LCLS-II: Scope, Status, Issues and Plans

Marc Ross
LCLS-II-HE

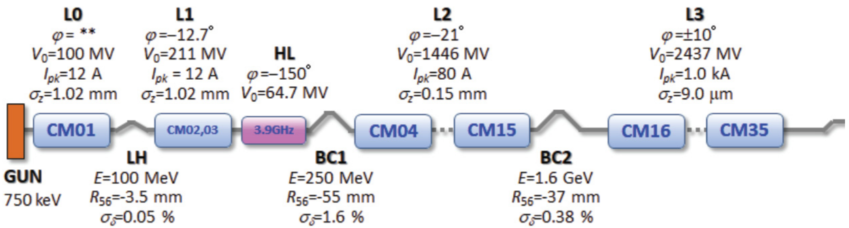
01 July 2019, 19th SRF Conference

SLAC NATIONAL ACCELERATOR LABORATORY

Fermilab Jefferson Lab

U.S. DEPARTMENT OF ENERGY | Stanford University

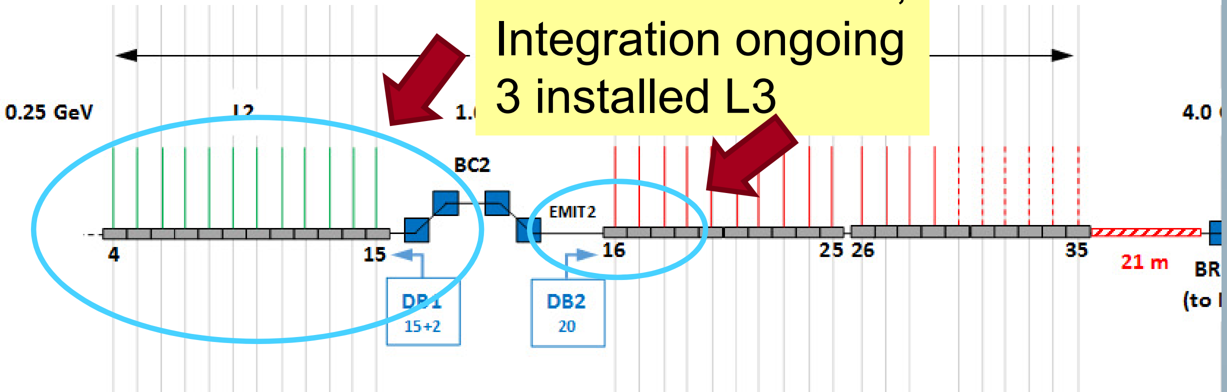
L2 CM in the SLAC tunnel – ready for interconnection

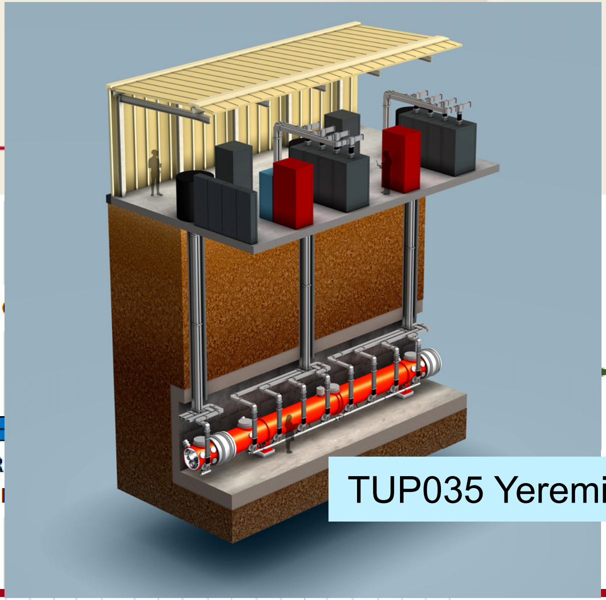


Tunnel View

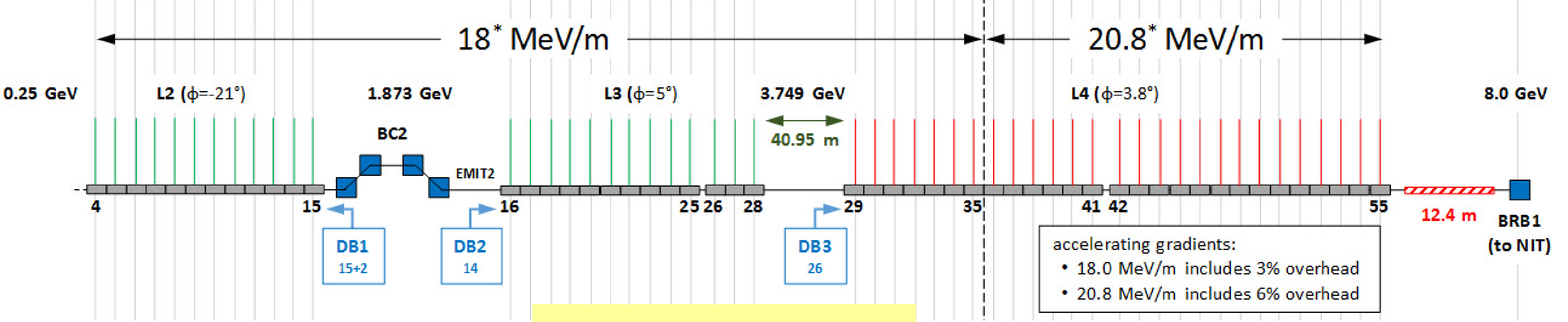
LCLS-II and LCLS-II-HE Layout

12 CM Installed L2;
Integration ongoing
3 installed L3



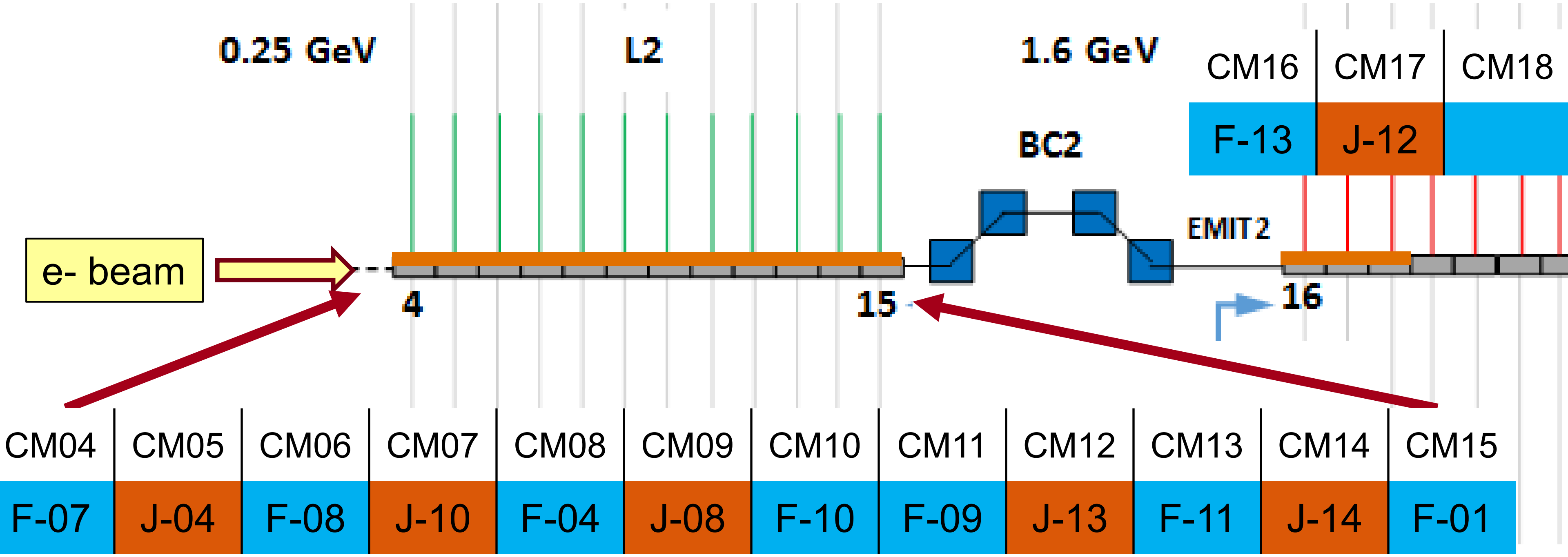


TUP035 Yeremian



LCLS-II-HE (2026)

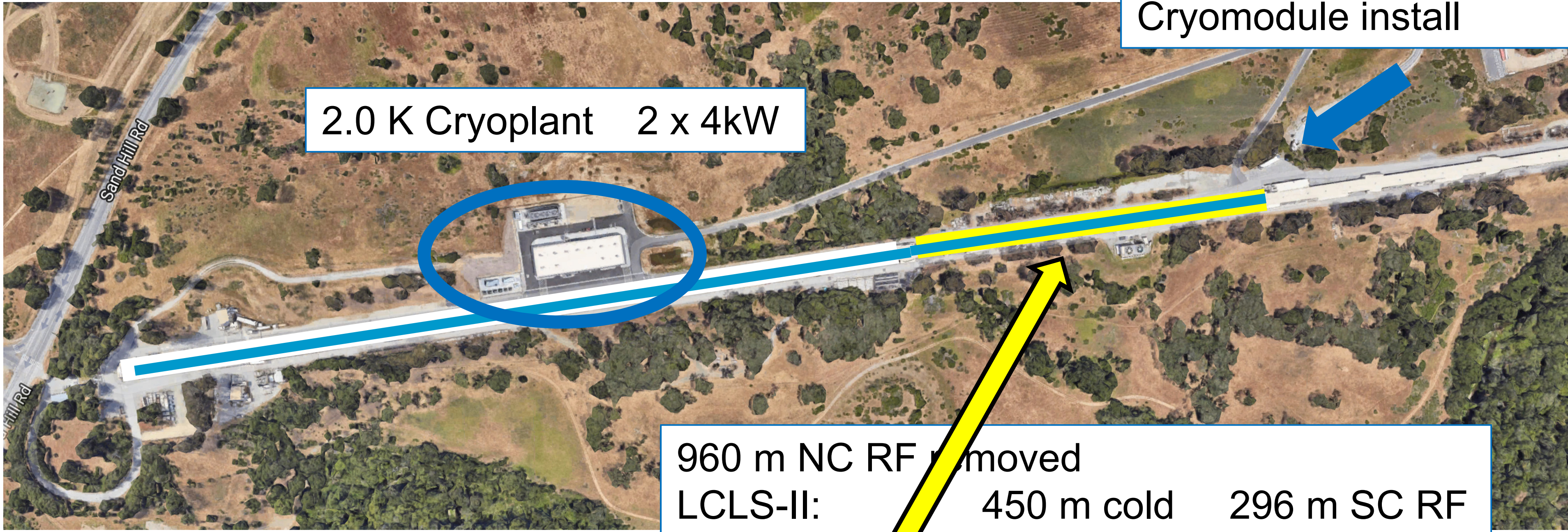
LCLS-II L2/L3 Cryomodule Assignments:



First 1300m of SLAC Linac

Grade Level Access for Cryomodule install

2.0 K Cryoplant 2 x 4kW



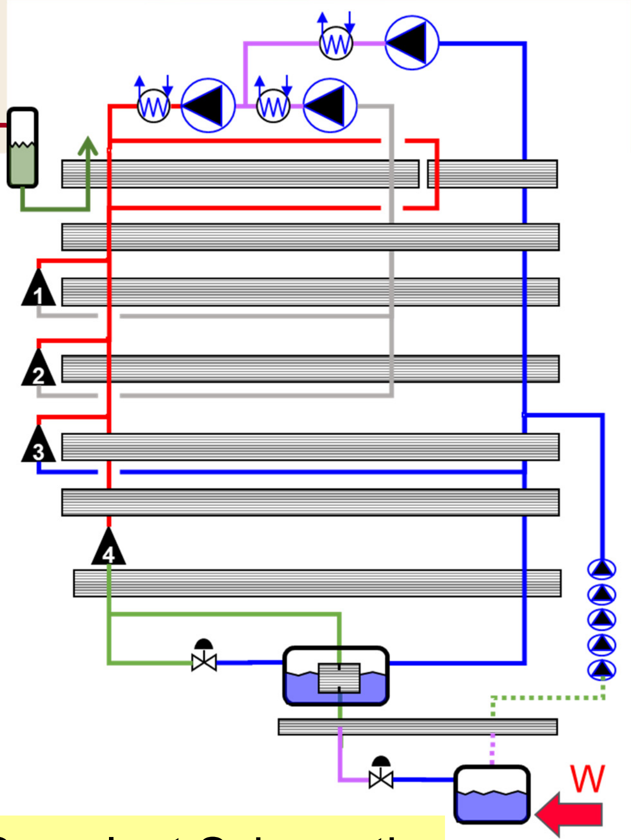
960 m NC RF removed

LCLS-II:	450 m cold	296 m SC RF
LCLS-II-HE:	250 m cold	170 m SC RF
LCLS Total SRF:	700 m cold	466 m SC RF

2x Cryoplant, Jefferson Lab contribution

2x4kW (@ 2K) = 8 kW capacity → 7.13 kW est. load
12% Margin (<Q0> 2.7e10)

Load	Circuit			Unit
LCLS-II	70	5-8	**2**	K
CM static heat	4.56	0.63	0.26	(kW)
CM dynamic heat	3.22	0.27	3.02	(kW)
CDS heat	4.29	0.21	0.25	(kW)
Total	12.06	1.11	**3.53**	(kW)
Total mass flow	115.6	58.0	174.6	(g/s)
+ LCLS-II-HE				
CM static heat	7.02	0.97	0.41	(kW)
CM dynamic heat	5.04	0.43	6.40	(kW)
CDS heat	8.37	0.36	0.32	(kW)
Total	17.6	1.63	**7.13**	(kW)



Cryoplant Schematic
Top: Compression
Bottom: Linac

LCLS-II Partnership

Fermilab

- CM engineering/design
- 50% of 1.3 GHz CM
- 3.9 GHz CM
- Cryo Distribution
- Processing for high Q – N doping

MOP092 Stanek

Jefferson Lab
EXPLORING THE NATURE OF MATTER

- 50% of 1.3 GHz CM
- Two 4 kW (2K) Cryoplants
- Processing for high Q

SLAC NATIONAL ACCELERATOR LABORATORY

- Linac Integration
- Cryoplant Integration
- Commissioning

Office of Science
U.S. DEPARTMENT OF ENERGY

LCLS-II Project: Inter-laboratory partnership under the sponsorship of DOE Office of Science, Basic Energy Sciences

Procurement responsibility divided among partners: (Cavities → JLab)

Introduction

For your consideration:

Three elements for technical advancement:

1. Science → Motivation
2. Technical development → Tools that enable
3. Industrial and Infrastructure backbone → Capability/Cost

Step 3 is sometimes called the 'Innovation Valley of Death'

2009: Success of LCLS at SLAC

→ Remarkable facility for remarkable *photon science* ←

What's next for photon science in the US? How to develop this valuable tool?

Extraordinary convergence (2010 – 2013):

1) LCLS Success
2) Technical Development and Industrialization of a core linac technology →

Superconducting Radio-Frequency (SCRF)

Old / new technology deployed together for LCLS-II hybrid FEL

CEBAF (94) → LEP2 (99) → LCLS-II (2021) → HE (2026)

SLAC

Three large CW Superconducting linacs:

Parameter	CEBAF 1994	LEP2 1999	LCLS-II 2021	LCLS-II-HE 2026
N_cav	338	288	280	440
E_acc (MV/m)	7.5	7.2	18.5	20.8
Meters of SRF	169	490	296	466
E_tot (GeV)	1.2	3.6	4.6	8.6
<Q0>	4.0e9	3.2e9	2.7e10	2.7e10
f (MHz)	1497	352	1300	1300
Temp (K)	2.08	4.5	2.0	2.0
Heat Load (kW)	5	53	3.7	7.3
Heat Load kW/GeV	4.2	14.7*	0.8	0.8
* @4.5K. Divide by 3.5 to convert to equivalent load at 2 K, (4.2 for LEP2)				

Substantial investment in CW SRF

Outline

Issues:

- Cavity → Industrial Production with Nitrogen-doping
  - Flux Expulsion (Minimizing trapped B_amb)
- CM → CW operation
  1. Field Emission / Multi-pactor Discharge
  2. Microphonics
  3. Shipping

Plans

LCLS-II Parameters:

Parameter	Value	Units	Tot
Energy	4	GeV	
Beam I	100	μ Amp	
Duty Factor	CW		
RF	1300	MHz	
Cavity	8	per CM	
Cryomodules	35	each	**40**
(add'l + spare)	5	each	
Linearizer CM	2	each	**3**
(spare)	1	each	
Cryoplant cap.	8	kW@2.0K	
SSA	4.8	kW	

3.9GHz: MOP051 Aderhold
MOP069 Khabibouline
MOP093 Kaluzny

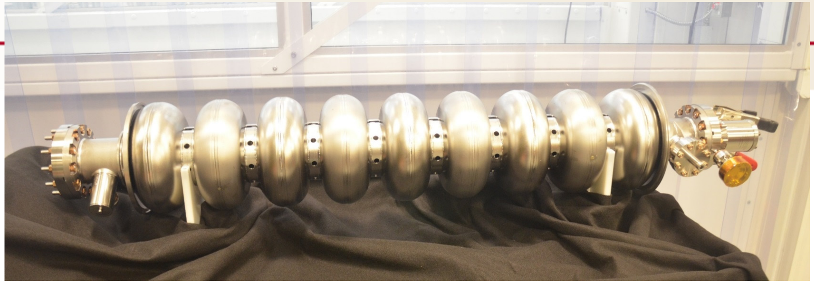
Cavity Vertical Acceptance:

Parameters	**Numbers**	**Unit**
E_acc	>19	MV/m
Q0	>2.5e10	(at 16 MV/m)
R	<10	nΩ
HOM power	<1.0	W
Field emission Onset*	>17.5	MV/m

***Field Emission limits changed 30% into production to require *No Detectable Field Emission* at maximum gradient**

FRCAA3 ***D. Gonnella***, *SLAC*
THP100 ***J. Iversen***, *DESY*

Nb Sheet and Cavities



Jefferson Lab
EXPLORING THE NATURE OF MATTER

ULTRA HIGH PURITY RARE METAL
TOKYO DENKAI

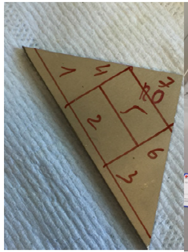
东方钽业
OTIC

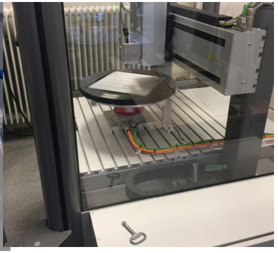
376 ordered: 211/165 RI/EZ
304 required for 38 CM
(2 prototype CM from ILC)
21 for LCLS-II-HE
51 remain (43 not qualified)

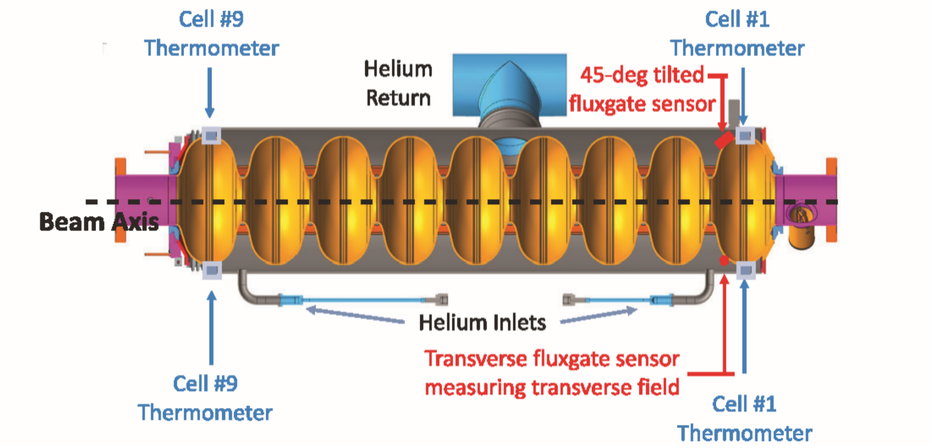
research instruments

E. ZANON

DESY.

