Introduction to NLC and SLC Feedback

Nanobeams

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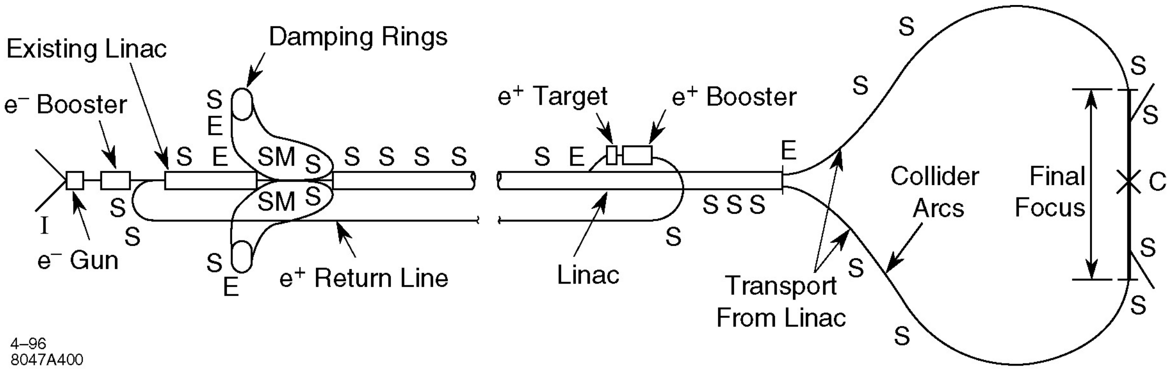
SLC Experience

- Beam-based feedback used extensively to stabilize energy, trajectory, intensity, collisions, etc.
- Sequence of linac feedbacks used 'adaptive linear cascade' to avoid overcorrection by multiple systems



- Still difficulties operating feedback at full design rates, mostly understood from experiments, simulation studies

Why is Feedback Needed

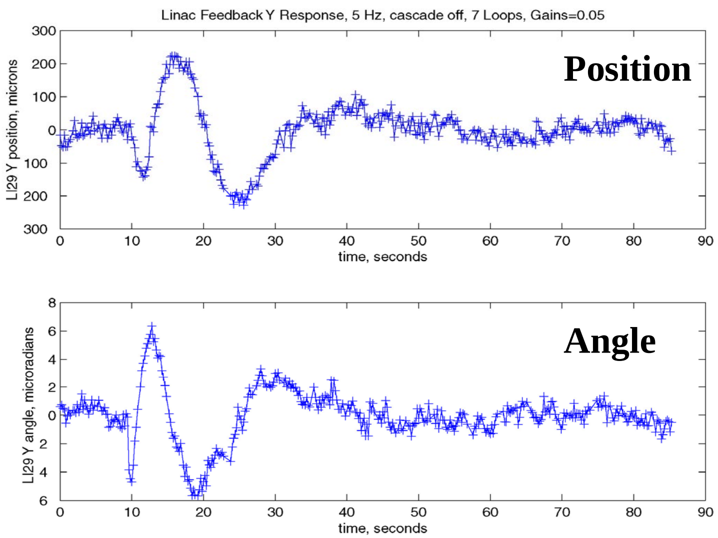
- Compensates for slow environmental changes
  Temperature drifts, Laser intensity
- Fast response to step changes
  Klystrons cycling
- Speeds recovery from downtime
- Improves operating efficiency
  Feedbacks don’t get tired or distracted
- Frees operators to study subtle problems
- Decouples systems for non-invasive tuning
  Tune Linac emittance and matching while delivering luminosity
- Powerful monitor of machine performance

At the SLC, if you could describe it, Feedback on it

Experiments

Used SLC system to study feedback behavior

- Ping tests to study time evolution of feedback response
- Frequency tests to map out Nyquist plot
- Different configurations, sample & control rates, gain factors
- Characterization of corrector speeds, modeling errors, BPMs



↑ **Disturbance**

Test example:

Response of last Linac feedback to an upstream disturbance showing ringing & overshoot due to multiple feedbacks responding to same input

‘Cascade’ between feedbacks Off

Simulations

Feedback simulations performed using MATLAB for the feedback routines and LIAR for the wakefield simulations. Simulations run on most platforms

Algorithm studies included ATL model of ground motion

A. Seryi talk described integrated simulations using
- DIMAD and LIAR for tracking
- more complete ground motion models (noisy,medium,quiet)
- model of detector noise, IR stabilization
- MATLAB for feedback, script control

