LCLS-II Project

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17 June 2014

Outline

Quick History

LCLS

LCLS-II

LCLS-II transmogrified

"transformed, especially in a surprising or magical manner"

Performance objectives

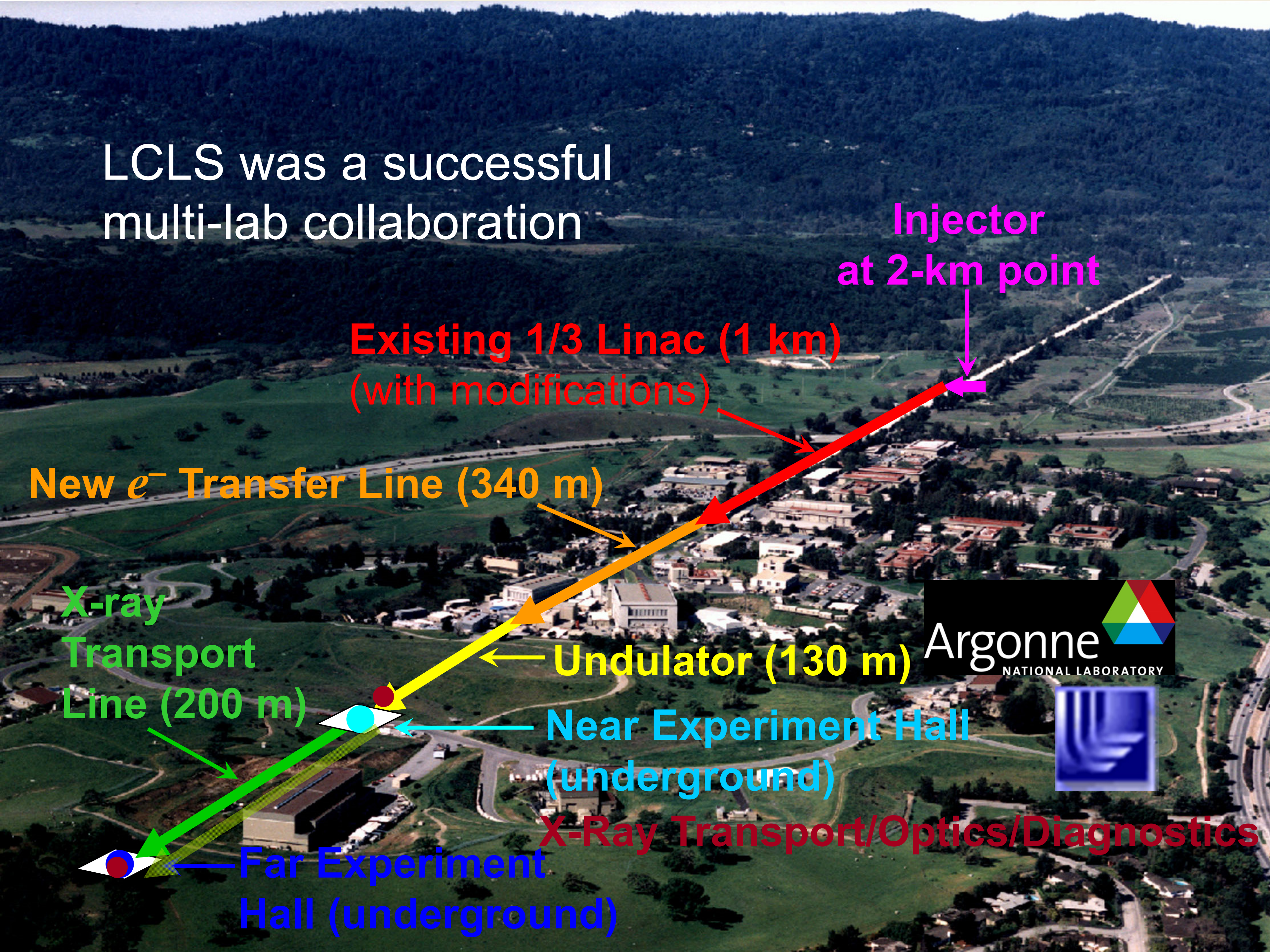
Overview description

Looking ahead


SLAC 3 km linac
1962: start construction
1967: first 20 GeV electron beam

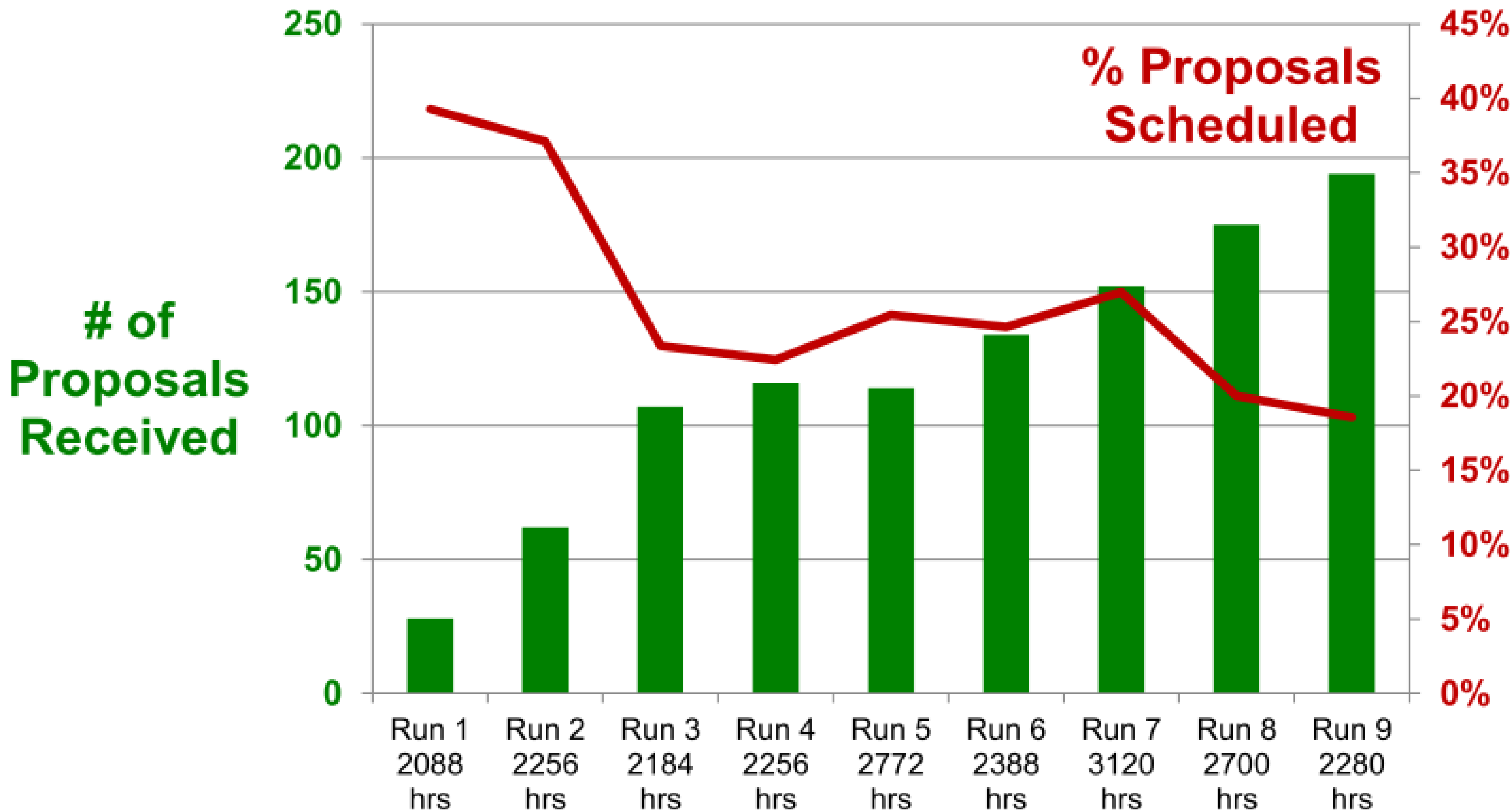
LCLS: 17 years from idea to first light

1992: Proposal (Pellegrini), Study Group(Winick)
1994: National Academies Report http://books.nap.edu/books/NI000099/html/index.html
1996: Design Study Group (M. Cornacchia)
1997: BESAC (Birgeneau) Report http://www.sc.doe.gov/production/bes/BESAC/reports.html
1998: LCLS Design Study Report SLAC-521
1999: BESAC (Leone) Report http://www.sc.doe.gov/production/bes/BESAC/reports.html
$1.5M/year, 4 years
2000: LCLS- the First Experiments (Shenoy & Stohr) SLAC-R-611
2001: DOE Critical Decision 0 – Permission to develop concept
2002: LCLS Conceptual Design
DOE Critical Decision 1 Permission to do Engineering Design
$36M for Project Engineering Design
2003: DOE Critical Decision 2A: accept estimate of
$30M in 2005 for Long Lead Procurements
2004: DOE 20-Year Facilities Roadmap
2005: Critical Decision 2B: Define Project Baseline
Critical Decision 3A: Long-Lead Acquisitions
2006: Critical Decision 3B: Groundbreaking
2009: First Light, 10 April 2009
2010: Project Completion

