Fermilab

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CM-2 Status

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Accelerator: SRF Working Group

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Outline

- Introduction
- Current situation
- Single cavity results
- Unit results
- Issues and lessons
- Conclusions & summary

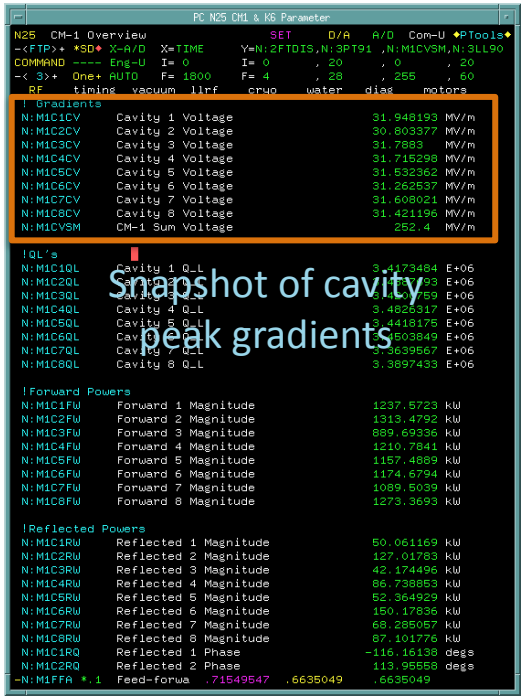
Introduction

- 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

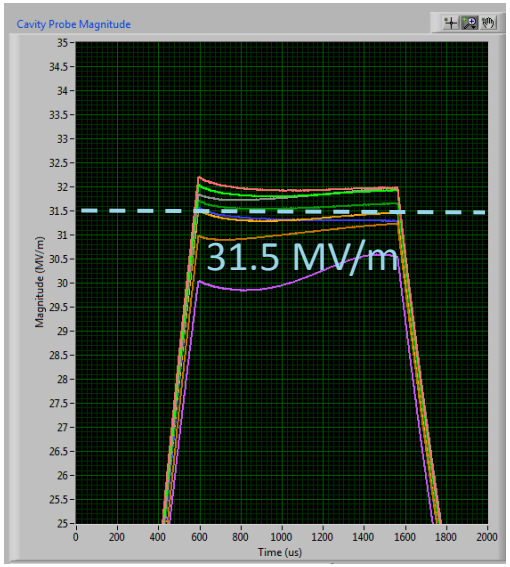

CM-2 installed in ASTA cave

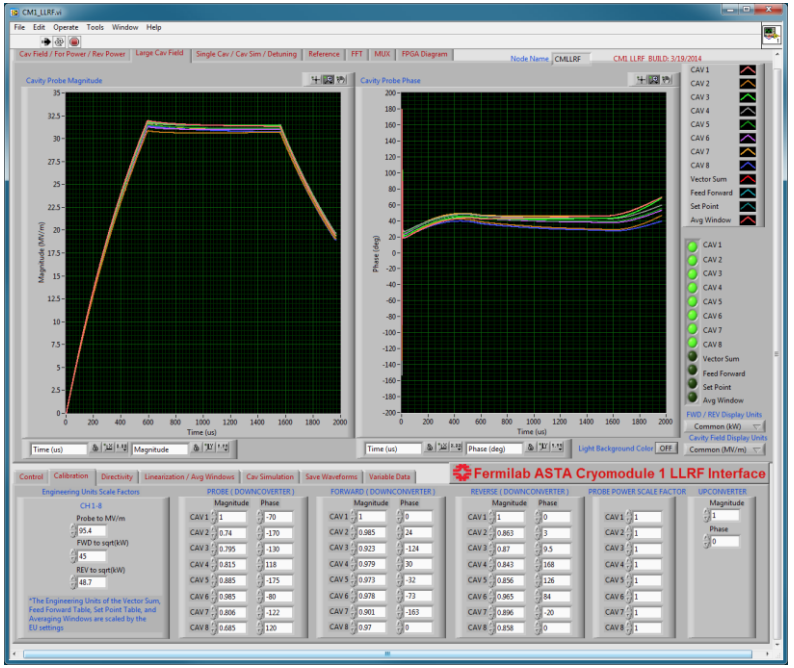
CM-2 Current situation

- CM-2 achieved an average cavity gradient of 31.5 MV/m this past Friday (3 October) with all 8 cavities powered simultaneously
- 1.6 millisecond pulse width, 5 Hz repetition rate
- Lorentz Force Detuning Compensation (LFDC) on and ‘adapting’
- Peak accelerating voltage = 252 MV



Snapshot of cavity peak gradients





CM2 Amplitude (MV/m, left) & Phase (right)

