



# Linac to ESA: a facility for LDMX and detector test at SLAC

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September 30-Oct 2, 2026

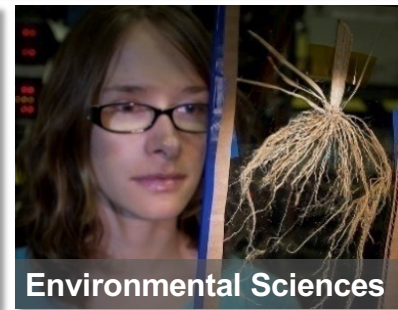
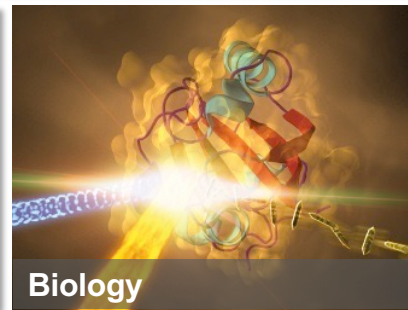
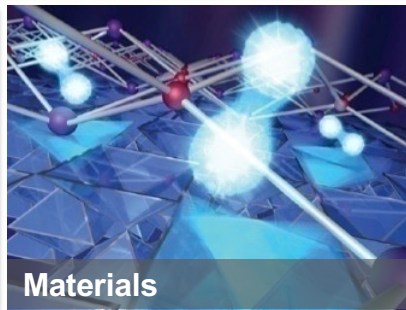
Accelerating the Search for Disappearing Light Dark Matter – a Community Workshop

# Outline

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- Brief introduction of SLAC accelerator facilities
- LESA Beamline and Endstation A
  - LESA for LDMX
  - Beamline layout and current status
- Future plan
  - Near term: test beam for detector development
  - Long term: LDMX

# SLAC Accelerator User Facilities



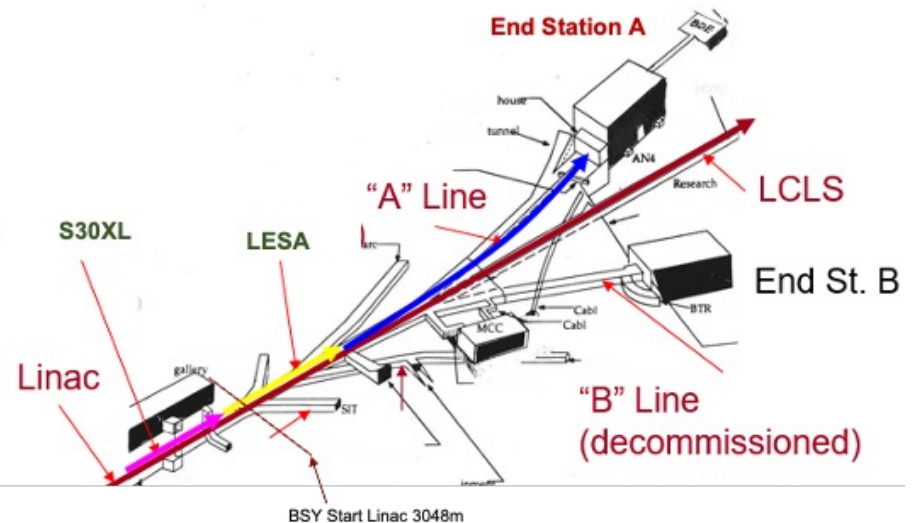
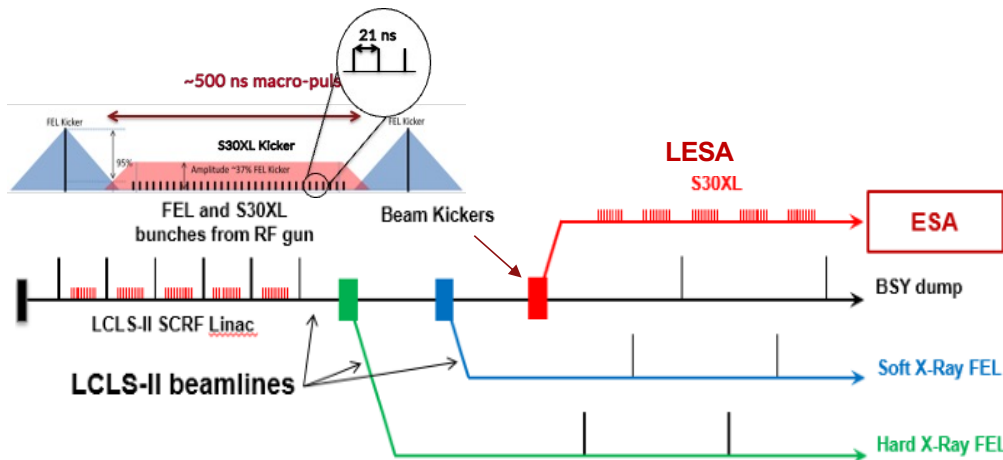
# LESA/ESA/LDMX at Glance

