



LCLS-II

Status of the LCLS-II Cavities & Cryomodules

Andrew Burrill (on behalf of the collaboration)

Oct 31st, 2019

Outline

- Superconducting Linac Overview
- Cryomodule Assembly & Testing Status
 - Performance
 - Challenges
- Cryomodule Installation Status
- Summary



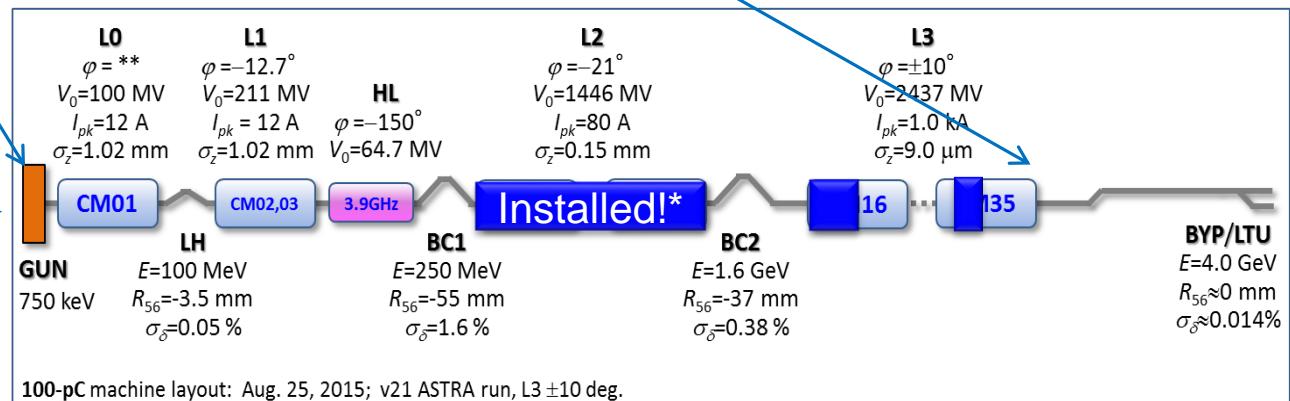
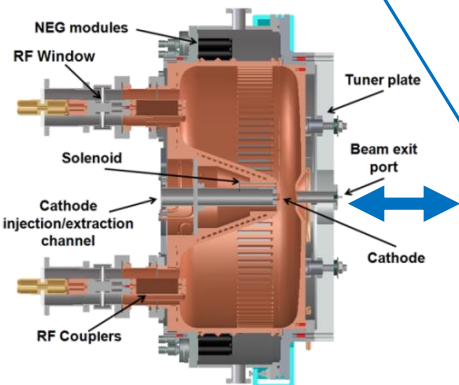
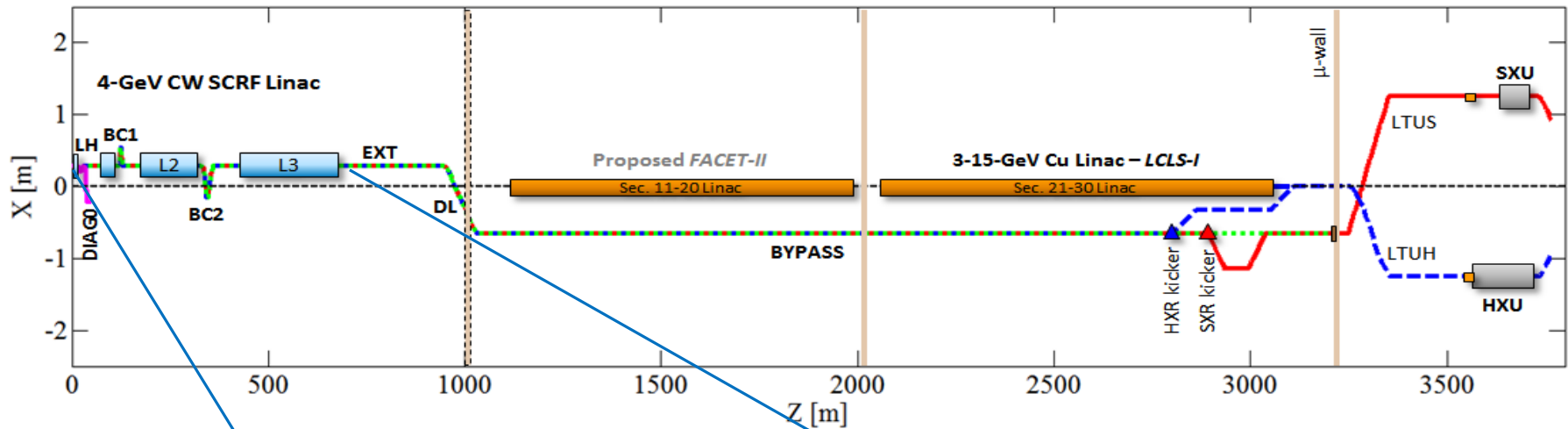
Project Collaboration: SLAC couldn't do this without...



