LCLS-II Status and Upgrades

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Representing the LCLS team.

FEL Conference Hamburg 8/26-30/2019

Outline

1. **Overview the LCLS-II FEL Facility**
   - Layout
   - Parameters
   - Project Schedule update

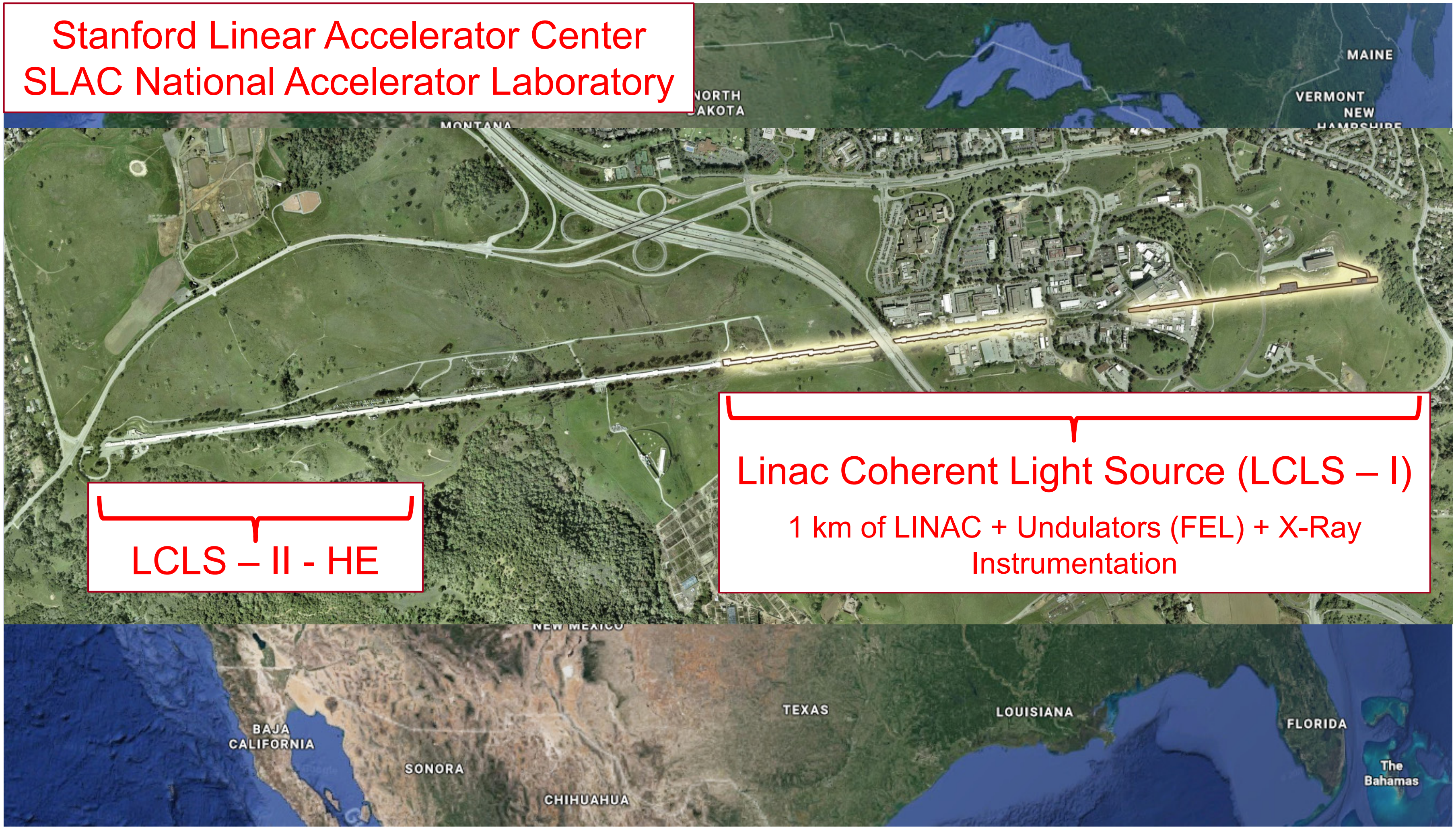
2. **Major LCLS-II Subsystems and Status**
   - Injector
   - Linac
   - Cryoplant
   - Undulator
   - Plans for advanced capabilities
   - X-Ray Systems