L. Hendrickson (next) will describe recent results

Still lots more to do

SLC 'Cascade' Implementation

- Each feedback sent measured states (position, angle) to next downstream feedback
- Transfer matrices between feedbacks were calculated adaptively from pulse-to-pulse jitter
  note: options constrained by bandwidth & connectivity

Problem 1:

Wakefields & BNS damping –> oscillations propagate differently depending on origin of disturbance

Solution:

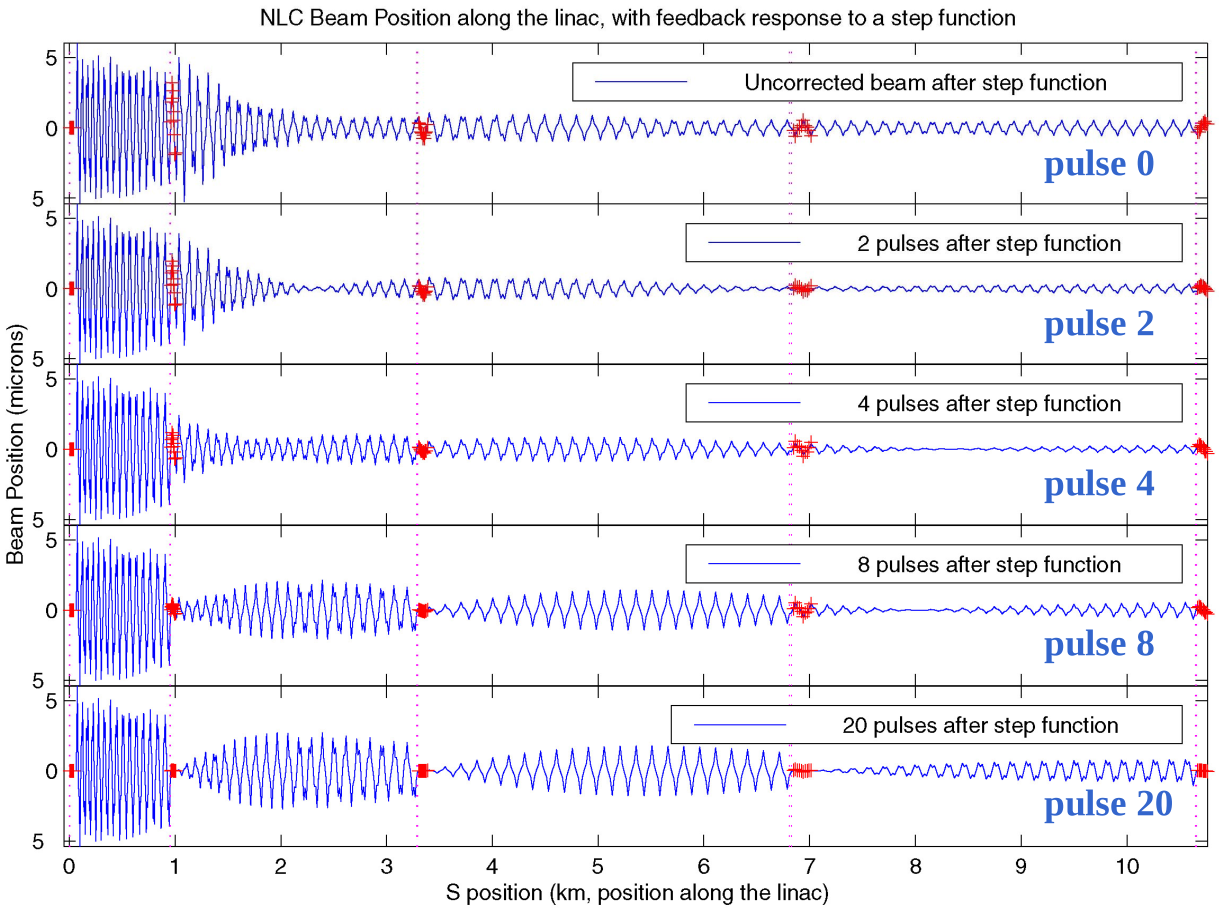
Each feedback must hear from every upstream feedback to identify source of disturbance and proper transport

SLC Feedback Response

Time evolution of Linac feedback response to a step disturbance.

SLC configuration with 1-to-1 cascade and localized correctors and BPMs for each feedback.

