Commissioning of the 2nd JLAB C75 Cryomodule

& Performance Evaluation of Installed C75 Cavities

M. McCaughan; G. Ciovati;
K. Davis; M. Drury; T. Powers;
A. Reilly

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Jefferson Lab

U.S. DEPARTMENT OF ENERGY | Office of Science

JSA

Types of Cavities / Cryomodules:

Parameter	Unit	C20 (Orig. CEBAF/Cornell}	C50 (Refurbished)	C100 (Low Loss)	C75 (High Current)
Number of cells		5	5	7	5
L act	M	0.4999	0.4999	0.7	0.4916
Energy gain/CM (design)	MeV	20	50	100	75
Eacc/cavity (design)	MV/m	5	12.5	17.86	19.07
Q_0 at 2.07 K		> 2.4e9	4.6e9	7.2e9	8.0e9
$Q_{ext,FPC}$ spec		6.6e6 (± 20%)	8.0e6 (± 25%)	3.2e7 (± 20%)	2.0e7 (± 15%)
R/Q [Ueff^2/(ω*W)]	Ω	482.5		868.9	525.4
R/Q per cell	Ω	96.5		124.1	105.1

F. Marhauser et al., "C75 Cavity Specifications and Commissioning of the Prototype Cavity Pair", JLAB-TN-17-055, 12/6/17

Gradient Degradation

Observed gradient loss per annum:

Cavity Type	$\frac{dG}{dt}$ (MV/m-yr)	$\mathcal{G}_\Delta$ (MV/m-ThermalCycle)
C25	0.14 ± 0.05	0.5 ± 0.1 or 7%
C50	0.42 ± 0.06	0.5 ± 0.1 or 7%
C100	0.00 ± 0.06	0.5 ± 0.1 or 7%

Table 11: 2014 values of the average gradients and gradients loss for the various cavity types in CEBAF. All values are identical to the 2012 values except the C50 $\frac{dG}{dt}$ which was 0.71 ± 0.08 MV/m-yr in 2012. The C100 annual loss remains at zero until there is enough data to provide an estimate of this loss.

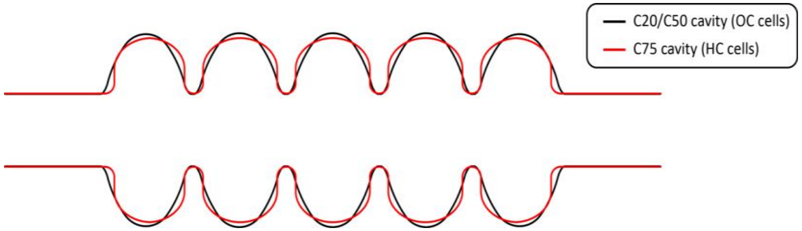
Degradation rates have been periodically remeasured since 2014 and levels have so far remained robust. These rates are used for planning estimates for machine operation energy and cryomodule maintenance and refurbishment. Data is being gathered on the 'High Current' C75 style cavities, but as-of-yet results have not reached statistical significance.

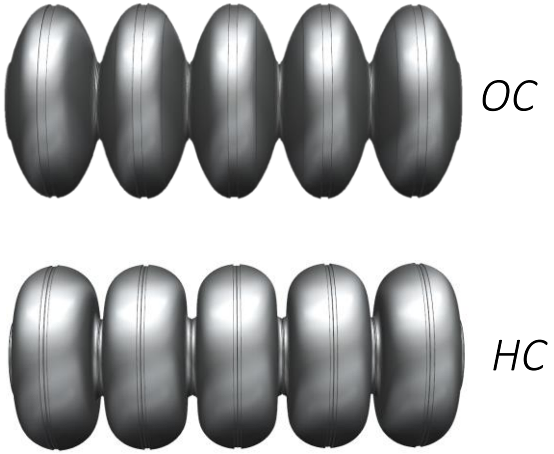
Projected loss: ~17 MeV/linac/year
(+ planned / unplanned thermal cycling losses)

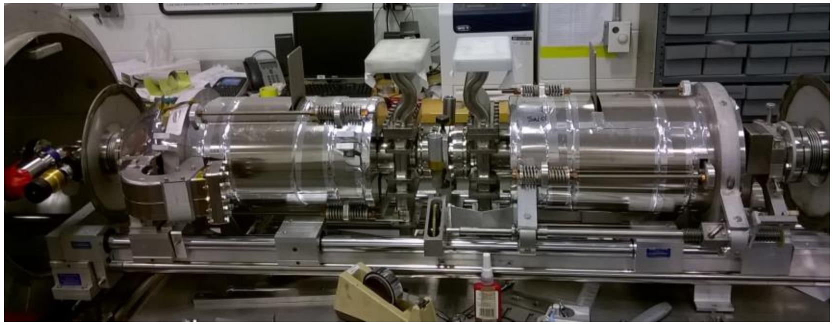
R. Bachimanchi et al., 2014 Update: CEBAF Energy Reach and Gradient Maintenance Needs, JLAB-TN-14-024, 4 Oct 2014.

C-20 (Original Cebaf) > C-75 (High Current) Conversion

- Replace existing fine grain Nb cells with large-grain 'HC' shaped cells developed for JLab FEL (recycling existing end groups). Tooling (Die set, Trimming fixtures, etc.) pre-existed thus allowing rapid prototyping/fabrication.
- 48mm radial stiffening rings added to C75 cells to make comparably stiff to C20s
- Tuners recycled; Aluminum End-cell holders adapt them to C75 end-cell shape.
- Dogleg waveguides (as seen on previous slide) used from previous C-50 design to mitigate window arcing.
- New digital LLRF control system; improve LLRF 2.0 design from C-100s. [Better reliability, improved channel-to-channel isolation, etc.] – compensates high gradient Lorentz force detuning.





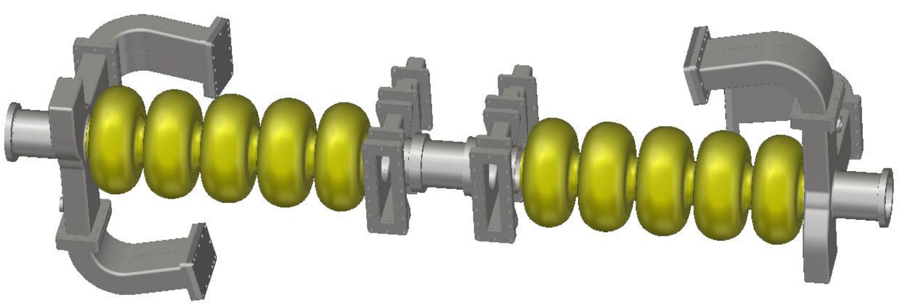


F. Marhauser et al., C-75 Cavity Specifications & Commissioning of the Prototype Cavity Pair, JLAB-TN-17-055 6 Dec. 2017
F. Marhauser, C75 Cavity Design, Prepared for the C75 Implementation and Project Review, 16 May 2018

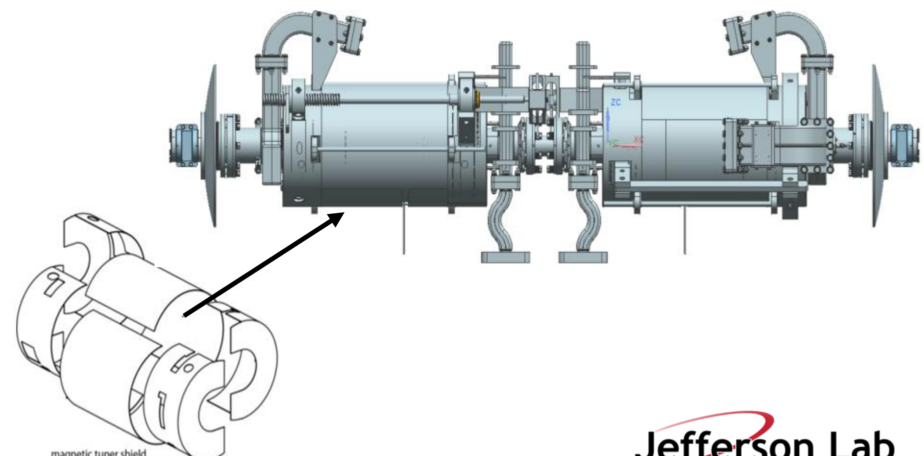
C-75 Conversion (Cont.)