3. **Commissioning plans**

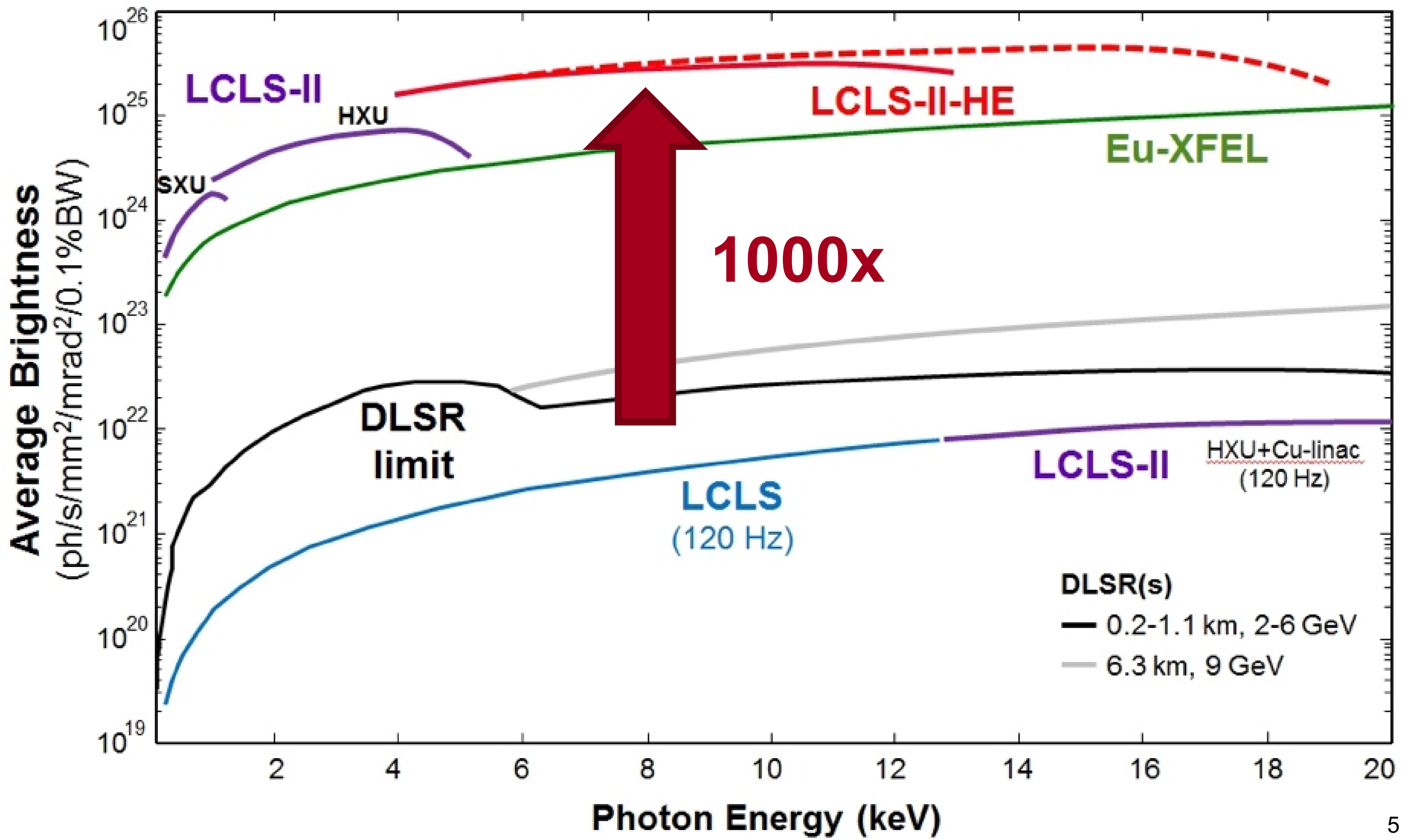
4. **Future outlook and upgrades**

SLAC's Main Accelerator Facilities

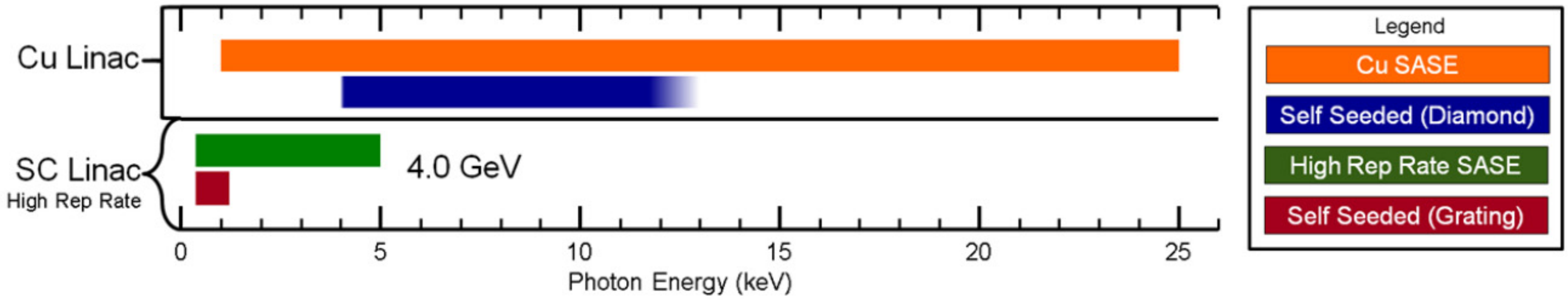
SLAC's Main Accelerator Facilities

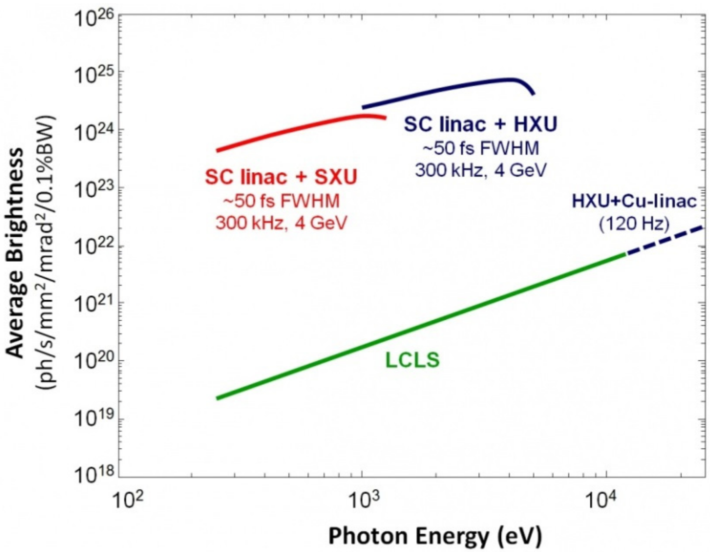


Performance of LCLS FEL's



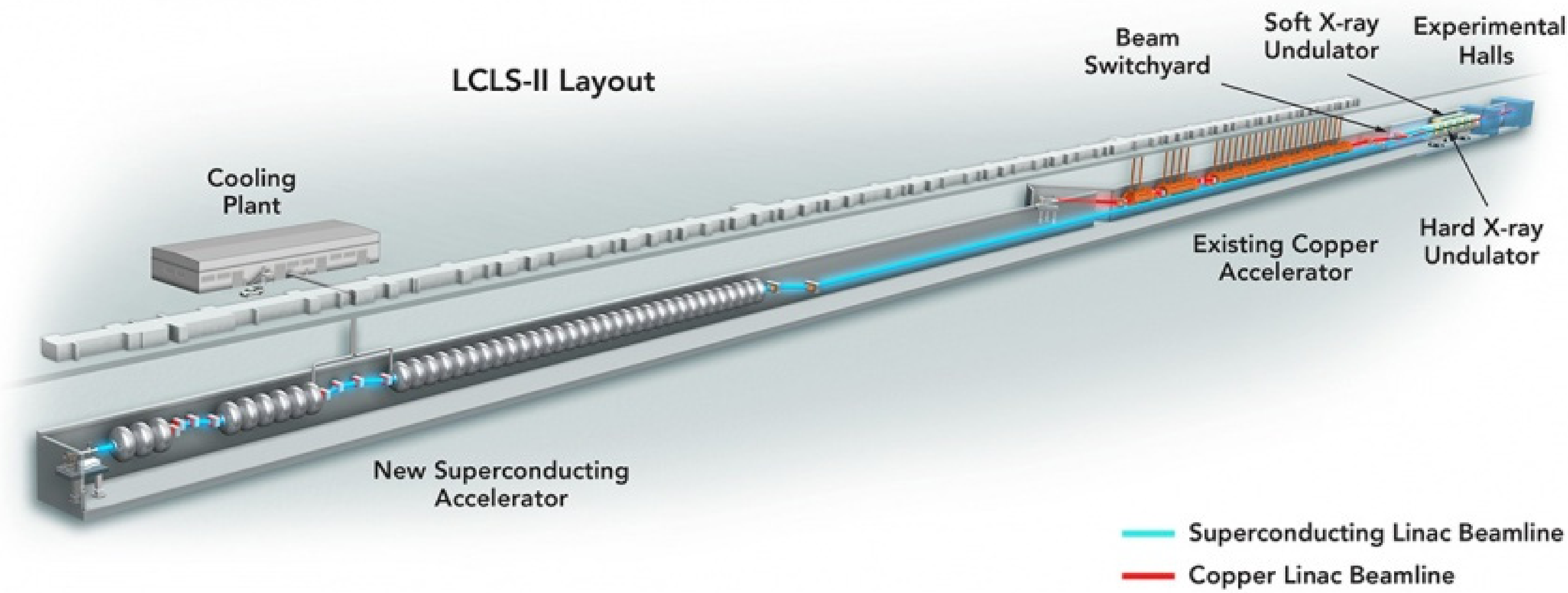
LCLS-II Key Parameters





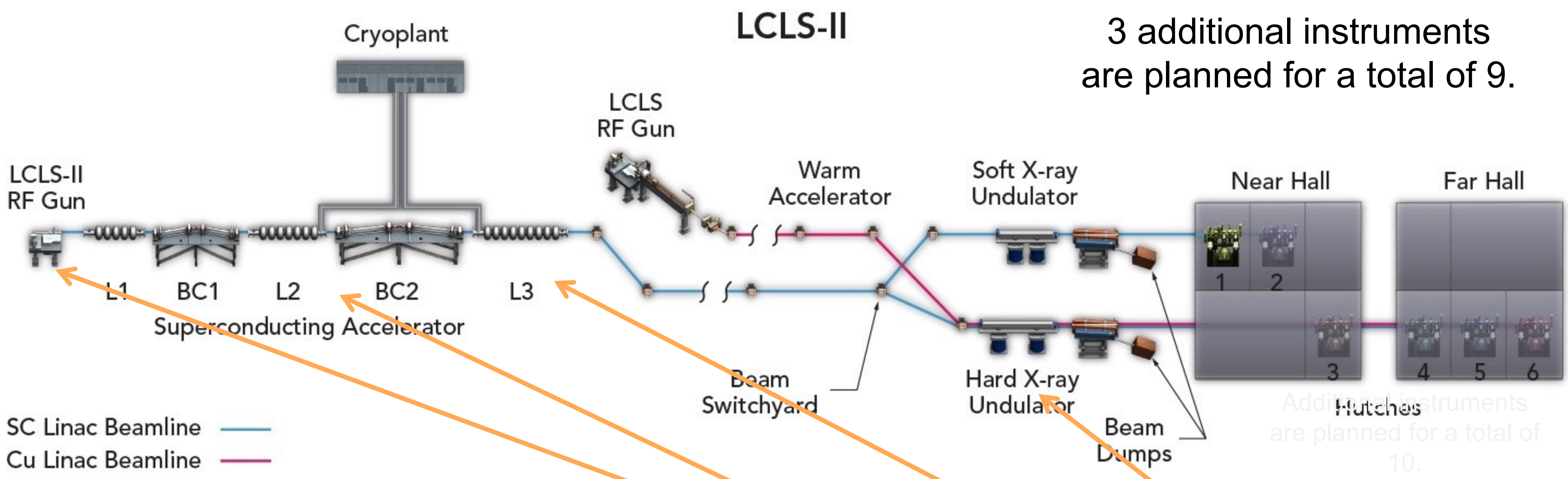
Performance Measure	Threshold	Objective
Variable Gap Undulators	2 (SXR & HXR)	2 (SXR & HXR)
Super Conducting Linac Based FEL System		
Super Conducting Linac Energy	3.5 GeV	≥ 4 GeV
Electron Bunch Repetition Rate	93 kHz	929 kHz
Super Conducting Linac Charge per Bunch	0.02 nC	0.1 nC
Photon Beam Energy Range	250-3,800 eV	200-5,000 eV
High Repetition Rate Capable End Stations	≥ 1	≥ 2
FEL Average Power (10^-3 BW)	$5x10^8$ (10x spontaneous @2,500 eV)	$>10^{11}$ @ 3,800 eV
Normal Conducting Linac Based FEL System		
Normal Conducting Linac Electron Beam Energy	13.6 GeV	15 GeV
Electron Bunch Repetition Rate	120 Hz	120 Hz
Normal Conducting Linac Charge per Bunch	0.1 nC	0.25 nC
Photon Beam Energy Range	1,000-15,000 eV	1,000-25,000 eV
Low Repetition Rate Capable End Stations	≥ 2	≥ 3
FEL Photon Energy (10^{-3} BW[a])	10^{10} (lasing @ 15,000 eV)	$> 10^{12}$ @ 15,000 eV

LCLS – II Accelerator Systems



LCLS-II FEL Systems

3 additional instruments are planned for a total of 9.

