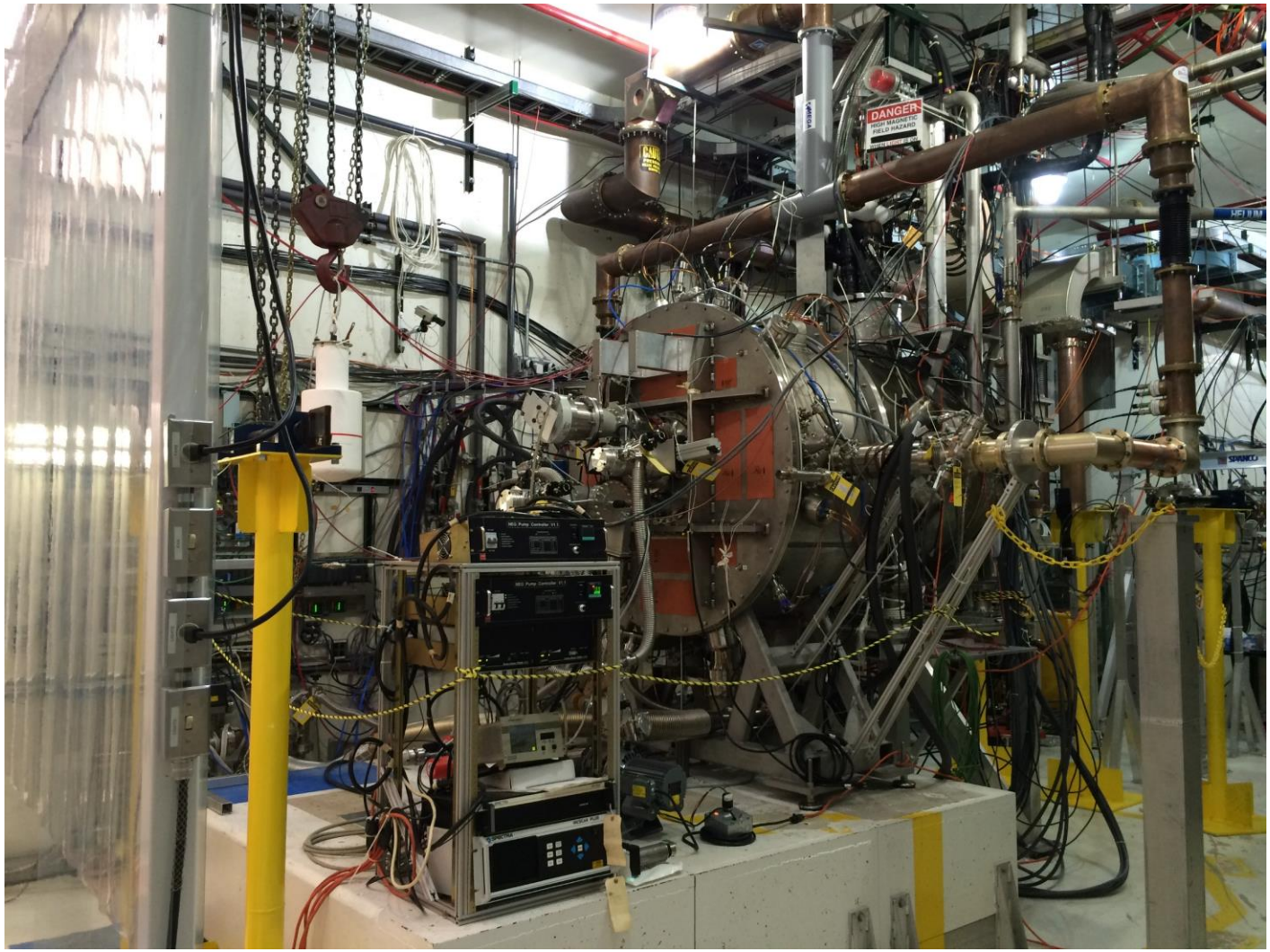
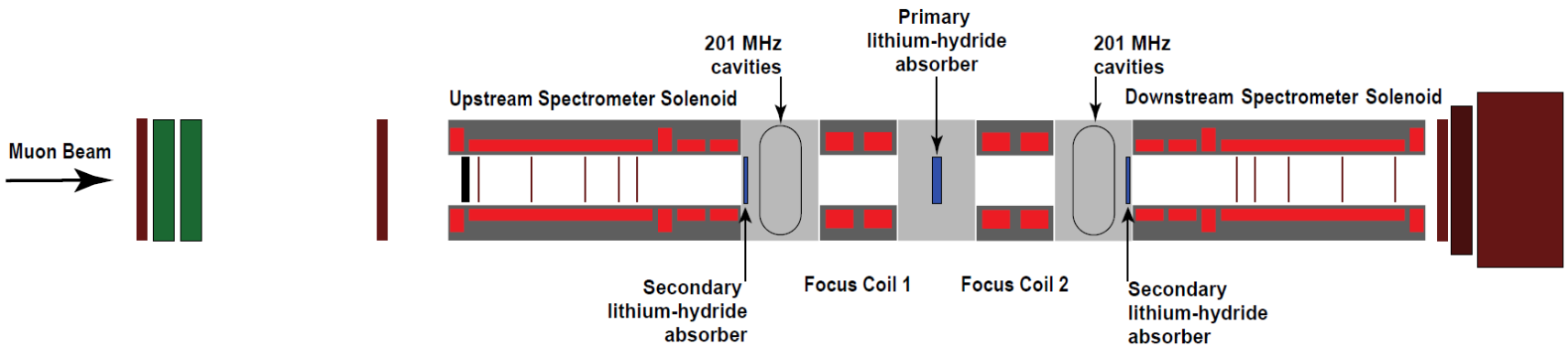
MICE Cavity Commissioning/Operation at MTA



