

# **Fermilab Cryomodule-1 Status**

E. Harms, Fermilab

*on behalf of the entire CM-1 team*

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# Outline



- **Recent (past 12 months) Milestones**
- **Activities to Date**
- **Current Activities**
- **Future Plans**
- **Summary**

# Milestones in Past Year



- **22 January 2010: CM-1 moved into final position and aligned**
- **23 February 2010: Warm side of Couplers under vacuum**
- **Cryogenic piping connections**
- **11 June 2010: permission to initiate RF commissioning and warm coupler conditioning**
- **RF/Klystron commissioning**
- **2 August 2010: Warm coupler conditioning begins, one cavity at a time, beginning with #8**
- **16 August 2010: Cavity #8 conditioning complete (14 days)**
- **26 August 2010: Cavity #7 conditioning complete (10 days)**
- **2 September 2010: Cavity #6 conditioning complete (8 days)**
- **17 September 2010: Cavity #5 conditioning complete (15 days)**
- **22 September 2010: Cavity #4 conditioning complete (6 days)**
- **27 September 2010: Cavity #3 conditioning complete (6 days)**
- **30 September 2010: Cavity #2 conditioning complete (4 days)**
- **3 October 2010: Cavity #1 conditioning complete (4 days)**

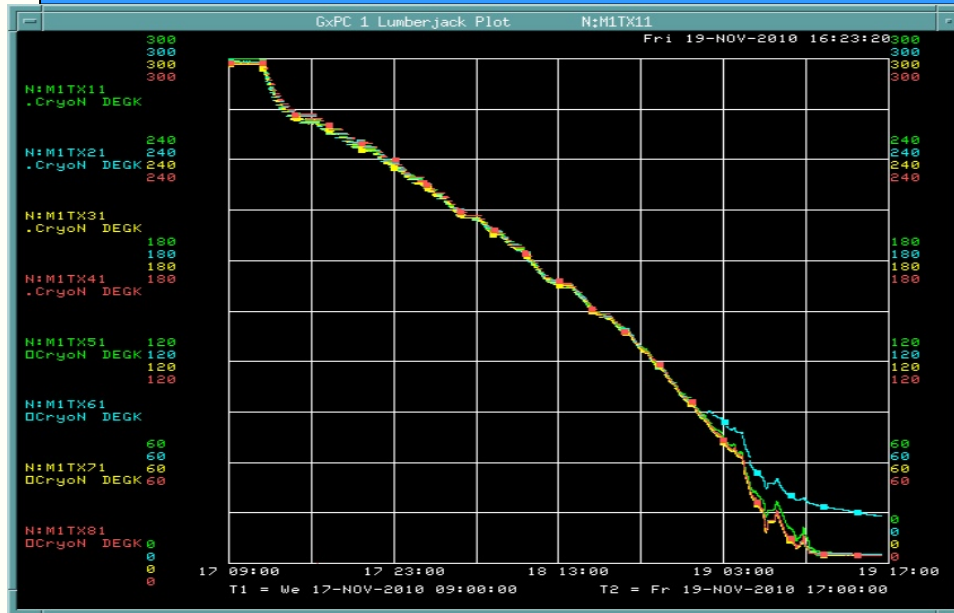


# Recent Milestones - 2

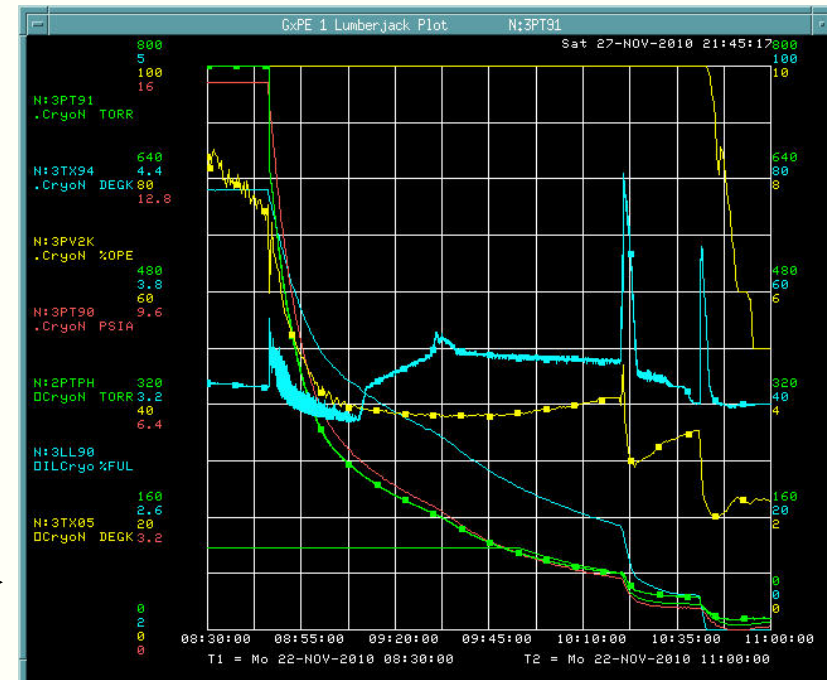


- **12 November 2010: Insulating vacuum space leak tight and pumped down**
- **23 February 2010: Warm side of Couplers under vacuum**
- **17 November 2010: Cool down begins**
- **19 November 2010: Cool down to 4.5 Kelvin complete**
- **22 November 2010: At 2 Kelvin**
- **10 December 2010: Permission to initiate cold RF operation**
- **17 December 2010: Cold coupler conditioning begins, one cavity at a time, beginning with #1 (Z89), first RF into CM-1 at Fermilab**
- **1 February 2011: Begin powering Cavity #8 (S33)**

# First Cool-down



Cool down to 4.5 Kelvin  
(2+ days)



Cool down to 2 Kelvin  
(~2 hours)

