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U.S. DEPARTMENT OF ENERGY | Office of Science

CM-2 Commissioning

Elvin Harms

ASTA Users Meeting

9 June 2014

Introduction

- CM-2 is
  - Type 3+ ILC type Cryomodule
  - 8 cavities (1.3 GHz) built by industry
  - Vertical and Horizontal tests at JLab & Fermilab (good to 35 MV/m)
  - Cryomodule assembled at Fermilab
  - first ILC type cryomodule which may(?) reach average gradient specification of 31.5 MV/m
  - Designed for pulsed operation
- Main accelerating device for ASTA
- Expect beam tests in FY2015

Commissioning Process

- Prerequisites
  - cryomodule installed
  - pipes welded and certified leak tight
  - pressure tests successful
  - vacuum circuits leak tight (beam tube, coupler, insulating vacuum)
  - instrumentation, tuners verified operational
  - warm conditioning completed
  - cooldown
- Measure frequency spectra both warm and cold
- Single cavity powering
- Power all cavities together, characterize system performance
- Follow-on studies

Single Cavity

- Tune cavity to resonance
- Map out and set Q_L
- System calibrations, calculate gradient, k
- On-resonance conditioning
- Determine peak performance
- Final (high power) LLRF calibration
- Lorentz Force Detuning Compensation set-up
- Document dark current, x-rays vs. gradient
- Dynamic Heat Load measurements (Q_0)

Commissioning Process

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ASTA/RFCA002 Run Plan for Single SRF Cavities

E. Harms
November 2013

Introduction:

This document specifies the measurements/data to be taken on cavities in RFCA002 aka CM-2 at NML. Additional help and links to software tools can be found in the HTS Wiki/Operations Help: *http://www-bd.fnal.gov/issues/wiki/HTSOperationHelp*
Elog: bweb3.fnal.gov:8080/ECL/nml/E/index *CM2/RFCA002/Studies*

Cavity Identity:

Location	1	2	3	4	5	6	7	8
Cavity Serial #	TB9AES008	TB9RI018	TB9AES010	TB9TI019	TB9ACC016	TB9AES009	TB9RI027	TB9RI028
Coupler Serial #								

Circle cavity to be tested

Completed by: _____ Date: _____ Elog entry #: _____

Room temperature measurements:

These measurements are taken after the cavity and input coupler have been installed and pumped down to < 10^{-7} Torr.

1. CAVITY FREQUENCY SPECTRUM
   This is performed using a Network Analyzer and an amplifier. RF is injected into a Waveguide launcher attached to the input coupler and S_{21} is measured from coupler to cavity pickup. The frequency of all 9 cavity passband modes is recorded.

9. DYNAMIC HEAT LOAD MEASUREMENT/DETERMINATION OF Q_0

Using a 'standard' 1.3 ms long pulse (nominally 500 µs fill and 800 µs flat-top) pulse and with the LLRF in closed loop mode, the heat generated by the cavity is measured thus allowing Q_0 to be determined. Typically these measurements are made at 5 HZ, but adjust the rate if needed for stable peak gradient performance.

- Record fill and flattop times Fill = _____µs Flattop = _____ µs
- Record repetition rate Rate= _____Hz
- Record start and end static heat load
- At least 5 high gradient points – 1 hour at each
- X-ray flux – look for dose rate real time and in datalogger
  - G:RD3227, G:RD3231, G:RD3241, G:RD3242
- Cavity dark current – look at Faraday cups
  - N:M1HW1A, NLM1HW1B

Completed by: _____ Date: _____ Elog entry #: _____

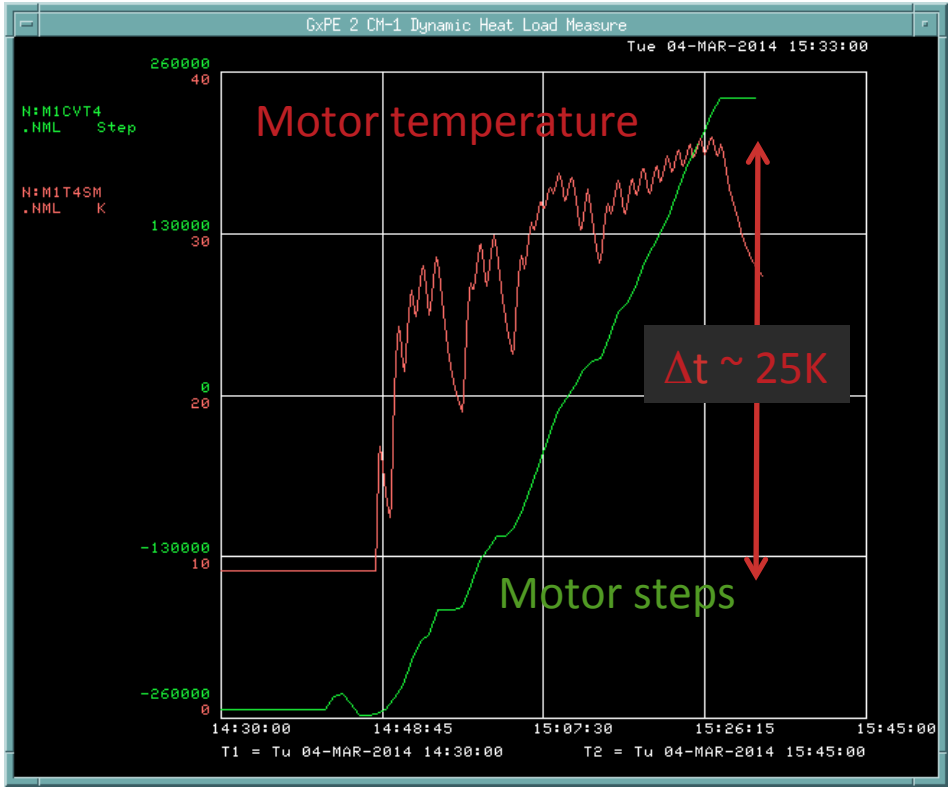
10. UNDERPERFORMING CAVITY

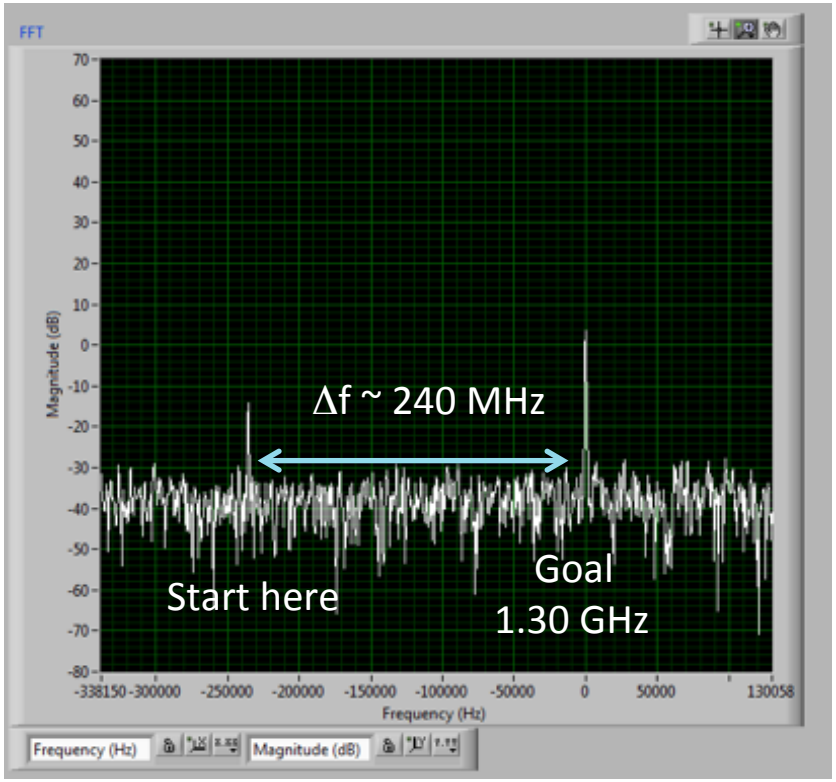
Should a cavity not meet performance specifications as determined in Vertical or Horizontal tests, the following additional checks should be made:

- Measure Q_L vs gradient; record where Q_L drop begins
- Reduce flattop length in 100 µs increments and repeat
- Attempt to measure non-π mode performance

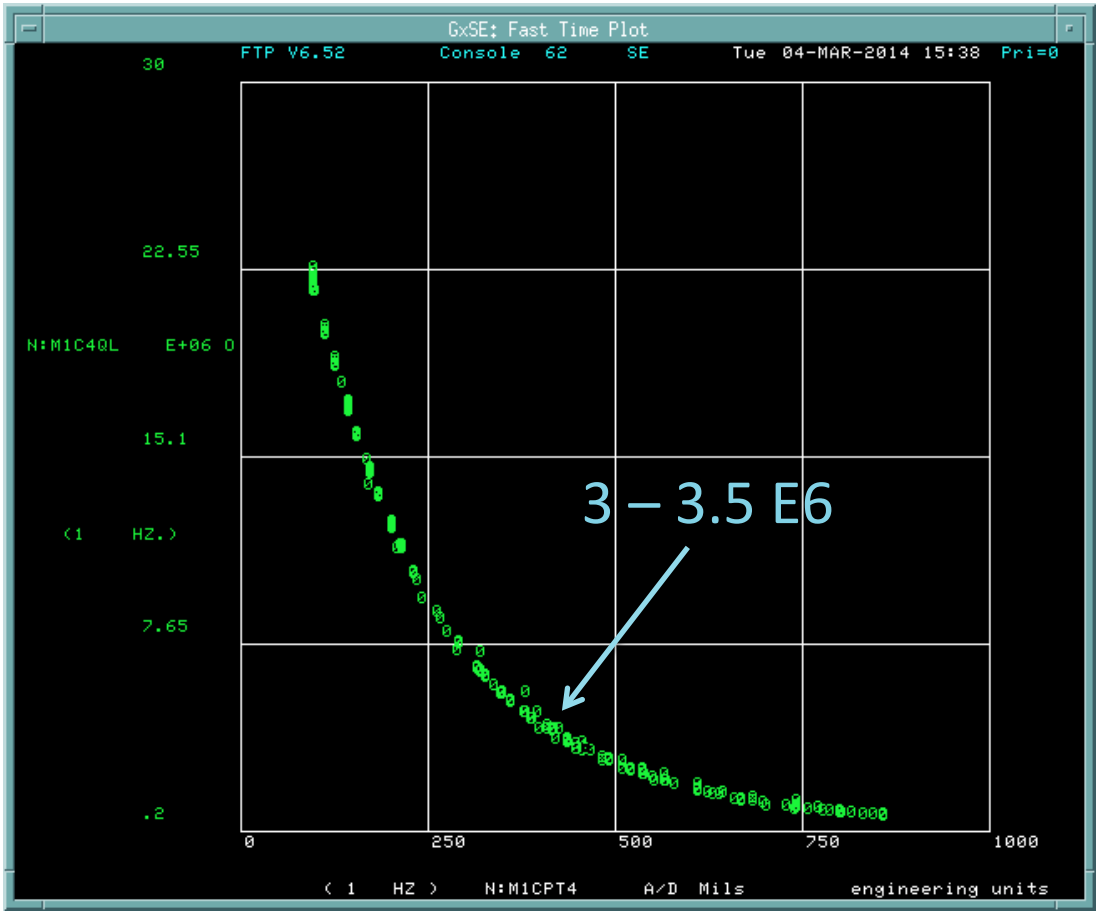
7

Tuning to resonance



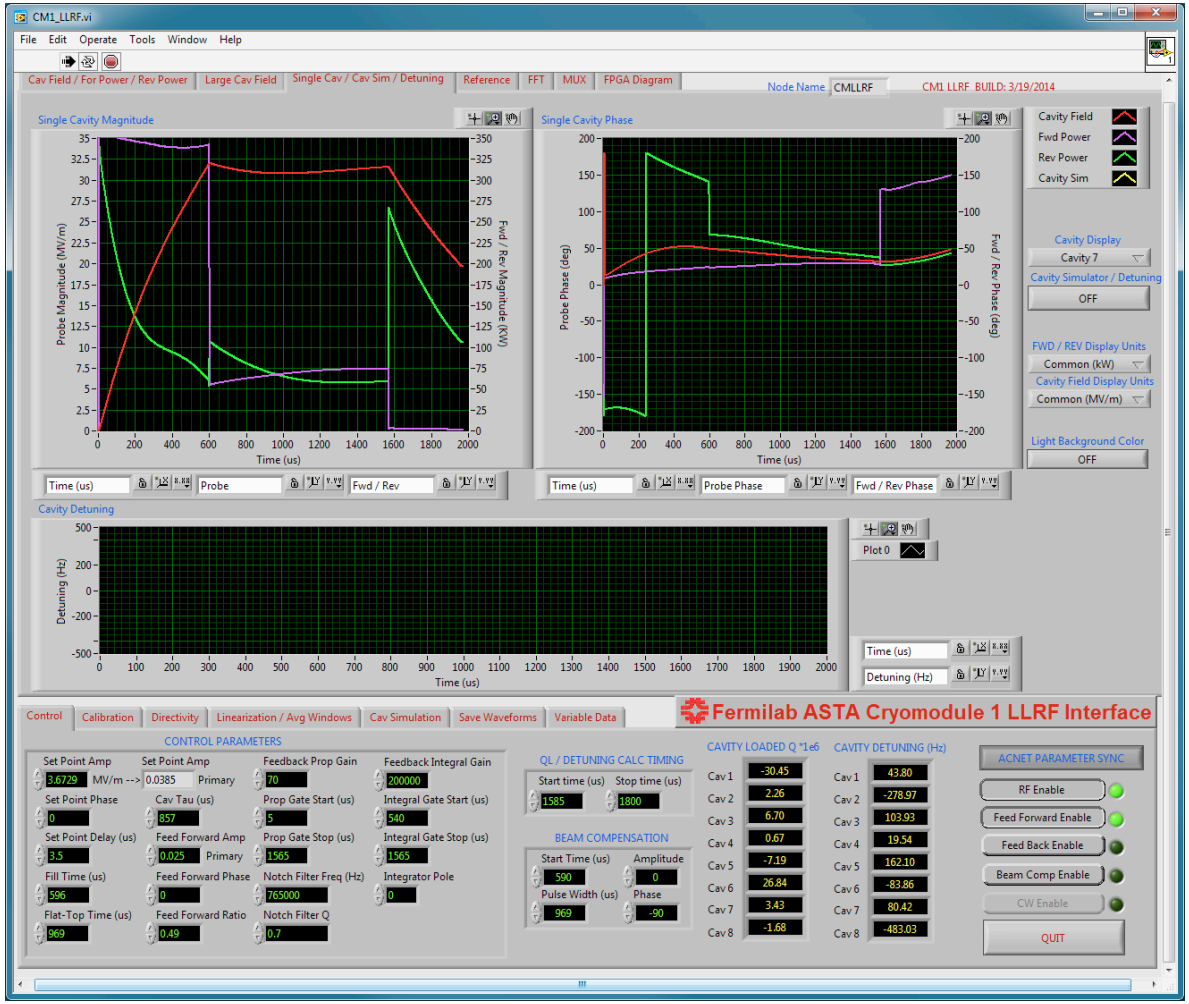


Setting Q_L


GxSE: Fast Time Plot
FTP V6.52
Console 62
SE
Tue 04-MAR-2014 15:38 Pri=0
30
22.55
N:M1C4QL E+06 0
15.1
(1 HZ.)
7.65
.2
0
250
500
750
1000
(1 HZ) N:M1CPT4 A/D Mils engineering units
3 – 3.5 E6