## Motivation:

- To extract the electron beams from SC-Linac to be directed to the existing End Station A (ESA) to serve HEP community (LDMX, test beam) in parallel to LCLS user operations.
- Primary beam specs: 8 GeV (dictated by LCLS user demands).

## Implementation:

- a long-pulse version of LCLS-II kicker and septa to extract electrons between the LCLS-II FEL bunches into the newly installed ~200 m beamline (S30XL+LESA) that connects to existing A-line that feeds to End Station A (ESA)



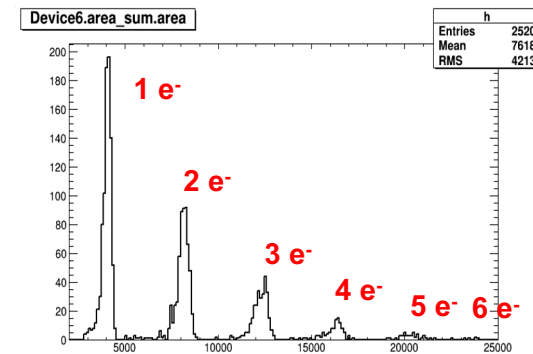
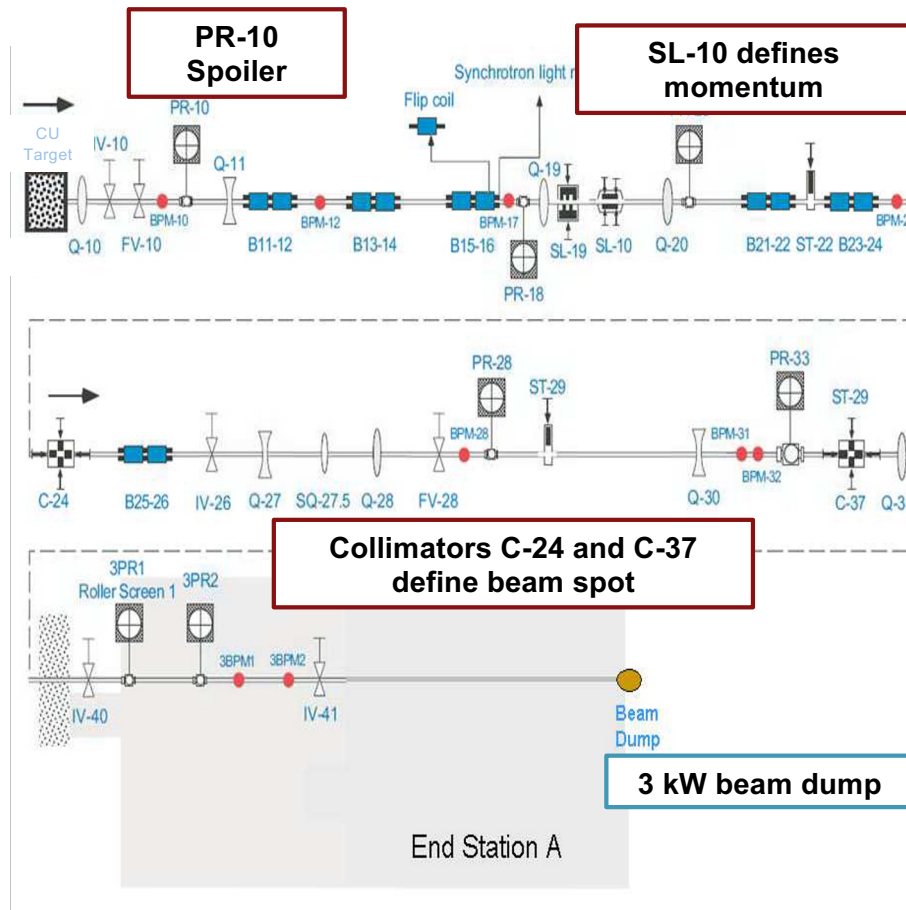
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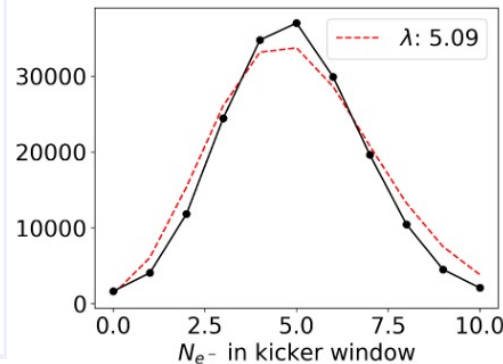
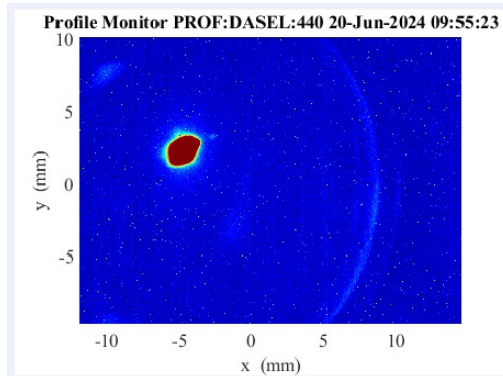


# A-Line Produces Secondary Beams for the End Station



Previous End Station Test Beam (ESTB) results shown by Carsten

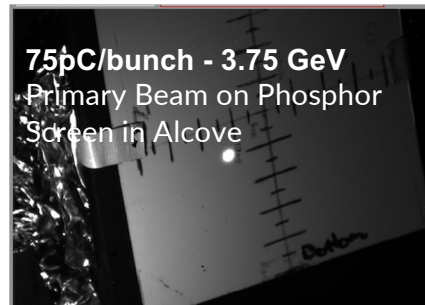
# LESA Status



LDMX Hodoscope Measurement of Dark Current in ~100 5.4ns buckets

First beam in the first part of LESA beamline was achieved with 4 GeV primary beam in 10Hz interleaved mode and dark current at the end of S30XL