How did we get here - timeline

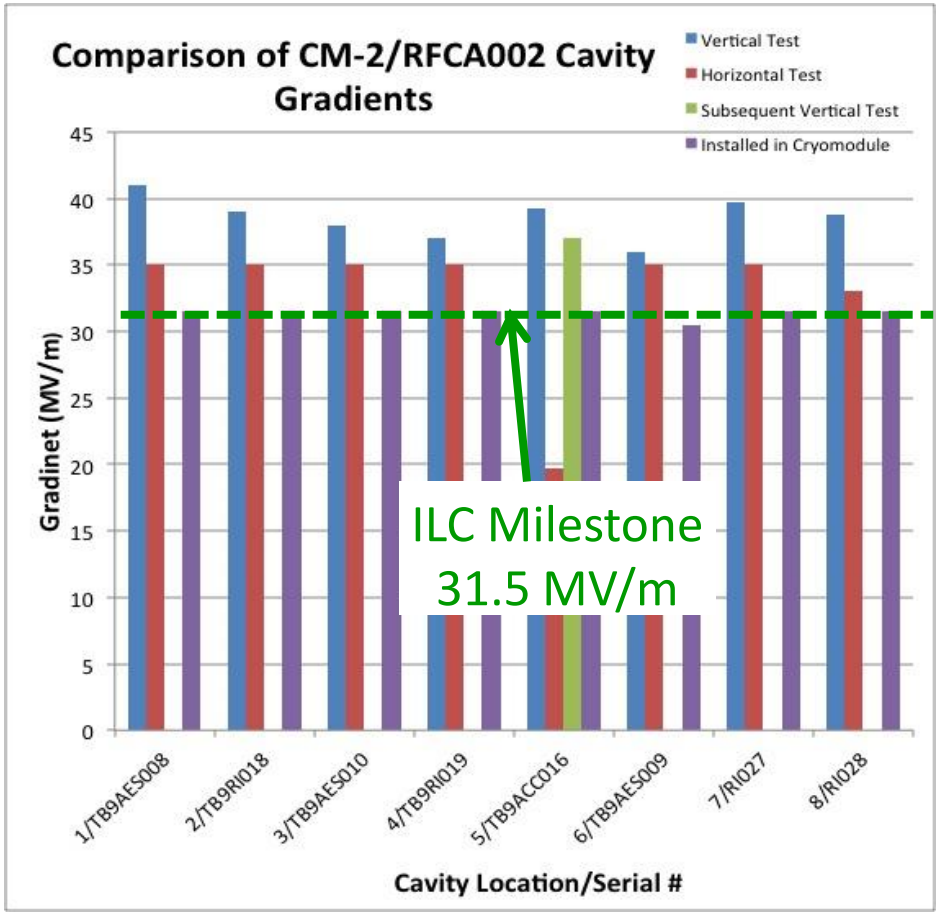
- Cryomodule installed in NML/ASTA – April 2013,
- Warm coupler conditioning (one cavity at a time) – 9 May to 18 June 2013
- Cooldown – 23 October to 11 November 2013
- Begin cold operation, Cavity 1 only – 13 November 2013
- Cavity 1 complete (13 November - 30 January)
- Cavity 2 complete (31 January - 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
- Revisit cavities 6 & 1 (1 -14 July)
- Cavity 1 – 7 unit test (25 July - 26 August)
- Revisit Cavity 8 warm coupler vacuum (26 August – 9 September)
- Complete unit, 8 cavities, test (9 September – present)

Single cavity results

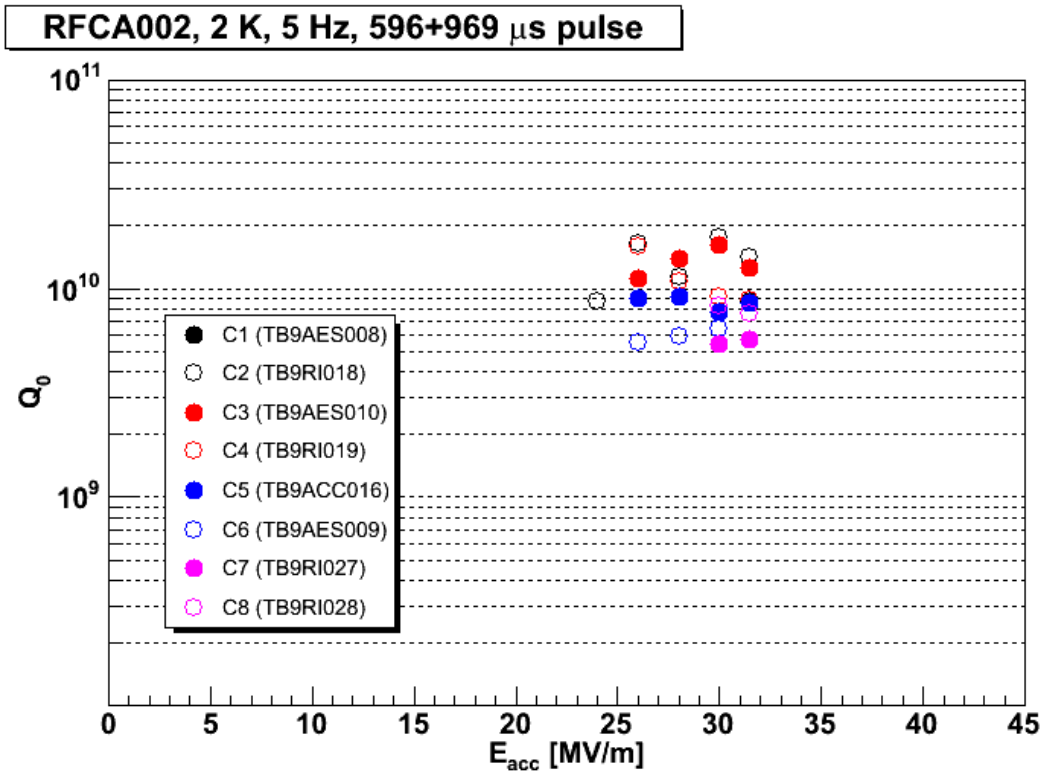
- Once cold, each cavity individually powered to determine performance characteristics
  - Tune cavity to resonance
  - Map out and set Q_L
  - System calibrations, calculate gradient, k
  - On-resonance conditioning
  - Determine peak performance
  - Final (high power) LLRF calibration
  - Lorentz Force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