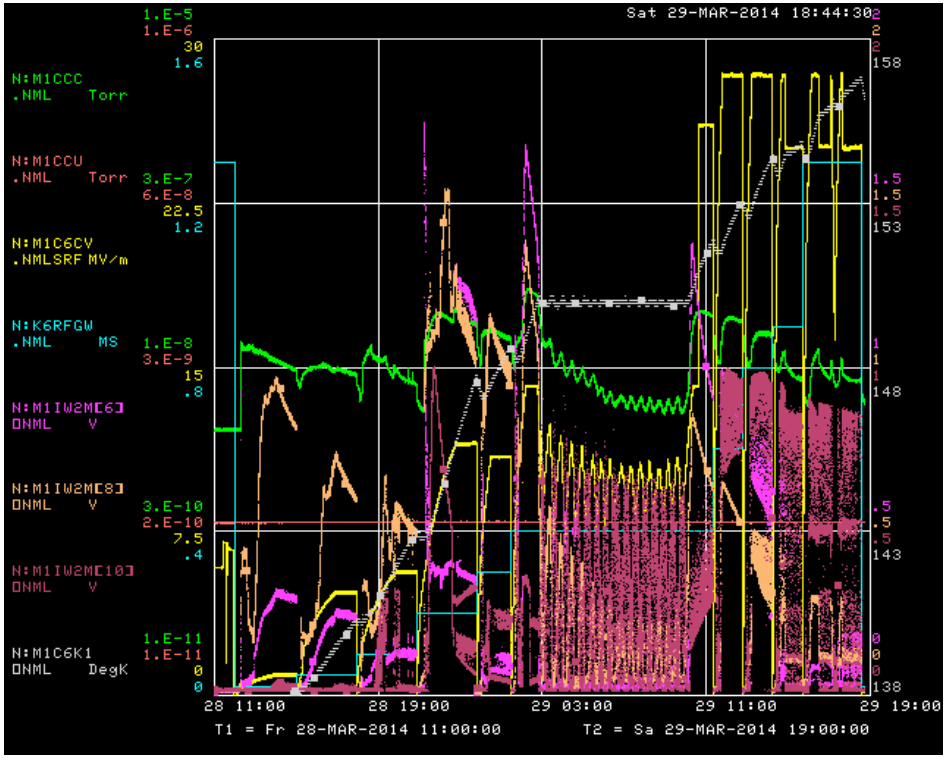
Low Level RF

- Labview vi with all parameters available in ACNET



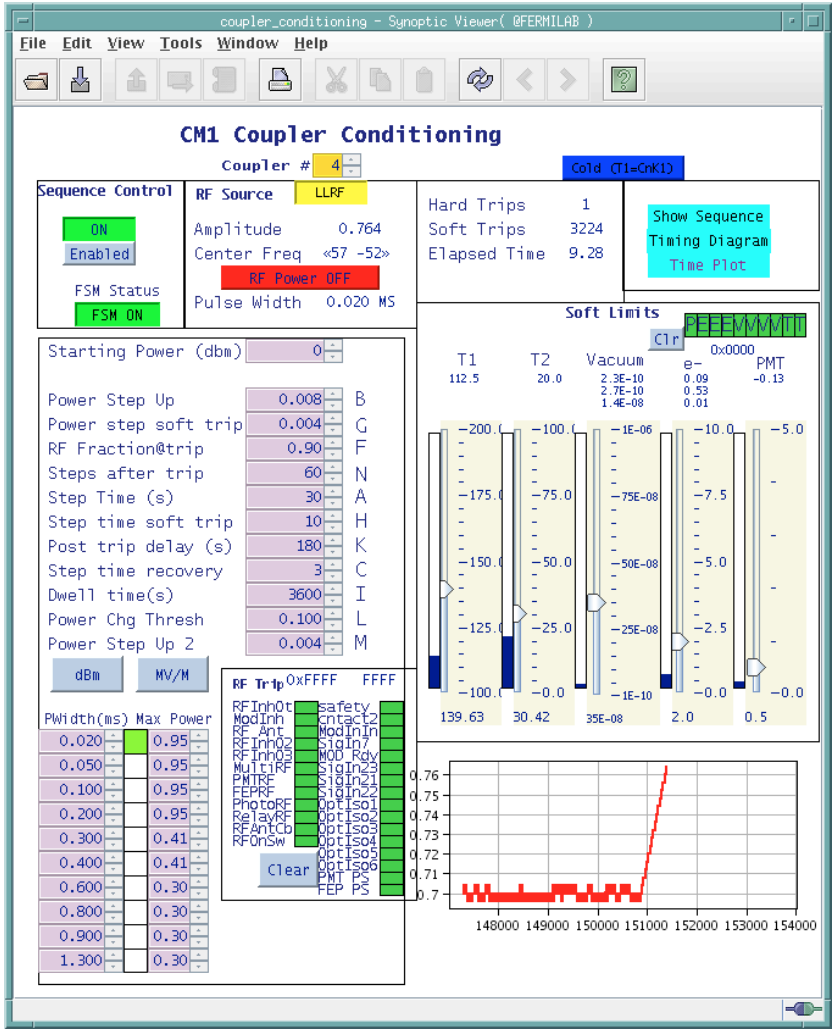
On-resonance conditioning

- 20 μs to 1.3 ms pulse width (500 μs fill time)
- 1-2 Hz repetition rate
- Peak power 1 MW (narrow pulse width) or < 25 MV/m
- Monitor
  - Vacuum
  - Field Emission (3 points)
  - PMT
  - Coupler window temperatures
- Automated process (mostly)

