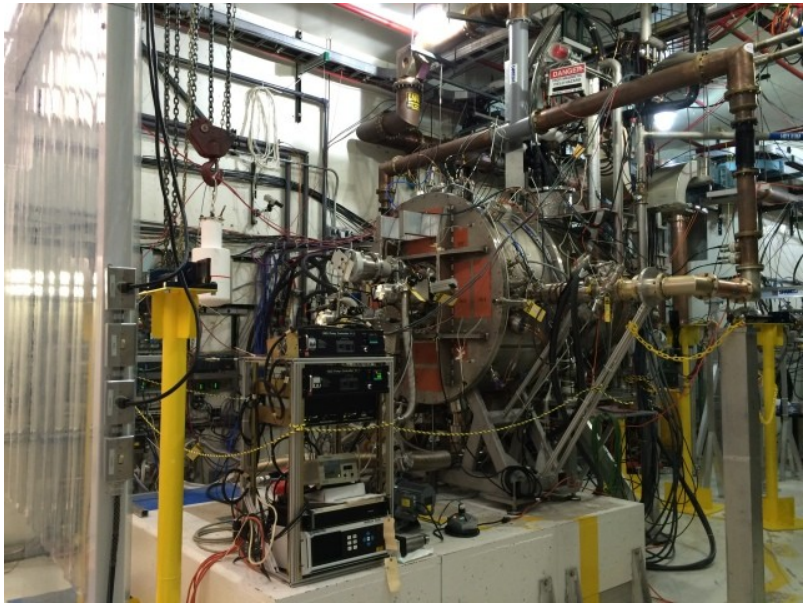
MTA Tests and Tuners



Daniel Bowring
Fermilab
June 21, 2015

We have met several major milestones since the last meeting.

(1) Circa CM41: Cavity run with **copper windows**, inspection, and reconfiguration for running with **beryllium windows**.

(2) 18 March – 6 April: B=0 run (Be)

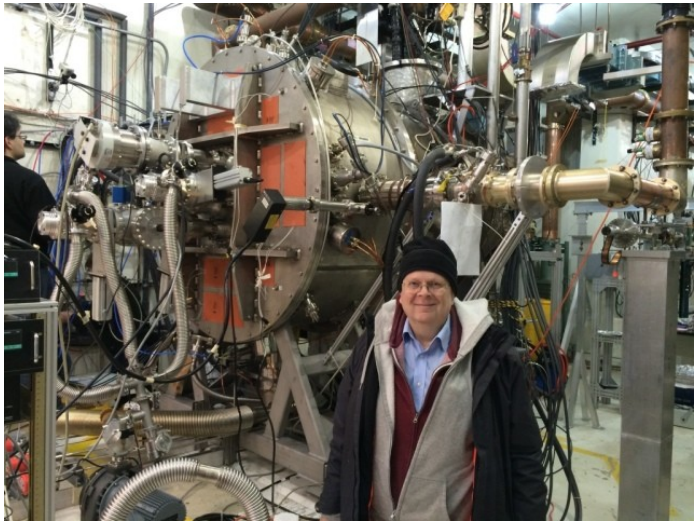
(3) 24 April – 20 May: B = 5 T run (Be)

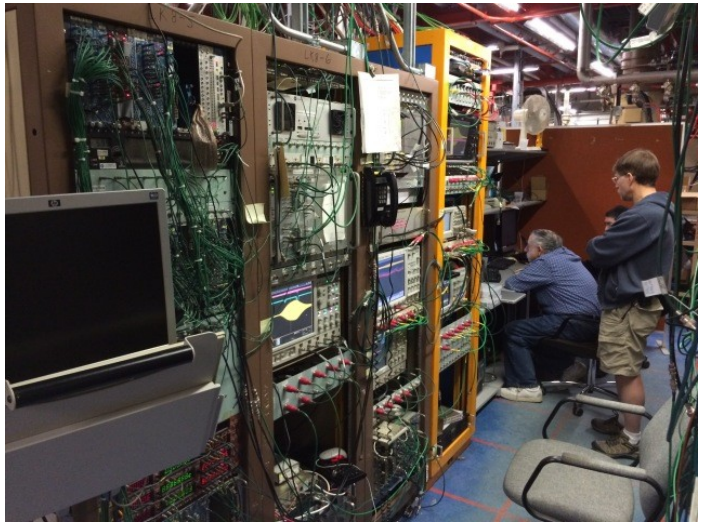
(4) 29 May – 3 June: tuner tests

- 26 May – 13 June: detector calibration
- Ongoing: dark current studies w/ new detector configuration.

