The New LCLS-II Project: Status and Challenges

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LINAC2014 - Geneva, Switzerland

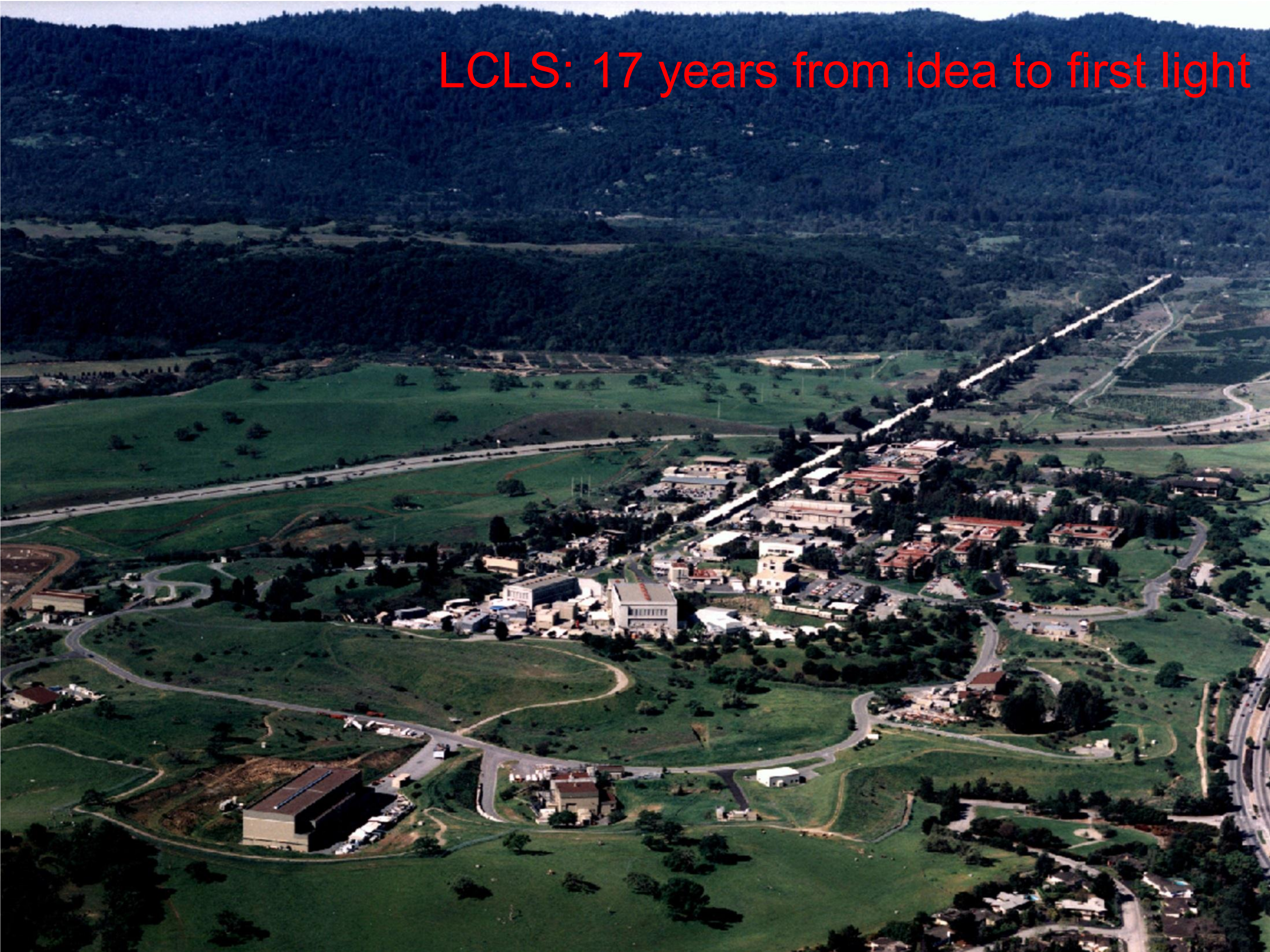
2 September 2014

SLAC NATIONAL ACCELERATOR LABORATORY
BERKELEY LAB Lawrence Berkeley National Laboratory
Argonne NATIONAL LABORATORY
Cornell University Founded A.D. 1865
Fermilab
Jefferson Lab

U.S. DEPARTMENT OF ENERGY Office of Science


SLAC 3 km linac
1962: start construction
1967: first 20 GeV electron beam
1979: first 30 GeV electron beam w/SLED
1989: first 50 GeV electrons & positrons
2006: first 84 GeV electrons: PWFA afterburner

LCLS: 17 years from idea to first light



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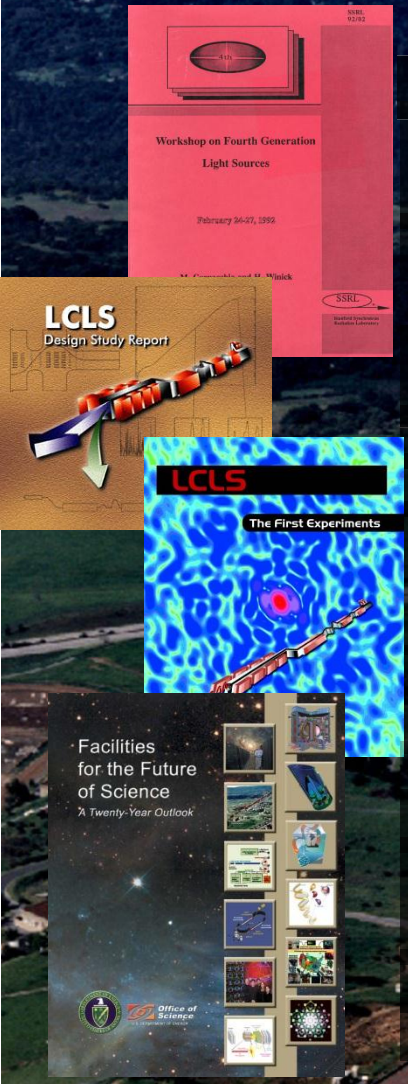


1992: Proposal (Pellegrini), Study Group(Winick)