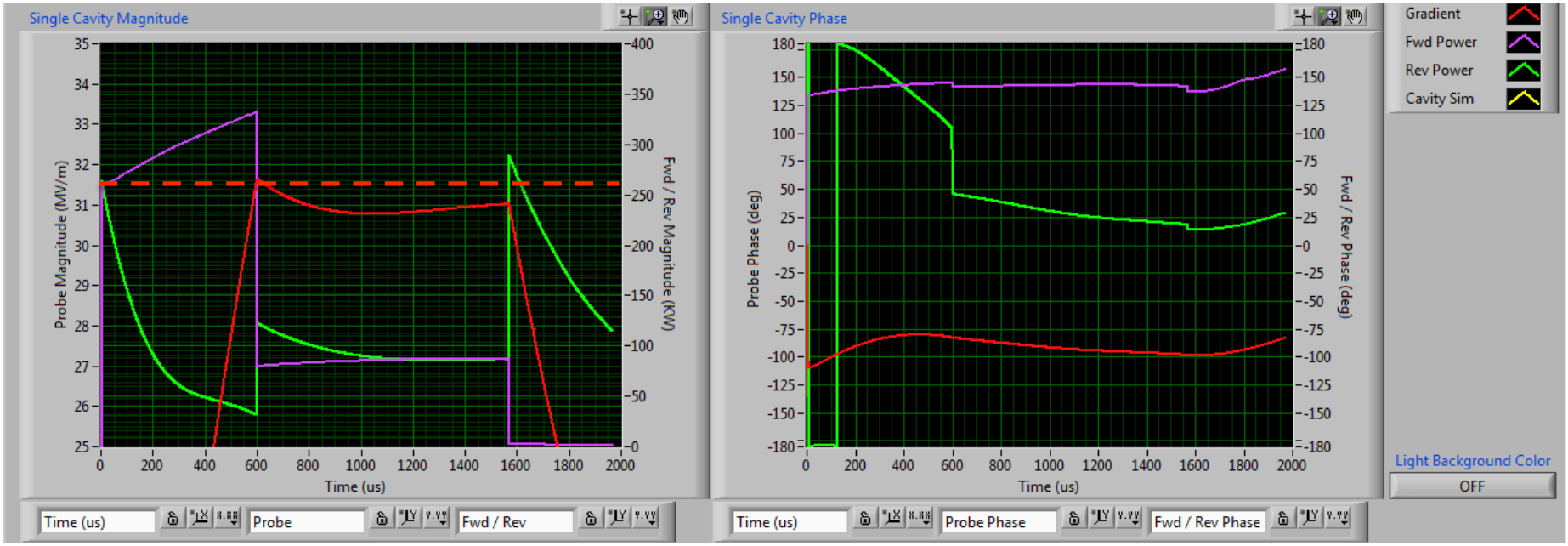


Cavity #6 Conditioning

Conditioning Sequencer

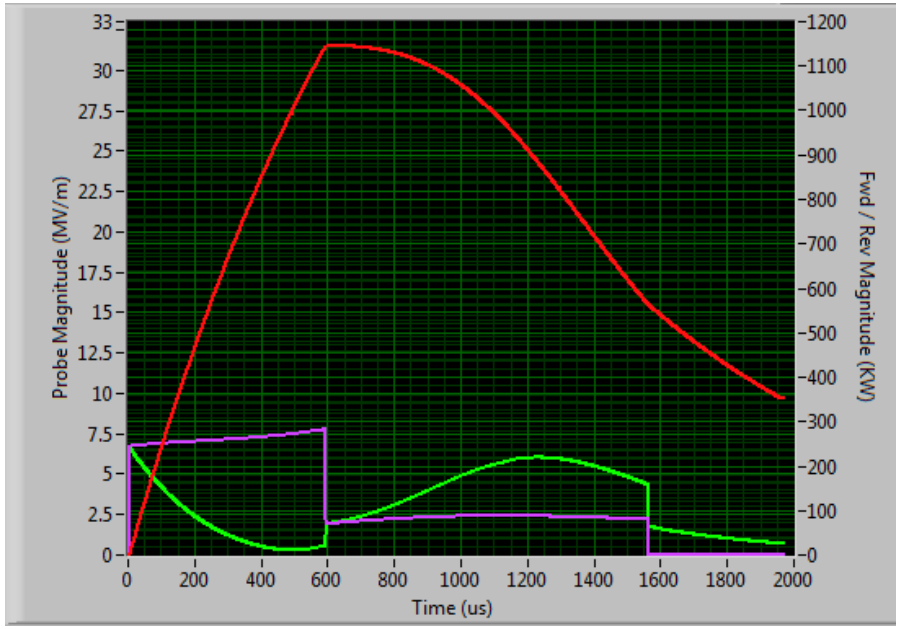


Peak Gradient

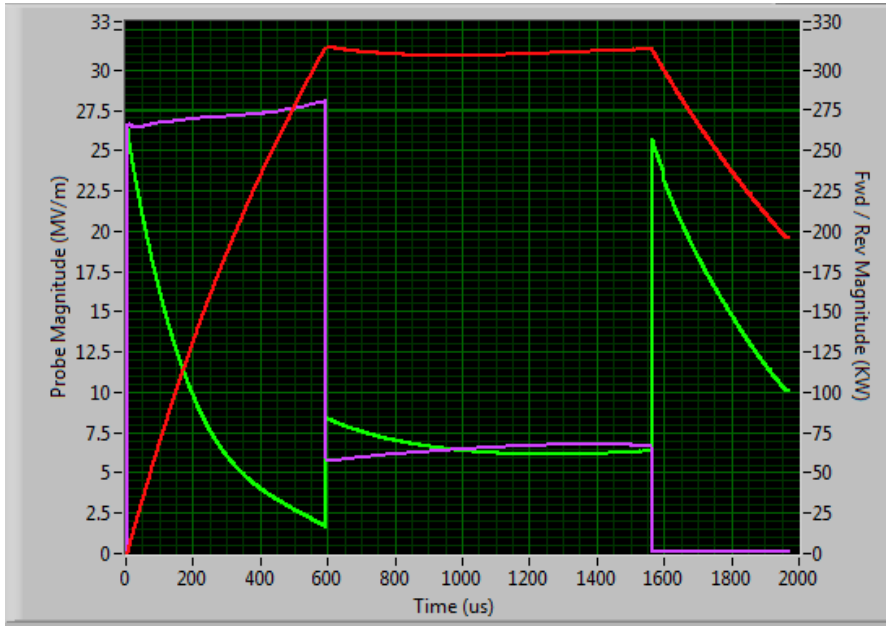


27 February 2014:
CM-2 Cavity 3 achieves 31.5 MV/m (Administrative limit)
5 Hz, 1.6 ms pulse width, LFDC Active

Lorentz Force Detuning



Off



On

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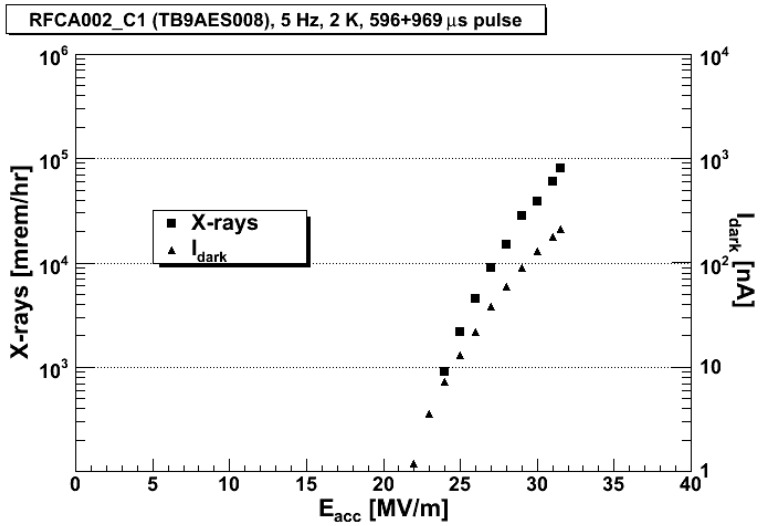
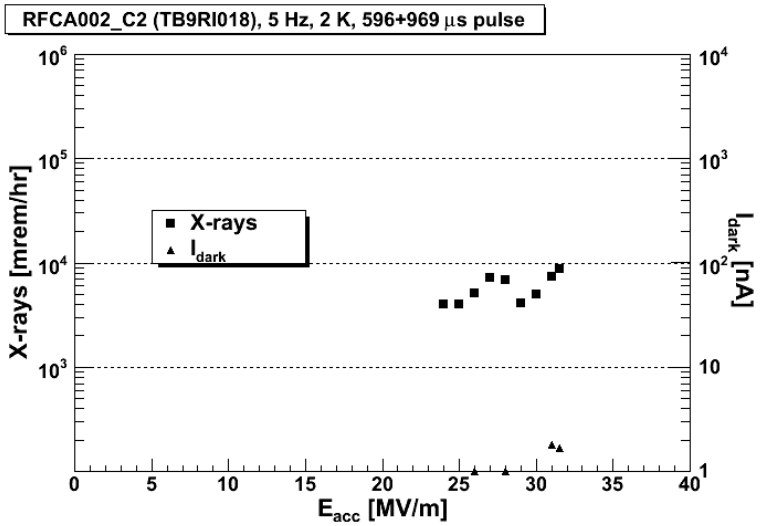
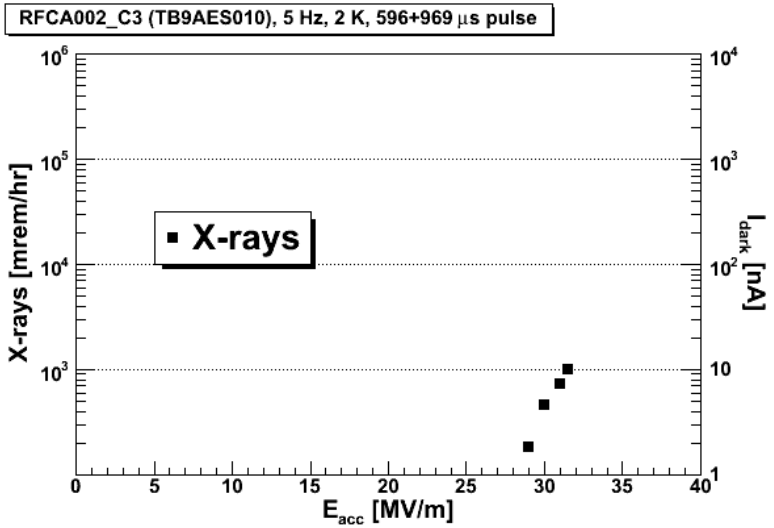
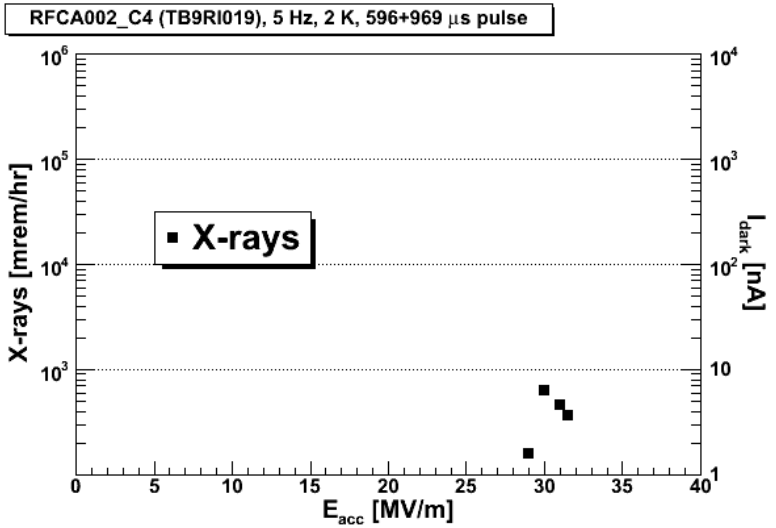
Dark Current/X-rays

