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ESTB: A NEW BEAM TEST FACILITY AT SLAC*

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Abstract

End Station A Test Beam (ESTB) is a beam line at SLAC using a small fraction of the bunches of the 13.6 GeV electron beam from the Linac Coherent Light Source (LCLS), restoring test beam capabilities in the large End Station A (ESA) experimental hall. ESTB will provide one of a kind test beam essential for developing accelerator instrumentation and accelerator R&D, performing particle and particle astrophysics detector research, linear collider machine and detector interface (MDI) R&D studies, development of radiation-hard detectors, and material damage studies with several distinctive features. In the past, 18 institutions participated in the ESA program at SLAC. In stage I, 4 new kicker magnets will be added to divert 5 Hz of the LCLS beam to the A-line. A new beam dump will be installed and a new Personnel Protection System (PPS) is being built in ESA. In stage II, a secondary hadron target will be installed, able to produce pions up to about 12 GeV/c at 1 particle/pulse.

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.

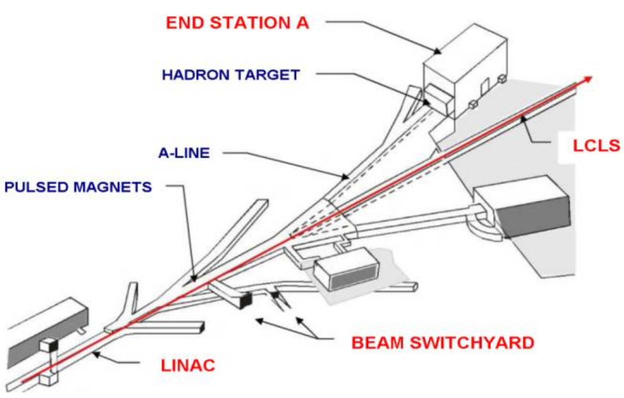

Figure 1: SLAC complex at the end of the 2-mile long linac. Pulsed magnets are used to kick the beam into ESA.

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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 3.5 - 13.6 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 to 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)	13.6	3.5
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 and with a repetition rate of 5 Hz. There are opportunities to increase the repetition rate when the beam 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)	13.6	13.6
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

The primary beam energy is 4 - 13.6 GeV, and the beam in ESA 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 13.6 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.

A layout of the 4 new BSY pulsed kicker magnets and drawings are shown in Figure 2. The kicker magnets including power supplies, modulators and ceramic vacuum chambers to reduce eddy currents are designed and components are being ordered and manufactured. Figure 3 shows a completed kicker magnet.

Furthermore, we are building a new Personnel Protection System and installing a new beam dump in ESA.

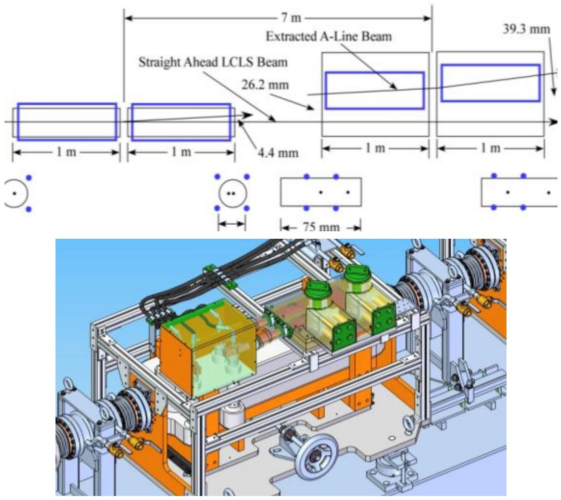

Figure 2: (top) Layout of the 4 kicker magnet system to kick the beam into ESA; (bottom) magnet assembly.

Figure 3: Kicker magnet ready for installation in the BSY.

Stage I: Primary Beam 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.

Tagged Photon Beams

A secondary electron beam generated and momentum-selected in the A-line can be made incident on a thin radiator in ESA. The photon beam is delivered while the electron beam is deflected and its energy measured in an energy spectrometer with a Si-strip detector, thereby tagging the photon energy. Needed infrastructure and possible experimental layouts are currently being developed. The submission of beam test proposals to determine the need for tagged photon beams is solicited.

