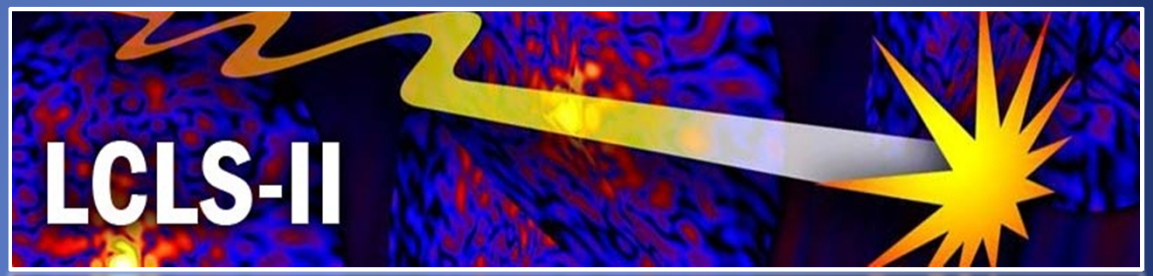
Status of the LCLS-II Project at SLAC

P. Emma (for the collaboration)

2017 FEL Conference



Argonne NATIONAL LABORATORY

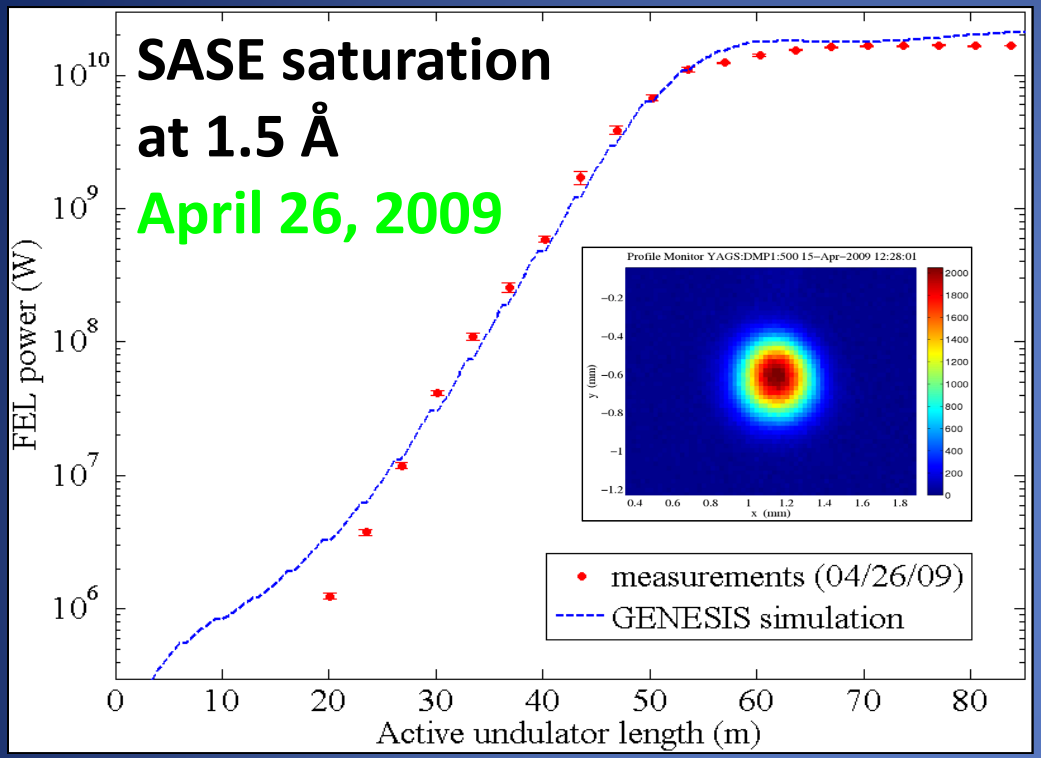
BERKELEY LAB
Lawrence Berkeley National Laboratory

Fermilab

Jefferson Lab

SLAC NATIONAL ACCELERATOR LABORATORY

LCLS Operating Well for 8 Years



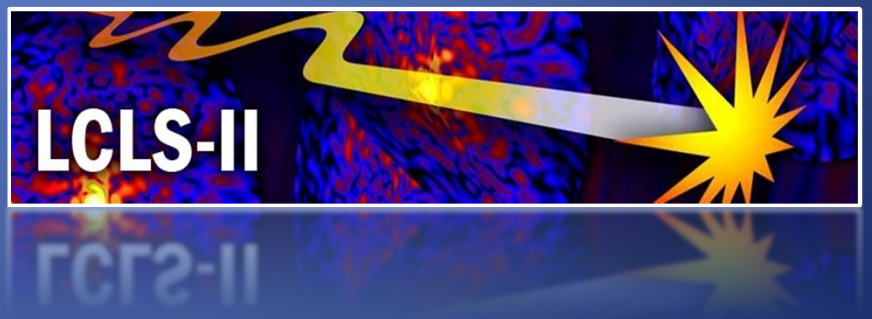
- FEL photons: 0.3 → 10 keV
- Hard & soft x-ray self-seeding
- Two-color and 'attosecond' pulses
- Circular polarization (Delta-undulator)
- fs-resolved diagnostic (X-TCAV)


LCLS-II
FEL'17


Remove old Linac from 1st km (done)
LCLS-II
FEL'17
Add new CW injector and new superconducting linac
2 New 4-kW Cryoplants
Existing Bypass Line
New Transport Lines
Two New Undulators and X-Ray Transport
Exploit Existing Experimental Stations

New Machine Features

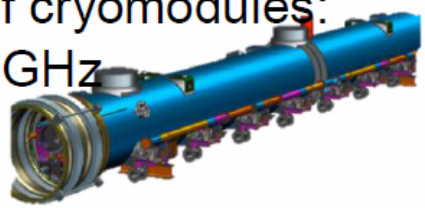
- CW RF gun (*APEX*/*LBNL*, 186-MHz RF)
- 4-GeV, 1.3-GHz CW SRF Linac ($\leq$ 1 MHz e^-)
- Keep existing 15-GeV Cu-Linac (120 Hz)
- 2 adjustable-gap undulators (0.2 – 25 keV)
- 2 new 4-kW cryo plants (2K)
- TPC = 1.045 B$



Project Collaboration

Fermilab

½ of cryomodules: 1.3 GHz



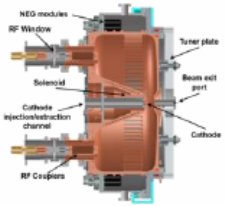
Jefferson Lab
EXPLORING THE NATURE OF MATTER

½ of cryomodules: 1.3 GHz

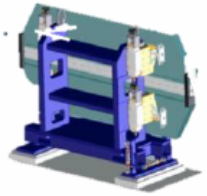
Cryoplant

BERKELEY LAB

e⁻ gun & associated injector systems



Undulators



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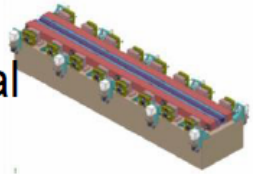
Undulator Vacuum Chamber