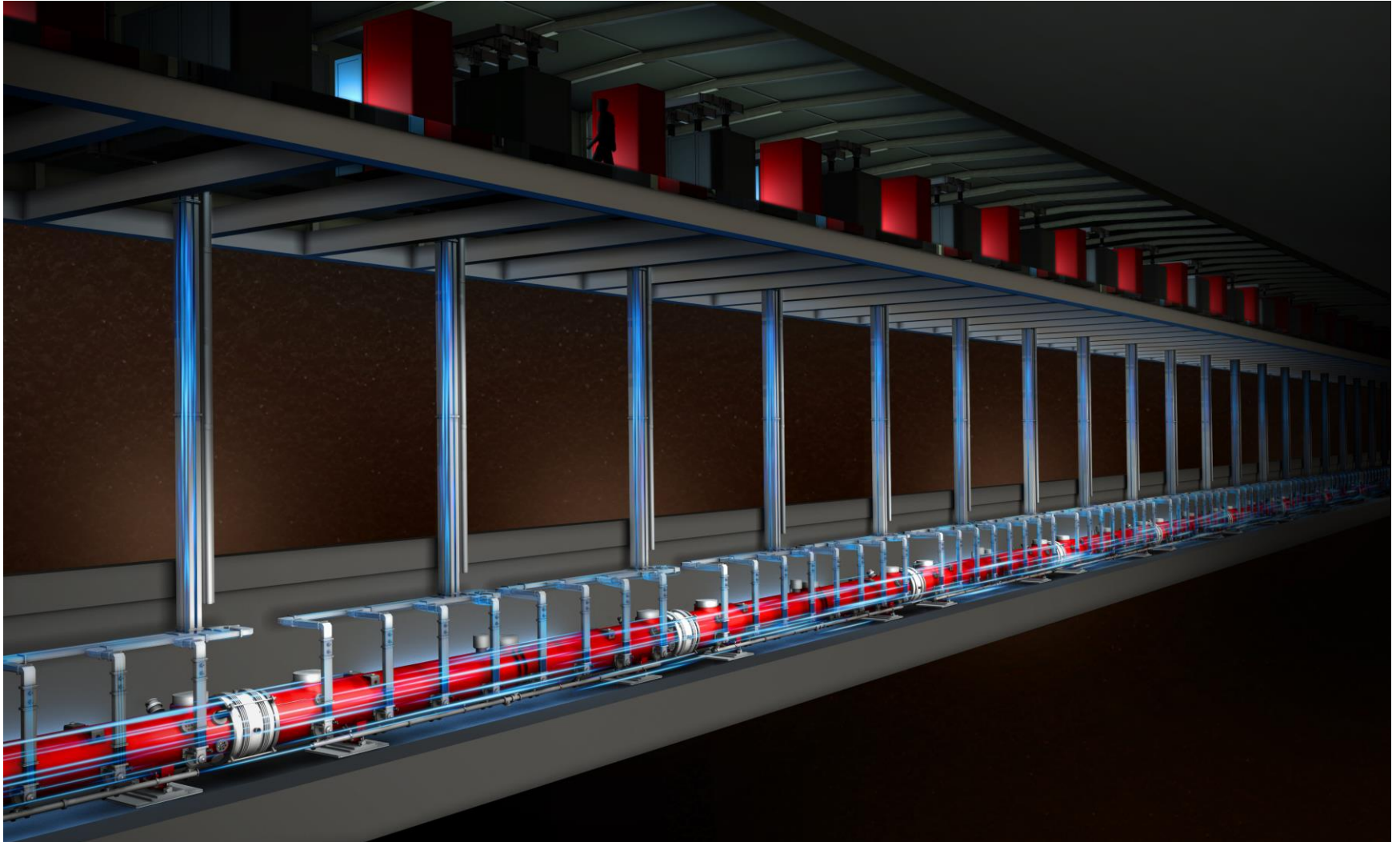
The Linac



Linac Layout



The Linac

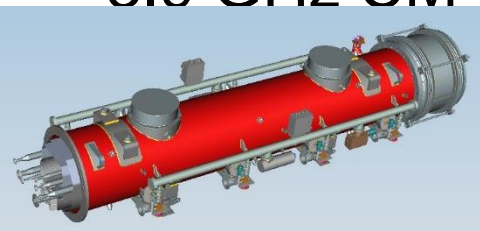


High-level comparison of 1.3 GHz & 3.9 GHz cryomodule

1.3 GHz CM



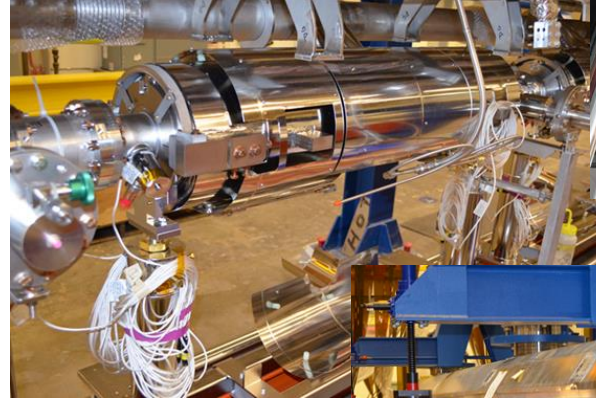
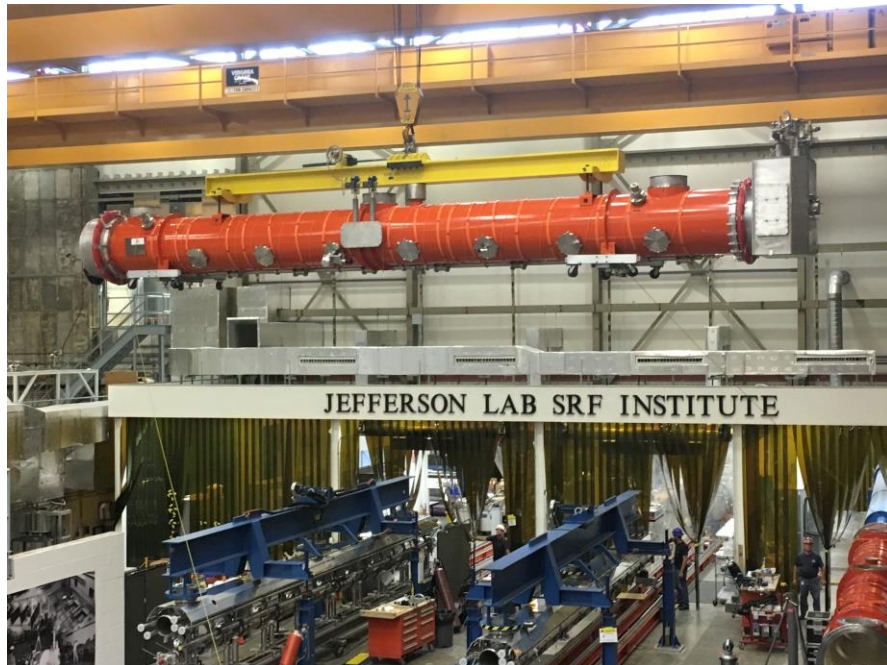
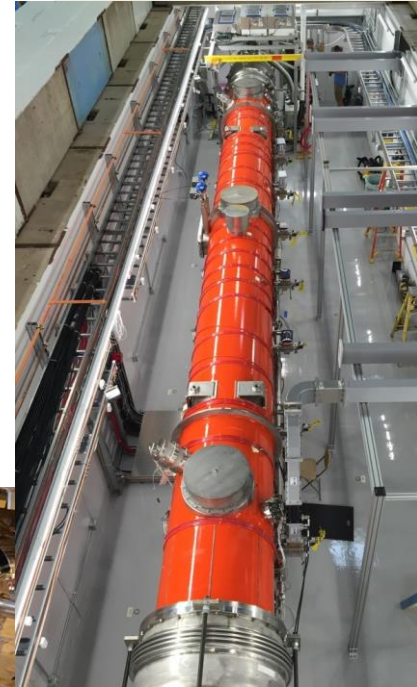
3.9 GHz CM



item	1.3 GHz CM	3.9 GHz CM
# installed (built) CM's	35 (40)	2 (3)
Length/CM	~12.5 m	~7 m
Weight/CM	19,000 lbs	9,700 lbs
#cavities/CM	8	8
Cavity nominal Q0@2K	2.7E10 (N2 doped)	2.0E9 (std process)
Cavity nom. Eacc	16 MV/m	13.4 MV/m
Cavity tuner	End-lever + piezos	Blade + piezos
Cavity magnetic shielding	He vessel external (<5 mG)	He vessel internal & external (<15 mG)
Power couplers	All one side	Alternating sides
Magnet	Split quad+dipole V/H	None
HOM feedthroughs, BPM, cryogenic valves, interconnect & stand	Identical	Identical