Later feedbacks overshoot & ring Oscillation does not fully damp even after > 20 pulses



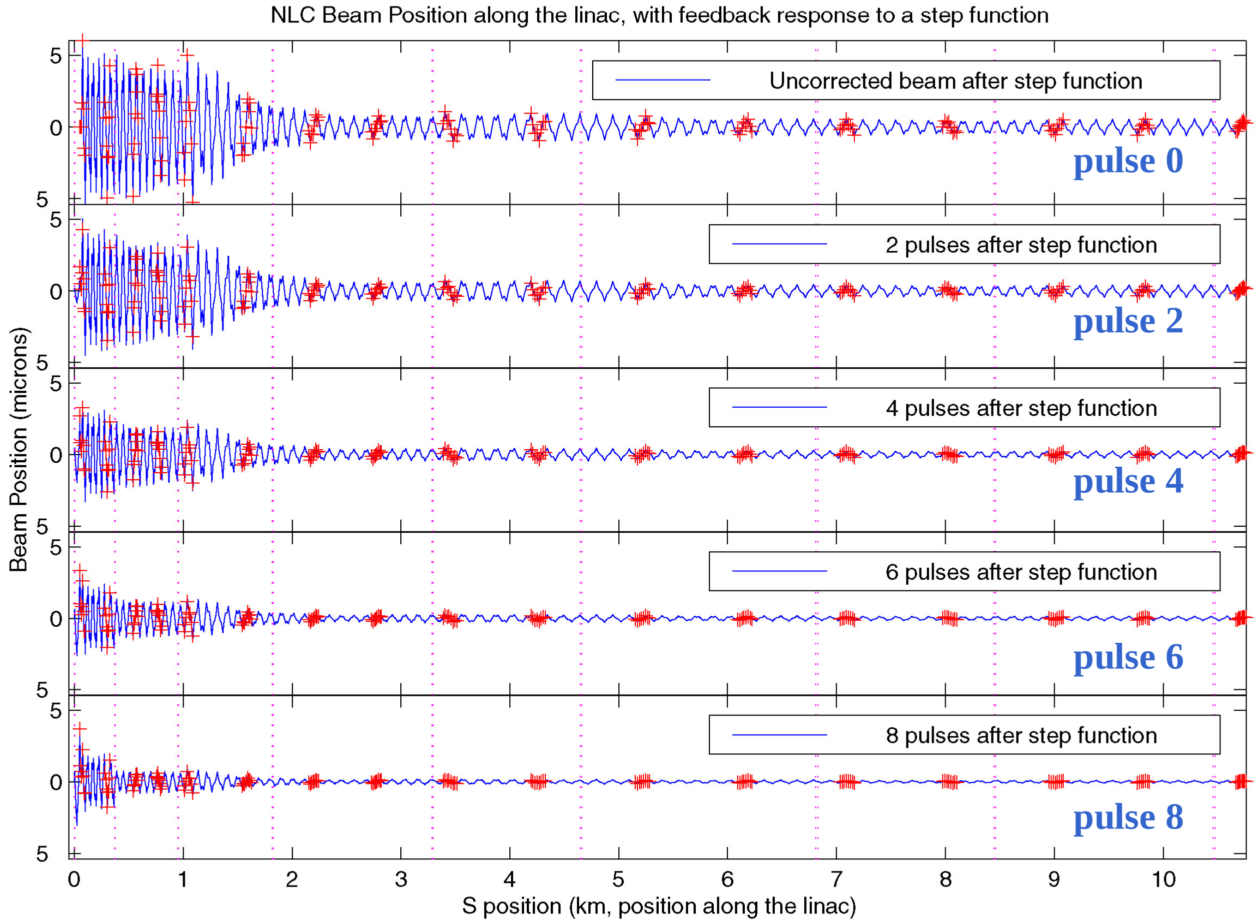
Distance along main Linac in km

NLC Feedback Response

Time evolution of Linac feedback response to a step disturbance.

Proposed NLC configuration is many-to-1 cascade with distributed correctors and BPMs for each feedback.

