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Performance Characterization of LCLS-II Superconducting Radiofrequency Cryomodules

Ruth Gregory

Lee Teng Internship Final Presentation

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In partnership with: Illinois Accelerator Institute, MICHIGAN STATE UNIVERSITY, LCLS-II

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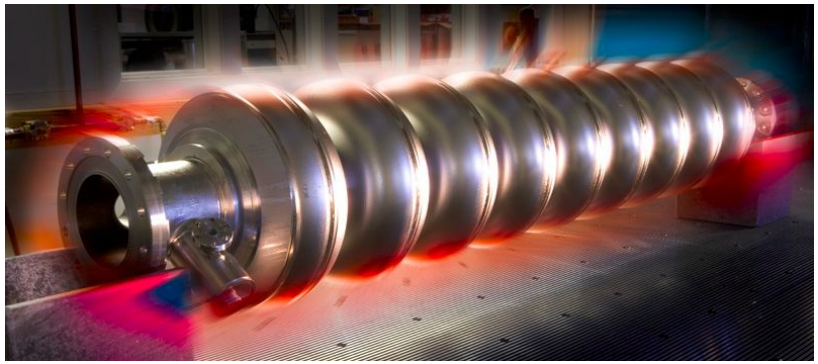
Outline

- Introduction
  - LCLS-II and Fermilab's Contributions
- Motivation for Cryomodule Testing
- Analysis Methods
- Results
- Conclusion/Outlook

Linear Coherent Light Source (LCLS-II) and Fermilab's Contributions

- LCLS II is a 2nd generation x-ray free electron laser being constructed at SLAC National Accelerator Laboratory.
- Fermilab's contributions to LCLS-II include designing, assembling, and testing seventeen 1.3 GHz and two 3.9 GHz cryomodules
- These cryomodules consist of eight nine-cell superconducting cavities.



1.3 GHz Superconducting Radio Frequency (SRF) cavity

SRF cavity at Fermilab's cryomodule test stand

Motivation for Cryomodule Testing

- Performance criteria are set for the level of field emission (radiation) and dark current produced by these cryomodules
- Assess which of the eight cavities produce the most (or any) radiation or dark current.
- Map out the radiation and dark current as a function of accelerating voltage.
- For each cavity determine:
  - Peak radiation
  - Cavity gradient (MV/m) where detectable radiation starts to appear
- This information will be included in the data travelers that will be sent to SLAC along with the cryomodules.