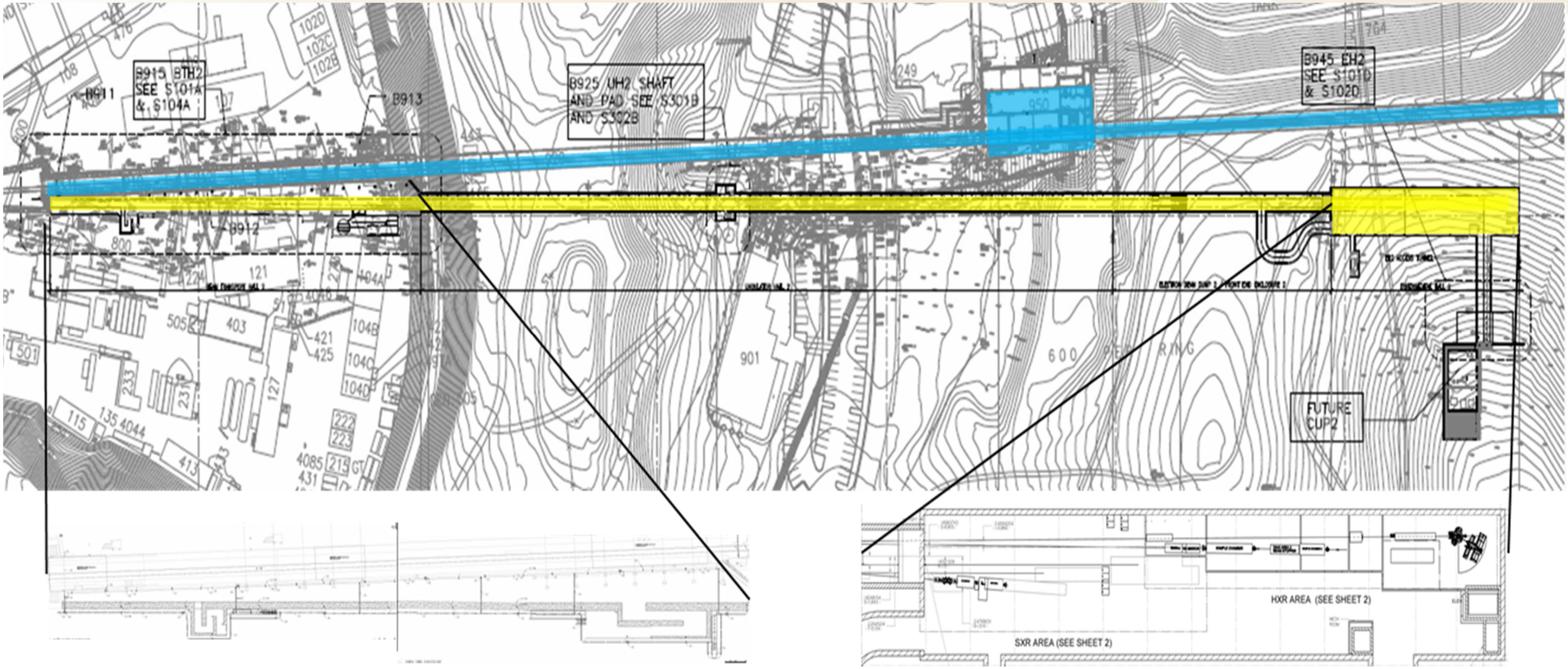

LCLS was a successful
multi-lab collaboration
Injector
at 2-km point
Existing 1/3 Linac (1 km)
(with modifications)
New e^- Transfer Line (340 m)
X-ray
Transport
Line (200 m)
Undulator (130 m)
Near Experiment Hall
(underground)
Argonne
NATIONAL LABORATORY
X-Ray Transport/Optics/Diagnostics
Far Experiment
Hall (underground)

Heavy Demand for Beam Time

October 2009 → August 2014



LCLS-II was… More LCLS: 120 Hz, High energy/pulse



BESAC Subcommittee Outcome: July 25, 2013

- Committee report & presentation to BESAC:
  - "It is considered essential that the new light source have the pulse characteristics and **high repetition rate** necessary to carry out a broad range of coherent "pump probe" experiments, in addition to a sufficiently broad photon energy range (**at least *~0.2 keV to ~5.0 keV***)"
  - "It appears that such a new light source that would meet the challenges of the future by *delivering a capability that is beyond that of any existing or planned facility worldwide is now within reach.* **However, *no proposal presented to the BESAC light source sub-committee meets these criteria*.**"
  - "The panel recommends that a decision to proceed toward a new light source with revolutionary capabilities be accompanied by a robust R&D effort in accelerator and detector technology that will maximize the cost-efficiency of the facility and fully utilize its unprecedented source characteristics."