Many thanks to all who have taken shifts during this effort!

M. Backfish
D. Bowring
B. Freemire
T. Hart
C. Hunt
A. Kochemirovskiy
P. Lane
M. Leonova
T. Luo
A. Moretti
D. Peterson
M. Popovic
D. Speirs
T. Stanley
Y. Torun
C. Whyte
K. Yonehara



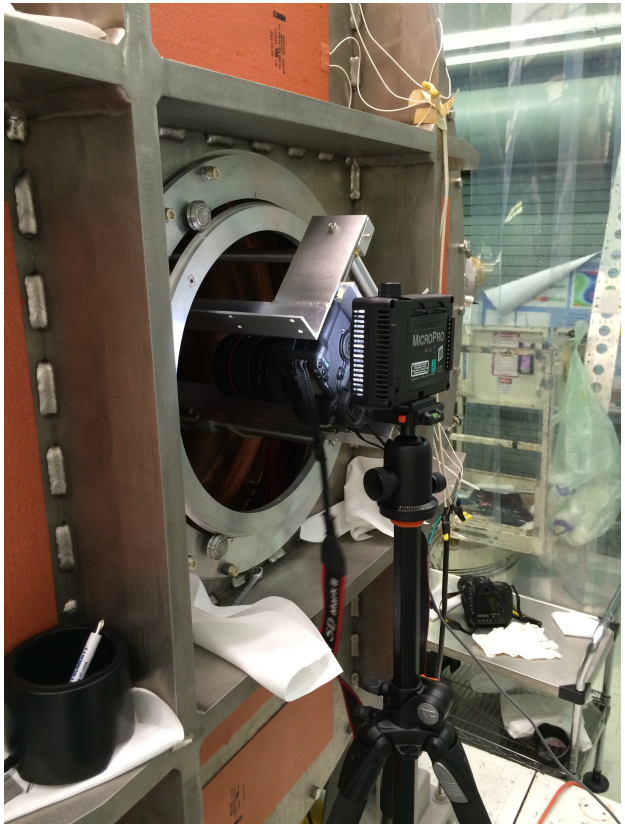


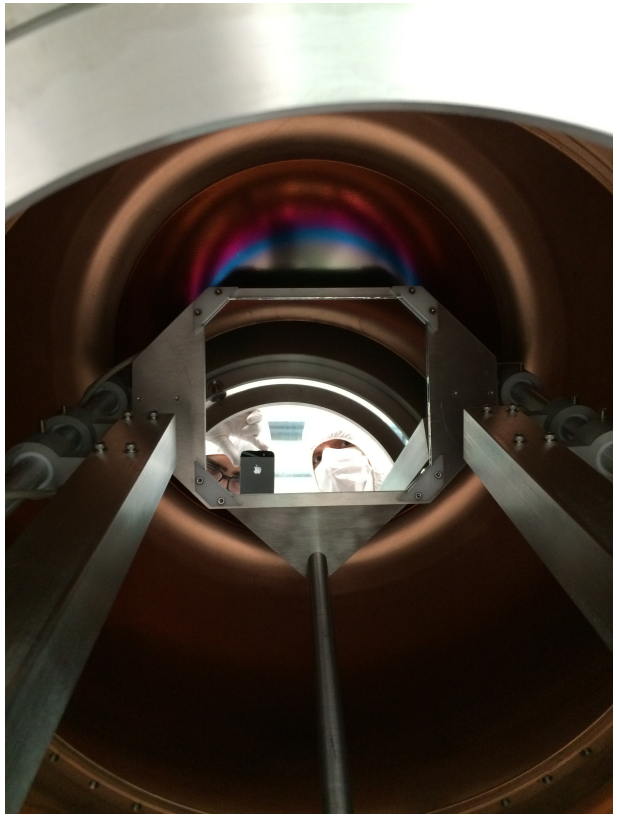
(1) System shakedown with Cu windows, discussed at CM41