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

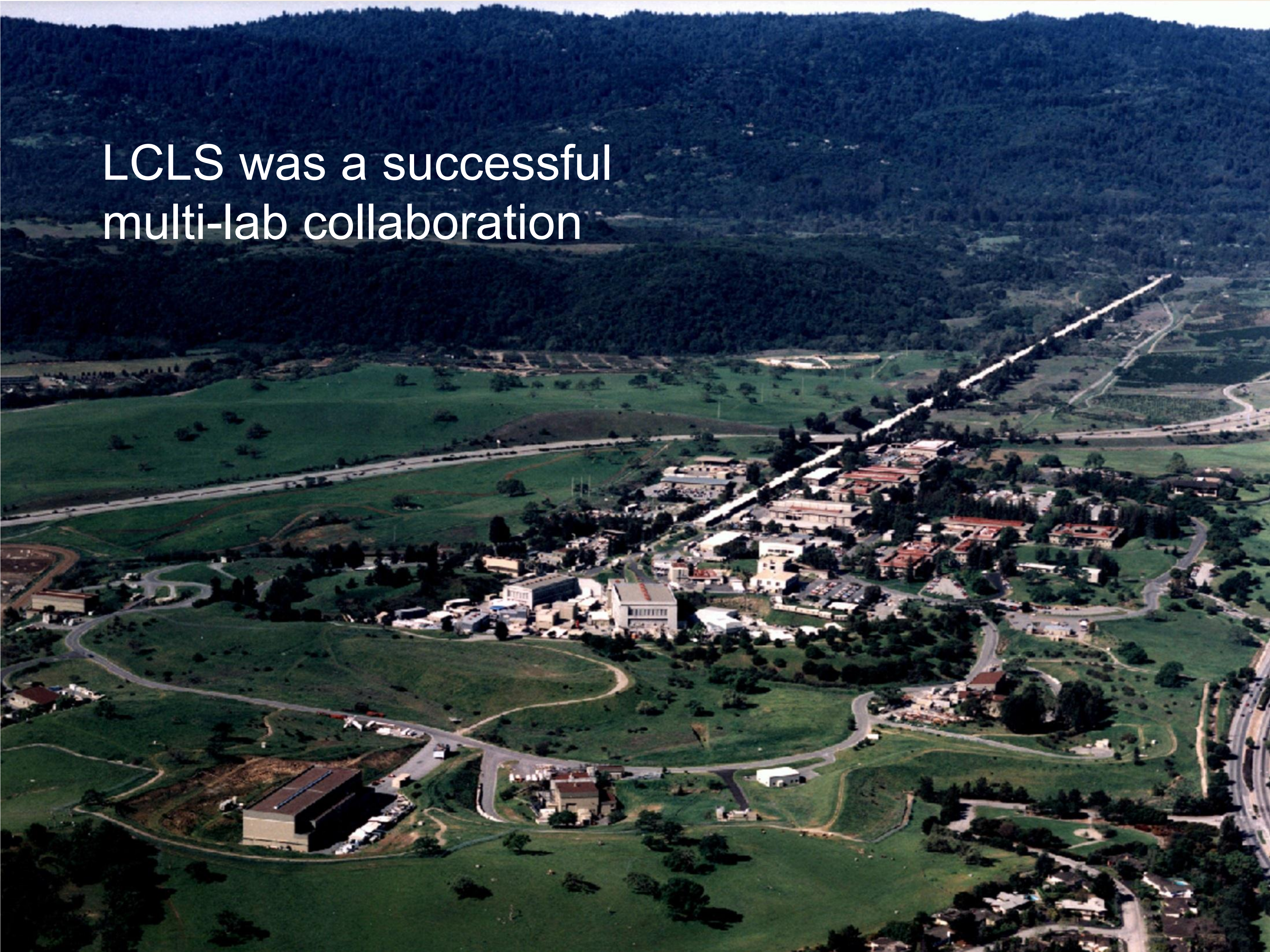
2004: DOE 20-Year Facilities Roadmap

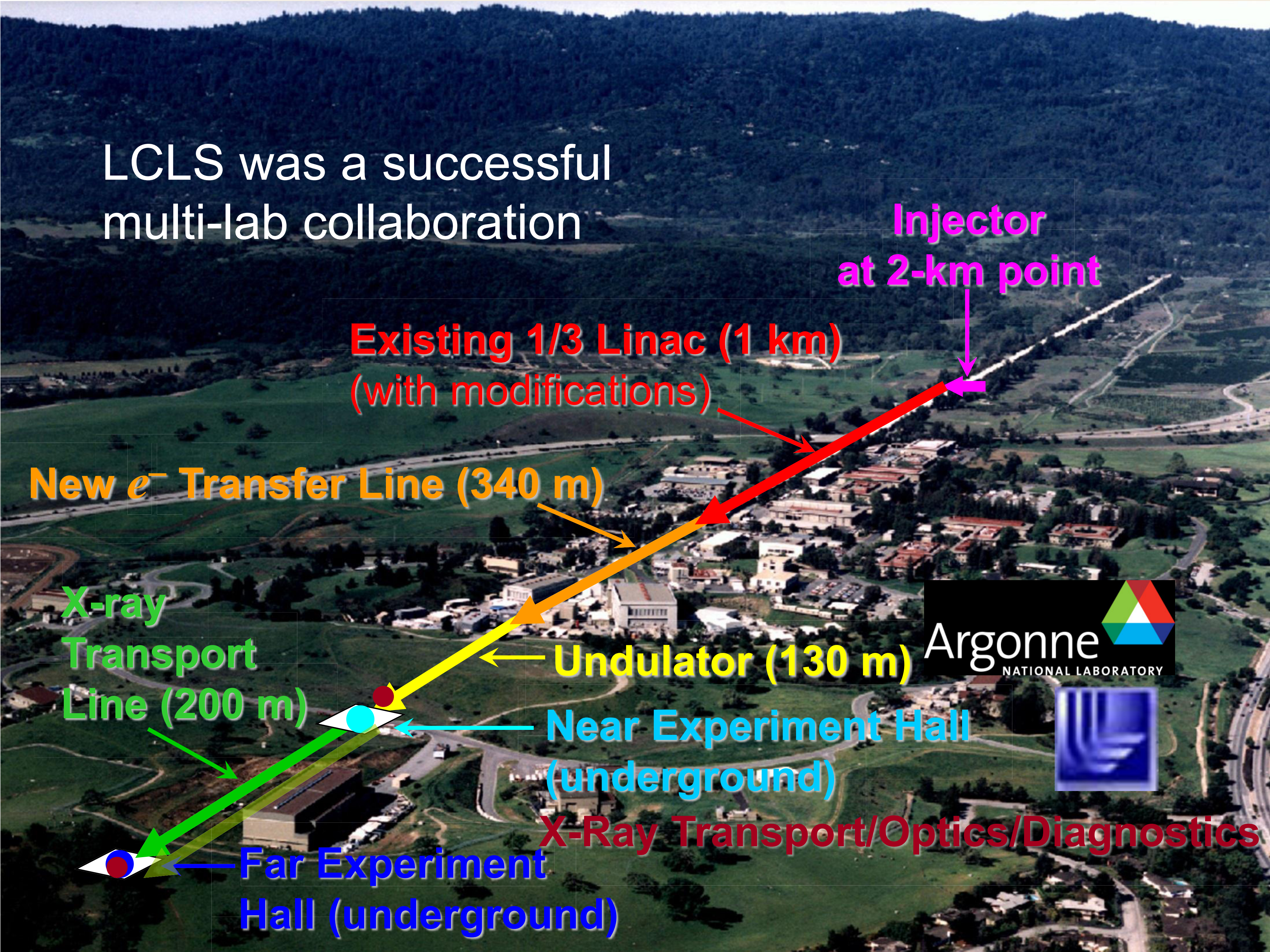
2005: Critical Decision 2B: Define Project Baseline
Critical Decision 3A: Long-Lead Acquisitions