LCLS-II Concept by August 2013

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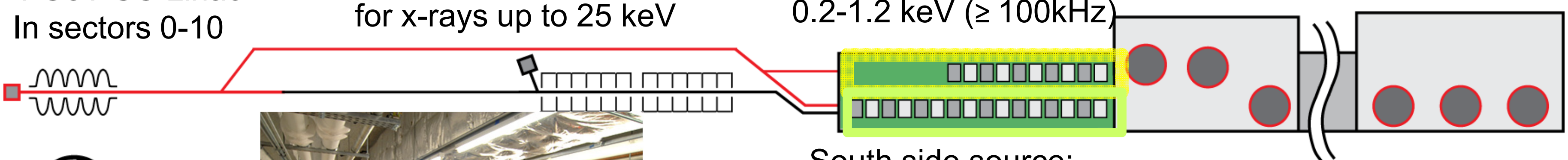
Accelerator	<u>Superconducting linac</u>: 4 GeV
Undulators in existing LCLS-I Tunnel	New variable gap (north) New variable gap (south), replaces existing fixed-gap und.
Instruments	Re-purpose existing instruments (instrument and detector upgrades needed to fully exploit)



Accelerator Layout

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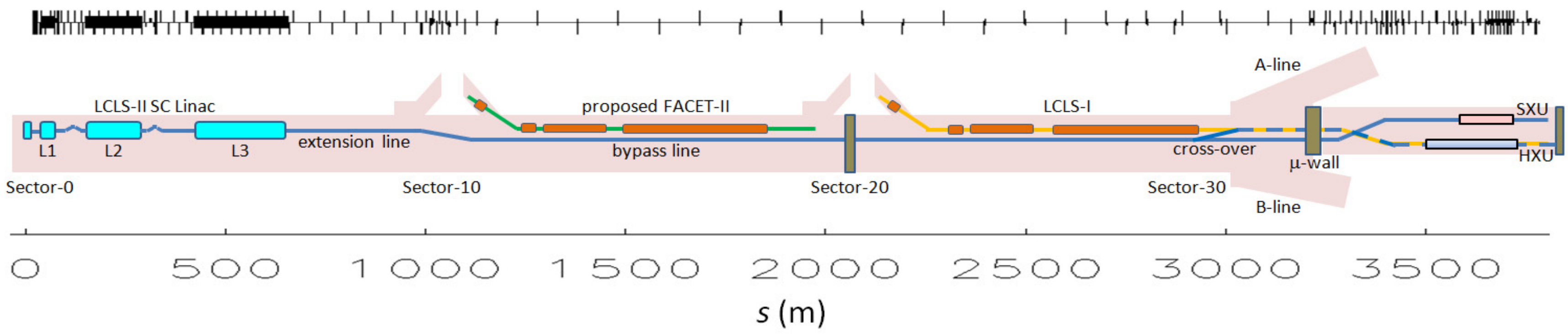
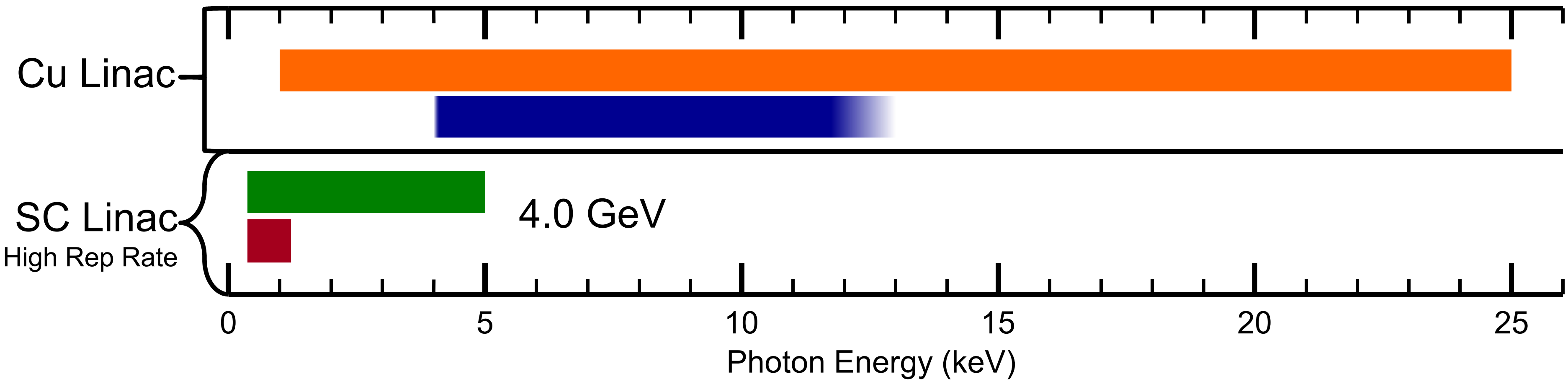


- New Injector, SCRF linac, and extension installed in Sectors 0-10
- Re-use existing Bypass line from Sector 10 → BSY
- Re-use existing high power dump in BSY and add rf spreader to direct beams to dump, SXR or HXR
- Install new variable gap HXR (replacing LCLS-I) and SXR
- Re-use existing transfer line (LTU) to HXR; modify HXR dump
- Construct new LTU to SXR and new dump line
- Modify existing LCLS-I X-ray optics and build new SXR X-ray line



Legend

- Cu SASE
- Cu Self Seeded
- High Rep Rate SASE
- Self Seeded (Grating)

- Hard X-Ray Source:
  - 1-5 keV w/ 4 GeV SC linac
  - Up to 25 keV with LCLS Cu Linac
- Soft X-Ray Source:
  - 250 eV-1.2 keV w/ 4 GeV linac
    - 200 eV requires <4 GeV

