STATUS OF THE SLC LINAC

F.-J. Decker, M.G. Minty, Y. Nosochkov, P. Raimondi, SLAC[1], Stanford, CA 94309, U.S.A.
R.W. Assmann, CERN, Geneva, Switzerland

Abstract

An important contribution to the increased luminosity of the SLAC Linear Collider (SLC) in 1997/98 is due to improved performance of the linac. New tuning and stabilization strategies have reduced the emittance growth to nearly negligible values (<10% in x and <30% in *y*). A stronger lattice has less sensitivity to wakefields. A new orbit correction scheme and a different emittance tuning procedure reduce the emittance growth further. The stability is improved by counteracting diurnal changes and additionally checking klystron phases. The jitter of the beam is monitored by analyzing the FFT spectrum for sources and keeping it under control. Careful attention is paid to the longitudinal setup from the rings to provide an optimal bunch length at the interaction point for maximum disruption enhancement.

1 INTRODUCTION

The SLC has just completed the most successful run in history with over 350,000 Z's delivered to the SLD detector. Here we describe the changes in linac procedures which contributed to the significant performance improvement.

2 STRONGER LINAC LATTICE

A stronger betatron lattice increases the effective BNS damping. This is good for wakefield tails and stability, but it needs some attention not to increase the chromaticity of the lattice. Fig. 1 shows the phase advance per cell of a lattice, which would be compatible with PEP2 (B-factory) running, where a lower phase advance is necessary for matching into the PEP2 transfer lines. The original SLC design lattice started with a phase advance of 90˚/cell till a distance of 400 m and then 76˚/cell. This was increased to 110˚ in *x* till 500 m and then slowly reduced to 75˚/cell in the middle of the linac. For the high energy extraction point for PEP2 (950 m) the strength had to be reduced to its original value (75˚/cell). The 300 m point for the low energy extraction point for PEP2 is also shown, but was not implemented for the 1997/98 run. In electron *y* the lattice is about 10˚/cell weaker to create a split tune lattice, so that long-range wakefields from the positrons (first bunch) don't drive the electrons (second bunch) [1]. The lattice was an instant success, providing good beams for SLC and PEP2 (HER) at the same time. But due to its big strength it changed some of the tuning procedures in the front part of the linac (see low).

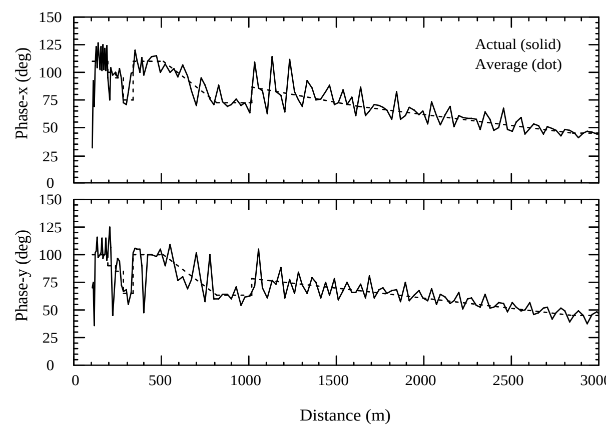

Figure 1: Phase advance of the 110˚/cell SLC lattice.

3 ORBIT CORRECTION

The two beam dispersion free steering (TBDFS) algorithm [2] was implemented in the on-line software (as SVD steering), which speeded up the steering procedure considerably. Additional on-line weighting possibilities between corrector values and absolute orbit measurements with BPMs adjusted to reduce fighting correctors at places, where probably false BPM data give a wrong trajectory. After this steering the emittances at the end of the linac were about half the values (in *y*) compared to former years, 6 (1 in *y*)$\cdot 10^{-5}$ m-rad instead of 8 (2 in *y*)$\cdot 10^{-5}$ m-rad.

4 NEW EMITTANCE TUNING STRATEGY

After steering, the emittances have to be further reduced by tuning, which is done by introducing betatron oscillations over a part of the linac to cancel wakefield tails [3]. The measured emittance near the end of the linac were normally minimized in the past.

In 1997/98 the wire scanners near the final focus became more reliable and trustworthy, and it was observed that there are sometimes inconsistencies with the measurements near the end of the linac. Optimizing in the final focus gave always reasonable (20-30%) emittances in the linac, while optimizing near the end of the linac gave up to a factor of two worse emittance in the final focus.

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Therefore we began optimizing beam sizes near the final focus where it counts, by making linac bumps between z = 1800-2300 m for x and z = 2300-2600 m for y.

Another difference is actually somewhat controversial and not understood in detail. By tuning the emittances locally at many places along the linac, it is believed to get the best emittance preservation. Therefore we tried to localize accelerator structure offsets by taking BPM difference orbits for various bunch lengths and calculating the most probable kicks. Fig. 2 shows the result where there was a 1.5 mm bump at z = 550 m, but also many unkown kicks.