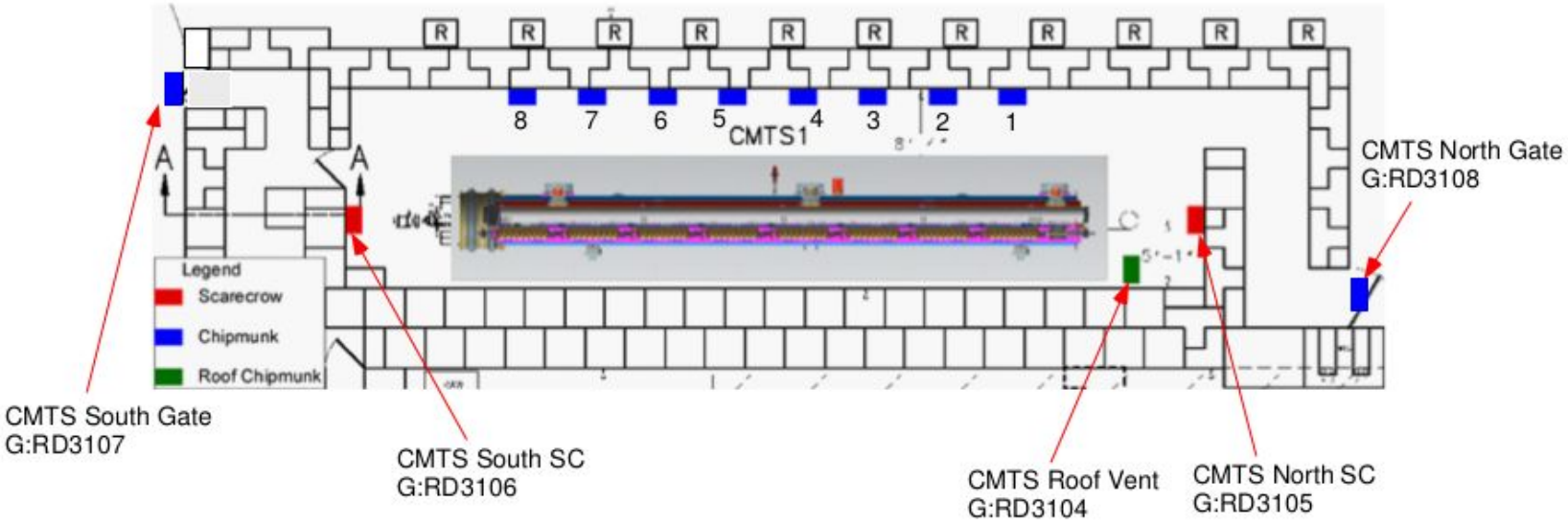
Analysis Methods

- Cryomodule data including gradient and radiation levels is collected through Fermilab's Accelerator Control System (ACNET) archiving routines.
- A C++/ROOT program was developed to view and analyze the cryomodule data.
- This program generates:
  - Plots of the data from each cryomodule device over time
  - Plots of cavity voltage vs radiation