Additional Changes:

- Cold magnetic shielding (1mm thick Cryoperm10) added; magnetic hygiene improved in module – mitigates Qo degradation. [Spec: <10 mG residual magnetic field @ cavity as measured by installed Flux Gate Magnetometers. **Achieved.**]
- Internal Higher Order Mode (HOM) Waveguides and stiffening brackets added; damps HOMs & shifts mechanical modes to higher frequencies.
- Fundamental Power Coupler (FPC) Waveguide Thermal intercept: Width of 50K intercept optimized for 8kW incident forward power. [Closer to cold flange by ~1.5"]
- FPC body further from cavity cell (~1“) to aise Qext
- Iris-to-Iris active length (Lact) reduced by 8.3mm relative to Original Cebaf cavities; bellows between cavity pairs accommodate for length variation in as-built cavities.
- 200 L/s (H_2) NEG-SIP combinations pumps for each FPC Waveguide vacuum space.



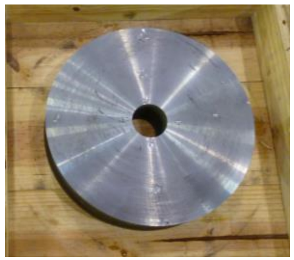
1497 MHz cavity pair with *HC* cells



F. Marhauser, C75 Cavity Design, Prepared for the C75 Implementation and Project Review, 16 May 2018

C75 cavity production

- Large-grain Nb discs cut by multi-wire slicing from CBMM ingots, RRR = 165 to 350

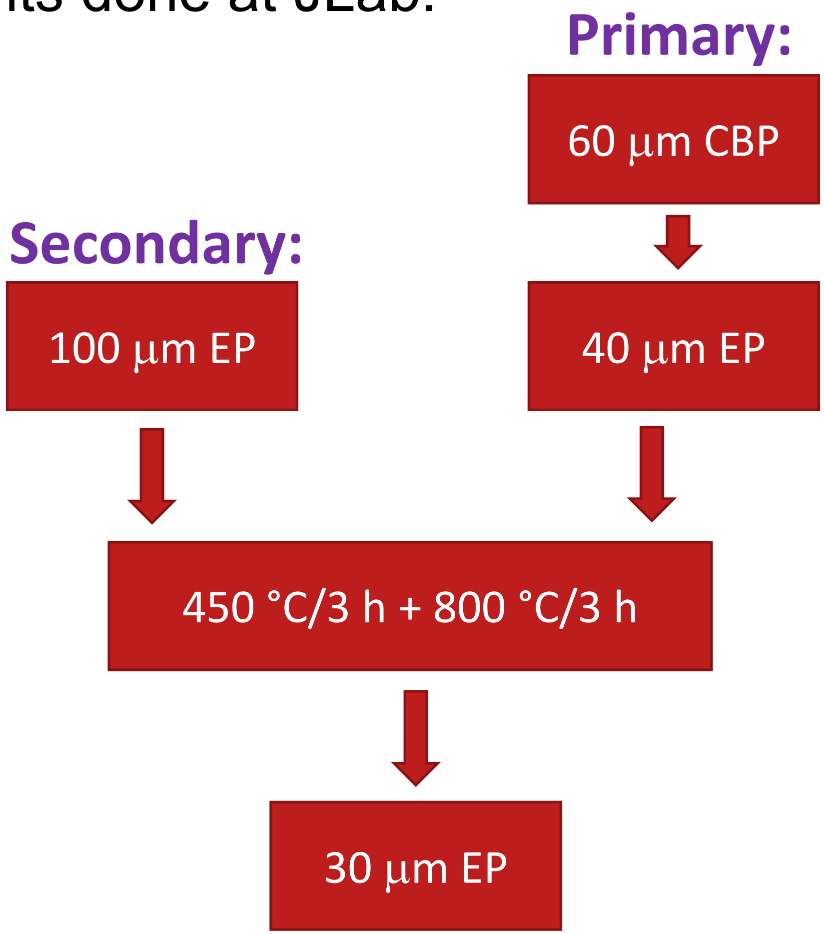


- End-groups cut from original CEBAF cavities & shipped to vendor.

- 44 cavities built so far by Research Instruments, Germany

C75 cavities surface treatment

Surface treatments done at JLab:



Primary path == When Centrifugal Barrel Polisher is available…

Low-level RF Controls (LLRF 3.0)

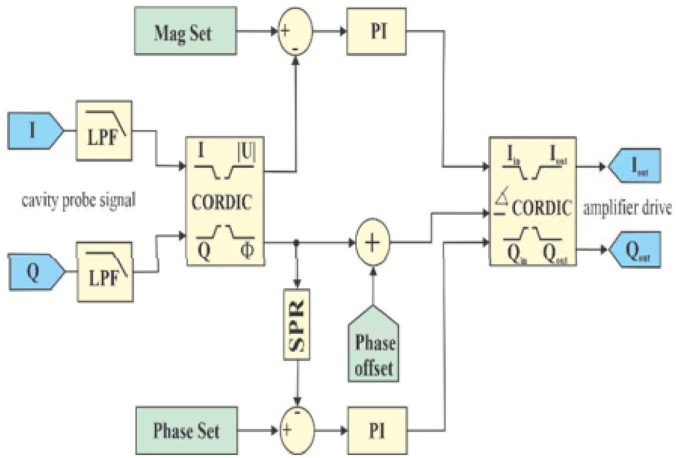
- Replaces legacy analog systems; build on success of LLRF2 / LCLS-II designs deployed on 96 C100 cavities.
- Dual FPGA-based Digital heterodyne transceiver samples I/Q:
  - FPGA #1: Field control chassis (FCC): 1497 MHz down-converted to 70 MHz (IF) & used w/ on-board PLL to make 56 MHz clock. IF sampled at 56Msps to create 14 MHz I/Q sin waves (w/ 56 MHz update rate) & fed to FPGA for digital signal processing.
  - FPGA #2: Resonance Control Chassis: PI-loop controls 8 cav. frequencies w/ mechanical tuners. (~800 Hz detuning experienced between 0 and 20 MV/m gradient.)
- Modular architecture: Receiver, transmitter, digitizer, & FPGA on separate boards for easy configuration / maintenance.
- Improved channel-to-channel isolation (>90dB)
- Main states:
  - Tone Mode (One frequency/var. amplitude to tune)
  - Self-Excited Loop (SEL): Detuning level noted & amplitude ramped as frequency tunes in across the ~800Hz range.
  - SELA: As SEL, but additional amplitude control PI-loop.
  - SELAP: SEL Amplitude & Phase locked; system phase-locked when sufficient power is exists.