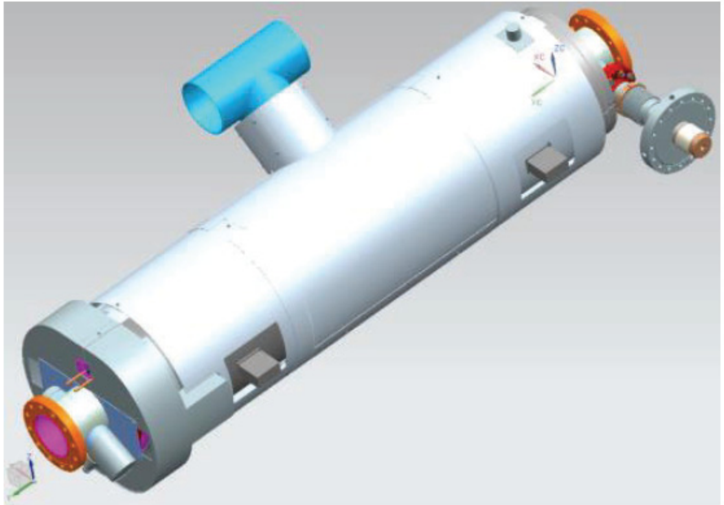


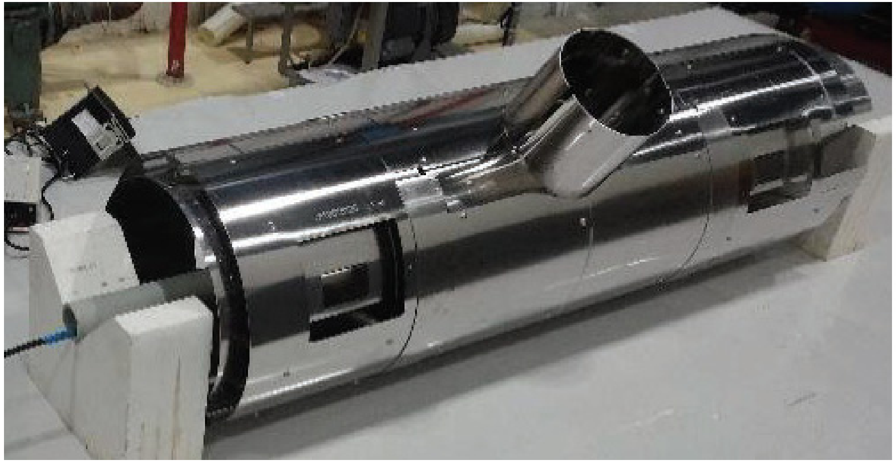




9-cell bulk Nb cavity integration

- Integration with flux-gates and thermometry inside He vessel
    - Only prototype CMs
- Double-layer hermetic magnetic shield

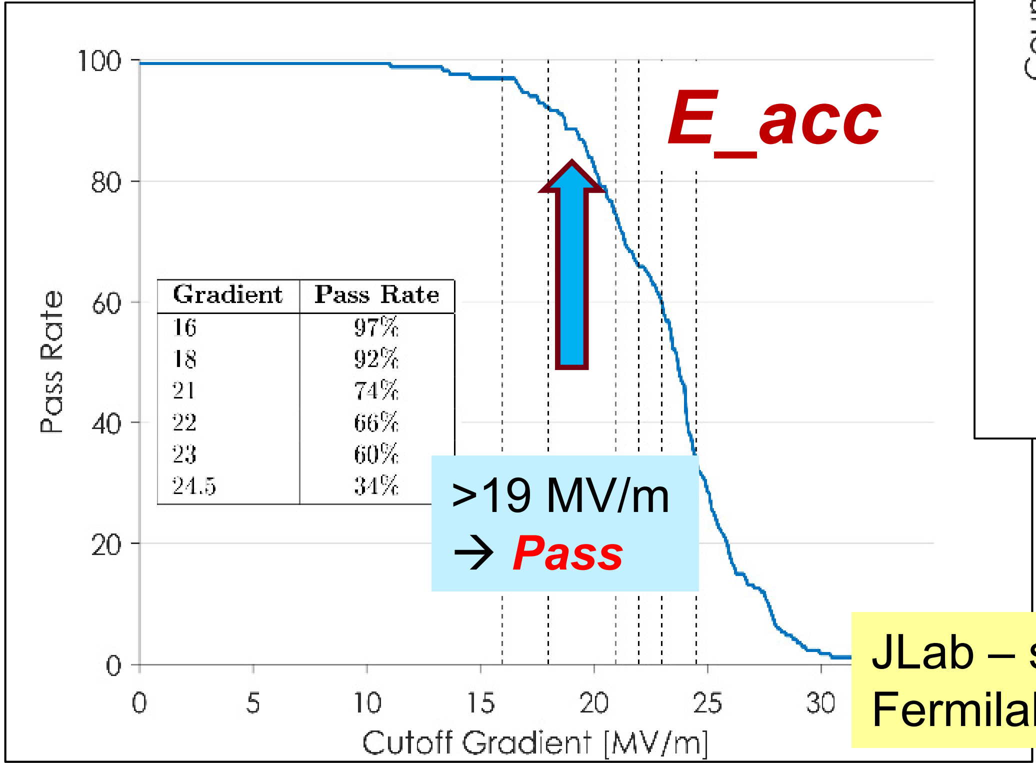




Vertical Test

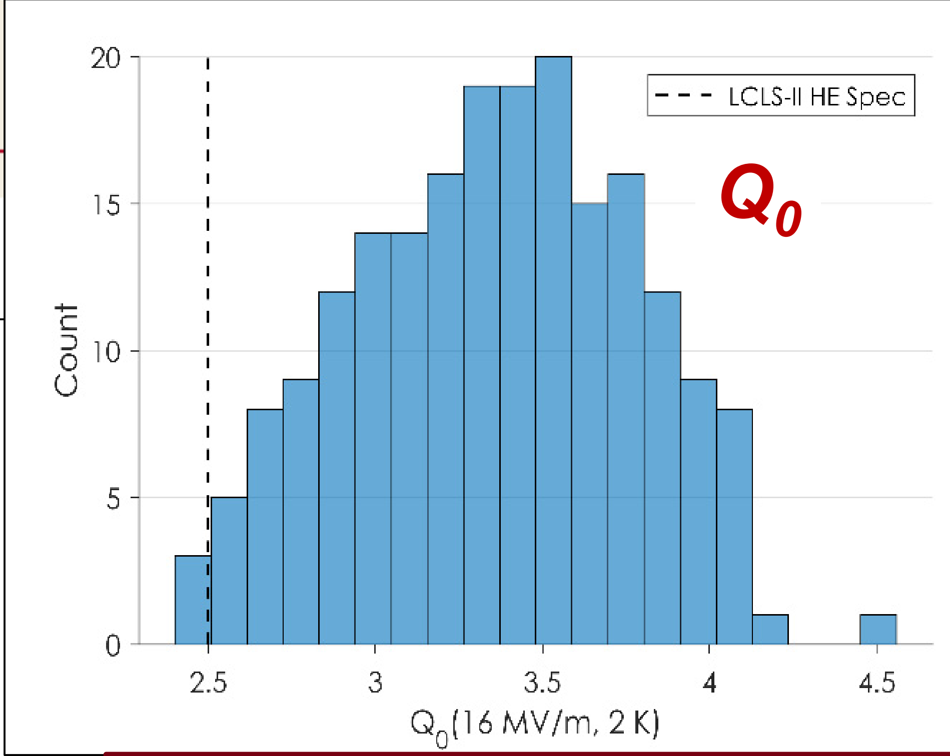
MOP044 Gonnella
FRCAA3 Gonnella

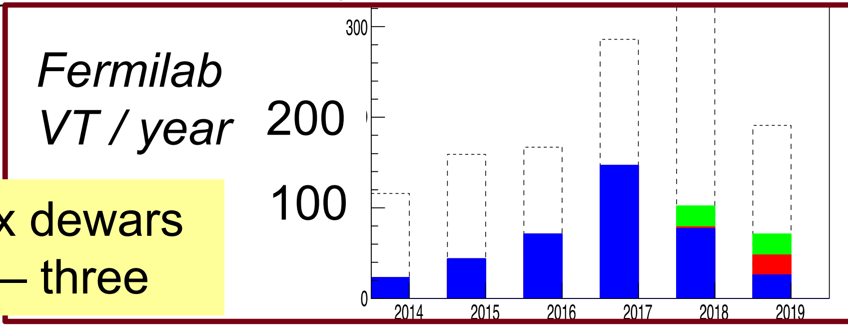
Testing Complete 07.2019



Gradient	Pass Rate
16	97%
18	92%
21	74%
22	66%
23	60%
24.5	34%

\>19 MV/m
→ ***Pass***





JLab – six dewars
Fermilab – three

Doping Summary – LCLS-II / LCLS-II-HE

2019 HE

<E_acc (max)> MV/m	Single Cell	Nine Cell
2/0 N-doping recipe	29.3 +/- 6	underway MOP045 Gonnella TUFUA3 Palczewski
2/6	24.9 +/- 5	
3/60	31.2 +/- 3	

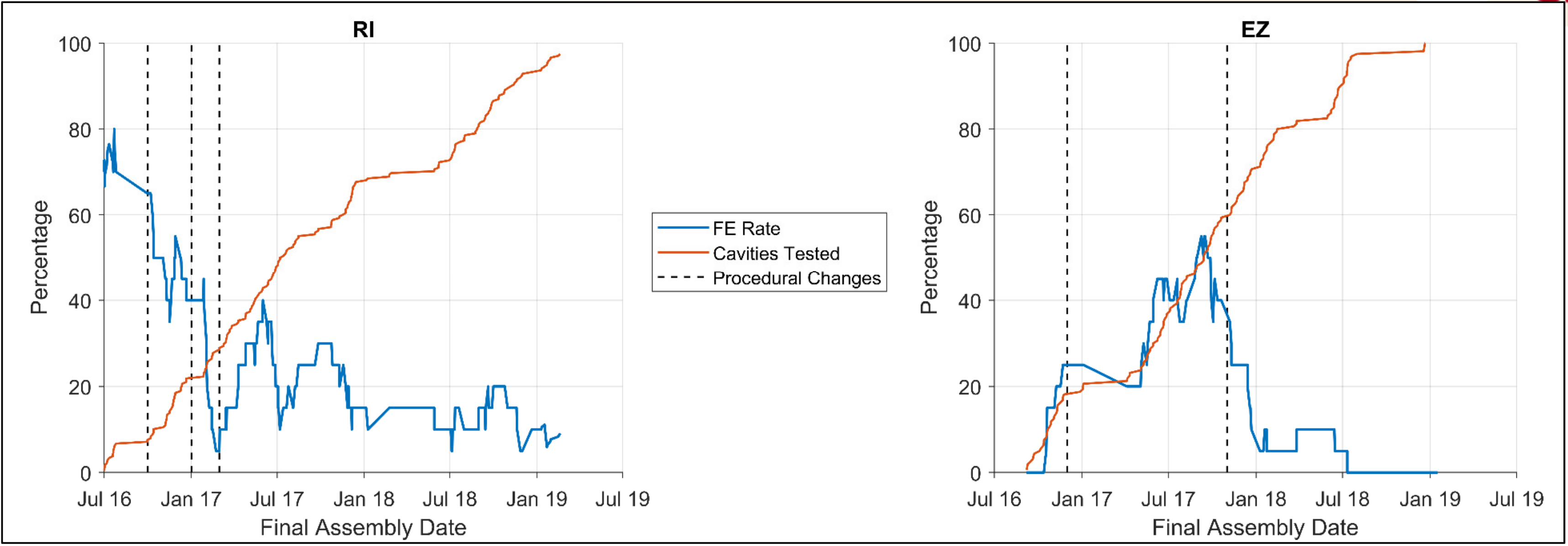
2016-19 LCLS-II Production (2/6 doping) 23.0 +/- 3

2014

<E_acc (max)> MV/m	Single Cell	Nine Cell
2/6	27 +/- 9	21.5 +/- 2
20/30	22.5	

Technical Challenges:

FE Performance Over Time – Vertical Test: 2 vendors



- Changes to clean room procedures has consistently resulted in improved field emission
- Typically see a field emission rate of <20%

Ari Palczewski, JLab

Outline

SLAC

Issues:

- Cavity → Flux Expulsion – minimizing trapped B_ambient
- CM →
    1. Field Emission / Multi-pactor Discharge
    2. Microphonics
    3. Shipping

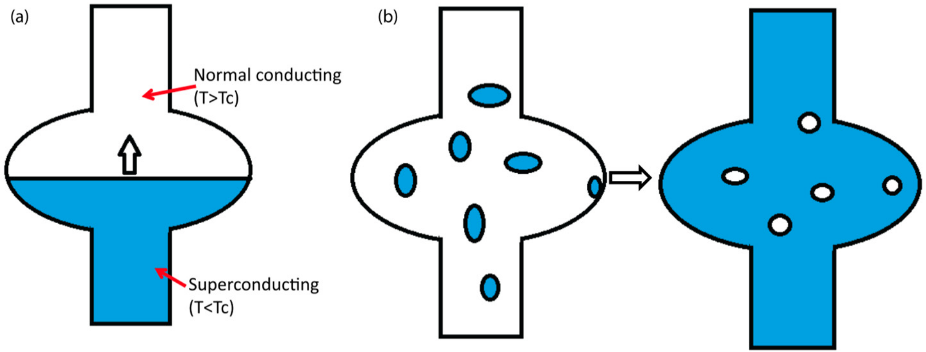
Plans

Three factors in Flux Expulsion:

TUP039 Posen
TUP057 Palczewski

1. *B_ambient* → from all sources: ***a) material magnetization***, Thermo-electric currents, earth's field
2. Nb Flux Expulsion Efficiency → ***b) bulk property, c) cool-down dynamics***
3. Heat dissipation per unit trapped flux → ***doping*** (doped Nb has increased heat 3x)

Optimum cool-down in vertical test; few vortices remain



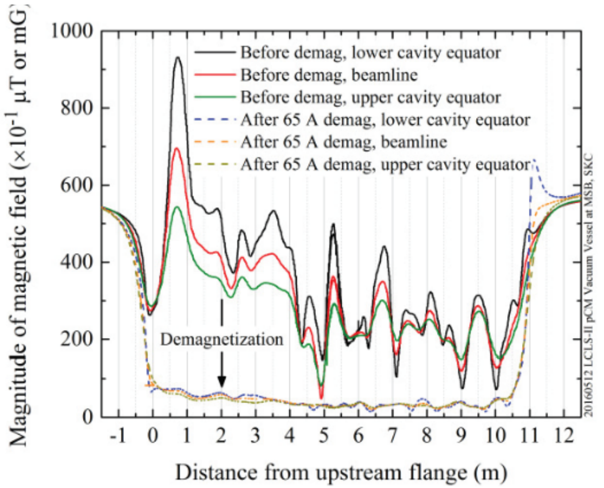
Cool-down characterized by ΔT (spatial)

High He mass-flow best

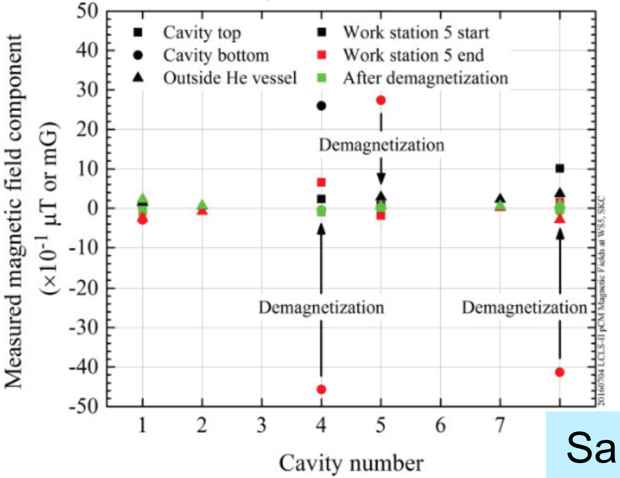
a) material magnetization

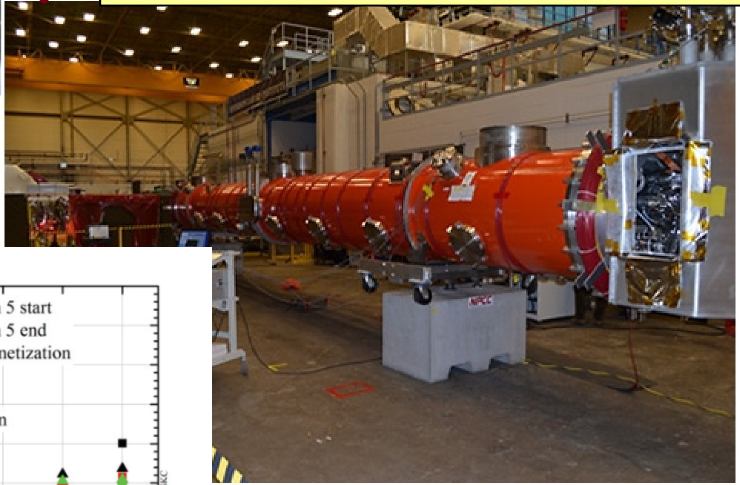
Magnetic shielding and Degaussing

CM degaussing
using demountable system
Fermilab
JLab
(goes to SLAC for in-situ use



Prototype CM





B_ambient limit: 5 mGauss max

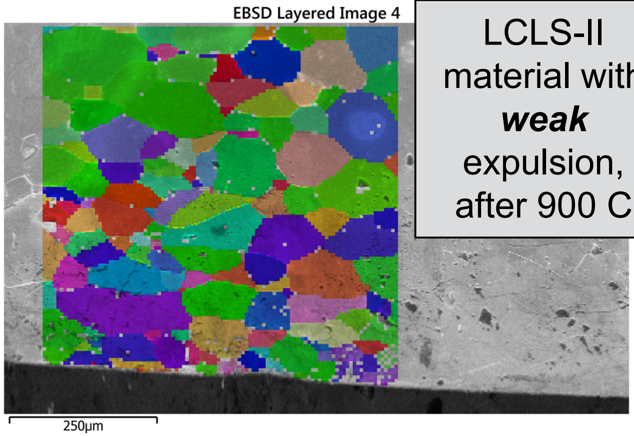
Saravan Chandrasekaran, FNAL

b) bulk property

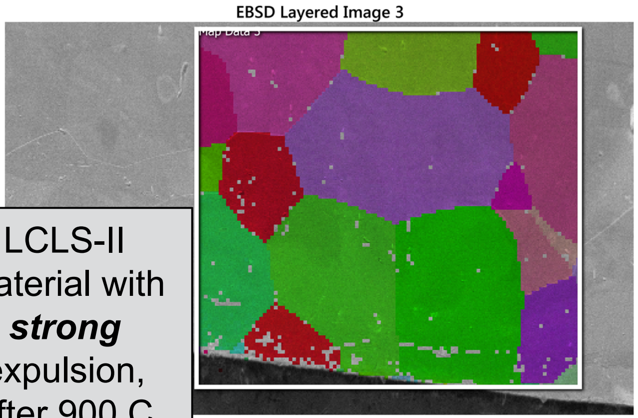
Improvement in expulsion is correlated with grain growth