  - Plots of dark current vs cavity voltage
  - Data tables containing:
    - Maximum values for each cryomodule device
    - Peak radiation within any gradient range

Cryo Module Test Cave
Radiation Detector Placement

As of September 21, 2016

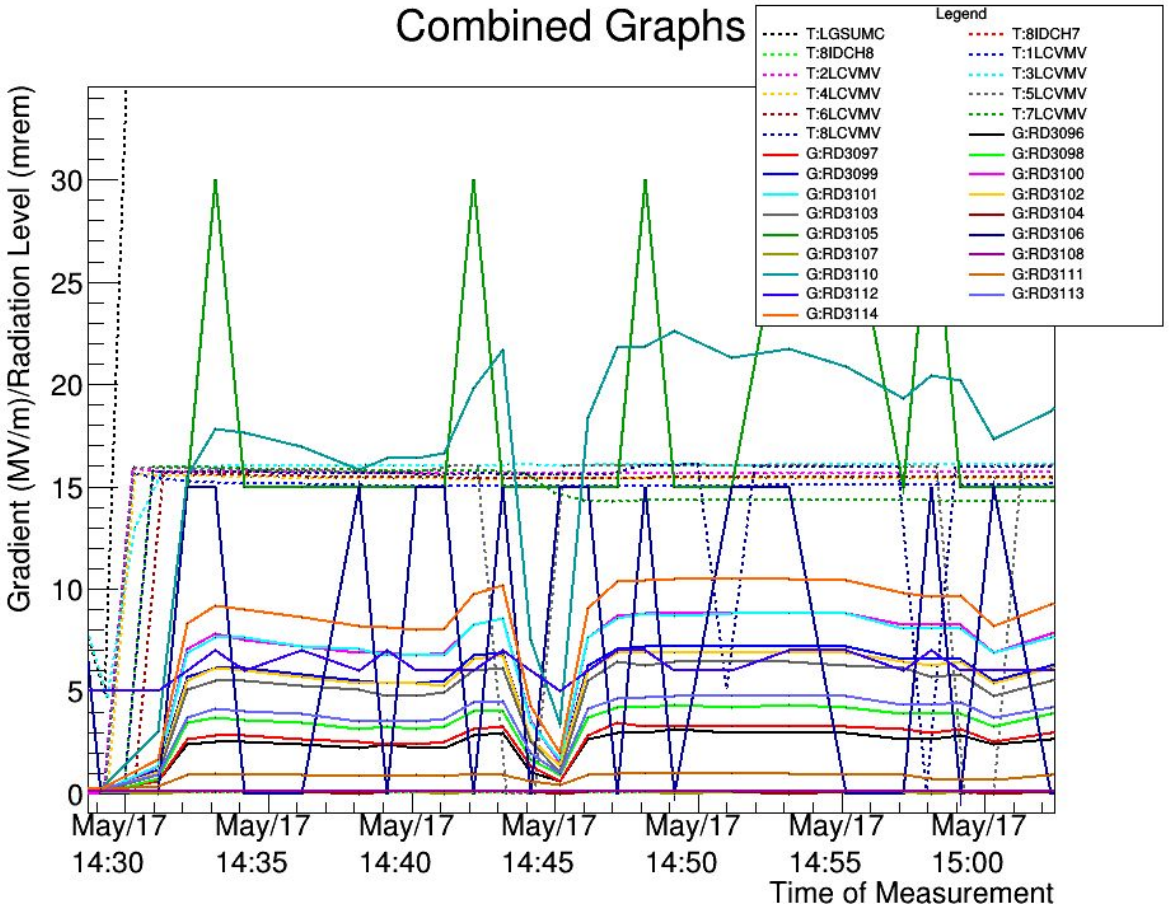
Chipmunks CMTS West Wall nos. 1-8 correspond to locations 1,2,3,4,5,6,7,8:
G:RD3096,G:RD3097,G:RD3098, G:RD3099, G:RD3100, G:RD3101, G:RD3102, G:RD3103