Timeline past/future

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- BESAC subcommittee report 25 July 2013
- Revised MNS signed 27 Sep 2013
    - Project planning meeting @ SLAC 9-11 Oct 2013
        - All partner labs attended
        - Defined roles for conceptual design
- First Cost Rollup 28 Oct 2013
- Lab Directors' Council: MoA signed 8 Nov 2013
- External review of draft CDR 28 Nov 2013
- Director's review of Project 9 Dec 2013
- DoE Review: CD-1 4-6 Feb 2014
- Niobium advance procurement Sep 2014
- First Light (if funding permits) Sep 2019
- DOE Critical Decision 4: Construction <u>done</u> Sep 2021

Very Basic Requirements from DOE

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"Threshold"

- Proves construction is "done"

"Objective"

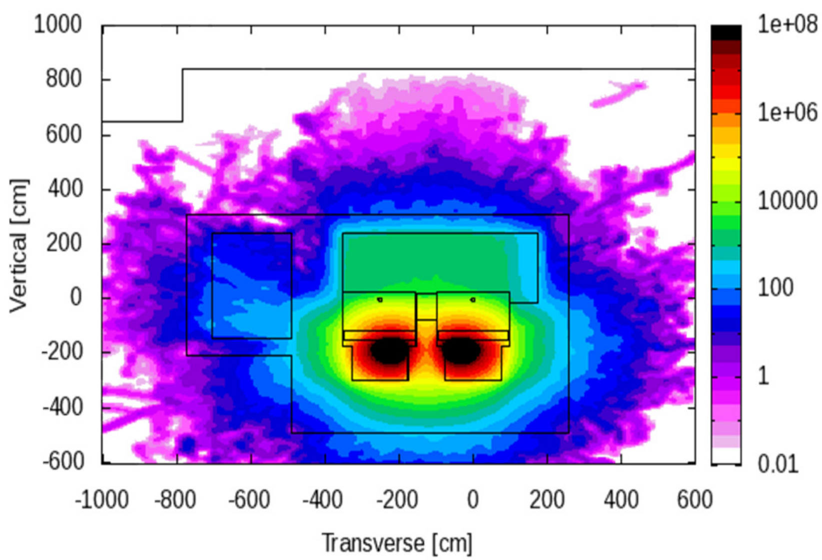
- Design must be capable of doing this

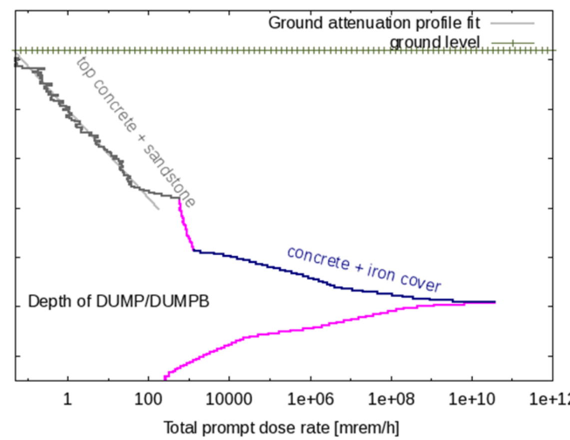
Performance Measure	Threshold	Objective
Variable Gap Undulators	2 (SXR & HXR)	2 (SXR & HXR)
Super Conducting Linac Based FEL System		
Super Conducting Linac Electron Beam Energy	3 GeV	≥ 4 GeV
Super Conducting Linac Repetition Rate	50 kHz	1,000 kHz
Super Conducting Linac Charge per Bunch	0.02 nC	0.1 nC
Photon Beam Energy Range	0.25-2 keV	0.2-5 keV
High Repetition Rate Capable End Stations	≥ 1	≥ 3
FEL per-pulse intensity on-axis	10X spontaneous	>10^11 photons in 10^-3 BW
Normal Conducting Linac Based FEL System		
Normal Conducting Linac Electron Beam Energy	13 GeV	15 GeV
Normal Conducting Linac Repetition Rate	120 Hz	120 Hz
Normal Conducting Linac Charge per Bunch	0.1 nC	0.25 nC
Photon Beam Energy Range	1-8 keV	1-25 keV
Low Repetition Rate Capable End Stations	≥ 2	≥ 3
FEL per-pulse intensity on-axis	10X spontaneous @ 8 keV	>10^12 photons in 10^-3 BW @ 13 keV

X-Ray Power

A stated project goal is to deliver at least 20 W X-rays from the SC linac, independent of repetition rate

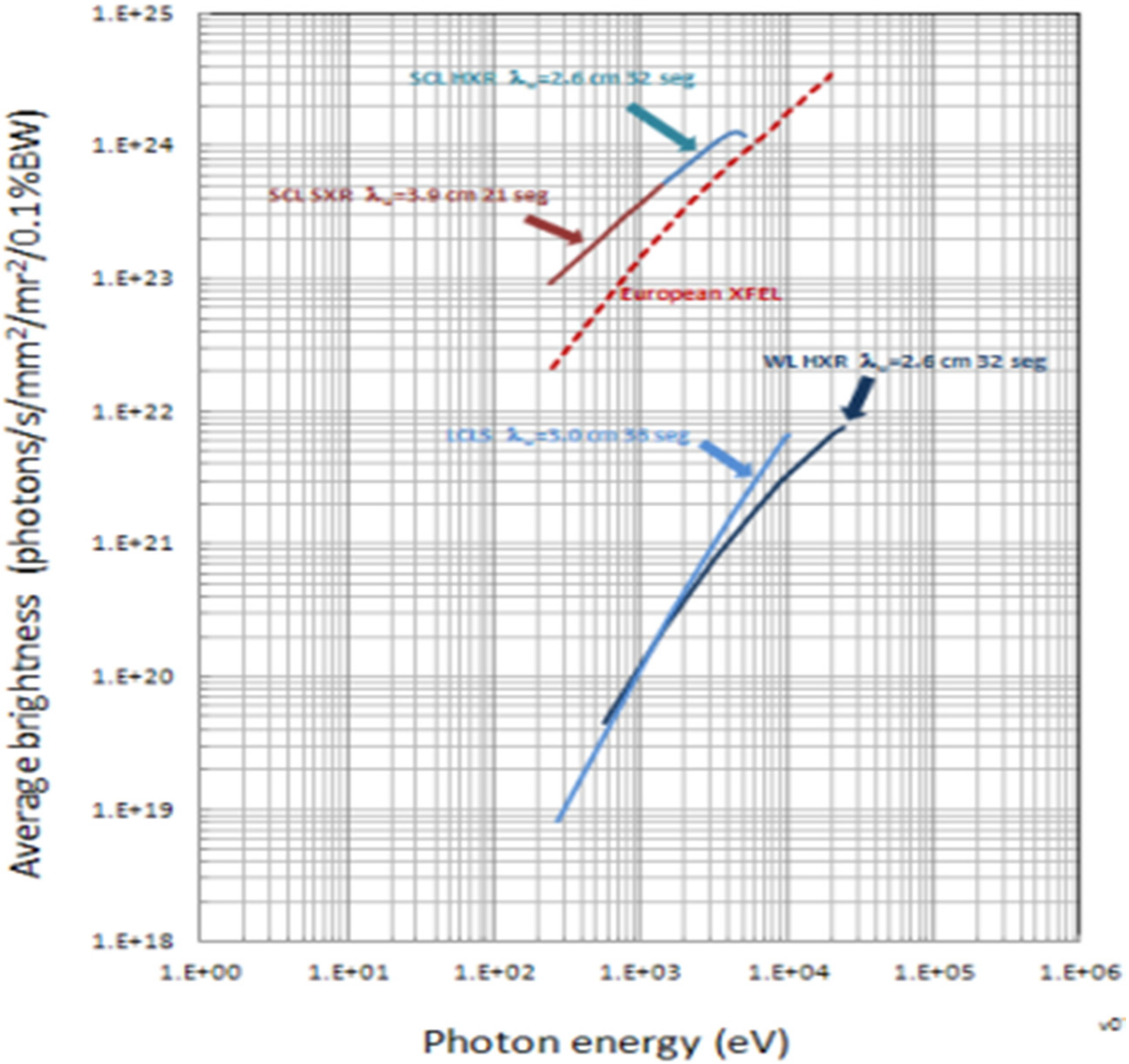
This goal can be exceeded by a large margin with 120 kW of electrons- design goal for beam dumps(M. Santana, THPIO86)