Nb Sheet
forging and rolling determine grain size, structure and inter-grain

Studies underway to update specification with metallurgical qualification



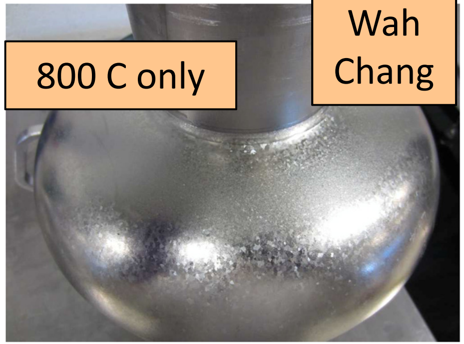
LCLS-II material with ***weak*** expulsion, after 900 C



LCLS-II material with ***strong*** expulsion, after 900 C

1000 C 4 hrs

Tokyo Denkai



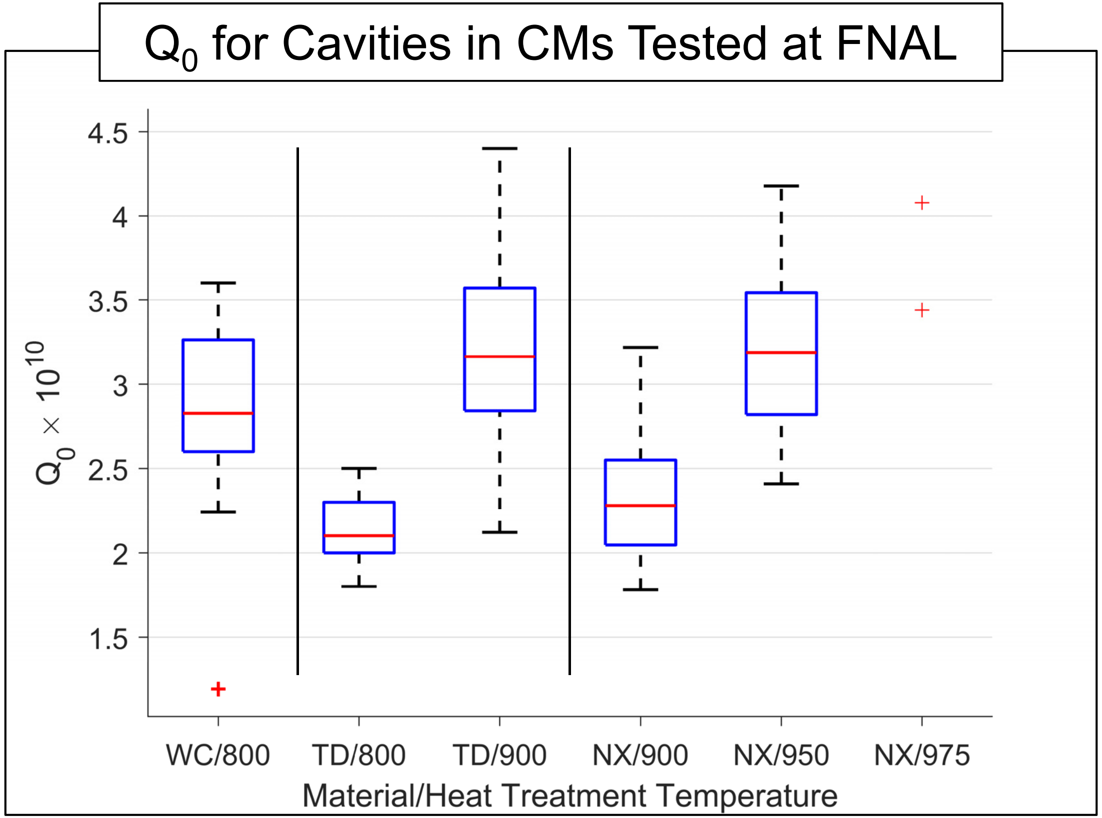
800 C only

Wah Chang

Sam Posen, FNAL

b) bulk property

Heat Treatment to improve Flux-expulsion efficiency



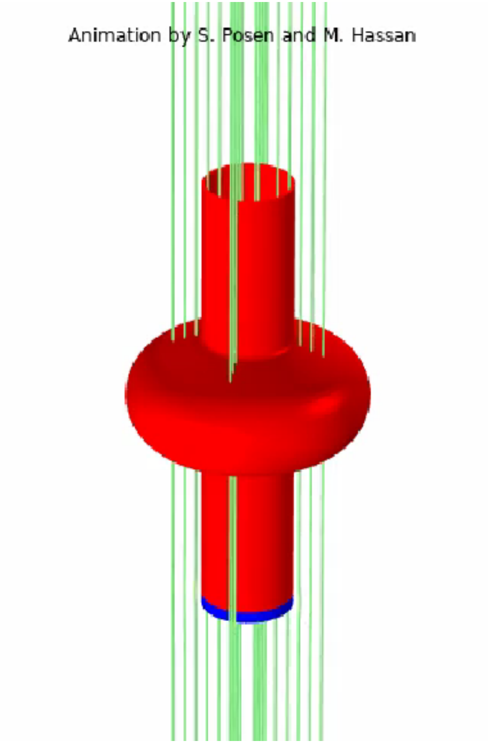
Flux-Expulsion annealing temperature change ***during production***

LCLS-II Annealing record	
Flux-expulsion Heat Temp. (ºC)	# Cavities
800	18
900	235
950	83
975	13

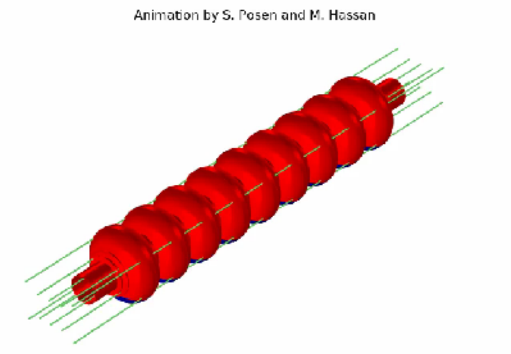
Magnetic Flux Expulsion

- Meissner Effect – well below T_c, niobium tends to expel applied magnetic flux
- However, flux can become trapped in superconductor during cooldown
- Only within the last 5 years has R&D made it possible to reliably achieve strong expulsion during cooldown

R&D in Vertical Test



Ambient magnetic field during cooldown



Implementation in LCLS-II Cryodmodule

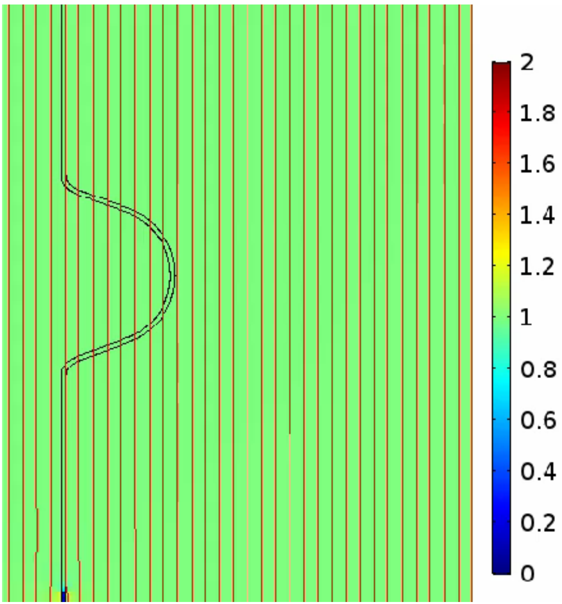
c) cool-down dynamics

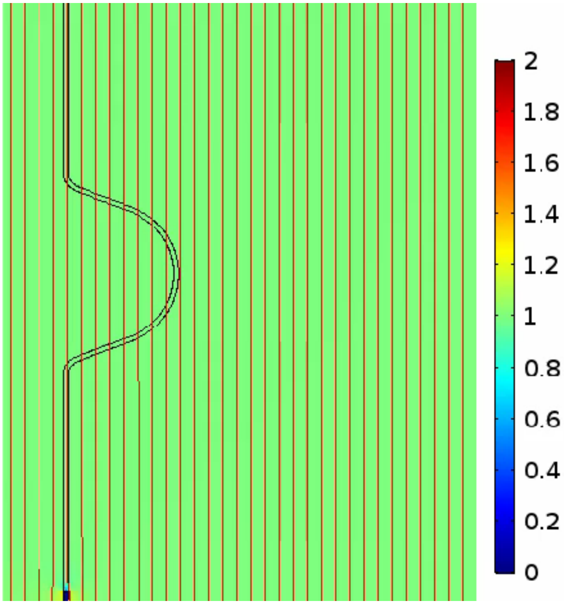
Single Cell in VT:

Expulsion vs. Trapping

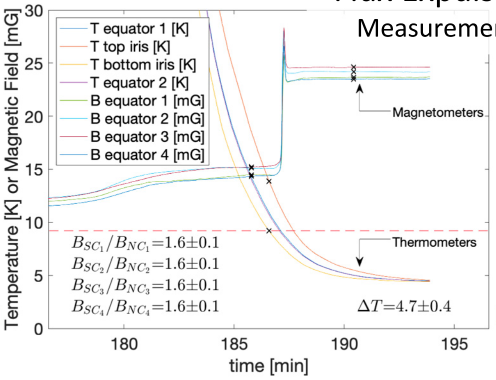
ΔT (iris to iris) =4.7 / 0.7

B_{SC}/B_{NC} ~1.7 / 1

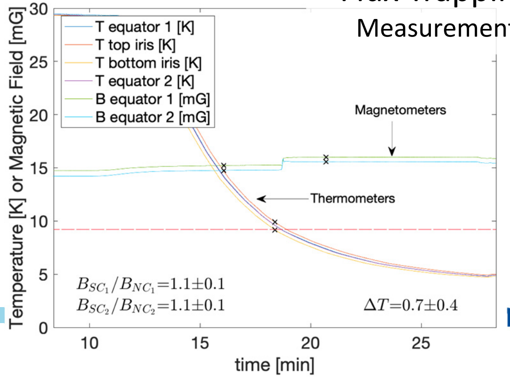




Flux Expulsion
Measurement



Flux Trapping
Measurement



Sam Posen, FNAL

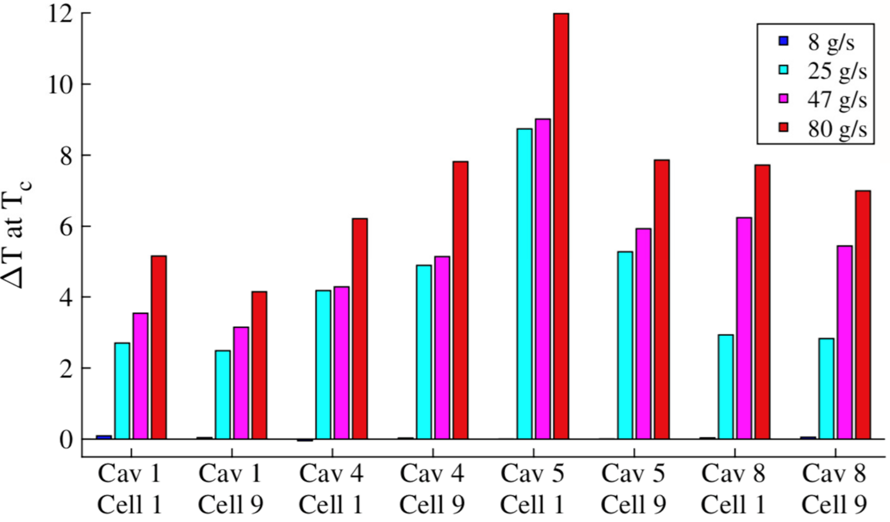
c) cool-down dynamics

Cooling a CM through T_c

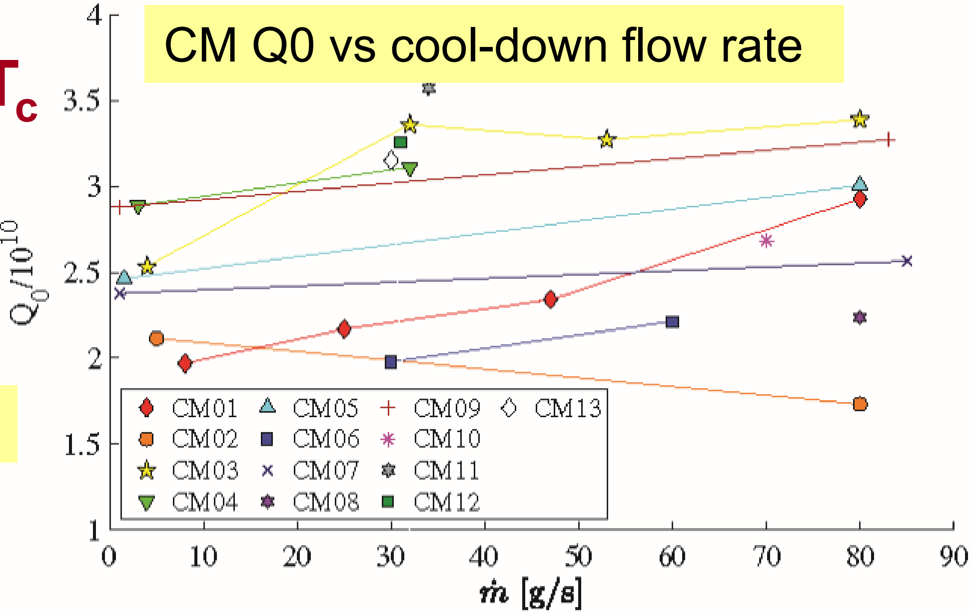
32 g/s spec

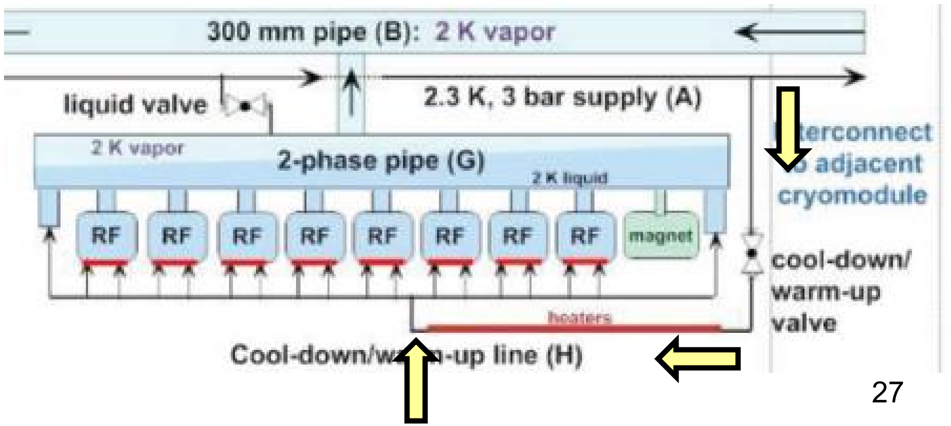
Instrumented cavities: Prototype CM
2.3K, 3 bar supercritical He supply
Center-feed

ΔT Equator: *Top to Bottom* vs cavity



CM Q0 vs cool-down flow rate





Outline

Issues:

- Cavity → Flux Expulsion
- CM → Two equivalent production lines; identical components and tooling
    1. Field Emission / Multi-pactor Discharge
    2. Microphonics
    3. Shipping

Plans

Two Production and Test Infrastructures; Common Supply Chain

- Fermilab:
  - Long history with TESLA-type CM, but no extended production experience
- Jefferson Lab:
  - Extensive production experience, but no direct experience with TESLA-type CM, monolithic (not segmented) linac

ILC-GDE Proposal:

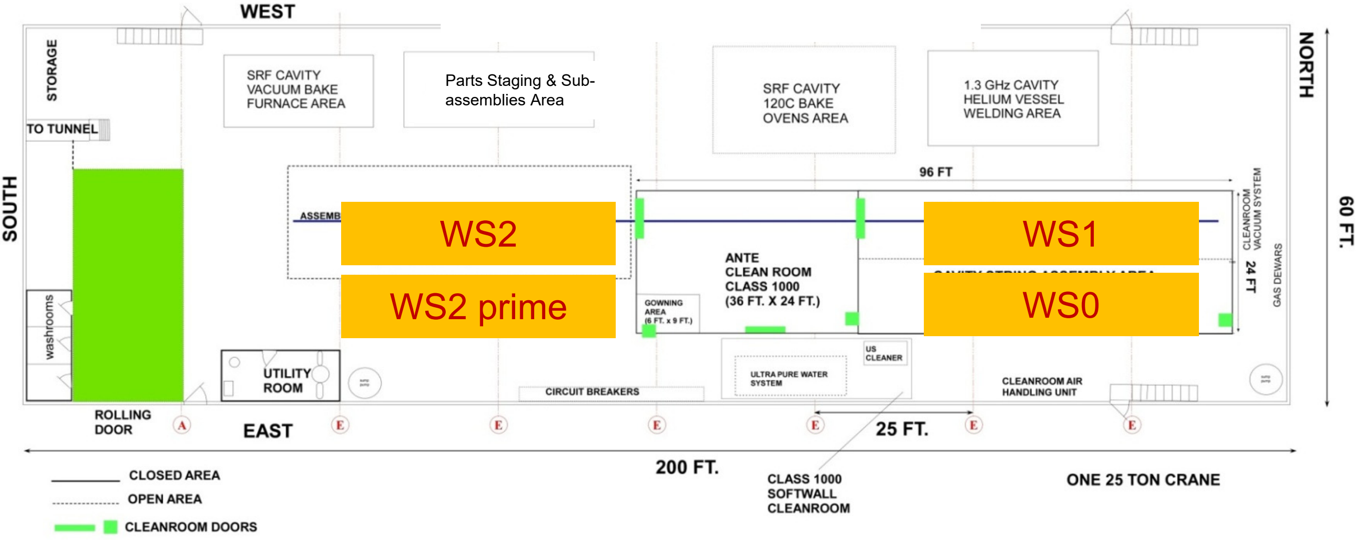
  - ‘Plug-Compatibility’ to allow independent development that meets interface requirements
  - For LCLS-II: Identical tooling, Identical parts, Equivalent Process leading to Equivalent Performance.

