

# Linac Final Focus Feed-Forward for Increasing the SLC Luminosity\*

J. T. Seeman, M. Browne, P. Emma, K. Jobe, T. Himel, and N. Walker  
 Stanford Linear Accelerator Center  
 Stanford University  
 Stanford, California 94309, USA

## Abstract

A concept is explored where the information from measured beam transverse offsets at the end of the linac of the Stanford Linear Collider (SLC) [1] is sent across the diameter of the transport arcs to the final focus and used to correct the beam offsets allowing head-on collisions. See Fig. 1. This feed-forward system would reduce the loss in average luminosity from offset bunches due to jitter. Design considerations of the feed-forward system and initial hardware choices for position monitors, processors, signal transmission, and kickers are discussed. The observed beam jitter spectra are analyzed. A system noise analysis of the feed-forward process is given. The expected increase in average luminosity is estimated to be 10 to 30%.

## 1. INTRODUCTION

The beams in the SLC have finite transverse position and angle errors at the end of the linac. These oscillations can easily be seen in the final focus. See Fig. 2. The position jitter in the final focus is highly correlated (about 60%) with those in the linac as seen in Fig. 3. Position errors of the beams at the collision point reduce the average luminosity. A scheme was invented many years ago [2] to measure the beam errors at the end of the linac, send the error signals across the diameter of the arcs and fix the offset errors on the same pulse. We have now considered this possibility in some detail

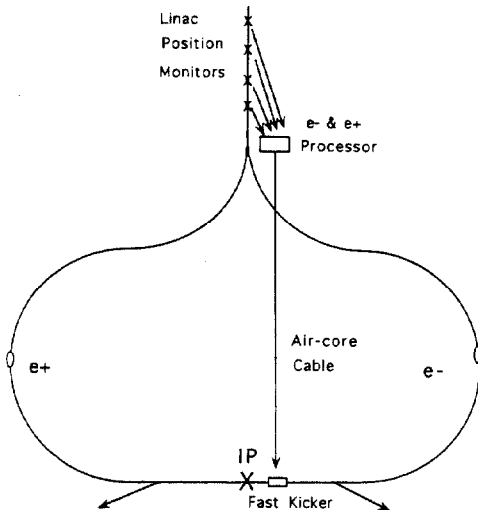


Fig. 1 Schematic view of a possible Linac-Final Focus Feed-Forward System at the SLC.

\* Work supported by US Department of Energy contract DE-AC03-76SF00515.

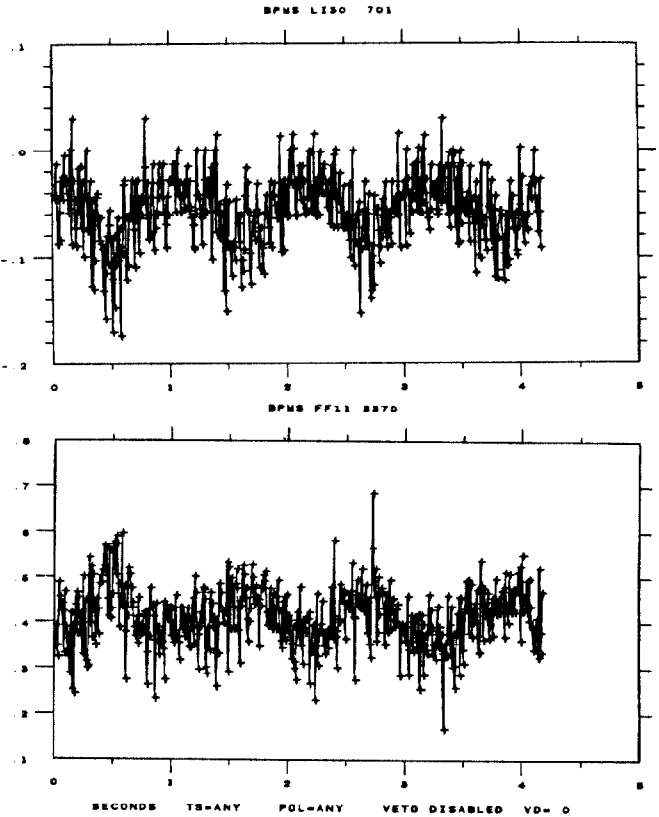


Fig. 2 Measured pulse by pulse vertical position jitter (100  $\mu\text{m}/\text{div}$ ) at the end of the SLC linac (upper) and in the final focus (lower) over 4 seconds. Note the slow oscillations and the fast jitter. Feedforward can reduce the slow jitter.