Undulator R&D: vertical polarization



CORNELL UNIVERSITY FOUNDED A.D. 1865

R&D planning, prototype support
e⁻ gun option

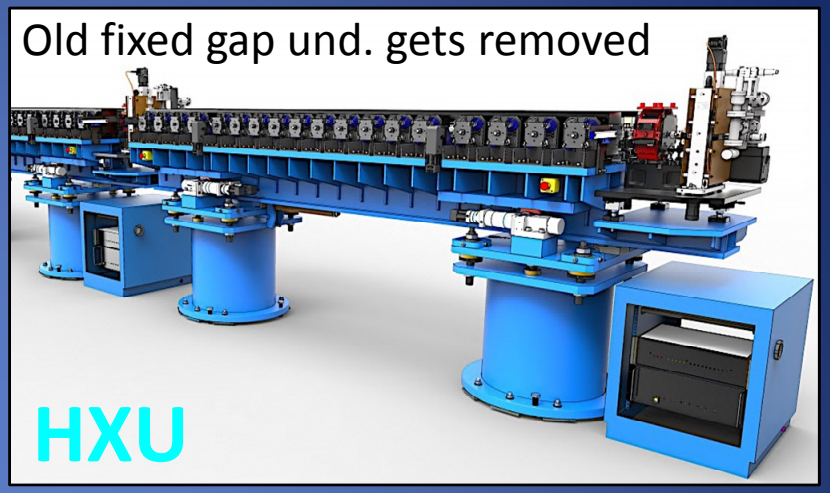
LCLS-II will have 2 linacs

- **Existing Cu-Linac**:
  - High e^- energy (**15 GeV**),
  - Low rate (**120 Hz**)
  - Pulsed RF
  - **1 km** length (*LCLS*)

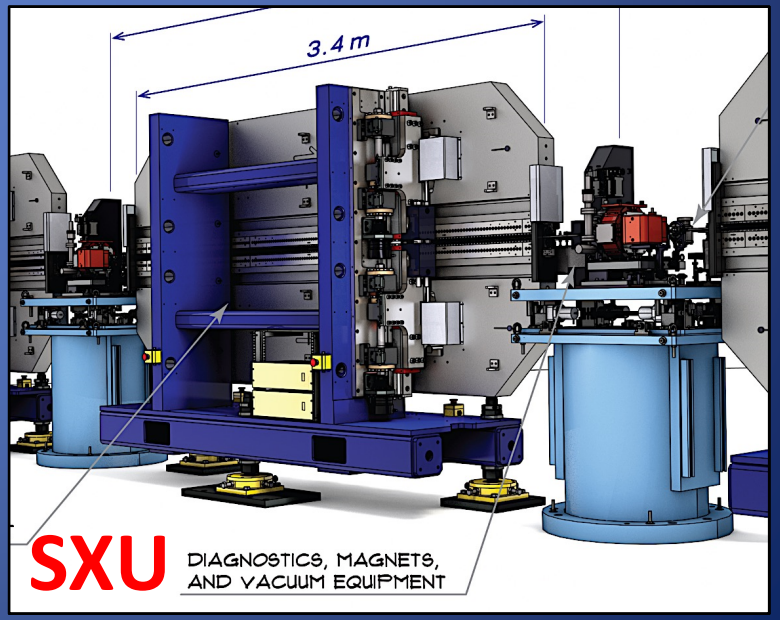
- **New CW SRF-Linac**:
  - High beam rate (**1 MHz**)
  - Low e^- energy (**4 GeV**)
  - 450 m length
  - Stable x-ray delivery

LCLS-II will have 2 undulators

- **Hard X-Ray FEL (HXU):**
  - Adjustable hor. gap (**VPU**)
  - **4 GeV** (≤ 1 MHz) or…
  - **15 GeV** (120 Hz)
  - $L_u \approx 110$ m, $\lambda_u = 26$ mm



- **Soft X-Ray FEL (SXU):**
  - Adjustable ver. gap
  - **4 GeV** (≤ 1 MHz) or…
  - **10 GeV** (120 Hz) – *optional*
  - $L_u \approx 70$ m, $\lambda_u = 39$ mm



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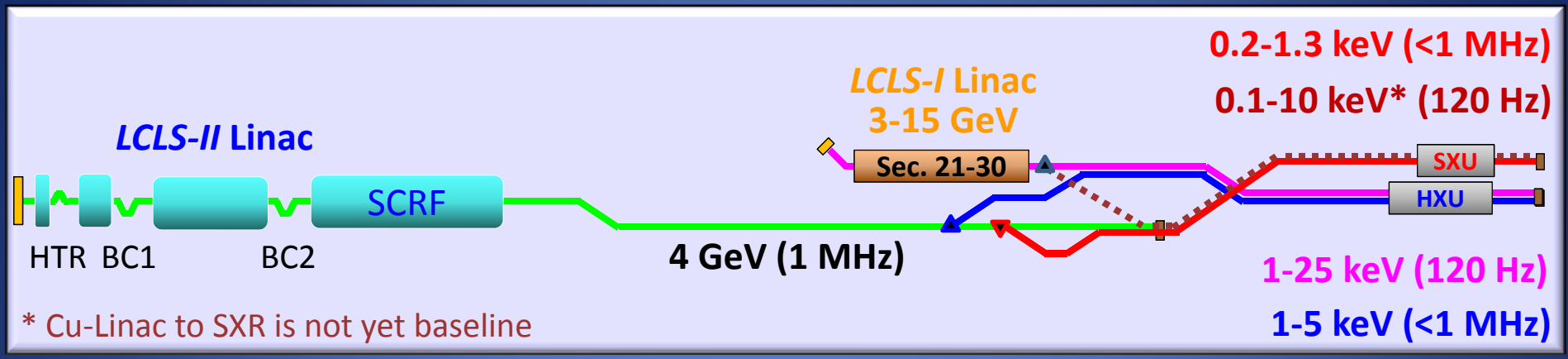
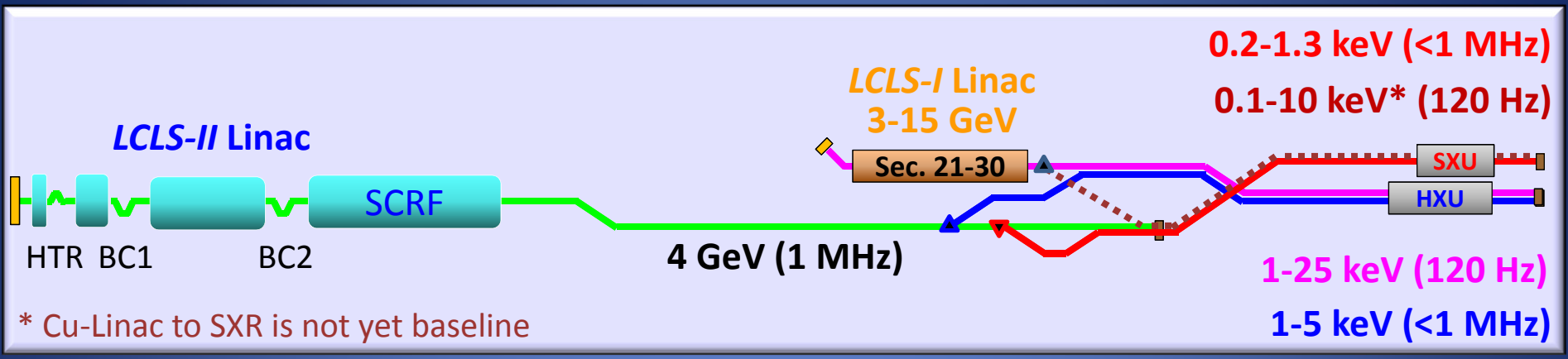
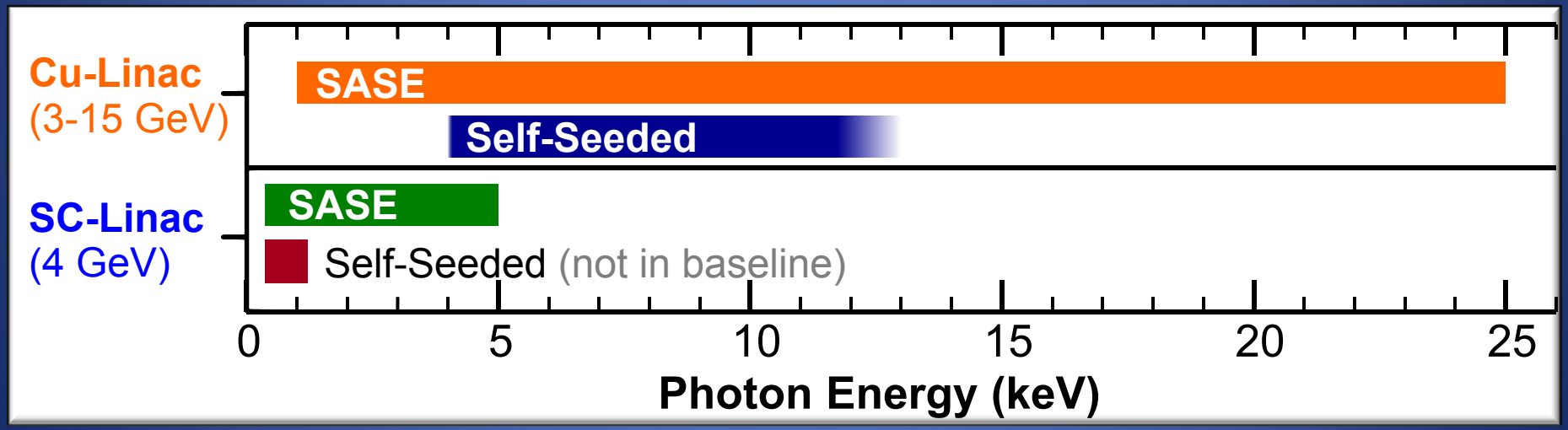
LCLS-II Layout and Performance