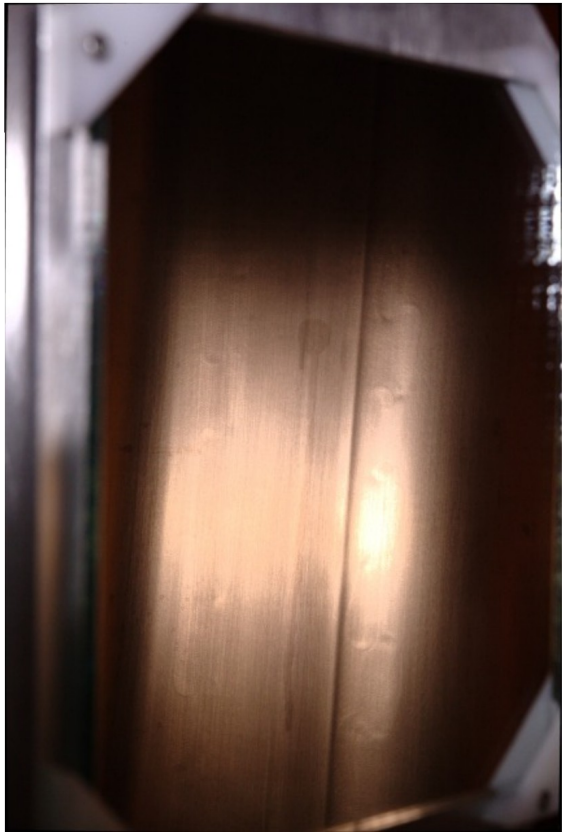
- August – November 2014
- Shifts 24/7 with ~100% coverage.
- B = 0 T
- **Breakdown probability of ~1e-6 at 13.6 MV/m (3.5+ MW).**
- Frequency control demonstrated with 5 tuners.
- January & February 2015: Cavity inspected, reconfigured for Be window operation.
  - Evidence of breakdown on unpolished Cu windows but NOT on electropolished surfaces.

Jan. – Feb. 2015: System inspected, reconfigured for Be window operation.

- Entire interior inspected, photographed: no evidence of breakdown on electropolished surfaces.