Used on 16 / 418 SRF Cavities [C75 cavities / 8kW klystrons] + Warm RF installation

Some advanced 3.0 software features are now being tested for back-propagation onto 2.0 architecture

(Cavity Parameters)

C100 (Low Loss)	C75 (High Current)
7-cell	5-cell
L = 0.7 m	L = 0.4916 m
E gain/CM: 100 MeV	Egain/CM: 75 MeV
Eacc/cav: 17.86	Eacc/cav: 19.07 MV/m
Qo@2.07K: 7.2e9	Qo@2.07K: 8.0e9
Qe,FPC: 3.2e7 (± 20%)	Qe,FPC: 2.0e7 (± 15%)
R/Q: 868.9 Ω	R/Q: 525.4 Ω
R/Q (per cell): 124.1 Ω	R/Q (per cell):105.1 Ω



Locked Amplitude and Phase (SELAP) concept.

T. Plawski et al., First SELAP Algorithm Operational Experience of the New LLRF 3.0 RF Control System, Proceedings of LINAC22, THPOA241, Liverpool, UK
T. Plawski et al., JLAB LLRF 3.0 Development and Tests, Proceedings of IPAC21, THPAB271, Campinas, SP, Brazil

C75-02 Cavity Commissioning: Gradient (Design 19.07/cavity)

Gradient Performance:

- Cavity tuned to resonance
- Forward, reflected, transmitted, drive, and HOM1 & 2 powers all sampled.
- Q_{ext}, Q_{FP}, Q_{HOM1}, and Q_{HOM2} extracted from pulse-mode power & decay measurements.
- In Pulse Mode:
  - $E_{emit} = \sqrt{p_{emit} * dt(2\pi f)(rQL)}$
  - $Q_{fp} = E_{emit}^2 \div p_t(rQL)$
  - $E_{pt} = \sqrt{P_t Q_{fp}(rQL)}$

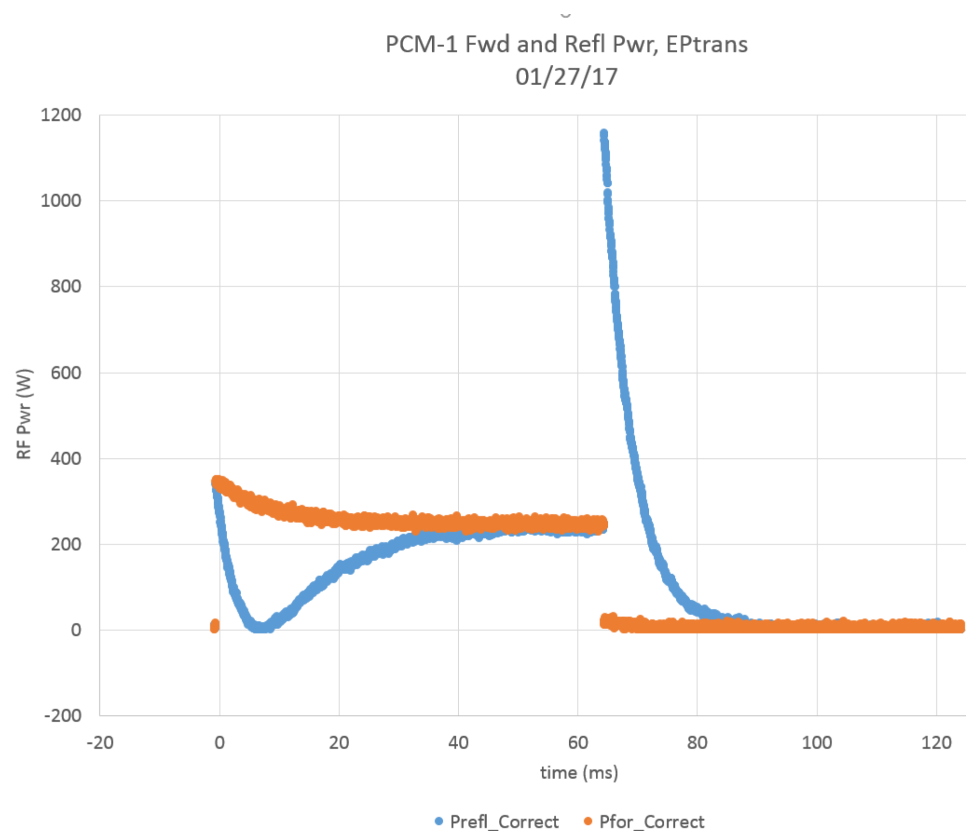
Boonton 4530 Peak Power Meter

Peak Power

- Frequency Range: 50 MHz To 40 GHz
- Dynamic Range: >60 dB
- Bandwidth: 20 MHz

CW Power

- Frequency Range: 10 kHz To 40 GHz
- Dynamic Range: 90 dB
- Effective sampling rates up to 50 MSamples/sec



- Ensure that $E_{emit} = E_{pt}$ (when pulsed)
- Measure as gradient increases: 2 MV/m intervals
- Repeat in continuous wave (duty factor=1) mode; establish $E_{pt,max}$. Attempt 1-hour run to establish operational gradient: E_{op}.
- E_{pt} is our standard
- E_{fwd} calculated but only used as a rough check

Typical calculated uncertainty in Qfp ≈ ±8%
Typical calculated uncertainty in Ept ≈ ± 4%
(at our Admin Limit, 21 MV/m ± 0.8 MV/m)

C75-02 Cavity Commissioning: Gradient (Design 19.07/cavity)

			VTA			CMTF				CEBAF	Operational	Present	Present
	Cavity	SN	Emax	Limit	Emax	Limit	Eop (1-hr)	Emax	SRF Eop	Limit	Date	ODVH	Limitation
c	1L10-1	5C75-RI-012	22	Admin	19	FE	18.1	21	21	Admin	06/03/22	10.0	Field Emission
7	1L10-2	5C75-J-005	18.2	Quench	18	Quench	16.9	17.2	16.7	Quench	06/03/22	15.0	Power limited
5	1L10-3	5C75-RI-017	15.6	Multipacting	16.3	Quench	15.4	21	20.5	Admin	06/03/22	14.1	Beam instability
-	1L10-4	5C75-RI-014	20.8	Cable	16.3	FE	15.1	21	20.5	Admin	06/03/22	18.0	Beam instability
o	1L10-5	5C75-RI-011	19.6		15.6	FE	15	21	20.5	Admin	06/03/22	18.0	Beam instability
2	1L10-6	5C75-RI-018	20.7	Quench	21	Admin	21	21	21	Admin	06/03/22	15.0	BLVF at 17
	1L10-7	5C75-RI-016	20.3	Admin	21	Admin	21	22	22	Admin	06/03/22	16.9	Beam instability
	1L10-8	5C75-RI-015	20.2	Cable	20.4	FE	20.2	11.5	11.5	BLVF	06/03/22	9.0	BLVF
		Averages:	19.7		18.5		17.8	19.5	19.2			14.5	

	C-75 cavs		CEBAF	CEBAF
Avg Values	**VTA**	**CMTF**	**Commissioning**	**ODVH**
Emax	19.7	18.5	19.5	
Eop		17.8	19.2	14.5

Design: 19.07/cavity – good **[Admin*: 21]**
(Limited there for heat load, FE, & Multipacting)

Requalification of cavity operating gradients (aka Ops Drive Highs / ODVHs) following the installation of new 8 kW circulators.