LCLS-II Layout and Performance

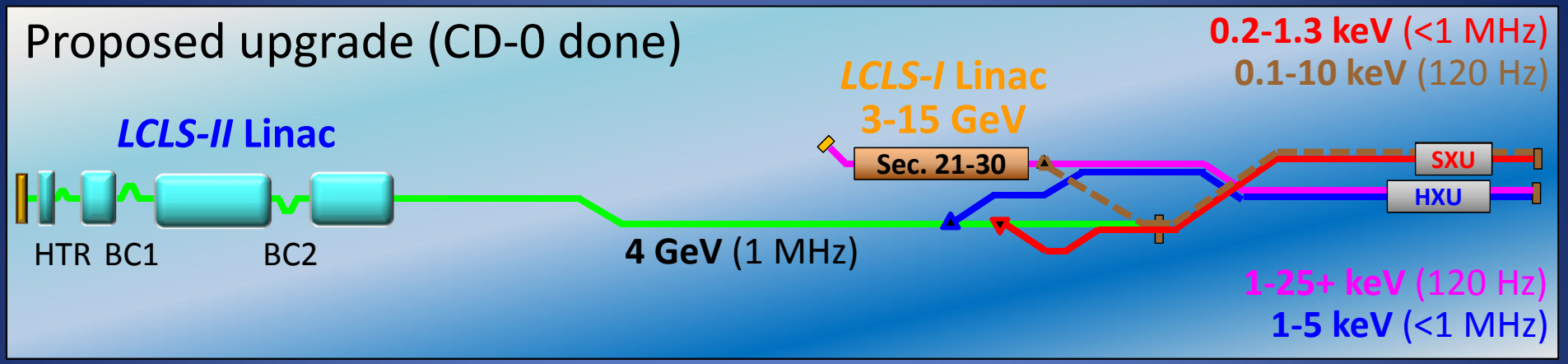
FEL'17

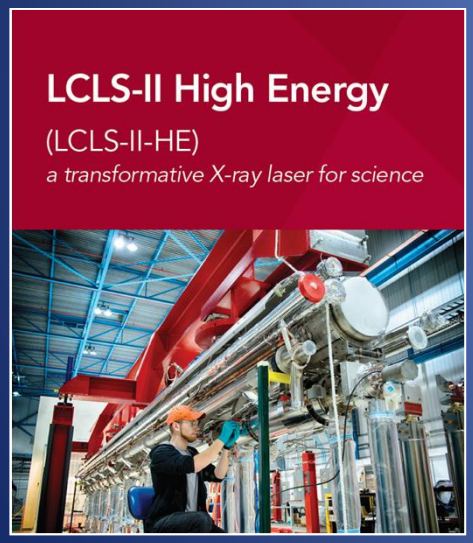




- Each main e^- dump is rated at 120 kW
- Beam rate must be reduced when charge is increased
- *e.g.*, 100 pC @ 300 kHz, or 30 pC @ 1 MHz

High-Energy Upgrade → *LCLS-II-HE*





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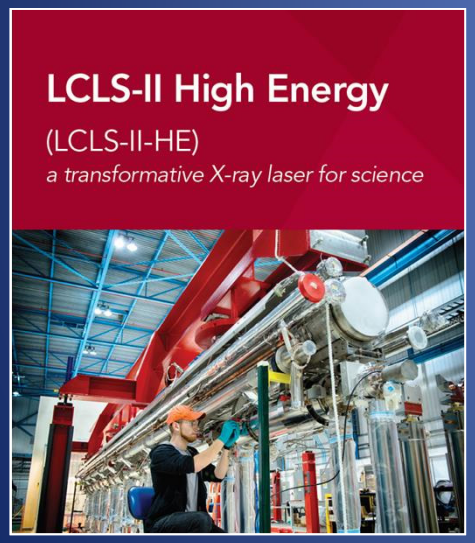
LCLS-II-*HE*

