SLAC–PUB–7302
September 1996

Emittance Dilution Due to Slow Alignment Drifts in the Main Linacs of the NLC*

R. Assmann, C. Adolphsen, K. Bane,
T.O. Raubenheimer, K. Thompson
Stanford Linear Accelerator Center, Stanford University,
Stanford, CA 94309, USA

Abstract

The tight tolerances in the main linacs of the Next Linear Collider (NLC) result in a large sensitivity of the beam emittance to slow alignment drifts. Once the accelerator is tuned, the optimized emittances must be maintained. Slow alignment drifts will make resteering and reoptimization necessary. The frequency of these linac reoptimizations is an important parameter that determines how well the linear collider can be operated. We present simulation results that address this question for the main linacs of the NLC. We will show that the effects of alignment drifts can indeed be handled.

Presented at the XVIII International Linac Conference (LINAC 96), Geneva, Switzerland, August 26-30, 1996

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

DISCLAIMER

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

EMITTANCE DILUTION DUE TO SLOW ALIGNMENT DRIFTS IN THE MAIN LINACS OF THE NLC*

R. Assmann, C. Adolphsen, K. Bane, T.O. Raubenheimer, K. Thompson

Stanford Linear Accelerator Center, Stanford, CA 94309, USA

Abstract

The tight tolerances in the main linacs of the Next Linear Collider (NLC) result in a large sensitivity of the beam emittance to slow alignment drifts. Once the accelerator is tuned, the optimized emittances must be maintained. Slow alignment drifts will make resteering and reoptimization necessary. The frequency of these linac reoptimizations is an important parameter that determines how well the linear collider can be operated. We present simulation results that address this question for the main linacs of the NLC. We will show that the effects of alignment drifts can indeed be handled.

1 INTRODUCTION

The alignment stability in the main linacs of NLC determines how often the alignment and correction algorithms need to be applied. It has been shown that static imperfections in NLC can be corrected down to the required levels [1]. Linac stability effects are dominated by quadrupole alignment drifts; the quadrupoles generally have the tightest alignment tolerances. Here, we do not discuss the BPM stability. However, the requirements are tight. For the alignment algorithm we require a 2 μm static rms offset between the BPM and quadrupole centers [1]. This tolerance can be achieved with a time consuming beam-based alignment procedure and it must be stable over significant periods of times (days). The question of BPM stability is discussed in [2]. Since quadrupoles and BPM's are mechanically mounted together, the BPM stability that can be achieved is mainly determined by the BPM electronics, cables and similar factors. Results from beam-based alignment experiments at HERA and LEP show that the BPM to quadrupole alignment presently is being done with an absolute accuracy of better than 10 μm [3, 4]. The results in HERA are found to be remarkably stable over years.

2 SIMULATION PARAMETERS

The simulations were done with the computer program LIAR [5] using the 500 GeV version of NLC-II as defined in [2]. We consider a single bunch with with a population of 1.1×10^{10} particles. The injection energy is 10 GeV, the bunch length is 150 μm, and we include an initial uncorrelated energy spread of 1.5%. The initial horizontal and vertical beam emittances are $\gamma\epsilon_x = 3.6 \times 10^{-6}$m-rad and $\gamma\epsilon_y = 4.0\times10^{-8}$m-rad. We assume that the chicanes in the diagnostics stations are switched off. The simulations were done for the vertical plane where the small initial emittance makes it much harder to avoid emittance dilutions. A realistic BNS damping setup is included [2].