2006: Critical Decision 3B: Groundbreaking

2009: First Light, 10 April 2009

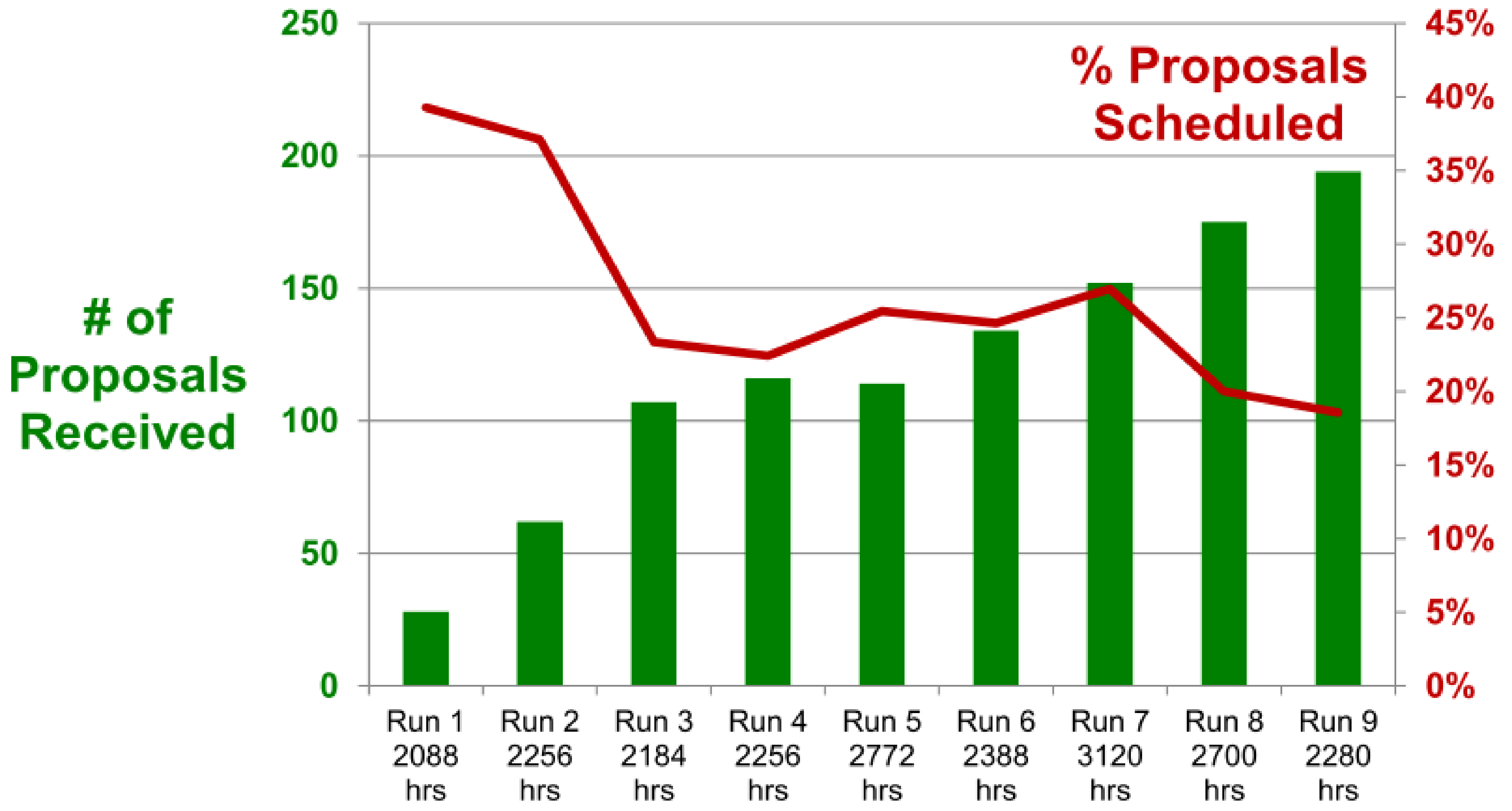
2010: Project Completion


LCLS was a successful
multi-lab collaboration


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)
Argonne
NATIONAL LABORATORY
Near Experiment Hall
(underground)
X-Ray Transport/Optics/Diagnostics
Far Experiment
Hall (underground)

Heavy demand for access to LCLS; only one undulator

October 2009 → August 2014



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."

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Timeline

So far:

• BESAC subcommittee report	25	July 2013
• DoE signed "mission need" for new source	27	Sep 2013
• First collaboration/planning meeting @ SLAC	9-11	Oct 2013
• First complete cost estimate	28	Oct 2013
• **LCLS-II Collaboration Agreement signed**	8	Nov 2013

- Critical Decision 1 – Dept of Energy permission to complete the design

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- Project completion – date not "frozen" yet

Project Collaboration: SLAC couldn't do this without…

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

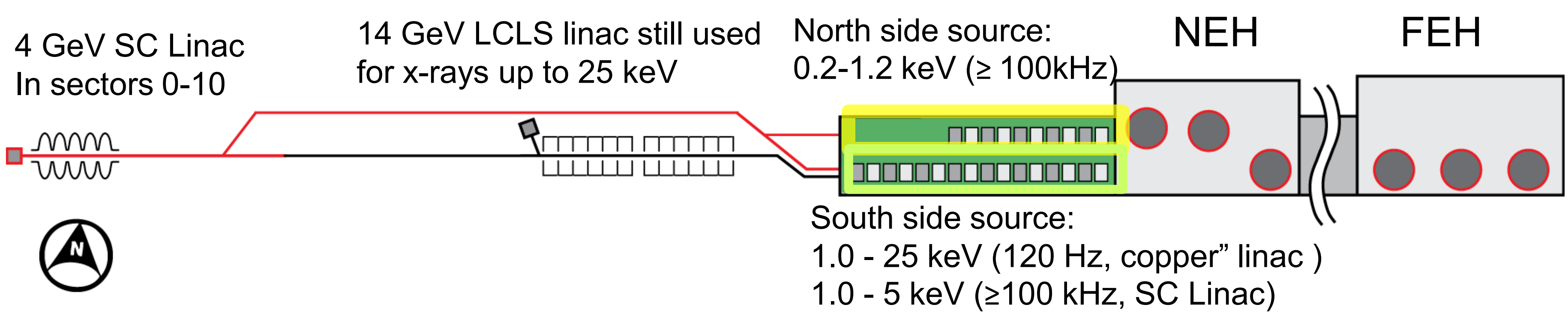
- Undulator Vacuum Chamber
- Also supports FNAL w/ SCRF cleaning facility
- Undulator R&D: vertical polarization