Drawing adapted from CMTS Preliminary Shielding Assessment v.4 Anthony F Leveling 12/4/2014

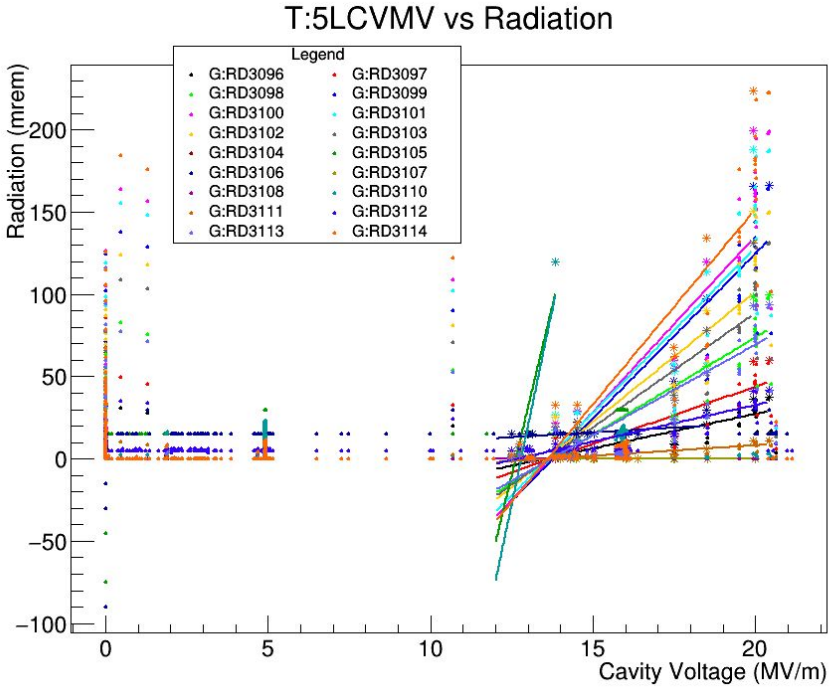
G. Lauten
AD Operational RSO

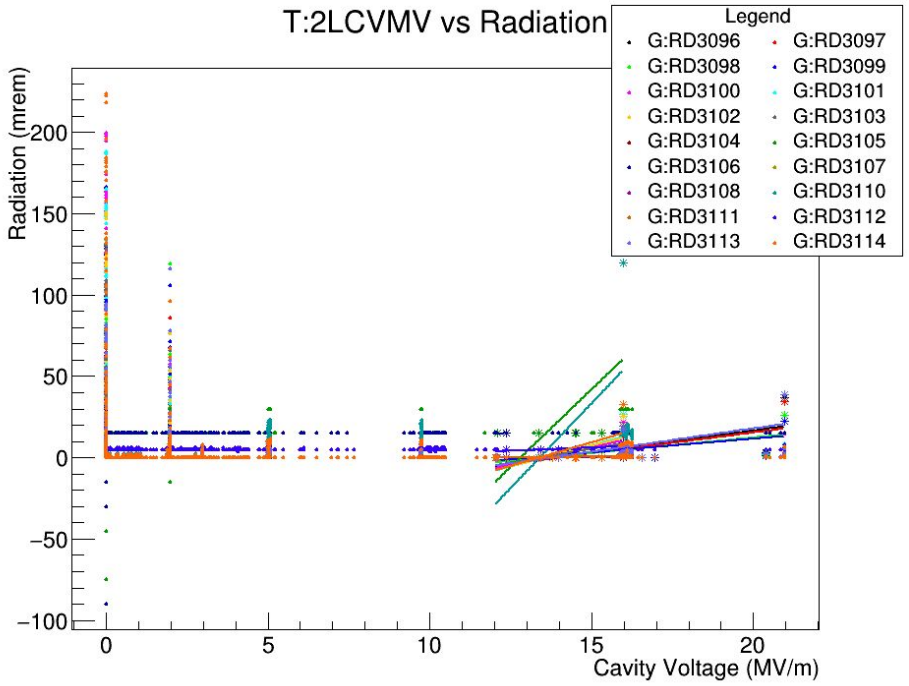
Results



This plot shows the data from each cryomodule device plotted over time. The voltage cavity data has y-axis units of MV/m, and is plotted with dotted lines. The radiation detector data has y-axis units of mrem, and is plotted with solid lines.

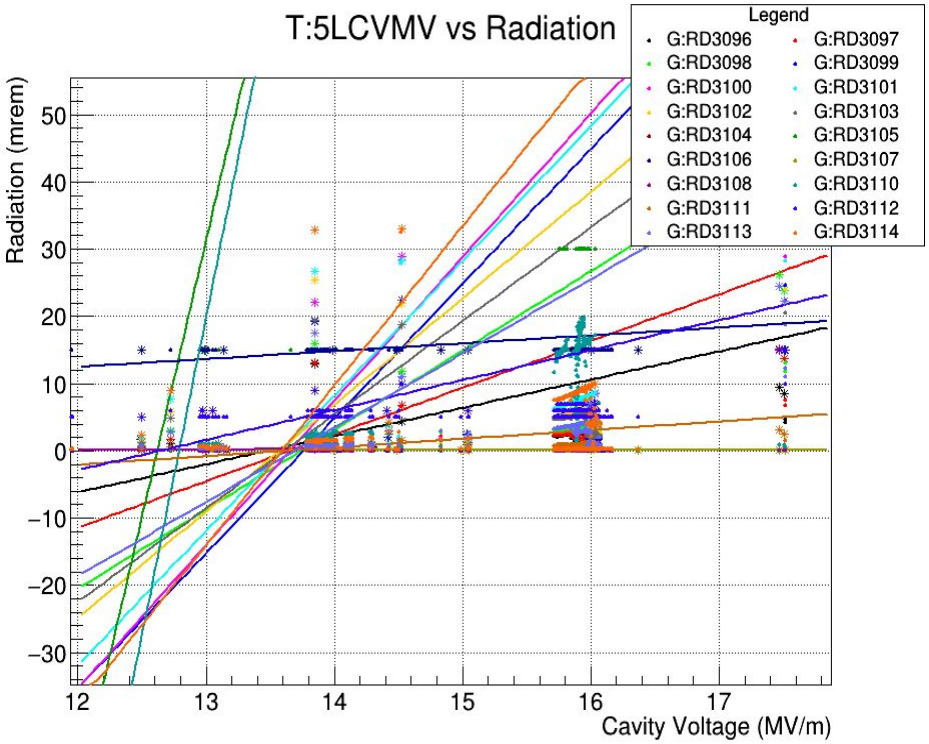
Results (cont.)