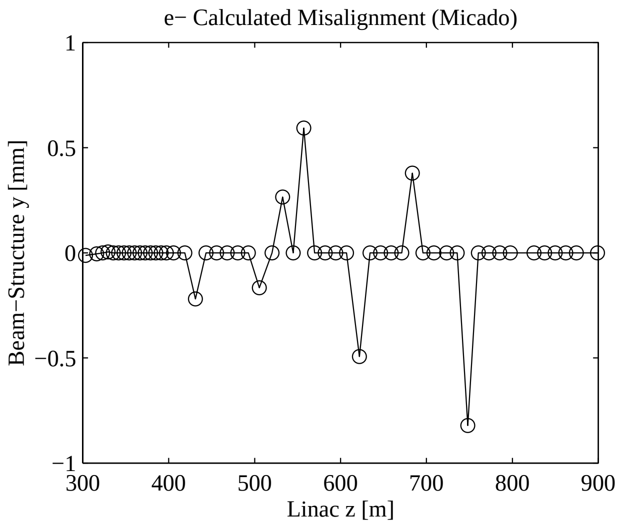

Figure 2: Calculated structure misalignment from observed difference orbit for different bunch length.

Originally we tuned at least in the first third and at the end of the linac, where there are wire scanners installed for emittance measurement. The orbit oscillations in the front were from z = 500-1000 m and tests in even earlier parts of the linac (z = 100-500 m) were not very effective, since in that region the BNS-damping is so strong that it is close to the auto-phasing condition. This means that the wakefield kick due to an offset in the accelerator structures is canceled on average with the dispersive kick due to an offset in the quadrupoles and the big correlated energy spread of up to 3% (σ_E).

Since the lattice in z = 500-1000 m got up to 45% stronger (110˚/75˚ per cell), the usual orbit oscillation technique was less effective, requiring bigger amplitudes, since the wakefield and dispersive effects nearly cancel. This is a less stable solution, since energy profile changes along the linac affect the dispersive part but not the wakefields. For stability reason and even better emittances at the end, the front end tuning was abandoned, which also freed up operators for other tasks. The performance over time can be seen in Fig. 3 for the smallest SLC emittance (e^+_y).

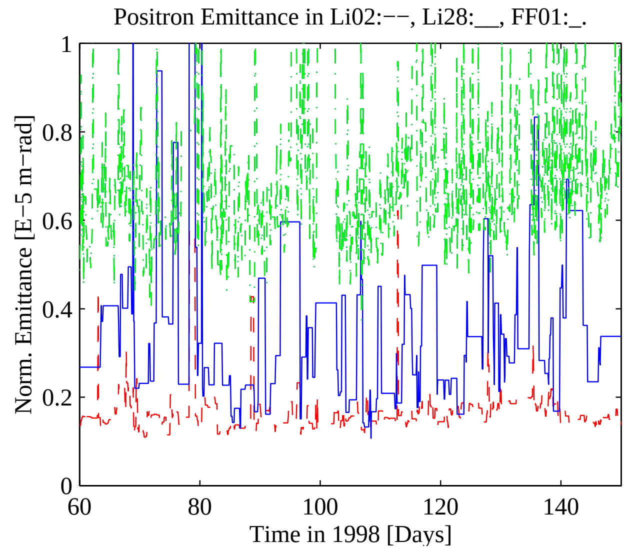

Figure 3: SLC emittance from March to May 98.

The positron y emittance is plotted which is the smallest emittance at the beginning of the linac (Li02). Often no increase is seen till the end of the linac (Li28), while there is some expected growth through the ARCs to the final focus (FF01).

5 BEAM JITTER AND DIURNAL CHANGES

The variations in the beam parameters were much reduced in the 1997/98 run. Here two effects are especially worth mentioning and discussed in detail in separate papers. The fast pulse-to-pulse variation or beam jitter is due to different sources of similar strength [4]: 59 Hz water pumps, 10 Hz support vibration, power supply ripple, feedbacks and microwave instability in the damping ring.

The day-night changes [5], which are mainly due to the rf distribution system, were checked frequently by a fast phasing (2 min) of the 30 subbooster klystrons [6]. The global daily change was counteracted by a feedforward system, which measures the temperature and corrects linearly the subbooster phases [5,7]. On top of this global change there were many local problems of 10˚-20˚ of individual subboosters which were found by this fast and therefore frequently used subbooster phasing.