CORNELL UNIVERSITY
FOUNDED A.D. 1865

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

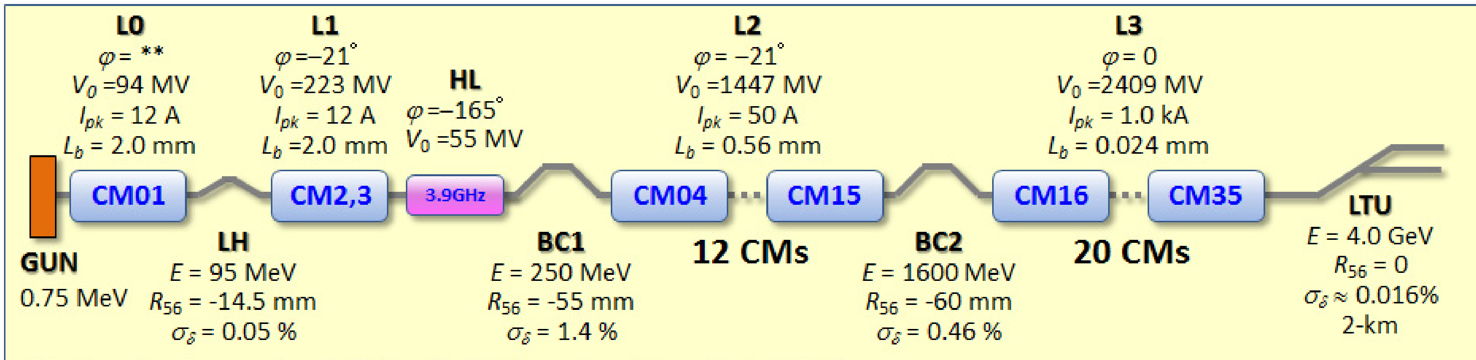
A New LCLS-II Project Redesigned in Response to BESAC

Accelerator	**Superconducting linac**: 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)



Linac Design

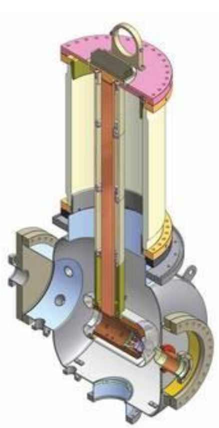
Linac Acceleration and Compression (100 pC)

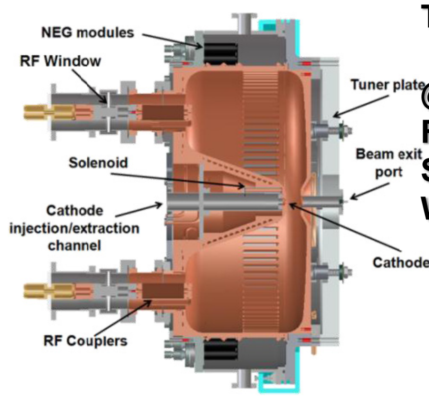


100-pC machine layout: Oct. 8, 2013; v21 ASTRA run; Bunch length L_b is FWHM

Also considering Cornell DC Gun

Gulliford, et al. PRSTAB 16 073401 (2013)



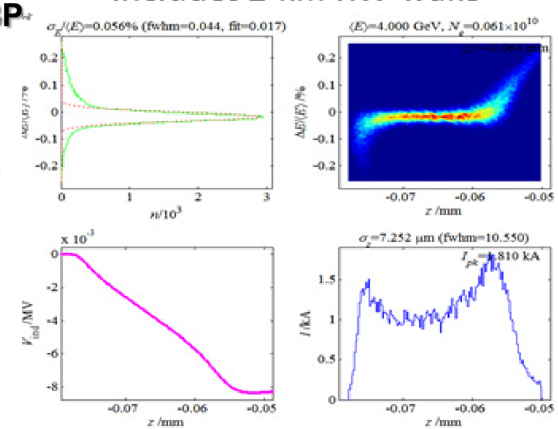


J. Staples, F. Sannibale, S. Virostek, CBP Tech Note 366, Oct. 2006

@ IPAC2014:
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



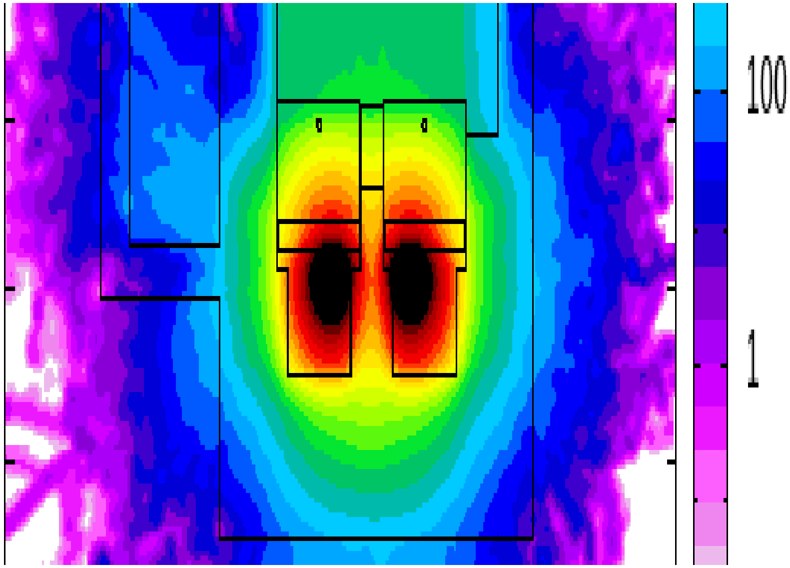
rms stability: ~0.01%, ~0.01°

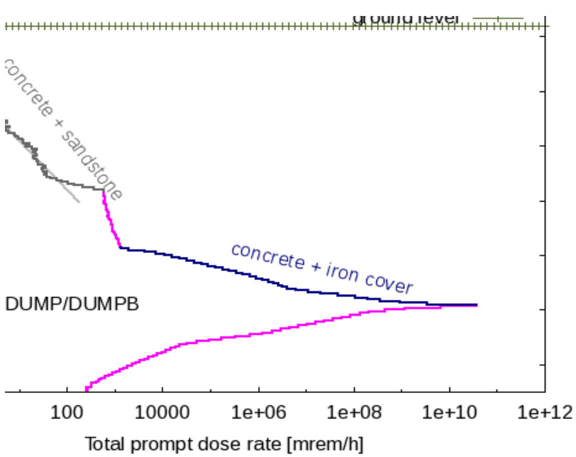
TUPP122 **Roughness tolerances in the undulator vacuum chamber of LCLS-II,** K.L.F. Bane et al.
MOPP127 **Wakefield effects of the bypass line in LCLS-II** K.L.F. Bane, et al.

