STATUS OF ESTB: A NOVEL BEAM TEST FACILITY AT SLAC*

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Abstract

End Station A Test Beam (ESTB) is a beam line at SLAC using a fraction of the bunches of the 15.0 GeV electron beam from the Linac Coherent Light Source (LCLS), restoring test beam capabilities in the large End Station A (ESA) experimental hall. ESTB provides one of a kind test beam essential for developing accelerator instrumentation and accelerator R&D, performing particle and particle astrophysics detector research, CLIC and ILC linear colliders and detector interface (MDI) R&D studies, development of radiation-hard detectors, and material damage studies. It has exceptionally clean and well-defined secondary electron beams for detector development, a huge experimental area and good existing conventional facilities. Recently, we have completed the installation of a new kicker magnet to divert 5 Hz of the LCLS low energy beam into the A-line and extracted the beam from the LCLS beam line and send it to the A-line. We are planning to install 4 new kicker magnets that allow diverting up to 15 GeV beams. A new beam dump and a new Personnel Protection System (PPS) are built in ESA. We report about the progress and the ESTB commissioning phase.

INTRODUCTION

Test beam activities have been interrupted at completion of PEP II operation and the start of LCLS. ESTB will be a unique HEP resource [1,2,3] as the world's only high-energy primary electron beam for large scale Linear Collider MDI and beam instrumentation studies; it will have exceptionally clean and well-defined secondary electron beams for detector development, a huge experimental area, good existing conventional facilities, and a historically broad user base. A secondary hadron beam can be made available as an upgrade.

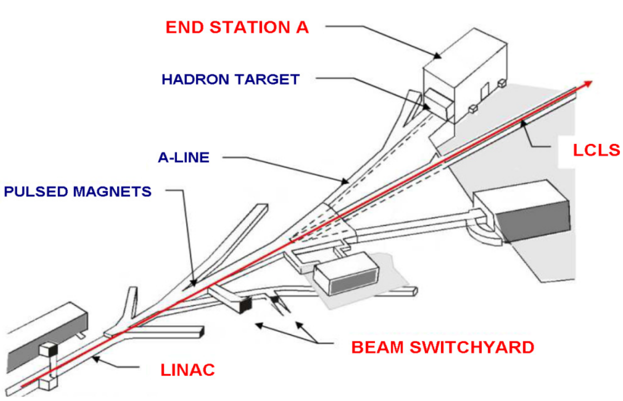

Figure 1: SLAC complex at the end of the 2-mile long linac. Pulsed magnets are used to kick the beam into ESA.

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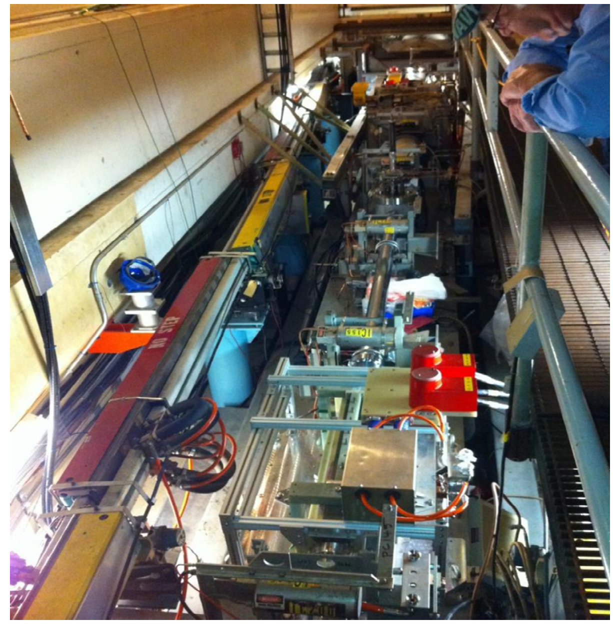

Figure 2: Pulsed Kicker Magnet recently installed in the Beam Switch Yard to divert LCLS beam into ESA.

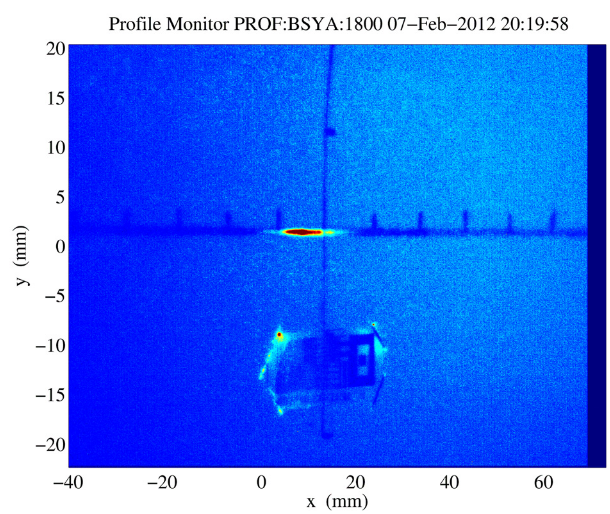

Figure 3: In early February 2012, we have started commissioning the kicker magnet and the LCLS beam has been successfully extracted into the A-line, as it is visible from the PR18 A-line monitor.