June 2024



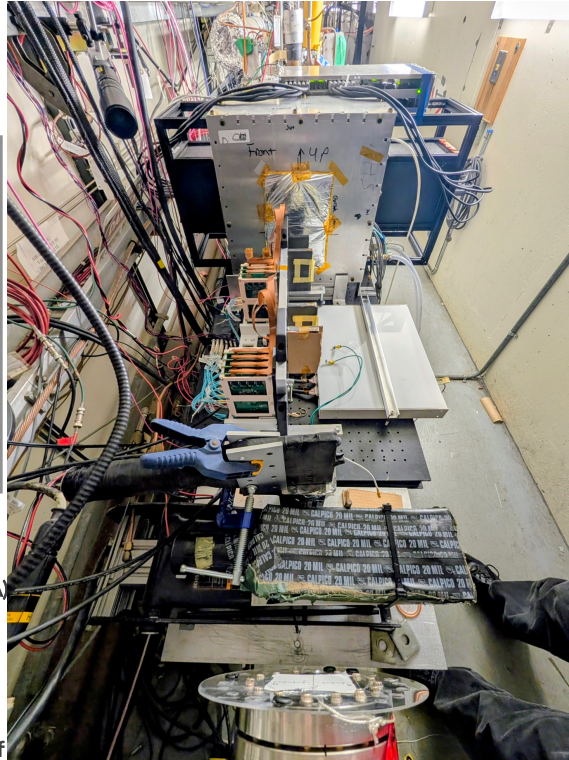
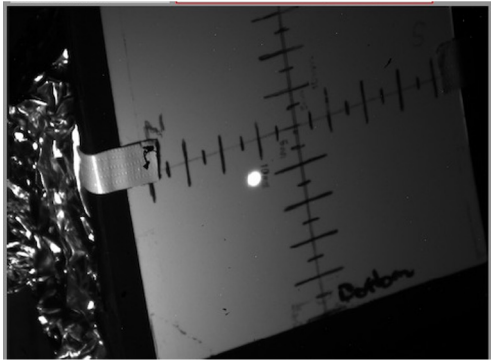
Nov-Dec 2026

Re-established beam, both primary and secondary in the ESA since ESTB program with 4GeV

# First LESA Beam in ESA in Nov/Dec 2025

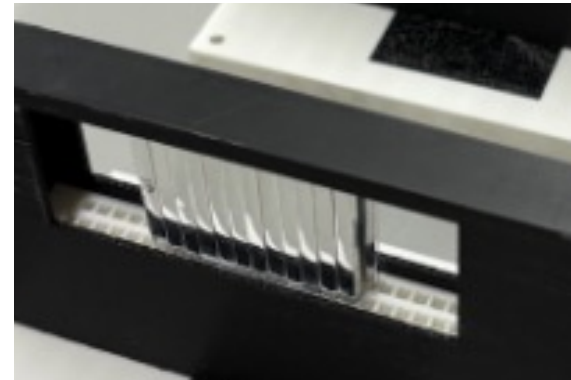
**75pC/bunch - 3.75 GeV**

Primary Beam on  
Phosphor Screen in Alcove



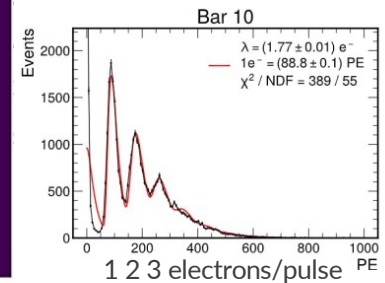
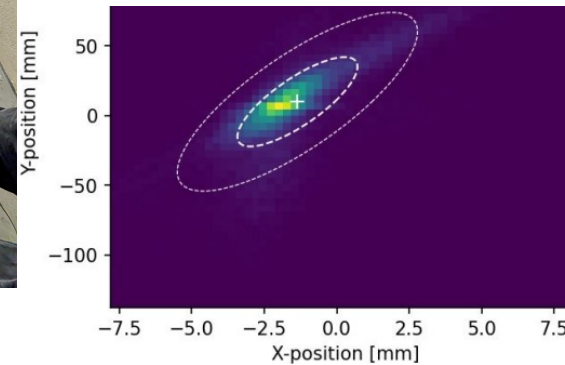
**~ few electrons/bunch - 3.00 GeV**