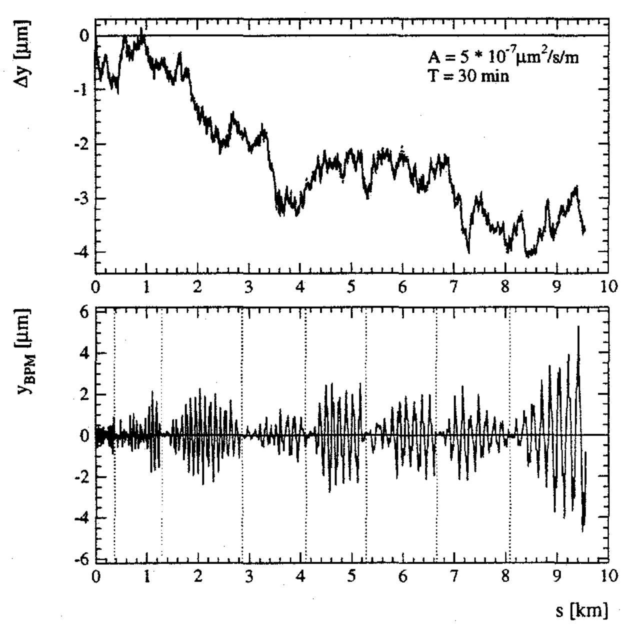

Figure 1: Example of ATL-like alignment drifts. The upper plot shows the displacements of quadrupoles, RF-structures and BPM's after 30 minutes with an A-coefficient of 5×10^{-7} μm^2/sec/m. The alignment was flat initially. The lower plot shows the corresponding trajectory offsets y_{BPM} at the BPM's. The dotted lines indicate the locations of trajectory feedbacks where y and y' are corrected back to zero. Thus the size of coherent betatron oscillations is constrained.

3 ATL-LIKE ALIGNMENT DRIFTS

In order to model alignment drifts, we use the ATL-model [6]. This predicts that the rms vertical misalignment $\sigma_{\Delta y}$ (in μm) deteriorates with time T (in seconds) and over the length L (in m) as follows:

$$\sigma_{\Delta y}^2 = A \cdot T \cdot L$$

Recent studies [7] show that a constant A of better than $5 \times 10^{-7}\mu$m^2/sec/m can be measured on the SLAC site.

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

We use $A = 5 \times 10^{-7} \mu\text{m}^2/\text{sec/m}$.

Figure 1 illustrates ATL-like alignment drifts. It shows the displacements Δy and corresponding trajectory offsets y_{bpm} at the BPM's after 30 minutes. The offsets of quadrupoles, BPM's, and RF-structures are overlaid in the plot and are essentially indistinguishable. The trajectory offsets at the BPM's show the coherent betatron oscillations that build up. The dotted lines indicate the locations of seven trajectory feedbacks that constrain y and y' to zero. The coherent betatron oscillations are thus broken up into eight smaller oscillations. The oscillation amplitude is a few μm and is large enough to be detected easily with the NLC single shot BPM resolution of 1 μm.

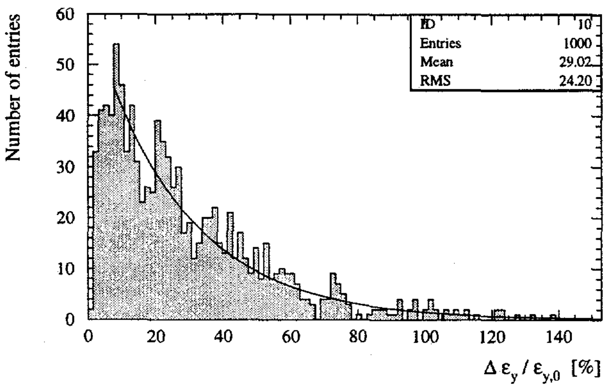

Figure 2: Histogram of vertical emittance growth $\Delta\epsilon_y/\epsilon_{y,0}$ for 1000 different error distributions. ATL-like alignment drifts over 30 minutes with an A of 5×10^{-7} μm^2/sec/m are assumed. The average emittance growth is 29.0% $\pm$ 0.8%. The solid curve shows an exponential fit for large emittance dilutions.

A histogram of the vertical single-bunch emittance growth from alignment drifts after 30 minutes is shown in Figure 2. The average emittance growth is found to be 29.0% $\pm$ 0.8%. Note, however, the exponential distribution for large emittance dilutions. The most probable emittance growth is only about 10%.

The average emittance growth along the linac is shown in Figure 3. The locations of the trajectory feedbacks are clearly seen. As a coherent betatron oscillation builds up the emittance starts to grow rapidly. The feedbacks stop the fast growth. More effective feedbacks can be imagined if the rms y trajectory is minimized up to the next feedback instead of correcting y and y' to zero locally.

Figure 4 shows the average vertical single-bunch emittance growth for different BNS configurations. All previous results were obtained using the standard NLC BNS configuration which requires an energy overhead of 1.3%. The standard BNS is optimized for the beam-based alignment algorithm and uses three different Rf phases along the linac. Figure 4 shows that BNS configurations using higher energy overheads reduce the emittance growth from 29% to about 16%. One can therefore imagine to trade alignment performance against better stability.