LCLS BEAM PARAMETERS

The Linac Coherent Light Source LCLS at SLAC is the world first X-ray light source [4]. During run III, the photon availability for users was 94.8% and electron availability was 96.7%. The LCLS beam covers an energy range from 2.5 – 15.0 GeV with a repetition rate of 120Hz. Typically, the bunch charge ranges between 20 and 250 pC. With the present photo-cathode, the practical limit for the bunch charge is 350 pC at 120Hz. This charge has been recently provided for tests. A summary of the LCLS beam parameters is shown in Table 1.

Table 1: LCLS Beam Parameters [2]: Hard / Soft X-Rays

Parameters	hard X	soft X
Beam Energy (GeV)	15.0	2.5
Repetition Rate (Hz)	120	120
Max Charge per Pulse (pC)	250	250
Final Bunch Length (μm)	7	20
Proj. emittance $\gamma\varepsilon_x$ (μm) injector	0.4	0.4
Proj. emittance $\gamma\varepsilon_x$ (μm) undulator	0.5	0.5
Proj. emittance $\gamma\varepsilon_y$ (μm) injector	0.6	0.6
Proj. emittance $\gamma\varepsilon_y$ (μm) undulator	1.6	1.6
Energy Spread	0.04%	0.07%

END STATION A TEST BEAM (ESTB)

ESTB Parameters

The SLAC complex at the end of the 2-mile long LINAC is shown in Figure 1. Pulsed kicker magnets in the beam switchyard (BSY) are used to kick the LCLS beam into ESA with a repetition rate of 5 Hz. There are opportunities to increase the repetition rate when the full rate is not needed for LCLS operations potentially doubling the available pulses to ESA.

Table 2: End Station A Test Beam (ESTB) Parameters [1]

Parameters	BSY	ESTB
Beam Energy (GeV)	15.0	15.0
Repetition Rate (Hz)	5	5
Max Charge per Pulse (pC)	250	250
Emittance $\gamma\varepsilon_x$ (mm mrad)	1.2	4
Emittance $\gamma\varepsilon_y$ (mm mrad)	0.7	1
Energy Spread (%)	0.058	0.058
Bunch Length (μm)	10	280
Spot size a waist $\sigma_{x,y}$ (μm)	-	< 10
Drift space available for tests (m)	-	60
Transverse space available (m)	-	5

Table 3: LCLS Beam Parameters for the Extracted Beam Shown in Figure 3

Parameters	LCLS
Beam Energy (GeV)	3.5
Repetition Rate (Hz)	1
Charge per Pulse (pC)	150
Kicker magnet current (Ampere)	618
Q-10 quadrupole strength (kg-m)	10
A-line Bend magnet settings	3.657
Vertical corrector in BSY (kg-m)	0.022
Vertical offset at kicker location (mm)	0.5

The primary beam energy is 2.5 – 15.0 GeV, and the beam available for ESTB is determined by LCLS operations. Depending on the beam operation modes, the number of particles in the primary beam is between 0.125×10^9 to 1.5×10^9 e^-/pulse. An exceptionally clean secondary electron beam can be also produced in the A-line with up to 15 GeV particle energy and from 0.1 e^-/pulse to 10^9 e^-/pulse. A summary of the ESTB parameters is shown in Table 2.

Stage I: Primary Beam and Secondary Electron Operations

ESTB can operate in several modes [1,2]. A full intensity, high energy LCLS electron beam can be delivered to ESA and the beam brought to a focus in the middle of ESA. Alternatively, the primary beam can be directed onto a target in the A-line. The resulting secondary electron beam is momentum-selected in the A-line and transported to ESA. Adjusting the gap in two existing slits, it is possible to provide secondary beams up to the incident energy and down to 1 particle/pulse or fewer.

STATUS AND COMMISSIONING

Kicker Commissioning

At end of 2011, the ESTB team installed a new pulsed kicker magnet in the Beam Switch Yard (BSY) as shown in Figure 2.

In early February, during the commissioning of the kicker magnet the LCLS beam was successfully extracted into the A-line. A profile image of the beam extracted by the Pulsed Kicker Magnet into the A-line is shown in Figure 3 with parameters shown in Table 3. In order to extract the beam a vertical correction and a horizontal beam offset at the kicker location of 0.5 mm with respect to the straight ahead LCLS orbit was needed. These are currently not demonstrated to be compatible with LCLS running. Thus, we are planning to install a second kicker magnet, which will be adjusted to eliminate the need for the orbit bump and y-corrector in the BSY, allowing to divert the beam into the A-line without affecting the LCLS beam. Long-term plans include four kicker magnets in the BSY to extract the LCLS beam at full energy, i.e. 15 GeV, and at a repetition rate of 5 Hz.