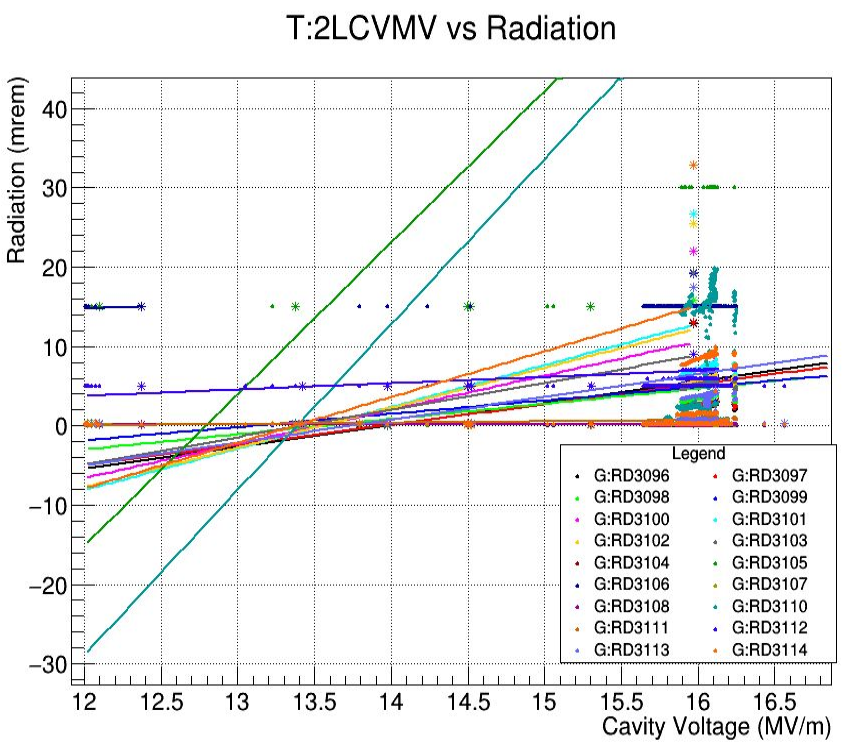




- These plots show the radiation levels for various radiation detectors plotted over the gradient for voltage cavities 5 (left) and 2 (right).
- The lines are linear fits of the data points in the range of 12 MV/m to the cavity voltage corresponding to the maximum radiation level for the given radiation detector.
- The data points included in the fit function are star-shaped.

Results (cont.)





- These are the plots from the previous slide zoomed-in on the point at which (most of) the fit lines intersect.
- This intersection point is approximated as the gradient at which field emission starts to appear.
- From these plots one can conclude that the onset of field emission for cavity 5 is just below 14 MV/m, and that cavity 2 has very little (if any) field emission.

Results (cont.)

Overall Maximum values for each device:

	Maximum Value
T:LGSUMC(V)	133.84217834
T:8IDCH7(MV/m)	0.0826
T:8IDCH8(MV/m)	0.16520000622
T:1LCVMV(MV/m)	21.254377365
T:2LCVMV(MV/m)	20.962310791
T:3LCVMV(MV/m)	20.95986557
T:4LCVMV(MV/m)	20.956142426
T:5LCVMV(MV/m)	21.126306534
T:6LCVMV(MV/m)	16.821933746
T:7LCVMV(MV/m)	21.049873352
T:8LCVMV(MV/m)	20.955867767
G:RD3096 (mrem)	66.000002623
G:RD3097 (mrem)	97.950003892
G:RD3098 (mrem)	142.50000566
G:RD3099 (mrem)	220.65000877
G:RD3100 (mrem)	256.20001018
G:RD3101 (mrem)	238.05000946
G:RD3102 (mrem)	193.05000767
G:RD3103 (mrem)	170.25000677
G:RD3104 (mrem)	0.30000001192
G:RD3105 (mrem)	120
G:RD3106 (mrem)	30
G:RD3107 (mrem)	0.30000001192
G:RD3108 (mrem)	0.30000001192
G:RD3110 (mrem)	119.57999733
G:RD3111 (mrem)	15.779999647
G:RD3112 (mrem)	54
G:RD3113 (mrem)	144.89999676
G:RD3114 (mrem)	227.9999949