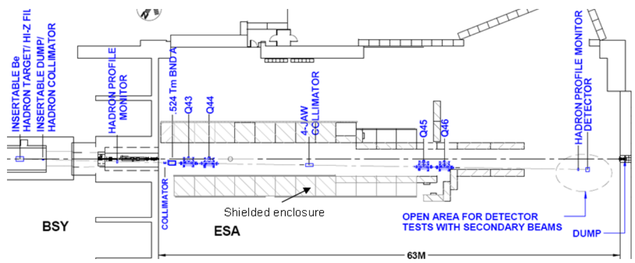

Figure 4: Layout of the hadron beam line diverging at 1.35° from the un-deflected beam trajectory.

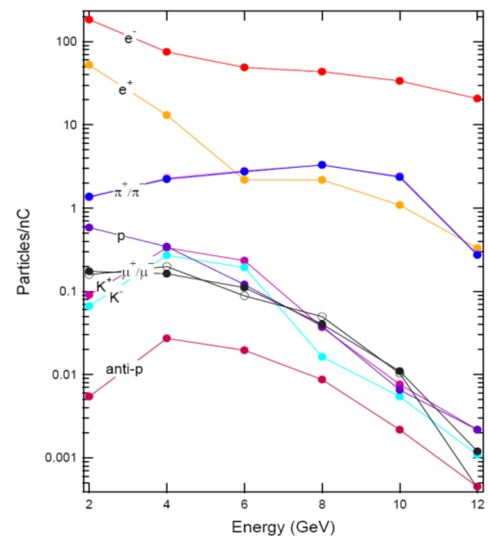

Figure 5: Secondary particle yields in ESA per nC of a 13.6 GeV LCLS beam incident on a Be target [1]. For 250pC beam current operating conditions, the yields are a factor of 4 lower.

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]. A layout of the hadron beamline is shown in Figure 4. 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 simulated hadron production rate is shown in Figure 5 in units of particles per nC of primary beam. Cherenkov and time-of-flight detectors can tag the produced hadrons cleanly.

The proposed hadron beam line is currently not funded.

Development: Bunch Length

Interest in beam tests using short bunches has been expressed from the CLIC project. Typically, the LCLS beam has a bunch length of 10 μm or smaller depending on the bunch charge.

In ESA, the bunch length increases due to a 24° bending angle in the A-line, thus a large 6 m dispersion and a large optical R56.

Figure 6: Energy spectrometer wiggler (left) and one chicane dipole (right) installed in ESA [**Error! Bookmark not defined.**,**Error! Bookmark not defined.**].

Figure 7: Collimator wakefield chamber test allows an exchange of collimators and adjustment of jaw aperture [**Error! Bookmark not defined.**,**Error! Bookmark not defined.**].

By tuning the LCLS energy spread, bunch lengths of 100 μm will be readily available in ESTB. Furthermore, we found an optics solution that would lower the bunch length further down to 44 μm (CLIC nominal bunch length) or even shorter, by installing just 4 more quadrupoles in the BSY.

PAST EXPERIMENTS IN ESA

Before the interruption of the activities in 2008, test beam were run in ESA with a 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 [6,7] and the collimator wakefield box [8,9] 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. Figure 6 shows the installation of the chicane and wiggler magnets in ESA. The collimator wakefield chamber shown in Figure 7 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 [1,10].

ESTB SCHEDULE

Current plans include installation of one kicker magnet in the BSY in October 2011. This will allow early commissioning of the kicker system, delivering beam into the A-line. As soon as the new ESA PPS is available later this fall, 4 GeV beam can be brought into ESA to start commissioning of the complete test beam line. In early 2012, 3 additional kicker magnets will be installed and operation of ESTB will commence at higher beam energy. The first ESTB physics run is planned for March 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, high energy LCLS beam in the energy range of 4 - 13.6 GeV can be delivered into End Station A and focused to small spots. Alternatively, the 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. First user experiments are expected for March 2012. We invite submissions of beam test proposals.

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