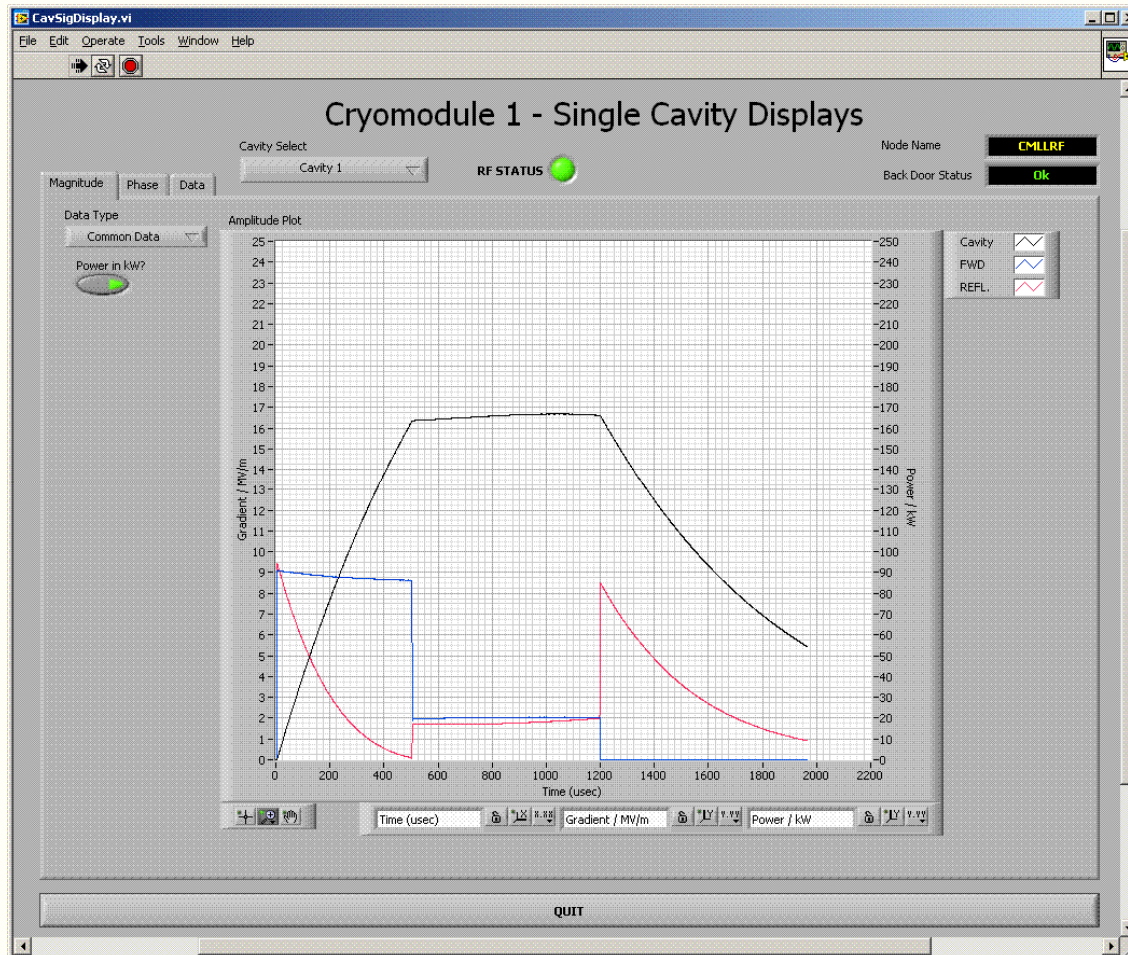


# Cavity #1 Performance



- Determination of Cavity gradient limit: *23-24 MV/m*, consistent with Chechia tests
- Q adjusted to  $3E6$
- RF signals calibrated
- Cold coupler conditioning per DESY recipe
- Operation with LLRF closed loop
- Lorentz Force Detuning Compensation demonstration
- Fast Thermometry
- HOM signals seen
- Dark current detected
- Interesting microphonics data
- Cryo Heat Load not as expected
- Large Q drop vs. gradient

# Cavity #1/Z89 Performance





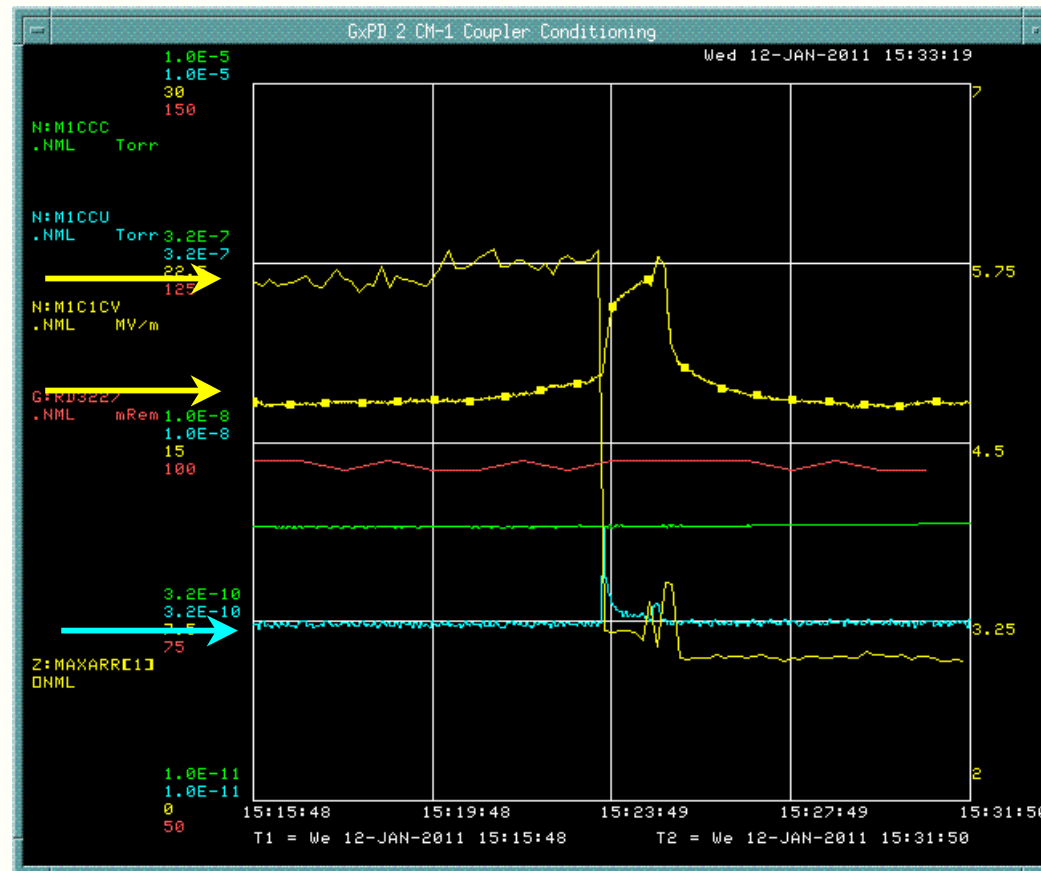
# Cavity #1/Z89 Performance



Gradient (22 MV/m)

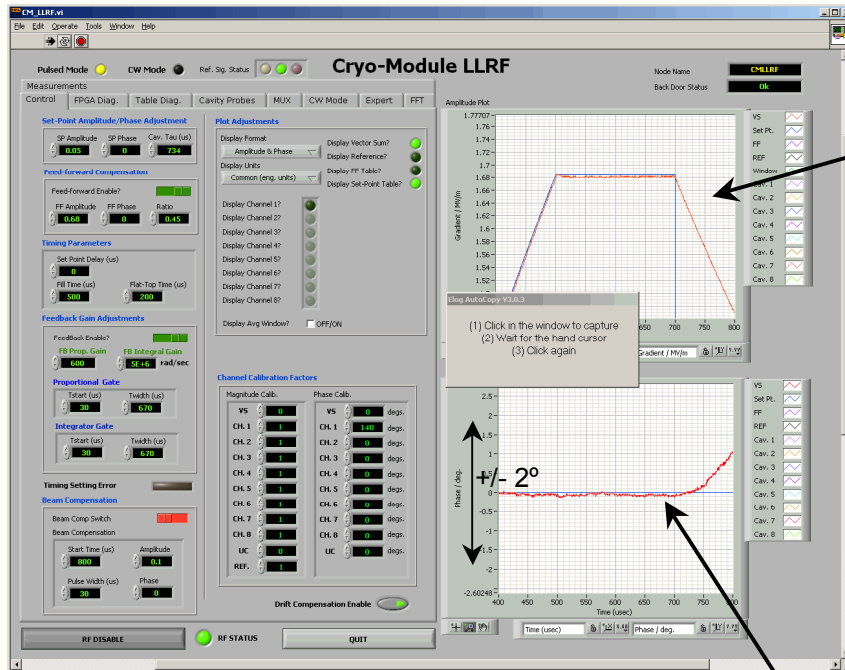
HOM temperature

Cavity vacuum



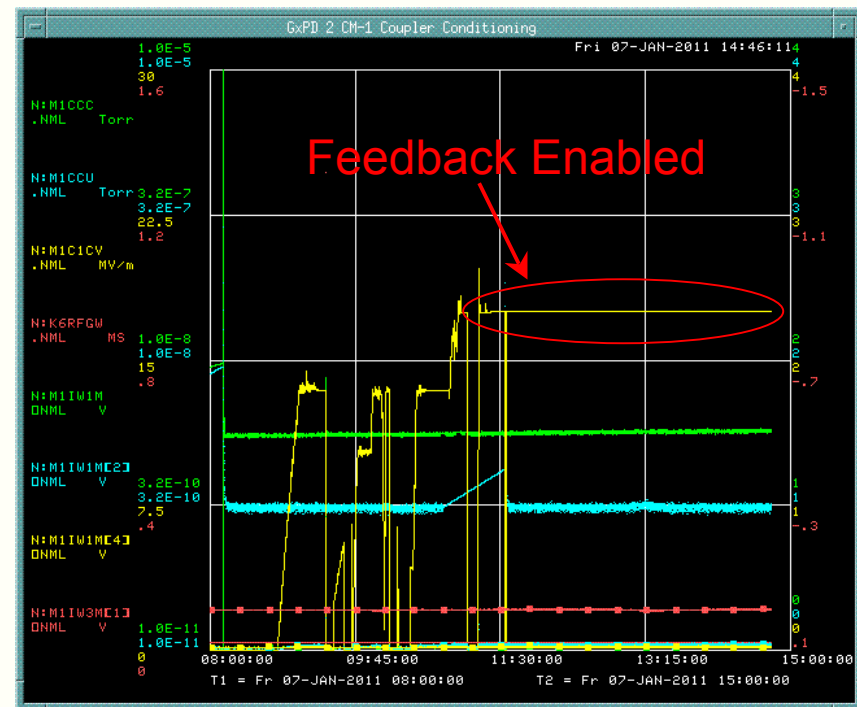
Fast Thermometry response during a possible quench