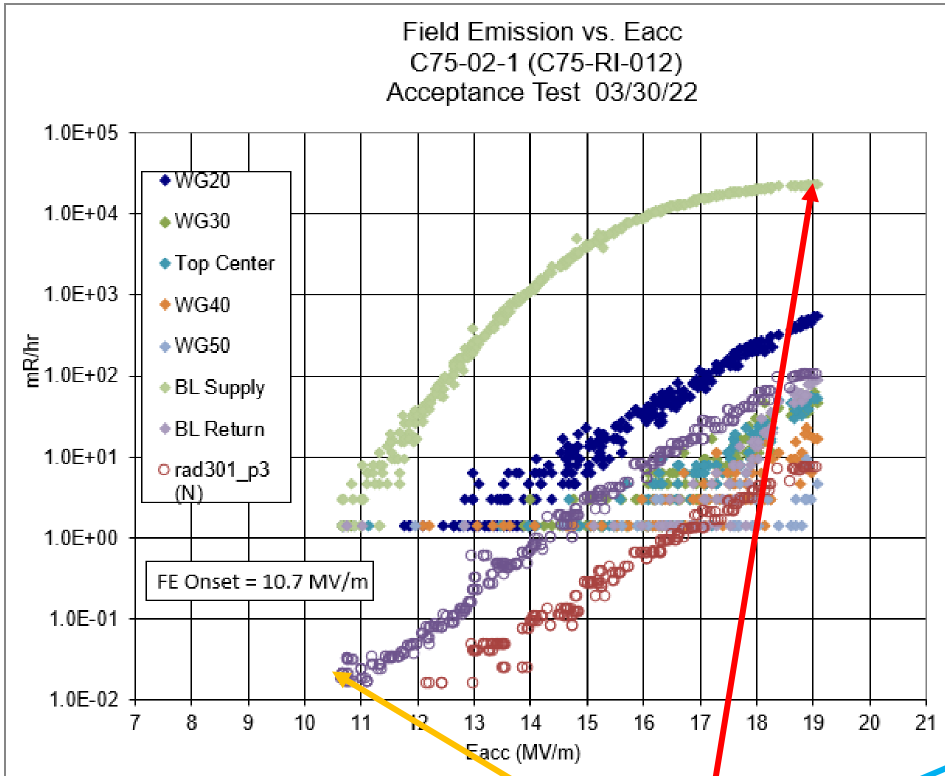
Circulators found not upgraded through mis-communication; only support 5.5 kW in operations vice 8kW klystron drive. This results in beam loading and instabilities for Operations as they drive the beam, and so gradients have been reduced to supportable levels.

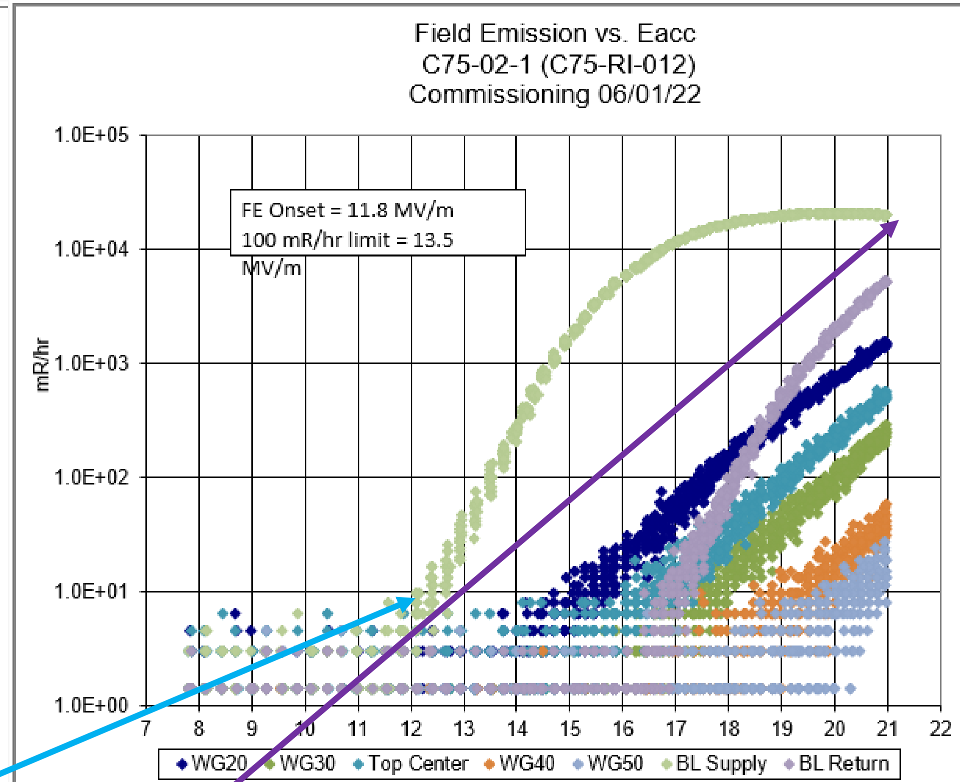
[Circulator upgrade in progress; delayed by supply chain issues…]

*G. Ciovati et al., Cavity Production and Testing of the First C75 Cryomodule for CEBAF, Proceedings of SRF'21, MOPCAV001. 28 June 2021

Cavity Performance: Field Emission

GM Detectors @ FPCs and fore and aft of the module.





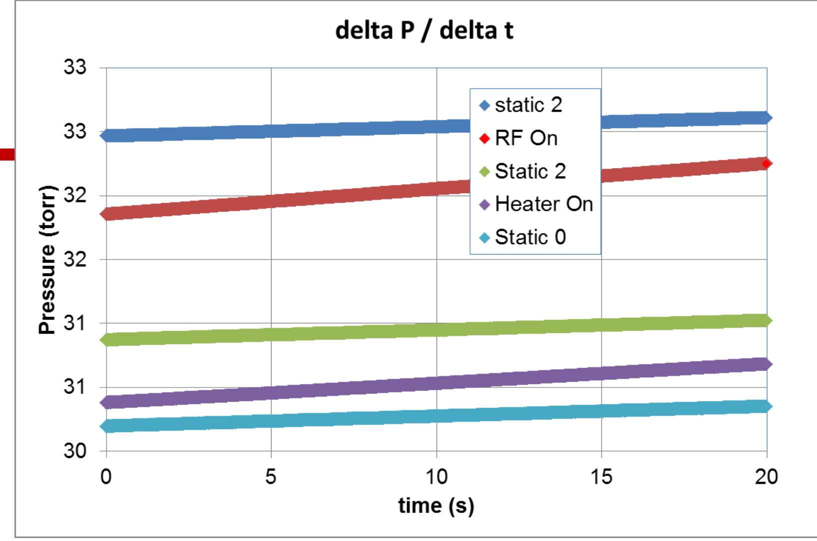
	Cavity	VTA FE onset	Max Rad (mRad/hr)	CMTF FE onset	MaxDose (R/hr)	CEBAF FE onset	MaxDose (R/hr)
	1L10-1	13.9	3.37	10.5	23.6	11.8	21.1
C	1L10-2	11.4	1.90	18	0	17.2	0
7	1L10-3	17.5	251.00	11.6	0.45	11.5	12
5	1L10-4	10	98.90	10.5	1.8	11.8	11.7
-	1L10-5	10.75	1000.00	10.5	0.37	10.9	11.7
0	1L10-6	15	3.61	17	0.18	17.1	2.1
2	1L10-7	20.3	0.00	21	0	22	0
	1L10-8	14	12.50	11.8	6.9	11.3	0.97