6 LONGITUDINAL PHASE SPACE

The setup of the longitudinal phase space in the linac [8] is very critical to get the highest luminosity enhancement at the interaction point (IP). With the slightly higher current and the much better beam spots at the IP the disruption enhancement was as high as 100%. This factor of two in luminosity can be easily reduced by a small change of the linac bunch length. A nominal 1.2mm (σ_z) length gives the smallest energy spread (<0.1%) at the end of the linac, which then doesn't get compressed in the ARCs (R_{56} = 150 mm). A shorter bunch (0.9 mm) would have a bigger energy spread (>0.2%) which would give an additional 0.3 mm (= 0.2% · 150 mm) ARC compression resulting in a σ_z = 0.6 mm bunch length at the IP with a much reduced enhancement.

It seems obvious to run with the right bunch length, but a shorter bunch has many real and apparent advantages. The transverse emittance preservation is easier for a short bunch due to less wakefields, although the

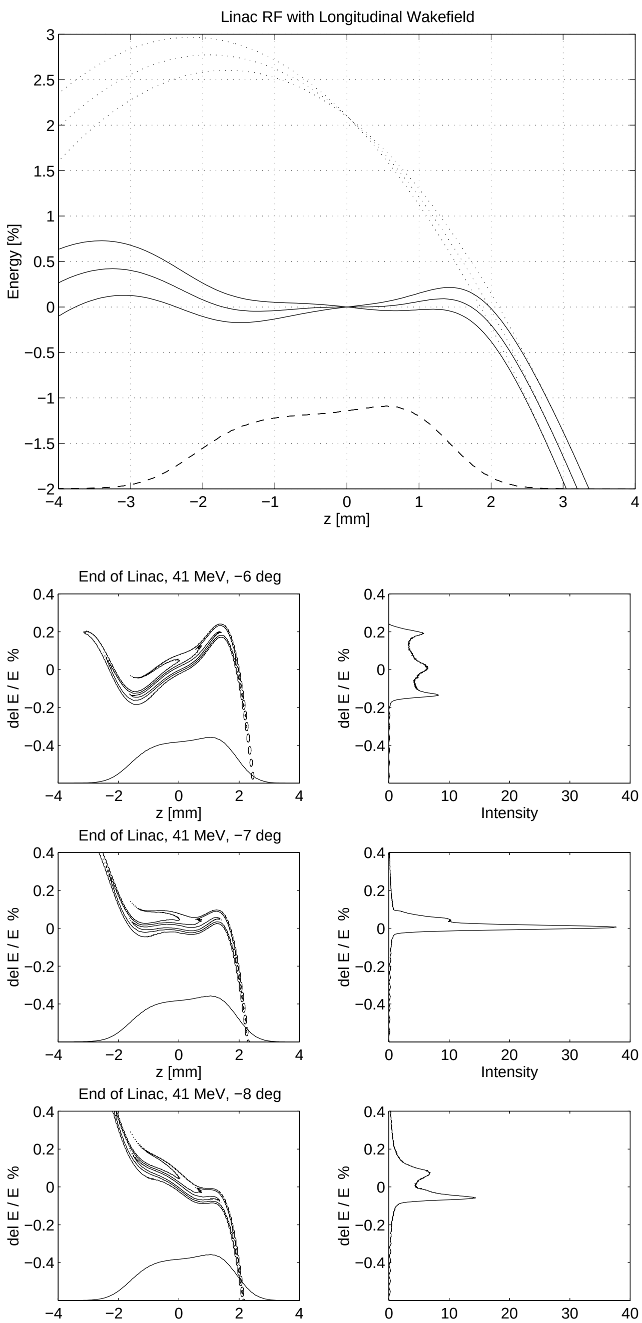

Figure 4: Energy–z correlation for different linac phase.

Small phase changes of ± 1° influence the energy–z correlation which changes the IP bunch length by 20%. The beam distribution is generated by over-compression. The lower plots show the energy distribution on the right.

jitter goes up due to less BNS damping from sitting further off the crest. The energy spread is adjusted “wide” (for a short bunch) to pull in the energy tails. The measured (not the effective) beam size at the IP looks better [9], and beam strahlung signals increase too, indicating more luminosity. But the ratio of real luminosity in the SLD detector divided by the predicted luminosity which includes the enhancement for a 1 mm long bunch is less than one. Many times when this ratio dropped below 80% for more than a day, we had to lengthen the bunches or encourage the operators not to run the energy spread “wide” by adjusting the injected phase more to the crest (see –6˚ in Fig. 4). This mostly required a new tuning setup of the emittances afterwards.

7 SUMMARY

Several improvements of the SLC linac have contributed to the outstanding performance of the SLC in the 1997/98 run. The move of the measurement part of the quantitative emittance tuning to the final focus has helped to maintain the peak luminosity increasing the average. The bunch length control ensured the high disruption enhancement. And the jitter or variation reduction allowed a final focus setup higher angular divergences, till again the background due to jitter was the limiting factor.

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