Oscillation damps in a few pulses



Distance along main Linac in km

SLC Feedback Calculation

- Feedback intended to minimize RMS of BPM offsets
- SLC feedback fit BPM readings to stabilize position, angle at a particular location
- This did not always result in minimum BPM RMS

Problem 2:

Sensitivity to model errors, errant BPMs
Numerical stability of solution

Solution (for now):

Fit for corrector setting to minimize BPM RMS
appears to give a more stable solution, still under study

SLC Feedback Configuration

- Each feedback used short range of BPMs with correctors immediately upstream (to minimize network links)
- Oscillations grew immediately downstream of feedback

<u>Problem 3</u>:

Feedback corrects centroid of beam but not tilt
(e.g. y-z correlations) caused by wakefields
Tail of beam continues to be kicked after correction

<u>Solution</u>:

Each feedback uses a distributed set of BPMs and correctors to effectively minimize both centroid and tilt

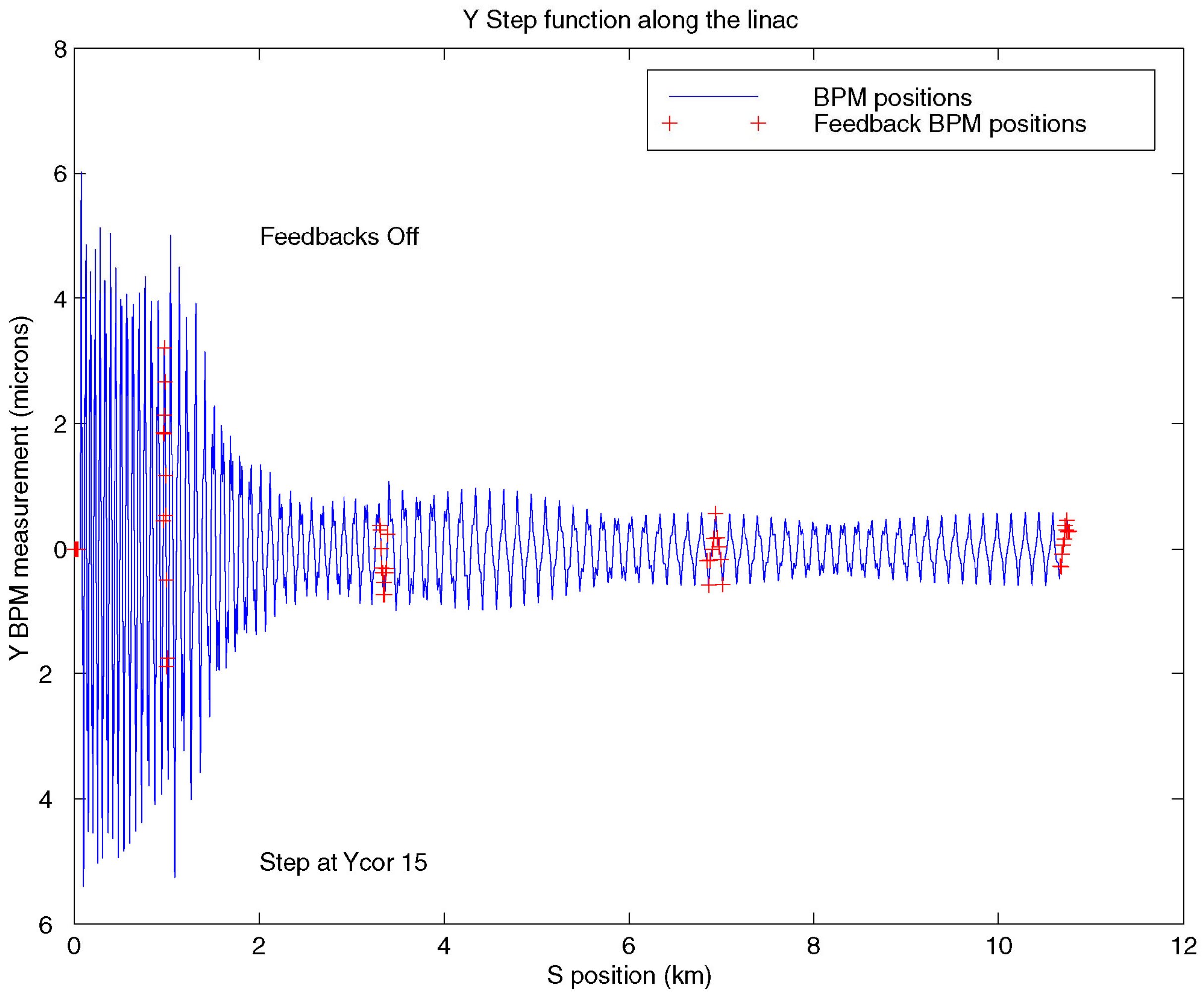
Feedback OFF simulation

Response to a perturbation early in NLC main linac

BPM readings are in blue

Feedback locations shown in red

BNS damping reduces amplitude



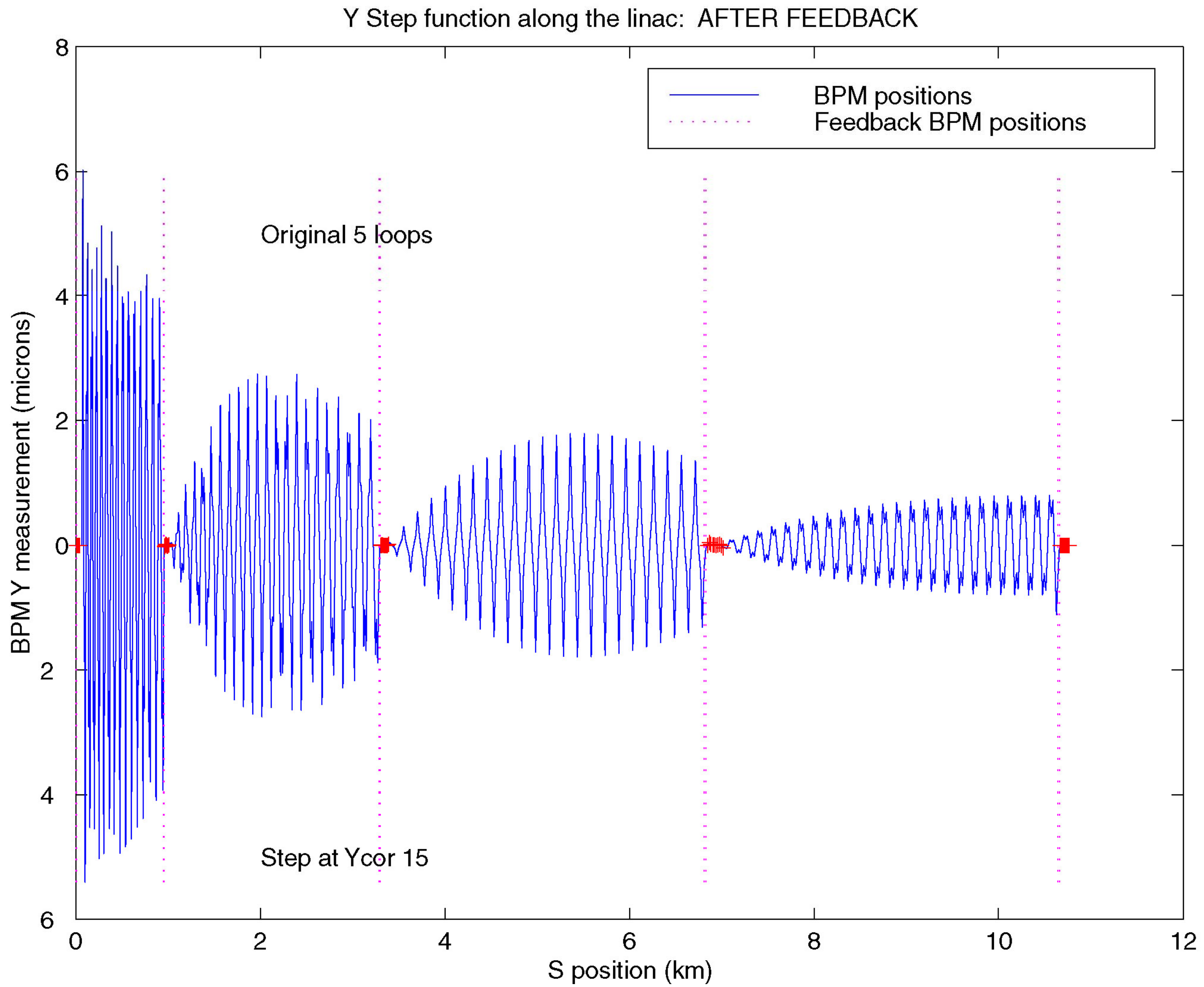
Distance along main Linac in km

SLC style Feedback ON simulation

Feedback BPMs and correctors localized

Oscillation grows downstream of each feedback due to Y-Z tilt caused by wakefields