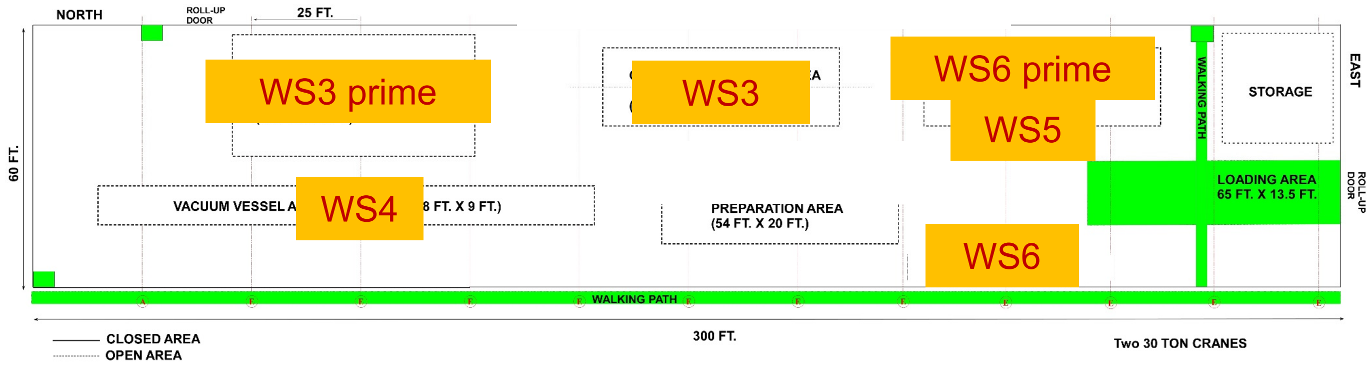
Example: CM assembly with string under vacuum

  - Evaluated 04.2007 for DESY, Recommendation: Not without development/check

MOP092 Stanek
TUP101 Arkan

Fermilab Assembly





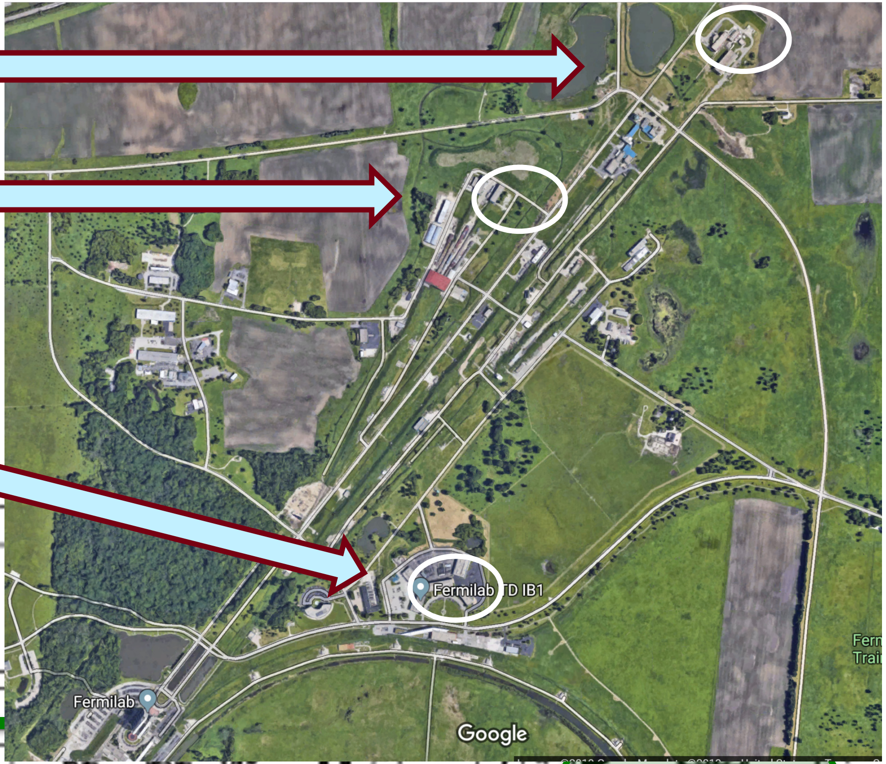
TUP060 Harms

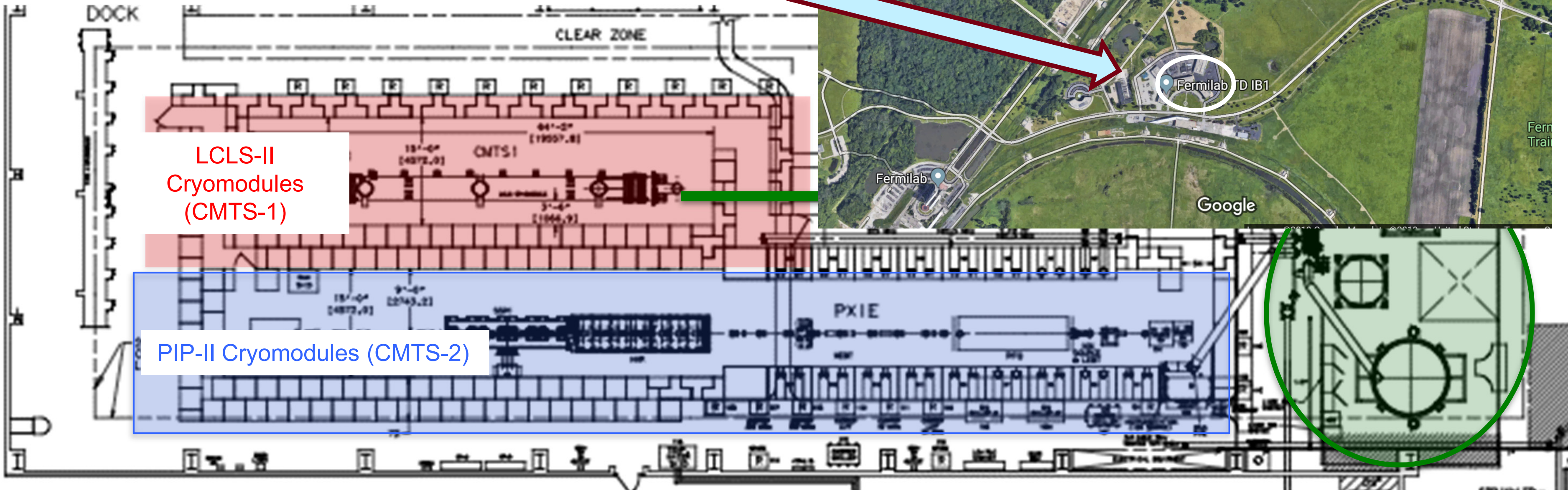
Fermilab CM Test

Test

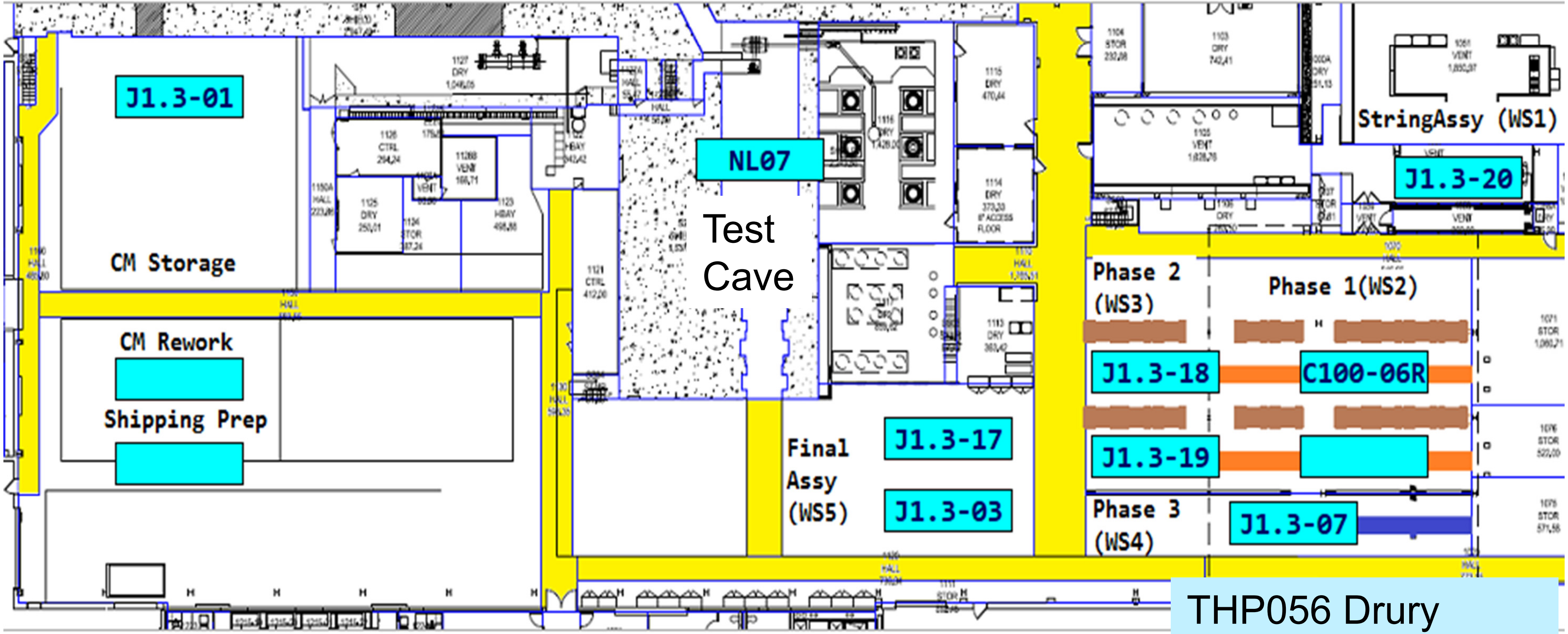
Clean room

Main Assembly





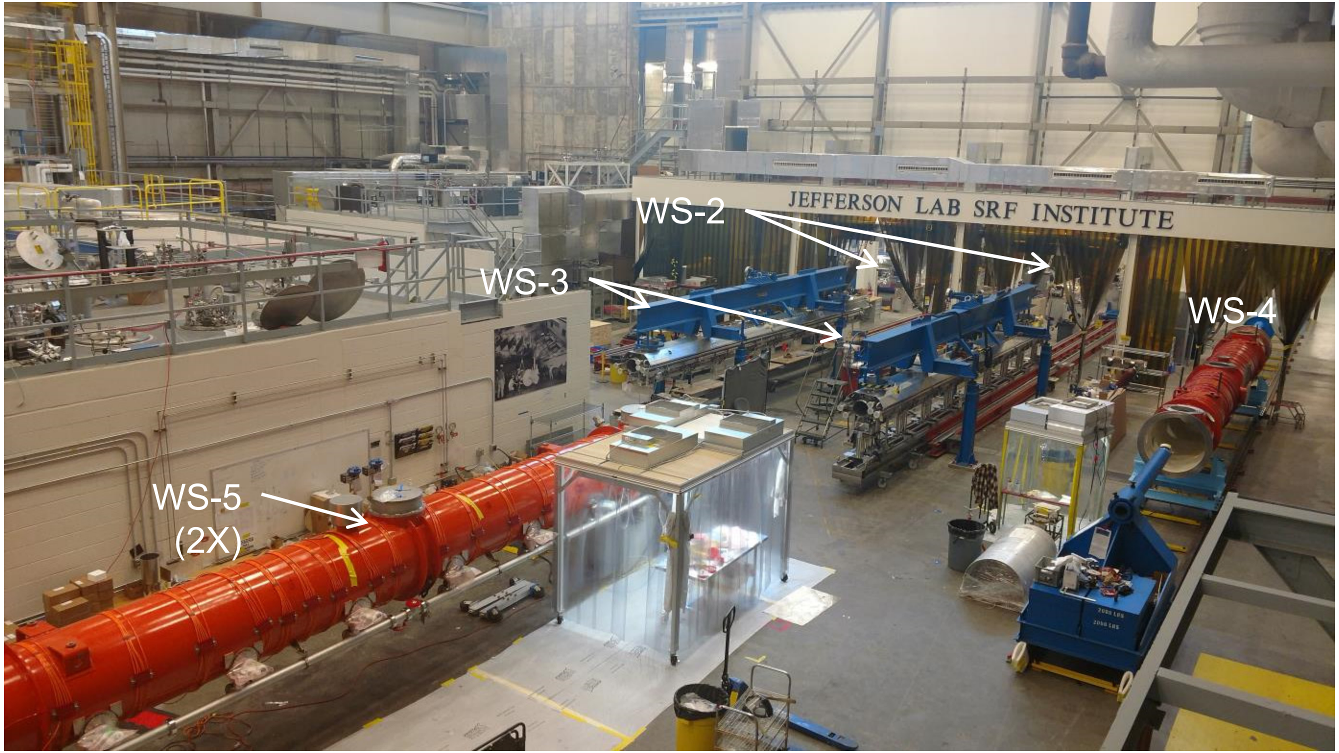
Jlab CM Assembly/Test



75 x 30 m

THP056 Drury
THP049 (LERF)
THP051 Huque
THP052 Bookwalter

Cryomodule Assembly at JLab



CM Testing

JLab –

1. CMTF 'cave'
2. LERF two CM end-to-end

Fermilab –

3. CMTS1

Basic Steps:

E_acc Max

- *Find the limit*, or reach admin.
- Limit 21 MV/m
- Record FE onset

E_acc Usable (128 MV)

- 0.5 below admin or
- 50 mr/hour
- One hour stable (SEL) operation

Q0 (2.7e10, 88W @2K)

- dP/dt with valves closed or
- Flow required for equilibrium

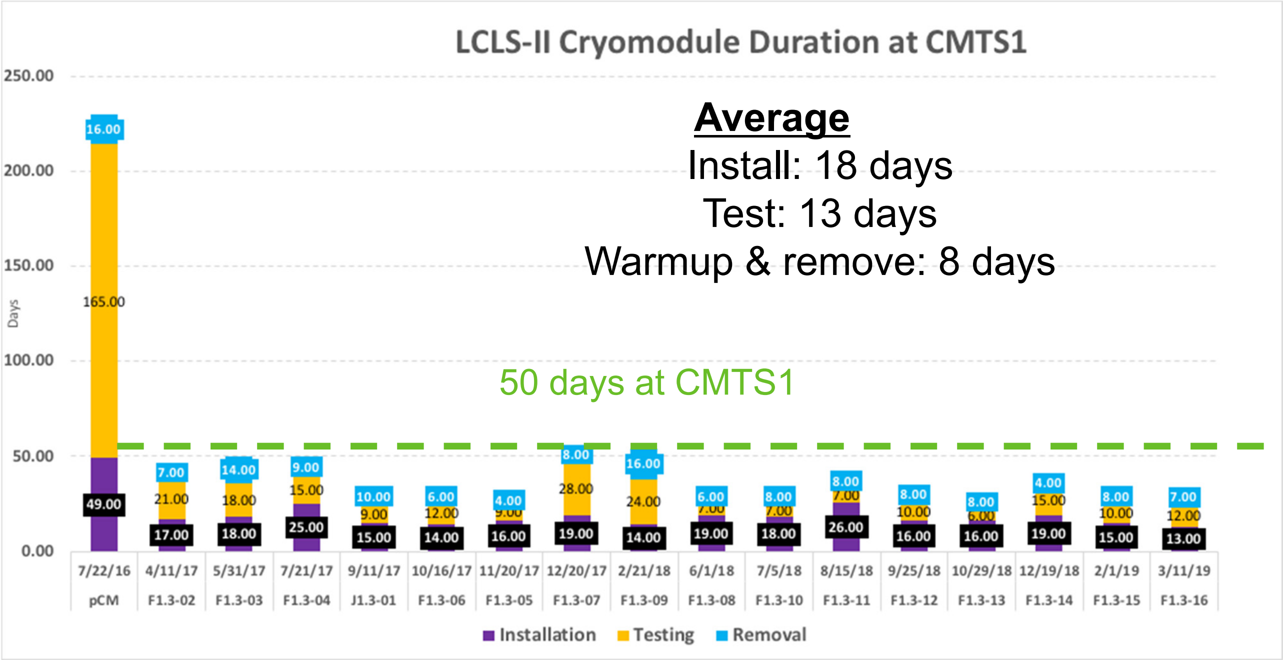
Endurance Test

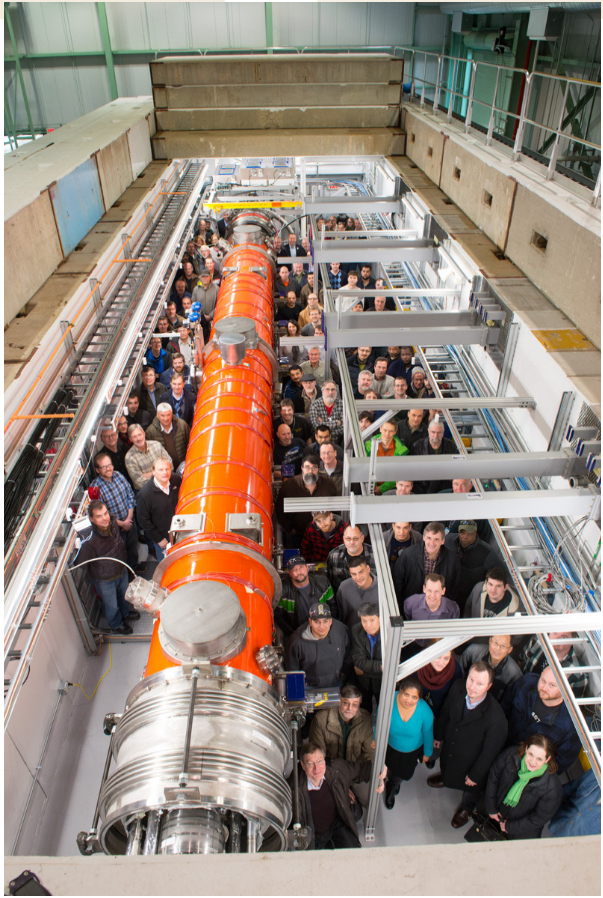
- 10 to 16 hours at nominal (CM) integrated E_acc = 128 MV
- In GDR as much as possible

Cryomodule testing at FNAL

SLAC

Based on LCLS-II CMs 02-16, avg is ~39 calendar days/CM

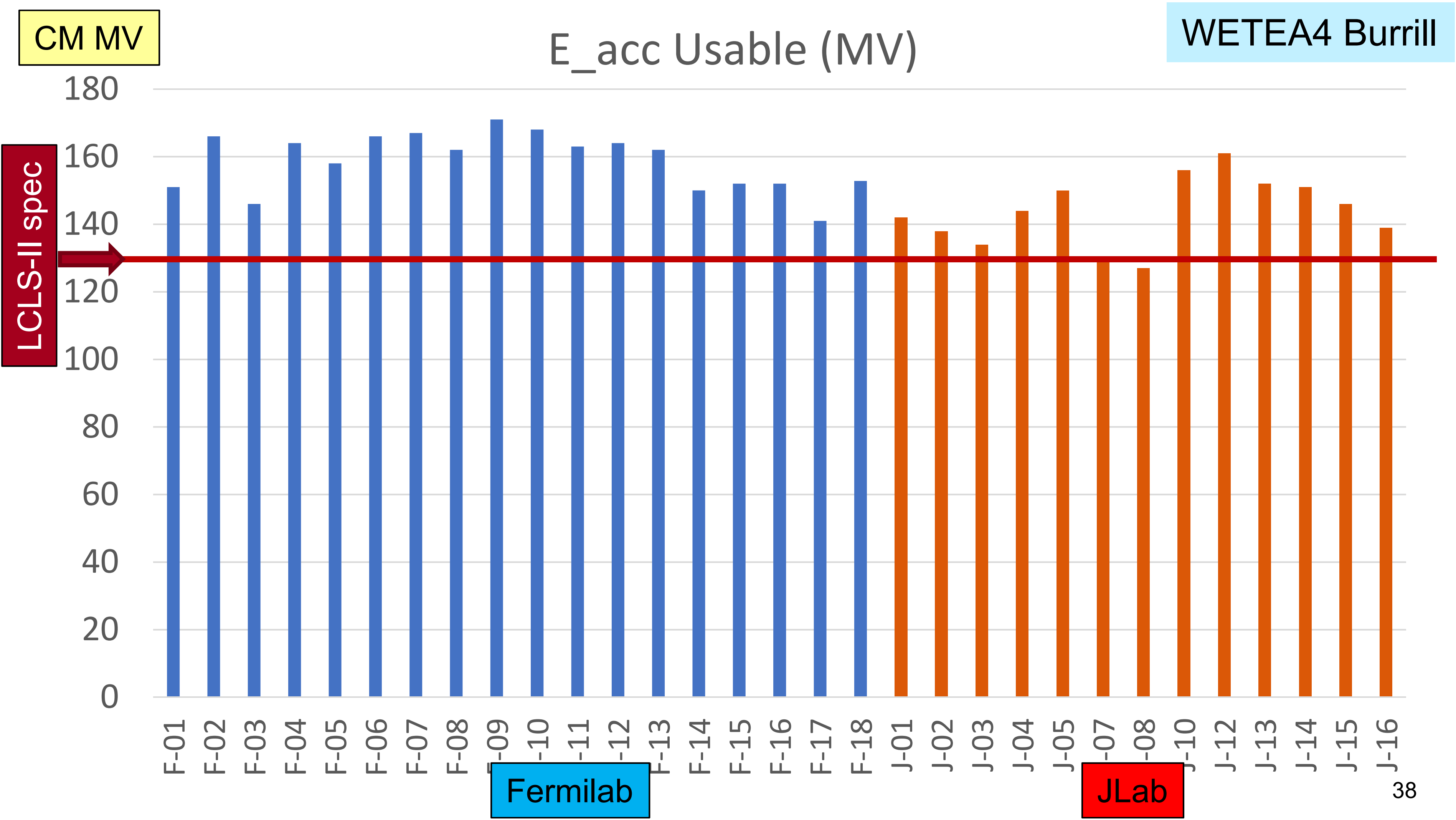




Typical Performance Summary (F-17, 04.2019)