M. Santana, S. Rokni

Average Brightness



Parameters for the Accelerator

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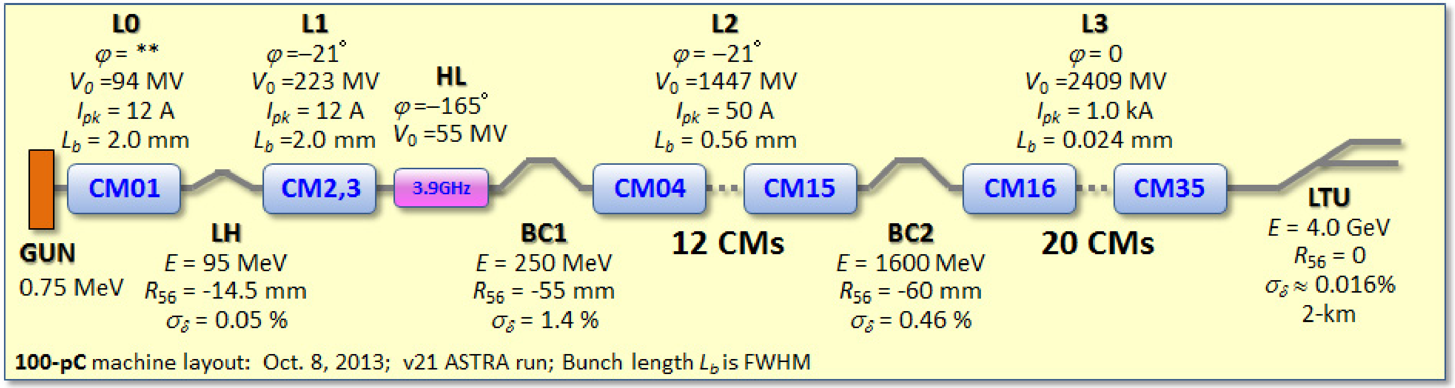
Table 1. LCLS-II Electron Beam Parameters

Parameter	Nominal	Range	Units
Final electron energy	4	2-4.14	GeV
Electron bunch charge	0.1	0.01-0.3	nC
Bunch repetition rate	0.62	0-0.93	MHz
Average linac current	62	1-300	μA
Average beam power	0.25	≤1.2	MW
emittance	0.45	0.2-0.7	μm
Peak current	1	0.5-1.5	kA
Bunch length	8.3	0.6-52	μm
Usable bunch length	50		%
Compression factor	85	25-150	
Slice energy spread	0.5	0.15-1.5	MeV
Beam stability goals			
Energy, rms	<0.01		%
Peak Current	<5		%
Bunch arrival time	<20		fs
beam stability (x, y)	<10		%

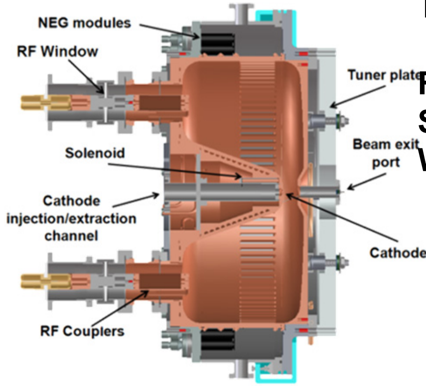
Linac Design

Linac Acceleration and Compression (100 pC)



Also considering Cornell DC Gun

Gulliford, et al. PRSTAB 16 073401 (2013)

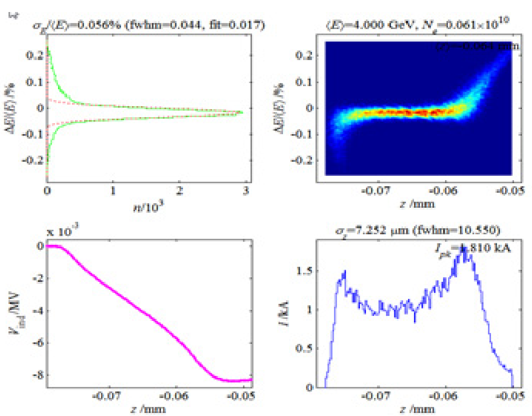


J. Staples, F. Sannibale, S. Virostek, CBP Tech Note 366, Oct. 2006

Filipetto, et al. MOPRI053, MOPRI055
Sannibale, et al. MOPRI054
Wells, et al. MOPRI056