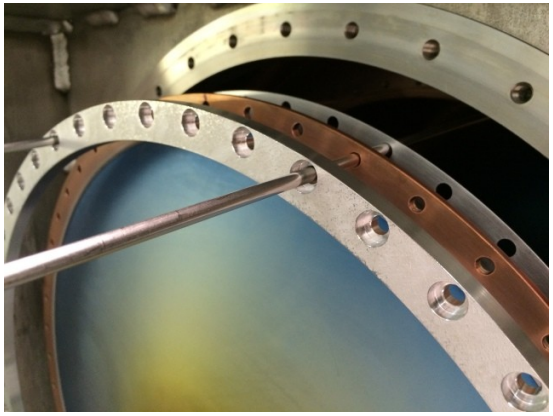


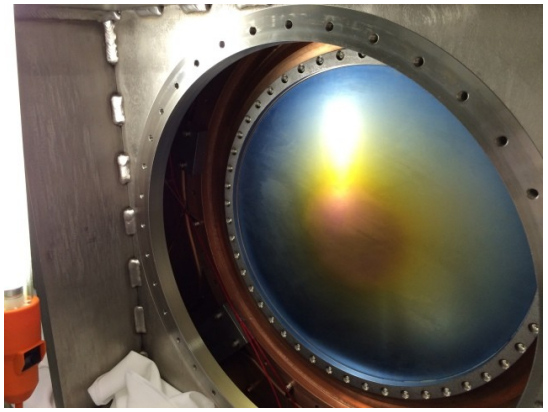


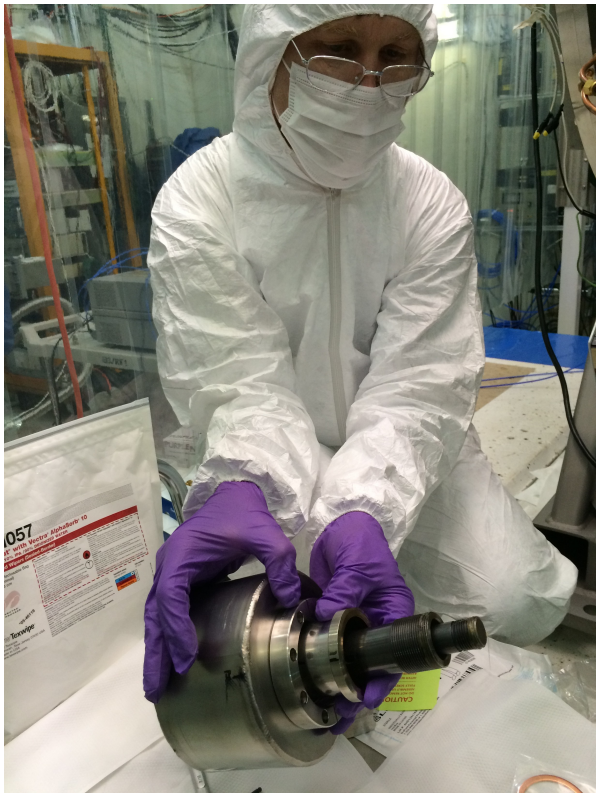


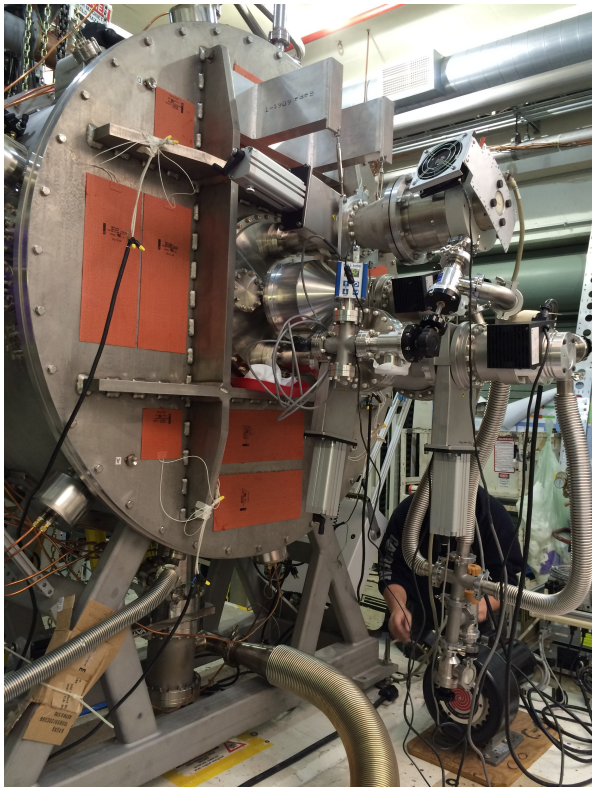
Jan. – Feb. 2015: System inspected, reconfigured for Be window operation.

- Be windows, teflon spacers installed. Frequency measurements agree well with simulations by T. Luo (LBNL).
- Actuator installation, maintenance.
- Vacuum system reconfigured.









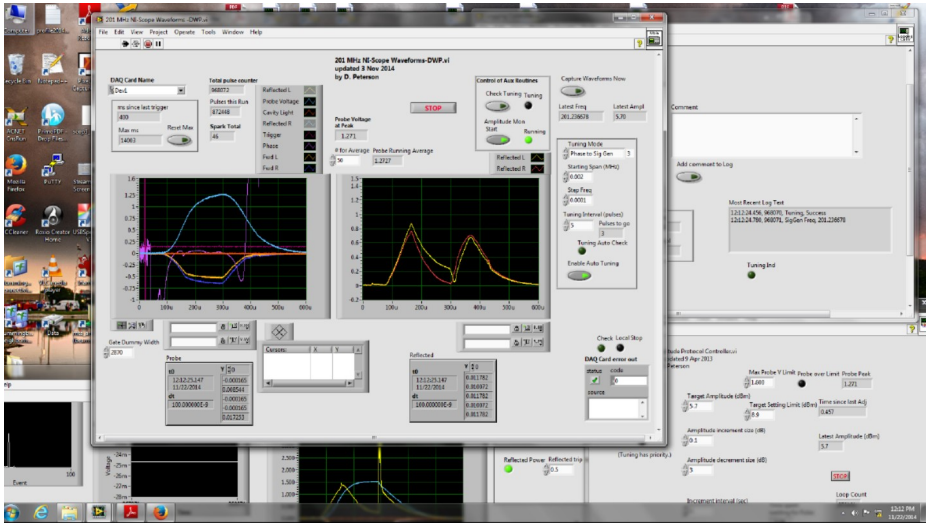
Interlude: Overview of cavity instrumentation, DAQ

- "Fast" channels:
  - RF pickup loops
  - Directional couplers @ coupler arms & near source
  - Cavity light: optical fiber + PMT
  - Field emission probes
  - Faraday cup
  - Fast plastic counters (more on these later)
  - NaI crystal detector
- Piezos for acoustic breakdown localization (P. Lane, IIT)
- Temperature, vacuum, radiation, water flow/pressure... For a complete list, see:

  http://mice.iit.edu/cgi-bin/mta/acnetize?Config=MICEShift

Interlude: Overview of cavity instrumentation, DAQ

- DAQ Labview-based software developed by D. Peterson. (c.f. Proc. PAC 2013) for amplitude, tuning control.
- Automated spark detection system triggered by cavity light OR time derivative of pickup probe signal OR reflected power.
- All “fast” waveforms recorded periodically



(2) B=0 run with Be windows

- 18 March – 6 April, 2015
- 0.5M+ pulses at 11+ MV/m (1.6 MW). Recall MICE baseline is 10.3 MV/m.
- Reached 14 MV/m for brief periods.
- **No evidence of breakdown.**
- Cavity services (vacuum, water, etc.) performed well.
- Instrumentation & DAQ performed well.