CMTF			CEBAF		
Emax	Limit	Eop (1-hr)	Emax	SRF Eop	Limit
19	FE	18.1	21	21	Admin
18	Quench	16.9	17.2	16.7	Quench
16.3	Quench	15.4	21	20.5	Admin
16.3	FE	15.1	21	20.5	Admin
15.6	FE	15	21	20.5	Admin
21	Admin	21	21	21	Admin
21	Admin	21	22	22	Admin
20.4	FE	20.2	11.5	11.5	BLVF

C75-02 Cavity Commissioning: Q_0s

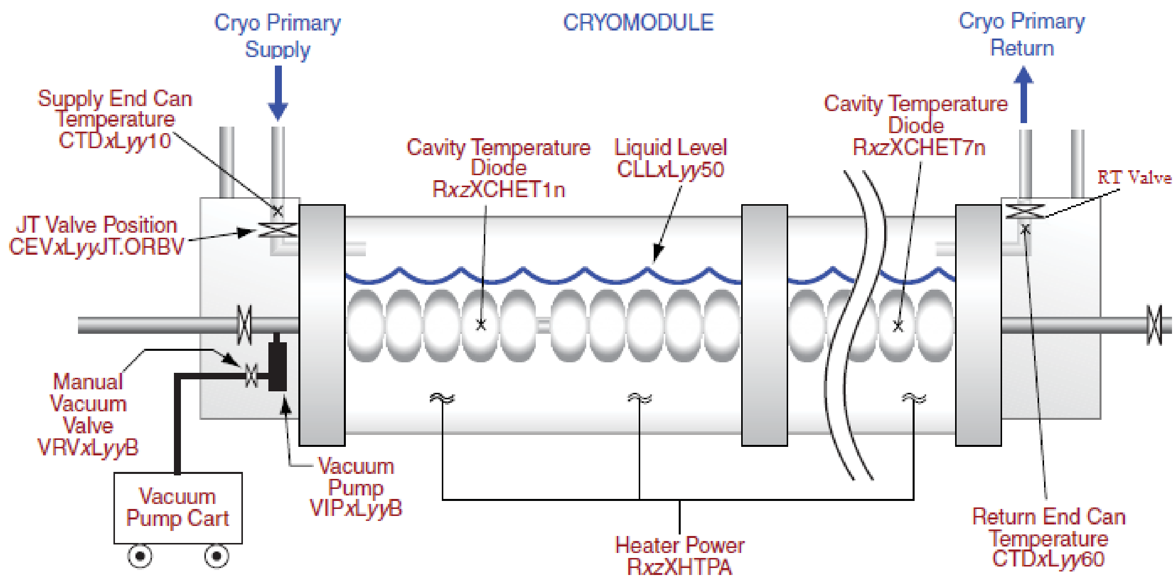
Qo measurement (Zone used as calorimeter):

- Cryo supply valve closed; Pressure -> Equilibrium
- Cryo return valve closed; liquid level allowed to stabilize (~ 2 minutes)
- dP/dt Measurements (20 s each w/ ~10 s delay):
  - ➢ Static Heat: Environmental; Heat leak into module / Heater off (Measured 3 times)
  - ➢ Electric Heat: Heater on (Calibrated; resistance measurable)
  - ➢ RF Heat: Evolved by cavity at gradient.
  - ➢ dP/dt from He boil-off used to calculated evolved heat & thus Qo.
- Value corrected for 2.07 K Ops
- Repeat until return valve needs to be opened to lower pressure below ~33 Torr OR supply must be opened to add liquid & compensate boil-off



$$Pwr_{RF} = Pwr_{Htr} \frac{(\Delta P_{RF+static} - average(\Delta P_{static1}, \Delta P_{static2}))}{(\Delta P_{htr+static} - average(\Delta P_{static0}\Delta, P_{static1}))}$$

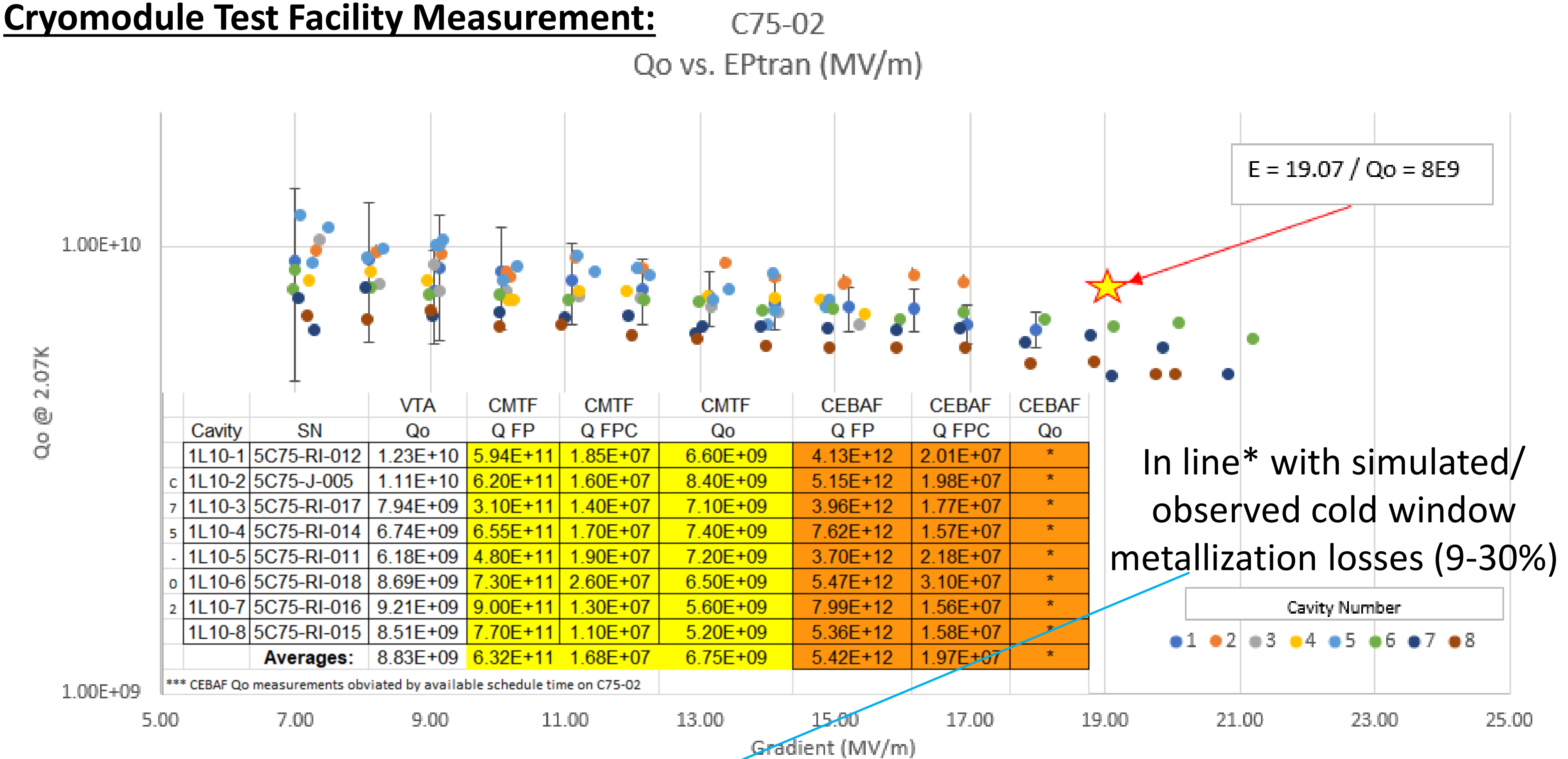
$$Q_0 = \frac{(E_{acc} \cdot L_{acc})^2}{R/Q \cdot P_c}$$