K. Baptiste, et al, NIM A 599, 9 (2009)

Includes 2-km RW-wake



rms stability: ~0.01%, ~0.01°

SCRF Linac in SLAC Tunnel

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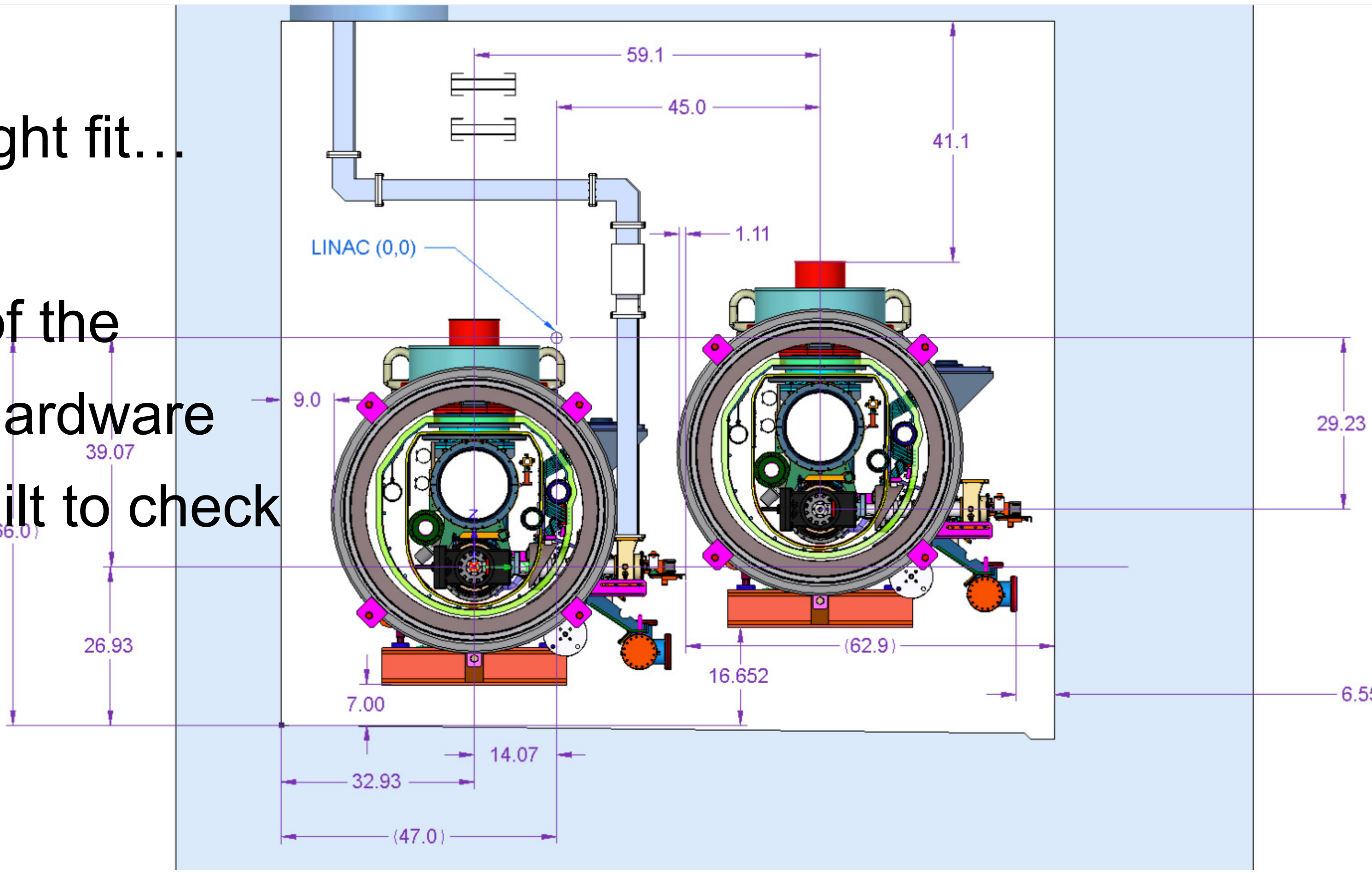
SLAC Linac Tunnel: 3.53m wide x 3.05 m high

It will be a tight fit…

A mock-up of the tunnel and hardware has been built to check clearances



S. Boo, J. Chan

Nitrogen Doping to enable 4 GeV linac, 4 kW Cryoplant
A Breakthrough for CW linac performance

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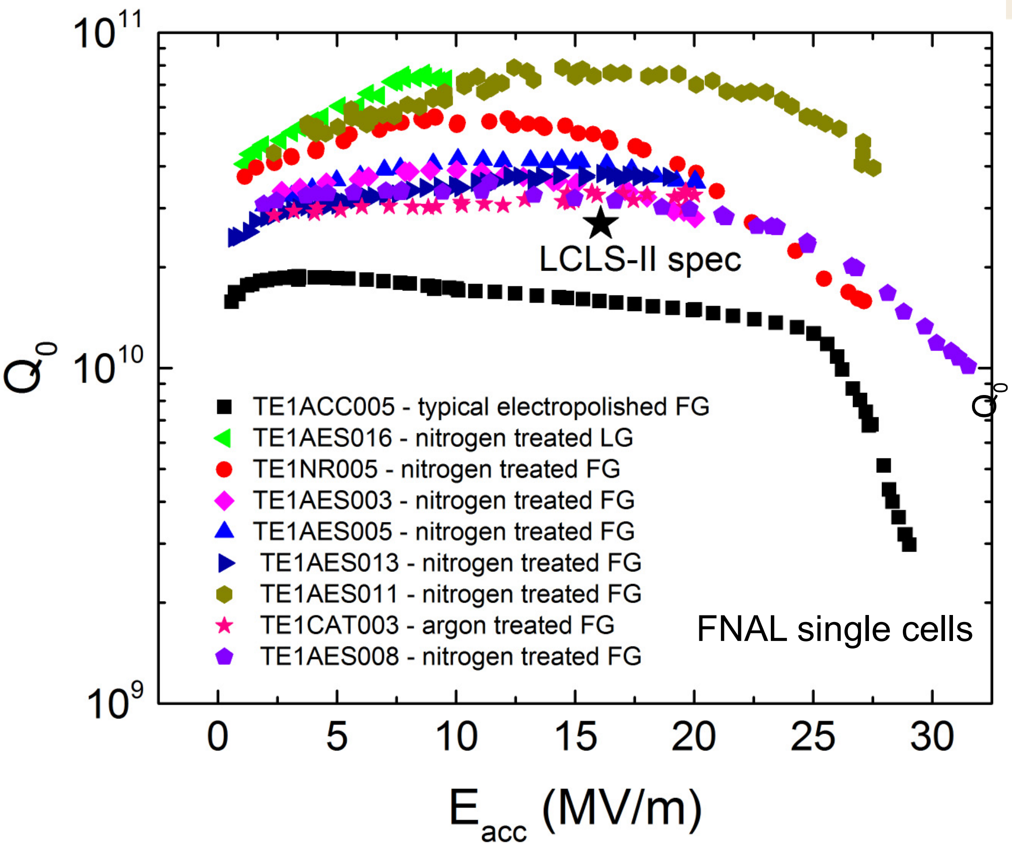
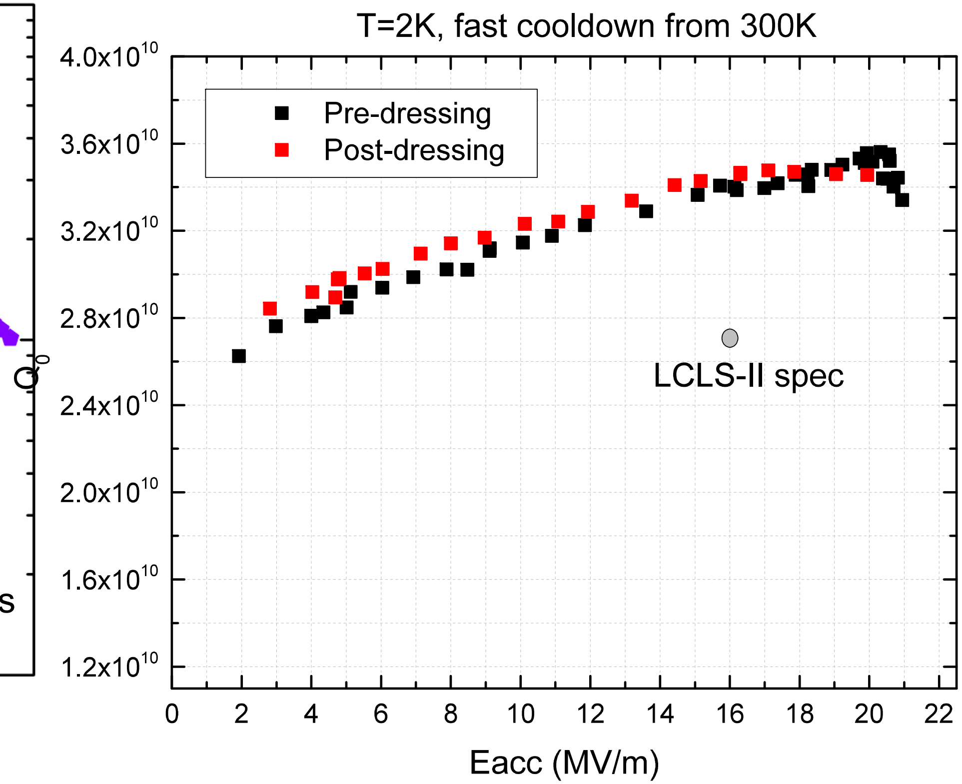