# Cavity #1/Z89 Performance



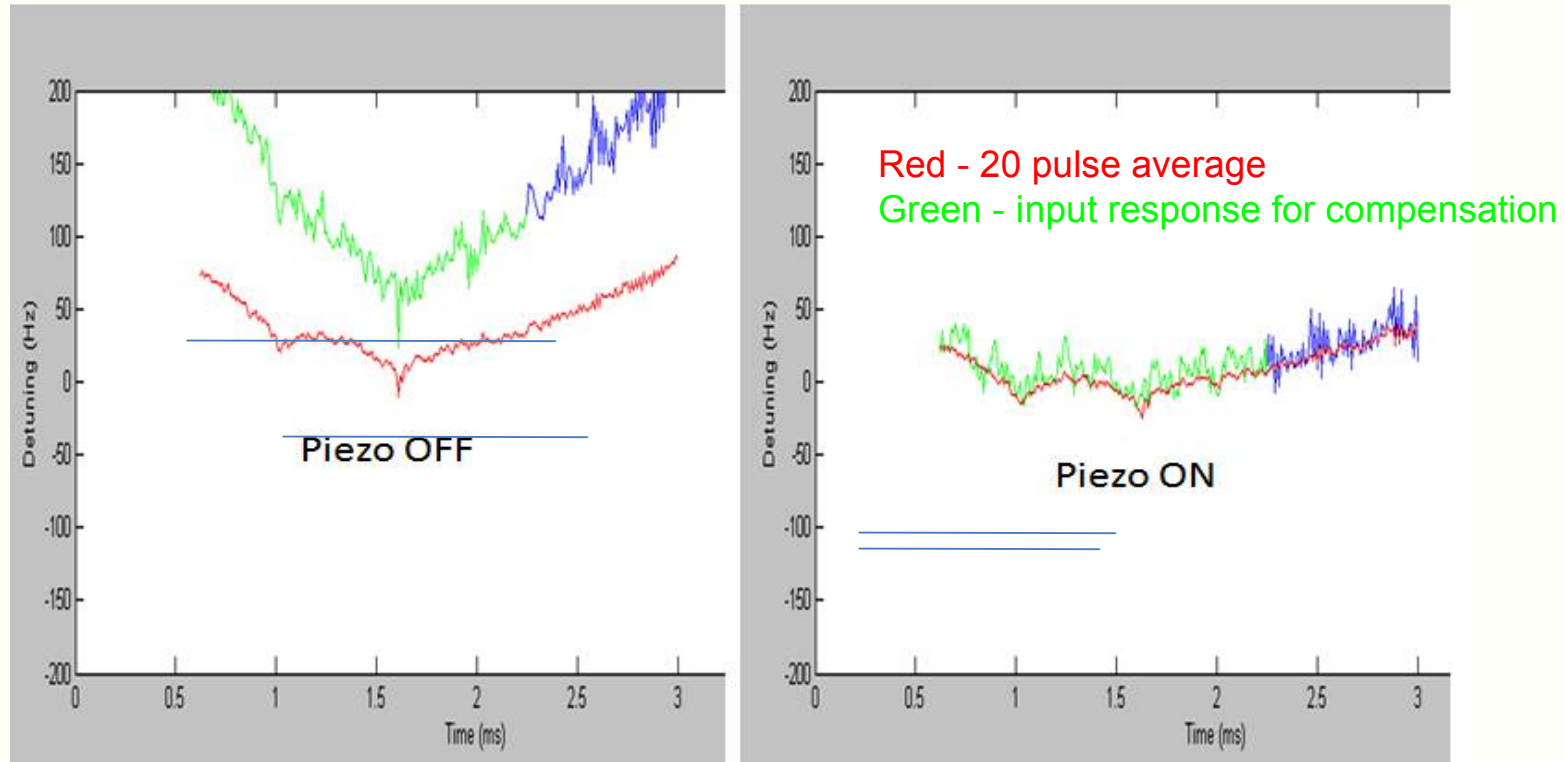
Amplitude

Phase



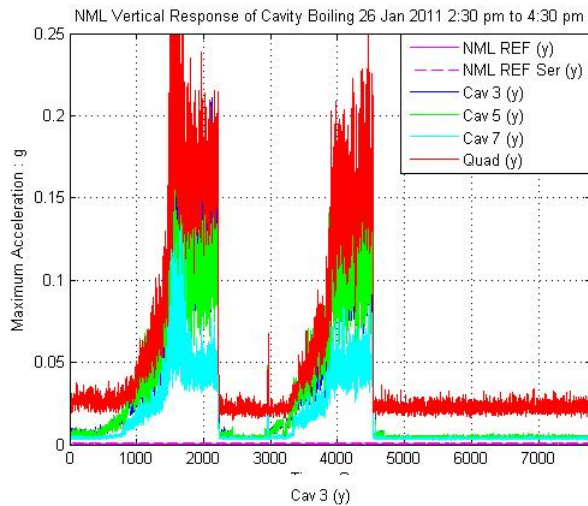
Low Level RF loops ON and Tuned

# Cavity #1/Z89 Performance

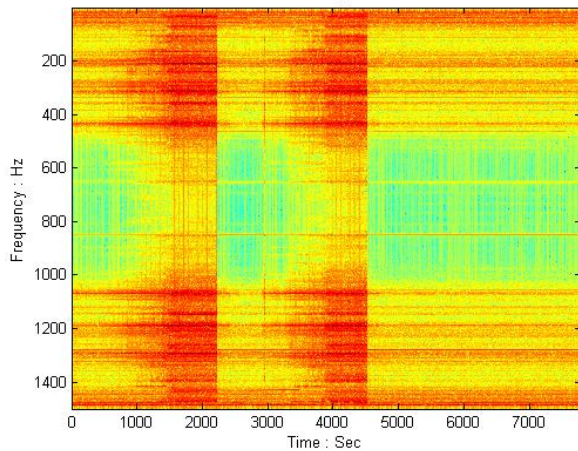
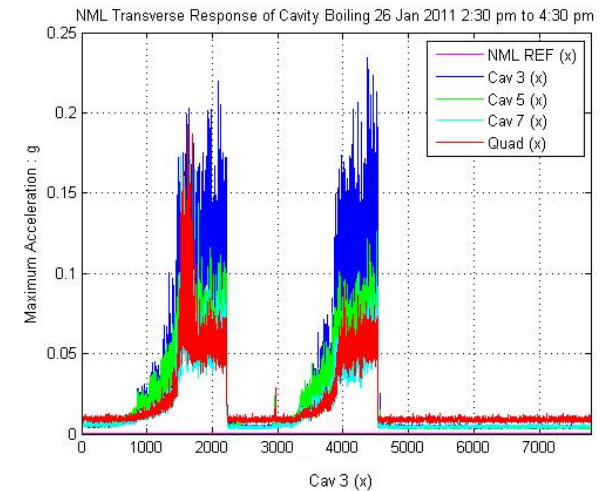


Cavity #1 (at 15MV/m)  
LS LFD Compensation Algorithm  
From 75Hz to 20Hz  
*Courtesy of Warren Schappert/Yuriy Pischalnikov*