Furthermore, we are completing the new Personnel Protection System and installing a new 150 W beam dump in ESA, of which a layout is shown in Figure 4.

ESTB DEVELOPMENT

Stage II: Hadron Beam Line

A target upstream of ESA and a beamline diverging at 1.35 degrees with respect to the straight ahead line will provide a secondary hadron beam line into ESA in ESTB Stage II [1]. The hadron beamline will produce pions at the rate of 1/pulse for 250 pC beam. The rate of pions can be further reduced with the insertion of collimators.

Protons and kaons will also be produced at a rate ~0.02/pulse. The proposed hadron beam line is currently not funded.

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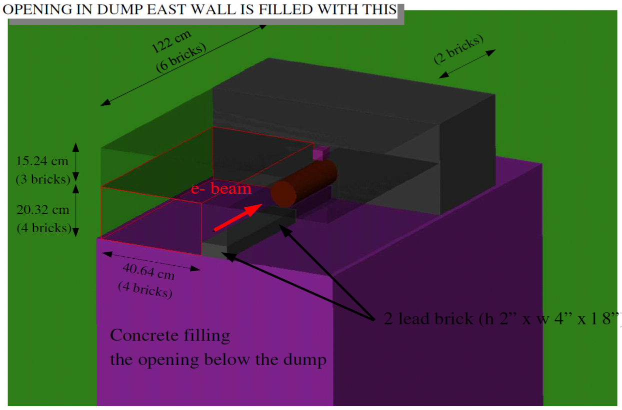

Figure 4: Layout of the new 150W ESA beam dump (courtesy N. Ludovic).

CLIC Collimation Wakefield Studies

CLIC is planning important collimation wakefield tests using short bunches in ESTB. Precise bunch length measurements are crucial and a newly developed Smith-Purcell Radiation beam profile monitor is being tested in FACET at SLAC for this purpose. CLIC's design bunch length is 44 μm while in ESA the bunch length would be 100 μm. With the installation of 4 additional quadrupoles the bunch length could be reduced to 20 μm. The "collimation wakefield box" which was used in the past for similar studies [7,8] will be available for CLIC tests as well. It is installed in ESA and shown in Figure 5.

Figure 5: Collimator wakefield chamber test allows an exchange of collimators and adjustment of jaw aperture.

PAST EXPERIMENTS IN ESA

Before the interruption of the activities in 2008, test beams were run in ESA with the 28.5 GeV primary beam at 10Hz repetition rate, simultaneously with PEP-II operations. At that time, the SLAC linac delivered beam into ESA up to five weeks per year with beam parameters comparable to ILC beams [5].

Major tests included the beam energy spectrometer [6] and the collimator wakefield box [7,8] for ILC. The energy spectrometer aimed at measuring beam energy with an accuracy of 100-200 ppm for the determination of particle masses including the top quark and Higgs boson in a Linear Collider. The collimator wakefield chamber shown in Figure 5 measured the beam deflection due to intra-bunch wakefields with a variety of collimator designs and materials. Both tests will resume in ESTB. Other ESA tests included studies of RF beam position monitors (BPM) for the ILC linac, ILC IP Feedback BPMs, bunch length diagnostics, detector development for LHC, ILC and Super-B, and particle astrophysics detector development [1,9]. With secondary electrons, new Cherenkov techniques with ultra fast photomultipliers were developped [10].

ESTB SCHEDULE

Current plans include installation of an additional kicker magnet for a total of two kicker magnets in the LCLS beam line in May 2012. This will allow diverting the beam without affecting LCLS operations. As soon as the new ESA PPS is available and the new beam dump installed this summer, an up to 4 GeV beam can be brought into ESA to start commissioning the complete test beam line. Later in 2012, two additional kicker magnets will be installed and operation of ESTB up to 15.0 GeV will be possible. The first ESTB physics run is planned for October 2012.

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SUMMARY

At SLAC, the End Station A Test Beam ESTB will use 5 Hz of the LCLS electron beam to provide a new beam test facility for detector and accelerator R&D. A full intensity LCLS beam in the energy range of 2.5 – 15.0 GeV can be delivered to End Station A and focused to small spots. Alternatively, this primary beam can be directed onto a thin target to provide secondary electron beams up to the incident energy and down to one e^-/pulse or fewer. We have installed one kicker magnet and during its commissioning successfully extracted the 3.5 GeV LCLS beam into the A-line. First user experiments are expected for October 2012. We invite submissions of beam test proposals.

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