Snowmass Letter of Interest — **Topical Groups: IF9, AF5**

Linac to End Station A (LESA) as an Electron Test Beam

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ABSTRACT

The SLAC Linac to End Station A (LESA) will extract low current near-CW 4-8 GeV beams from the SLAC LCLS-II SRF linac, and transport this beam to End Station A (ESA). This LOI focuses on the features that make LESA attractive and unique as a test beam, as well as some examples of potential test beam applications.

1 Introduction to LESA

S30XL-LESA is a staged concept to provide an upgradeable near-CW beam of multi-GeV electrons at 46.5 MHz to the SLAC End Station A (LESA) for experiments in particle physics requiring pA to 25 nA currents. This capability is achieved parasitically by extracting unused bunches from the LCLS-II linac. We briefly summarize key features of LCLS-II and capabilities of LESA (see also [1, 2, 3]), before describing the applications of this facility as a test beam.

The LCLS-II is an x-ray free electron laser based on a 4.0 GeV superconducting linac [4, 5], fed by an RF gun [6] operating at up to 186 MHz. The baseline LCLS-II design has a maximum bunch rate of 929 kHz. These bunches are diverted from the dump line to the undulators by high-speed kickers. Even at full-rate operation, the FEL program uses a tiny fraction of the RF gun repetition rate. In between every two LCLS-II bunches, up to 200 "empty" RF buckets from the gun impinge on the dump. These are populated at some (unknown) level by dark current originating from the gun; in addition, the existing gun laser oscillator could be used to produce a well-defined, low-current beam at 46 MHz repetition rate within a $\sim$500 ns macro-pulse between LCLS-II primary bunches spaced at 1.1 μs.

The S30XL and LESA improvements will enable delivery of this low-current beam to SLAC's End Station A. This is achieved through the addition of (1) a long-pulse kicker and septum magnet to divert low-current bunches off the LCLS-II dump line, (2) a 250m long transfer line from the kicker in Sector 30 to the existing A-line, delivering beam to End Station A, (3) minor improvements in the existing End Station A infrastructure, and (4) a laser oscillator that augments the dark current with a well-defined, low-current beam at 46 MHz repetition rate within a $\sim$500 ns macro-pulse between LCLS-II primary bunches.

The first phase, S30XL, is currently under construction. This stage comprises the kicker and a short beamline, with a program focused on technical demonstrations and accelerator physics studies. The LESA phase could be completed by FY22, with a source laser commissioned either in parallel with the beamline in FY23 or shortly after.

The presently envisioned program for LESA comprises dark sector physics, electron-nuclear scattering measurements for the neutrino program, and a test beam program (see [1]). This LOI focuses on the test-beam capabilities of the facility.

2 Distinctive features of LESA

Several features of LESA make it attractive as a test beam:

Variable Current LESA can deliver currents up to 25 nA with $\sim$50% duty cycle, useful for example to study radiation damage or integrating detectors. Most test beam studies, however, call for a Poisson mean of one electron at a time (or fewer). This is achieved at LESA by attenuating the primary 25 nA beam using spoilers and collimators in the existing A-Line, as was successfully used in the decade-long End Station Test Beam program [7].

Repetition Rate LESA can deliver a high repetition rate of up to one pulse every 21 ns. This allows direct study, in test-beam, of high-rate performance and out-of-time pile-up. The repetition rate can also be reduced for detectors not designed for such high rates, while maintaining a well-defined time structure, by filling only specific bunches within each $\sim$500 ns long macro-pulse and/or decreasing the kicker repetition rate. By varying the current and bunch structure, LESA can deliver up to 10^7 1-electron bunches per second to a detector being tested, enabling the rapid accumulation of high statistics.

Short Pulses LESA will deliver a ps or sub-ps scale pulse length, advantageous for calibrating precision timing detectors.

Fixed Energy LESA operation is most flexible in terms of beam characteristics when the delivered electron energy is either equal to the LCLS-II linac energy (for primary beam) or very slightly lower (for attenuated beam). This beam energy will generally be 4 GeV initially, and 8 GeV after the LCLS-II-HE upgrade. Lower-energy test beams can in principle be obtained by tuning the A-line to a lower energy, but with dramatically reduced current.

Beam Availability Because LESA beam delivery is parasitic to normal LCLS-II operations, the core activity at SLAC, a high beam availability $\sim$250 days/year is anticipated. This will be shared between test beam and other HEP applications.

3 Example Use Cases

To illustrate the breadth of test beam applications for LESA, we provide a high-level summary of the use cases described in [1]. These can be loosely organized into three areas of application:

1. Detector studies for LHC upgrades and related experiments, such as characterizing position and timing resolution, and material distributions, in ATLAS silicon detector prototypes; studying EM shower response and pileup effects in the CMS HGCAL; and testing pixel tracking and fast timing detectors for ATLAS and future colliders

2. Basic detector R&D efforts, including tests of timing vertex detectors, low-gain avalanche detectors, R&D towards high-rate and high-resolution calorimetry using the fast scintillation component of BaF_2, and studies of EM-induced radiation damage for high-luminosity electron colliders and EIC

3. Detector development for other experimental programs in HEP and NP, including the Physics Beyond Colliders umbrella and the MOLLER integrating detectors (in both single-electron and integrating regimes)

4 Plans for Broader Engagemement of Instrumentation Community During Snowmass

The LESA team continues to explore new opportunities for our test beam capabilities that would be relevant to the HEP program. If you have questions about capabilities or ideas for exploiting the test beam, please contact Tim Nelson, Tor Raubenheimer, or Natalia Toro who are coordinating this LOI.

References

1. A description of LESA and its science program can be found in SLAC-R-1147.The LESA beamline has been known as DASEL, S30XL, and YABBL.

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