A Letter of Interest for Snowmass'21

Linac to End Station A (LESA): A Multi-GeV Source of near-CW e–*

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Introduction

The SLAC LESA (Linac to End Station A) will connect the SLAC LCLS-II/LCLS-II-HE superconducting RF (SRF) linac to End Station A [1]. The LCLS-II/LCLS-II-HE [2,3] is a 4 to 8 GeV SRF linac operating in a CW mode that is built to deliver bunches to a Free Electron laser (FEL) at a 1 MHz repetition rate. LESA will use a high-rate kicker to extract a low-current, high-repetition-rate beam in between the FEL bunches to End Station A, a large experimental hall built in the 1960's at SLAC. The low-current LESA beam can be either the dark current from the gun or sourced by a gun laser at 46 MHz or subharmonics thereof (with potential upgrades up to 186 MHz). This will provide a near-CW beam of electrons with currents ranging from pA to nA at energies of up to 8 GeV.

Construction of the LESA beamline is ongoing. Operation with a 4 GeV electron beam expected in 2023 and operation with an 8 GeV beam expected in 2027. The range of possible beam parameters are listed in Table 1. Upgrades to increase the beam current to μA's are possible. An additional beamline extracting the primary FEL bunches to a beam dump in End Station B is also possible with expected annual number of electrons on the dump of 10^{21} e-/yr.

Table 1. LESA electron beam parameters for an ultra-low-current beam (baseline) as well as two possible upgrade modes.

Experiment Parameters	**Ultra-low-current**	**Low current (upgrade)**	**Dump-Style (upgrade)**
Energy	4.0 GeV (upgrade to 8.0 GeV in 2027)	4.0 GeV (upgrade to 8.0 GeV in 2027)	4.0 GeV (upgrade to 8.0 GeV in 2027)
Bunch spacing	5.4 – 65 ns	5.4 ns	LCLS-II nominal (1.1 μs)
Bunch charge	0.04 – 10,000 e^-	70,000 e^- (10 fC)	Up to 300 pC
Macro pulse beam current	0.1 – 25 nA	2 μA	Up to 62 μA
Duty cycle	55% (600 ns out of 1.1 μs)	55% (600 ns out of 1.1 μs)	Roughly 50%, depending on photon science experiments
Norm. emittance (rms)	~100 μm; < 1000 μm	~1 μm	<1 μm
Bunch energy spread	<1%	<1%	<1%
IP spot size w/ rastering	4 cm x 4 cm	<250 μm including jitter	TBD
Electrons per year	10^{15} e- / year	10^{19} e- / year	10^{21} e- / year

Motivation

The scientific impact of multi-GeV, CW electron beams is underscored by the high demand for beam time at Jefferson Lab's CEBAF (the only facility in the world delivering such a beam) from both Nuclear and High-Energy Physics

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experiments. CEBAF is optimized for the needs of the NP community, such as exquisite beam polarization and precisely tunable beam energy. HEP fixed-target experiments have looser beam requirements but call for longer run-times than are practicable at CEBAF. LESA can host these experiments at modest operating costs of ~1M$/yr by parasitic use of LCLS-II/LCLS-II-HE. In parallel, LESA can provide new test beam capabilities for detector development. Some of the possible science experiments can be found in Ref. [1].

LESA will enable multiple important directions in HEP science, supporting a portfolio of small projects as recommended by P5 that address three P5 science drivers (neutrinos, dark matter, and exploring the unknown):

Neutrino Physics: Measurements of forward pion, neutron, and proton electro-production inform modeling of neutrino-nucleus scattering and are complementary to wide-angle and low-acceptance measurements performed at JLab [4,5]. Improving these models mitigates a key systematic uncertainty in measurements of neutrino oscillation parameters (see e.g. [6,7,8]).

Test Beam Physics: LESA can be used as a test beam to study detector response to low-charge electron pulses (down to single electrons) with precise timing. Its high repetition rate enables studies of high-rate performance and out-of-time pileup for the LHC and other next-generation HEP, BES, and NP experiments. Applications to the development of high-rate X-ray photon detectors, relevant to instrumentation for high-rate LCLS-II operation for example, are also being explored.

Dark Matter Physics: LESA could support missing momentum experiments (e.g. LDMX [9,10,11]) sensitive to light dark matter and related interactions over the uncharted keV to GeV mass range. A multi-GeV CW electron beam is key for such experiments. Complementary beam dump dark matter searches (e.g. BDX [12]) may also be possible.

Searches for New Forces: Next-generation searches for new forces (e.g. dark photons) call for spectrometers downstream of a thin target in a ~1 μA beam to explore a challenging region of parameter space. The required current is near the maximum achievable with a laser upgrade.

References

[1] LESA is described in SLAC-R-1147 as well as arXiv:1801.07867. The LESA beamline has been known as DASEL, S30XL, and YABBL.

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