Secondary Beam LDMX Fiber Tracker



scintillator bars  
2mm x 3 mm x 30  
mm

- ~~Elizabeth Berzin (Poster)~~  
Beam Tests of an LDMX Trigger Scintillator  
Prototype in the Linac to End Station A (LESA)  
Beamline at SLAC
- ~~Erik Wallin (Calorimeter Talk)~~  
The Light Dark Matter eXperiment Slice Test  
and HCal Test Beam  
Many more details and much nicer pictures of  
the setup and ESA



## LESA Works at Least as Good as ESTB

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## LESA Science Program

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### **Test Beam: Estimated timeline: Sept 2027 --**

- Builds on success of ESTB, strong community interest (e.g. 80 participants at last fall's workshop)
- Particular need during CERN, FNAL, DESY downtimes
- Short bunches + high repetition rate uniquely enable tests of fast timing and high-rate detectors.
- Envisioned as primary user through ~2031, then several mo/yr

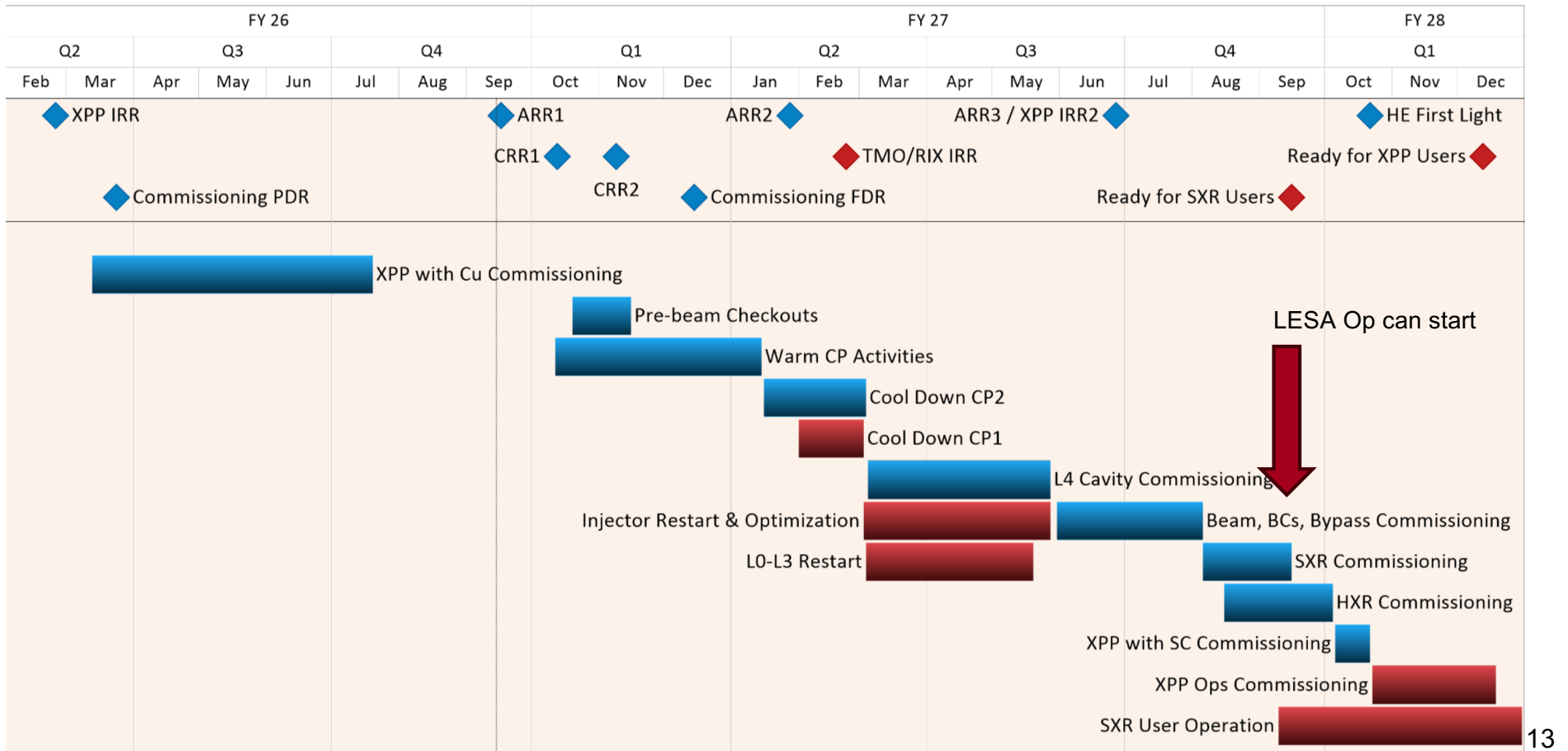
### **Light Dark Matter eXperiment (LDMX): in discussion**