courtesy Andy Hocker, TD





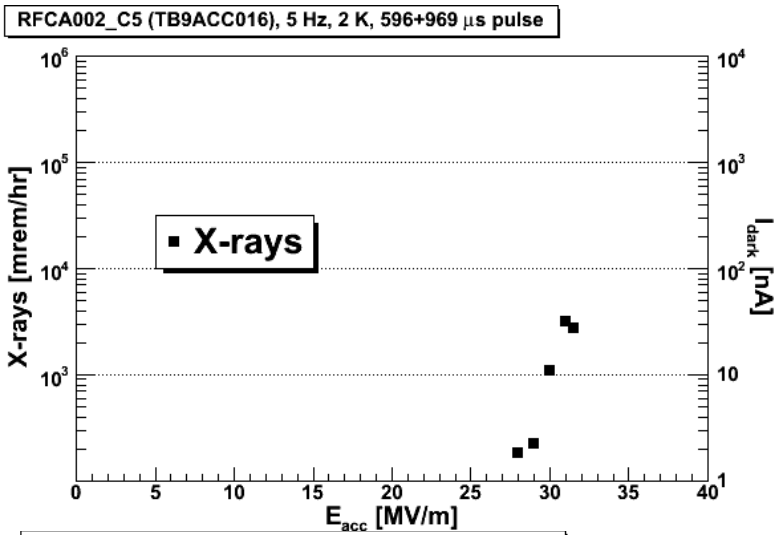


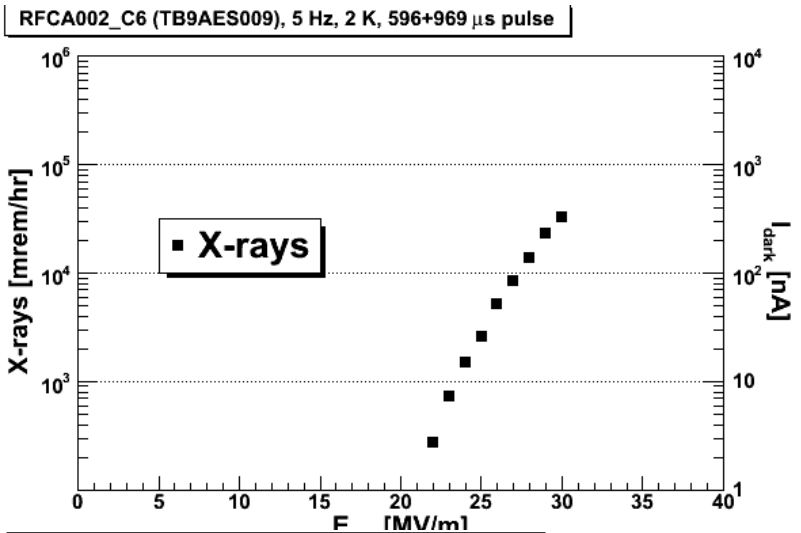


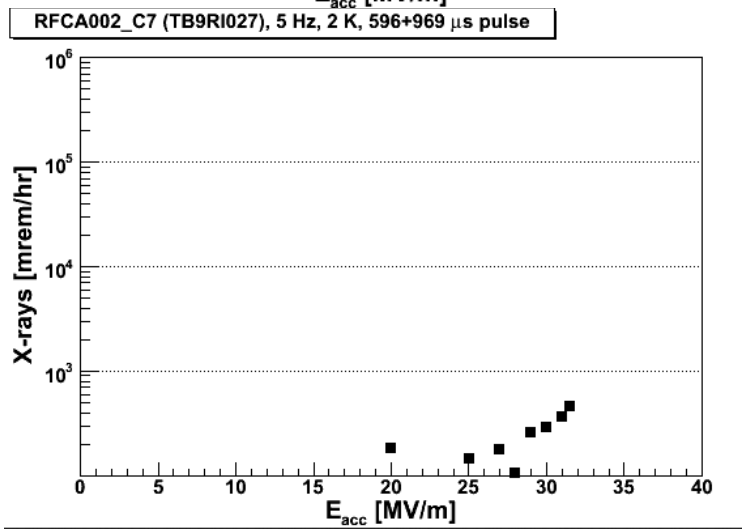
Threshold ≥ 20 MV/m

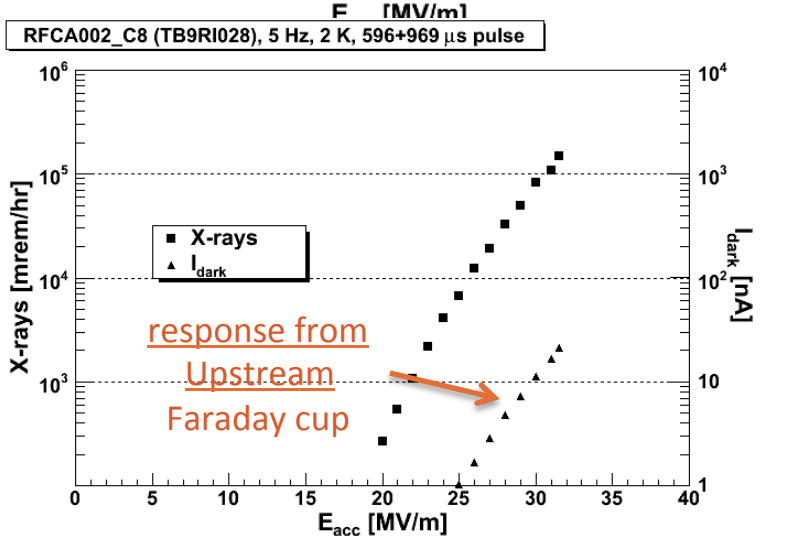
Dark Current/X-rays

courtesy Andy Hocker, TD



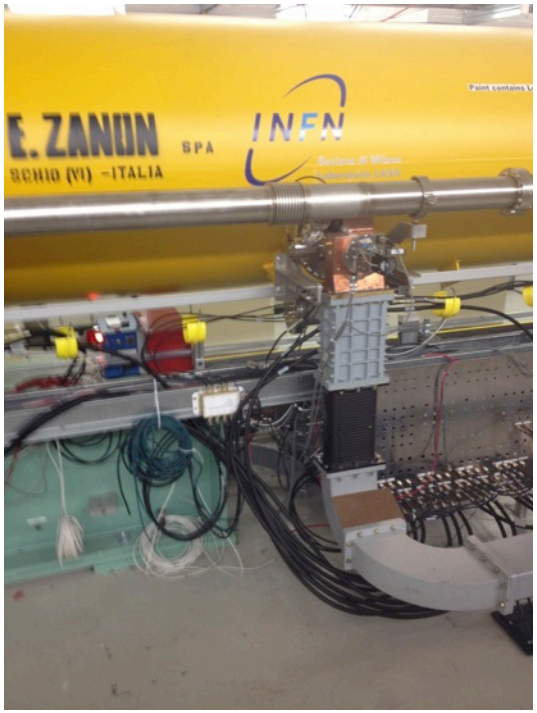


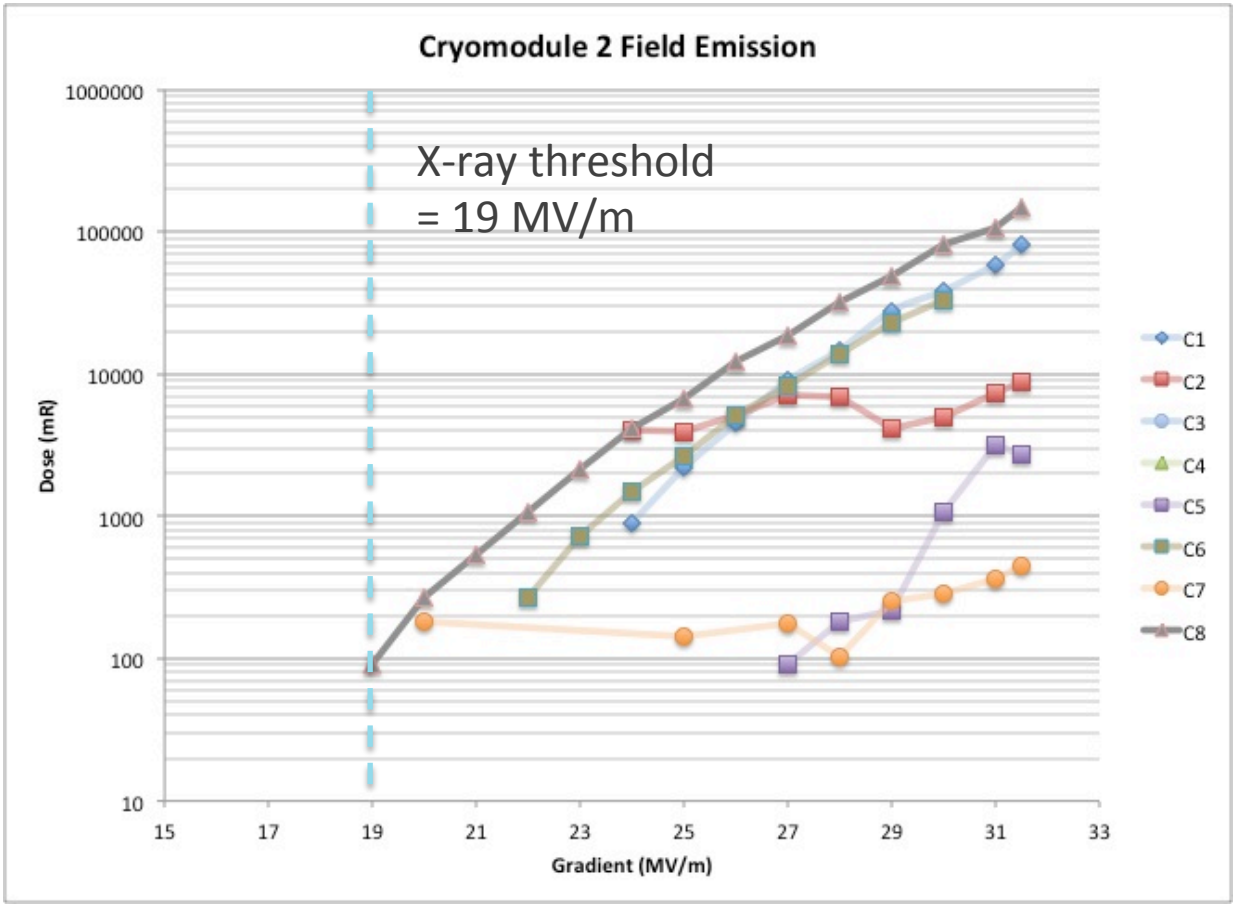




Threshold ≥ 20 MV/m

Dark Current/X-rays