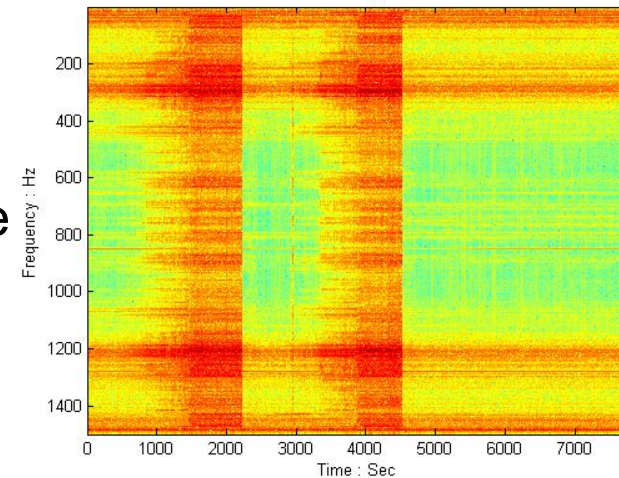
# Cavity #1/Z89 Performance



Displacements

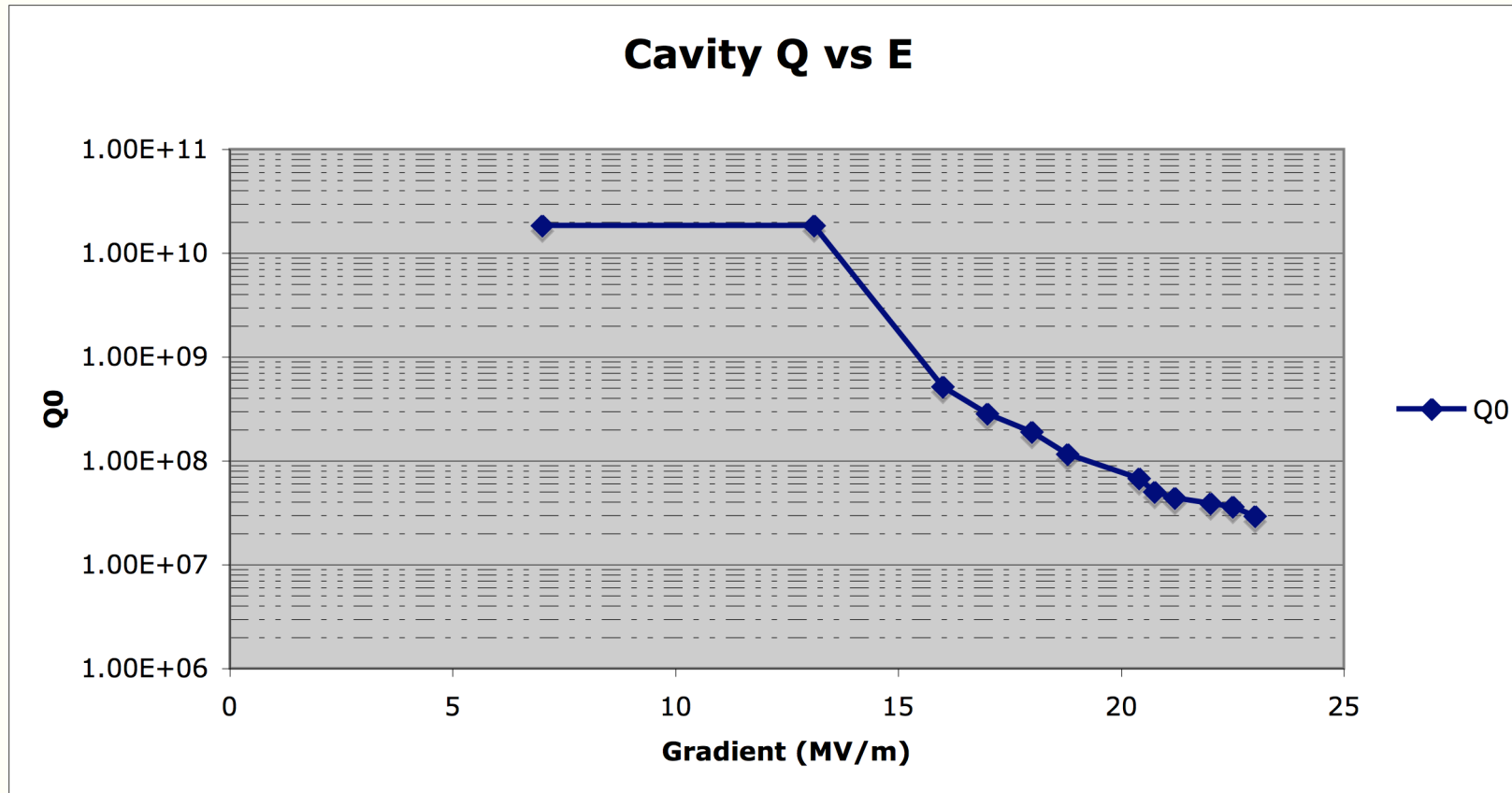


Frequency Response



Microphonics - *courtesy of Mike McGee*

# Cavity #1/Z89 Performance



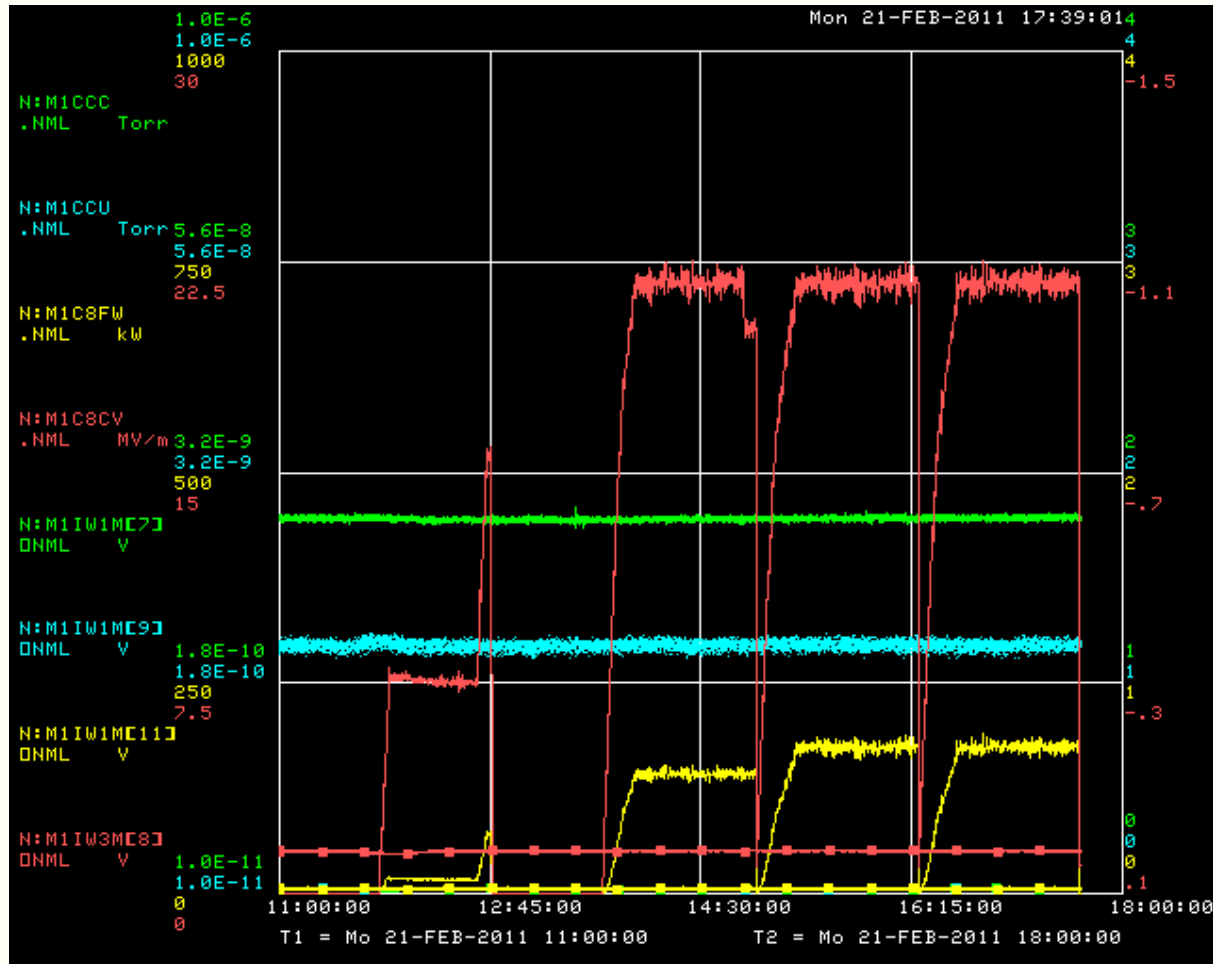
Calculated  $Q_0$  vs. E - NOT a direct measurement!