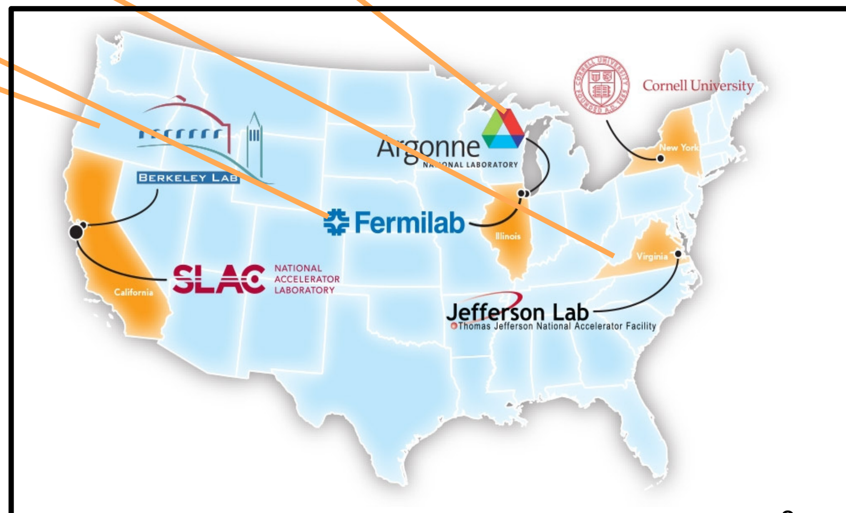


The LCLS-II project is funded by the US Department of Energy,

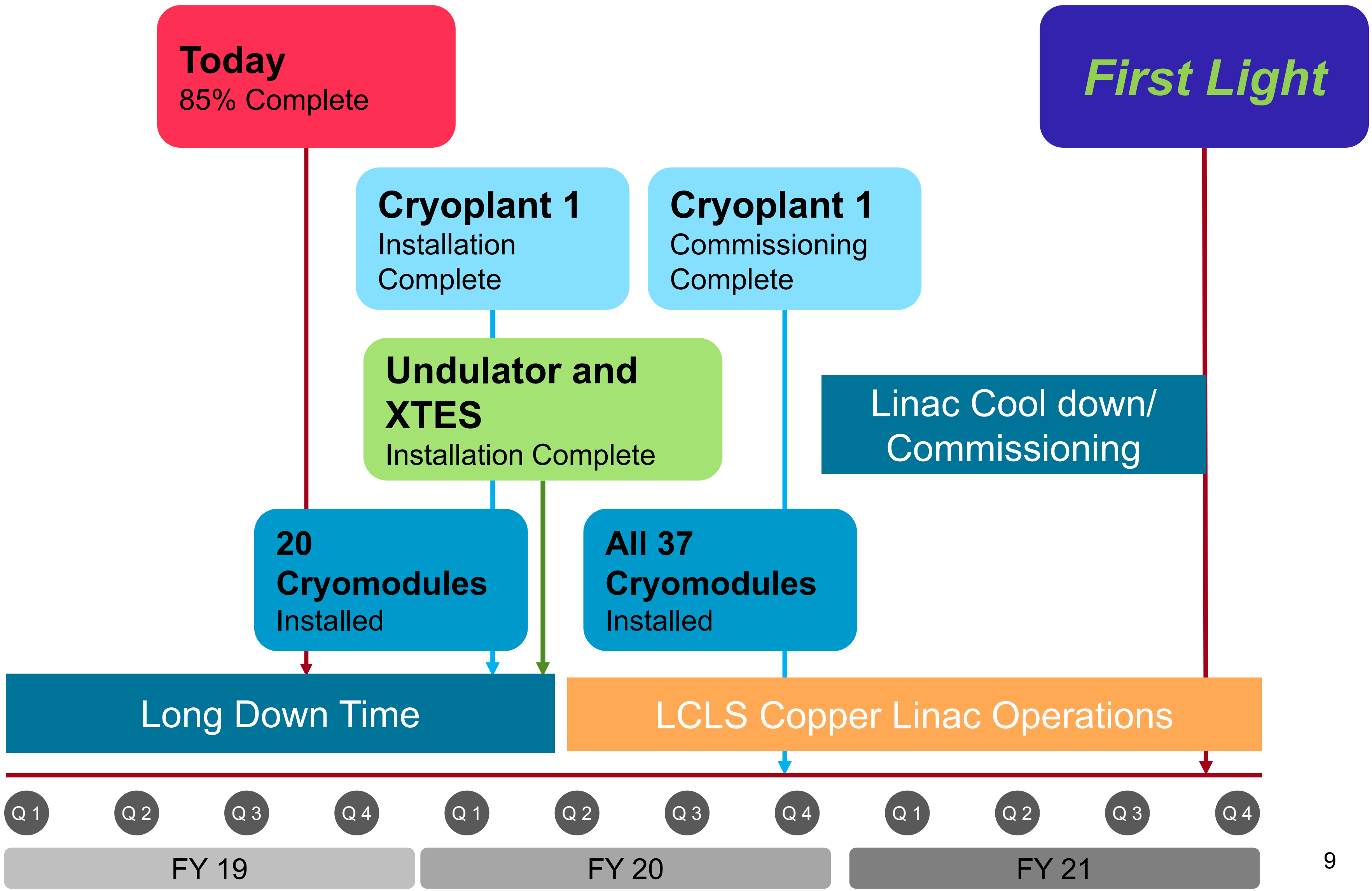
Collaboration of 5 national labs and Cornell University.

Collaboration and exchange of expertise with DESY/EuXFEL

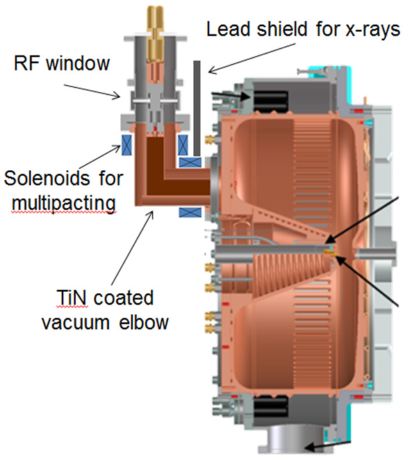
Industrial partners also important.

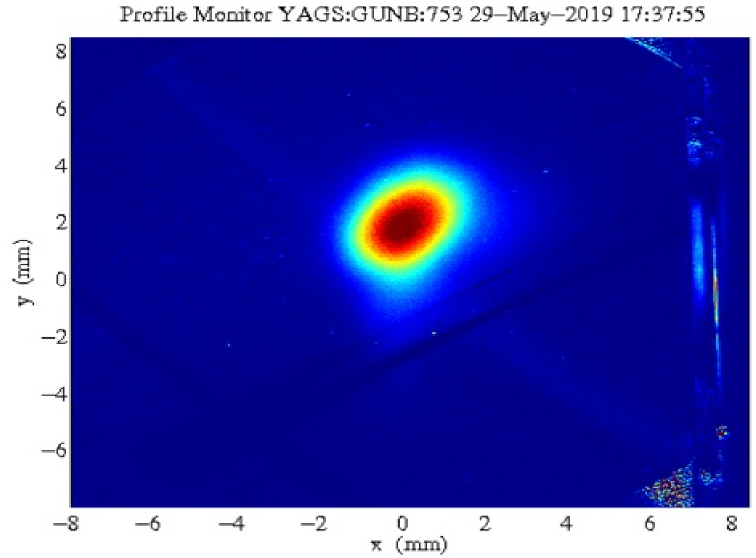


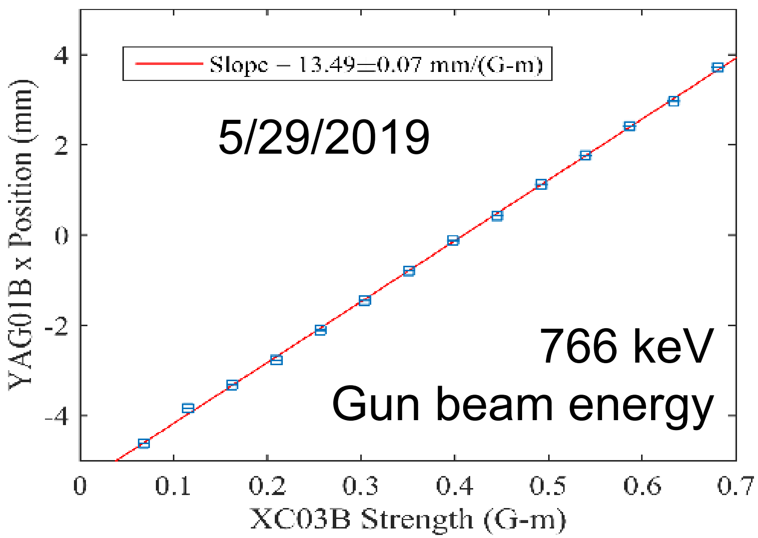
LCLS-II Project Timeline

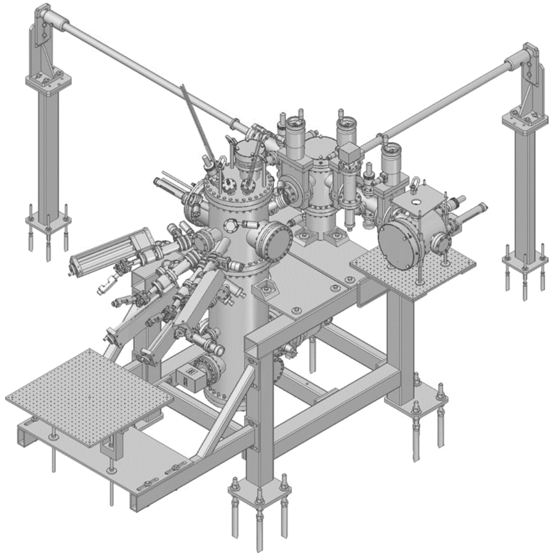


Gun and Injector Commissioning









Cathode growth apparatus is near completion.