M.A Leonova MAP CM Spring 2015

MICE Cavity Commissioning/Operation at MTA

Schematic of MICE cooling channel in final configuration



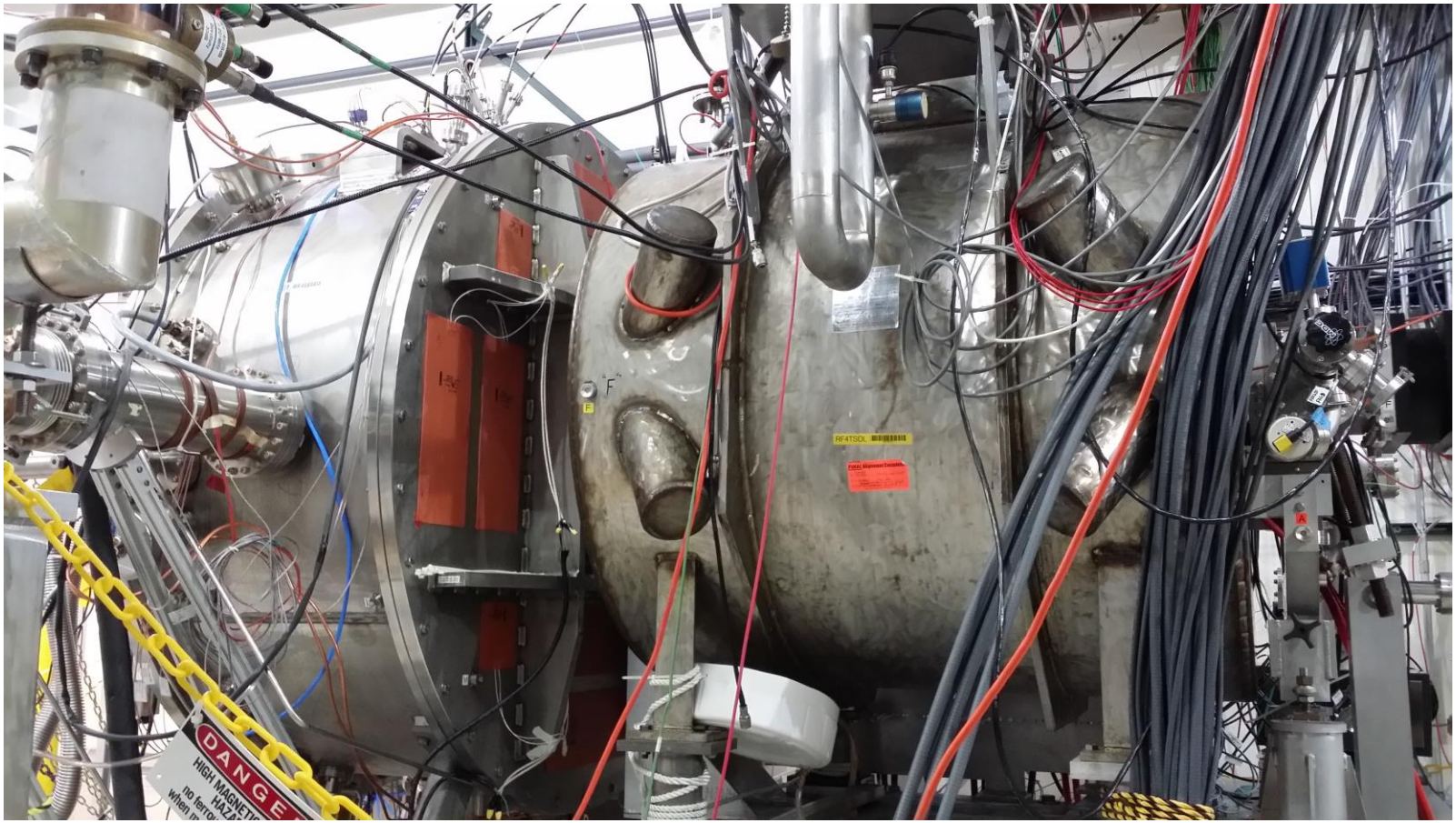
Final MICE channel configuration contains two RF Assembly (RFA) modules very similar to the module being tested at the MuCool Test Area (MTA).