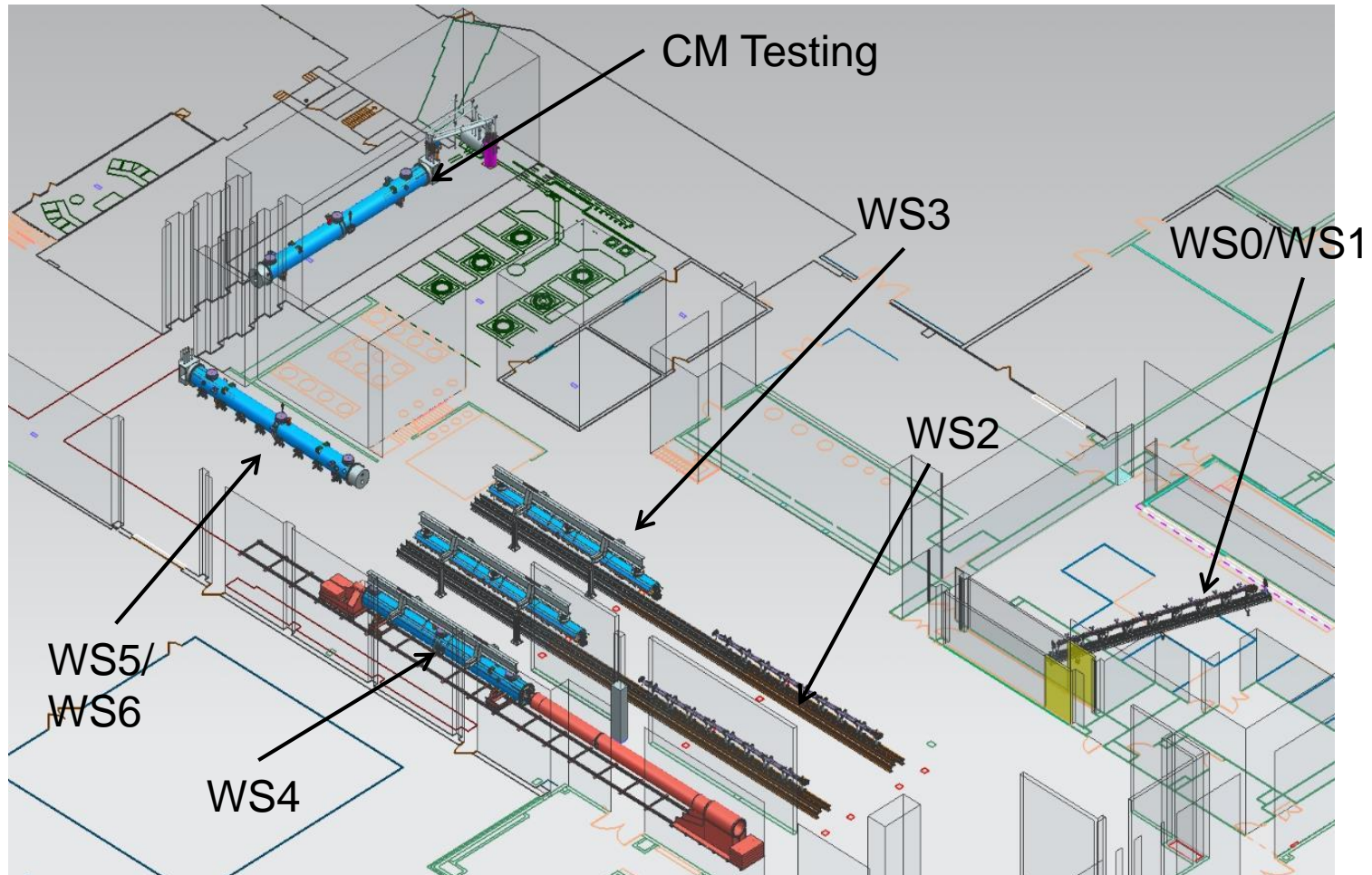
LCLS-II Cavity and CM Statistics

- 320 1.3 GHz Cavities required
 - 304 from Vendors, 16 from ILC R&D program
- **312 of 320 cavities qualified to date***
- 33 of 40 1.3 GHz cryomodules tested**
- 7 cryomodules currently being assembled