(3) B=5 T run with Be windows

- 24 April – 20 May, 2015
- > 7.5M pulses total:

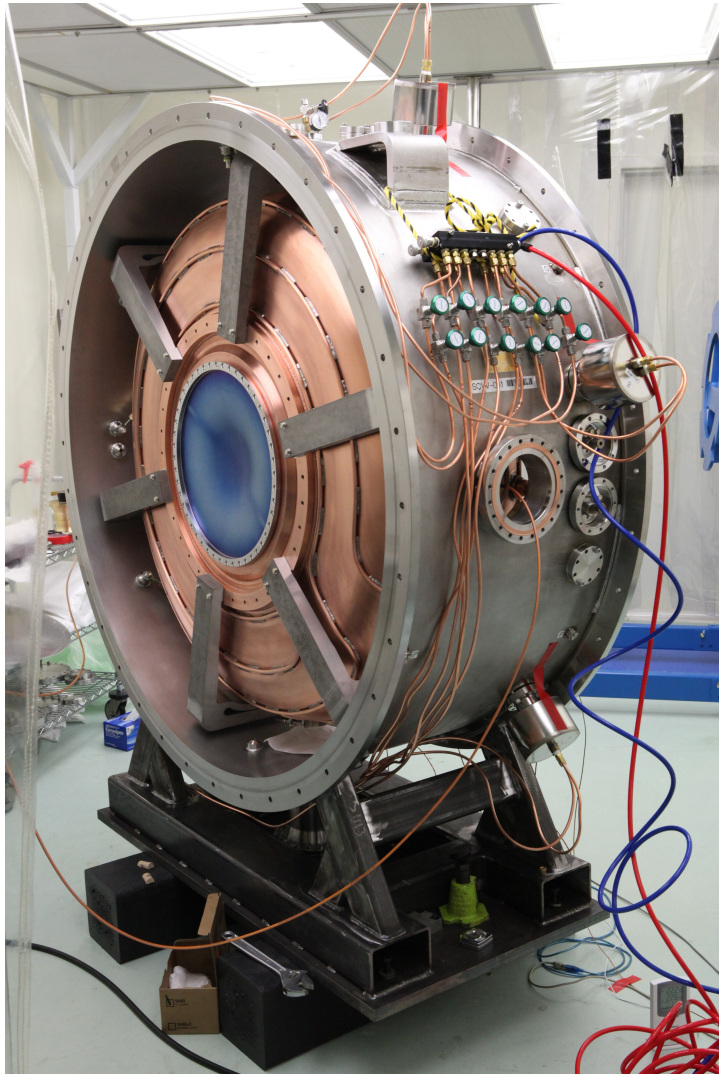
Million Pulses	Gradient (MV/m)	Peak Power (MW)
1	8	1
3	10.7 – 11.2	1.7 – 1.9
1.3	13 – 13.7	2.5 – 2.8
0.36	13.8 – 14.5	2.9 – 3.2

- **No breakdown events** below ~14 MV/m.

Several critical conclusions here:

- MICE prototype cavity has met its performance goals for B = 5 T operation.
  - B = 5 T in the MTA solenoid gives a field distribution very similar to that for the ultimate MICE configuration.
- Careful "SRF-style" surface preparation enables cavity commissioning to design gradient with **no breakdown**.
- DAQ, instrumentation, subsystems are all viable.