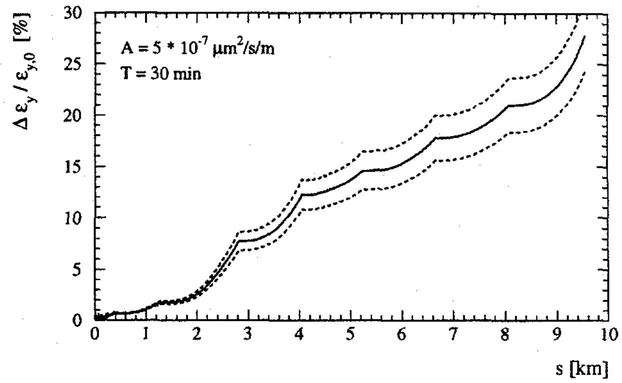

Figure 3: Average vertical emittance growth $\Delta\epsilon_y/\epsilon_{y,0}$ along the linac for ATL-like drifts after 30 minutes. We assume an A-coefficient of 5×10^{-7} μm^2/sec/m. The dashed curves specify the errorbands around the average (solid curve).

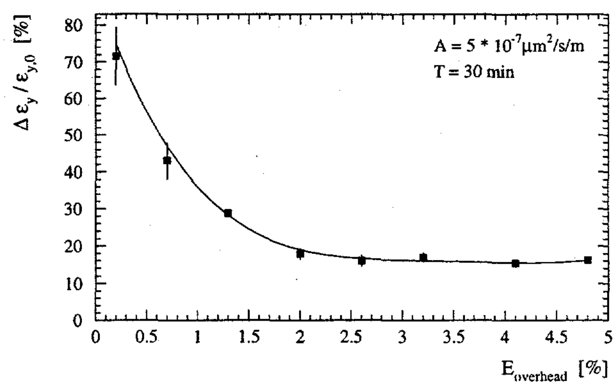

Figure 4: Average vertical emittance growth $\Delta\epsilon_y/\epsilon_{y,0}$ from ATL-like alignment drifts for different BNS configurations. The BNS configurations are specified in terms of the associated BNS energy overhead. That is the percentage of the beam acceleration that is lost due to the Rf phases required for a given BNS scheme.

Let us relate the ATL-like alignment drifts to the other results. Since the emittance growth is linear in time we would get an additional average emittance growth of about 15% when we assume a beam-based alignment every 30 minutes. This is about a factor of six smaller than the emittance growth expected after beam-based alignment of quadrupoles and RF-structures. It is small enough not to be an important limitation of the NLC linac performance as long as the linacs are corrected on an half-hourly to hourly basis. Since the alignment and correction algorithm does not interfere with the standard operation, its frequent application should be no major obstacle.

4 CONCLUSION

The dominant stability problem in the NLC main linacs is caused by drifts of the quadrupole alignment. We simulated this effect by using the ATL-model with a coefficient $A = 5 \times 10^{-7} \mu m^2$/sec/m as measured at SLAC. We showed that the alignment drifts drive coherent betatron oscillations that lead to rapid emittance growth. The addition of seven trajectory feedbacks breaks the coherent betatron oscillation into eight smaller oscillations. Assuming a beam-based quadrupole alignment every 30 minutes, we would expect an additional average emittance growth contribution of 15%. Since the emittances roughly add up in quadrature, this is small compared to the 110% average emittance growth after beam-based alignment. The alignment algorithm does not interfere with the normal linac operations, so that it can be applied very frequently. We conclude that slow alignment drifts can be handled safely for the NLC linacs, if we assume a beam line stability similar to or better than the one observed in the Final Focus Test Beam (FFTB) experiment at SLAC.

5 REFERENCES

[1] R. Assmann et al., "Emittance and Trajectory Control in the Main Linacs of the NLC", these proceedings.

[2] The NLC Design Group, "Zeroth-Order Design Report for the Next Linear Collider", SLAC report 474 (1996).

[3] M. Böge and R. Brinkmann, "Optimization of Electron Spin Polarization by Application of a Beam-Based Alignment Technique in the HERA Electron Ring", proc. of the 4^{th} IWAA95, Nov. 14-17, 1995, KEK, Japan. V 413.

[4] I. Barnett et al., "Dynamic Beam-Based Calibration of Orbit Monitors at LEP", proc. of the 4^{th} IWAA95, Nov. 14-17, 1995, KEK, Japan. V 421.

[5] R. Assmann et al., "LIAR - A Computer Program for Linear Collider Simulations", SLAC-AP 103 (1996).

[6] V. Shiltsev, "Space-Time Ground Diffusion: The ATL Law for Accelerators", proc. of the 4^{th} IWAA95, Nov. 14-17, 1995, KEK, Japan. IV 352.

[7] R. Assmann and C. Montag, "Beamline Stability Measurements with a Stretched Wire System in the FFTB", these proceedings.