STUDY OF EMITTANCE BUMPS IN THE ILC MAIN LINAC *

Nikolay Solyak#, Kirti Ranjan,

Fermi National Accelerator Laboratory (FNAL), Batavia IL 60510, U.S.A.

Abstract

We present a first look at simulation results of emittance bumps implemented to preserve the emittance growth in the main linac of the proposed International Linear Collider (ILC). It is found that global orbit bumps used as a static tuning option after dispersion free steering can be extremely beneficial in further limiting the emittance growth in the main linac. Two kinds of emittance bumps, dispersion and wakefield, are studied in the present study. The effect of varying the location of these bumps along the main linac and the number of these bumps are studied. The influence of combining these bumps on the emittance growth is also discussed.

INTRODUCTION

In order to achieve the desired luminosity in the proposed ILC machine, it is very important to preserve small transverse beam emittances in beam propagation through the main linac. The importance of beam-based alignment (BBA) techniques for static tuning of the main linac, or for that matter in the whole low emittance transport region, can hardly be overemphasized. A detailed study of one attractive option of static tuning, Dispersion Free Steering (DFS), has been presented elsewhere for the main linac of the ILC [1]. However, owing to various reasons like extremely stringent requirements on the emittance dilution budget in the proposed ILC machine, limitations of the static tuning techniques, and also to increase robustness in the tuning options, emittance bumps are suggested as an effective means for emittance preservation. Emittance bumps as a global correction technique for the NLC and TESLA have been studied [2,3]. However, a detailed study is needed to optimize these bumps for the ILC machine, and the present work is an effort in this direction. We present here our first simulation results on the effectiveness of these bumps, performed using the simulation program Lucretia [4]. The full optimization of these bumps for the ILC main linac is underway.

The ILC main linac considered in this study is an adaptation from the design envisaged in the ILC Baseline Configuration Document [5]. A fully loaded gradient of 31.5 MeV/m is considered for the 9-cell 1.3 GHz accelerating cavities. The main linac cryogenic system is divided into cryomodules (CM), with 8 cavities per CM. A quad package consisting of a quadrupole magnet, a cavity-style BPM, and horizontal and vertical corrector magnets is installed in every fourth CM. The magnet optics is a FODO lattice with a phase advance per cell of 75^0 (60^0) in the horizontal (vertical) plane. For the purpose of present studies we considered 50 FODO cells (almost half of the design) and a single bunch charge of 2 x 10^{10}. Various realistic sources of emittance dilution in the main linac, like dispersion originating from misaligned quadrupoles and BPMs, pitched cavities and cryomodules, wakefields generated from cavity offsets, and coupling between the transverse planes coming from rotated (or skew) quads are considered. The nominal installation precision for various beamline elements is given in Table 1. As challenges in the vertical plane are far more severe, in the present work we have considered emittance growth in the vertical plane only. The linac is first tuned using one-to-one and dispersion-free steering, and the further beneficial effects of emittance bumps on such machines are investigated.

Table 1: RMS alignment tolerances for a curved ILC main linac in the vertical plane.

Misalignment	With respect to	Tolerance
Quad offset	CM	300 µm
Quad rotation	CM	300 µrad
BPM resolution	-	1 µm
BPM offset	CM	300 µm
Cavity offset	CM	300 µm
Cavity pitch	CM	300µrad
CM offset	Survey Line	200 µm
CM pitch	Survey Line	20µrad

EMITTANCE BUMPS

Because of the limitations of static tuning techniques, a residual emittance growth takes place in the main linac due to both dispersive and wakefield effects. Although the wakefield effects are in general smaller than the dispersion effects in the main linac of the ILC machine, after incorporating various tuning options the residual effects may become comparable. Thus, two different global bumps, dispersion bumps and wakefield bumps, are considered for the present study.

For the dispersion bumps, a closed bump was generated by energizing a pair of correctors 180^0 apart,

*Work supported by U.S. Department of Energy
#solyak@fnal.gov

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with appropriate energy scaling for the change in beam energy between the two correctors. In this configuration, dispersive emittance growth continues after the bump. A wire scanner to measure the beam size was placed very close to the end of the main linac, at a D quad and at an F quad 90^0 away. For each bump a wire-scanner target was selected by determining which wire saw a larger fractional change for a given bump. The scan range was set by the bump value needed to double the extracted emittance, given an otherwise perfect linac. For the present case, perfect wire scanner resolution was considered. The bump value was optimized by measuring the beam size at the wire scanners and finding a minimum by fitting the square of the beam size with a parabola. Figure 1 shows the effect of generating a dispersion bump at the start of the linac (~16 GeV). The dispersive emittance growth generated by the dispersion bump continues once the bump is excited.