Maximum Radiation values between 15.500000 and 16.600000 MV/m for each cavity

	T:1LCVMV	T:2LCVMV	T:3LCVMV	T:4LCVMV	T:5LCVMV	T:6LCVMV	T:7LCVMV	T:8LCVMV
G:RD3096	12.9	12.9	12.9	23.4	3.3	2.85	3	3
G:RD3097	13.05	13.05	13.05	33.75	5.25	3	3.15	3.15
G:RD3098	15.9	15.9	15.9	49.8	6.75	4.05	4.2	4.2
G:RD3099	19.2	19.2	19.2	51.3	7.95	6.75	6.9	6.9
G:RD3100	22.05	22.05	22.05	35.7	8.55	8.4	8.55	8.55
G:RD3101	26.7	26.7	26.7	26.7	8.7	8.4	8.7	8.7
G:RD3102	25.5	25.5	25.5	25.5	6.45	6.45	6.45	6.45
G:RD3103	19.35	19.35	19.35	19.35	5.85	5.85	5.85	5.85
G:RD3104	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
G:RD3105	120	120	120	120	30	30	30	30
G:RD3106	15	15	15	15	15	15	15	15
G:RD3107	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
G:RD3108	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
G:RD3110	119.58	119.58	119.58	119.58	19.86	19.86	19.86	19.86
G:RD3111	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08
G:RD3112	9	9	9	11	7	7	7	7
G:RD3113	17.46	17.46	17.46	46.92	7.08	4.32	4.44	4.44
G:RD3114	32.88	32.88	32.88	32.88	9.96	9.72	9.96	9.96

- These are screenshots of the data tables produced by the ROOT/C++ program.
- The table on the left shows the maximum values recorded by each cryomodule device.
- The right table on the right shows the peak radiation values for each voltage cavity and for each radiation detector in the range of 15.5 and 16.6 MV/m.

Conclusion and Outlook

- Cryomodule field emission and dark current Data can now be obtained mostly automatically using an ACL script and the Root/C++ program.
- The Root/C++ program can be used to analyze data from any cryomodule.
- Next steps:
  - Find a more precise and objective way of finding the cavity gradient where detectable radiation starts to appear.
  - Perform a more complete analysis of dark current production.
  - Make a short tutorial for future users on how to use the ACL script and ROOT/C++ program.

Acknowledgements

Thank you to:

- Elvin Harms, my mentor
- Brian Hendricks, for creating the ACL scripting language
- Eric Prebys and Rosa Foote for coordinating the Lee Teng Internship