LCLS-II Cryomodules installation at SLAC

SLAC

Fermilab

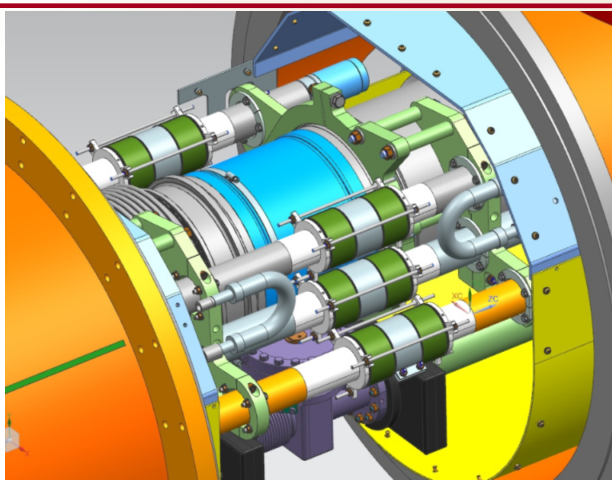
Jefferson Lab

More than half of all LCLS-II CM’s are now located in the tunnel.

CM Placement

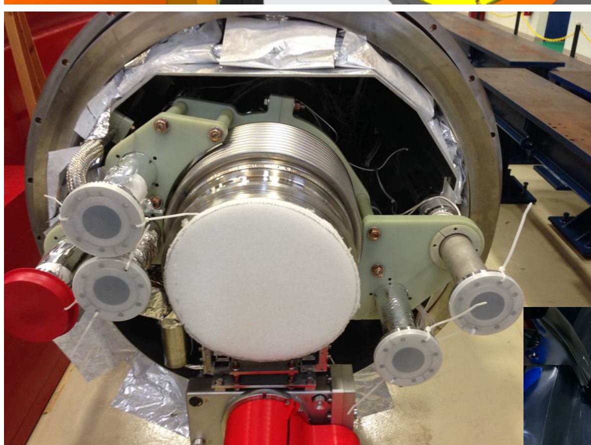
SM Installation

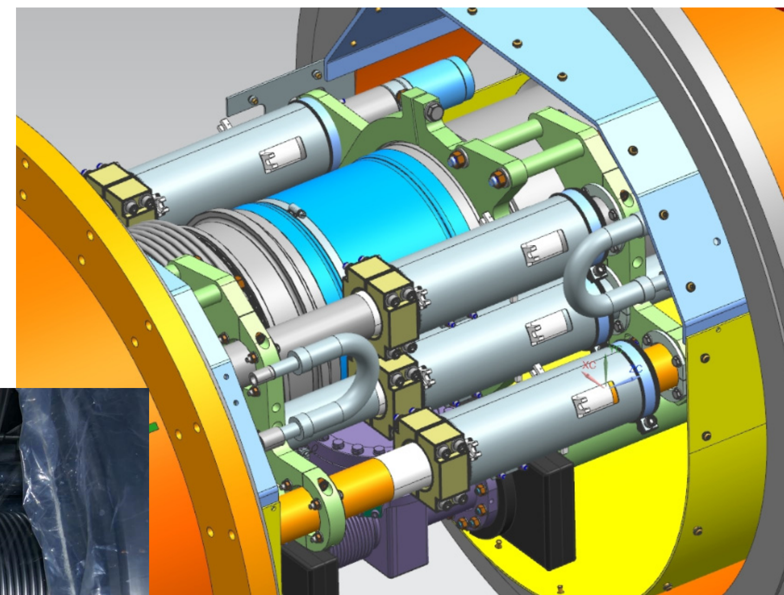
Cryomodule interconnects – welding preparations

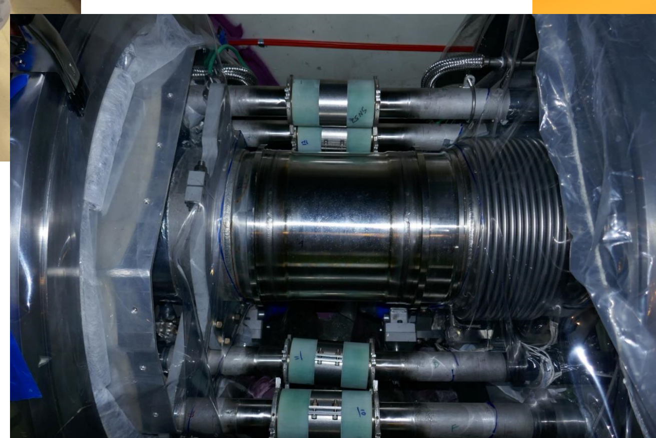


First welding tests are complete

→ Orbital automated welding procedure
→ Alignment of connections ensured by purpose designed fixtures.