- **19 of 24 3.9 GHz cavities qualified**



Cryomodule Assembly Sequence

Each Lab has 6 workstations, similar to XFEL



JLab Cryomodule Production



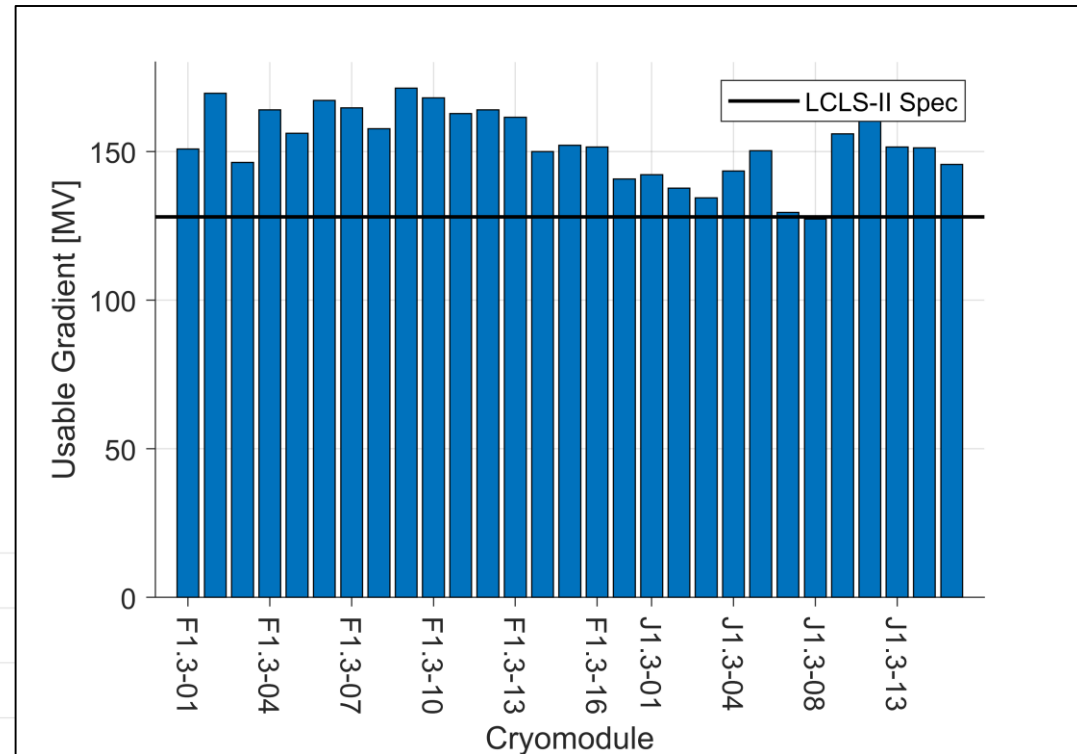
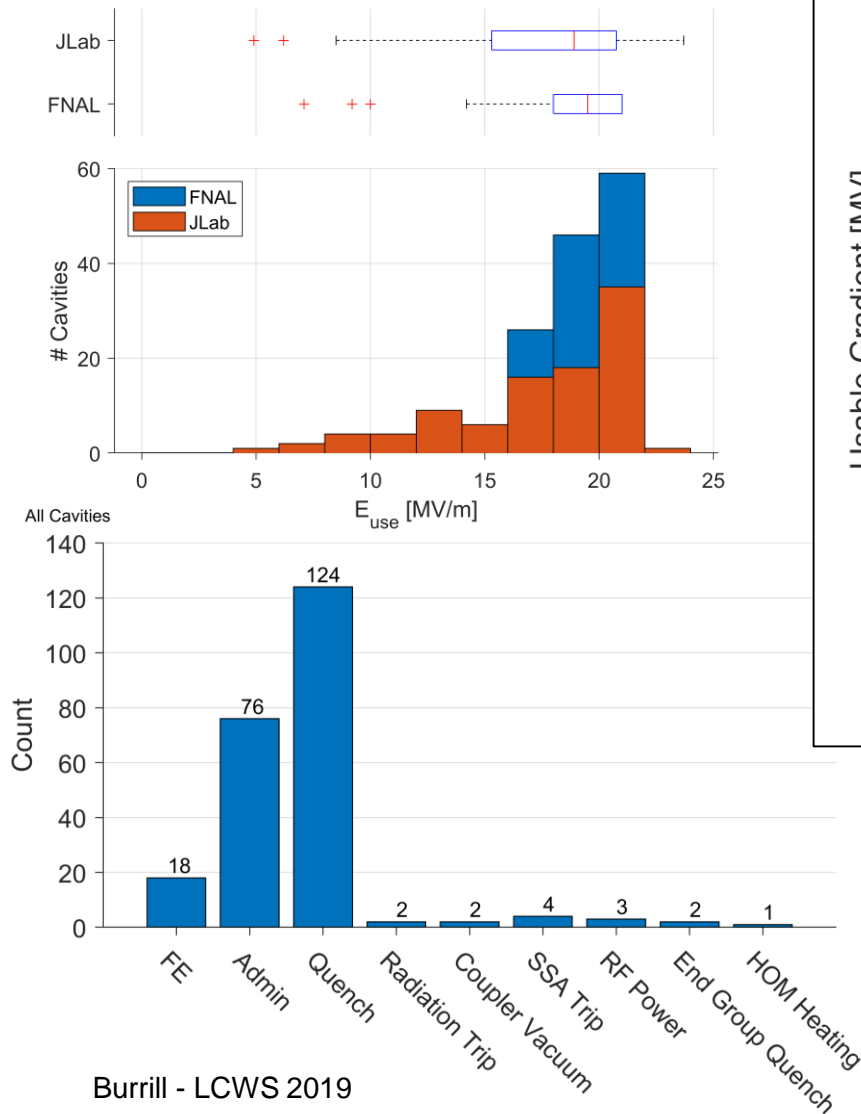
CM Status Dashboard - JLab

