A Proposed Architecture for the NLC Diagnostic Regions

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1 introduction

The NLC Main Linac CD-1 design contains 4 diagnostic regions (injection, extraction, and at the junctions between supersectors); the injector and beam delivery regions contain additional diagnostic regions modelled on those in the main linac, and one additional region may be added to the main linac (at the 330 GeV point, halfway through the third supersector). Each diagnostic region must support a variety of different beam measuring and manipulating tasks. In this Note we propose an overall architecture which permits all of these requirements to be met.

2 Requirements

The main linac diagnostic regions must provide the following:

- Beam position monitors for use by the conventional fast feedback system, and actuators (DC correctors) for same, which cover the entirety of the (x, x', y, y') parameter space
- Beam position monitors for use by the sub-train fast feedback system, and actuators (high-bandwidth striplines) for same
- Sufficient laser wires at correct phase advances to reconstruct the uncoupled beam ellipse in each plane
- A beam position monitor at a point of nonzero dispersion to provide information for energy feedback for the upstream supersector.

In addition to the overall design requirements, there are several implied constraints on the overall layout, which are described below.

2.1 Beam Position Monitors

Present NLC design philosophy envisions two types of BPMs: the "Q" BPMs, which are present in every standard quad and provide readout of the average position of the bunch train (and possibly a few of its low-frequency modes), and the "FB" BPMs, which are required to read out the positions of individual bunches within the bunch train to high precision. At present, a worst-case design envisions using identical stripline installations for "FB" and "Q" BPMs, with different processing electronics for each. Additionally, it is considered possible that the "FB" BPMs will use a hybrid to perform an analog subtraction of the Top/Bottom or Left/Right striplines, so that the signals which go to the processor would be T-B, T+B, L-R, L+R, rather than T, B, L, R.

The "Q" BPMs are required to report the position of the beam with high accuracy, and to limit the slow drift of the BPM electrical center to 1 micron; this will involve a calibration procedure which sends a pulse down the top or bottom electrode to calibrate the left and right electrode channels, and a similar pulse to calibrate the top and bottom channels. This will not be as readily available for the "FB" BPMs, due to the hybrid; however, the assumption is that the "FB" BPMs are *only* expected to provide accurate bunch-to-bunch information.

Furthermore, it is expected that the "FB" BPMs will have their maximum precision near the electrical center of the chamber, and that the beam should be held to within 100 μ of the electrical center.

2.2 Wire Scanners

The laser wire scanners are different from fiber scanners in that the laser has a characteristic focal depth of 15 μ, unlike a fiber which has a constant diameter for several millimeters. This means that if the beam is far from the "sweet spot" of the wire the beam size will be convolved with a larger wire than expected and will appear larger. To prevent this the beam's position with respect to the laser wire apparatus should be held constant to within roughly 5-10 μ.

In order to measure the beam size of different bunches within a train accurately, it is necessary to have a photon/electron detector which is fast enough to tell which bunch in the train a signal came from, and also to have BPMs (for jitter correction) which can read positions of each bunch.

2.3 Fast Feedback

In order to function as a closed-loop feedback, the fast feedback needs BPMs downstream of the actuators which perform the correction. Both the BPMs and the actuators need to cover both phases and both planes.

3 Architecture

A schematic of the architecture is shown in Figure 1. The optical system consists of 5 cells of a 45 degree FODO lattice followed by a shallow chicane. Both the feedback magnets and the feedback stripline correctors are placed upstream of the first and third D quad; wire scanners are placed downstream of the third, fourth, fifth, and sixth D quads; "FB" BPMs are placed in each quad, and "Q" BPMs are placed immediately downstream of each wire scanner. The system is followed by a chicane containing a BPM for energy measurement.

The "FB" BPMs are placed in quadrupoles because of the requirement that the beam pass near the center of the BPM. Experience in FFTB indicates that the quad-BPM offset can be held to under 200 microns; since the quads are on movers, we can determine the quad offset by beam-based alignment and move the quad until the quad is centered, which will put the BPM within 200 microns of being centered. This cannot be done as easily for a fixed BPM.

Since the "FB" BPMs are not expected to have very stable electrical centers (by "very stable" we mean stable at the micron level), the feedback system also needs "Q" BPMs. By placing the "Q" BPMs used by feedback at the wire scanner locations, we ensure that the fast feedback maintains the beam at the "sweet spot" of the wire scanners. Since each scanner is also located next to a "FB" BPM, the scanner will have position information on each bunch within the train available to it. In summary: the feedback system must use the "FB" BPMs only for bunch-to-bunch offsets, and the "Q" BPMs only for the DC offset of the bunch train; the "Q" BPMs are *not* the ones in the quads in this case!