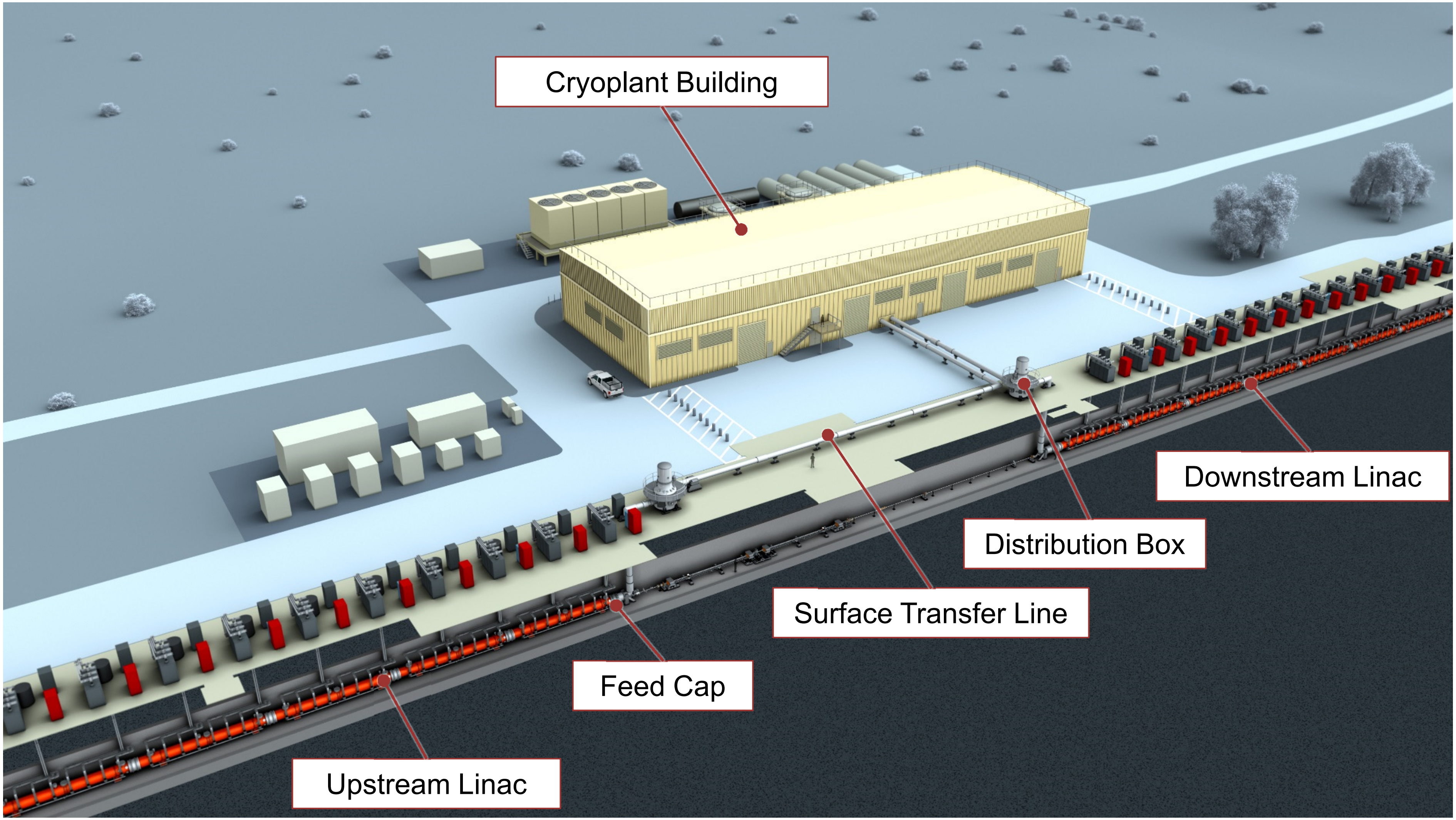




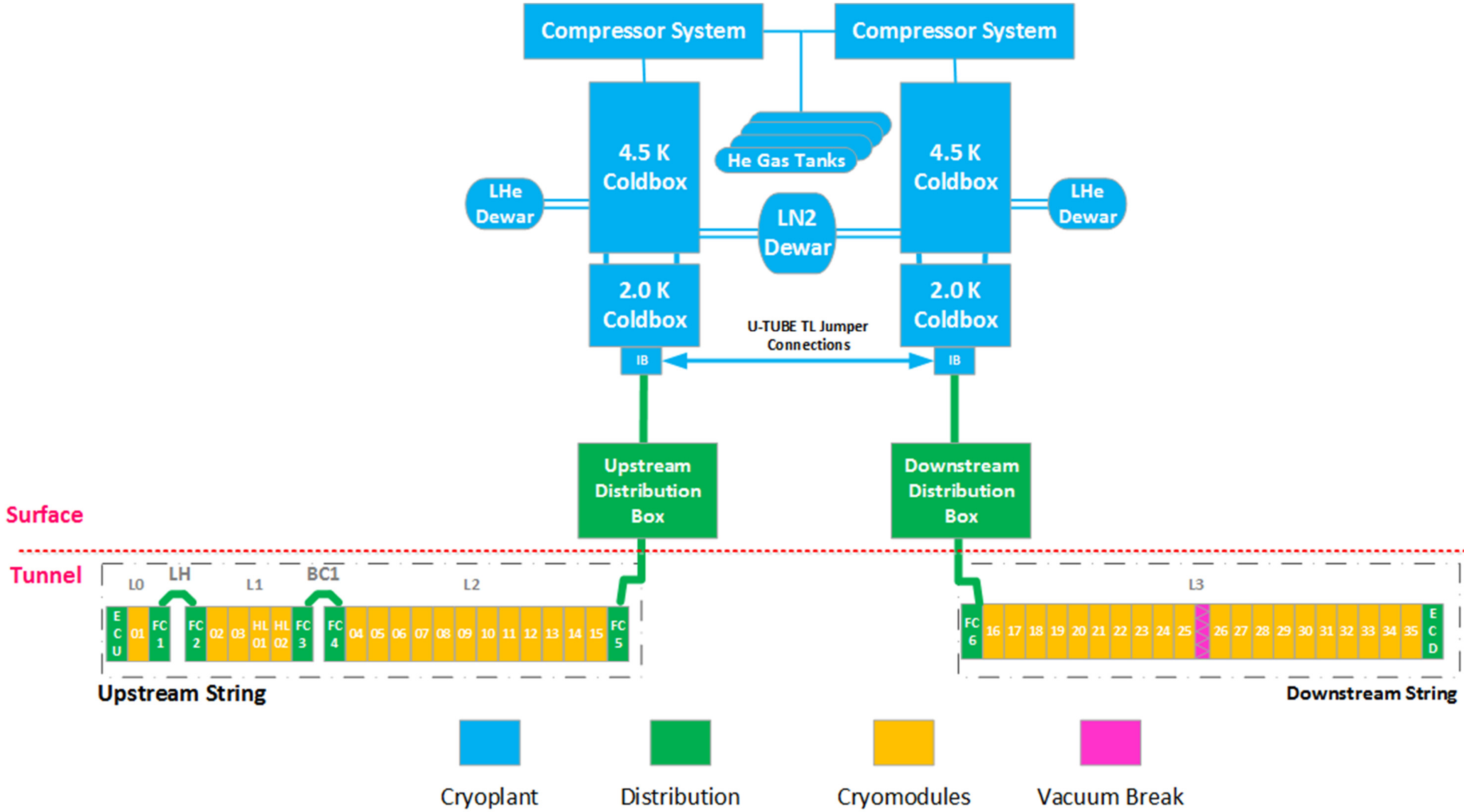
3.9 GHz cryomodule string assembly underway at Fermilab

3.9 GHz SC cavities are being assembled for injector 'linearizer'.

Cryoplant Overview - Location



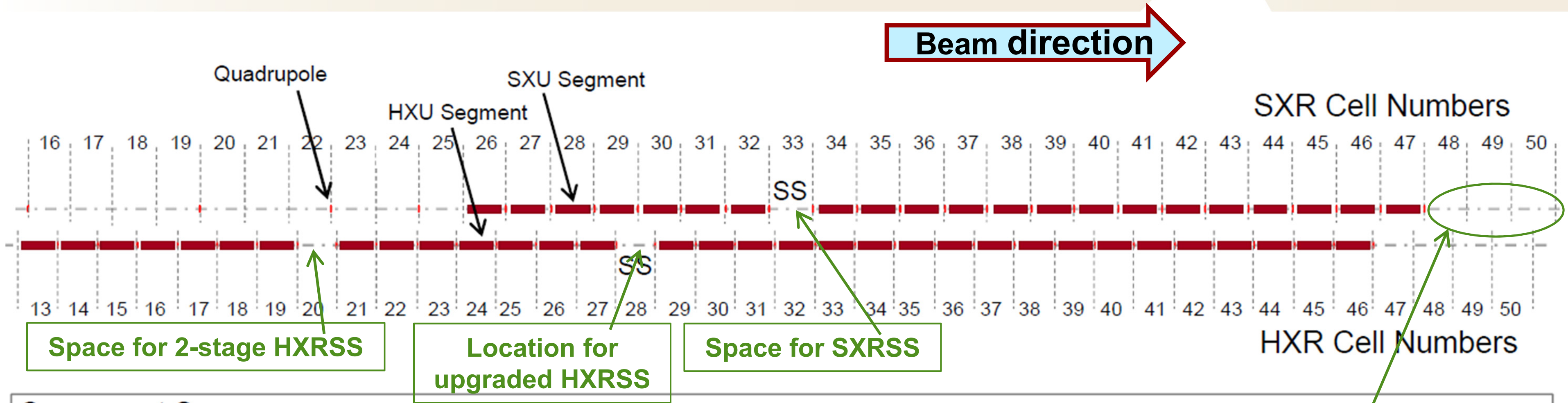
Overview – Dual Plant based on Jlab Design



Cryoplant Equipment Installation - Examples

- *Cryoplant Construction continues*
- *Control System Development is ongoing.*
- *Commissioning is imminent.*

Undulator System Overview
Schematic of HXR & SXR Beamlines



Component Summary:

SXU (#21) : SXR26-SXR32; SXR34-SXR47

HXU (#32) : HXR13-HXR19; HXR21-HXR27; HXR29-SXR46

Quad⁺ (#60) : SXR15; SXR19; SXR22; SXR24, SXR26-SXR47; HXR13-HXR46;

RFBPM ⁺⁺ (#60+2) : SXR24; SXR25; SXR26-SXR47; (+1); HXR12; HXR13; HXR14-HXR46; (+1)