WorkStation /CM	WS1	CM Assembly				CM Testing Complete	rework	Ready for Shipping	CM Installation
		WS2	WS3	WS4	WS5				
J1.3-01								yes	in progress
J1.3-02							hold		
J1.3-03								yes	in progress
J1.3-04								Yes	in progress
J1.3-05									
J1.3-06			in progress						
J1.3-07									
J1.3-08								yes	in progress
J1.3-09	in progress								
J1.3-10								yes	in progress
J1.3-11	requires rebuild						N/A		
J1.3-12							N/A	yes	in progress
J1.3-13							N/A	yes	in progress
J1.3-14							N/A	yes	in progress
J1.3-15							N/A	yes	in progress
J1.3-16							N/A	in progress	
J1.3-17							N/A		in progress
J1.3-18							N/A	in progress	
J1.3-19						in progress	N/A		
J1.3-20					progress		N/A		
J1.3-21			in progress				N/A		

CM Status Dashboard - FNAL

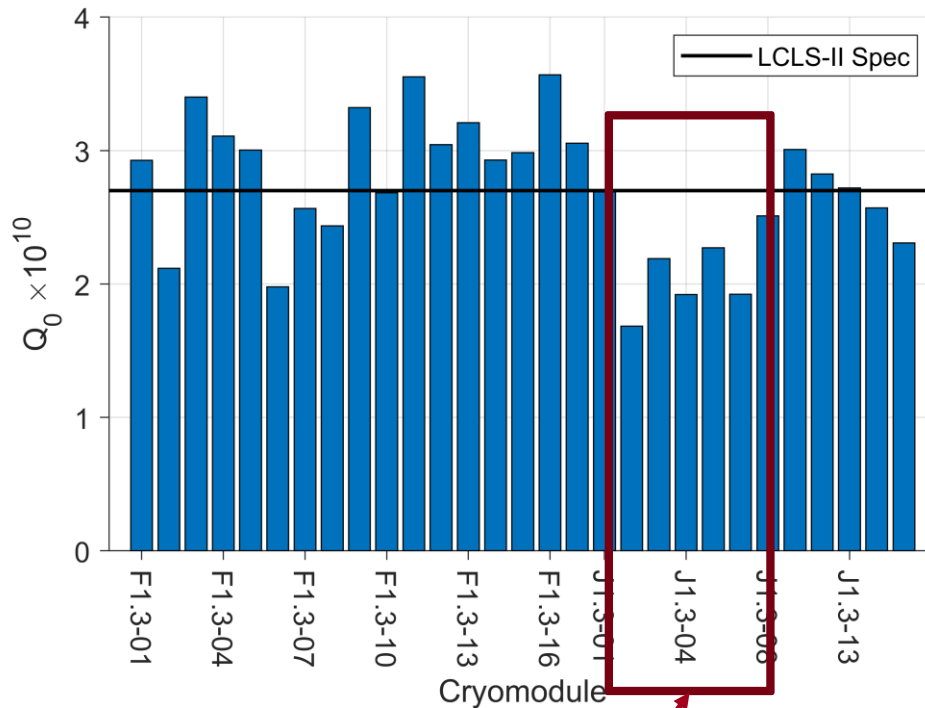
WorkStation /CM	WS1	CM Assembly				CM Testing	rework	Ready for Shipping	CM Installation
		WS2	WS3	WS4	WS5				
F1.3-01								yes	in progress
F1.3-02									in progress
F1.3-03						in progress			
F1.3-04								YES	in progress
F1.3-05	hold								
F1.3-06	requires rebuild								
F1.3-07								YES	in progress
F1.3-08								YES	in progress
F1.3-09								yes	in progress
F1.3-10								YES	in progress
F1.3-11								YES	in progress
F1.3-12	hold								
F1.3-13							N/A		in progress
F1.3-14							N/A		in progress
F1.3-15							N/A		in progress
F1.3-16							N/A	yes	in progress
F1.3-17							N/A	yes	in progress
F1.3-18							N/A	yes	in progress
F1.3-19							N/A		in progress
F3.9-01		in progress							
F3.9-02	in progress								
F3.9-03									