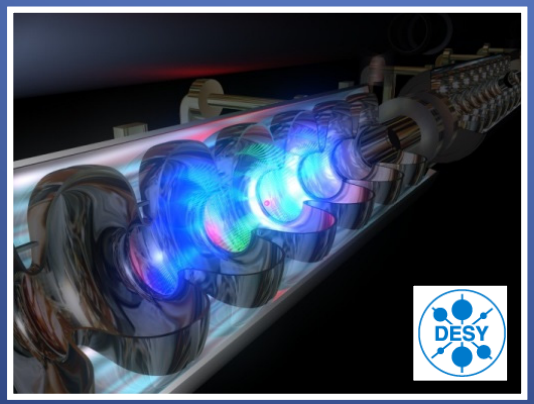
High-Energy Upgrade → *LCLS-II-HE*



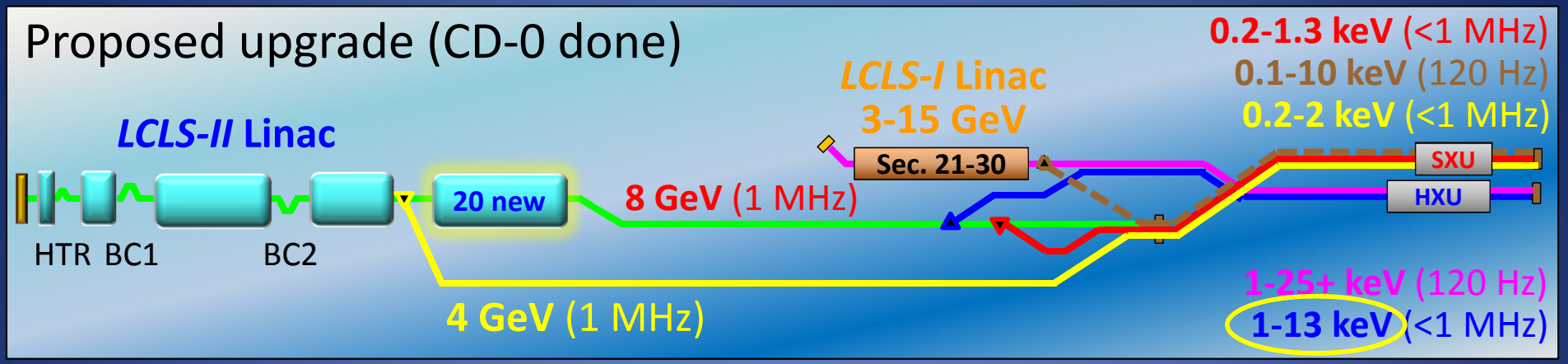
SLAC NATIONAL ACCELERATOR LABORATORY

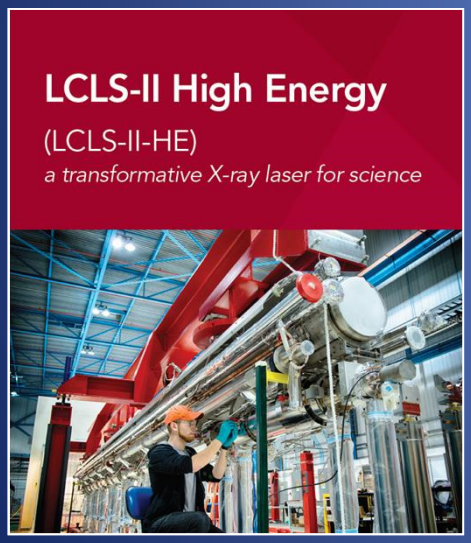
LCLS-II-*HE*

- Add 20 CM's and increase grad. to 8 GeV
- Allows up to 13 keV photons in **HXR** (was 5 keV)



High-Energy Upgrade → *LCLS-II-HE*

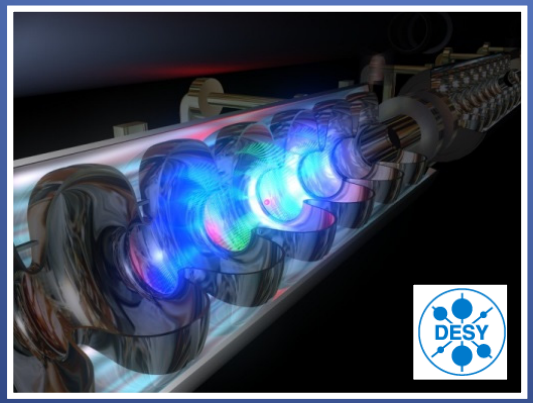




SLAC NATIONAL ACCELERATOR LABORATORY

LCLS-II-*HE*

- Add 20 CM's and increase grad. to 8 GeV
- Allows up to 13 keV photons in HXR (was 5 keV)
- Add new beam take-off kicker at 3.8 GeV…
- …and transport to SXR (0.2 to 2 keV)
- Allows simultaneous 8-GeV in HXR & 4-GeV in SXR