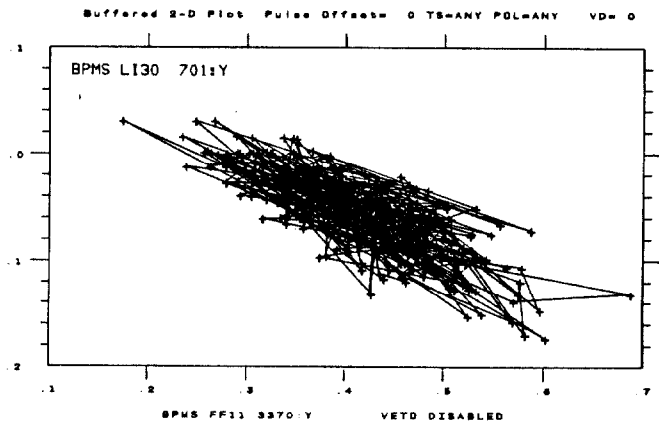


Fig. 3 Correlated position changes in the IP with those at the end of the linac.

The normal pulse-by-pulse feedback [3] has observed these oscillations more or less over the life of the SLC. The amplitude varies from 0.25 to 0.75 beam sigma and the phase also changes with time. Also, the cascaded feedback often lets oscillations through which come and go on the order of a second, which is the unity gain frequency of the normal feedback. Plots of the observed beam amplitude and position jitter over long periods are shown in Fig. 4.

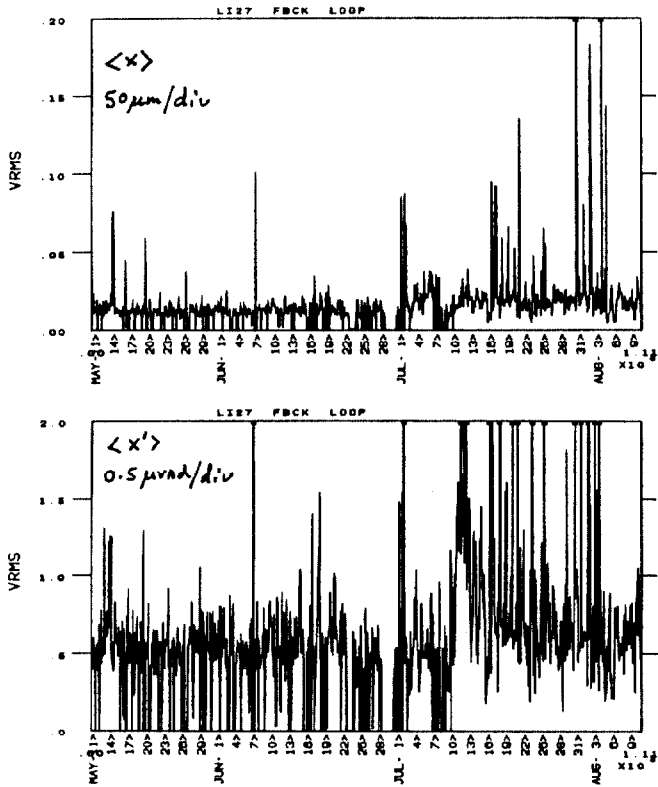


Fig. 4 Averaged position and angle jitter at the end of the linac as determined by the standard SLC feedback system which has gain less than one up to about 1 Hz.

## 2. POSITION MEASUREMENTS

The positron and electron positions and angles are to be detected on a single linac pulse using eight position monitors [BPM] [two per beam per plane] spaced 90 degrees apart in betatron phase. At bunch charges of  $3 \times 10^{10}$  the BPM resolution for one shot is about 10 microns. With more BPMs the resolution is better ( $7.5 \mu\text{m}$  for 12 BPMs) but the processing time is longer. The signals from the strip lines along the beamline are split to provide some signal to the existing slow electronics and most of the signal to fast analog addition / subtraction units to be built for this feed-forward. The  $x$  and  $x'$  signals for each beam are combined into a single signal to be sent to the final focus to tell the single kicker there how to correct the beam separation at the IP on this pulse. The same for  $y$  and  $y'$ . In principle, both the position and angle could be corrected on each pulse but then four kickers per plane would be needed and the kickers are much harder to build. See below. Most of what is needed is given by one kicker per plane near the IP fixing both beams together.