# Cavity #8/S33 Performance

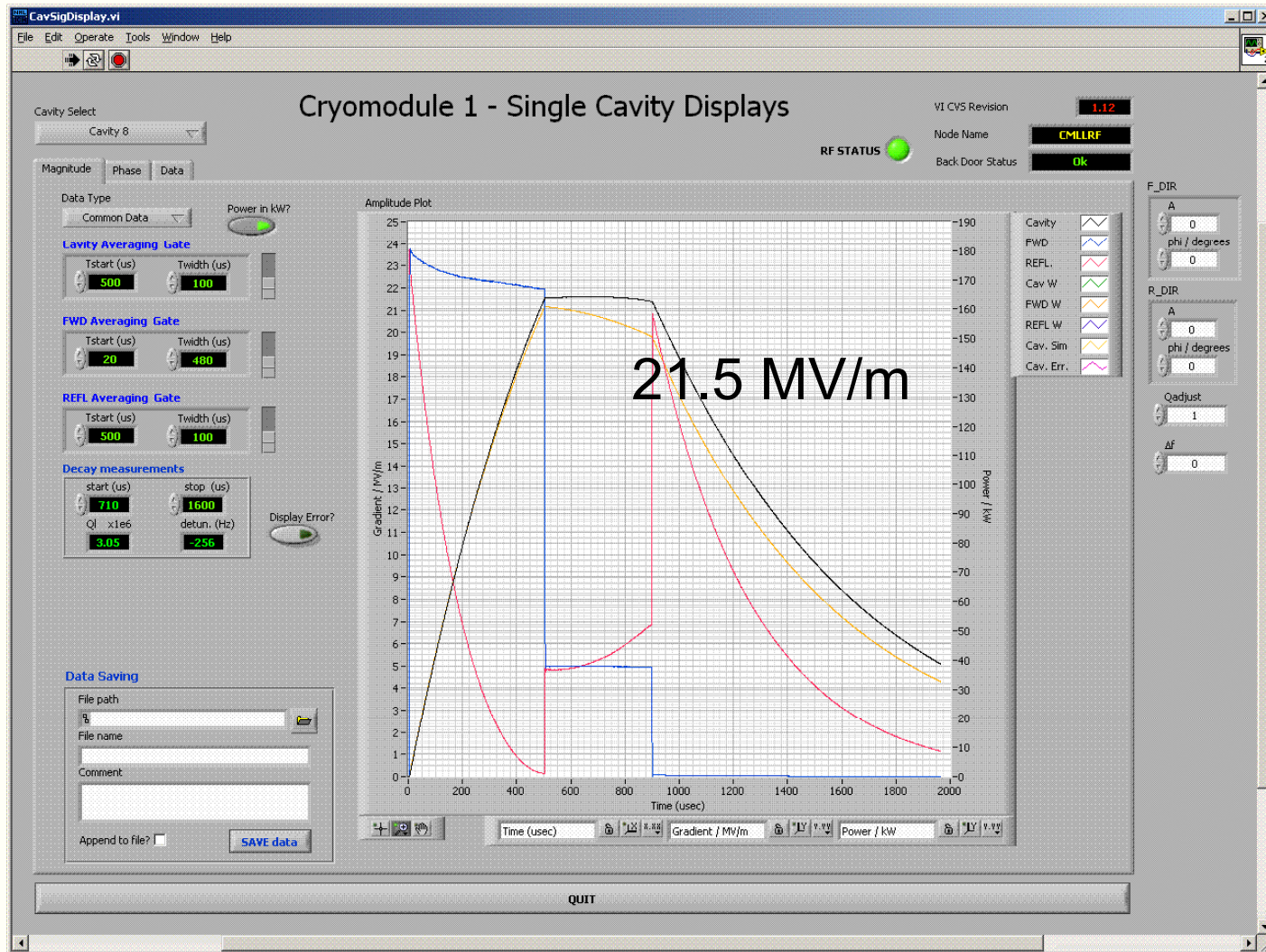


- High Power (to 1 MW forward power) conditioning is complete
- Began operation with flat top last week
- So far, so good
  - 700 us flat top achieved
  - Stable cryogenic system
  - Some dark current, x-rays
  - Minimal activity otherwise
  - Quench limit = 23.4 MV/m
    - 26.6 MV/m at Chechia
  - LLRF Feedback loop tuned and closed
  - Lorentz Force Detuning Compensation enabled
  - Dynamic Heat Load measurement
    - Difficult to determine  $Q_0$