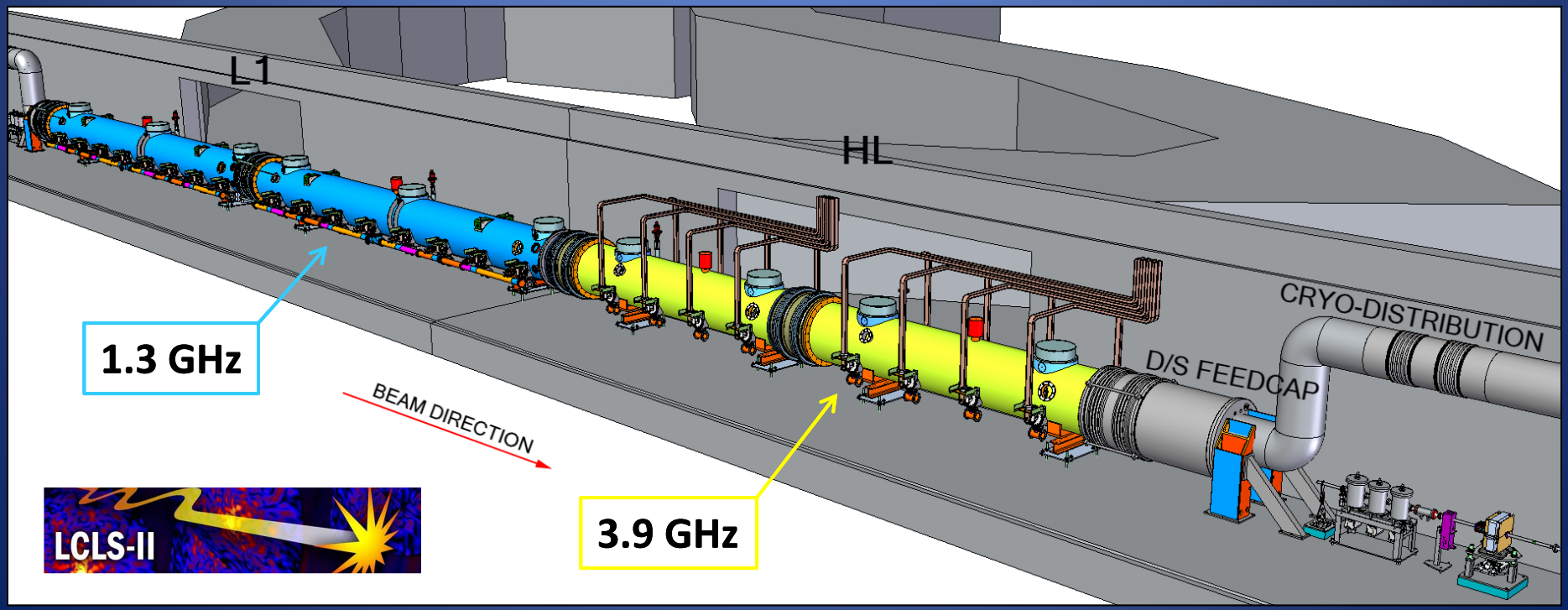


Old *SLAC* Linac Removed in 1st km

Old *SLAC* Linac Removed in 1st km

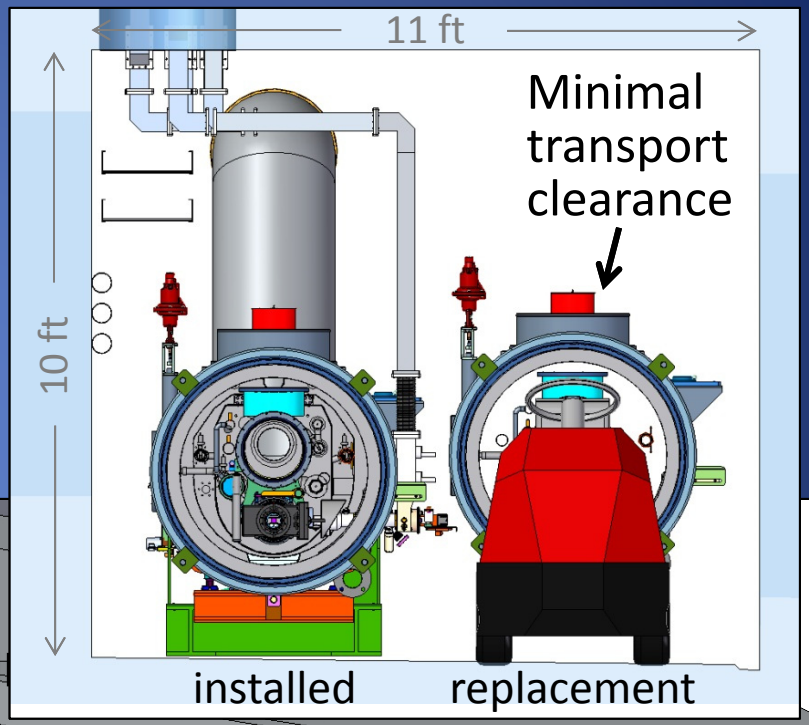
Install New SRF-Linac

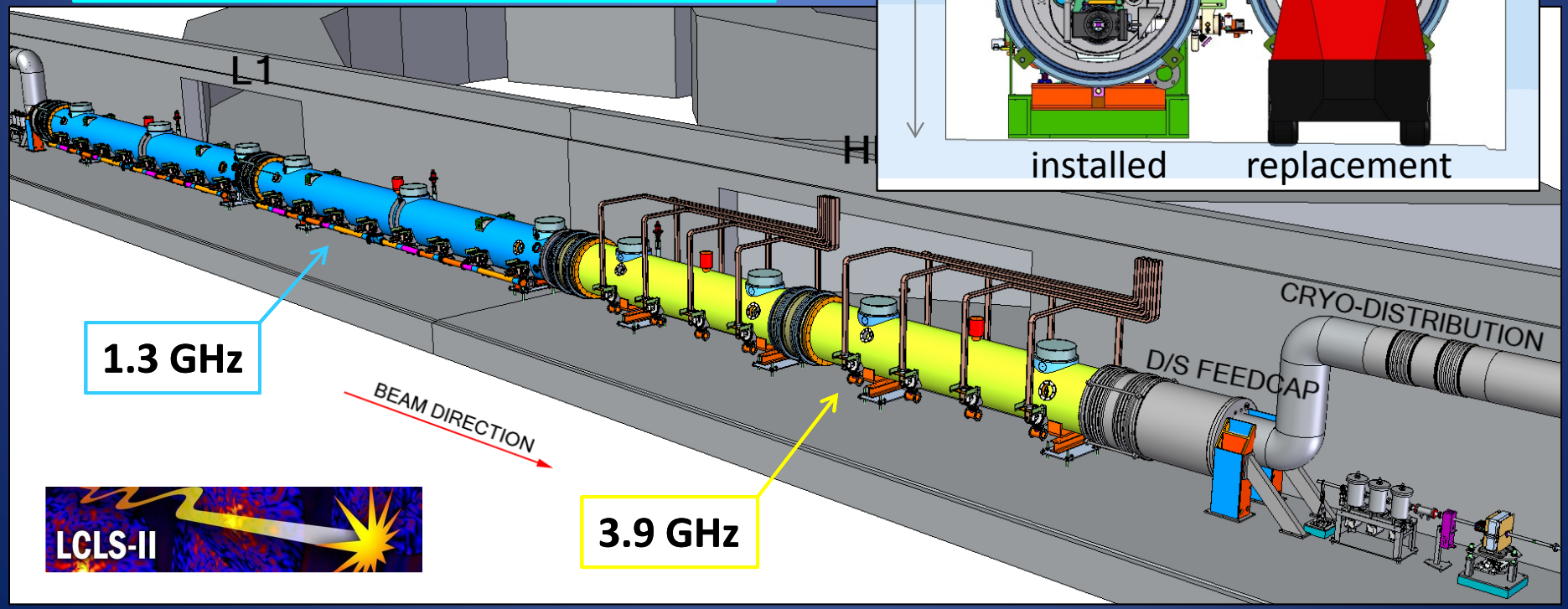
- Install 35 + 2 cryomodules
- Start in Fall 2018



Install New SRF-Linac

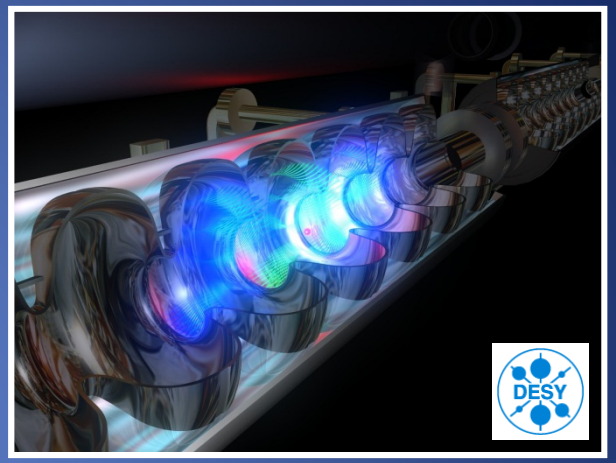
- Install 35 + 2 cryomodules
- Start in Fall 2018
- Tunnel clearance is tight →





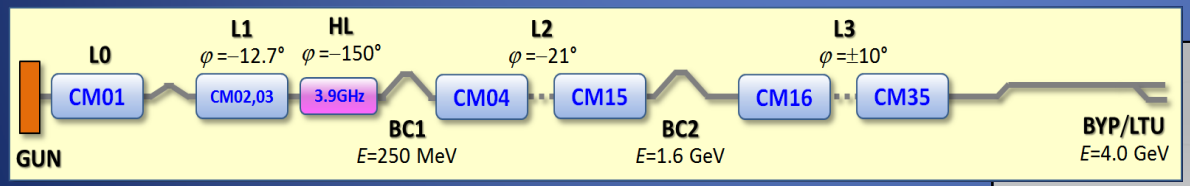
Superconducting CW RF

Parameter	Value	Unit
RF frequency (L-band)	**1.3**	GHz
Operating temperature	**2.0**	K
Number of cavities per CM	**8**	-
Number of 12-m CM's	35	-
Mean operating gradient	**16**	MV/m
Cavity quality factor, $\langle Q_0 \rangle$	**2.7**	10^{10}
External quality factor, $\langle Q_{ext} \rangle$	4.1	10^7
RF power/cavity (0.1 mA)	3.8	kW
Total cryo power (2 plants)	4 + 4	kW

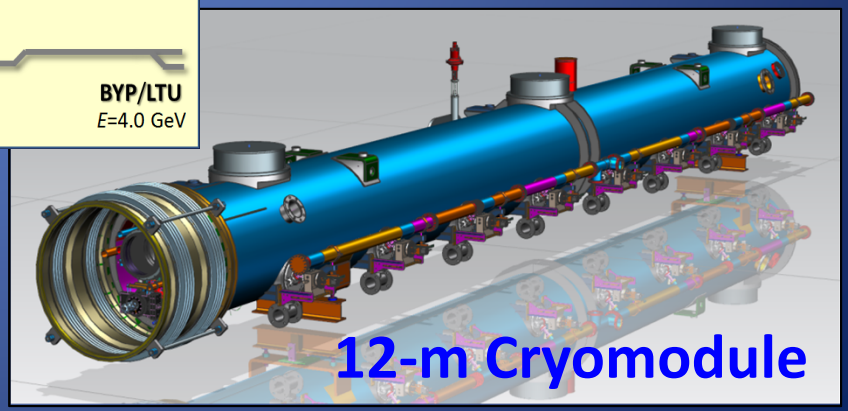


Fermilab

Jefferson Lab



- Avg. current ≈ 0.1 mA
- **One solid-state amplifier per cavity**
- 3rd-harmonic cavities (16) also used