M. Drury, Qo Measurements, 22 Feb 2018

C75-02 Cavity Performance: Qs (Cont.)

Cryomodule Test Facility Measurement:



Cavity	SN	VTA Qo	CMTF Q FP	CMTF Q FPC	CMTF Qo	CEBAF Q FP	CEBAF Q FPC	CEBAF Qo
1L10-1	5C75-RI-012	1.23E+10	5.94E+11	1.85E+07	6.60E+09	4.13E+12	2.01E+07	*
1L10-2	5C75-J-005	1.11E+10	6.20E+11	1.60E+07	8.40E+09	5.15E+12	1.98E+07	*
1L10-3	5C75-RI-017	7.94E+09	3.10E+11	1.40E+07	7.10E+09	3.96E+12	1.77E+07	*
1L10-4	5C75-RI-014	6.74E+09	6.55E+11	1.70E+07	7.40E+09	7.62E+12	1.57E+07	*
1L10-5	5C75-RI-011	6.18E+09	4.80E+11	1.90E+07	7.20E+09	3.70E+12	2.18E+07	*
1L10-6	5C75-RI-018	8.69E+09	7.30E+11	2.60E+07	6.50E+09	5.47E+12	3.10E+07	*
1L10-7	5C75-RI-016	9.21E+09	9.00E+11	1.30E+07	5.60E+09	7.99E+12	1.56E+07	*
1L10-8	5C75-RI-015	8.51E+09	7.70E+11	1.10E+07	5.20E+09	5.36E+12	1.58E+07	*
	Averages:	8.83E+09	6.32E+11	1.68E+07	6.75E+09	5.42E+12	1.97E+07	*

*** CEBAF Qo measurements obviated by available schedule time on C75-02

Avg Values	VTA	CMTF	CEBAF
Qo	8.83E+09	6.75E+09	
Qfp		6.32E+11	5.42E+12
Qfpc		1.68E+07	1.97E+07

Spec:

8e9

2e7±15%

Notes:

- CEBAF in-situ Qo measurements were omitted due to Physics schedule pressure.
- FPC Qs adjusted in-situ via stub tuners to meet specification.

*F. Marhauser & G. Ciovati, Evidence of increased RF losses in CEBAF cavities from the FPC Cold Window, PRAB 24, 092001. 27 September 2021

Ensemble Cavity Performance: Gradient (Design 19.07/cavity)

	Cavity	SN	VTA Emax	VTA Limit	CMTF Emax	CMTF Limit	CMTF Eop	CEBAF Emax	SRF Eop**	CEBAF Limit	Operational Date	Present ODVH	Present limitation
C50-13	1L13-1	5C75-001	19.4	Quench	19.1	Quench	18.6	19	18.3	Quench	11/13/17	8.8	Fault rate mgmt
LLRF 1.0	1L13-2	5C75-003	13.7	Quench	14.2	Quench	13.7	14.3	14.3	Quench	11/13/17	8.0	Test push
C	1L05-1	5C75-RI-008	20.2	Multipacting	18.4	Quench	18	13.9	13	Quench	07/28/21	12.5	Beam loading/Power
7	1L05-2	5C75-J-004	13.15	FE	16.7	Quench	10.3	17.5	17	Quench	07/28/21	13.4	Beam loading/Power
5	1L05-3	5C75-RI-001	19.3	Multipacting	18.5	Quench	18.1	18.3	17.8	Quench	07/28/21	18.0	Beam instability
-	1L05-4	5C75-RI-003	19.6	Multipacting	21	Admin	17.7	21	21	Admin	07/28/21	19.0	Beam instability
0	1L05-5	5C75-RI-002	20.2	Multipacting	17.8	Quench	15.2	18.6	17.5	Quench	07/28/21	14.8	Quench
1	1L05-6	5C75-RI-005	21.1	Multipacting	18.5	Quench	18	18.5	18	Quench	07/28/21	18.7	Test push
MeV:	1L05-7	5C75-RI-007	19.9	Quench	18.7	Quench	18.1	21	20.5	Admin	07/28/21	15.0	Beam loading/Power
61.1	1L05-8	5C75-RI-006	20.15	Quench	21.1	Admin	20.6	21	21	Admin	07/28/21	12.7	Beam instability
C	1L10-1	5C75-RI-012	22	Admin	19	FE	18.1	21	21	Admin	06/03/22	10.0	Field Emission
7	1L10-2	5C75-J-005	18.2	Quench	18	Quench	16.9	17.2	16.7	Quench	06/03/22	15.0	Power limited
5	1L10-3	5C75-RI-017	15.6	Multipacting	16.3	Quench	15.4	21	20.5	Admin	06/03/22	14.1	Beam instability
-	1L10-4	5C75-RI-014	20.8	Cable	16.3	FE	15.1	21	20.5	Admin	06/03/22	18.0	Beam instability
0	1L10-5	5C75-RI-011	19.6		15.6	FE	15	21	20.5	Admin	06/03/22	18.0	Beam instability
2	1L10-6	5C75-RI-018	20.7	Quench	21	Admin	21	21	21	Admin	06/03/22	15.0	BLVF at 17
MeV:	1L10-7	5C75-RI-016	20.3	Admin	21	Admin	21	22	22	Admin	06/03/22	16.9	Beam instability
57.1	1L10-8	5C75-RI-015	20.2	Cable	20.4	FE	20.2	11.5	11.5	BLVF	06/03/22	9.0	BLVF
		Averages:	19.1		18.4		17.3	18.8	18.5			14.3	

** Prototype C-75 cavities immediately limited to 14.0 (C50 Admin) operationally as stability issues with LLRF 1.0 were feared above that.