# Cavity #8/S33 Performance

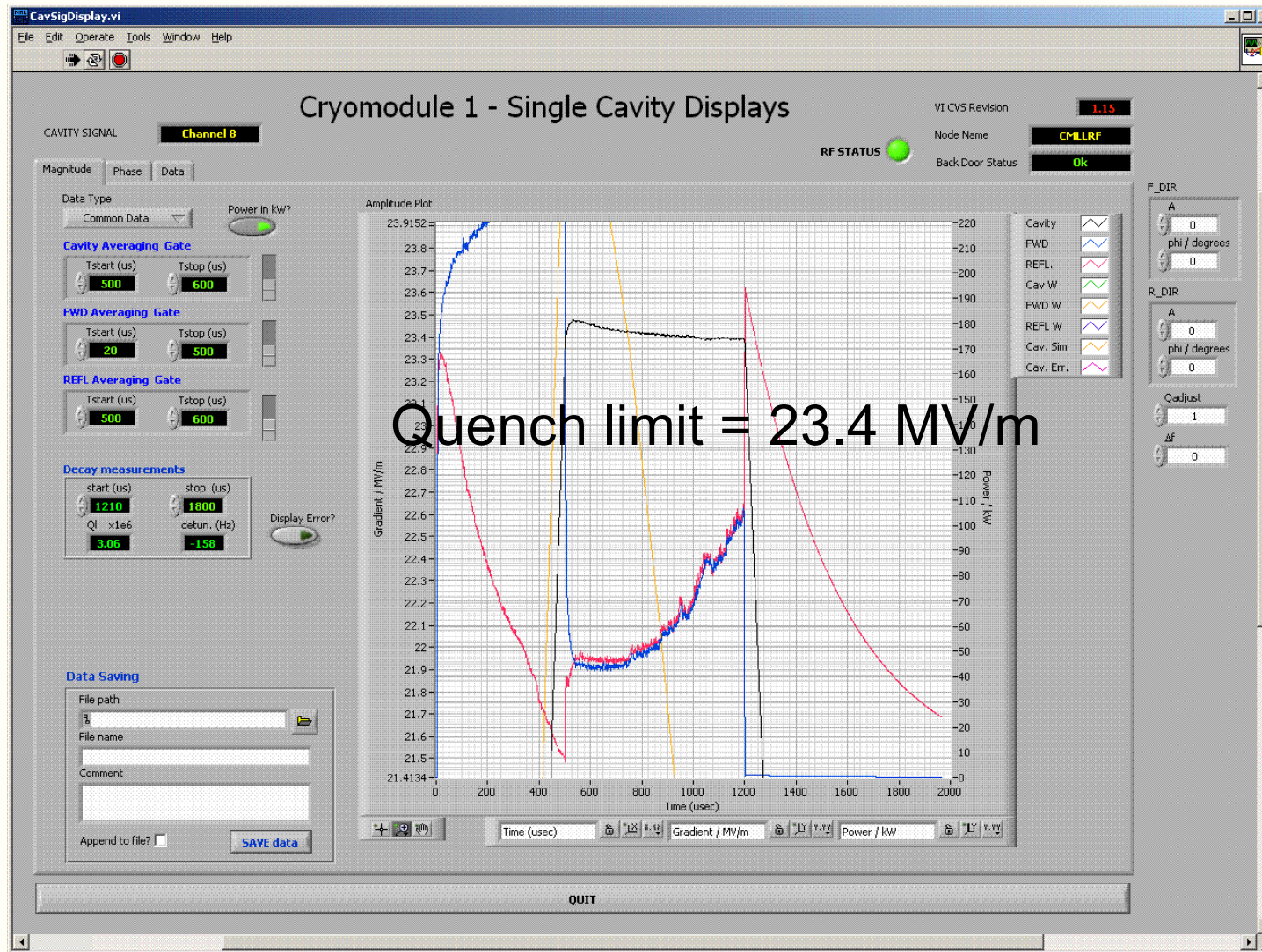


# Cavity #8/S33 Performance

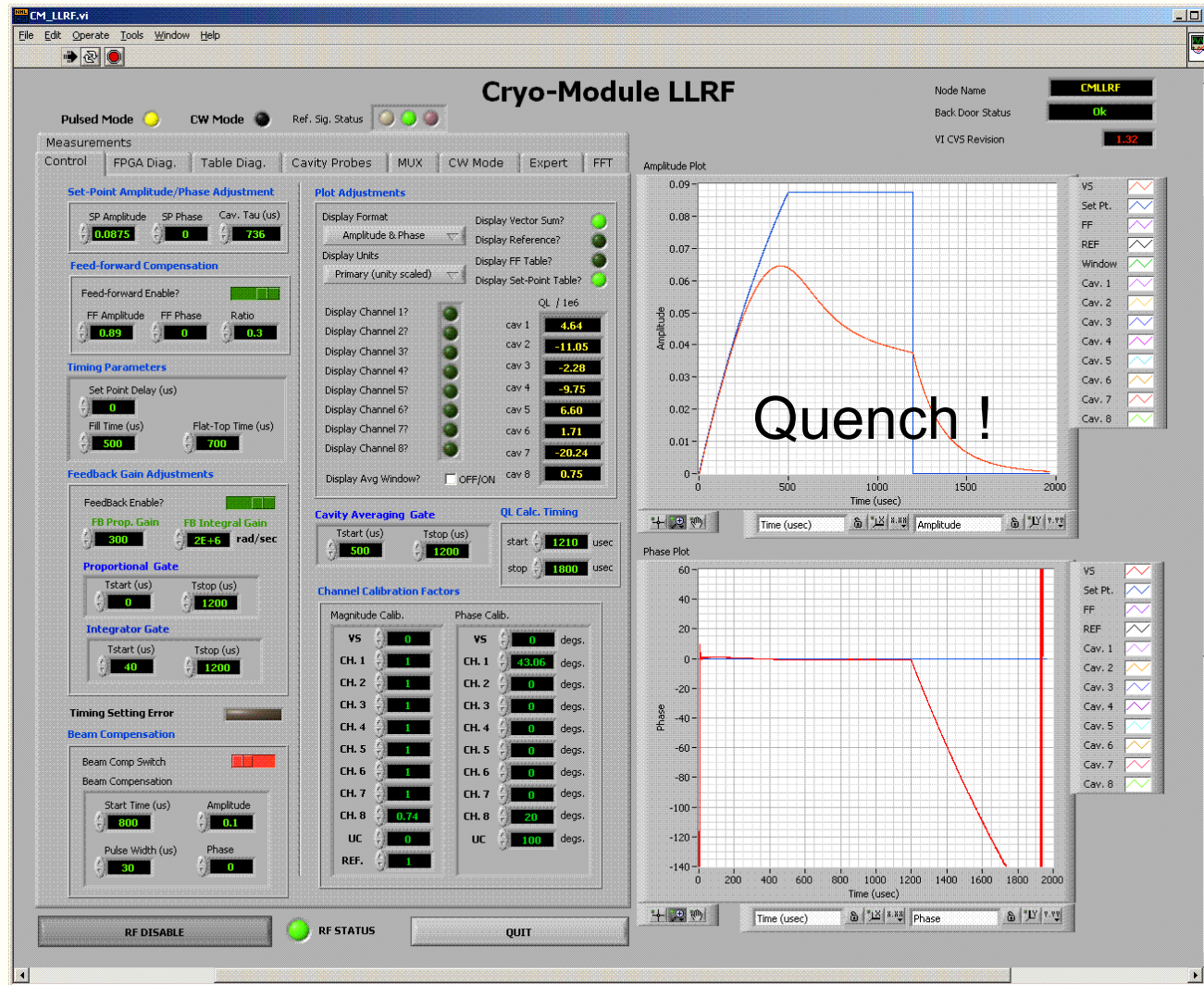




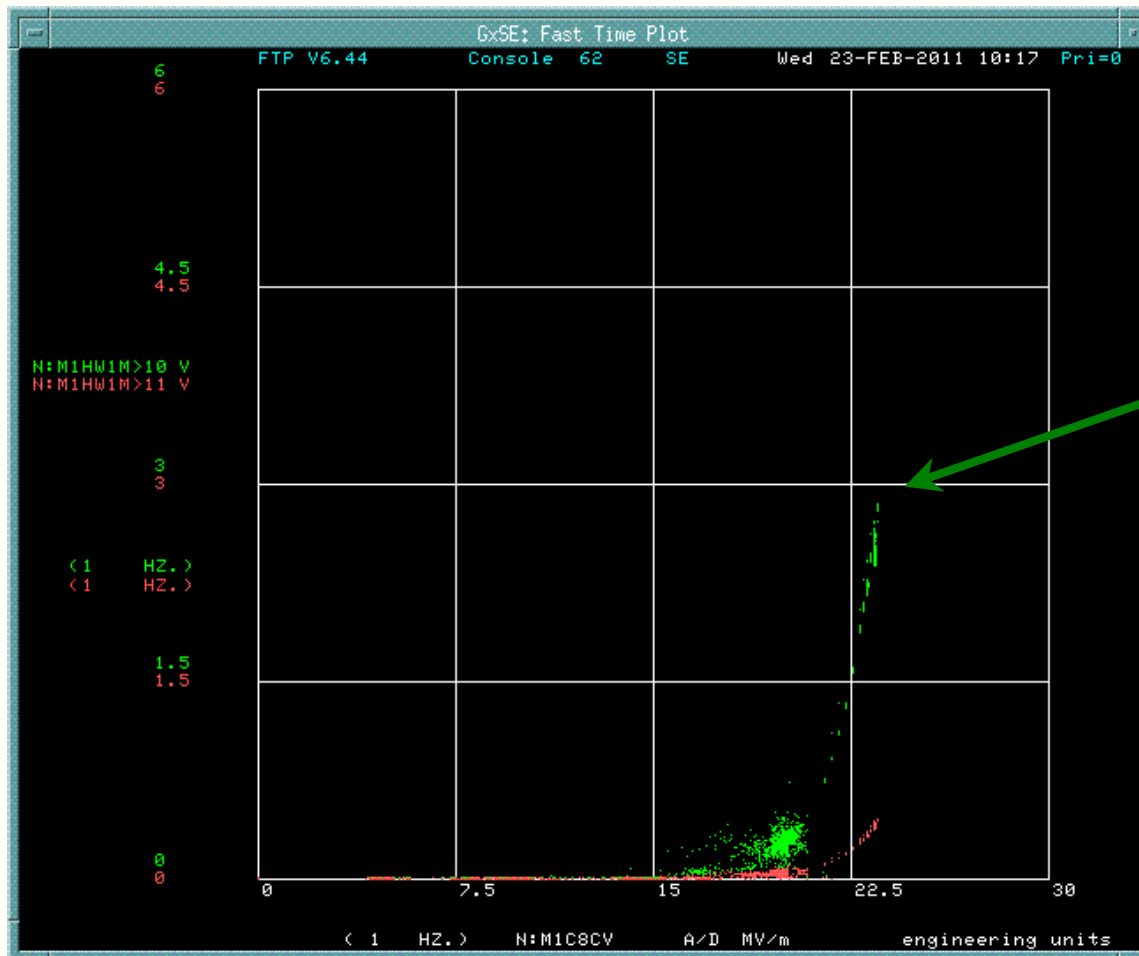
# Cavity #8/S33 Performance



# Cavity #8/S33 Performance



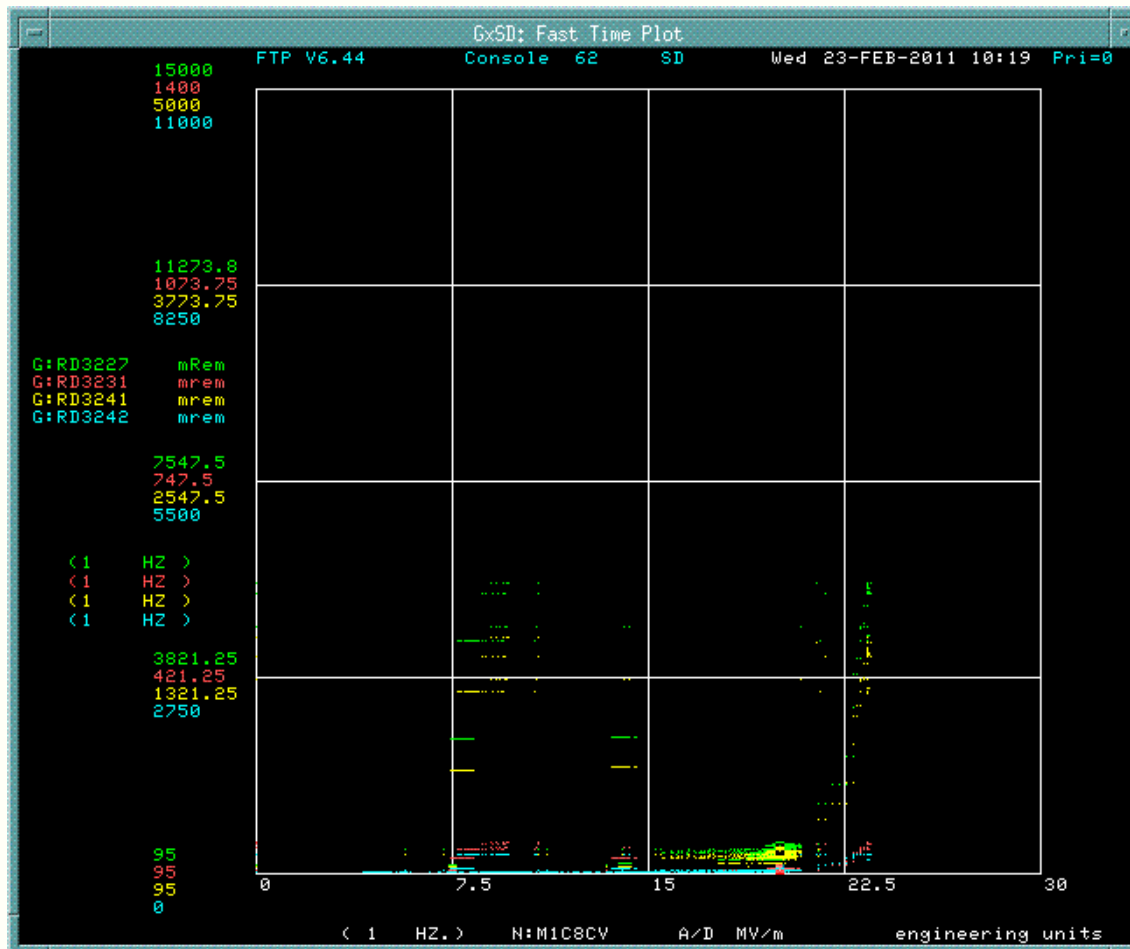
# Cavity #8/S33 Performance



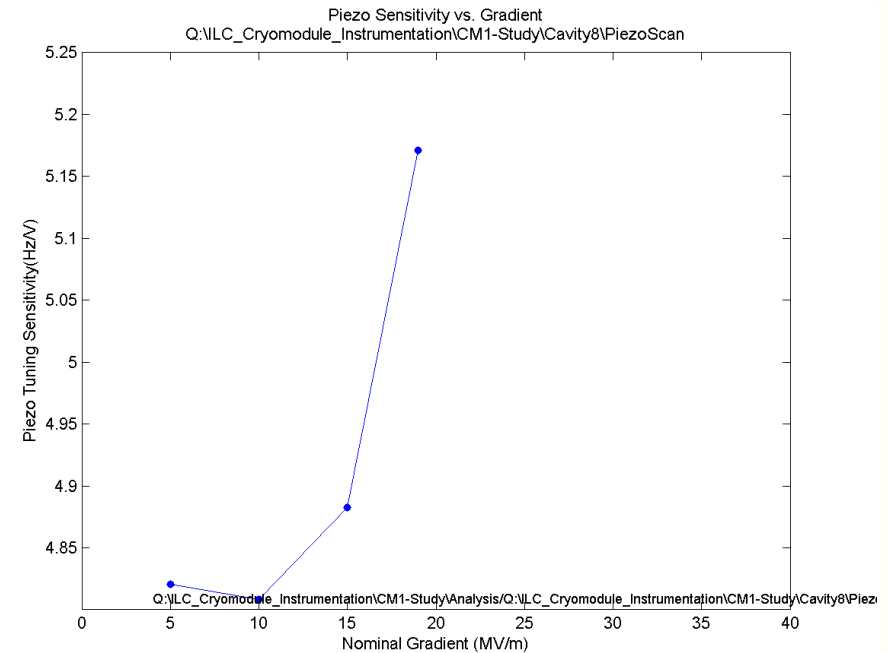
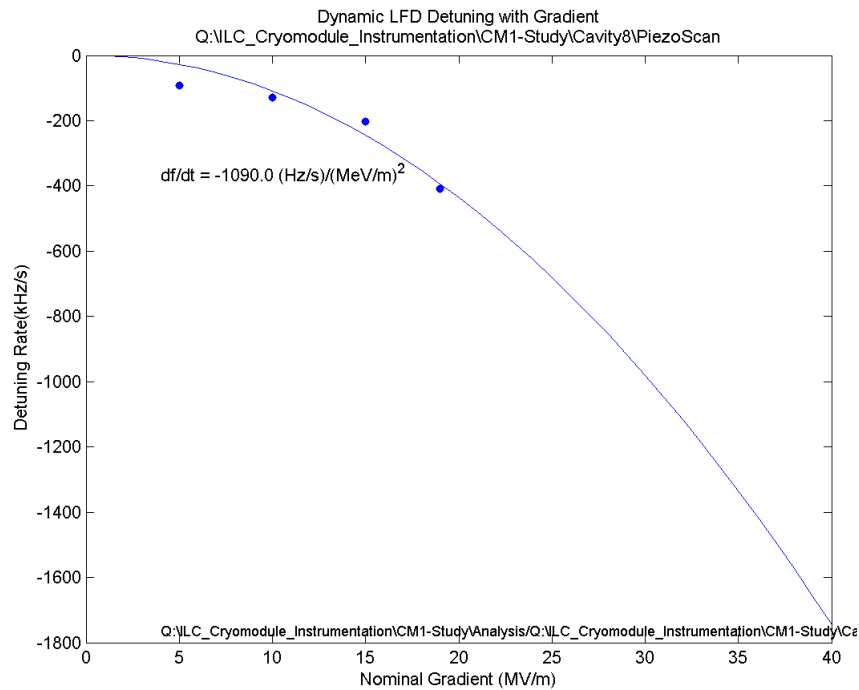
300 nA seen at opposite end of Cryomodule