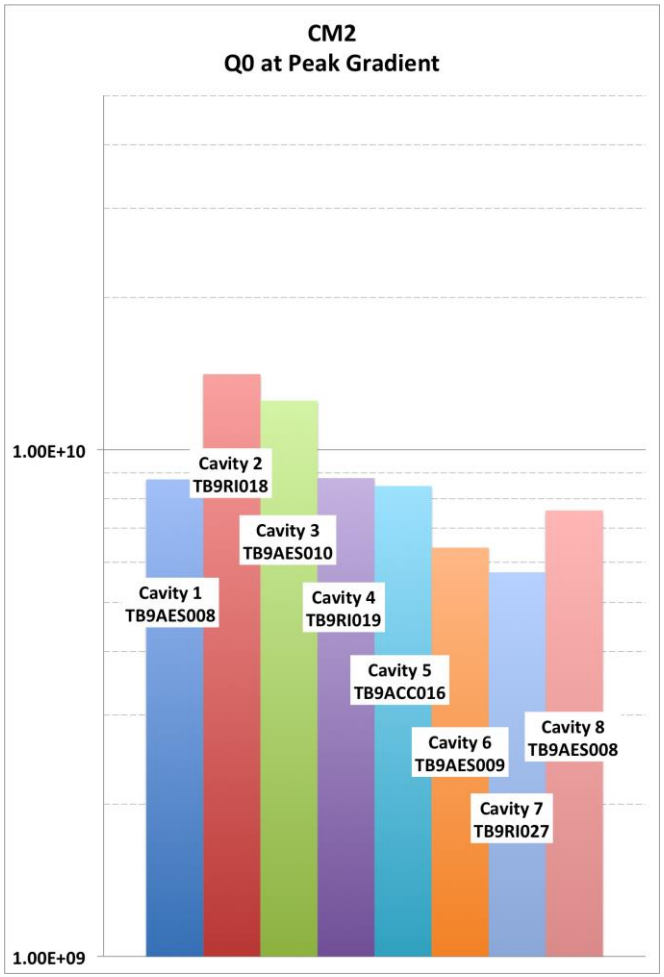
Single cavity results

- Operating conditions
  - 2 Kelvin (23 Torr)
  - Pulsed operation
  - 1.6 ms pulse
    - 590 μs fill + 969 μs flattop
  - 5 Hz repetition rate
  - Q_L set to 3.5 E6, variable coupling
  - LFDC active
- Results
  - 7/8 cavities achieve 31.5 MV/m (administrative limit)
  - Cavity #6 quenches at 30.5 MV/m