Cryomodule Performance – Usable Gradient

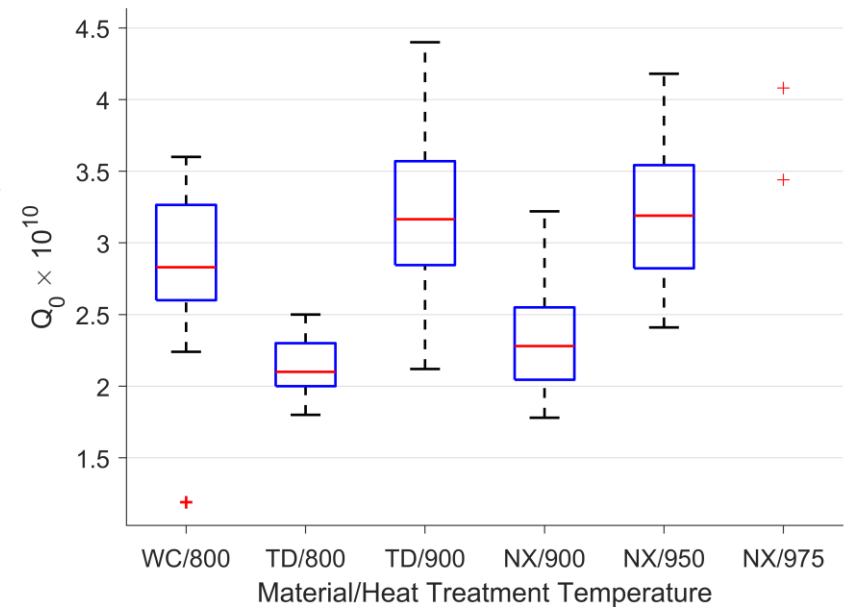


Usable gradient is either:
 21 MV/m (admin limit)
 FE < 50 mR/hr
 Cavity quench

Cryomodule Performance – Quality Factor



Insufficient cooldown rate



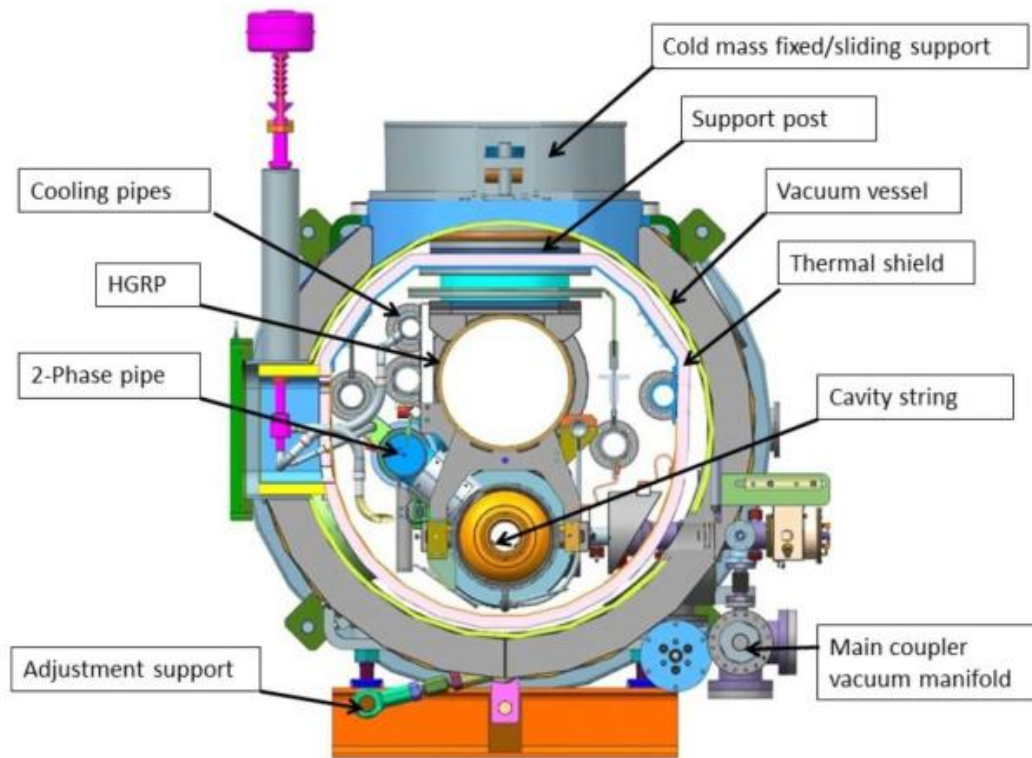
Gradient Optimization for 4 GeV Beam

JLab Q's	$P_{\text{diss}}/\text{CM}$ [W]	Extrapolated Total CP Load [kW]
Estimated	68.25	3.38
As Measured	72.85	3.54

Single cryoplant operation with overhead is 3.8 kW

Both cases demonstrate single-cryoplant operation is feasible with average cavity gradient of 15.4 MV/m

CM Installation Workflow



6 Major Install Phases

- Unloading
- Receiving / acceptance testing
- Physical install / alignment
- Welding cryo pipes
- Particle free beamline install
- Insulation vacuum / cryo equip.