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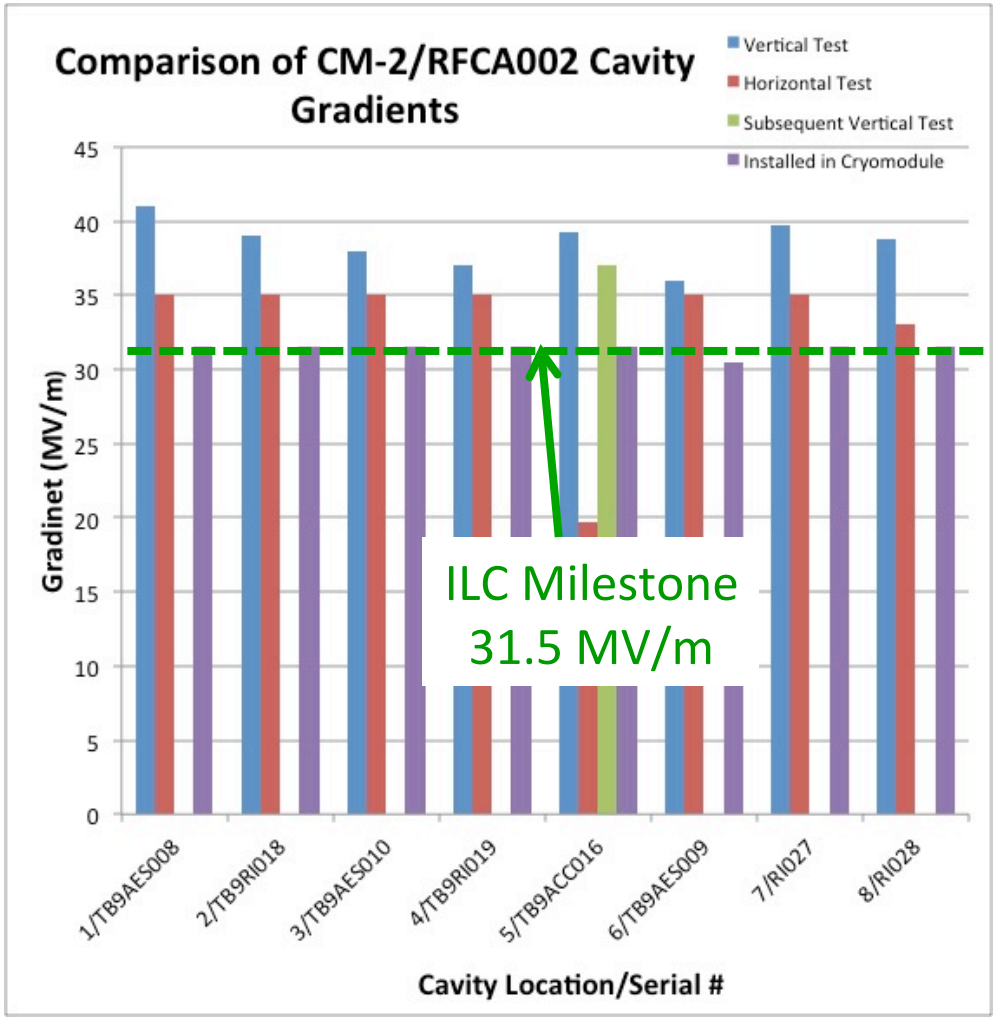
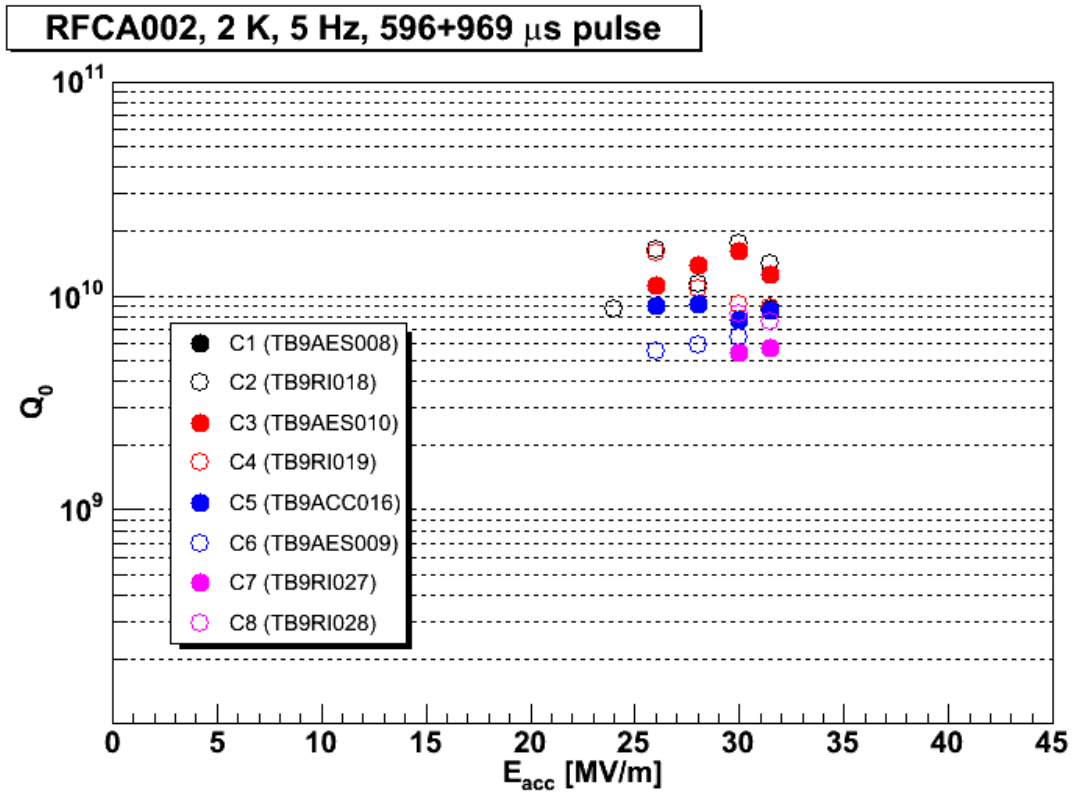
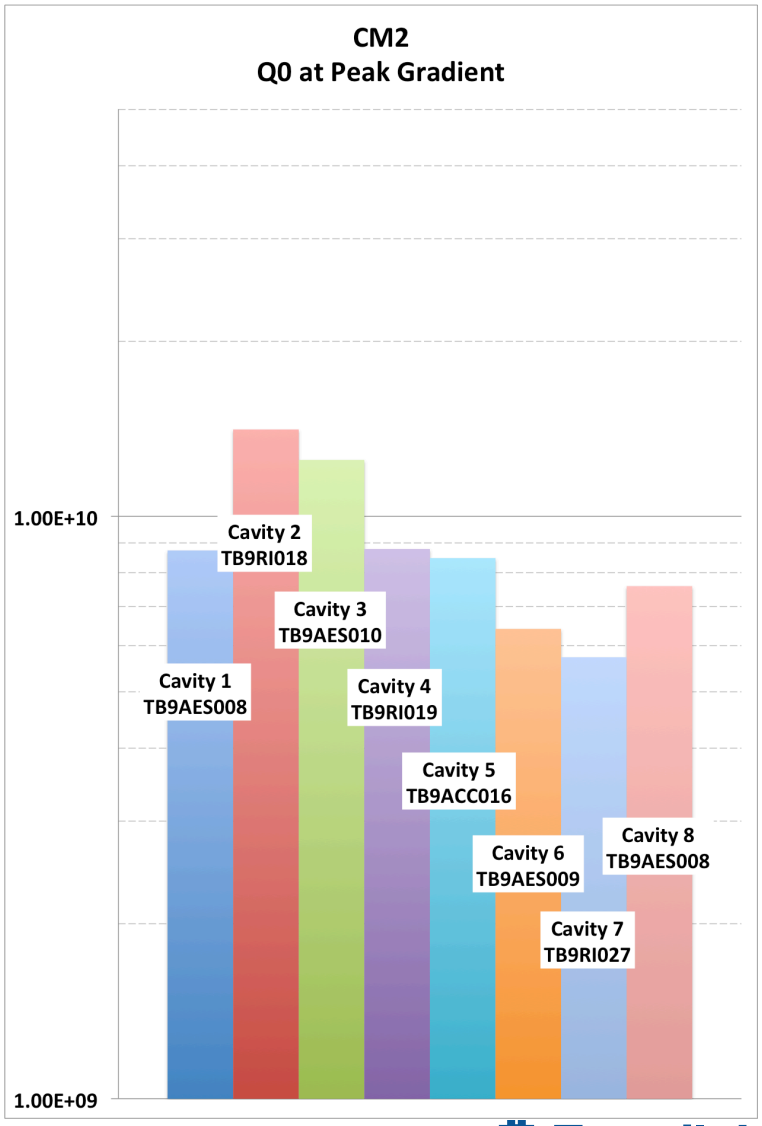
Performance to Date - Gradient



Performance to Date – Q_0



courtesy Andy Hocker, TD



Timeline

- Cryomodule installed in NML/ASTA – April 2013,
- Warm coupler conditioning (one cavity at a time) – 9 May to 18 June 2013
- Cooldown – 23 October to 11 November 2013
- Begin cold operation, Cavity 1 only – 13 November 2013
- Cavity 1 complete (13 November - 30 January)
- Cavity 2 complete (31 January - 15 February, 16 days)
- Cavity 3 complete (24 February – 4 March, 9 days)
- Cavity 4 complete (4 – 10 March, 6 days)
- Cavity 5 complete (18 - 26 March, 9 days)
- Cavity 6 complete (28 March - 3 April, 7 days)
- Cavity 7 complete (4 April – 7 May, mostly done by 8 April, coupler vacuum)
- Cavity 8 complete (23 May – 6 June) warm coupler vacuum issue