Single cavity results – DHL/Q_0

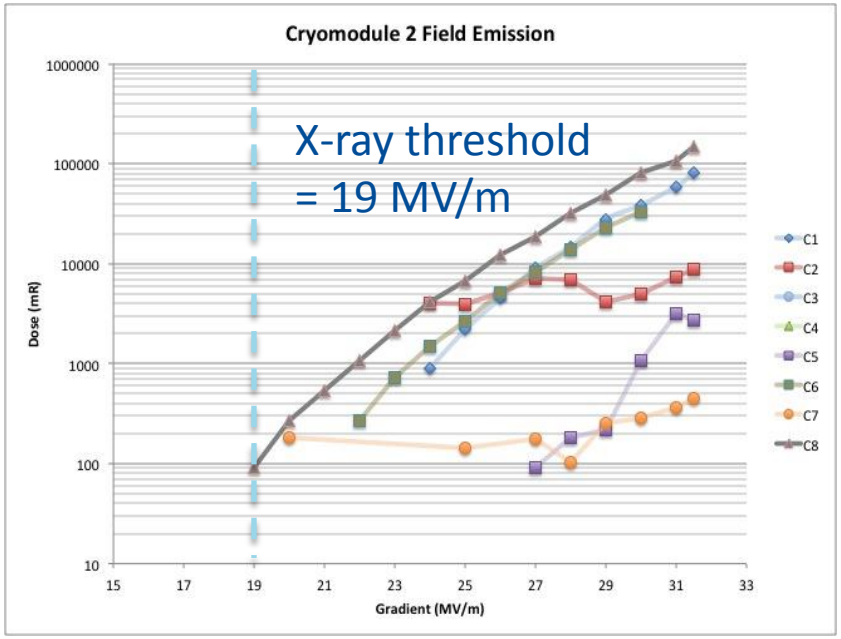




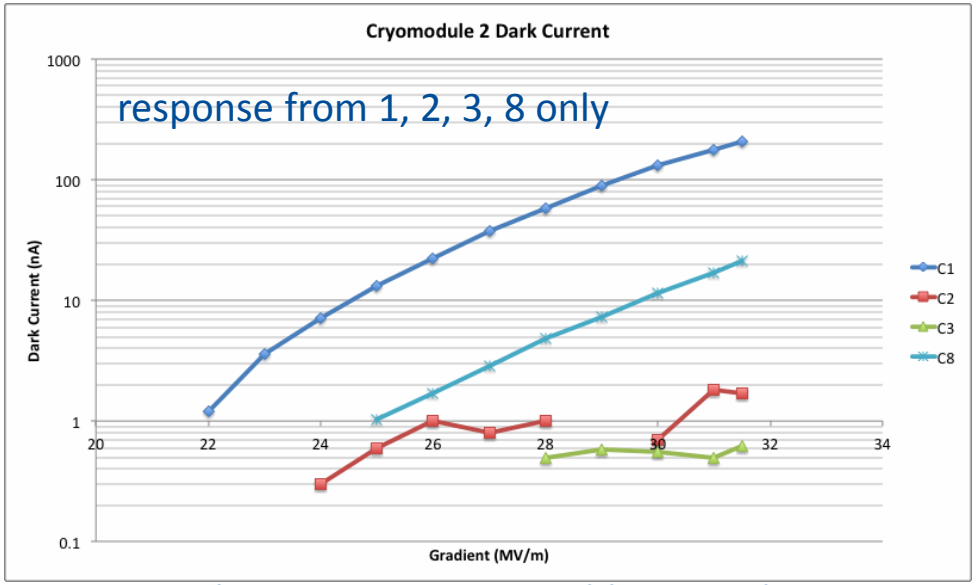
Q_0 vs. gradient

courtesy Andy Hocker, TD

Single cavity – field emission, dark current



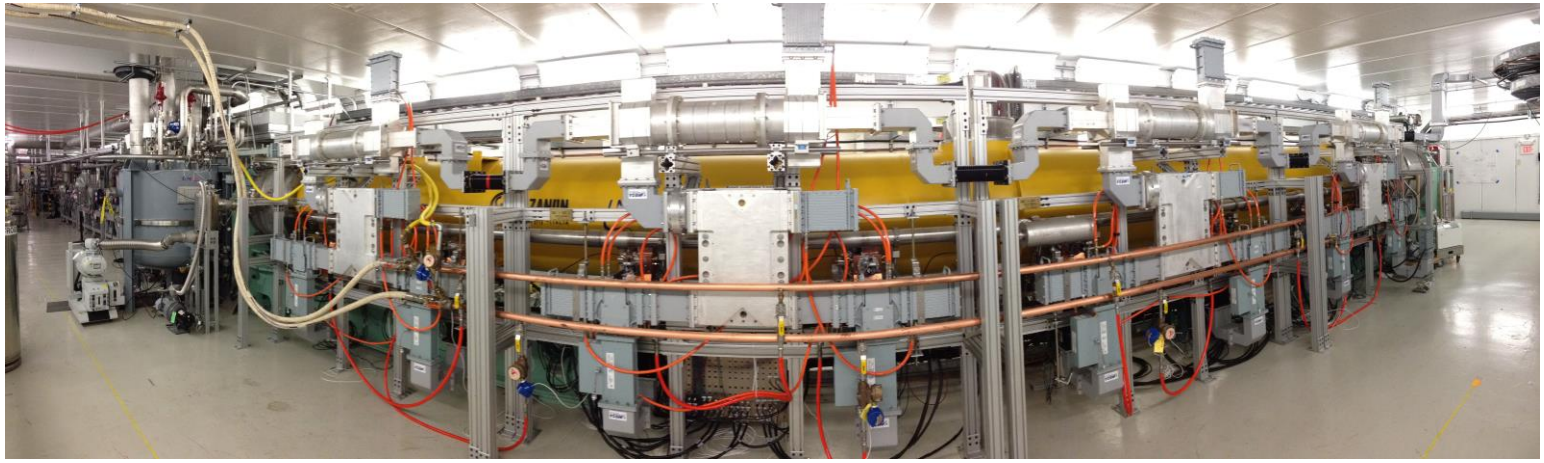
Field Emission measured by 'chipmunk' placed below cavity under test



