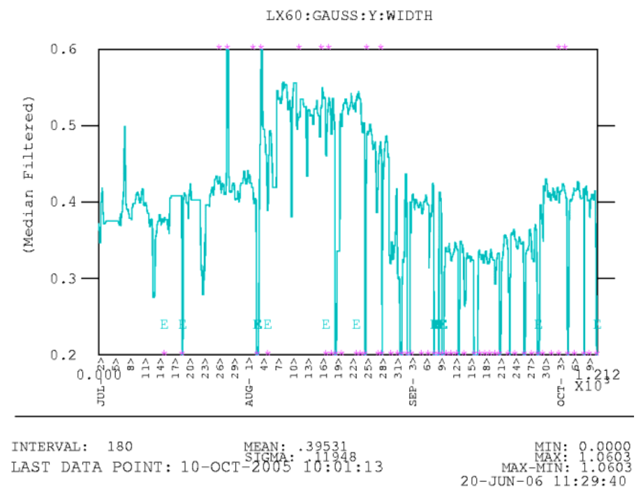

Figure 7: LER x-ray spot size in y versus time.

SUMMARY

It is pretty disappointing, that the problem with the luminosity droop in PEP-II causing a 30% lower luminosity for 3 month in 2005 is still not fully understood. This article tries to mention most of the likely candidates, and focuses on the arguments that the problem was caused mainly by the LER x size. The list of events should help if the problem ever comes back.

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