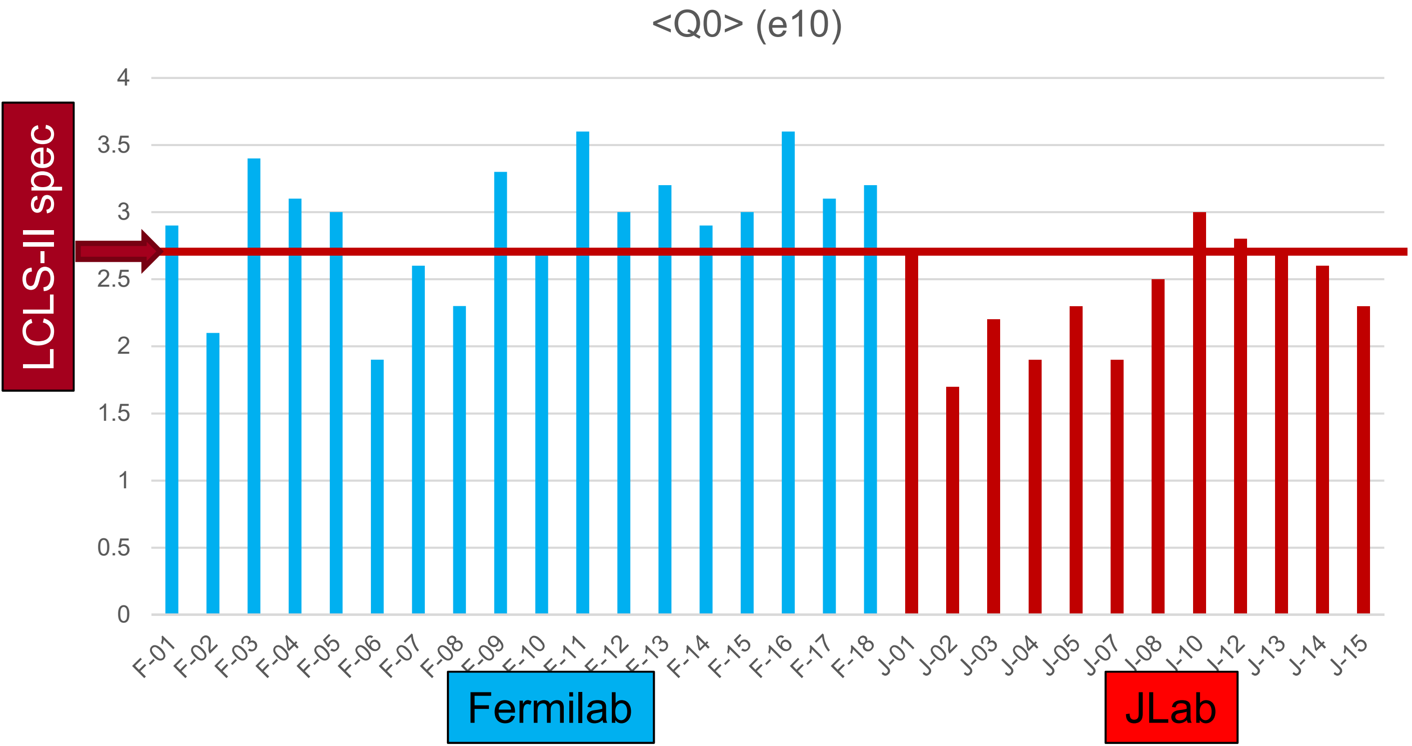
SLAC

	VTS			CMTF Test				
Cavity	Eacc* [MV/m]	FE onset	Q0@16MV/m	Max** Gradient [MV/m]	Usable Gradient*** [MV/m]	FE onset [MV/m]	Q0 @16MV/m 2K @ 30 g/s	Material
CAV0540	21.4	none	2.8E+10	20.5	20.5	none	3.19E+10	TD 200/900
CAV0530	20.6	24	2.9E+10	19	17	none	2.56E+10	TD 200/900
CAV0533	25	none	3.0E+10	18.5	18.5	none	3.22E+10	TD 200/900
CAV0529	19	none	3.2E+10	18.5	18	none	3.16E+10	TD 200/900
CAV0525	19.5	none	3.3E+10	19	17	none	3.84E+10	TD 200/900
CAV0535	25.7	none	3.5E+10	19	18.5	none	3.77E+10	TD 200/900
CAV0067	18.8	none	3.4E+10	19	19	none	3.44E+10	NX-C, 200/975
CAV0517	18.8	none	3.0E+10	10	7.1	6	2.12E+10†	TD 200/900
Average	**21.1**		**3.13E+10**	**17.9**	**16.9**		**3.16E+10**	
Total Voltage	**175.2**			**148.9**	**140.7**			



CM MV
E_acc Usable (MV)
WETEA4 Burrill
LCLS-II spec
180
160
140
120
100
80
60
40
20
0
F-01
F-02
F-03
F-04
F-05
F-06
F-07
F-08
-10
-11
-12
F-13
F-14
F-15
F-16
F-17
F-18
J-01
J-02
J-03
J-04
J-05
-07
-08
J-12
J-13
J-14
J-15
J-16
Fermilab
JLab

THP051 Huque



- JLab Q0 notes:
  - Initial JLab CM cooldown did not produce the high Q0
  - J-01 tested at Fermilab
  - Modifications (J-08…) and upgrades of the cryogenic system produced high Q0 results
- Different measurement methodology (dP/dt vs flow-rate)

Outline

Issues:

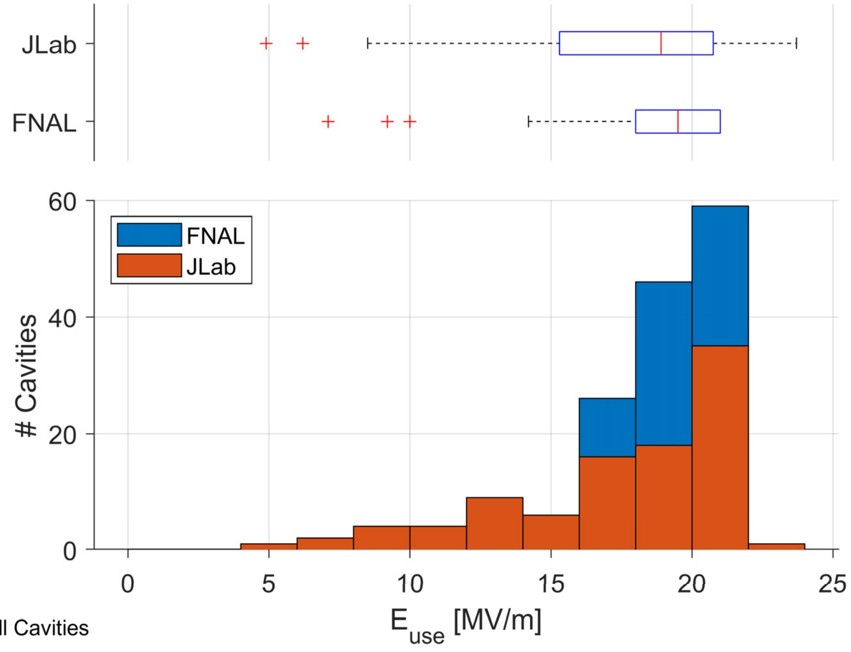
- Cavity → Flux Expulsion
- CM →
  1. Field Emission / Multi-pactor Discharge
  2. Microphonics
  3. Shipping

Plans

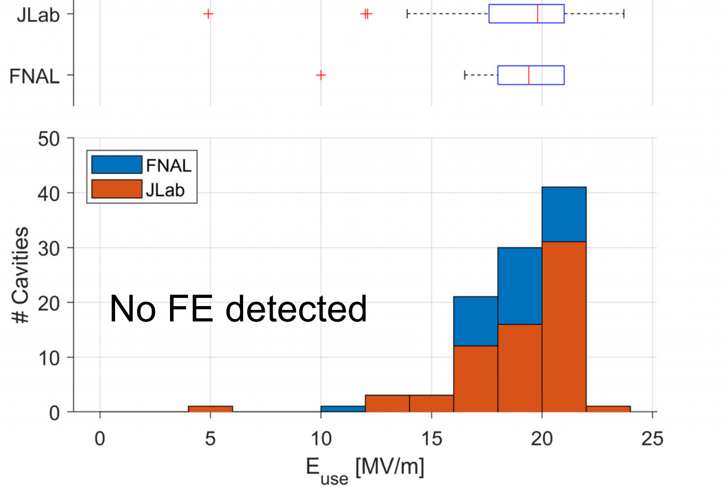
Cavity E_acc Usable

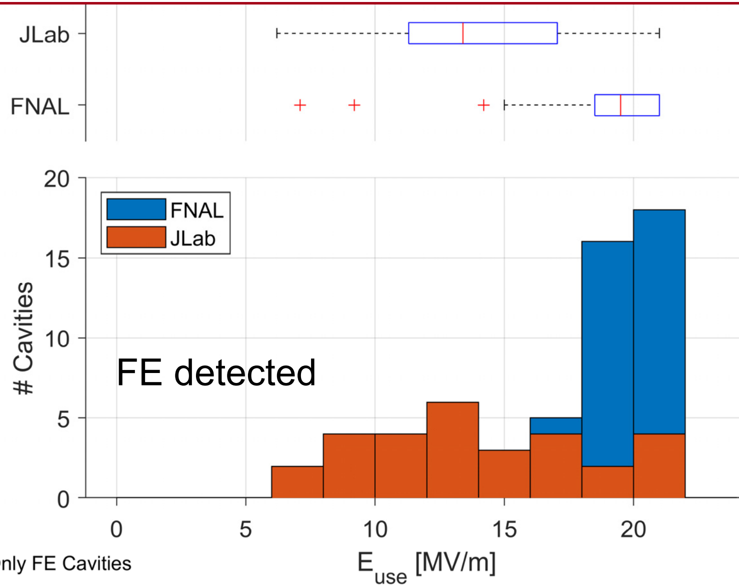
From CM testing, with / without detectable FE

All Cavities



All Cavities

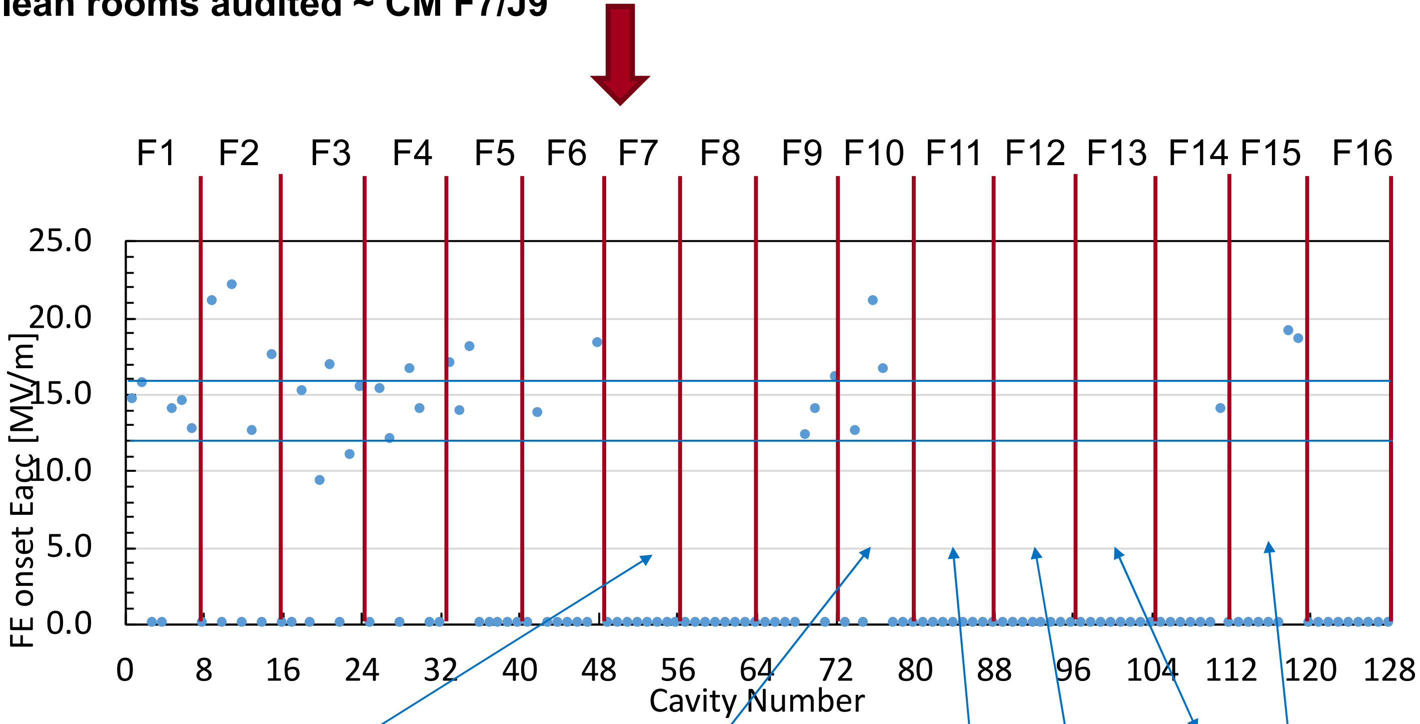




Only FE Cavities

Field Emission Onset Eacc of FNAL Cryomodules vs CM

Both Clean rooms audited ~ CM F7/J9



1. Internal audit changed the procedure to back fill WS0 slowly

1. WS0 backfill upgraded
2. Procedure upgraded

1. WS1#8 backfill upgraded

1. New staff training

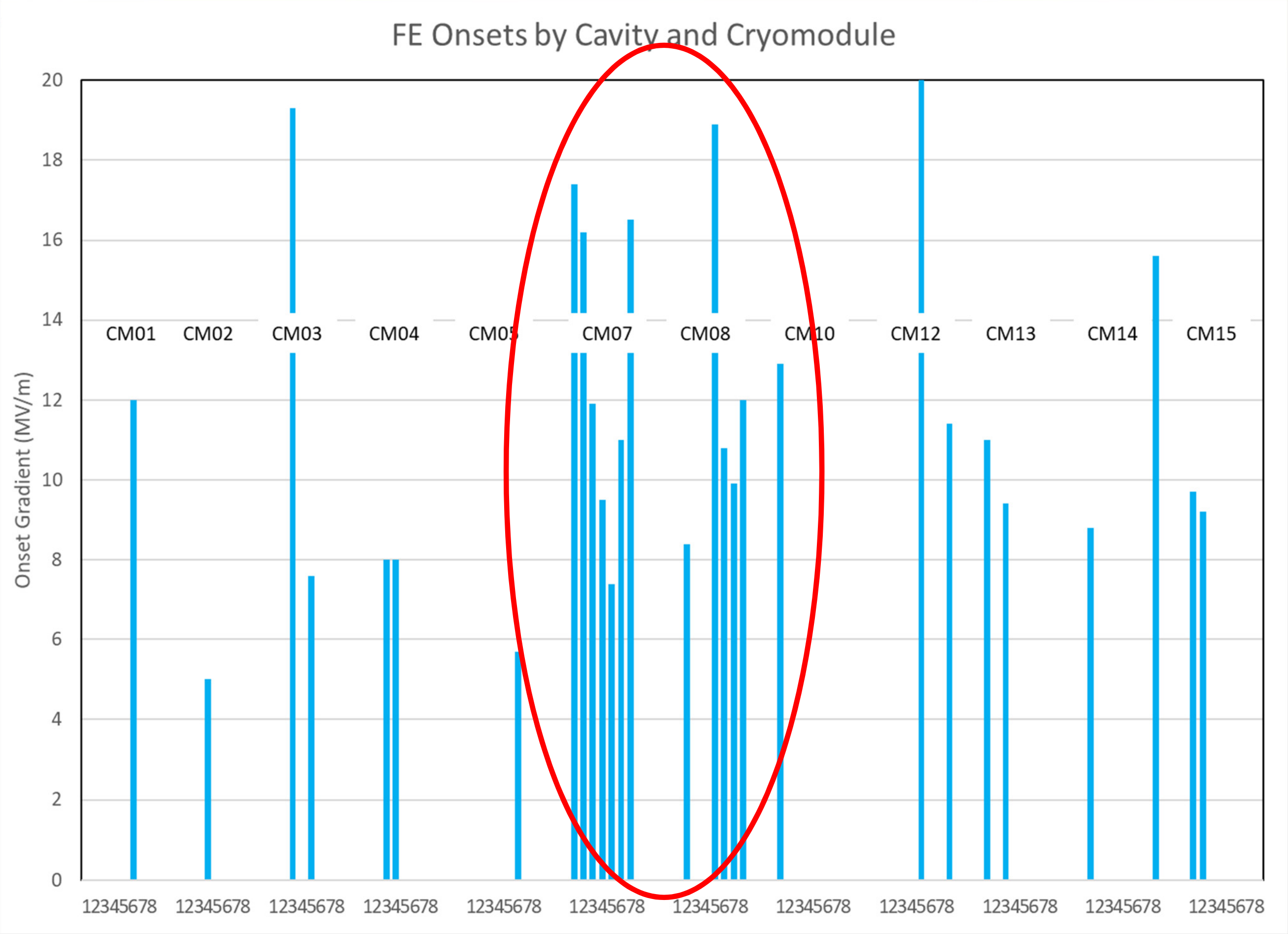
1. One HEPA filter fan failed

1. New staff training

Field Emission Onset Eacc of JLab Cryomodules vs CM

- Gradient Onset
  - Field emission on two CMs has been tracked to process variation in the clean room
    - This has been fixed