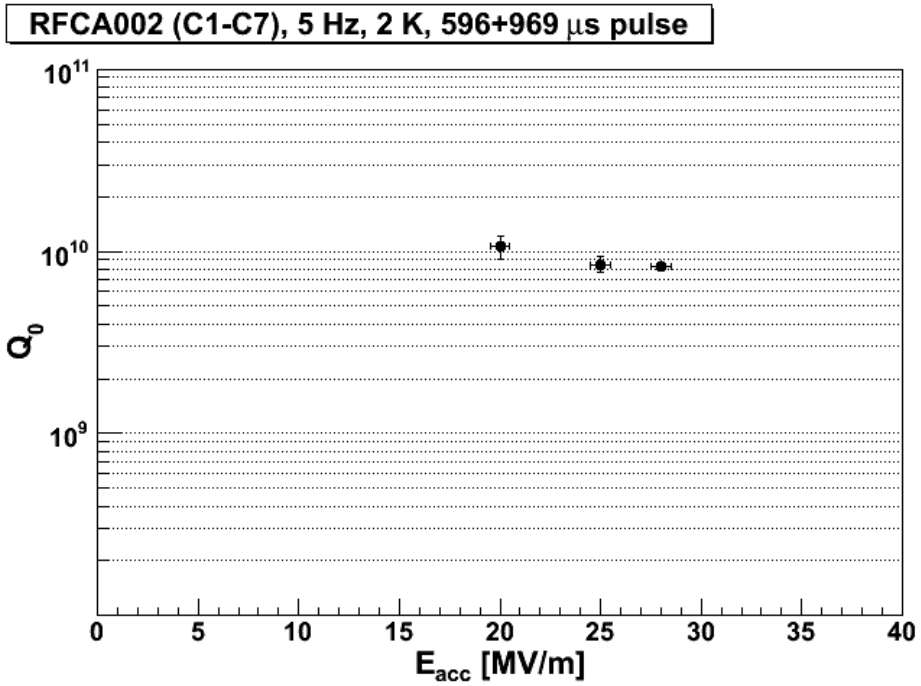
Dark current measured by Faraday cups at end end of cryomodule

Unit results

- Warm coupler vacuum issues prompted with cavity #8 prompted initial unit test powering only 1-7 initially
- Leak checking, nitrogen purge, luck? finally allowed full unit operation
- 5 days of coupler conditioning was required before high power testing was possible – cavity 8 vacuum and warm window field emission
- Peak gradient limited by cavity #6 (hard) quench (30.5 – 31 MV/m)

