

TEST BEAM STUDIES AT SLAC END STATION A, FOR THE INTERNATIONAL LINEAR COLLIDER*

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Abstract

The SLAC Linac can deliver to End Station A (ESA) a high-energy test beam with similar beam parameters as for the International Linear Collider (ILC) for bunch charge, bunch length and bunch energy spread.[1] ESA beam tests run parasitically with PEP-II with single damped bunches at 10Hz, beam energy of 28.5 GeV and bunch charge of $(1.5-2.0) \cdot 10^{10}$ electrons. A 5-day commissioning run was performed in January 2006, followed by a 2-week run in April. We describe the beamline configuration and beam setup for these runs, and give an overview of the tests being carried out. [2] These tests include studies of collimator wakefields, prototype energy spectrometers, prototype beam position monitors (BPMs) for the ILC Linac, and characterization of beam-induced electro-magnetic interference (EMI) along the ESA beamline.

ESA BEAMLINE CONFIGURATION, AND BEAM SETUP TO ESA

The ESA beamline is shown in Figure 1 for the April 2006 Run. Installation of a beamline girder supporting the BPM3-5 triplet is shown in Figure 2. The long (5mm rms) bunch length out of the damping ring is compressed in the Ring-to-Linac transfer line and in the 24.5-degree A-line bend from the Linac to ESA to achieve $\sim 300\mu\text{m}$ bunch length in ESA. Four diode detectors were installed for bunch length diagnostics near a ceramic gap in the beamline upstream of the Wakefield Box, one each with sensitivities at 16GHz and 23 GHz and two with sensitivity at 100GHz. The radiated power spectrum at the gap is given by

$$P(\omega) \propto Q^2 \cdot \exp\left(-\frac{\omega^2 \sigma_z^2}{c^2}\right).$$

For a bunch length $\sigma_z=500\mu\text{m}$, the 1/e decrease in the power spectrum is at 100GHz. A plot of the bunch length diode signals versus the phase of the beam with respect to the accelerator RF is given in Figure 3. Typical energy spread is 0.2% rms and is measured in

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the A-line at a point of high dispersion, $\eta \sim 1$ meter, using a synchrotron light monitor. Beam emittance is measured in the ESA by scanning quadrupole strengths and measuring the corresponding spot sizes with the ESA wire scanners. We measured normalized emittances in ESA to be 310 mm-mrad horizontal and

13 mm-mrad vertical, for beam emittances of 80 mm-mrad horizontal and 11 mm-mrad vertical at the end of the Linac. The increase in horizontal emittance is consistent with expectations from synchrotron radiation in the A-line.

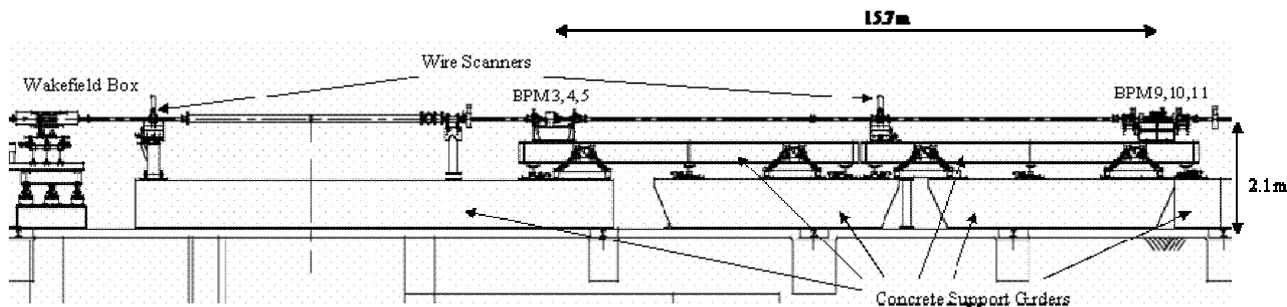


Figure 1: ESA Beamline Configuration for the April 2006 Run. Beam height is 2.1 meters above the floor. Two BPM-triplet stations, BPM3-5 and BPM9-11, are shown; they are separated by 15.7 meters. There are two additional BPM-doublet stations upstream of the Wakefield Box: BPM1-2 is in ESA ~ 3 meters upstream of the Wakefield Box and an additional BPM doublet is ~ 40 meters further upstream at the end of the A-line.



Figure 2: Installing the girder supporting the BPM3-5 triplet.

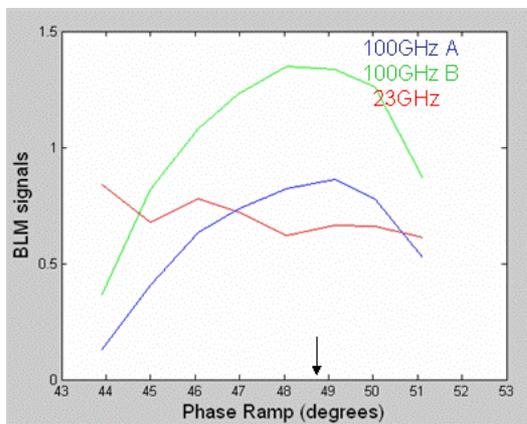


Figure 3: Bunch length diode signals versus beam phase with respect to the accelerator RF (with arbitrary offset).