## 3. SIGNAL TRANSMISSION

The signal needs to carry the required kicker strength. We investigated laser links, microwave links, and fast cables. Cables are presently the best solution as they are stable, known, and fairly inexpensive. The initial R&D effort into the other solutions seemed high. We also investigated whether the signal should be a timing signal to trigger a ramped kicker, an analog signal to an amplifier kicker, or a digital signal to a digital receiver and amplifier. We concluded that the amplitude signals would take too long to translate at both ends. Sending out a timing pulse to trigger a linearly ramped kicker is likely the best. A question on how the DC and drifting positions of the two beams at the IP could be corrected was answered by the fact that there is a slow feedback system existing at the IP using beam-beam deflections to center the beams.

## 4. KICKER LOCATION AND STRENGTH

The best location for the kicker in the IP is found by looking at the betatron function at the final focus (Fig. 5) and the sine and cosine beam trajectories starting at the collision point (Fig. 6). The best location is where the  $\beta$  is large and is not sensitive to the beam angle at the IP. This location is about 10 m from the collision point. We chose the north (e-) side for convenience. Recall that the single pair  $(x,y)$  must fix the offsets of both beams. The kicker strength can be calculated by the required offset at the IP ( $x,y=1,2 \mu\text{m}$ ), the betatron function at the IP ( $0.007\text{m}, 0.0015\text{m}$ ) and at 10 m ( $4000\text{m}, 15000\text{m}$ ). The phase advance is about 90 degrees. The beam energy is 47 GeV. Thus, we need 0.35 g-m for  $y$  and 0.63 g-m for  $x$ , both modest kickers. We have built a fast rise time kicker for the SLC linac which have a fast rise (20 ns), a 60 ns flattop, and a 6KV-200Amp pulser. The air core magnet is shown in Fig. 7. A circuit must be added to the pulser to

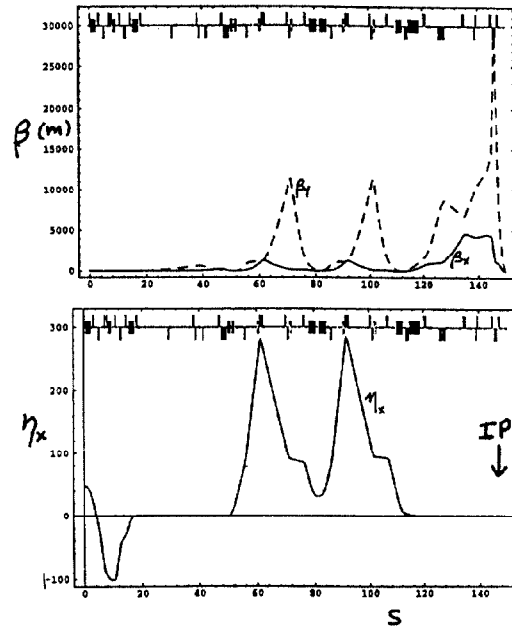


Fig. 5 Betatron functions in the final focus. The highest betatron functions are about 10 m from the IP where a kicker would require the minimum strength.

make a linear ramp. The feed-forward signal fires the kicker. The time budget for the full system is shown in Table 1. The best location for the other pair of kickers to make a full position and angle feed-forward system is about 100m from the IP where the betatron functions are low making for strong kickers and making feed-forward sensitive to the phase advances in the interaction region.

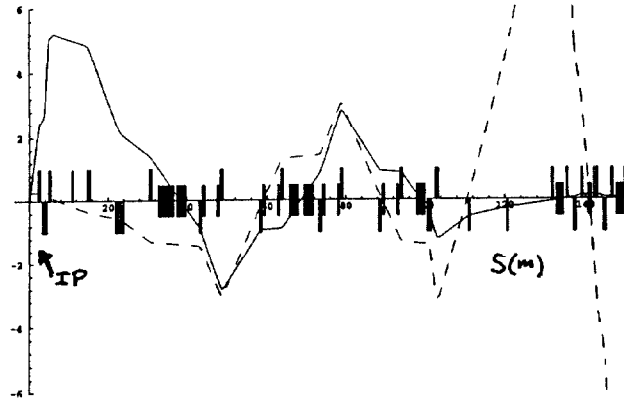


Fig. 6 Sine and cosine like rays in the final focus starting at the collision point. Note the good separation at 10m.