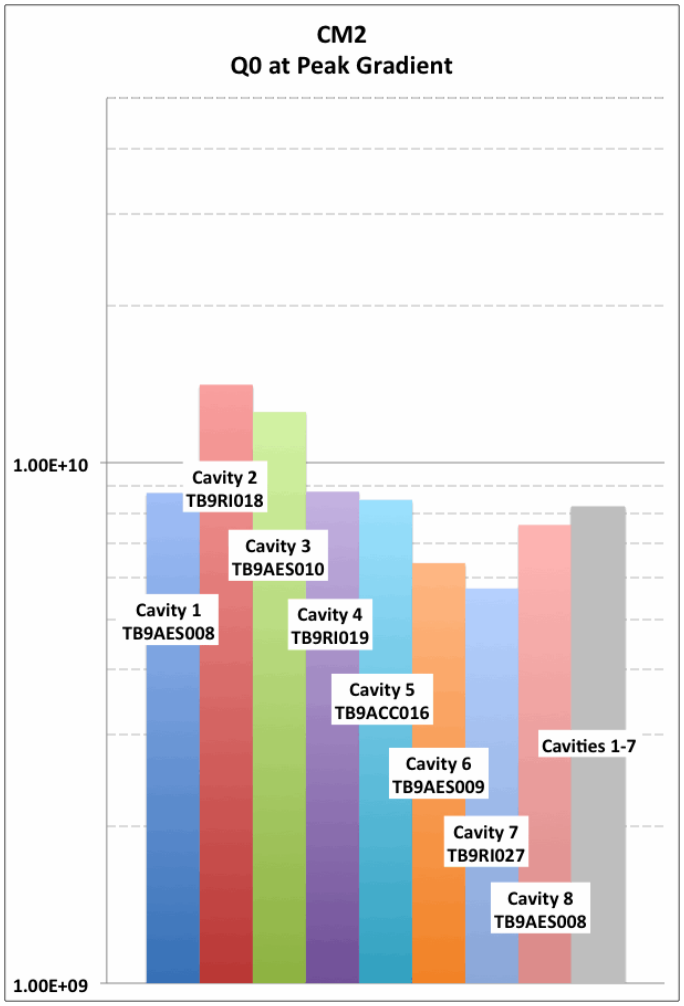


Unit test – DHL/Q_0



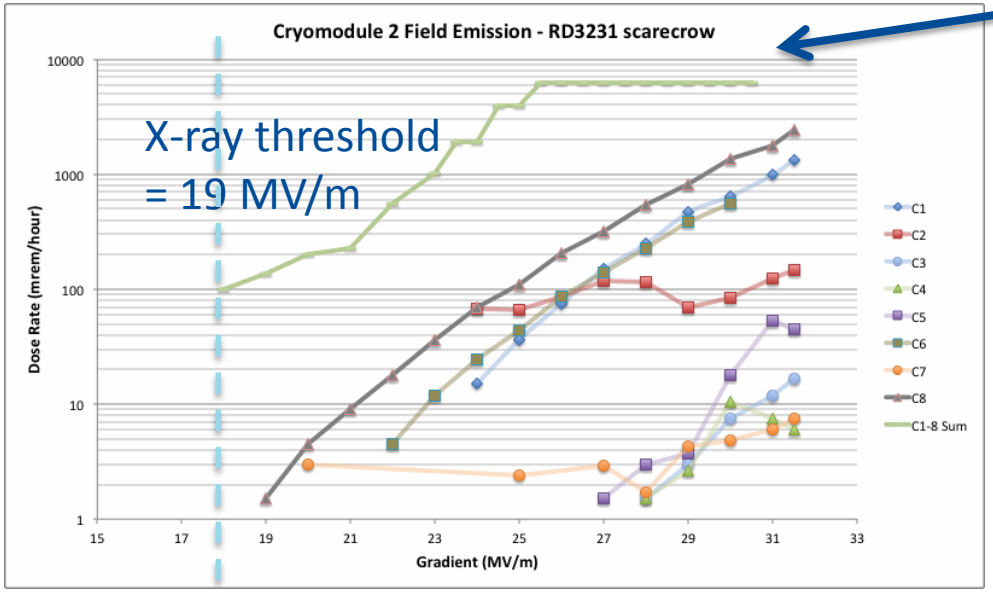
Q_0 for cavities 1-7 powered together
(1-8 results under analysis)

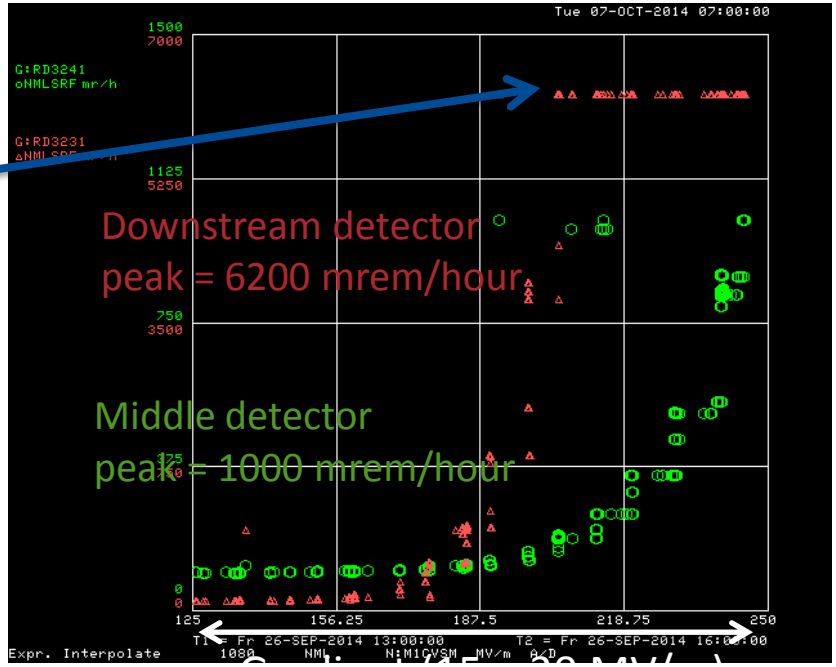
courtesy Andy Hocker, TD



Unit test – field emission (scarecrows)

- No response below ~19 MV/m from any cavity
- Varied results from cavity to cavity
- More response from end detector (~X5)
- Saturation (needs investigating)