Cavity 8 Vacuum

- Warm coupler vacuum issues on cavity #8
  - the only significant hiccup

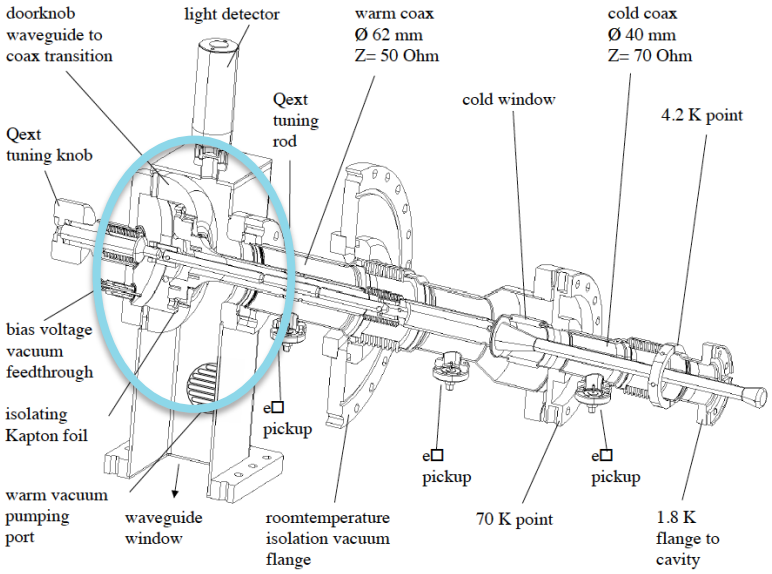
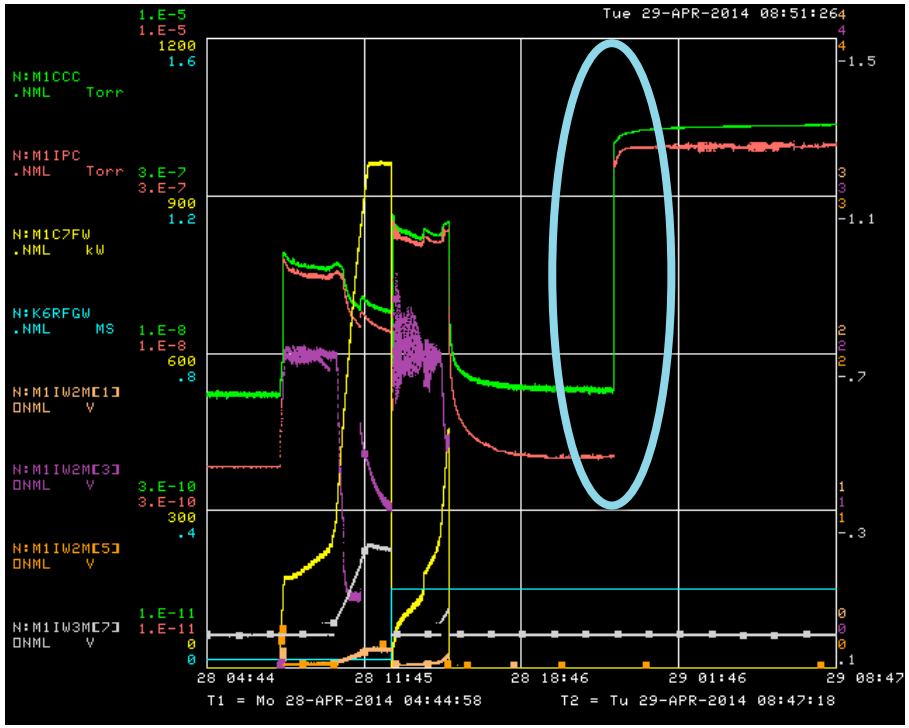
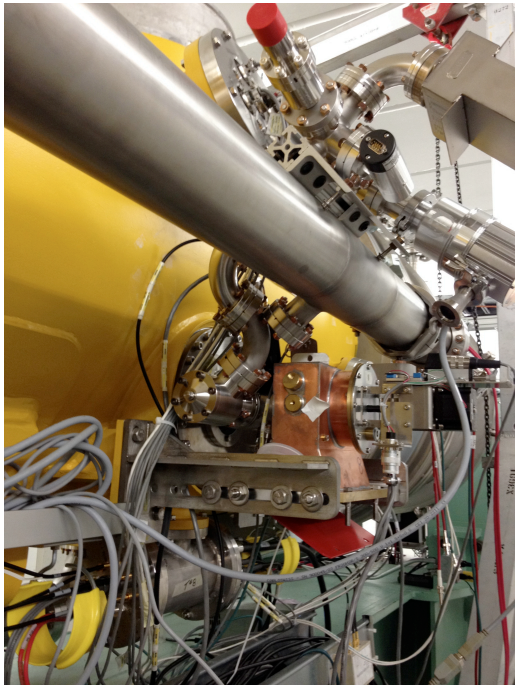


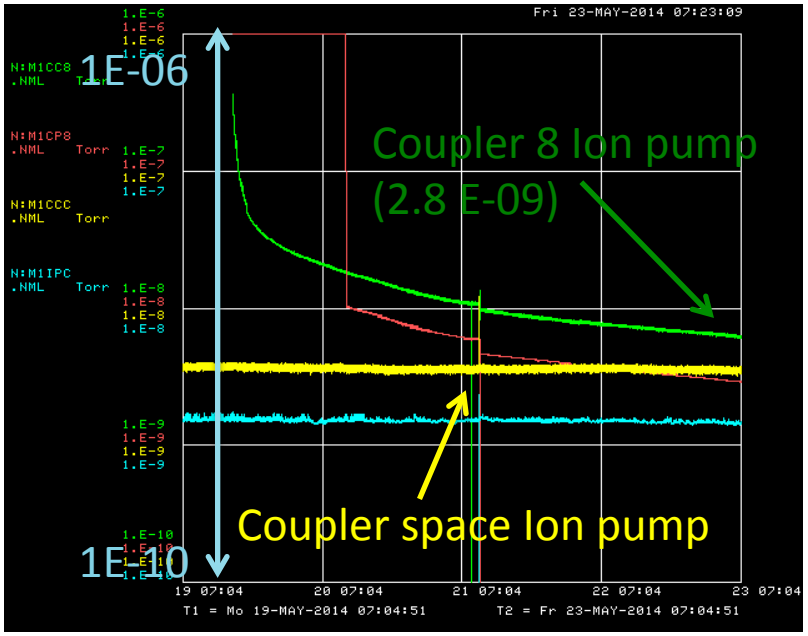
Fig. 1 The TTF2 coupler design has a wave guide window. The insulating Kapton foil is in the vacuum.



Cavity 8 Vacuum

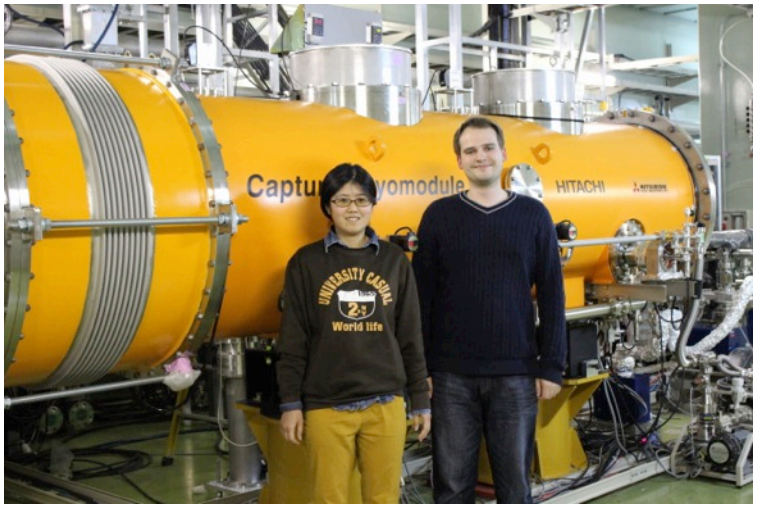
- Warm coupler vacuum issues on cavity #8
  - Unable to localize leak
  - Isolated C8 from coupler system and pumped independently with 20 l/s ion pump backed by a turbo
  - Success!





Students

- In addition to ongoing studies by Auralee Morin from CSU
- Visit in March by 2 PhD students from KEK
  - Ayaka Kuramot
    - supervised by Hitoshi Hayano
    - HOM spectra characterization
    - comparison with other Tesla style 9-cell cavities at DESY and KEK
  - Mathieu Omet
    - supervised by Shinichiro Michizono
    - extensive measurements of the klystron driving CM2
    - developed an algorithm in firmware to cancel the klystron nonlinearities in both amplitude and phase
  - Additional visitors welcome!



On the horizon

- Revisit selected cavities (8, 6, 1)
- Install waveguide distribution system
- Power all cavities together
- Additional studies
  - LLRF
  - LFDC
  - Long pulse
  - thermal cycling/Q_0
  - others as requested
- Beam in 2015

Summary

- CM2 cold commissioning since December
- 8/8 of the Cavities are now characterized
  - Average Gradient = 31.375 MV/m
- Estimated ~2 weeks/cavity, 1 week achievable
- Performance almost as hoped for so far
- Fewer problems than with CM1
- Full cryomodule testing in this summer
  - anxious for results!
- Welcome visitors and additional studies requests
- Collaborative effort by MANY people, especially TD & AD

Thank you for your attention