- 18 installed cavities:
  - 13 of 16 of those in C-75 zones limited by instabilities/beam loading.
  - 2 prototypes on analogue LLRF w/o other C75 modifications.
- Circulators found to have not been ordered/replaced due to oversight / mis-communication.
- Upgraded 8kW Circulators scheduled to be installed in both zones this maintenance period.
- Cavities gradients scheduled to be re-examined under load in Fall 2023 run.
- Many quench limitations due to multipacting @ E > 17 Mv/m – see G. Ciovati poster. **(WEPWB049)**

C-75 cavs Avg Values	VTA	CMTF	CEBAF Commissioning	CEBAF ODVH
E_{max}	19.1	18.4	18.8	
E_{op}		17.3	18.5	14.3

Ensemble Cavity Performance: Qs

	Cavity	SN	Qo VTA	CMTF Q FP	CMTF Q FPC	Emax Qo CMTF	CEBAF Q FP	CEBAF Q FPC	CEBAF Qo	
C50-13	1L13-1	5C75-001	9.00E+09			7.60E+09	8.02E+11	1.26E+07	7.60E+09	
LLRF 1.0	1L13-2	5C75-003	8.30E+09			7.70E+09	7.66E+11	1.89E+07	7.70E+09	
	1L05-1	5C75-RI-008	1.13E+10	7.49E+11	1.56E+07	6.70E+09	6.80E+11	1.10E+07	7.00E+09	
C	1L05-2	5C75-J-004	2.39E+09	3.94E+11	1.20E+07	8.70E+09	3.30E+11	1.70E+07	2.40E+09	
7	1L05-3	5C75-RI-001	8.86E+09	9.10E+11	2.30E+07	6.80E+09	6.10E+11	2.50E+07	6.10E+09	
5	1L05-4	5C75-RI-003	8.40E+09	1.10E+12	2.00E+07	7.00E+09	1.10E+12	1.80E+07	5.80E+09	
-	1L05-5	5C75-RI-002	8.60E+09	3.00E+11	1.80E+07	6.90E+09	2.30E+11	2.20E+07	6.90E+09	
0	1L05-6	5C75-RI-005	7.30E+09	2.60E+11	1.20E+07	6.90E+09	2.20E+11	1.60E+07	6.10E+09	
1	1L05-7	5C75-RI-007	8.75E+09	5.30E+11	1.60E+07	7.80E+09	3.50E+11	1.90E+07	5.50E+09	
	1L05-8	5C75-RI-006	8.78E+09	4.30E+11	1.60E+07	8.00E+09	4.40E+11	1.70E+07	6.10E+09	
	1L10-1	5C75-RI-012	1.23E+10	5.94E+11	1.85E+07	6.60E+09	4.13E+12	2.01E+07		…
C	1L10-2	5C75-J-005	1.11E+10	6.20E+11	1.60E+07	8.40E+09	5.15E+12	1.98E+07		…
7	1L10-3	5C75-RI-017	7.94E+09	3.10E+11	1.40E+07	7.10E+09	3.96E+12	1.77E+07		…
5	1L10-4	5C75-RI-014	6.74E+09	6.55E+11	1.70E+07	7.40E+09	7.62E+12	1.57E+07		…
-	1L10-5	5C75-RI-011	6.18E+09	4.80E+11	1.90E+07	7.20E+09	3.70E+12	2.18E+07		…
0	1L10-6	5C75-RI-018	8.69E+09	7.30E+11	2.60E+07	6.50E+09	5.47E+12	3.10E+07		…
2	1L10-7	5C75-RI-016	9.21E+09	9.00E+11	1.30E+07	5.60E+09	7.99E+12	1.56E+07		…
	1L10-8	5C75-RI-015	8.51E+09	7.70E+11	1.10E+07	5.20E+09	5.36E+12	1.58E+07		…
			8.46E+09	6.08E+11	1.67E+07	7.12E+09	2.72E+12	1.86E+07	6.12E+09	

… CEBAF Qo measurements obviated by available schedule time on C75-02

Avg Values	VTA	CMTF	CEBAF
Qo	8.46E+09	7.12E+09	6.12E+09
Q_{fp}		6.08E+11	2.72E+12
Q_{fpc}		1.67E+07	1.86E+07

Spec:

8e9

2e7 +/- 15%

- Will revisit Q_{FPC} w/ stub tuners after circulator installation.
- O-doping under investigation to raise Qo in a C75-03 cavity.

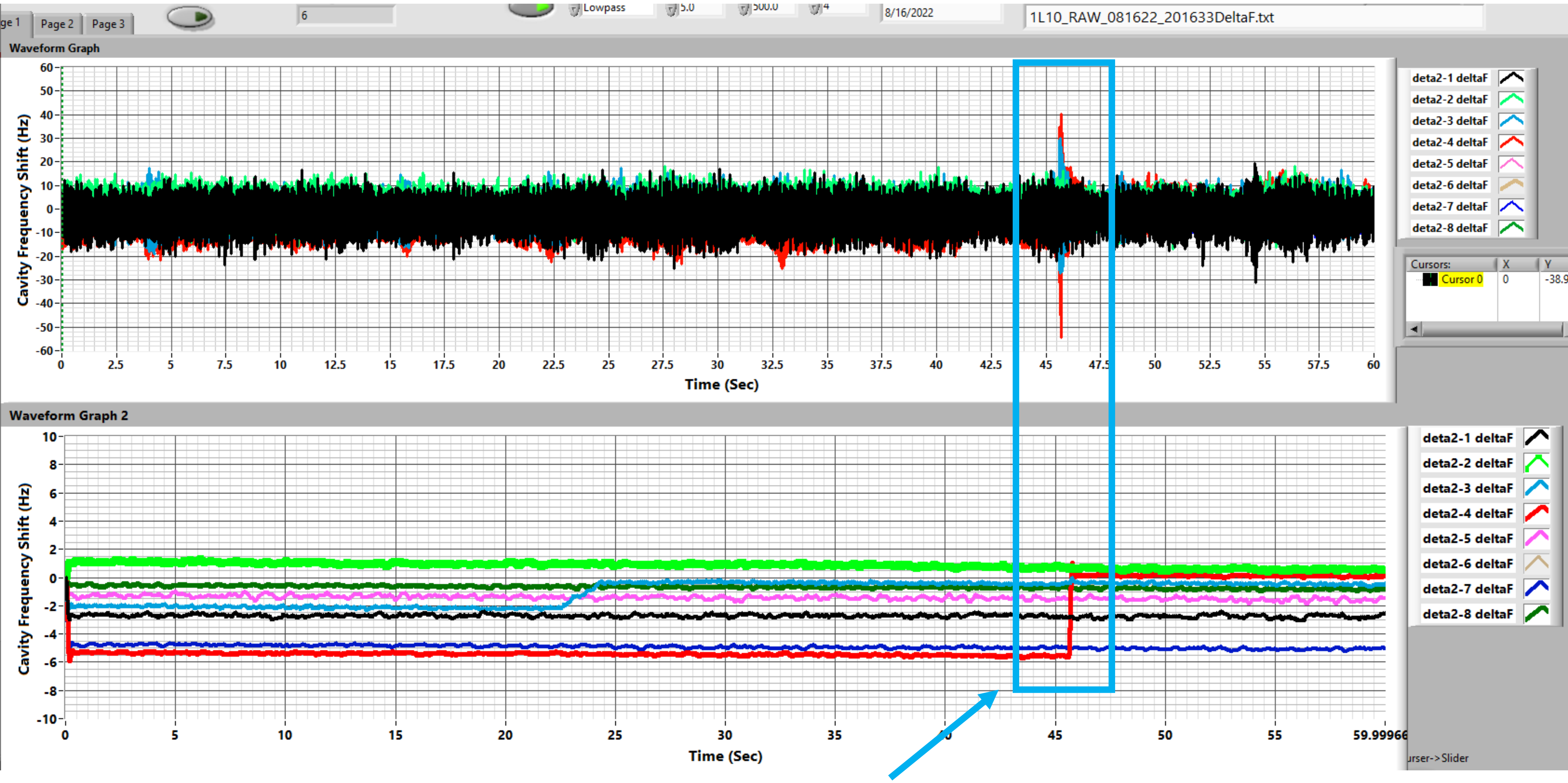
Ensemble Cavity Performance: Field Emission (Cont.)