(4) Tuner tests

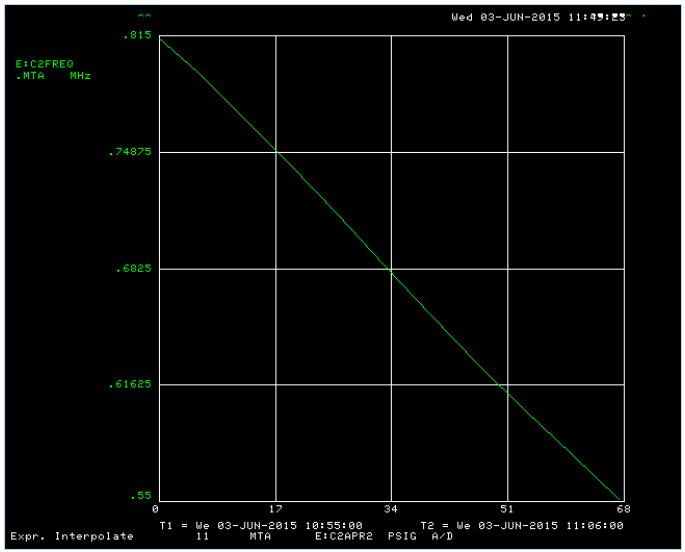


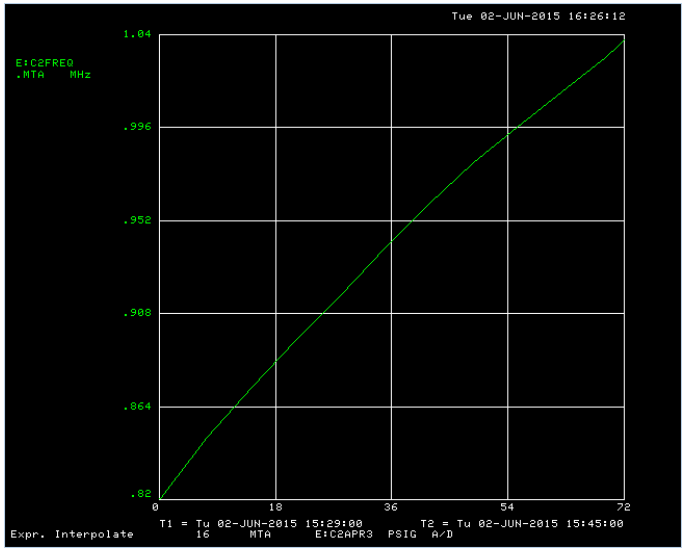
- 29 May – June 3, 2015
- Transfer function (frequency vs pressure) measured for push, pull modes.
- Results consistent w/ low-power measurement (c.f. L. Somaschini's thesis) w/ no couplers.

(4) Tuner tests, cont'd.

- Fixed-frequency measurements (200.91 MHz):
  - 0.275M pulses @ 10 Hz rep rate
    - B=0, >1 MW (8 MV/m) peak, 1.6 kW avg. power
  - 0.55M pulses @ 5 Hz
    - B=5 T, >1.6 MW (10.3 MV/m) peak, 1.4 kW avg.
  - 1 second update interval, as for MICE

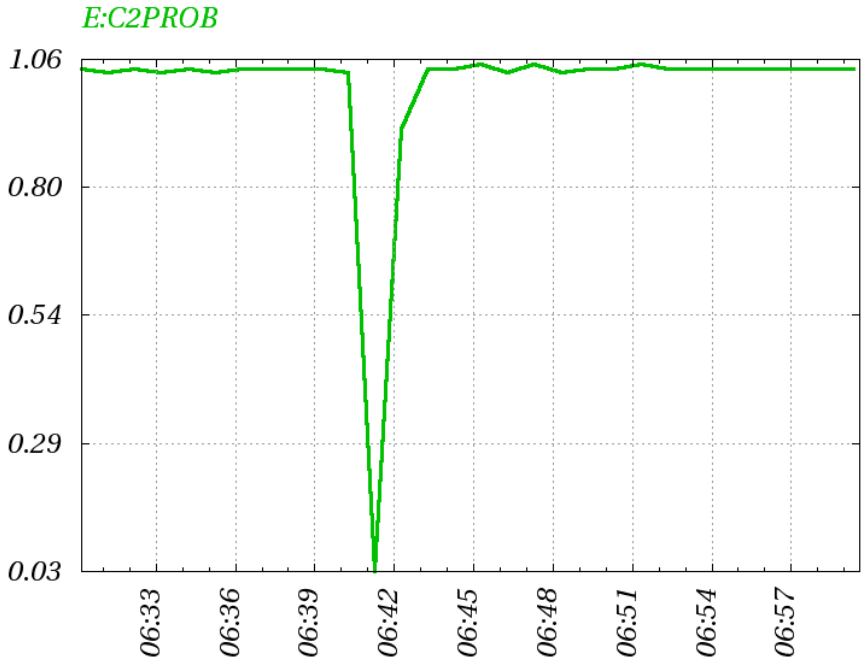
(4) Tuner tests, cont'd.