ILC BEAM TESTS

Collimator Wakefields (T-480)

Precise collimation of the beam halo is required in the ILC to prevent beam losses near the Interaction Region that could cause unacceptable backgrounds for the Detector. The tight apertures of the collimators, however, cause wakefields that can result in beam deflections and increased emittance. We have installed a “Wakefield Box” in ESA, which contains a sandwich holding four collimator insertions (Figure 4). Two sandwiches, each containing four collimator insertions are available. First measurements have been taken on 8 different collimator sets to measure resistive wakes in copper and study two-step tapers.[3] The BPMs described in Figure 1 are used to measure the wakefield kick angles. The beam is set up with a small 75-micron vertical waist at the Wakefield Box for these studies (Figure 5). The vertical $\frac{1}{2}$ -gap in the collimators is 1.4mm and beam deflection angles (due to wakefield kicks) are measured as the collimator is moved vertically over ± 1.2 mm.

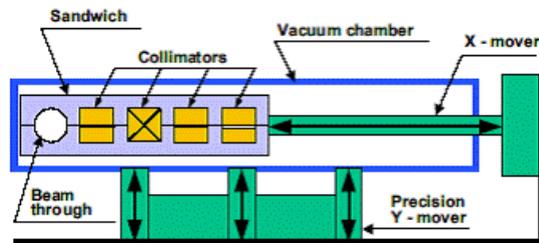


Figure 4: Wakefield Box containing 4 sets of Collimators.

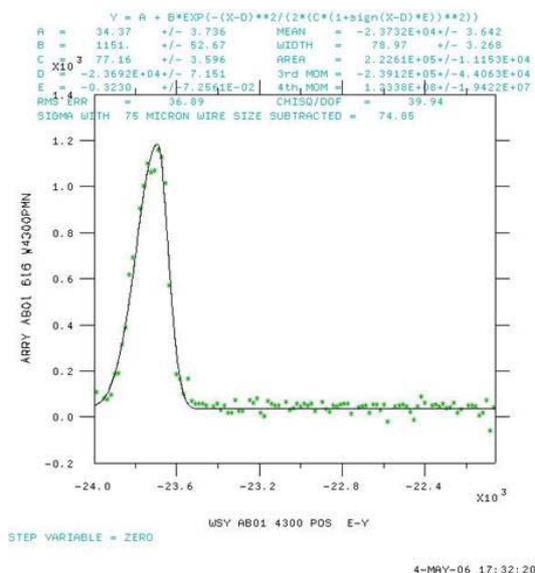


Figure 5: Wire scanner measurement gives 75-micron vertical rms spot size at Wakefield Box.

Energy Spectrometers (T-474, T-475) and Prototype Linac BPMs

At the ILC, beam energy measurements with an accuracy of 100-200 parts per million (ppm) are needed for the determination of particle masses, including the top quark and Higgs boson. We are implementing prototype BPM (T-474) and Synchrotron Stripe (T-475) energy spectrometers in ESA. For 2006, T-474 is studying mechanical and electrical stability for 8 rf BPMs at 3 BPM stations (BPM1-2, BPM3-5 and BPM9-11) in ESA. We are also studying sensitivity of the relative BPM offsets to changes in the beam parameters: bunch length, bunch charge, beam energy, beam trajectory. The BPMs in the BPM3-5 triplet are new prototype ILC Linac BPMs [4]. T-475 is commissioning a prototype quartz fiber detector at the synchrotron light monitor location in the A-line.

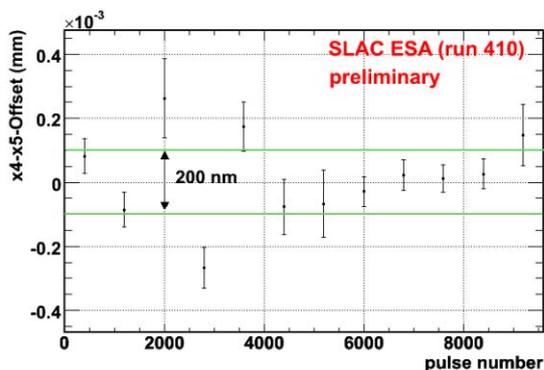


Figure 6: Stability of BPM4X-BPM5X offset over 15 minutes. 200nm offset will correspond to a 40ppm energy change at the “mid-chicane” location when the chicane magnets are installed for the 2007 run.

EMI and Bunch Length Studies

Two broadband antennas with sensitivity up to 7.5GHz for EMI studies have been installed. Signals are brought over heliax cable to a 2.5-GHz bandwidth scope. Measurements were taken at different beamline locations and compared with the higher frequency bunch length monitor diode detectors. The EMI antenna signal was as large as 70 Volts near the ceramic gap at the diode detector location. The antenna signal voltage was observed to have a linear dependence on bunch charge and no dependence on bunch length.

FUTURE PLANS

A 2-week run is scheduled for July 2006. We will continue studies for the beam tests described above. For the EMI studies, we are installing a new ceramic gap just downstream of BPM11. We will locate some electronics there from the SLD vertex detector to try to reproduce and understand an EMI-failure mode observed with that system. In addition, the T-488 experiment will install a mock-up of the Interaction Region configuration for the BPMs used for fast feedback to stabilize collisions, and study the sensitivity of this system to backgrounds.[5]

We are planning two additional 2-week runs in 2007 and again in 2008. For the 2007 run we will install a 4-magnet chicane between the two BPM triplets BPM3-5 and BPM9-11, and will install additional BPMs at the mid-chicane location. A wiggler magnet will be installed in the last leg of the chicane to generate a synchrotron stripe to a quartz fiber detector further downstream. T-487 will study and determine the longitudinal bunch profile by measuring the wavelength distribution of coherent radiation produced from the interaction of the bunch passing close to a periodic structure (Smith-Purcell radiation).

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