- LESA flagship experiment
- SLAC-led accelerator-based DMNI proposal with world-leading light dark matter sensitivity, broad search and measurement program —Tim will say more later

### **Electro-Nuclear Scattering for Neutrino-Scattering: proposed**

- eN scattering data is key input to improve and validate neutrino scattering models – e.g. see e.g. e4nu program at JLab
- LCLS-II energy well matched to DUNE, forward LDMX detector offer excellent acceptance for hadrons (esp. neutrons).
- Dedicated TPC being pursued in Europe may also be viable, offers complementary acceptance

# SLAC SC Linac timeline



# LESA accelerator parameters

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The accelerator beam parameters of the LESA system

| Accelerator Parameters                    | Interleaved          | XLEAP Laser                       | LESA Laser                 | <del>Dark Current</del>      |
|-------------------------------------------|----------------------|-----------------------------------|----------------------------|------------------------------|
| SRF Linac Energy                          | 8 GeV                | 8 GeV                             | 8 GeV                      | <del>8 GeV</del>             |
| Max Current in LESA                       | <10 nA               | 25 nA                             | 25 nA                      | <del>&lt;~ 1pA</del>         |
| Maximum Kicker Rate<br># bunches per Kick | 100 Hz<br>1          | 929 kHz<br>1                      | 929 kHz<br>18              | <del>929 kHz<br/>100</del>   |
| Avg. Bunch Charge<br>Bunch spacing        | 10-100 pC<br>> 10 ms | > 167ke-(27 fC)<br>> 1.08 $\mu$ s | >4.2ke-(0.7 fC)<br>26.9 ns | <del>0.07 e-<br/>5.4ns</del> |
| Max beam power                            | 8-80 W               | 200W                              | 100W                       | <del>8mW</del>               |

# LESA Operation Modes

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**Interleaved mode:** LESA is added as an additional destination in the global LCLS-II-HE timing system. Up to 100Hz of primary LCLS-II-HE pulses could be sent into ESA.

**LESA laser mode** A dedicated laser is required to achieve LESA's full design rate of up to 37MHz with controlled bunch charge for LDMX physics. This laser would fire approximately every 27ns for every 5th 5.38ns bucket. When used for test beams this will provide the ultimate flexibility in bunch charge and bunch train shaping.

***XLEAP laser mode:** A second gun laser superimposed on the primary one for pump-probe experiments at LCLS-II-HE. When LCLS operates in modes that do not involve this laser, the XLEAP laser could instead be timed to the LESA kicker, allowing up to MHz pulses to LESA for test beams.*

~~**Dark current mode:** The S30XL kicker will be timed in between the LCLS-II-HE FEL pulses. Any electrons in the 5.38ns spaced buckets are sent to ESA providing CW-like very low current electron beam. The number of electrons per bucket is subject to gun performance. LCLS-II-HE operations would like this number to be as close to 0 as possible. In 2025 in the beam switch yard, we measured on average 7 electrons per kicker pulse (about 100 buckets).~~