Final amplitude larger than feedback off



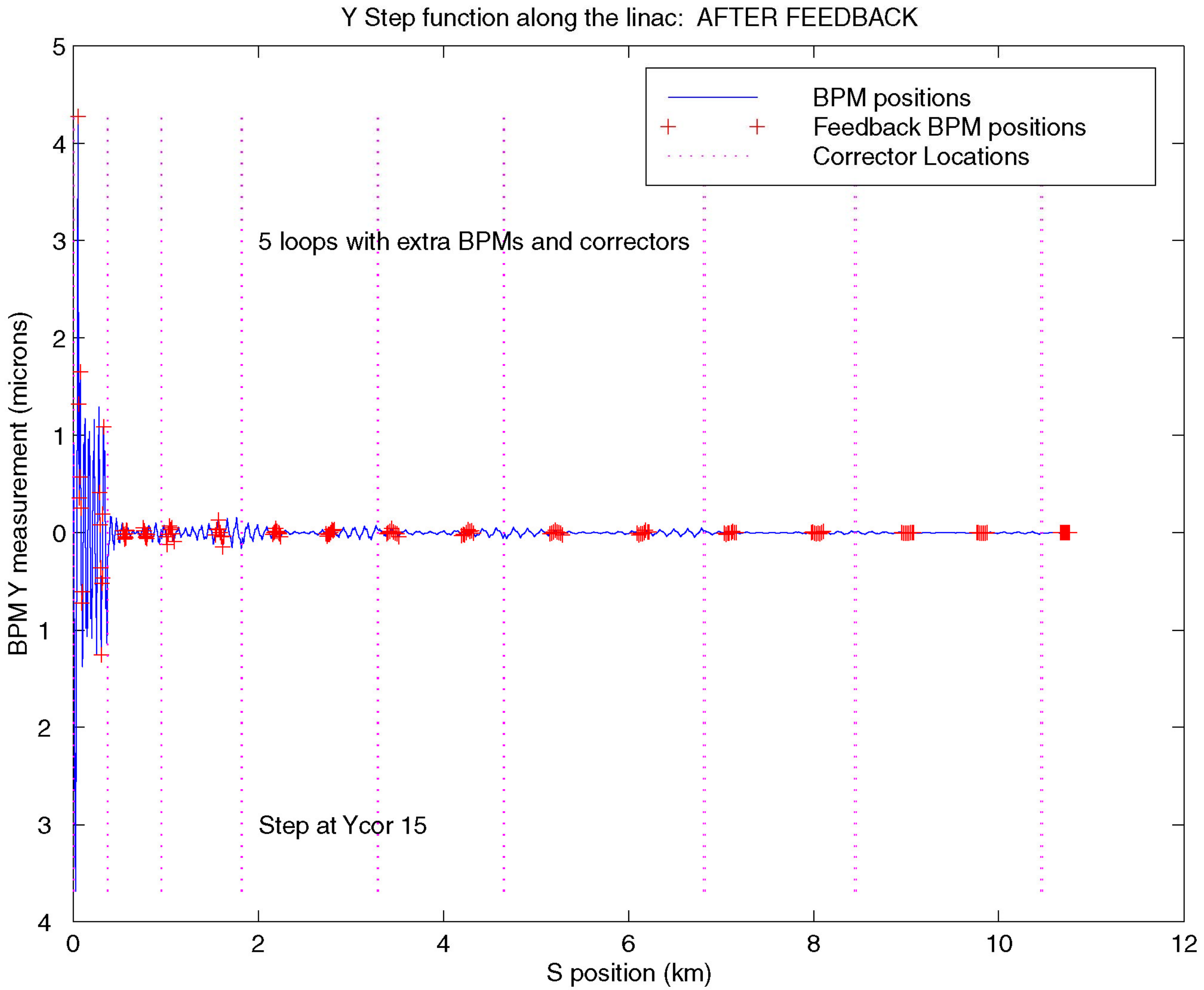
Distance along main Linac in km

NLC style Feedback ON simulation

Feedback BPMs and correctors distributed

Dotted lines show location of extra BPMs and correctors

Oscillation well controlled even early in Linac



Distance along main Linac in km

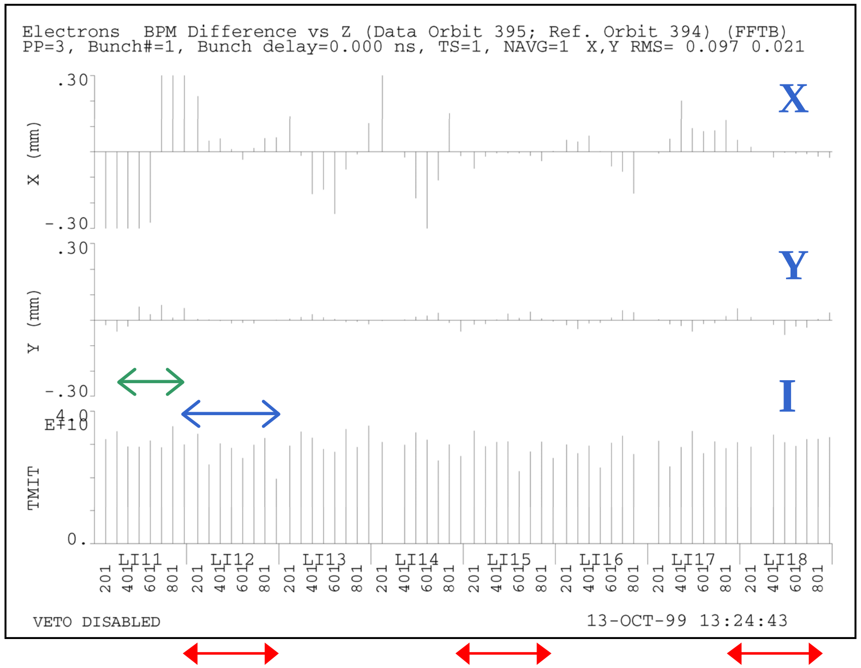
Test of SLC & NLC layouts