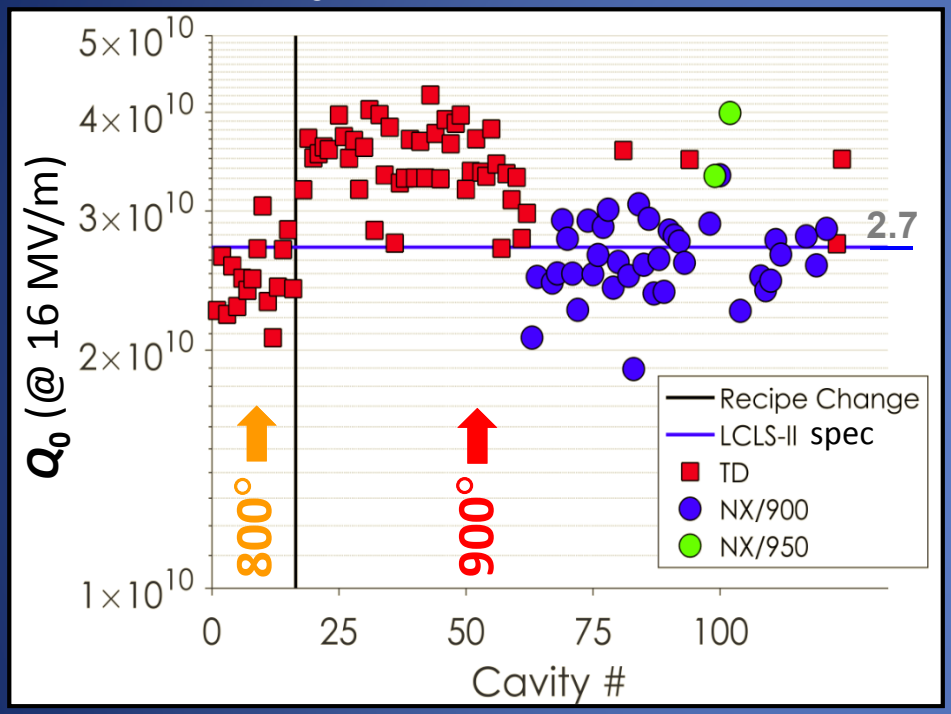
Q_0 and Grad. Measured in Single-Cavity Vertical Testing