	Cavity	SN	VTA FE onset	Max Rad (mRad/hr)	CMTF FE onset	MaxDose (R/hr)	CEBAF FE onset	MaxDose (R/hr)
C50-13	1L13-1	5C75-001	17.9		12.8		12.8	0.8
LLRF 1.0	1L13-2	5C75-003	9.9		10.9		10.4	0.1
C75-01	1L05-1	5C75-RI-008	20.2	0.00	18.4	0	13.9	0
	1L05-2	5C75-J-004	6.94	347.00	8.2	27	9.7	20.2
	1L05-3	5C75-RI-001	14.5	400.00	13.2	0.04	18.3	0
	1L05-4	5C75-RI-003	15	1.46	13	1.7	14.8	0.16
	1L05-5	5C75-RI-002	18.16	0.17	11.1	0.9	12.7	0.84
	1L05-6	5C75-RI-005	19.67	0.96	18.5	0	18	0
	1L05-7	5C75-RI-007	19.9	0.02	18.7	0	14.2	0.45
	1L05-8	5C75-RI-006	17.52	0.26	16.3	0.1	15.5	0.42
C75-02	1L10-1	5C75-RI-012	13.9	3.37	10.5	23.6	11.8	21.1
	1L10-2	5C75-J-005	11.4	1.90	18	0	17.2	0
	1L10-3	5C75-RI-017	17.5	251.00	11.6	0.45	11.5	12
	1L10-4	5C75-RI-014	10	98.90	10.5	1.8	11.8	11.7
	1L10-5	5C75-RI-011	10.75	1000.00	10.5	0.37	10.9	11.7
	1L10-6	5C75-RI-018	15	3.61	17	0.18	17.1	2.1
	1L10-7	5C75-RI-016	20.3	0.00	21	0	22	0
	1L10-8	5C75-RI-015	14	12.50	11.8	6.9	11.3	0.97
		15 cavities:	18.2	132.57	19.38	3.94	19.53	4.59
			3 of 18 cavities clean		5 of 18 cavities clean		5 of 18 cavities clean	

Zones under discussion for possible plasma processing to damp field emission.
(See poster by T. Powers – this conference [WEPWB054])

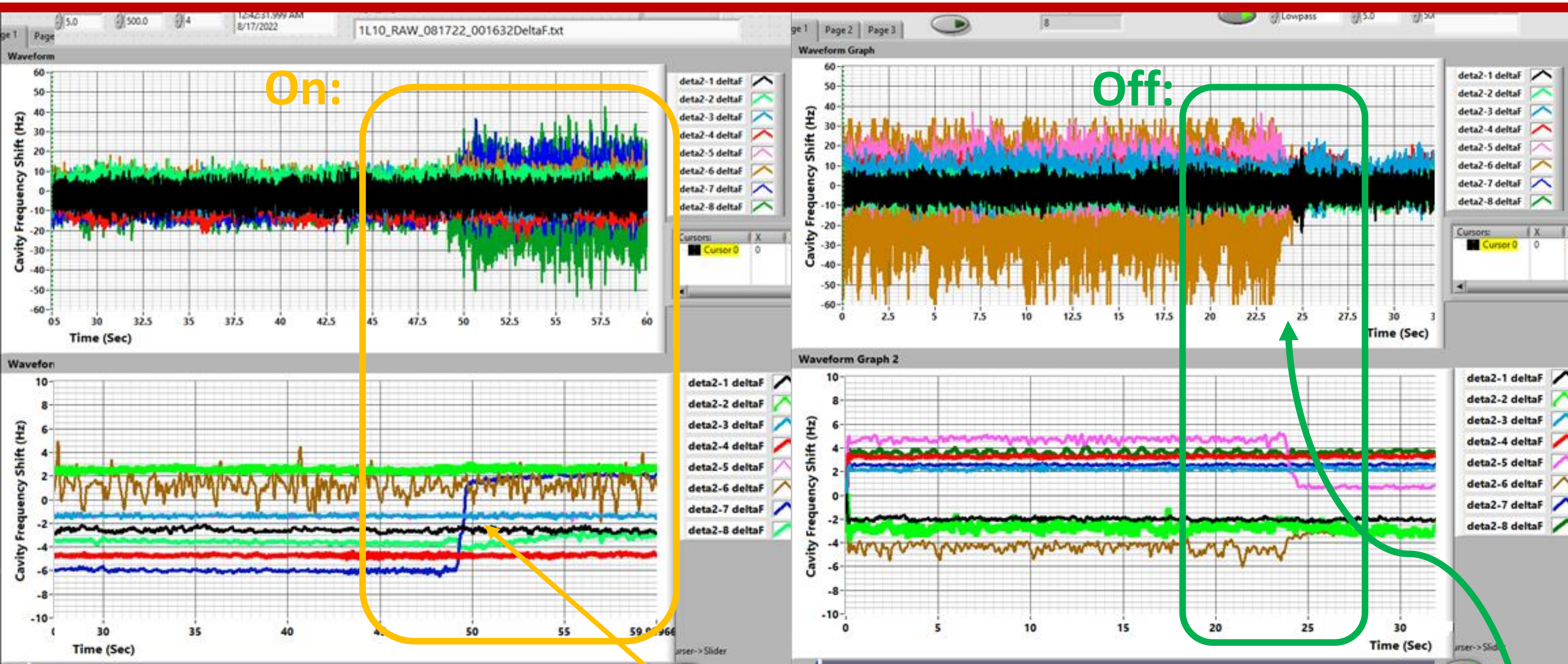
Ensemble Cavity Performance: Microphonics

Two Phenomena of Interest Identified:



#1: Occasional microphonics outbursts with tuner motion; occurs sporadically – not with every movement.

Ensemble Cavity Performance: Microphonics (Cont.)



#2: Coupled effect; a tuner moves and it & its neighbor become microphonically agitated. Moving one of the tuners again stops this…

Both modes to be studied further following circulator replacement…

May result in performance limitation post circulators – TBD.

Summary

- C75s cost-efficient & novel use of large grain boundary ingot Nb. Process industrialized with RI & CBMM.
- Enhanced gradient over legacy C50 program very helpful for the purposes of the CEBAF Performance Plan (CPP) and establishing / maintaining 12 GeV energy reach.
- Circulators limit primary barrier preventing installed C75 zones from operating at potential; remedying now – gradient limits & microphonics studies will be revisited.
- Steady state operational data and any possible performance degradation data (if it exists) will be extracted over next year+ and studied.
- C20 to C75 refurbishment schedule planned to continue at ~2 modules/year through at least C75-10.

A. Freyberger et al., The 12 GeV CEBAF Performance Plan; V. 1.1, JLAB-TN-17-022, 19 June 2017

M. McCaughan
(w): 757-269-5572
michaelm@jlab.org

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