CM Unloading (LCLSII-4.5-PP-0989)



- Successfully unloaded 25 of 37 CMs
- Extensive focus on procedure development and process improvement and training
- Planned deliveries of about ~2 per month, peak delivery of 4 per month

CM Acceptance Tests (LCLSII-4.5-PP-0703)

	SLAC Spec	Delivered Units
Mechanical – Inspection	No Visible Issues	Generally Meet Spec
Shock Logger Review	< 1.5 G	Transit Upgrades Meet Spec
Beam Vacuum	< 10^{-5} mBar	Meet Spec
Coupler Vacuum	< 10^{-5} mBar	Generally Meet Spec
Alignment	< 0.2 mm Δ	Difficulty meeting spec
RF Cavity Check	< 10 kHz Δ	Generally Meet Spec
Electrical Tests	No open / short	Generally Meet Spec
Leak Test (CM iso-vac)	< 10^{-5} mBar-L/sec	Meet Spec

Physical Install Preparation (LCLSII-4.5-PP-1372)



- Beamline gauge tree removal
- Conflat flanges removed from cryo pipes
- Shipping fixture removal



Physical Install



- Tunnel installation successfully completed for 22 units
- Clearances are very tight, but adequate



Welding – Installation

- Several early challenge:
Accommodation of the line liquid level assembly and gate valve support
- Simplified CM Model for Interconnect did not show interference
- Solution tested and implementation in progress
- New tooling developed to pull pipes into position

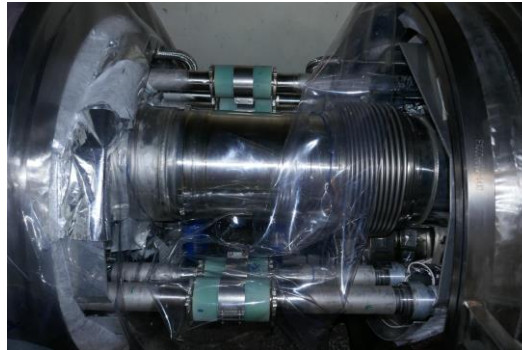


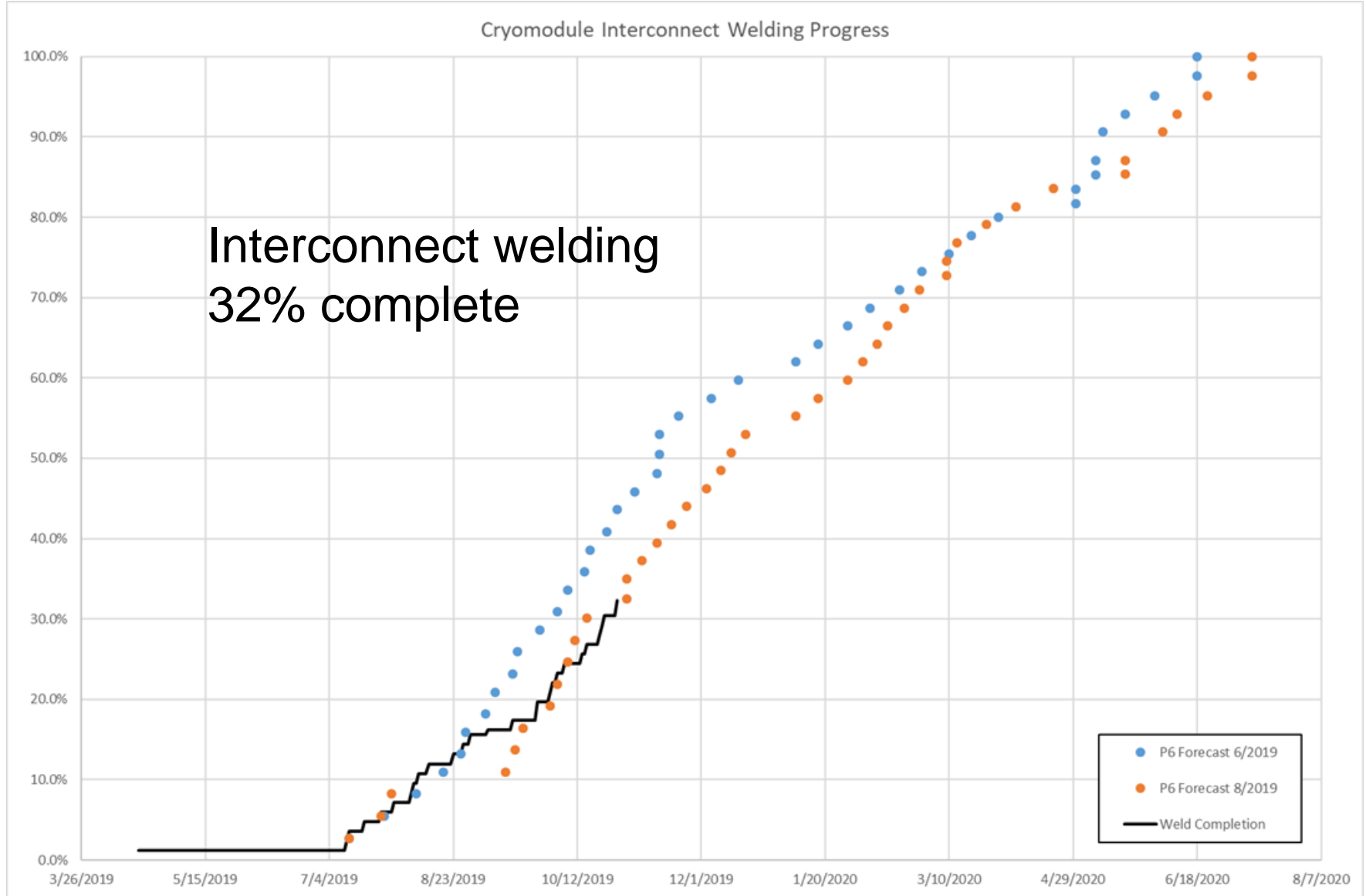
L2 and L3 cryomodule installation status