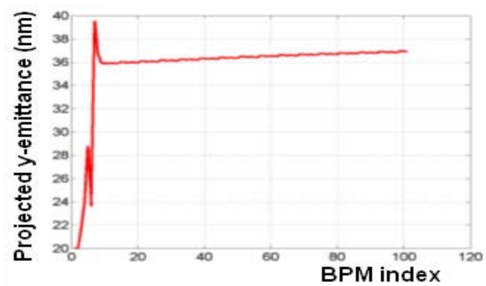

Figure 1: Projected emittance growth due to an excited dispersion bump placed very close to the main linac entrance in an otherwise perfect linac.

For the wakefield bumps, the methodology is quite similar to dispersion bumps. In this case, the idea is to generate a wakefield dominated effect and globally correct it by measuring the beam size near the end of the linac. We used the same wire scanners and respective locations that were used for the dispersion bumps optimization process. The wakefield bump was generated by placing three correctors 180^0 apart such that the generated dispersion is cancelled after the bumps, and only the wakefield induced emittance growth continues. Figure 2 shows the emittance growth in an otherwise perfect linac where a wakefield bump is placed near the main linac entrance.

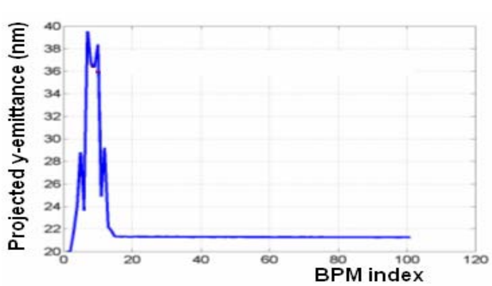

Figure 2: Projected emittance growth due to an excited wakefield bump placed very close to the main linac injection in an otherwise perfect linac.

RESULTS

The main aim of this present study is to understand the effectiveness of the emitttance bumps on the performance of the main linac. Figure 3(a) shows the mean emittance growth in the main linac for 30 independent machines, where one dispersion bump is implemented after incorporating dispersion free steering. It is clear that even a single dispersion bump placed near the entrance of the linac helps to significantly reduce the emittance growth when implemented after dispersion free steering. Figure 3(b) shows the emittance growth for 30 individual machines. Again, it is observed that a single dispersion bump helps in limiting the emittance growth for all the seeds. The result is very encouraging; even if the final machine turns out to be one in which the emittance dilution budget is not met by quasi-local beam based alignment techniques, then emittance bumps can be used to correct it.

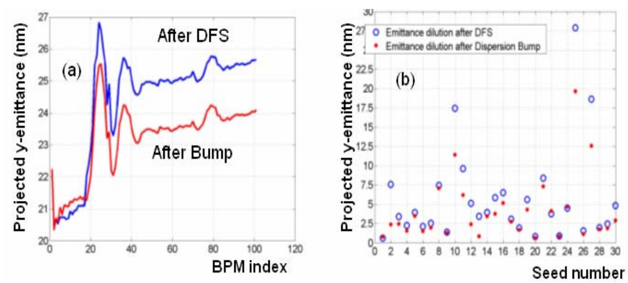

Figure 3: (a) Average projected emittance growth in a nominally misaligned linac for 30 seeds after dispersion free steering, and then implementing a dispersion bump near the entrance of the linac. (b) Results for the individual machines.

Figures 4(a) and 4(b) show the results of randomly varying the location of the single dispersion bump through the main linac. It is found that the placement of the dispersion bump is crucial to get the optimal result.

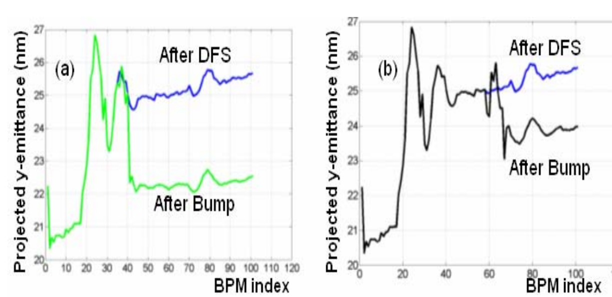

Figure 4: Average projected emittance growth in a nominally misaligned linac for 30 seeds after dispersion free steering, and then implementing a dispersion bump (a) at corrector no. 36, and (b) at corrector no. 59.

It is also important to optimize the number of dispersion bumps. Figures 5(a) and 5(b) show the results of implementing two dispersion bumps in the linac at different positions. It is evident that two dispersion bumps are beneficial, but at the same time their respective locations in the linac are also crucial to optimize. No significant improvement in the emittance growth was observed after using three bumps; however, a detailed study is in progress for further results.