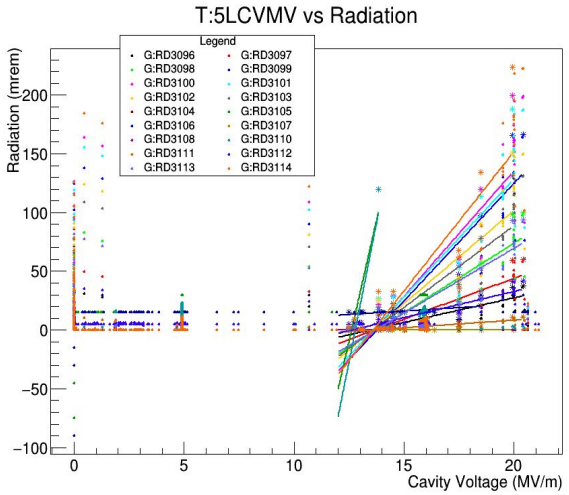
References

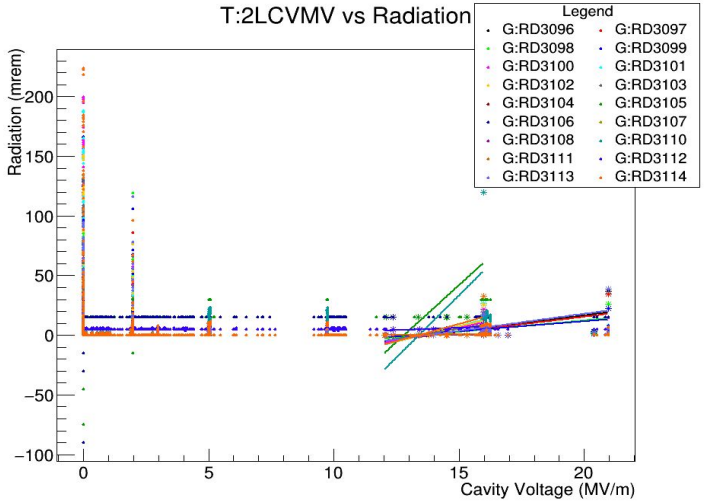
[1] T. Arkan et al., “LCLS-II 1.3 GHz Design Integration for Assembly and Cryomodule Assembly Facility Readiness at Fermilab,” in Proc. 17th Int. Conf. on RF Superconductivity (SRF2015) , Whistler, BC, Canada, Sep. 2015.

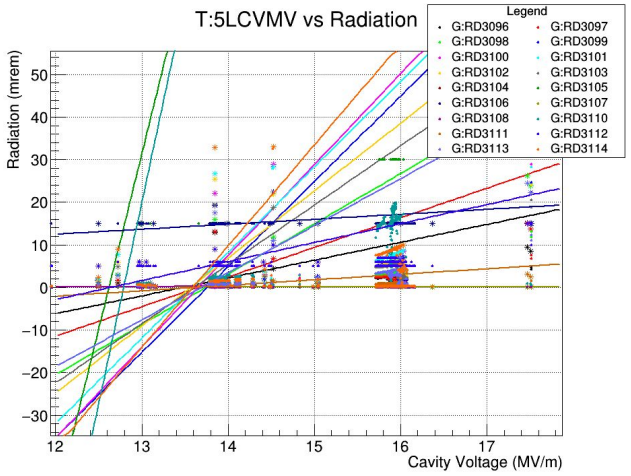
[2] E. Harms et al. , “ Fermilab Cryomodule Test Stand Design and Plans,” in Proc. 17th Int. Conf. on RF Superconductivity (SRF2015) , Whistler, BC, Canada, Sep. 2015.

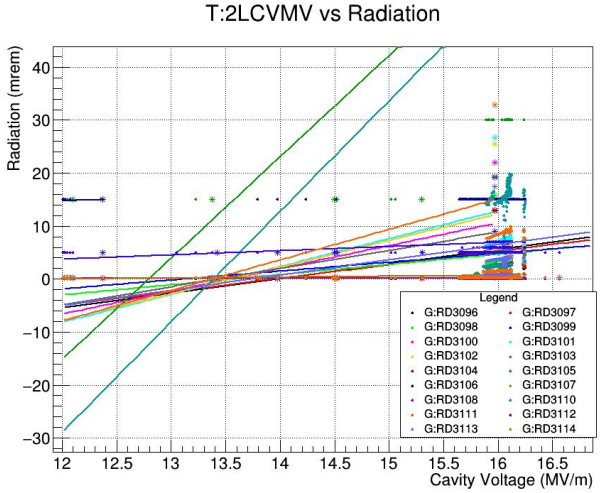
Backup Slides

Results (cont.)









Top Plots: Full graph of cavity voltage vs radiation for cavities 5 (left) and 6 (right).
Bottom Plots: Close up of the regions where the fit lines on the plots intersect.