X-Ray Power

A stated project goal is to deliver at least 20 W X-rays from the SC linac to an experiment, 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

Parameters for the SC Accelerator

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		%

Copper LCLS accelerator will continue to run unchanged

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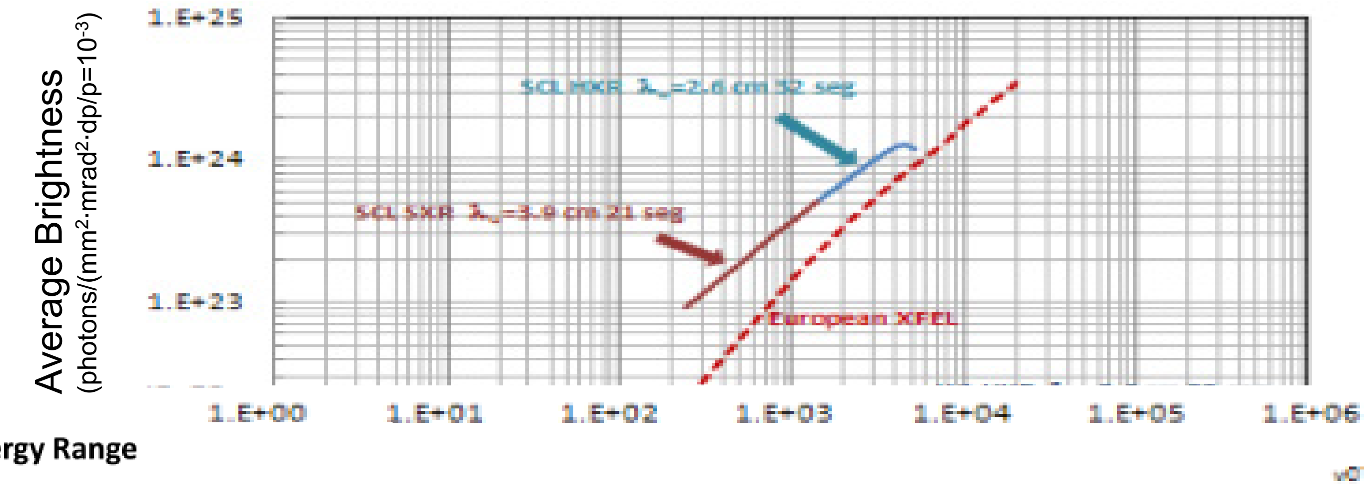
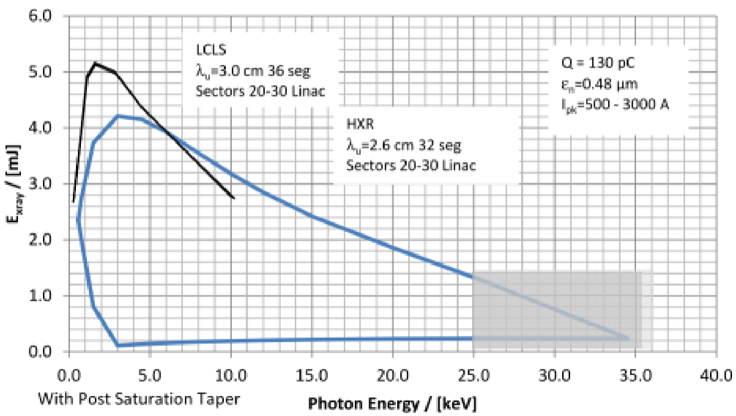
LCLS-II Performance: Average Brightness, photons/pulse



SC Linac Photon Energy Range (eV)

Cu-Linac Photon Energy Range



Calculated X-ray pulse energies versus photon energy for the CuRF linac (blue) and the similar curve for the existing LCLS (black).

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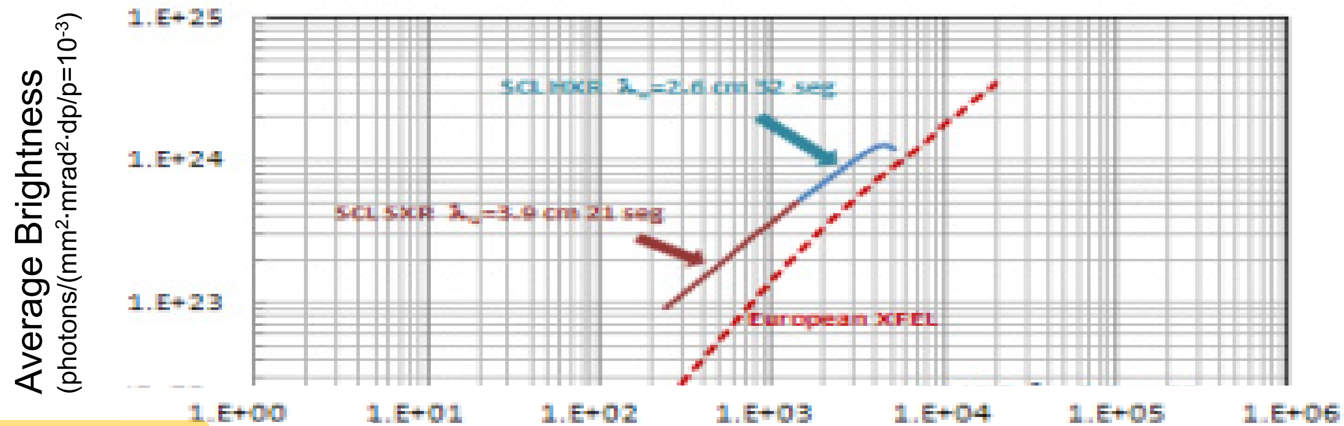