- JLab process is different: **CM is assembled with string under vacuum.**

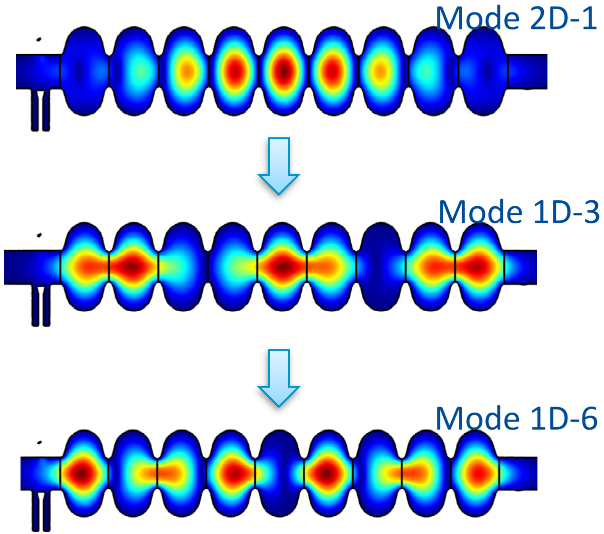


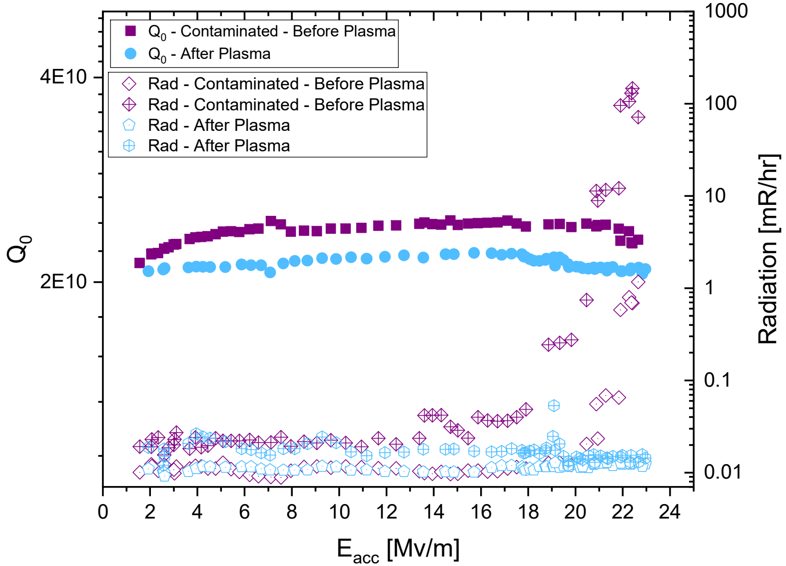
n.b. Chemically-reactive Plasma processing (SNS)

Cell-by-cell Neon-Oxygen processing has been successful at SNS (M. Doleans)

Adapted to high QL 9-cell cavities and tested

- Use HOM coupler to feed 1st/2nd dipole pass-band
- No effect on doping performance





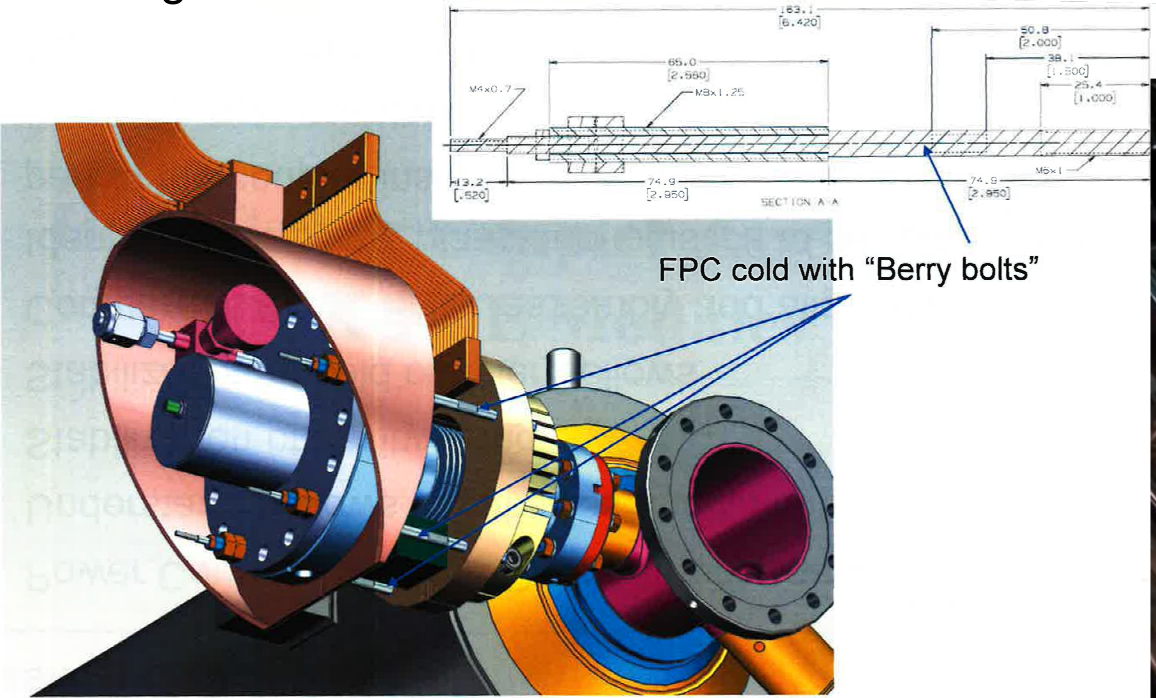
FRCAB7 *B. Giaccone*
TUP065 *P. Berrutti*
TUP067 *B. Giaccone*

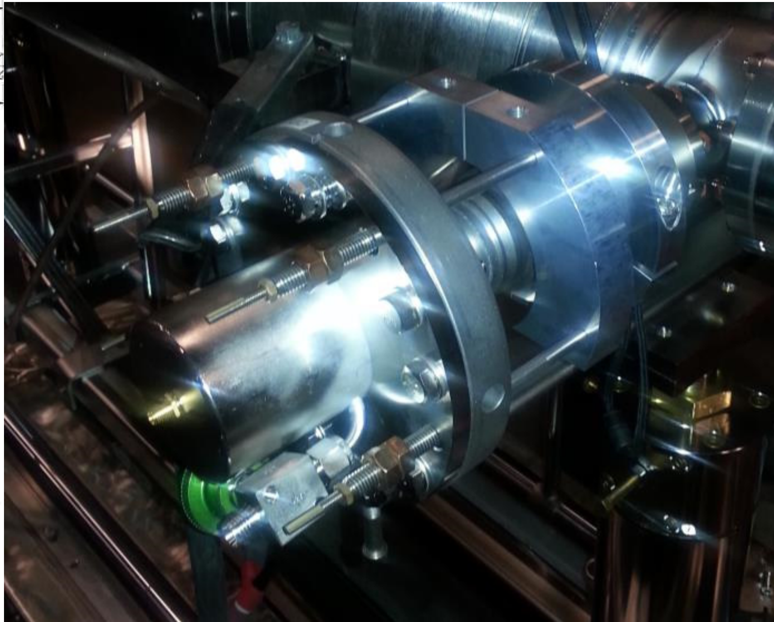
CM Assembly with String under vacuum – JLab practice →

Removable FPC (cold)
bellows restraint
Cage of thin rods

Assembled String *<u>actively pumped ~ 2 months: Surface gas removed</u>*

1) **Base pressure 30x lower on arrival at SLAC**
2) **Multipactor processing reduced**





Usable Gradient Limitation Mechanism at FNAL

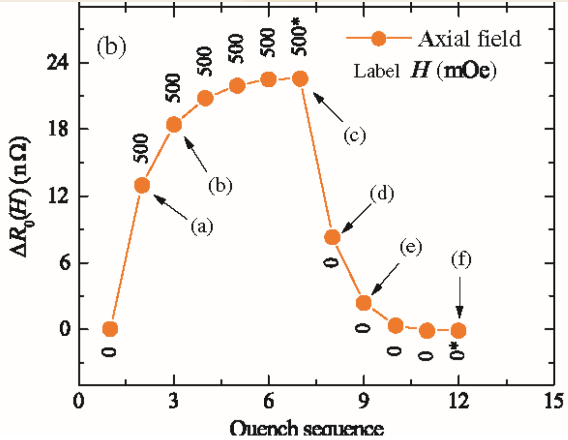
TUP038 S. Posen

- We regularly see usable gradients in the 17.5-18.5 MV/m range when the maximum gradient is closer to 20-21 MV/m
- Usable gradient requires 1 hour without quench, but regularly see cavities stable for many minutes then suddenly quench → Multipactor likely
- What could be causing these "sporadic" quenches?

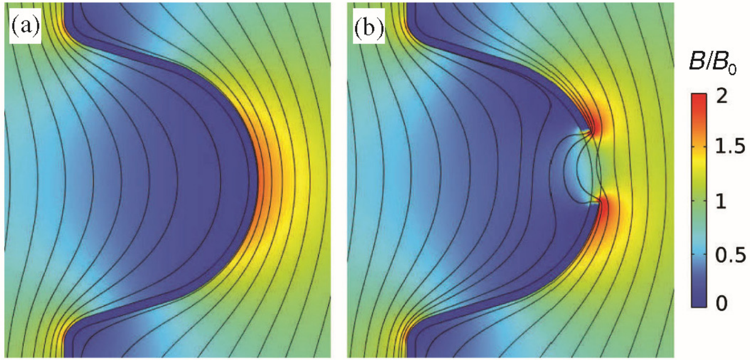
		VTS		CMTF Test					
	Cavity	Eacc* [MV/m]	Q0@16MV/m	Max** Gradient [MV/m]	Stable at CMTF*** [MV/m]	Q0 @16MV/m 2K @ 80 G/s	Q0 STDEV	Additional Trapped Field [mG]	Material
1	CAV0139	25.8	3.14E+10	21	19.5	3.32E+10	14.8%	0.24	TD 200/900
2	CAV0225	24	3.50E+10	19.5	18.5	3.74E+10	13.2%	0.22	TD 200/900
3	CAV0096	21	4.03E+10	20	17.5	3.83E+10	13.4%	0.82	TD 200/900
4	CAV0154	24.6	3.91E+10	20	17.5	3.74E+10	10.9%	0.79	TD 200/900
5	CAV0230	24	3.87E+10	19.5	17.5	3.34E+10	15.2%	1.36	TD 200/900
6	CAV0205	22.3	3.26E+10	19.5	19.0	3.47E+10	17.5%	0.21	TD 200/900
7	CAV0324	24	3.35E+10	20.5	17.5	3.77E+10	18.4%	-0.06	TD 200/900
8	CAV0150	21.4	3.46E+10	19	19.0	3.24E+10	15.8%	0.95	TD 200/900
	Average	**23.4**	**3.57E+10**	**19.9**	**18.3**	**3.56E+10**		**0.6**	
	Total Voltage	**194.2**			**151.5**				

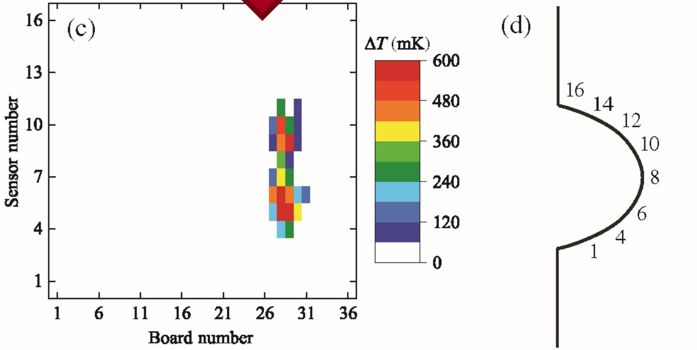
MP Quench can increase flux trapping – Integration mechanism

- Flux concentration can be high just outside the equator;
- Each quench admits more flux (depends on size of NC region and B_amb), increasing R until equilibrium is reached
- Thermal reset – fast cool-down is required



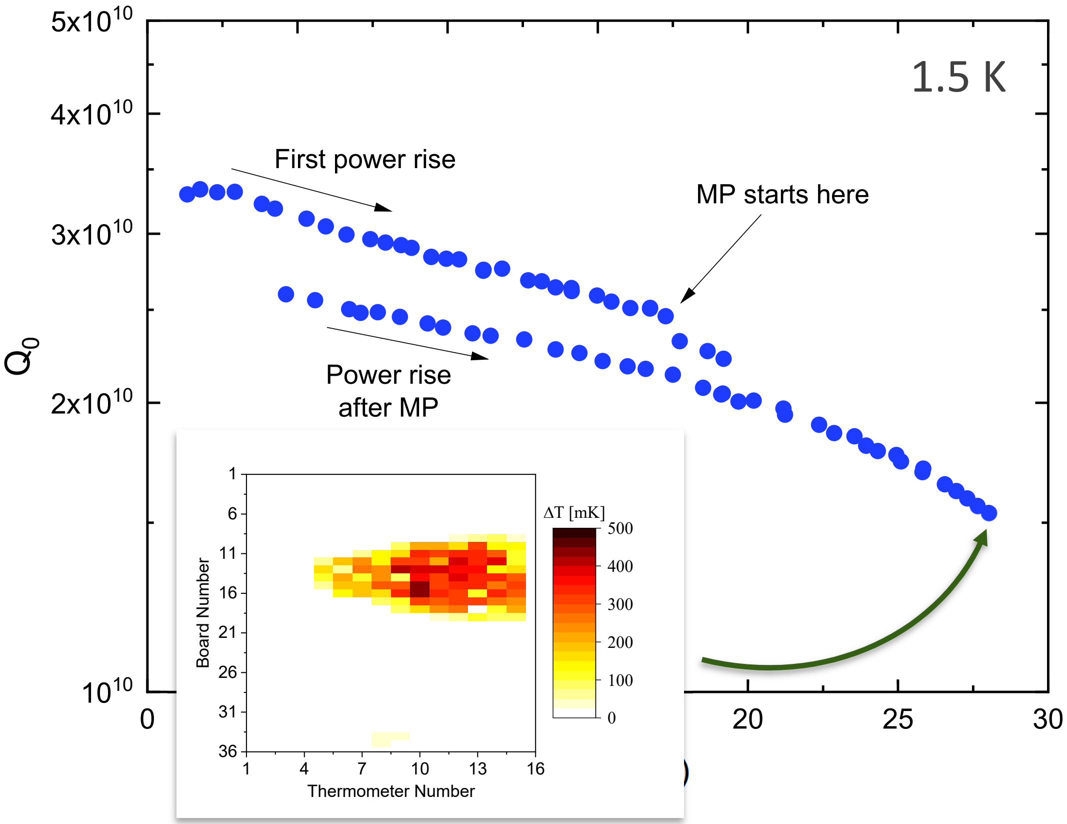
Direct Tmap measurement of local increase R (M. Checchin)





Ultimate quench

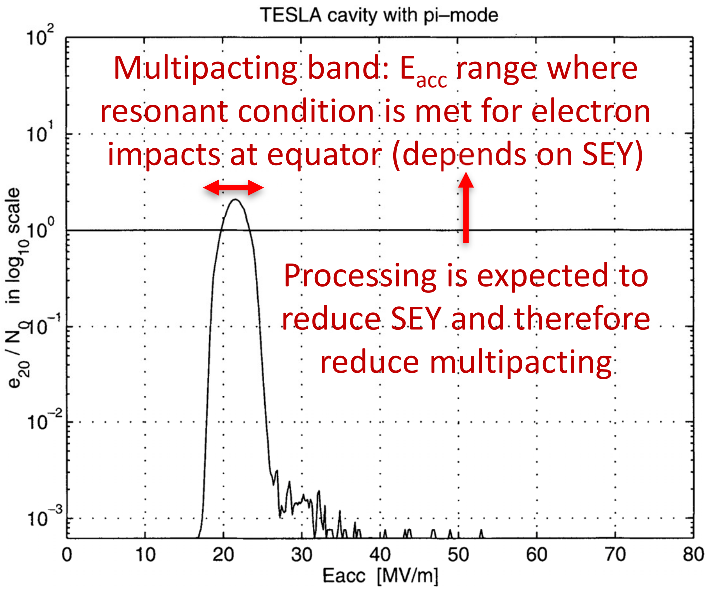
Multi-pactor ←→ Quench

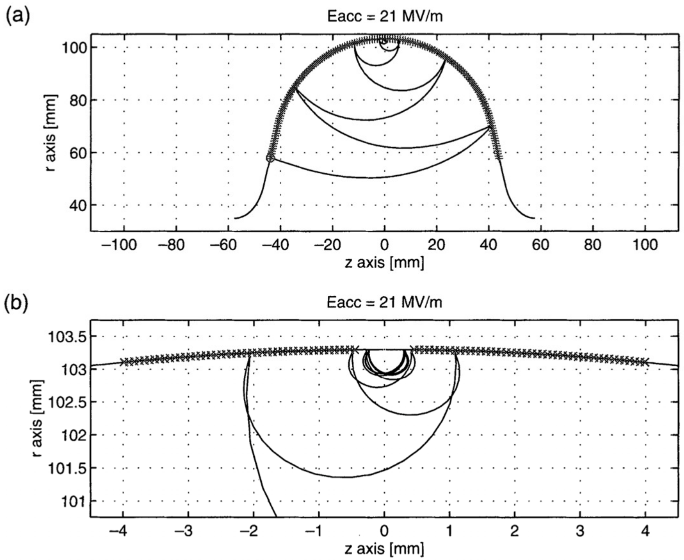


Multipacting in Elliptical Cavities

- Range of fields in which quenches are observed is right where multipacting band is for this cavity shape

LCLS-II: 16 MV/m
LCLS-II-HE: 21 MV/m





Pasi Yla-Oijala, "Electron multipacting in TeSLA cavities and input couplers," *Particle Accelerators*, Vol. 63, pp. 105-137 (1999)

Must stay on for one hour without trip to set E_acc usable

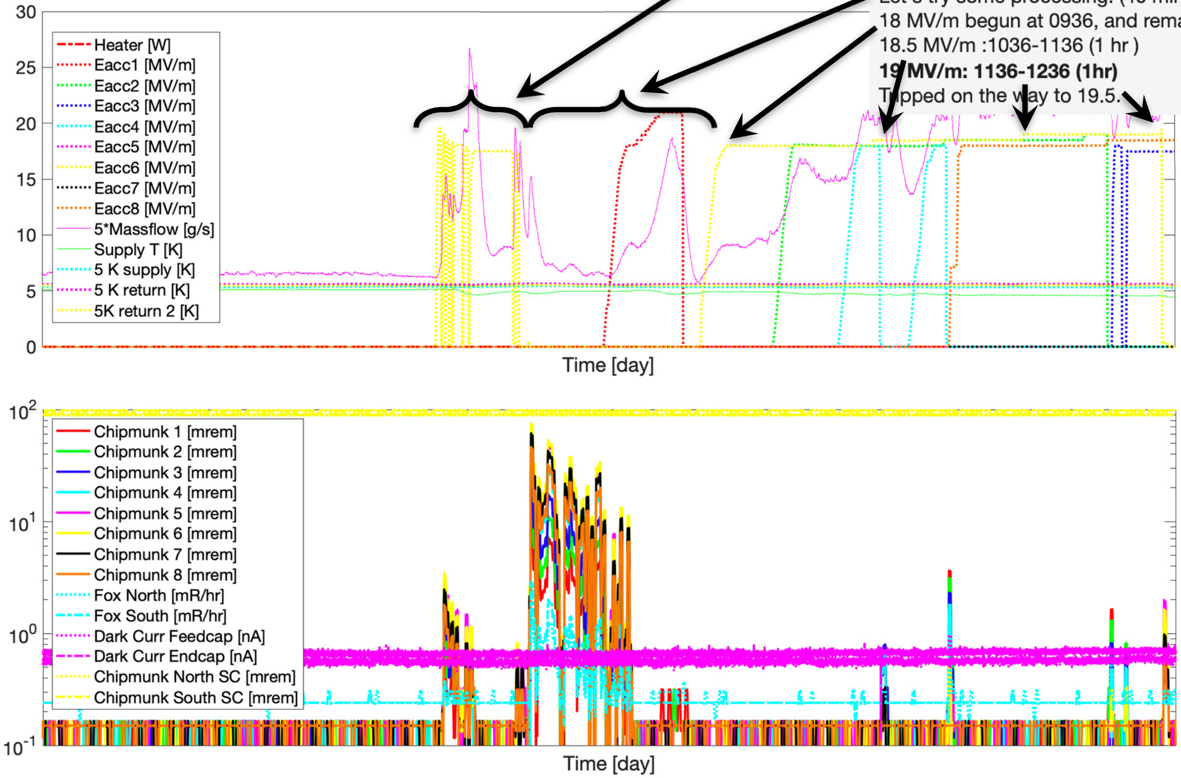
JLab / Fermilab experience differ

See

TUP038 S. Posen

Wed 2019-03-27 07:46:33 F1.3-16 Usable Gradient

Starting with cavity #6 this morning.
Begin at 19.5 MV/m - quickly quenches
19 MV/m - ditto
18.5 MV/m - ditto
18.25 MV/m - 1 minute
18 MV/m begun at 0743, ended at 0747
17.8 MV/m begun at 0748, ended at 0749
17.5 MV/m begun at 0751, ended at 0808.
17.25 MV/m begun at 0809 and off right away.
Let's try some processing. (40 minutes at 21 MV/m, see plo
18 MV/m begun at 0936, and remained stable to 1036 (1 hr
18.5 MV/m :1036-1136 (1 hr)
19 MV/m: 1136-1236 (1hr)
Tripped on the way to 19.5.