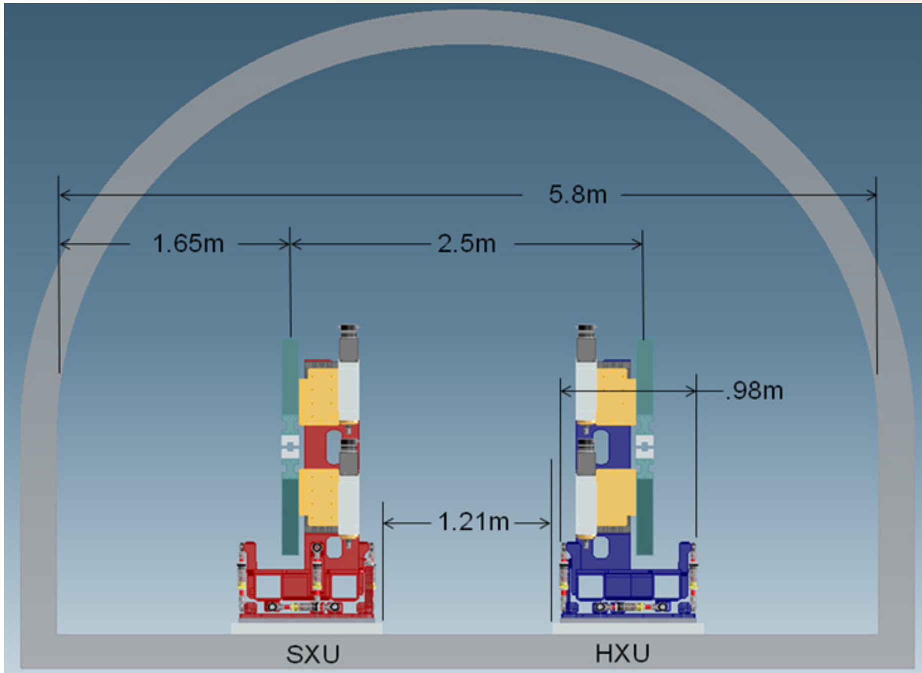


Sample of FNAL single cells results. More than 40 cavities have been nitrogen treated so far systematically producing 2-4 times higher Q than with standard surface processing techniques.

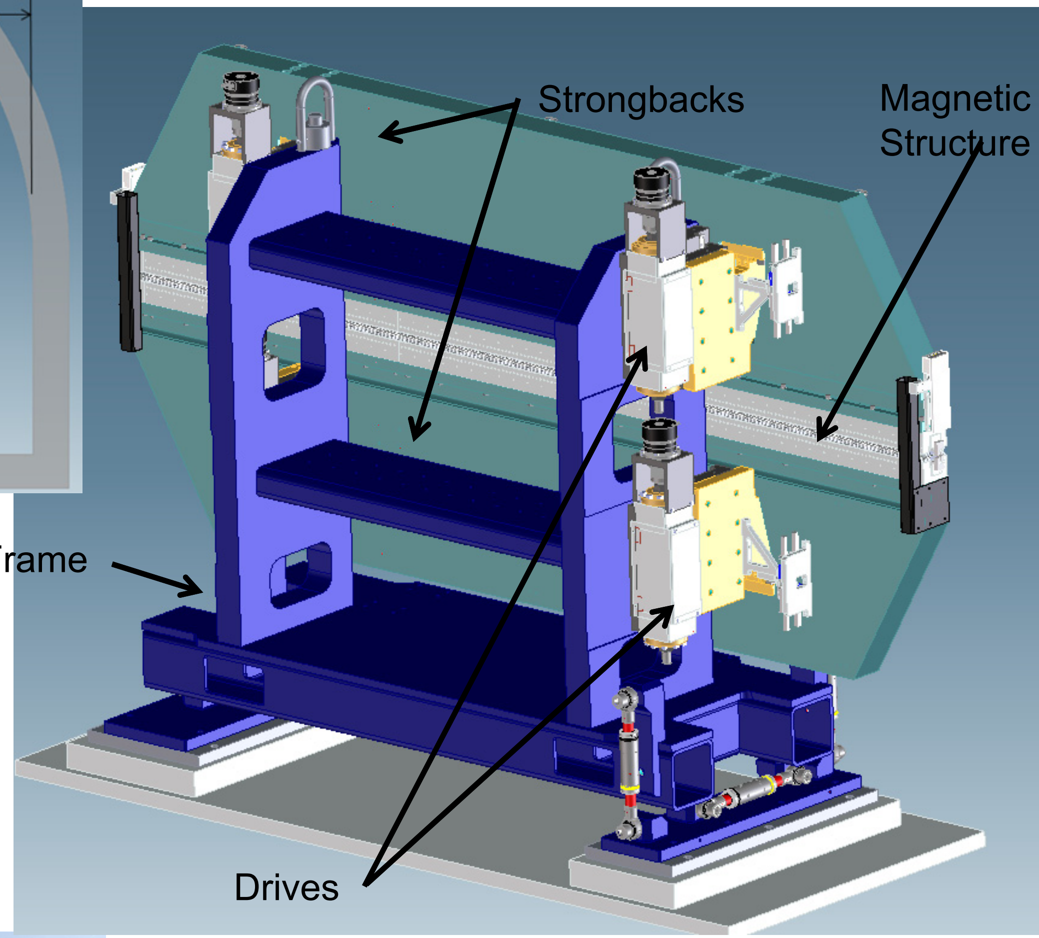
First high Q dressed cavity preserving identical performance pre-post dressing