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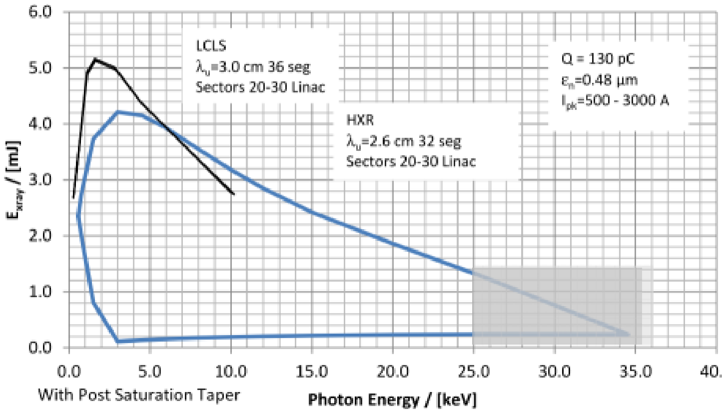

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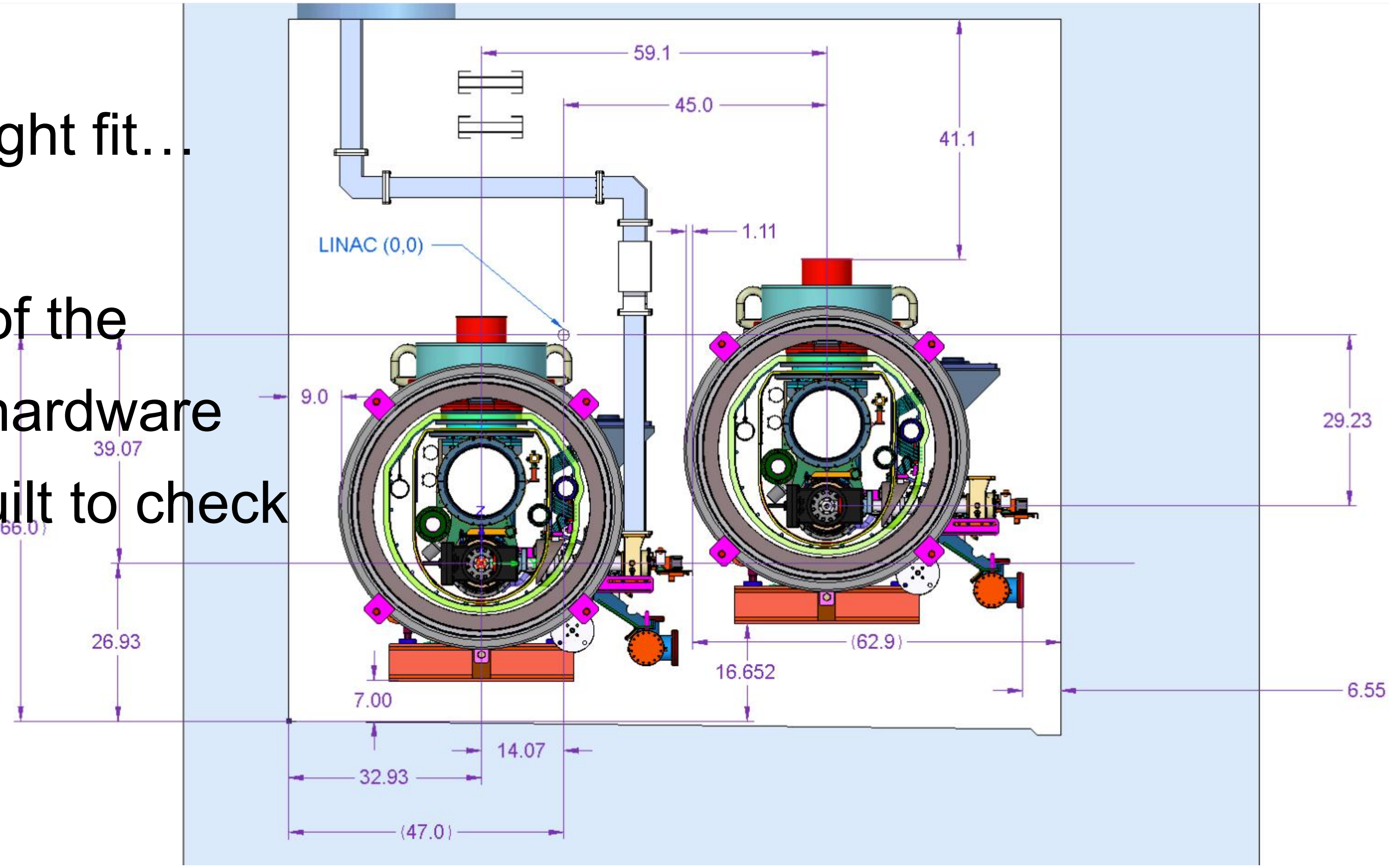
SCRF Cryomodules will go into the SLAC Tunnel

<u>SLAC Linac Tunnel: 3.53m wide x 3.05 m high</u>

It will be a tight fit…

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



S. Boo, J. Chan

Cryomodule:
ILC Type 3 + Some Modifications for LCLS-II

Component design – existing designs

- Cavities – XFEL identical
- Helium vessel – XFEL-like
- HOM coupler – XFEL-like or –identical
- Magnetic shielding – increased from XFEL/ILC to maintain high Q0
- Tuner – XFEL or XFEL-like end-lever style
- Magnet – Fermilab/KEK design split quadrupole
- BPM – DESY button-style with modified feedthrough
- Coupler – XFEL-like (TTF3) modified for higher QL and 7 kW CW