SXR-PS ⁺⁺ (#20) : SXR26-SXR32; SXR34-SXR46

HXR-PS ⁺⁺ (#31) : HXR14-HXR19; HXR22-HXR27; HXR29-HXR46

BLM ⁺ (#53) : SXR26-SXR32; SXR34-SXR47 ; HXR13-HXR19 ; HXR21-HXR27; HXR29-SXR46

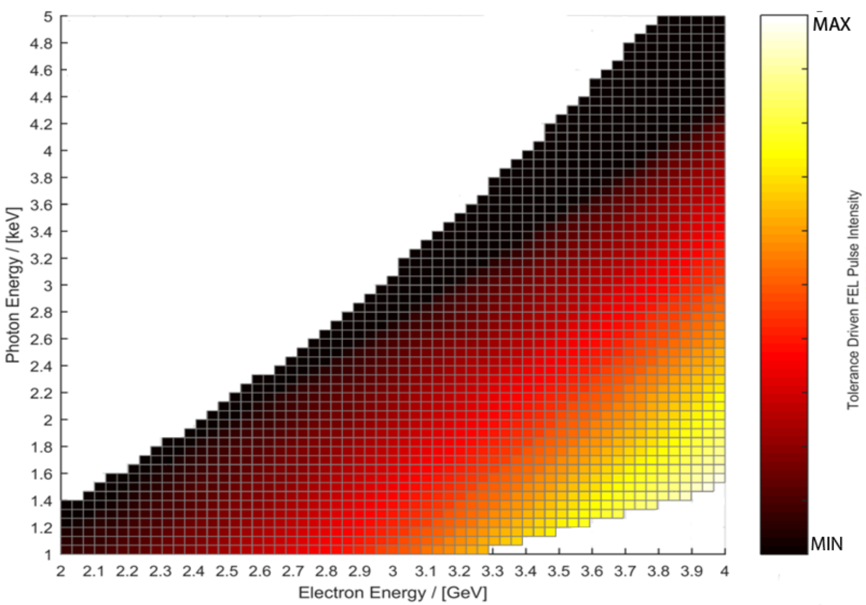
⁺ Same Cell as following segment

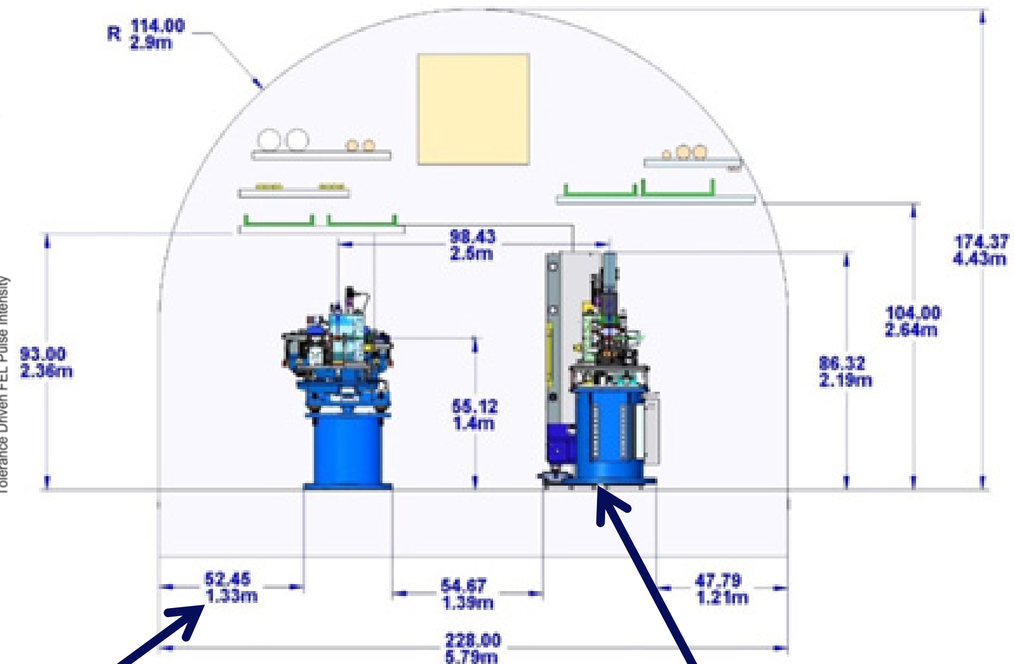
⁺⁺ Same Cell as previous segment

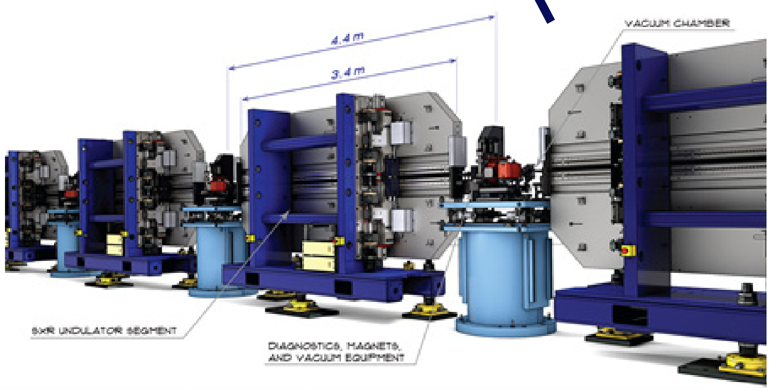
Space for 3 Polarization Control Undulators

Transformation of the undulator system fixed → variable gap for dedicated SXR and HXR

SLAC







Dedicated variable gap undulators for SXR and HXR

Undulator Installation

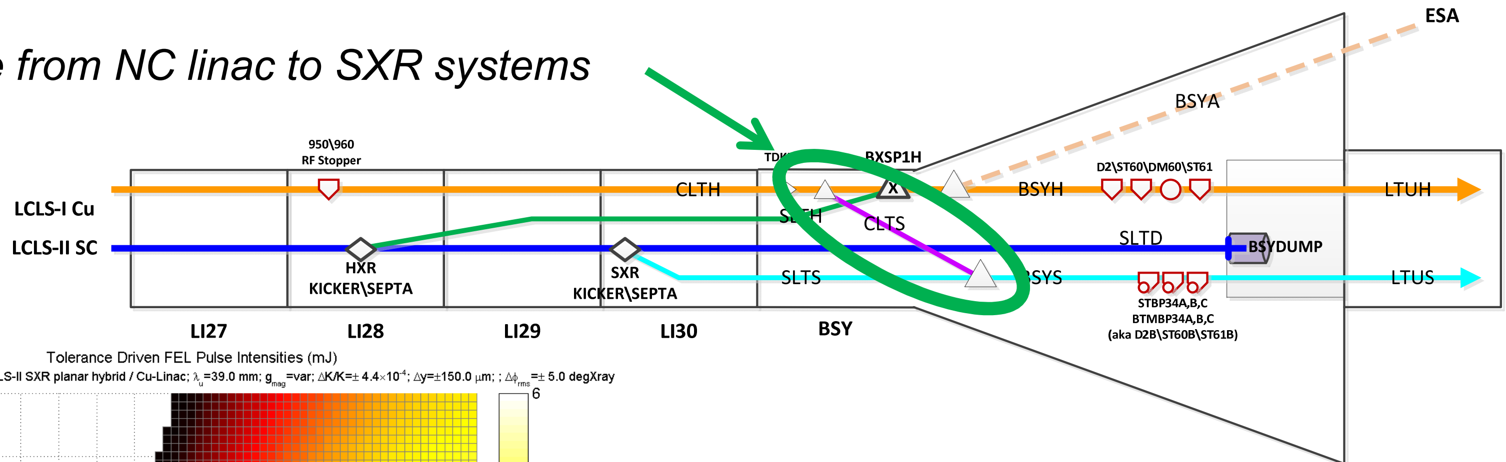
SLAC

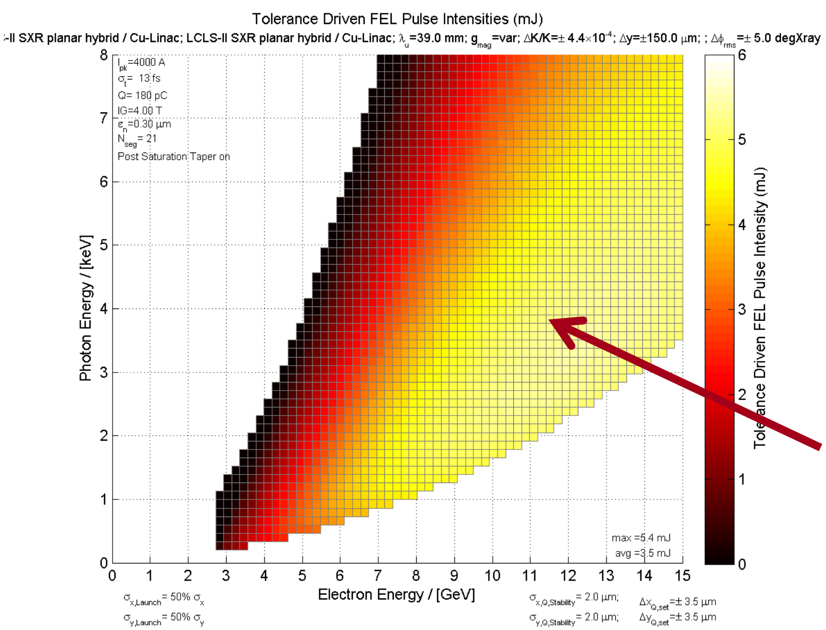
- Began installing SXR undulators – **13 Aug '19**
- 7 (of 21) SXR undulators installed in the Undulator Hall
- Will begin installing HXR undulators on **27 Aug. '19**

Cu-Linac – SXR beamline

Beyond LCLS-II baseline:

Transfer line from NC linac to SXR systems

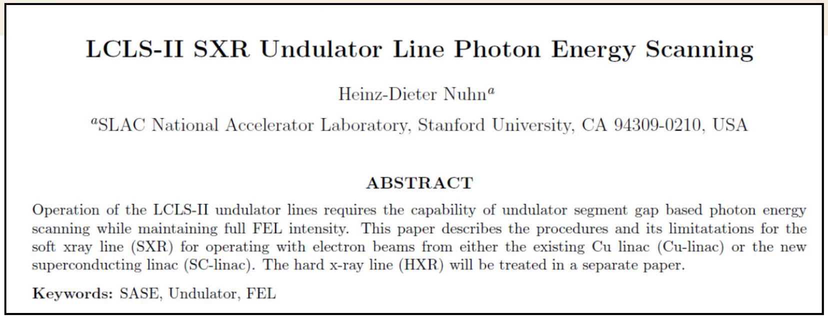




Commissioning of SXR systems with NC linac, independently of SCRF but in parallel of HXR program

- *SXR VGU & SXR instruments*
- *Maintaining high peak power capability for SXR*

Photon Energy Scanning with VGU’s



LCLS-II SXR Undulator Line Photon Energy Scanning

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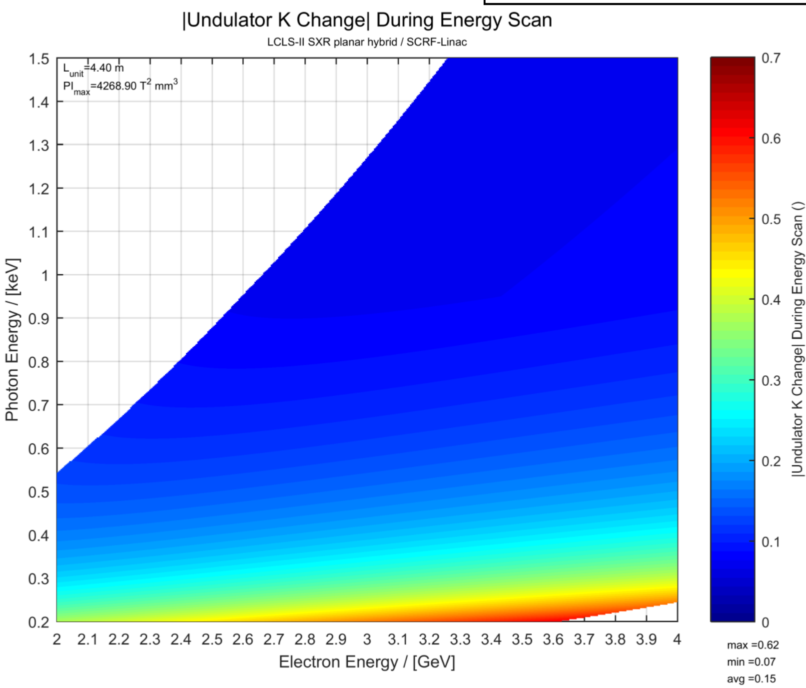
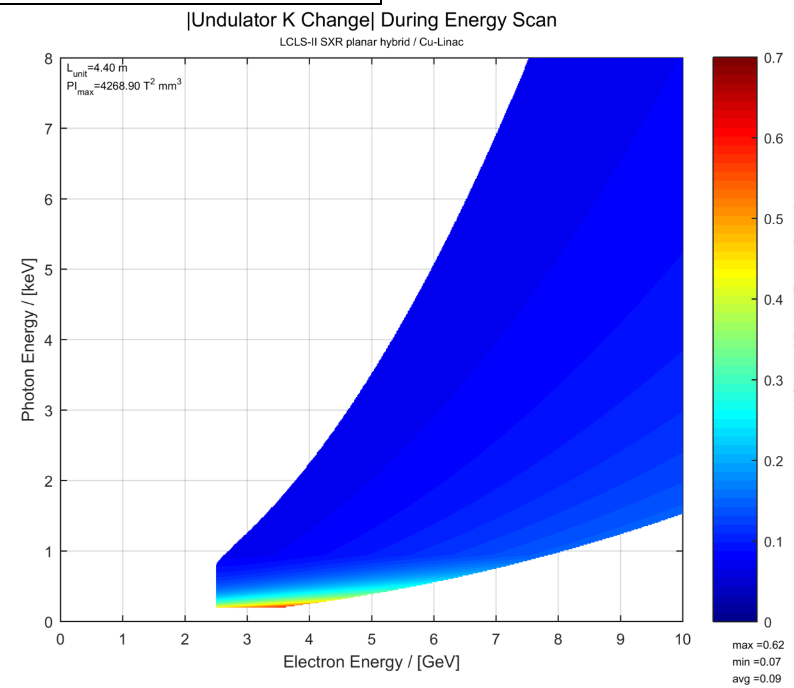
ABSTRACT