Fermilab

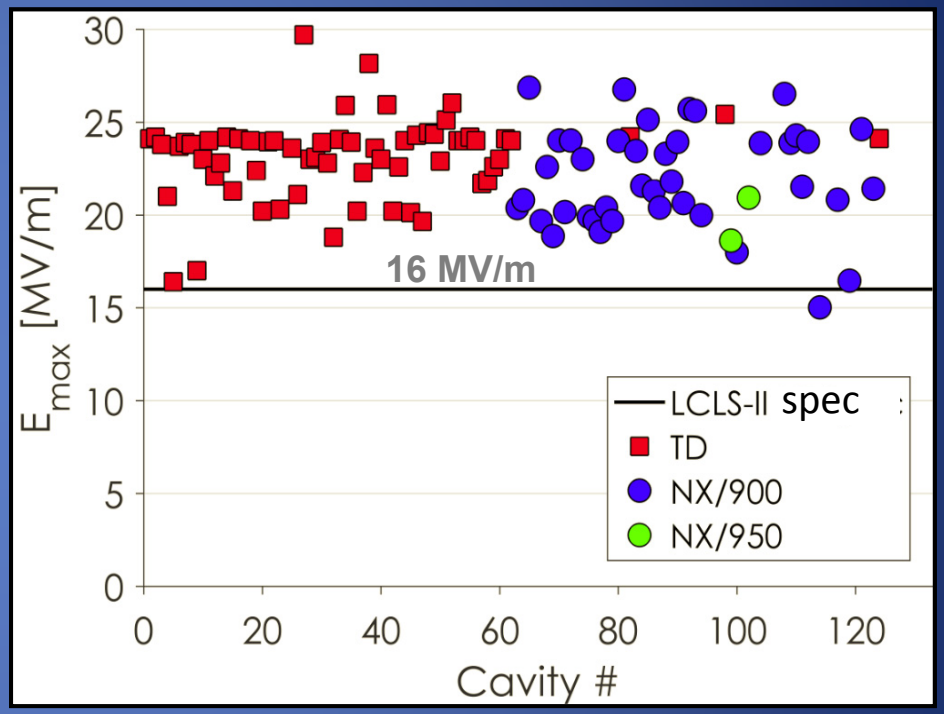
Jefferson Lab

Aug. 15, 2017

Cavity Q_0 Performance in VT

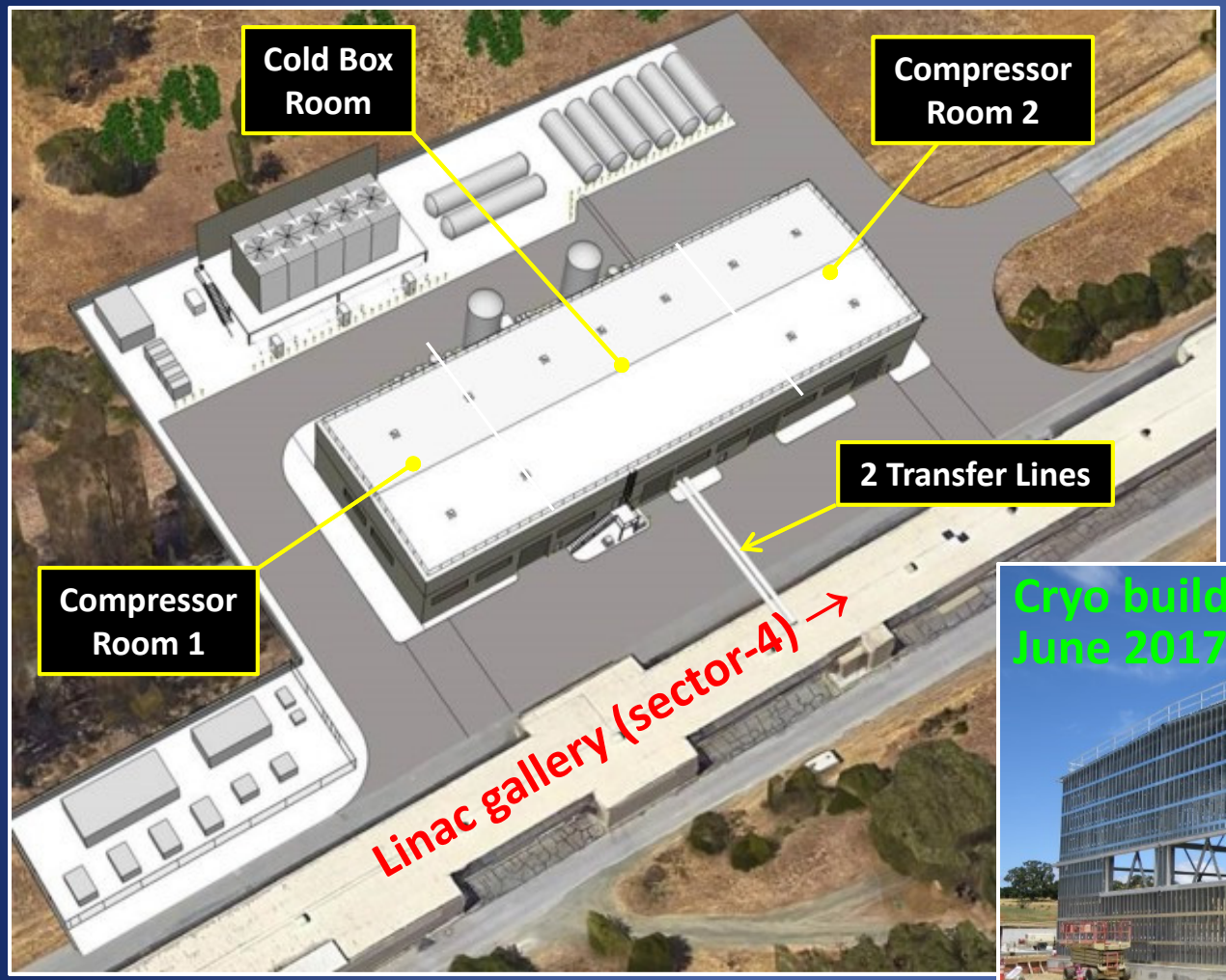


Cavity Gradient in VT



- Best cavities manufactured with TD niobium
- Cavities from NX material do not perform as well
- Bake temperature increased (950 C) for last 2 NX

Cryoplant Building – Two 4-kW plants (2K)



- Construction delayed 7 weeks due to heavy rains (26”)
- Progressing rapidly now
- Beneficial occupancy: Sep. 28, 2017

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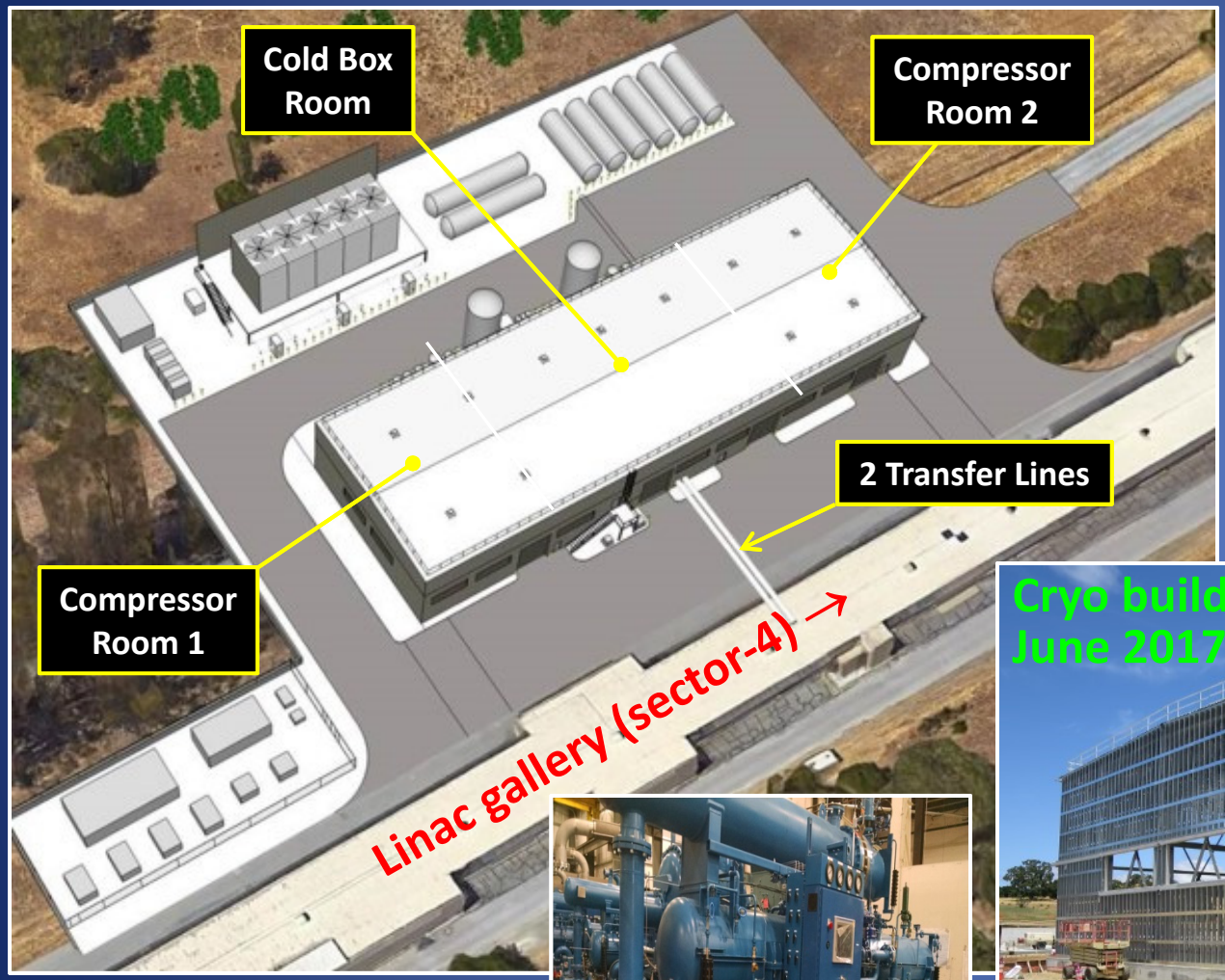
Cryoplant Building – Two 4-kW plants (2K)



- Construction delayed 7 weeks due to heavy rains (26”)
- Progressing rapidly now
- Beneficial occupancy: Sep. 28, 2017

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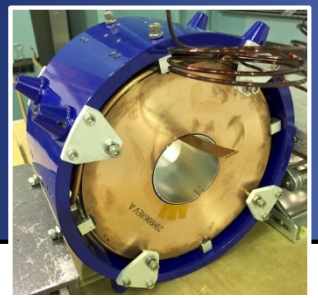
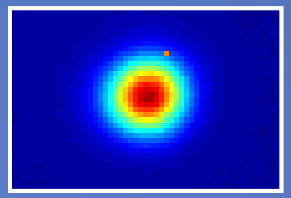
Warm Helium compressors now shipping to *SLAC* →

Gun and Injector Status

- *APEX* gun at *LBNL* has demonstrated *LCLS-II* beam brightness at 20 pC
- Gun in fab. – Delivered to *SLAC* in Sep. 2017
- Early injector commissioning starts Jan. 2018