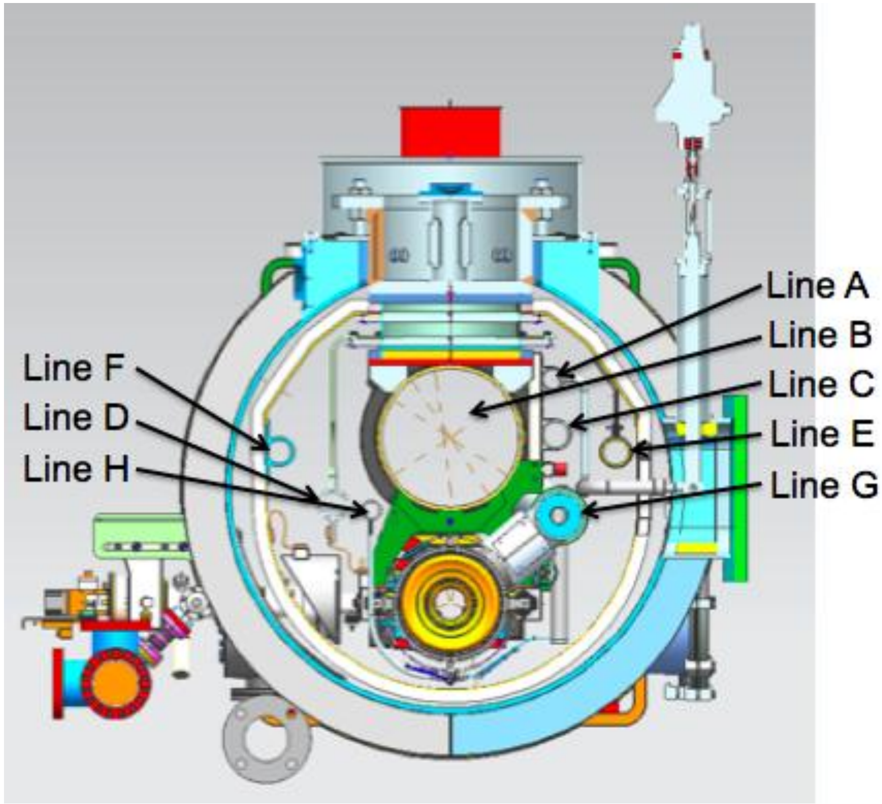
Concerns based on global experience

- Tuner motor and piezo lifetime: access points may shorten time-to-repair
- Maintain high Q0 by minimizing flux trapping: possible constraints on cooldown rate through transition temperature

- **Tom Peterson, FNAL**

MOPP053
TTF3 Coupler Modification for CW operation, I.V. Gonin, et al.
MOPP126
Untrapped HOM radiation absorption in the LCLS-II cryomodules
K.L.F. Bane,, et al.
THPP054
Study of Coupler's effect in Third Harmonic Section of LCLS-II SC Linac, A. Saini

LCLS-II Cryomodule & Cryogenic Circuits



Circuit (Line)

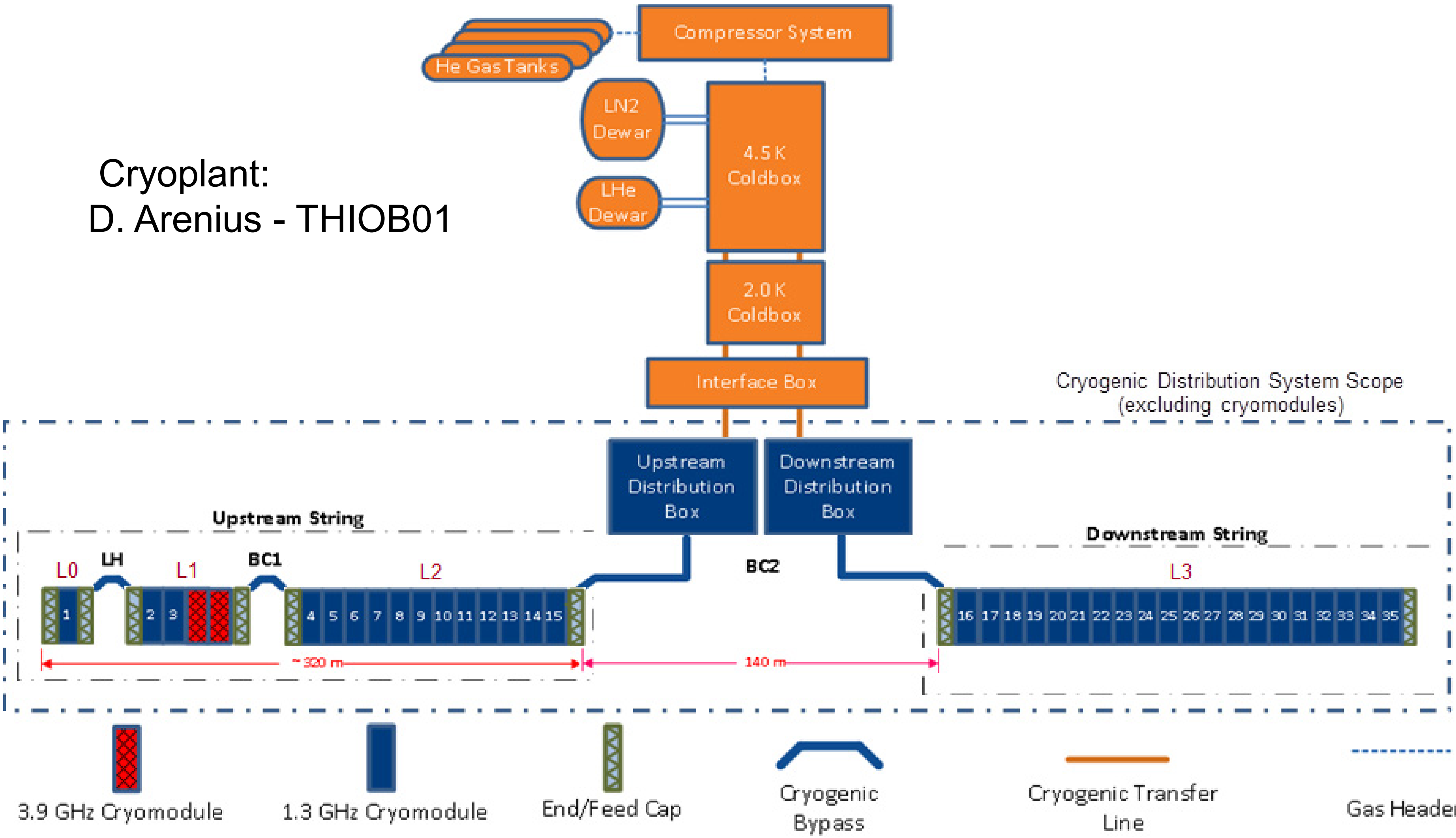
A. 2.2 K subcooled supply
B. Gas return pipe (GRP)
C. Low temperature intercept supply
D. Low temperature intercept return
E. High temperature shield supply
F. High temperature shield return
G. 2-phase pipe
H. Warm-up/cool-down line

No 5K shield

Extra magnetic field shield

Operating Parameters	A	B	C	D	E	F	G	H
Pressure, [bar]	3	0.031	3	2.8	3.7	2.7	0.031	3
Temperature, K	2.4	2.0	4.5	5.5	35	55	2.0	2.0