Operation of the LCLS-II undulator lines requires the capability of undulator segment gap based photon energy scanning while maintaining full FEL intensity. This paper describes the procedures and its limitatations for the soft xray line (SXR) for operating with electron beams from either the existing Cu linac (Cu-linac) or the new superconducting linac (SC-linac). The hard x-ray line (HXR) will be treated in a separate paper.

Keywords: SASE, Undulator, FEL





$$E_{ph} = hcn \frac{2\gamma^2}{\lambda_u(1+\frac{K^2}{2})}$$

γ – Electron beam energy

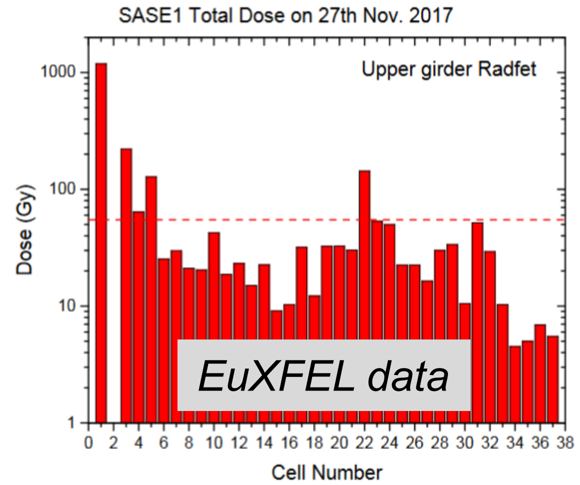
K^2 - Undulator system

LCLS-II Commissioning – Conservative Ramp of Power

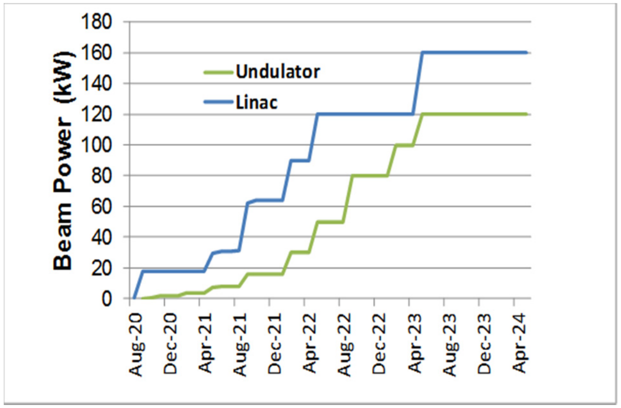
Concern: Undulator Radiation Damage

Mitigation plan

- Start commissioning with Cu-linac beam
- Stepwise ramp of beam power during commissioning
- Beam optimized at tune-up dump upstream of the undulator
- Beam loss monitor and BPM interlocks will be required
- Measure dose rates in real time on each undulator and beam current administratively controlled to stay below defined dose rate threshold
- Developing real time magnetic measurement monitoring system that measures magnetic field as the gap is changed



Initial dose rate about 700 times higher than LCLS-I because of insufficient machine protection systems.



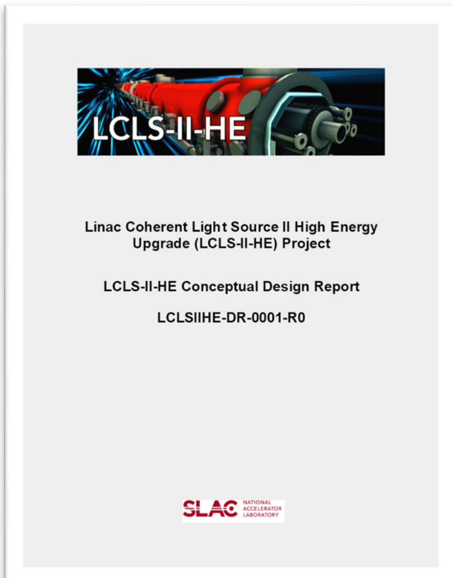
Slow ramp up of beam power to mitigate undulator radiation damage.

Capability Development to support Users/Science program

We plan to upgraded and adapted capabilities developed for LCLS-I for LCLS-II high repetition rates:

XLEAP-II	***Sub femtosecond pulses***
XTCAV-II	***Few femtosecond diagnostics***
SXRSS-II	***SXR Self Seeding***
HXRSS-II	***HXR Self Seeding***
DELTA-II	***Polarized X-Rays***

LCLS-II-HE Scope


LCLS-II-HE

Linac Coherent Light Source II High Energy Upgrade (LCLS-II-HE) Project

LCLS-II-HE Conceptual Design Report

LCLSIIHE-DR-0001-R0

SLAC NATIONAL ACCELERATOR LABORATORY

Double the electron energy of the accelerator (4 → 8 GeV)

- Extends X-ray energy limit from 5 keV to 12.8 keV

Install a second bypass line to provide a dual source

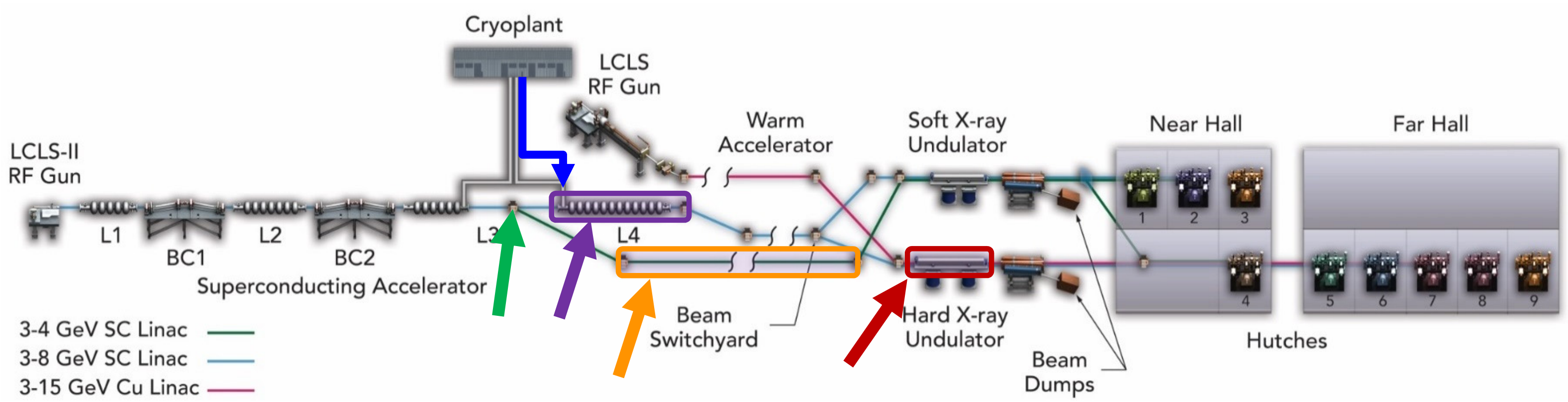
- Delivers simultaneous soft X-ray and hard X-ray beams at high rep-rate

Provide specialized instruments for unique new source

- Delivers optimized measurement capabilities and enables science immediately from the onset of commissioning

This provides a qualitatively new capability, unique in the world, delivering ultrafast, Ångström performance at high average power.

LCLS-II-HE accelerator upgrades will enable hard X-rays at high rep-rate and increase the experimental capacity.