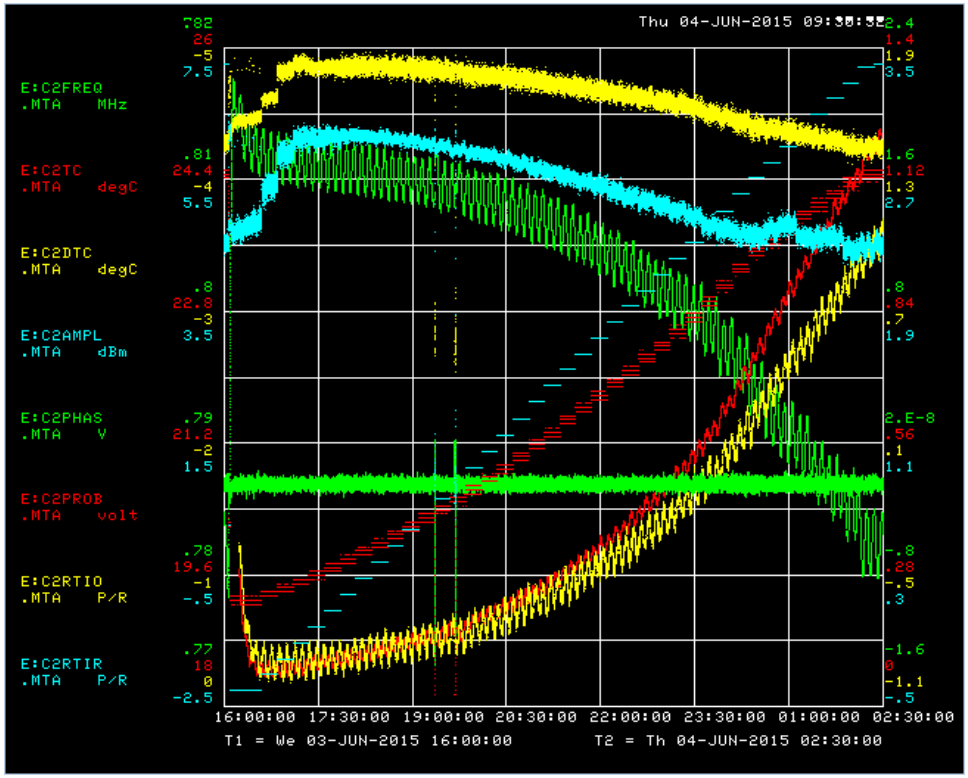
- Left: Push & pull xfer functions
- Below: Tuner-assisted trip recovery, pickup voltage vs time.

  2-pulse update interval.



Gradient scans

- Conducted at several B-field values to study:
  - Cavity frequency vs temperature
  - Radiation signals & backgrounds via:
    - Ionization chambers
    - Scintillator detectors, including one equivalent to a MICE tracker channel
  - Detector calibration w/ cosmics ongoing.