A. Grassellino, et al., "New insights on the physics of RF surface resistance", TUIOA03, 2013 SRF Conference, Paris, France

Undulators in LCLS Undulator Hall



LBNL VG Undulator Design



Well on our way to a full scale prototype as part of LCLS-II$_{\text{Phase I}}$

D. Bruch, S. Marks, M. Rowen

Possible Instrument Layout

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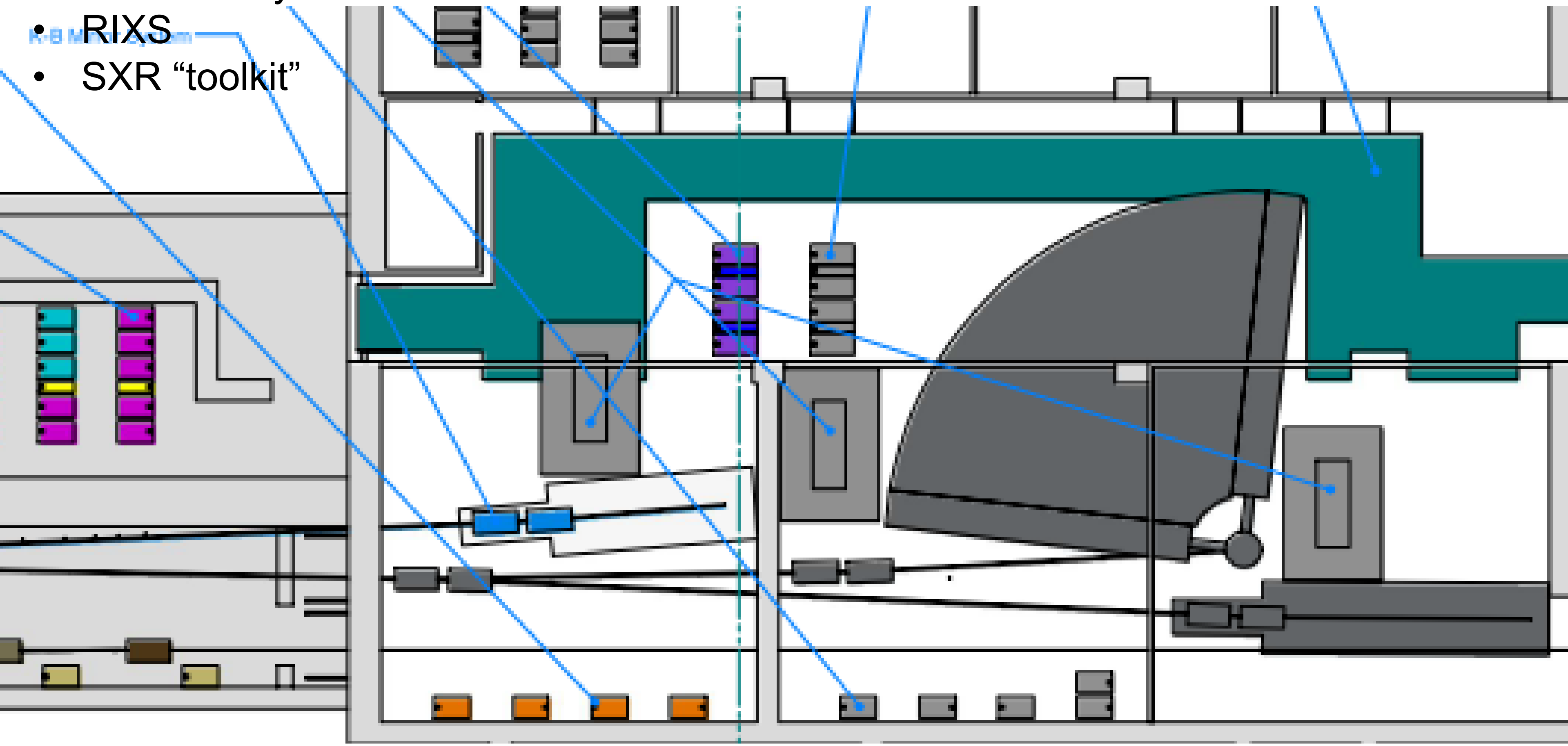
Room for
- Hi Field Phys.
- RIXS
- SXR “toolkit”



Project Collaboration: SLAC couldn't do this without…

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Fermilab

- 50% of cryomodules: 1.3 GHz
- Cryomodules: 3.9 GHz
- Cryomodule engineering/design
- Helium distribution
- Processing for high Q (FNAL-invented gas doping)

Jefferson Lab – EXPLORING THE NATURE OF MATTER

- 50% of cryomodules: 1.3 GHz
- Cryoplant selection/design
- Processing for high Q

Berkeley Lab

- Undulators
- e^- gun & associated injector systems

Argonne NATIONAL LABORATORY

- Undulator Vacuum Chamber
- Also supports FNAL w/ SCRF cleaning facility
- Undulator R&D: vertical polarization

Cornell University – Founded A.D. 1865

- R&D planning, prototype support
- processing for high-Q (high Q gas doping)
- e^- gun option

Acknowledgements

JNG and the LCLS-II collaboration gratefully acknowledge invaluable help that LCLS-II has received from colleagues in the ILC Global Design Effort, as well as the European XFEL Project and DESY. Special thanks go to Reinhard Brinkmann and Hans Weise.

JNG also thanks Tor Raubenheimer, Paul Emma and Anna Grasselino for the use of their presentation materials.

LCLS-II

End of Presentation