Response to an incoming X oscillation with SLC localized feedback compared with NLC distributed feedback

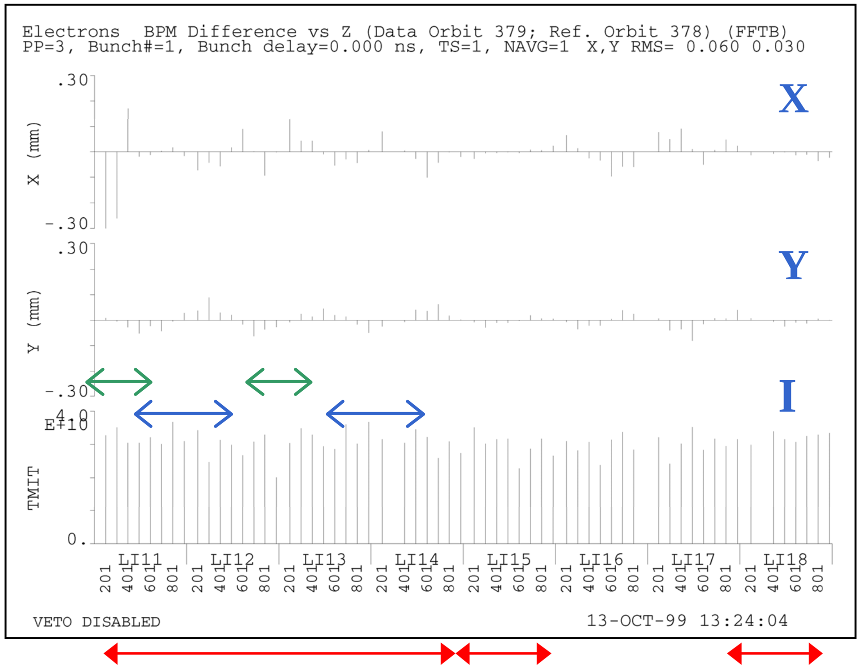
Red arrows show location and length of feedback regions

Blue arrows show locations of BPMs, Green arrows correctors

SLC layout



NLC layout



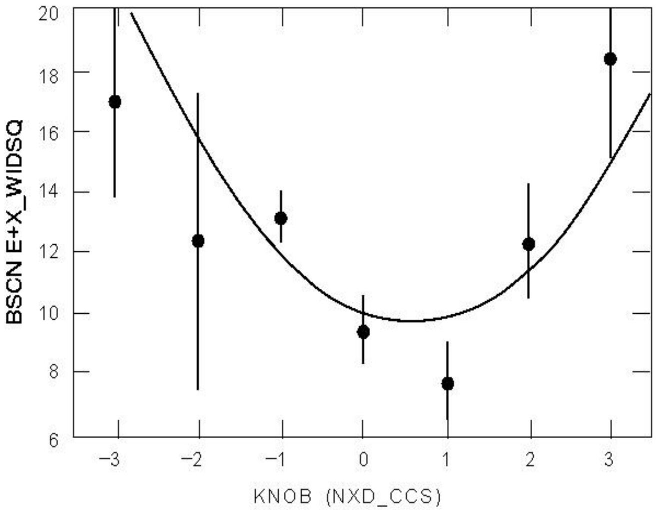
Luminosity Optimization

To optimize SLC luminosity, 5 correction knobs/beam were used routinely – X/Y waist, X/Y dispersion, coupling