# LESA beam parameters

## LESA beam parameters

|                                                 |                        |
|-------------------------------------------------|------------------------|
| Beam Parameters Before Spoiler                  |                        |
| Beam spot size (rms)                            | ~100μm                 |
| Bunch length (rms)                              | <3 ps                  |
| Beam Parameters in ESA, no spoiler              |                        |
| Bunch energy spread                             | <1%                    |
| Nominal spot size                               | 1 mm                   |
| Spoiler Parameters                              |                        |
| Spoiler thickness                               | 0 – 0.5 r.l.           |
| Charge transmission                             | 0 – 100%               |
| Beam Parameters in ESA, with spoiler            |                        |
| Energy                                          | 2.0—8.0 GeV            |
| No. of electrons per bucket                     | 0 to few % of original |
| Nominal spot size                               | 1 cm                   |
| Spot size w/ quads and modified ESA collimation | 2 cm x 4 cm            |

## Beam power in ESA in Watts for secondary beams at the maximum rate allowed by each running mode at 8 GeV

| Energy                       | 8 GeV     | #electron<br>s/pulse | 5                    | 10                   | 100                  | 1000                 |
|------------------------------|-----------|----------------------|----------------------|----------------------|----------------------|----------------------|
| Mode                         | Rate (Hz) | Duty<br>Factor       | Beam<br>Power<br>(W) | Beam<br>Power<br>(W) | Beam<br>Power<br>(W) | Beam<br>Power<br>(W) |
| Interleaved                  | 10        | 1                    | 6.41E-08             | 1.28E-07             | 1.28E-06             | 1.28E-05             |
| Interleaved                  | 100       | 1                    | 6.41E-07             | 1.28E-06             | 1.28E-05             | 1.28E-04             |
| XLEAP at<br>reduced<br>rate  | 1000      | 1                    | 6.41E-06             | 1.28E-05             | 1.28E-04             | 1.28E-03             |
| XLEAP at<br>Max Rate         | 9.29E+05  | 1                    | 5.95E-03             | 1.19E-02             | 1.19E-01             | 1.19E+00             |
| LESA<br>Laser at<br>Max Rate | 3.71E+07  | 0.5                  | 2.38E-01             | 4.76E-01             | 4.76E+00             | 4.76E+01             |

# What to Expect in Summer 2027

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- Primary Beam for beam physics or limited irradiation studies
  - 8GeV
  - Up to 100Hz
  - Beam power max. 80W
  - 10nA current ==  $6.2 \times 10^{08}$  e<sup>-</sup> per pulse
- YAG and other screens to see beam profiles
- Beam synchronous timing/trigger system
- Timing/Trigger can be integrated into your DAQ (inquire about details)
- Multiple x/y and rotation stages
- HV for PMTs
- Secondary Beam for experimental hardware tests (6mm Cu-Target in BSY)
  - 2GeV to 8GeV
  - Up to 100Hz
  - Beam power small to nothing
  - 0, 1 to few or 100<sup>th</sup>-1000<sup>th</sup> e<sup>-</sup> per pulse
- Everything from “Primary Beam”
- Caladium EUDET Telescope
- Lead-glass calorimeter blocks
- Maybe 1 layer of LDMX fiber tracker for particle position
- Maybe acquiring ALPIDE Beam Telescope for faster data rate

Basically, the Same as During ESTB Operation but at 100Hz

## Summary

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- LESA beamline extends the SLAC SC Linac beam for particle physics research with flagship experiment LDMX
- Expect the 8 GeV SC linac to be commissioned and beam available for LESA Test beam program in Sept. 2027
  - Upcoming test beam mode is expected to be delivered 8 GeV beam in interleaved mode with up to 100 Hz, and dark current mode up to 230kHz
  - Should either XLEAP mode or LESA laser be available, dedicated photoelectron beam can also be available for test beam up to 230kHz
- Beyond 2027, LESA is expected to provide more flexible beam including 929kHz low current beam to ESA assuming the successful upgrade of LESA extraction kicker