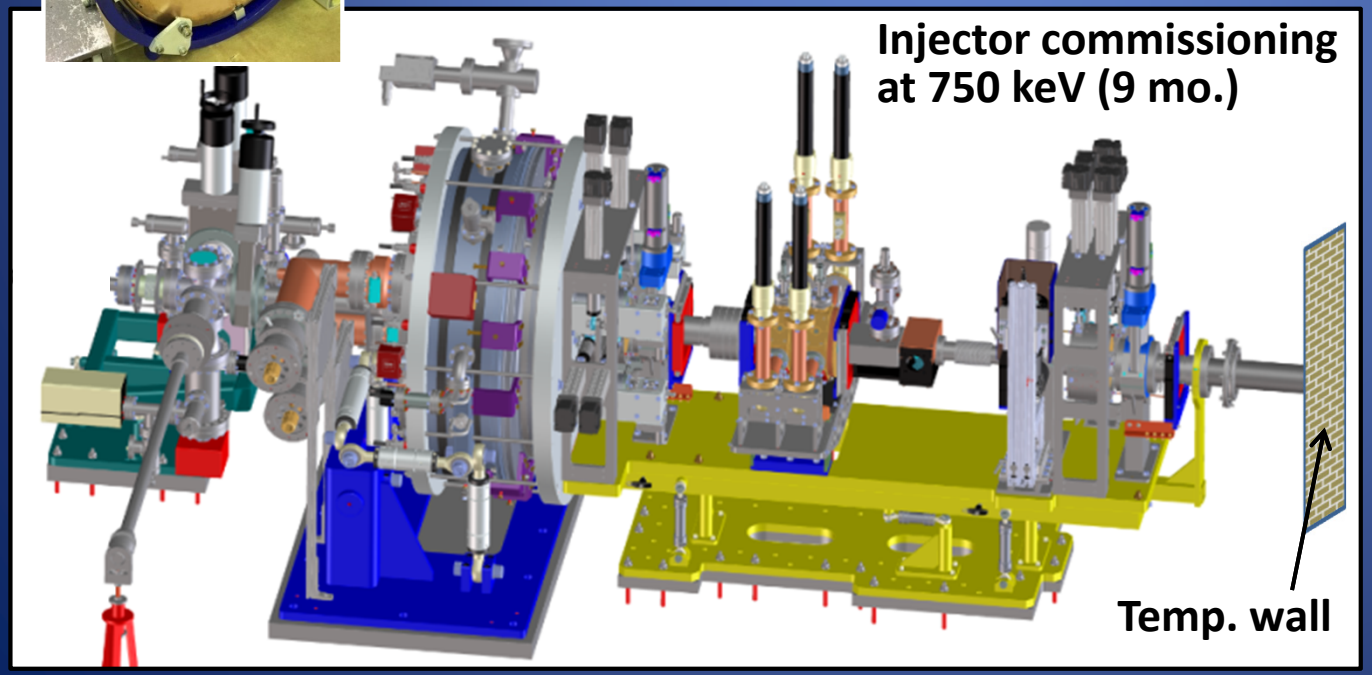


Gun solenoid



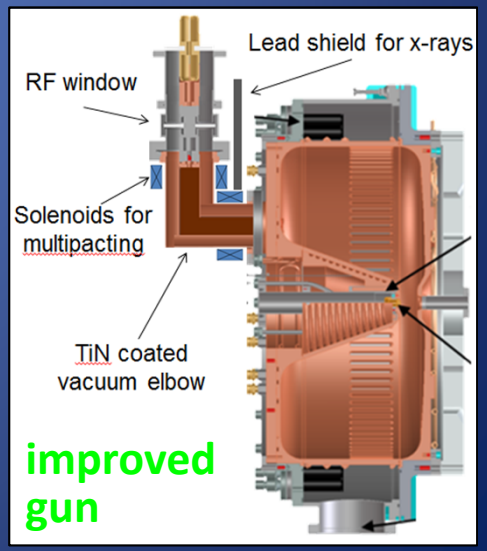
APEX beam

Gun in fab. at *LBNL*



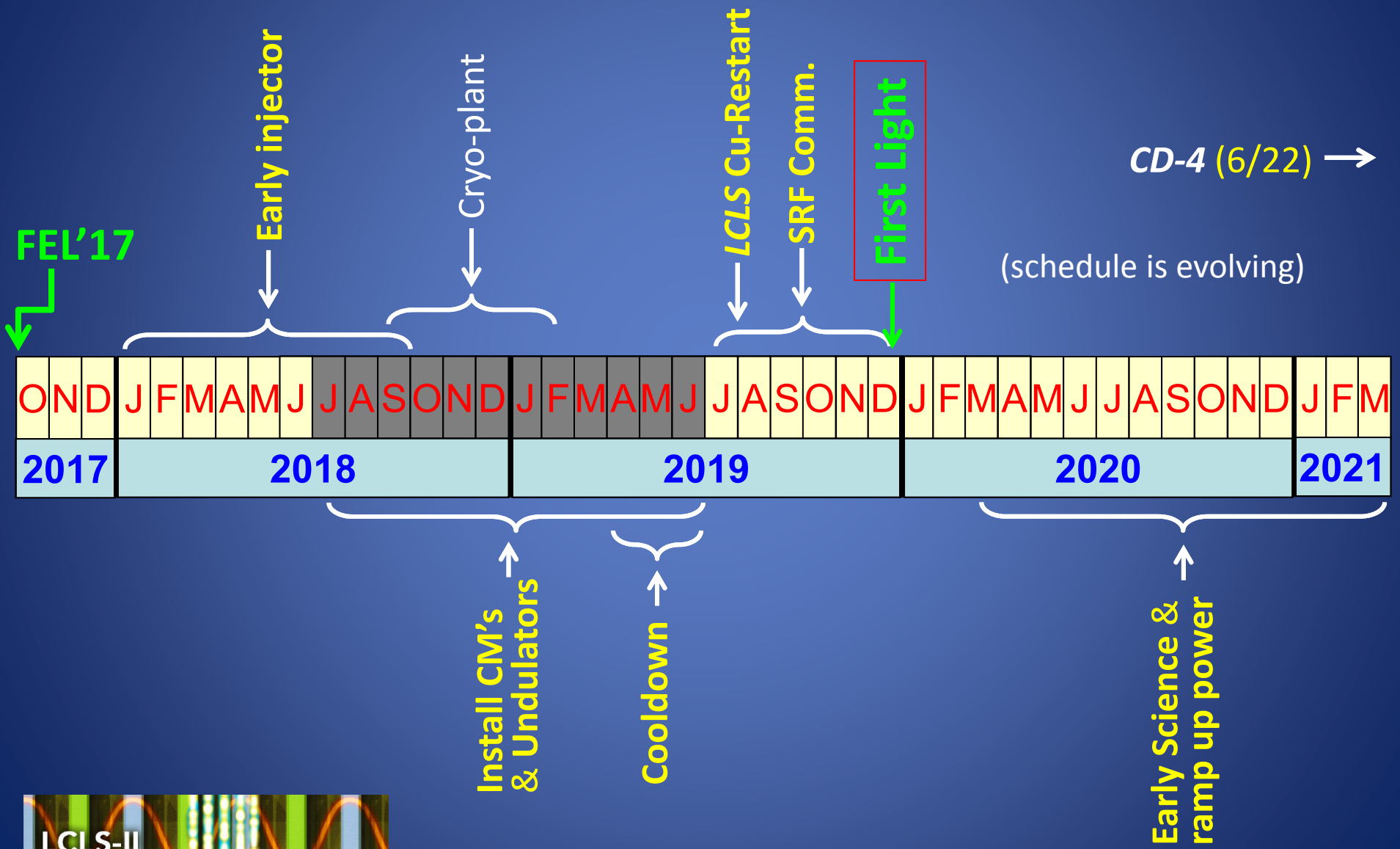
Injector commissioning at 750 keV (9 mo.)

Temp. wall



improved gun

LCLS-II Time Line



LCLS-II

Summary

- *LCLS-II* will be a highly flexible machine with…
  - Two separate linacs (CuRF & SRF)
  - Two separate undulators (variable gap)
  - High-rate x-rays at 0.2-5 keV (13-keV upgrade)
  - Low-rate x-rays at 1-25 keV
  - Variable wavelength, pulse length, power, and rate
- Avg. electron power up to 1 MW (in linac)
- Avg. x-ray power approaching 1 kW
- "First Light" at end of CY-2019
- Upgrade paths (8 GeV, SXRSS, SC-undulators, $\gamma\varepsilon\downarrow$)

Thank You