	FC2	CM04	CM05	CM06	CM07	CM08	CM09	CM10	CM11	CM12	CM13	CM14	CM15	FC5
Install		F07	J04	F08	J10	F04	J08	F10	F09	J13	F11	J14	F01	
Line B														
Line A														
Line C														
Line D														
Line E														
Line F														
Beamline														

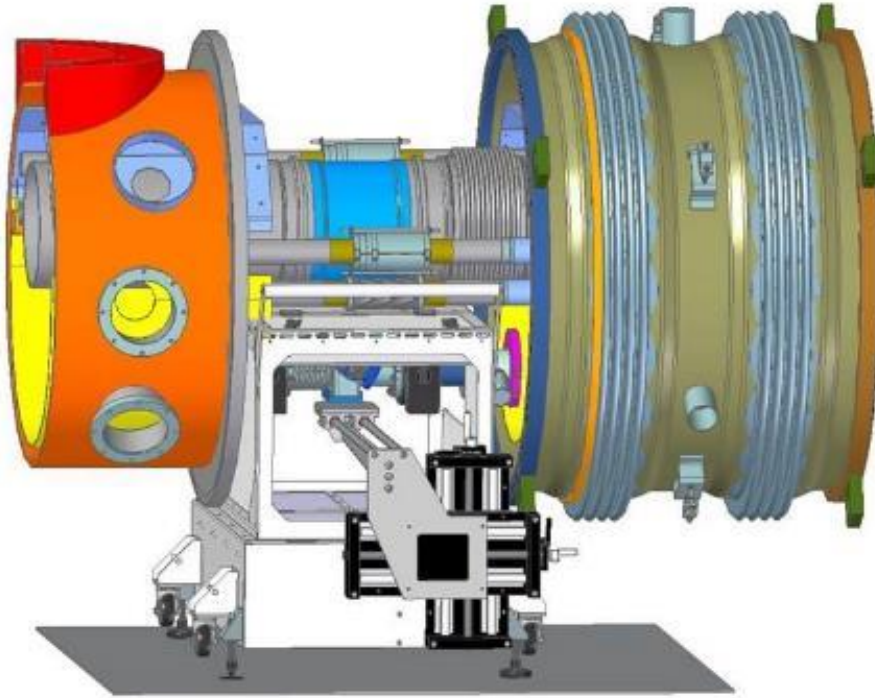
	FC6	CM16	CM17	CM18	CM19	CM20	CM21	CM22	CM23	CM24	CM25	VBB	CM26	CM27	CM28	CM29	CM30	CM31	CM32	CM33	CM34	CM35	ECD	
Install		F13	J12		F17	F18	J15	F14	F15	F16				F02	J03									
Line B																								
Line A																								
Line C																								
Line D																								
Line E																								
Line F																								
Beamline																								

- Welded interconnect pipes shown at right.
- CM18 slot to be filled after gutters, waveguides, etc. are Installed due to water leak.





CM Beamline Install



CM Beamline:

- BLA install – particle free clean
- Clean-zone (Ready)
- Particle free pump cart (Ready)
- SLAC staff and program for Particle free cleaning and assembly is maturing
- Process development continues
- **Goal to begin BLA installation in Dec 2019**



Schedule

- 3.9 GHz Cryomodules delivered to SLAC – March 2020
- 35 Cryomodules delivered to SLAC – April 2020
- Linac Installation complete – August 2020
- Linac Cooldown – Oct 2020
- RF Commissioning – Jan 2021
- Linac beam checkout – April 2021
- First Light – July 2021

Summary

- 25 Cryomodules are at SLAC!
- LCLS-II is well positioned to operate with average $Q_0 \geq 2.7 \times 10^{10}$ @ 16 MV/m long term.
 - **130 MV Energy gain CW per CM = 80 W to 2K**
- Cryomodule Assembly is nearing completion
- Cryomodule Installation is going well

The next 18 months at SLAC will be very exciting!



The End

SLAC NATIONAL
ACCELERATOR
LABORATORY



 **Fermilab**

 **Jefferson Lab**