The wire scanners are placed at the D quads because the vertical beam size is largest here. By measuring at this point, we ease the requirements on the wire scanners, since the vertical beam sizes at full energy are not expected to go below 1 micron and the aspect ratio will be around

5. The phase advance was chosen to optimize coverage of the phase ellipse, and by measuring at nominally equal beta points we ensure that a matched beam has all beam sizes the same. This eliminates the onerous requirement that the wire scanners be wildly different from one another as they are in some parts of the SLC. The diagnostic chicane will separate the electron beam from the degraded electrons and compton photons which occur when the electron beam hits the wire's laser, and provides an ideal point for placing detectors (though this means that if the chicane is turned off the signal will go away).

Table 1 shows the energy, RMS beam size for best possible emittances, betatron functions, and Compton-edge energies (assuming a first-harmonic Nd:YAG laser, $\lambda = 1.064\ \mu$) for the four main linac diagnostic sections. Note that diagnostic section 1 will probably need to detect the Compton-scattered photons from the laser wires due to the low Compton-endpoint energy, while the other sections are likely to detect the degraded electrons.

Diagnostic Section	Energy (GeV)	Length (m)	$\beta_{\max}$ (m)	$\beta_{\min}$ (m)	$\sigma_{x,y}$ at wire (μ)	Compton Edge (GeV)
1	10	40.2	15.6	7.0	33×4.9	0.82
2	54	61.8	15.5	7.0	14×2.1	17.6
3	167	120.3	31.1	14.1	11×1.7	100.0
4	500	115.6	38.8	17.6	7.3×1.1	408.5

Table 1: Parameters of the main linac diagnostic sections. The beam sizes are computed assuming damping-ring extraction emittances, $\gamma\epsilon_{x,y} = 3 \times 0.03$ m.rad, and are likely to underestimate the actual beam sizes.

Since only 1 BPM is used for energy measurement, the algorithm for computing energy must make use of the other BPMs in the diagnostic region to cancel betatron jitter at the energy BPM. It may be that on every machine pulse, the "Q" BPMs and the energy BPM combine to generate a solution for the bunch train's position in (x, x', y, y', δ), and that this information is then sent to the appropriate position and energy actuators, ie, that the "position" feedback and the "energy" feedback are part of a single overall feedback.

Table 2 shows the critical parameters of the diagnostic section chicanes. Section 4 does not have a chicane; its energy diagnostics are in the arc from the linac to the collimation section. Note that all parameters in Table 2 are approximate.

Diagnostic Section	Overall Length (m)	Bending Field (kG)	Bend Angle (mrad)	η_x peak (mm)	R_{56} (mm)	$\Delta\gamma\epsilon_x$ (mm.mrad)	$\Delta E/E$ (ppm)
1	6	2.5	37.5	46.8	4.68	0.017	214
2	12	1.1	6.59	18.1	0.32	0.037	552
3	18	0.63	2.01	8.53	0.046	0.038	1173

Table 2: Parameters for chicanes at downstream ends of diagnostic sections. Energy resolution assumes that the BPM in the chicane has a 10 μ resolution and that upstream BPMs allow subtraction of betatron jitter.

Note that the current plan calls for shallow diagnostic chicanes with wide vacuum chambers, so that the beam can be delivered with the chicane bends deactivated. This has implications for the energy feedback BPM which must be examined, especially if that BPM is to generate sub-train information.

4 Diagnostic Region Group

The membership of the Diagnostic Region Group is: Paul Emma, Joe Frisch, Linda Hendrickson, Yuri Nosochkov, Nan Phinney, Tor Raubenheimer, Steve Smith, Peter Tenenbaum, Mark Woodley. Additional people are invited to join.

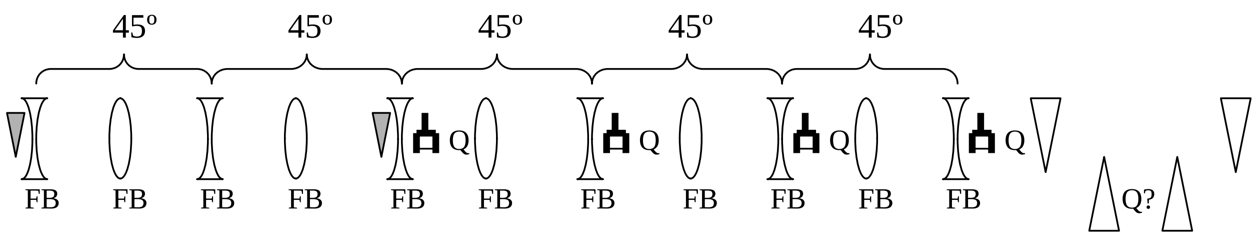

Figure 1: Cartoon diagram of a diagnostic station. "FB" represents an FB BPM, "Q" represents a Q BPM, forks represent wire scanners, dark triangles are feedback actuators (correctors and kickers), light triangles are chicane bends.