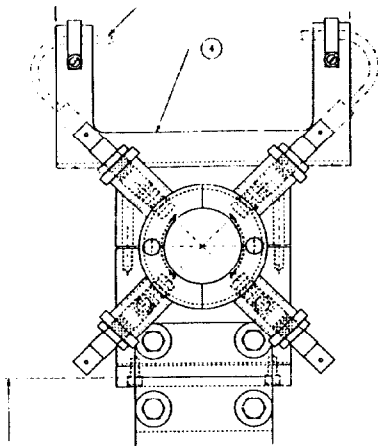


Fig. 7 Proposed pulsed magnet in the final focus. The position errors in both beams can be fixed with one pair of x-y kickers. Input and output cable pairs power the one turn coil.

Table 1 Time budget (nsec) for the feed-forward system

Line of sight - beam flight time	+1576
Cable over survey hill	-130
Use of existing cable routes	-100
Vertical shaft near IR	-65
Speed of light delay in 3500 ft cable	-250
Signals traveling upstream in IP tunnel	-100
Position monitor processing	-150
Position monitor summation	-300
Kicker turn on	-100
Kicker delay in pulse	-50
<hr/>	
Total spare time (nsec)	+331

## 5. EXPECTED LUMINOSITY GAIN

The gain in luminosity can be calculated given the noise spectrum and amplitude [4]. The loss in luminosity with an offset  $\Delta x$  is  $L/L_0 = \exp(-(\Delta x/\sigma_x)^2 * 2/2)$ . The jitter spectrum used is shown in Fig. 8. There are two components: pulse by pulse gaussian jitter and slow sinusoids which can be set with different strength ratios. The resulting lost luminosity is shown in Fig. 9. The different jitter distributions have essentially the same effect in the range of interest here.

From the data in Fig. 4, the typical rms jitter is about 30  $\mu\text{m}$  which reduces the average luminosity by about 10%. During poor operating periods the jitter is about 3 times worse, losing upwards of 40% of the peak average luminosity. Of course, if the beam jitter is due to wakefield tails, this feed-forward will not provide all the potential benefit. However, the potential improvement is well worth the modest investment.

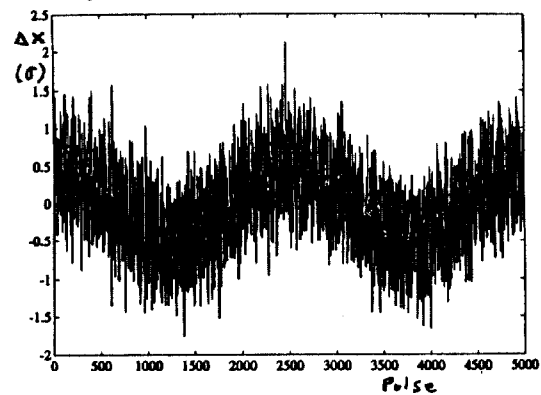


Fig. 8 Simulated beam jitter to study luminosity loss.

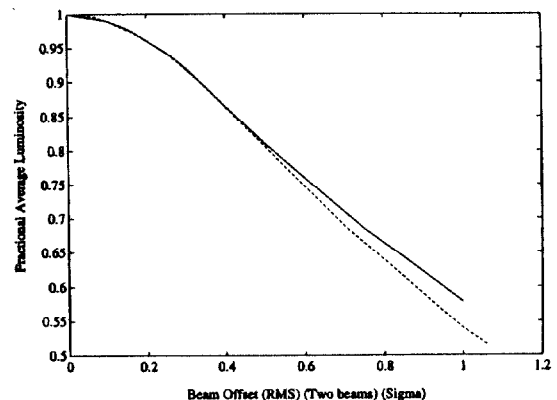


Fig. 9 Fractional loss of luminosity versus jitter oscillation amplitude. Both beams have the same but independent jitter. Two distributions are used: gaussian (upper) and sinusoidal.

## 5. REFERENCES

- [1] SLC Design Handbook, R. Erickson, ed., SLAC 1985.
- [2] R. Steining, "Feedback Compensation of Space Charge Forces in the Linac-Collider, SLAC AATF-1, July, 1979.
- [3] T. Himel, et al., 1993 USAPC, Washington, May, 1993.
- [4] V. Ziemann and W. Kozanecki, "Luminosity Degradation due to Tilted and Offset Beams," SLAC ABC-50, Oct. 1991.