Fermilab

Outline

Issues:

- Cavity → Flux Expulsion
- CM →
  1. Field Emission / Multi-pactor Discharge
  2. Microphonics → Active Compensation with fast tuner
  3. Shipping

Plans

Cavity Detuning

C. Adolphsen

SLAC

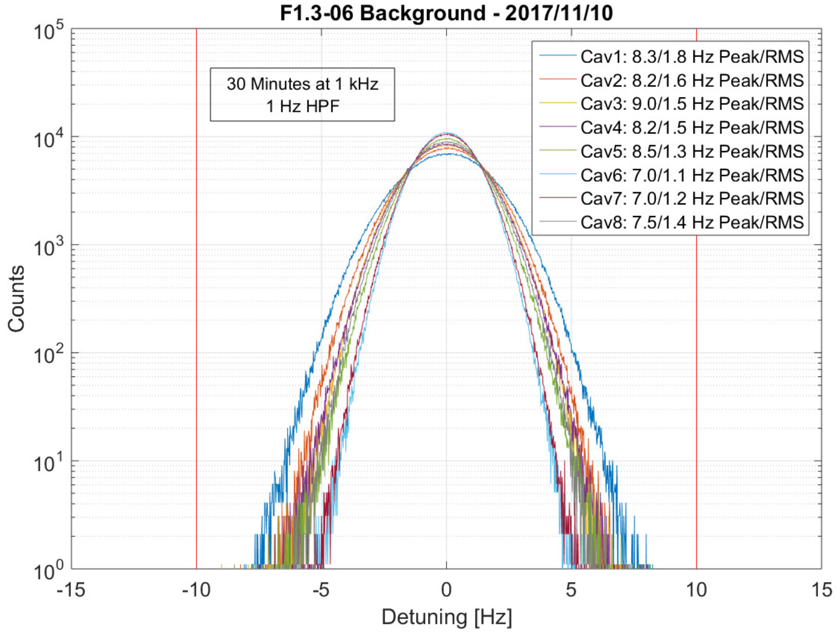
- Required RF input power (P_i) depends on the beam current (I_b), beam phase (ϕ_b) and cavity voltage (V_c), R/Q, detuning (Δf_c) and QL (~ coupler Q_{ext}) as

$$P_i(Q_L, \Delta f_c) = \frac{V_c^2}{4(R/Q)Q_L}\left[\left(1+\frac{I_b}{V_c}\frac{R}{Q}Q_L\cos\phi_b\right)^2 + \left(2Q_L\frac{\Delta f_c}{f}+\frac{I_b}{V_c}\frac{R}{Q}Q_L\sin\phi_b\right)^2\right]$$

LCLS-II	Q_L 4.1e7
LCLS-II-HE	Q_L 6e7

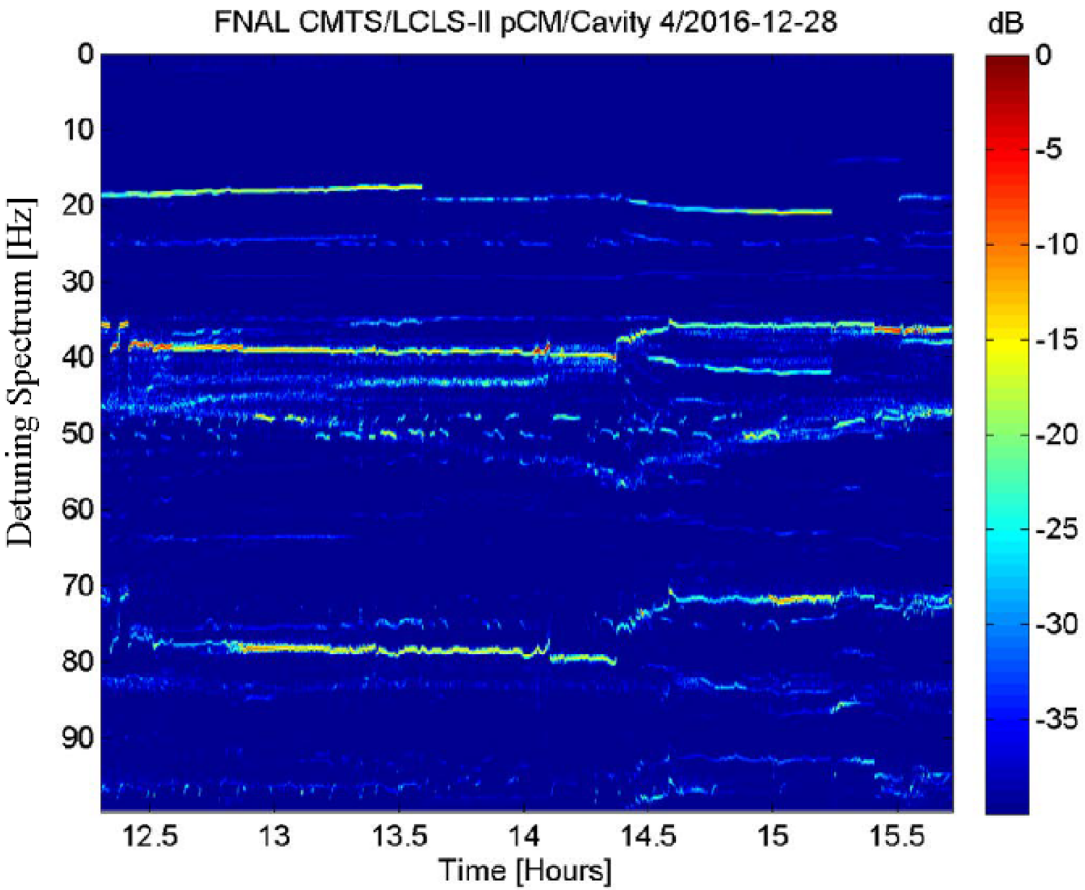
- RF power depends quadratically on microphonic cavity detuning
- For a Gaussian distribution with sigma =1.7 Hz only one cavity per day in the linac would exceed our 10 Hz max assumption - measured sigma's are typically < 1.7 Hz
- Can use active detuning compensation with piezo actuators if needed.

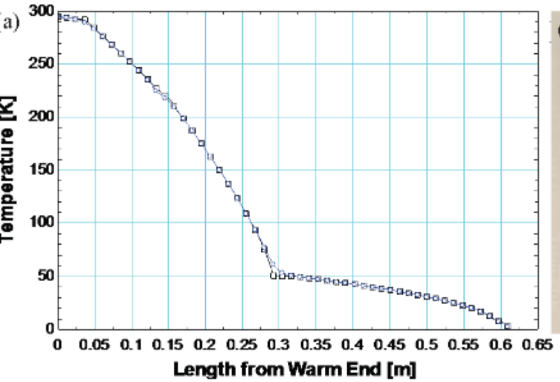
Detuning Distribution Measured at FNAL for CM06 – 30 minutes



Thermo-Acoustic Oscillations

2 valves in each CM to manage heat load – 88W (~8x EXFEL)

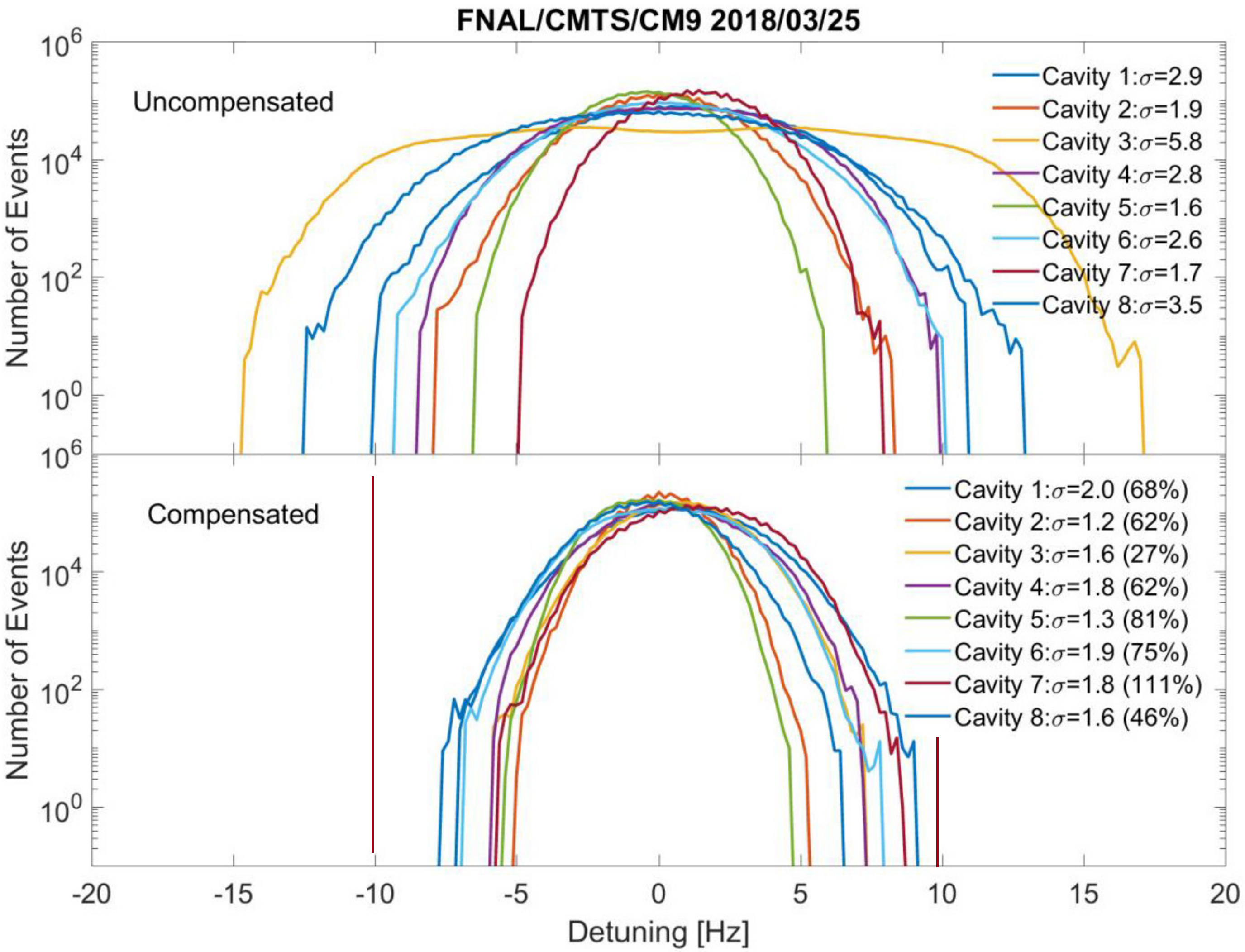




Fast (Piezo) Compensation

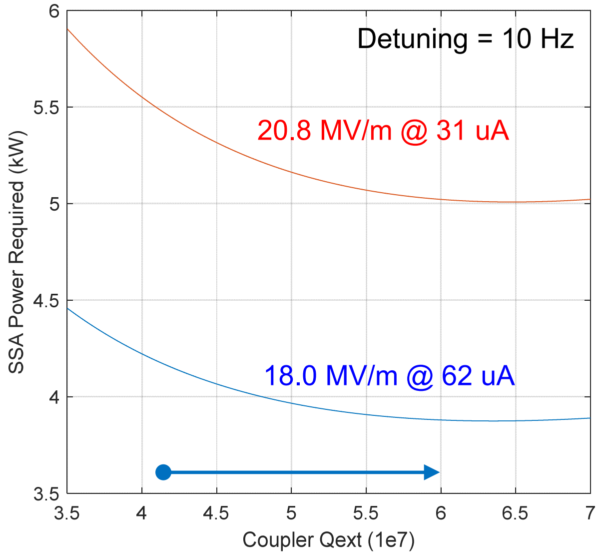
Fermilab LLRF
J. Holzbauer, W. Schappert

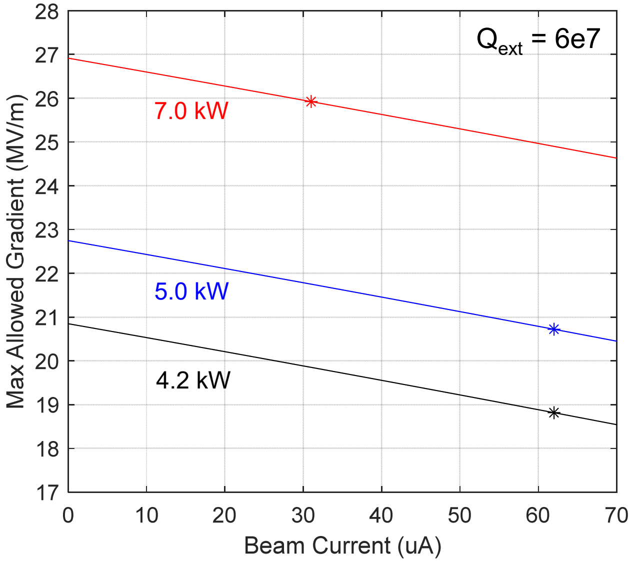
Successful demonstration using standard LCLS-II LLRF hardware.
Compensation typically not needed to achieve 10 Hz detuning spec during test



Optimal Qext and Allowed Gradients: LCLS-II-HE

- An increase of Q_{ext} from 4.1e7 to 6.0e7 reduces the required SSA power as shown in the left plot and increases the allowed maximum gradients by about 1 MV/m
  - Will likely optimize Qext for each cavity depending on its gradient and peak detuning
- With this choice of Qext, the right plot shows the allowed gradients as a function of SSA power and beam current (nominal currents are shown by asterisks)





Outline

Issues:

- Cavity → Flux Expulsion
- CM →
    1. Field Emission / Multi-pactor Discharge
    2. Microphonics
    3. Shipping – Recovery from serious setback

Plans

Shipping to SLAC

Floating platform on wire-rope springs

Loaded into shipping frame and ready to leave Fermilab for SLAC

Unloading at SLAC's grade-level entryway

shipment to SLAC: two severe beamline loss-of-vacuum incidents

SLAC

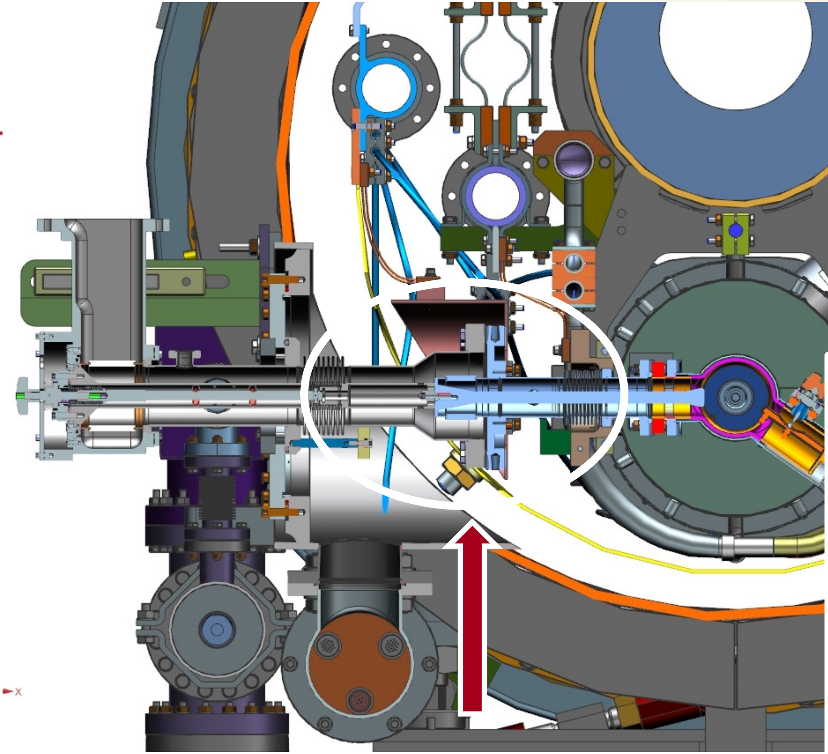
2 shortcomings:

1) semi-trailer shipping frame springs were too stiff and
2) the FPC central ‘floating flange’ was insufficiently restrained
   → resonantly driven

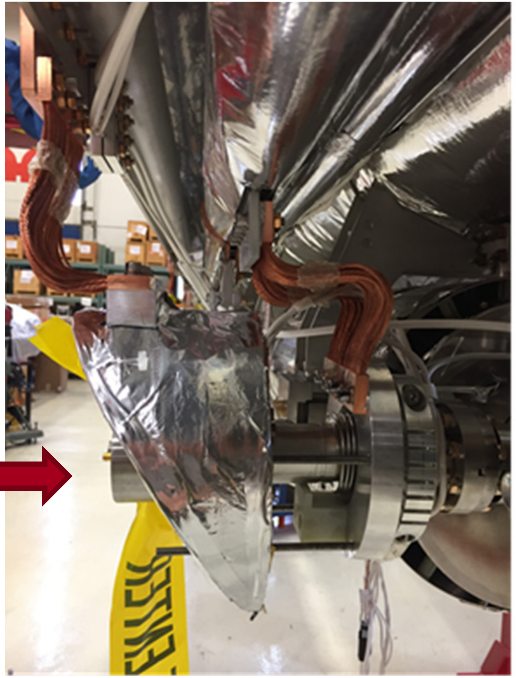
Failure of cold-side FPC bellows:

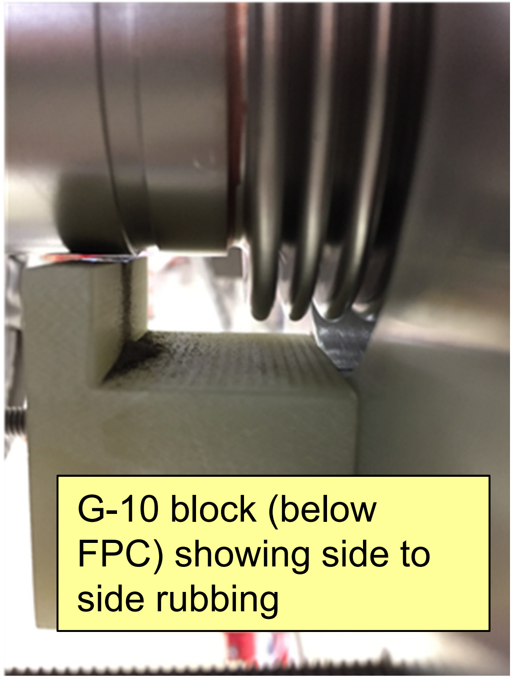
- The coaxial FPC is articulated and can move ~10 mm for cool-down.
- Central flange pair and thermal anchor shroud weigh 5 kg
- no mechanically stiff connection
- oscillates at roughly 15 Hz natural frequency