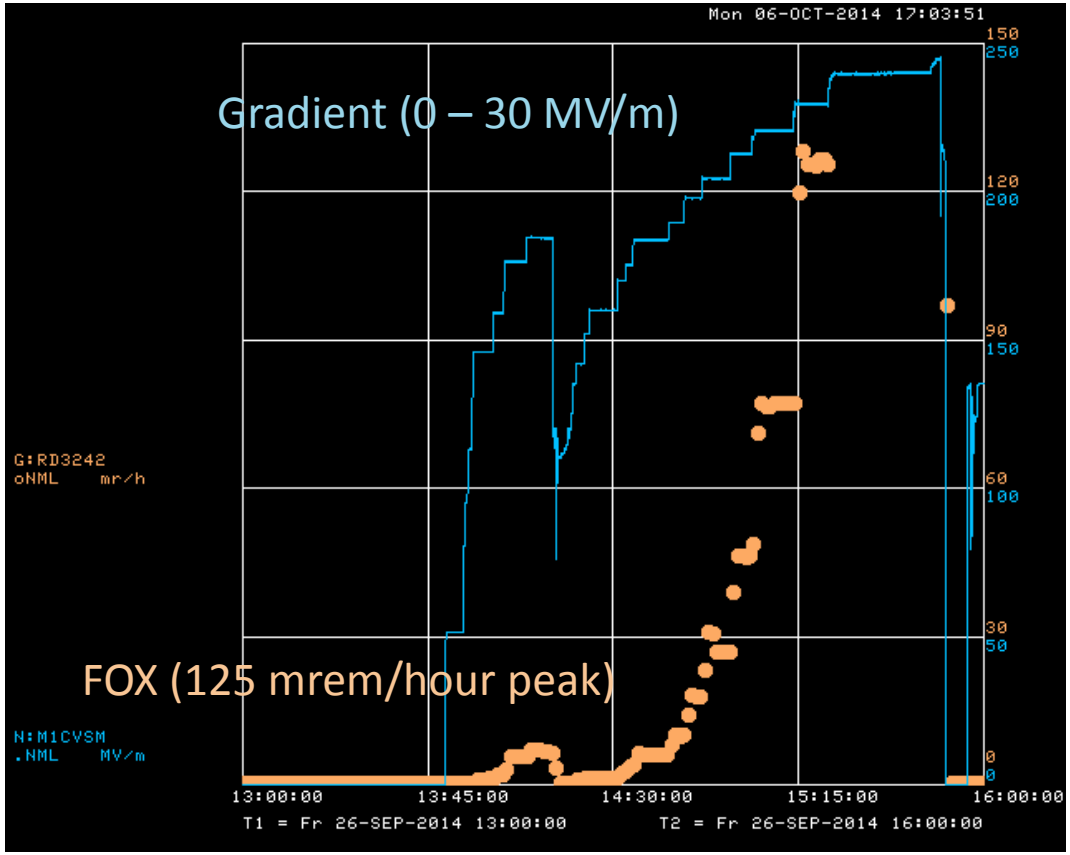




Unit test measurements

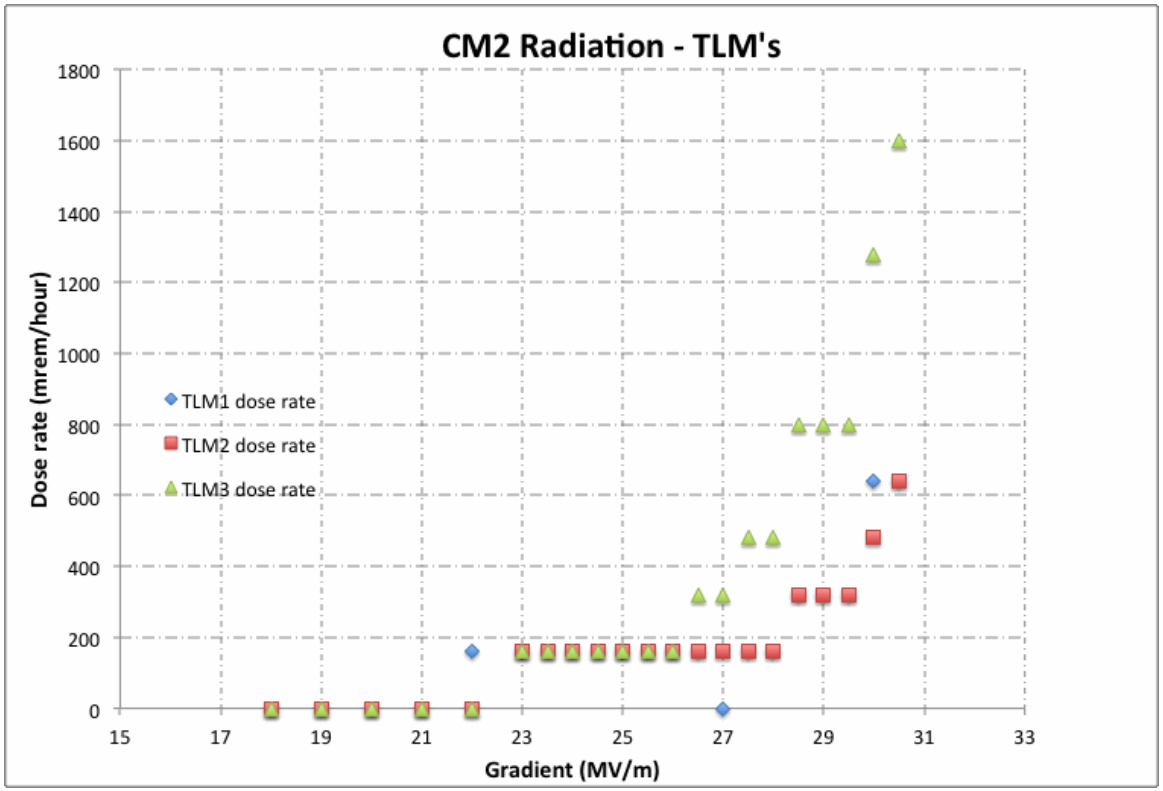
Unit test – field emission (FOX detector)

- Fermilab detector (propane-filled ion chamber) designed to be more sensitive to x-rays
- Placed at middle of cryomodule
- More analysis needed, correlate with scarecrow