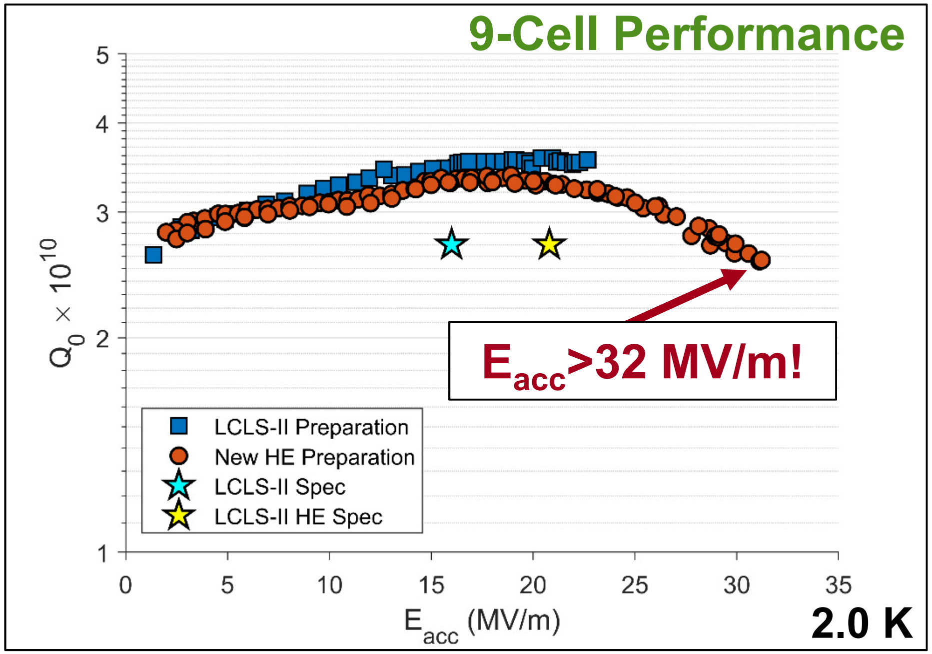
1. Add 20 additional cryomodules (L4 linac) to increase the LCLS-II accelerator energy to 8 GeV.
2. Install new cryogenic distribution box and transfer line between the cryoplant and the new L4 linac.
3. Add low-energy extraction point at 3.8 GeV to enable quasi-independent operation of the soft-X-ray and hard-X-ray programs.
4. Use existing transport line to bypass downstream linacs and install new dump in the beam switch yard
5. Install high rep-rate Hard X-ray Self Seeding capability in the hard X-ray undulator

LCLS-II-HE Project Collaboration

SLAC NATIONAL ACCELERATOR LABORATORY	• Accelerator and FEL Design • Cryomodule and accelerator installation • Cryoplant modifications & Helium distribution installation • High Power RF, low-level RF, and Controls • X-ray instruments design & installation
Fermilab	• High Q0 & High Gradient R&D • Cryomodule design and prototype demonstration • 50% of cryomodule production • Processing for high Q • Helium distribution system design and procurement
Jefferson Lab EXPLORING THE NATURE OF MATTER	• High Q0 & High Gradient R&D • 50% of cryomodule production • Processing for high Q
CORNELL UNIVERSITY FOUNDED A.D. 1865	• High Q0 & High Gradient R&D
BERKELEY LAB	• Accelerator Physics

LCLS-II HE SRF Cavity R&D:
Pushing the Boundaries of Nitrogen Doping

SLAC



Cornell University, Fermilab, Jefferson Lab

- LCLS-II has demonstrated **repeatable high Q_0** production SRF cavities
- An R&D program between SLAC, Fermilab, Jefferson Lab, and Cornell University has looked to push nitrogen-doping performance further
- New **doping protocols** have enabled higher quench fields in single and 9-cell cavities while maintaining excellent Q_0!

R&D Goal:

Develop a cavity processing method to consistently produce cavities that reach 24.5 MV/m in VT with a Q_0 of 2.7×10^{10} at 21 MV/m.

Top-level process used to define our plan of action for LCLS facilities (includes LCLS-I,II, HE)

SLAC

Current Capabilities

LCLS-II Project

Science Opportunities

Facilitiy Response

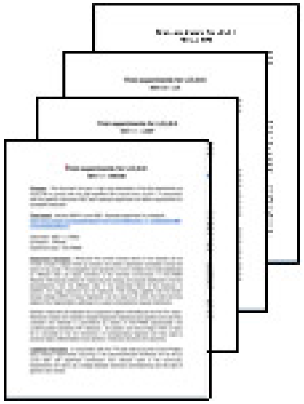
Details on LCLS website:

- Science Drivers
- New instrument designs
- First Experiments documents

Prioritized Plan

Group	Item
Ongoing Developments	Data Systems and Algorithms
	Detector Development
	Laser Developmenet
	X-ray Optics and Diagnostics Development
"Day 1"	CuRF in SXU
	DELTA Undulators
	High Rep Rate Laser
	High Rep. Rate Tender Capability in XPP
	NEH 1.1 [LAMP, COLTRIMS] Build Out
	NEH 2.2 [LJE, RCI, RSXS]
	NEH Reconfiguration
	Very Hard X-ray Detectors
"Day 2"	NEH 1.2
	NEH 2.1
	RIXS Detectors
	SX Imaging Detectors
	TES Detector
	TIXEL Detector
Additional End Station	PES Endstation
	SurfSpec Endstation
High Rep. Rate Hard X-ray	ePixHR Detectors
	High Rep Rate Optics

First Experiments



Our current focus: optimizing the delivery plan for Early Science, consistent with available resources (people, $, time)

Near Experimental Hall extension for LCLS-II

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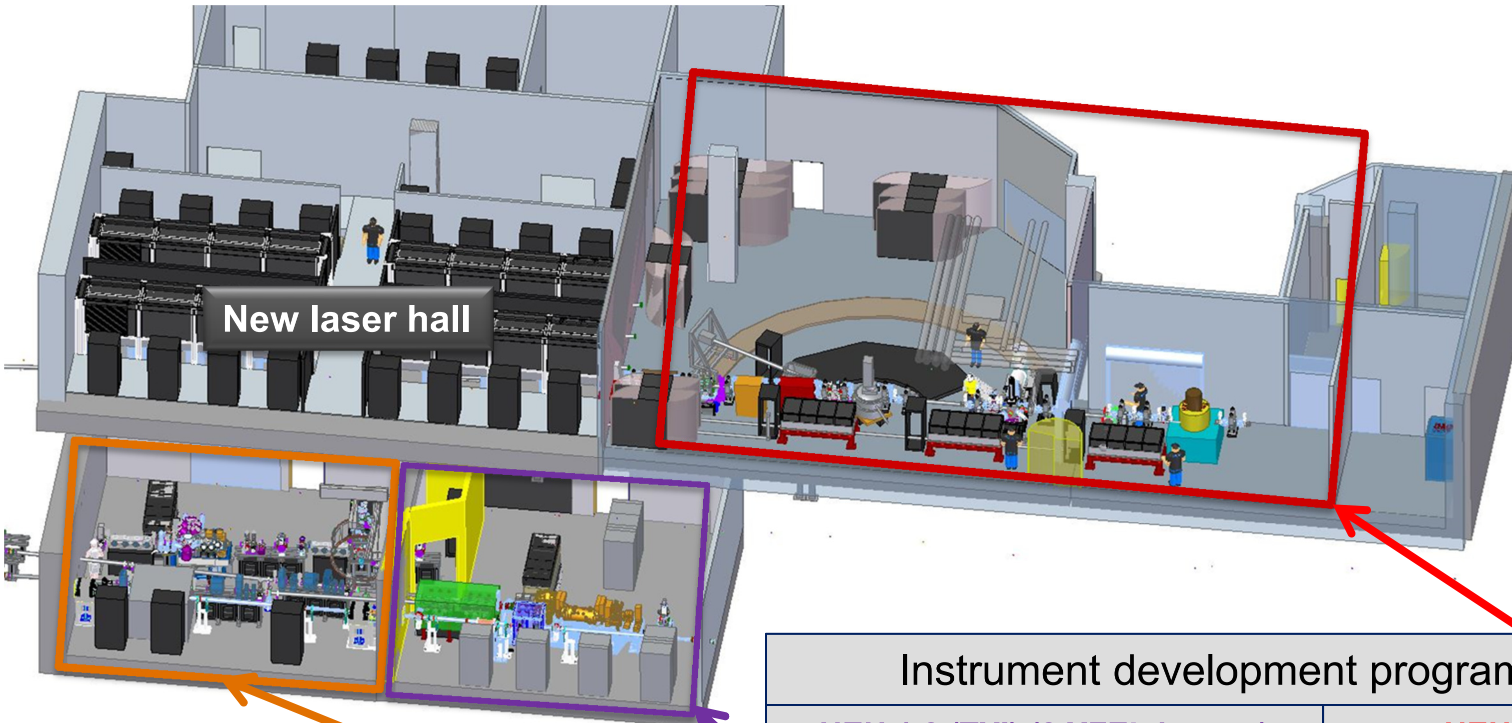

Instrument development program for LCLS-II

NEH 1.2 (TXI) (2 XFEL beams)
- Tender X-ray Instrument
- 400 – 7000 eV

NEH 1.1 (TMO)
- High Flux Soft X-ray
- 250 – 2000 eV

NEH 2.2 (RIXS / MMI)
- 250 – 1350 eV
- **RIXS** endstation (30,000 resolving power)

XPP modified for high rep-rate "tender X-ray" operation

Extension of x-ray instrumentation in parallel with LCLS-II accelerator & FEL development.

Thank you for your Attention!

Accelerator Physicist https://careers.slac.stanford.edu/

Job ID	3816
Location	SLAC - Menlo Park, CA
Department	AD LFD LCLS Acc Physics
Job Family	
Job Function	
Business Unit	SLAC National Accelerator Lab
Posted Date	08/07/2019
Close Date	Open Until Filled