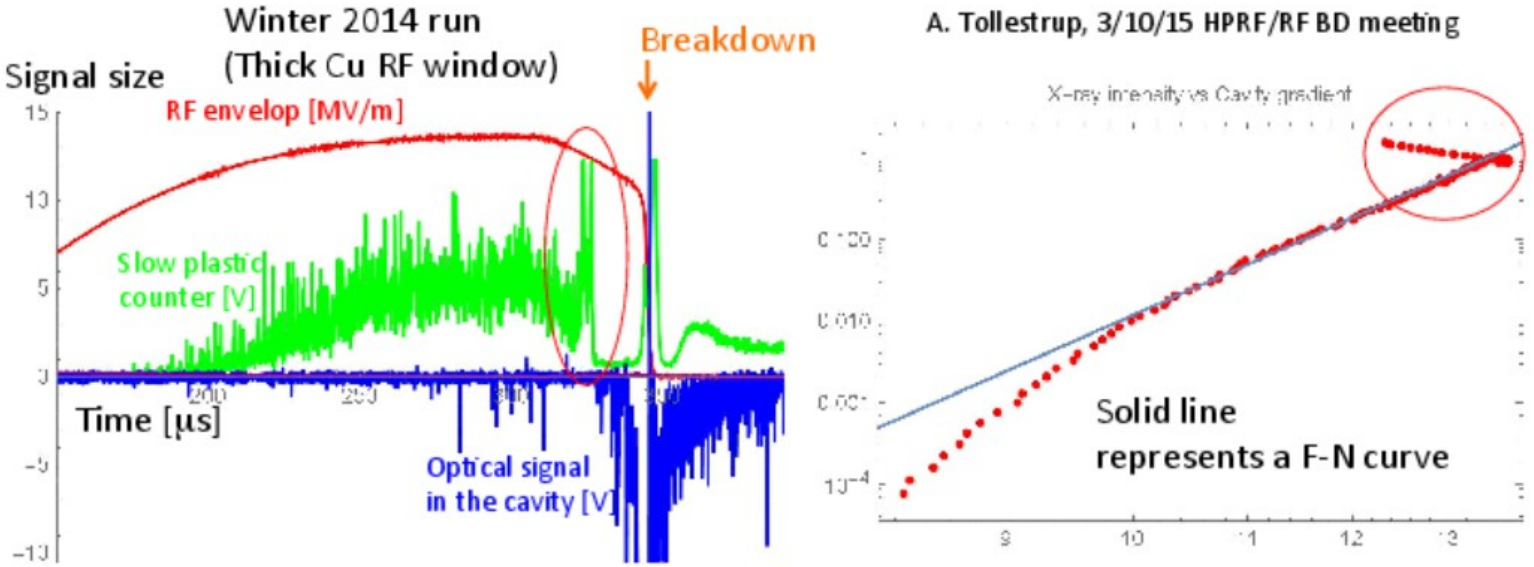


Dark current studies

- In many ways, the MTA's MICE cavity is an ideal tool for studying field emission.
  - RF period is 5 ns @ 200 MHz vs 1.25 ns @ 805 MHz.
  - MICE cavity is *extremely* well instrumented.
- Goal 1: Characterize radiation load on MICE detectors
- Goal 2: Study field emission using fast instruments and a slow cavity.
- A summary follows. For more detail, see K. Yonehara & A. Tollestrup's recent work:
  - https://indico.fnal.gov/getFile.py/access?contribId=1&resId=0&materialId=slides&confId=10079
  - https://indico.fnal.gov/getFile.py/access?contribId=48&sessionId=7&resId=0&materialId=slides&confId=9752

Dark current studies (K. Yonehara)

Mystery of slow counter measurement in Winter 2014 run



- A slow counter sees field emission currents (F-N curve) in the cavity

However…

- Radiation seems to be highly activated even the driving RF power was ramped down (A red oval in left plot)
- High activating radiation makes a big deviation from the normal Fowler-Nordheim curve (A red oval in right plot)

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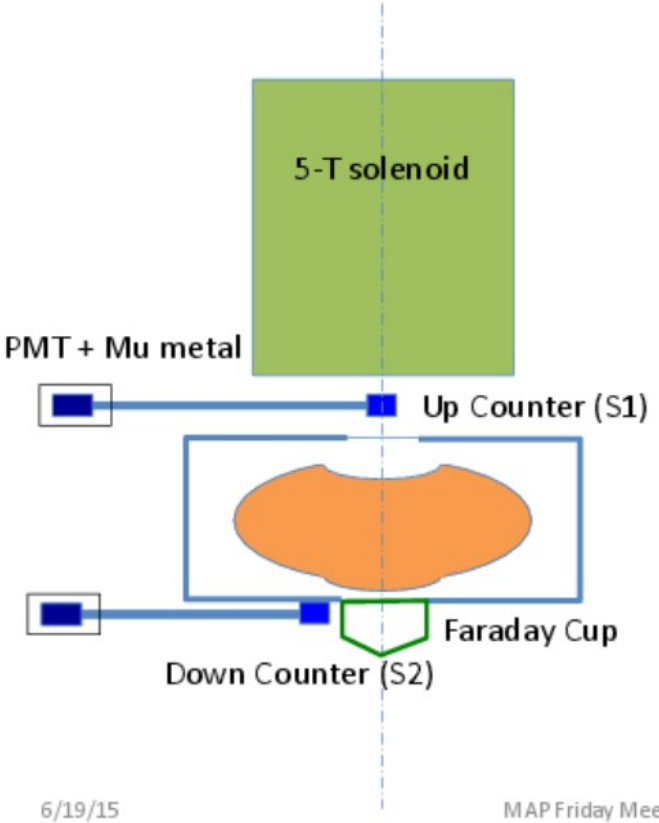
Dark current studies (K. Yonehara)

Radiation measurement with B



- Plastic counter (BC408, 2.5 cm x 2.5 cm x 1 cm)
- 6-ft optical fiber (8 ϕmm)
- PMT (H10721-10) inside Mu-metal

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Dark current studies (K. Yonehara)

- This work is ongoing. A brief summary:
  - Strong timing correlation observed between fast counter signal & RF phase.
  - Fast counter signal is intermittent. Do emitters burn out immediately? Low detector efficiency? Poor time resolution?
  - When B > 0, multipacting seems dominant.
- Planned work:
  - Coincidence measurements
  - Improve detectors' time resolution.

Conclusions

- Major MTA performance milestones have been successfully met:
  - Cavity & subsystems perform well at and above MICE gradient, power, and B-field specifications.
  - At and above MICE spec, we see no (difference in) breakdown behavior for B=0, B=5 T.
  - Tuners work as intended.
- Ongoing work:
  - Characterization of radiation load for detectors
  - Dark current studies