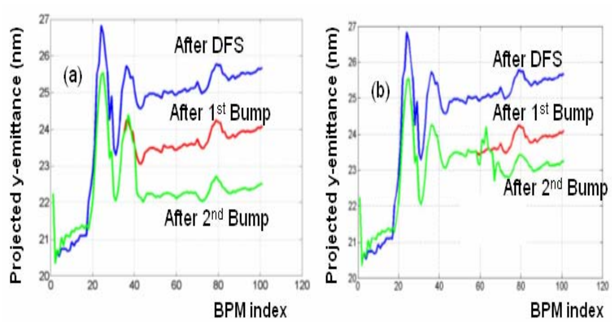

Figure 5: Average projected emittance growth in a nominally misaligned linac for 30 seeds after dispersion free steering, and then implementing two dispersion bumps (a) at corrector no. 3 and 36, and (b) at corrector no. 3 and 59.

Figures 6(a) and 6(b) show the mean emittance growth in the main linac for 30 independent machines, implementing one wakefield bump after dispersion free steering at two randomly chosen locations. Wakefield bumps are also found to be useful in limiting the emittance growth after dispersion free steering, indicating the presence of residual wakefield based emittance growth in the linac after static tuning. However again, it is important to optimize the number and location of wakefield bumps in the linac for the most effective performance in the ILC.

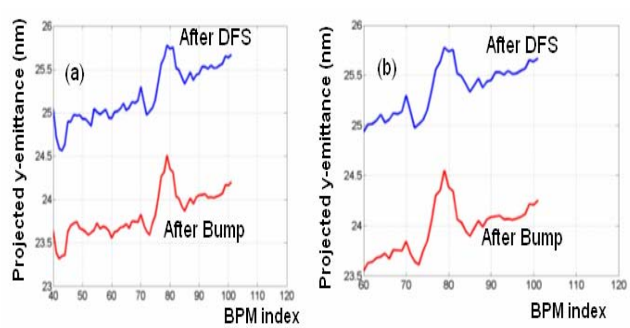

Figure 6: Average projected emittance growth in a nominally misaligned linac for 30 seeds after dispersion free steering, and then implementing one wakefield bump (a) at corrector no. 3, and (b) at corrector no. 39.

Figure 7 shows the mean emittance growth in the main linac for 30 independent machines, combining one dispersion and one wakefield bump in the main linac. As already mentioned, because of the presence of residual dispersive and wakefield related emittance growth in the main linac after DFS, the combined results of the two emittance bumps are very beneficial. A more general method of optimizing the emittance bumps [6] will also be considered and compared with the present study.

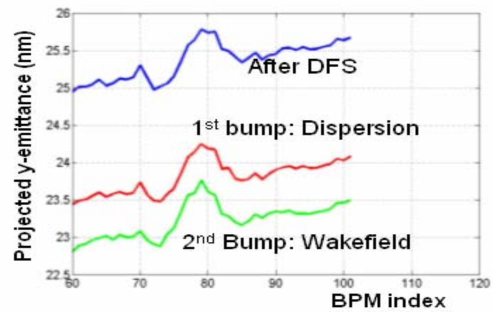

Figure 7: Average projected emittance growth in a nominally misaligned linac for 30 seeds after DFS, and then implementing one dispersion bump at corrector no.3, and one wakefield bump at corrector no. 39.

Figure 8 shows the effect of only one dispersion bump for entire ILC lattice with 114 FODO cells.

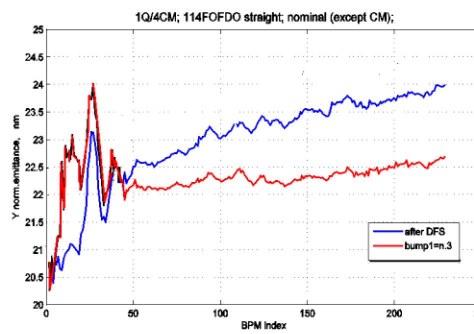

Figure 8: Average projected emittance growth in a nominally misaligned linac for 30 seeds after DFS, and then implementing one dispersion bump at corrector no.3.

SUMMARY

A first look at the beneficial effects of implementing emittance bumps after dispersion free steering for the proposed ILC machine is described. Because of the presence of residual emittance growth from dispersion and wakefield related emittance growth after static tuning, these global bumps are found to be very important to further limit the emittance growth. Two different emittance bumps, dispersion and wakefield, are studied Both of them are found to be important; however, a careful optimization of the number of these bumps and their location are crucial. Further studies to optimize these bumps for the realistic ILC machine is in progress.

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