Dark current (100 nAmp/Volt) vs.  $E_{acc}$

# Cavity #8/S33 Performance

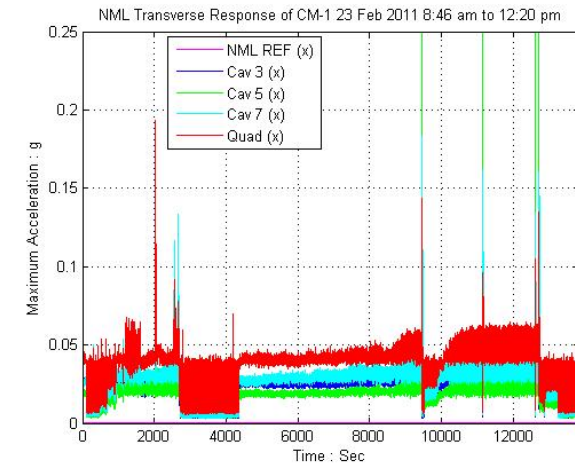
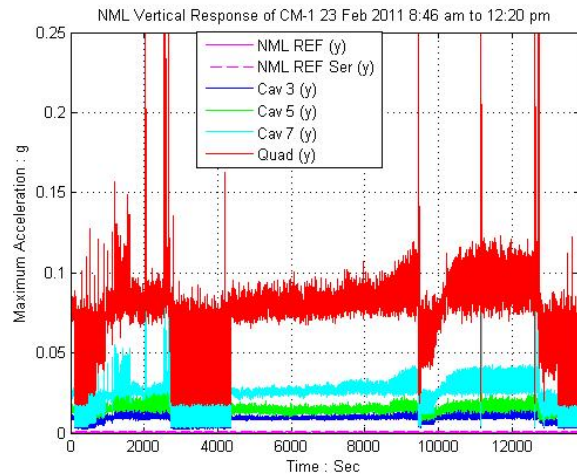


# Cavity #8/S33 Performance

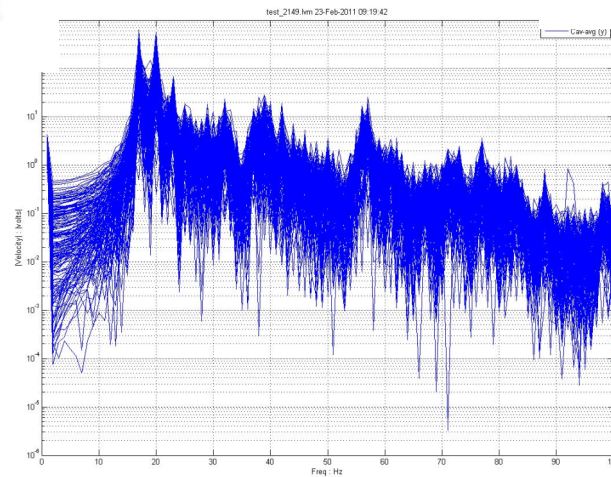


Lorentz Force Detuning Compensation tuned

# Cavity #8/S33 Performance

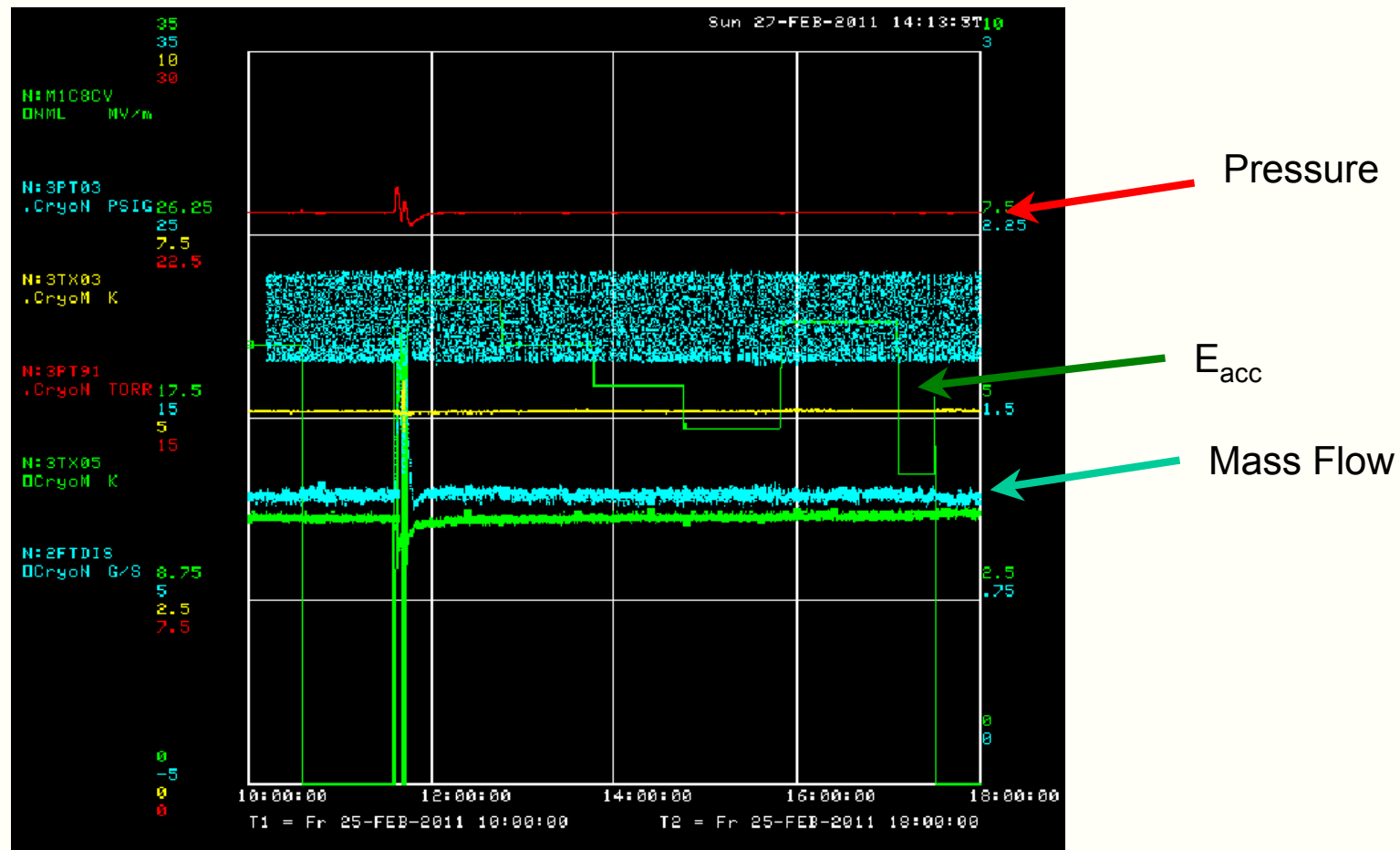


Displacements



FFT of Frequency Response  
Microphonics - *courtesy of Mike McGee*

# Cavity #8/S33 Performance



Conditions during DHL measurements - 25 Feb 2011  
 $Q_0$  appears to be at least  $10^7$

# Cavity #8/S33 Performance



- **Stuck Tuner Motor investigation**
  - All motors exercised warm and cold
  - This motor operated ~20 minutes (120 kHz) before stopping
  - Fault appears to be external to windings per TDR measurement (preliminary determination)
  - Studying specifications of motor (Sanyo)
  - Building test stand with similar spare motor
  - Investigating alternate controllers
  - Investigating more robust protection scheme



# Future Plans



- **Cold Coupler Conditioning and cavity performance one cavity at a time (#2 next, starting next week)**
- **As cavity pairs are completed, connect RF distribution**
- **Complete module test**

# Summary



- Cold operation of CM-1 in progress since November 2010
  - NML still a construction area!
- Single cavity performance measurements in progress
  - Cavity #1/Z89 shows large heat load, yet to be understood
  - Cavity #8/S33
- All systems being understood and characterized
- Many successes
  - Stable cryo
  - LLRF
  - LFDC
  - Controls
- A Few issues
  - Z89 heat load
  - S33 tuner motor
- Developing list of enhancements for CM-2

# CM-1 Team at Fermilab



Thank you to our TTC partners!