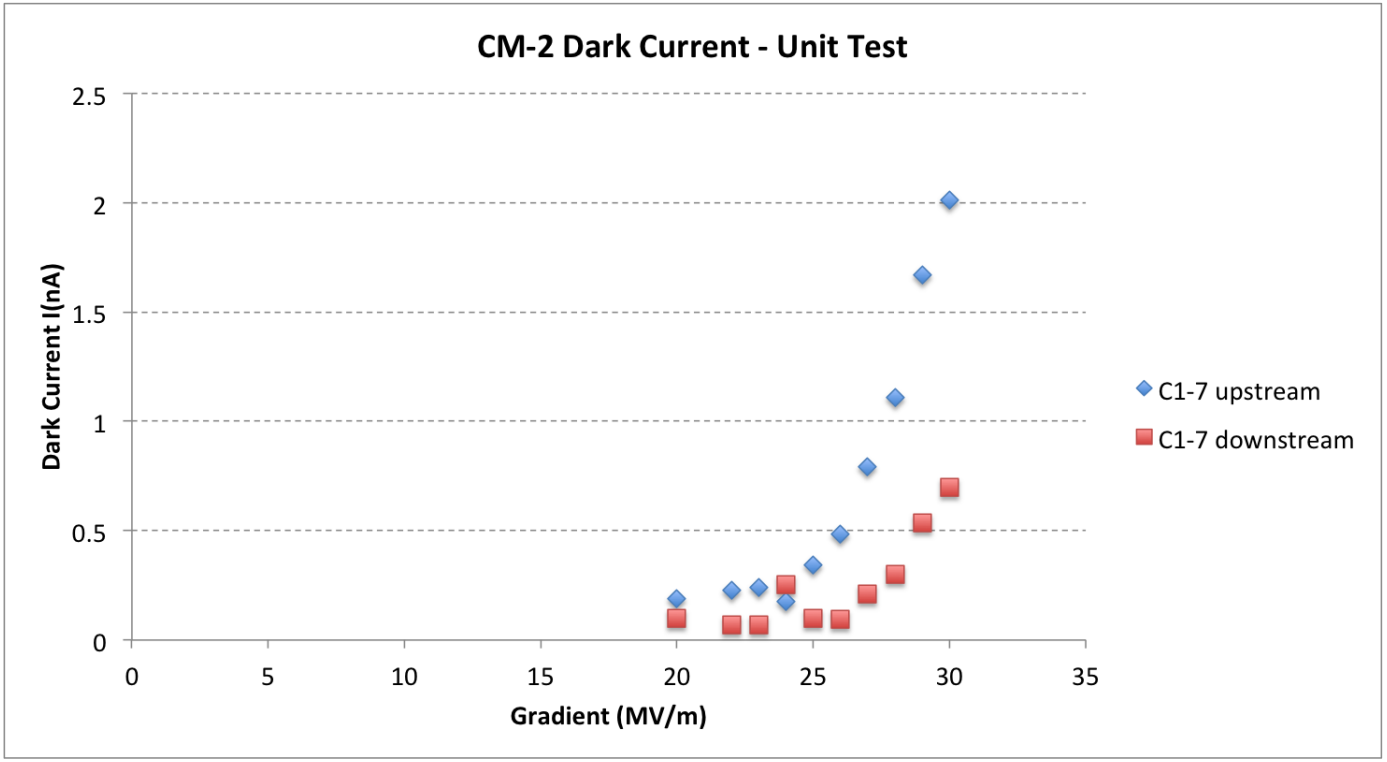
Unit test – field emission (TLM's)

- TLM = Total Loss Monitor
  - proposed alternate detector to Fermilab 'chipmunk' ion chamber
  - $ArCO_2$ filled heliax
  - length at user discretion
  - 4 installed under CM2
  - 2nd two read out in sum
  - 1 cpm ~ 160 mrem/hour



Unit test – dark current

- No response < 20 MV/m
- Greatest response at upstream end



Short term plans

- Operate LLRF in closed loop – only limited work on this so far
- Ongoing LFDC investigations
- Cavity 6 coupler temperature – can interlock limit be raised (-98 C)?
- Dark current energy spectrum
- Internal radiation detectors
- Long-term (reliability) testing
- Adjust VTO's to lower cavity 6 power, determine peak gradients
- Room temperature thermal cycle
  - repair/replace warm coupler vacuum
  - investigate Q0
  - cryogenics & electrical maintenance

Issues & Lessons

- Reliability ok
  - 3+ days continuous operation at moderate gradient
- Cavity 8 warm coupler vacuum
- Cavity 6 cold window temperature
  - limits high gradient operation to ~ 2 hours
- Radiation detection
  - TLM's
  - Commission & investigate detectors installed within CM-2
- Issues not as numerous as encountered with CM1
  - failed slow tuner
  - failed piezo
  - 3 cavities with 'soft quench' limits

Conclusions & Summary

- This is a team accomplishment
- Thank you and congratulations to our many international partners!

thank you for your attention

Back up slides

Cavity 8 warm coupler vacuum