Cryoplant:
D. Arenius - THIOB01

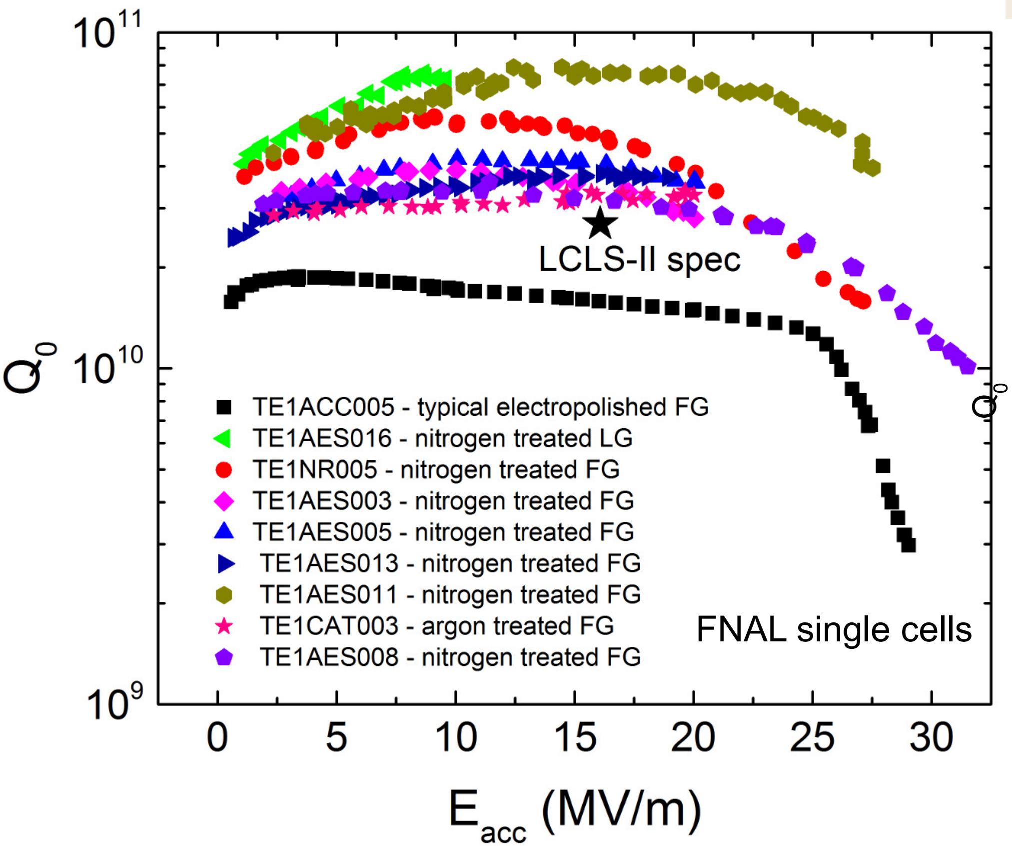


Fermilab-developed 'gas-doping' process →

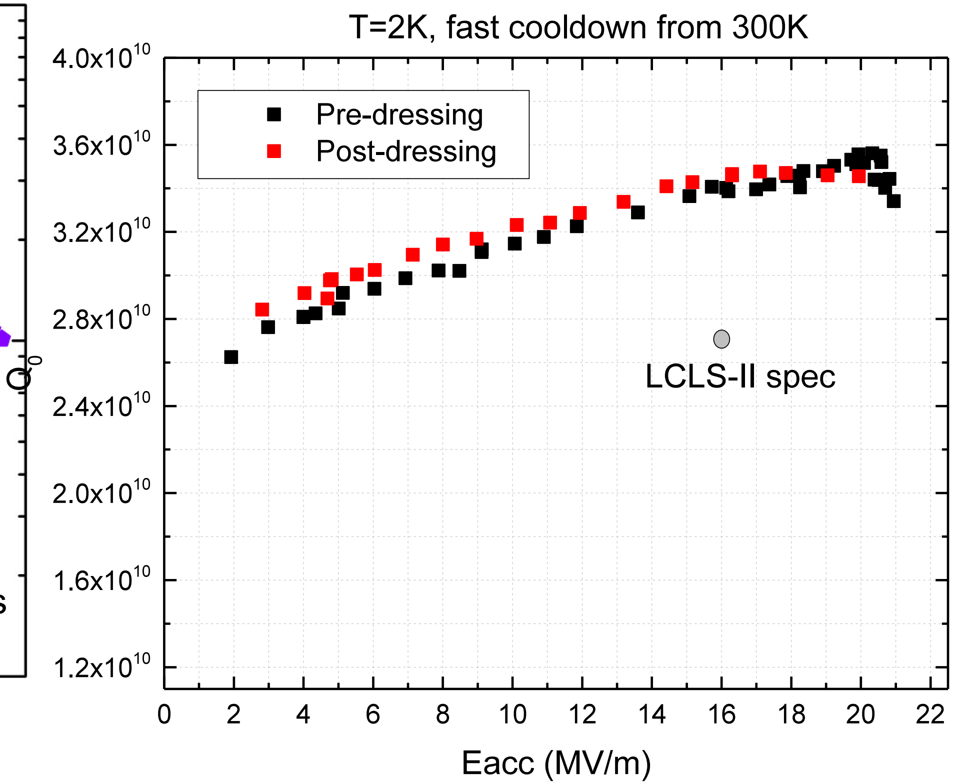
- *A. Grassellino, et al., "New insights on the physics of RF surface resistance", TUIOA03, 2013 SRF Conference, Paris, France*

- A cavity processing recipe that results in high quality factors (>3E10) at operating gradients between 10 and 20 MV/m.
- Starting 2/2014, Fermilab has led a "Qo for LCLS-II" program in collaboration with Cornell and JLab.
- The primary goal is to develop a reliable and industrially compatible processing recipe to achieve an average Q0 of 2.7E10 at 16 MV/m in a practical cryomodule; minimum 1.5E10.
- To reach this goal, the collaborating institutions processed and tested single-cell and 9-cell 1.3 GHz cavities in a successive optimization cycle.
- The deliverable is industrial capability and cost-effective production yield.
  - Supporting the cryoplant design choices

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



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

High Q0 R&D program making rapid progress

High Q0 testing done at 3 labs: Fermilab (from 2012), JLab, and Cornell

MOPP054
Continuous-wave horizontal tests of dressed 1.3 GHz SRF cavities for LCLS-II
A. Hocker, et al.

TUIOC02
Breakthrough technology for very high quality factors in SCRF cavities
A. Romanenko

TUPP138
Analysis of New High-Q0 SRF Cavity Tests by Nitrogen Gas Doping at Jefferson Lab
C.E. Reece

High Q0 Program 9 cell results – ***inclusive*** (through August 5)		
	Q0	E_acc (MV/m)
Average	3.14E+10	18.3
Number of 9 cell tests		Number of test cavities
22		11

Includes 2 horizontal tests (and one dressed-cavity VTS)
Only one vertical test Q0 below 2.3E10

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 thanks Dana Arenius, Paul Emma, Anna Grasselino, Arkadiy Klebaner, Yuri Orlov & Marc Ross & Tom Peterson for the use of their presentation materials.

JNG is fortunate to have the privilege to represent this extraordinary collaboration

End of Presentation

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