Fundamental Power Coupler



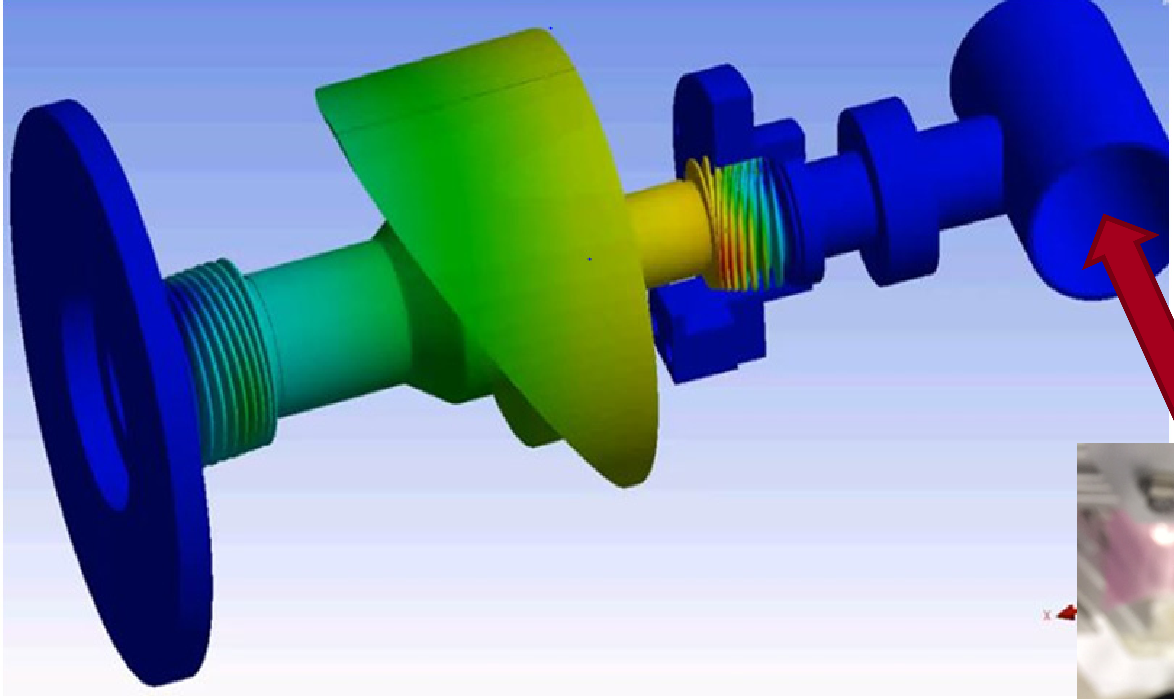
FPC central flange-pair and shroud

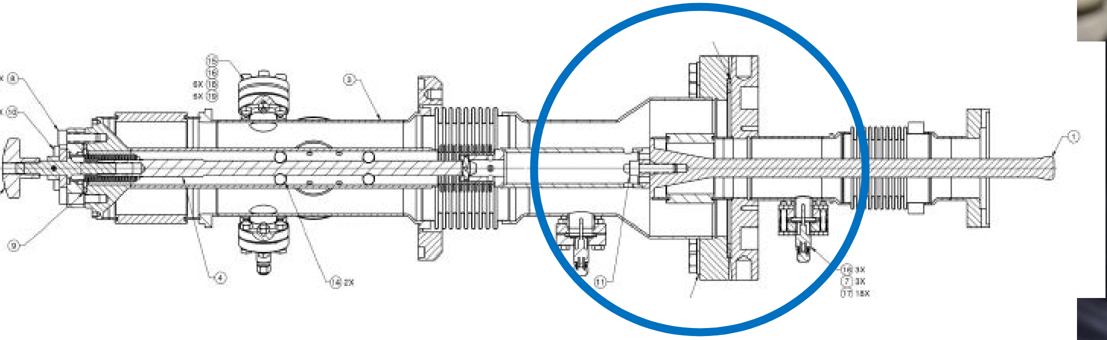




G-10 block (below FPC) showing side to side rubbing

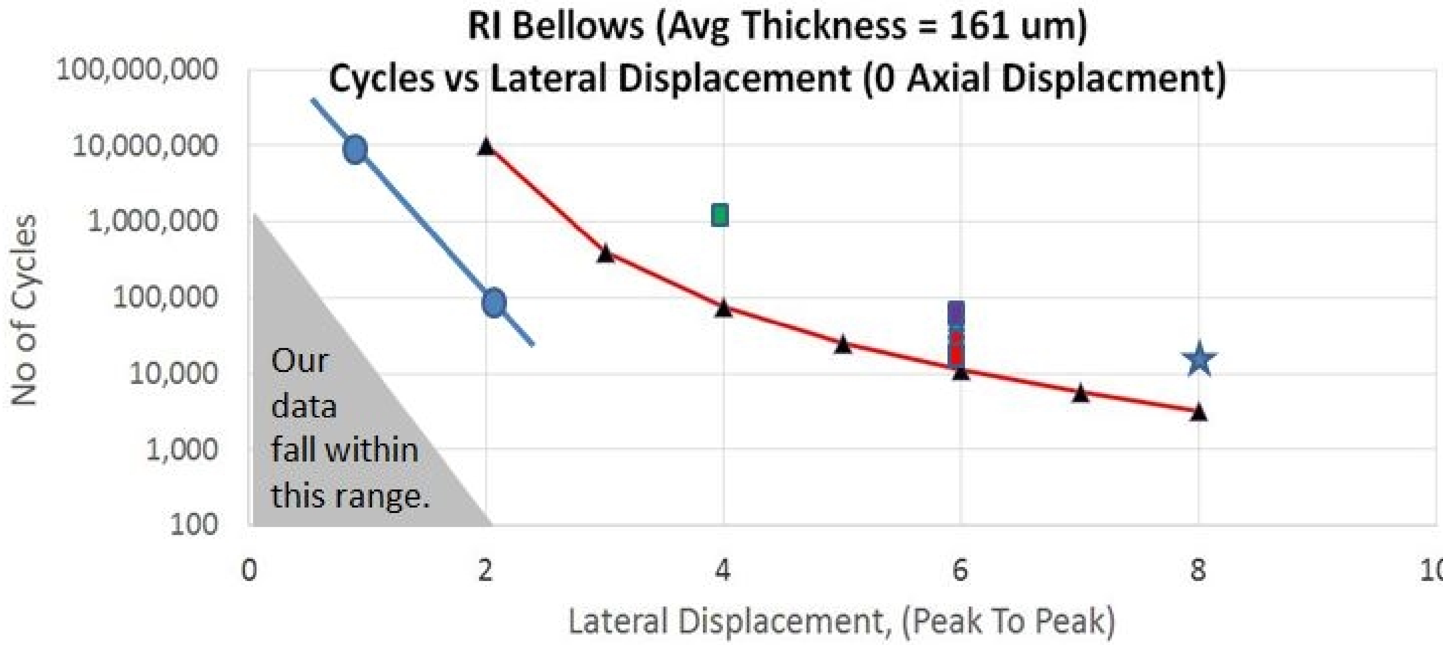
Damaged Bellows: Fatigue failure from cyclic motion





Power Coupler Bellows Fatigue limit

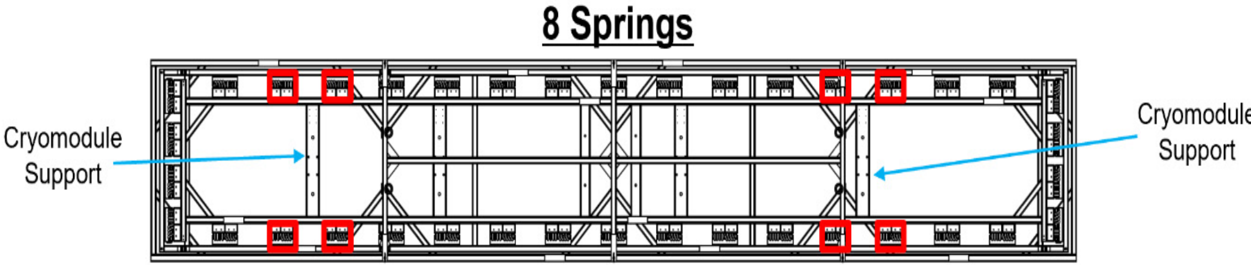
- Fatigue prediction (from manufacturer)
- Bench Tests (done by BNL)
- Specification (readily achieved)



Fixes: Implemented 11.2018

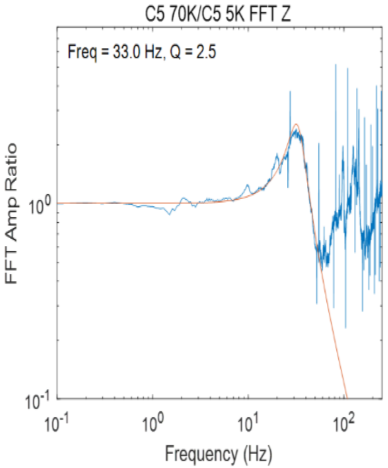
- Shipping frame – reduce springs 4x
- Add neoprene spacer and cable tie
- (done through access ports after test;
- Removed at SLAC)

Improved shipping frame spring configuration

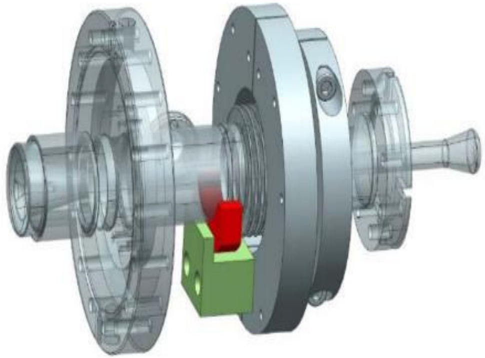


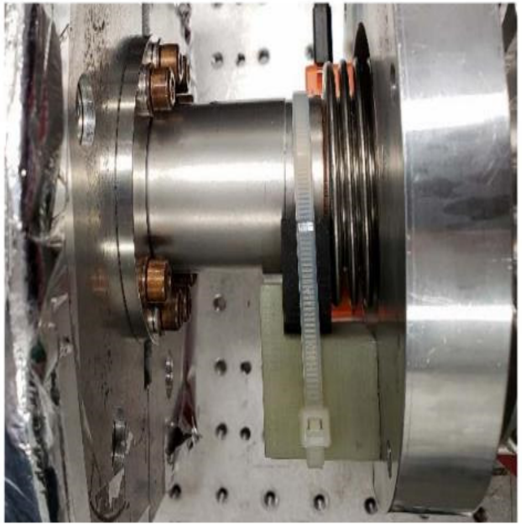
Reconfigured CM isolation frame springs: lowered frame Z motion resonance from 13 Hz to 7 Hz

Constrained bellows motion: increased coupler Z motion resonance from 15 Hz to > 30 Hz



Neoprene restraint with cable tie





Neoprene constraint sits on G-10 block, held with tie-wrap.
Limits Z (coupler lateral) motion but permits axial movement.

Outline

Issues:

- Cavity → Flux Expulsion
- CM →
  1. Field Emission / Multi-pactor Discharge
  2. Microphonics
  3. Shipping

Plans: LCLS-II-HE

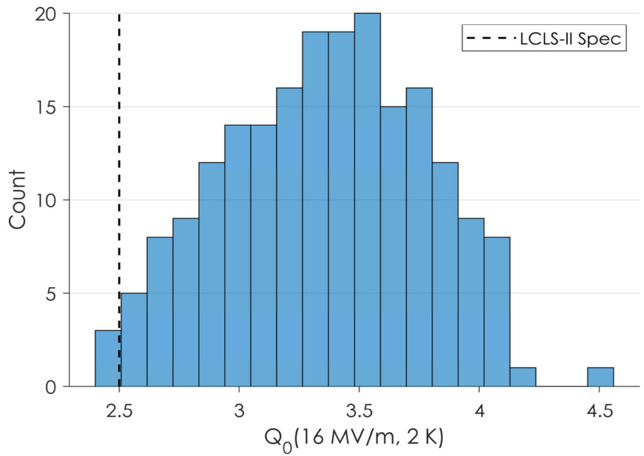
LCLS-II CM testing:

Fermilab tests: 17/19

JLab tests: 12/21

15/35 linac-ready at SLAC

- Expect to finish CM shipping March 2020



<E_acc> $_{CM}$ = 18.5 MV/m;

→ Need 2.5 MV/m more for HE→ R&D (Gonnella)

<Q0> $_{CM}$ = 2.8e10, → OK for HE

- (recent LCLS-II Q0 results excellent; provide margin)

LCLS-II-HE Parameters:

Parameter	Value	Units	Tot
Energy	8	GeV	
Beam I (@8 GeV)	30	μ Amp	
New Cryomodules	20	each	61
55 CM Installed			
(add'l + spare)	1	each	
Cryoplant cap.	8	kW@2.0K	
SSA	7	kW	

HE Cavity Vertical Acceptance:

Parameters	Numbers	Unit
E_acc	>23	MV/m
Q0	>2.5e10	(at 16 MV/m)
R	<10	nΩ
Field emission Onset*	>22	MV/m

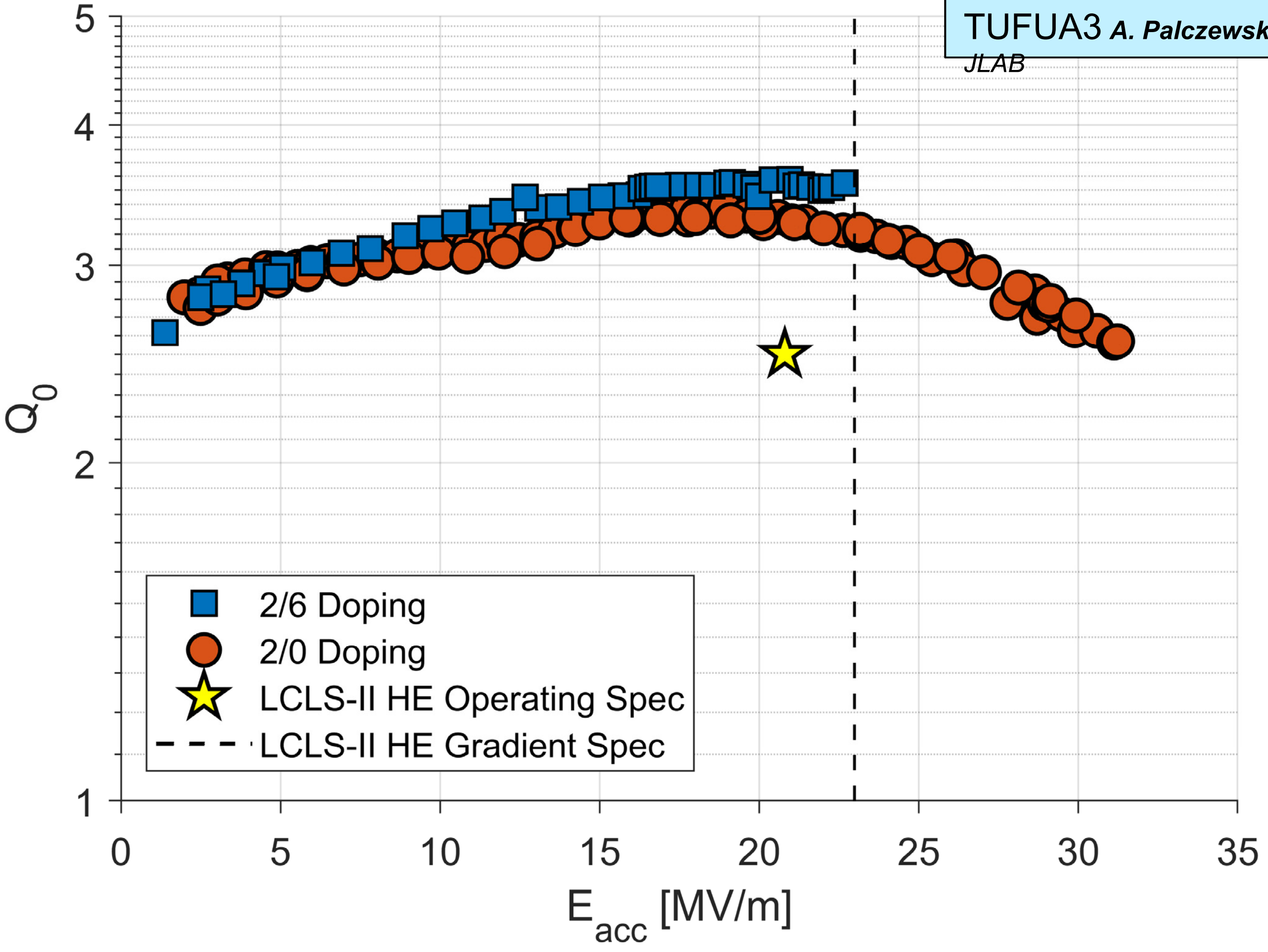
8GeV 1 MHz FEL timeline:

Date	SRF Production Milestone
Jan 2020	LCLS-II-HE CM procurement underway
March 2020	Last LCLS-II CM shipped to SLAC; LCLS-II prototype in assembly
June 2020	Improved cavity process; Prototype CM in test
Mid-2021	LCLS-II first beam
Begin 2023	LCLS-II-HE CM assembly complete (20 each + prototype)
2025/2026	Two 6-month downtime for LCLS-II-HE installation
Early 2027	Commissioning LCLS-II-HE

MOP045 ***D. Gonnella***, *SLAC*
TUFUA3 ***A. Palczewski***, *JLAB*

HE Cavity Process under development: 2/0

9-cell result, 06.2019



LCLS-II-HE Principal Technical Risks

1. Can the LCLS-II cryomodules operated at an ***average gradient of 18.5 MV/m***?
   - LCLS-II CM cavity testing encouraging
   - linac integration and commissioning 2022

2. Can LCLS-II-HE build cryomodules that operate on ***average at 20.8 MV/m***?
   - R&D plan underway; prototype CM spring 2020

3. Can the LCLS-II-HE linac be operated ***reliably in the multipactoring band (17-23 MV/m)***? ***With acceptable field emission***?
   - LCLS-II testing planned this summer

Wrap up

SLAC 2012 (50 anniv)

First of 4 cold-boxes from PHPK, May 2018.
MILLER
MILLER


cryogenics
PHPK
TECHNOLOGIES


PHPK
TECHNOLOGIES

Retrospective

- LCLS-II CM performance meets requirements
- **→Notable achievement by the JLab/Fermilab team←**
- (started closeout process for LCLS-II CM)
- Five-year period has been extraordinarily productive; setbacks notwithstanding
- HE R&D encouraging, N-doping giving improved performance

Acknowledgements:

- The technical leadership at Fermilab and JLab: Ed Daly, Camille Ginsburg, Joe Preble, Rich Stanek, Dana Arenius, John Hogan, and Arkadiy Klebaner.
- At SLAC, the integration team led by Andrew Burrill.
- Close and effective collaboration with
  - DESY (Hans Weise),
  - CEA/Saclay (Olivier Napoly) and
  - Cornell (Matthias Liepe).

End