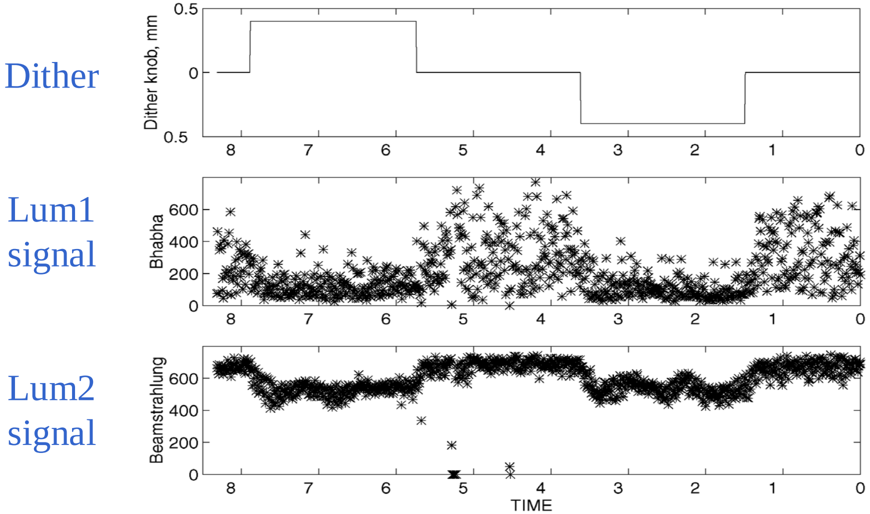
Old method:

Automated scan of beam size vs knob measured with deflection scan, but for small beams, poor resolution (1 mm on Y waist) + luminosity loss w scan

Waist **scan**



Dither **scan**



Solution:

Feedback which ‘dithers’ knobs, 1 at a time, maximizes signal ∝ luminosity

Dither Optimization Feedback

Benefits:

Resolution improved * 10 (0.1 mm Ywaist)

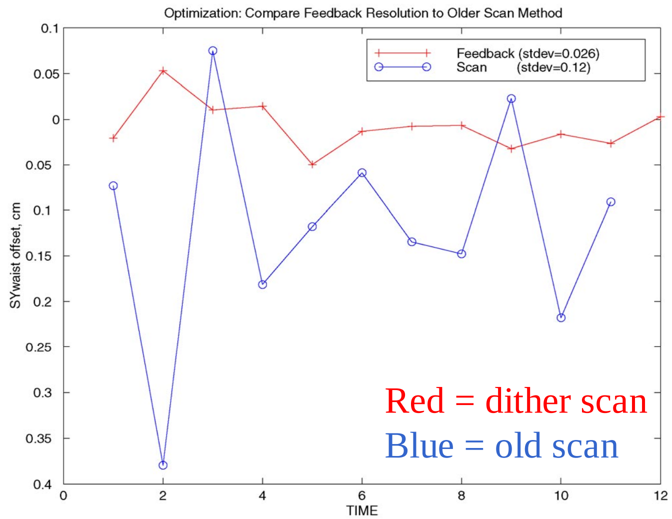
Large # of samples gives high precision even with a noisy signal

High resolution used to align FF sextupoles, octupoles, geometric sextupoles

Operational - all crews tune equally + freed up almost 1 FTE for other tuning

Technique also tried for wakefield cancellation but not fully commissioned

Calculated waist shift vs time



Result: Luminosity loss from mis-optimization reduced to a few %

Technique with wide applicability in future linear colliders

NLC Feedback plans

Pulse-pulse feedback (120 hz)

- stabilize orbit, energy throughout injector, linac, BDS
- maintain collisions (deflection feedback), also IP angle
- + specialized systems, e.g. laser intensity, polarization

Optimization feedback (‘Dither’)

- IP aberration tuning and linac emittance bumps
- + determine setpoint for deflection feedback

Intra-train feedback

- straighten out train w fast kicker, ~same correction each pulse
- remove residual collision offset

‘Slow’ tuning feedback

- re-steer linac orbit (+ DR, etc.) during operation

Requires flexible controls, full connectivity, high bandwidth

FF Tuning Studies

Yuri Nososhkov

Beam size vs Tuning Knob

Dash line: beam size without errors
Red: beam size with errors before correction
Blue & green: 1st & 2nd iterations of 17 knob correction including Orbit correction
Knob order: coupling, y-waist, x-waist, Dy, Dx, T122, T162, T168, T342, T364, T322, T344, T362, T366, U3422, V34222, V35422