Cavities need to operate at 10.3 MV/m gradient in fringe fields of multi-tesla solenoidal magnets.

MTA has a 5-T superconducting solenoid that provides operational conditions similar to MICE channel.

MICE Cavity Commissioning/Operation at MTA

Single-Cavity Module next to 5-T solenoid

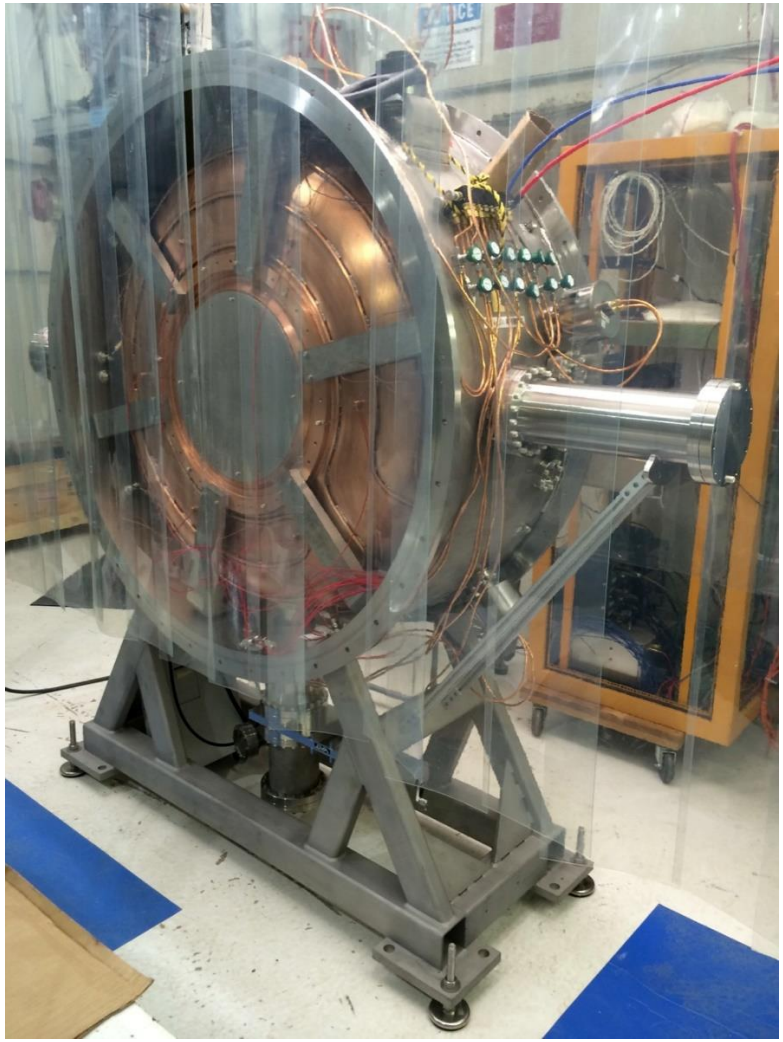


<u>Magnetic fields in Cavity:</u>

0.1 T @ downstream wall, **0.17** T @ center; **0.33 T** @ upstream wall

MICE Cavity Commissioning/Operation at MTA

Single Cavity Module in MTA clean room



RF Cavity – Electro polished cavity body

RF Couplers – Two couplers: one on either side

RF Tuner Forks
6 tuner forks can provide “pull” and “squeeze”

Actuators and Controls
Pneumatic system can handle pressure up to 100 PSI; provides ~ 4 KHz/PSI tuning sensitivity

Beryllium windows – TiN coated
Also used Cu windows for MTA tests

Cavity Support struts

RF Vacuum Vessel

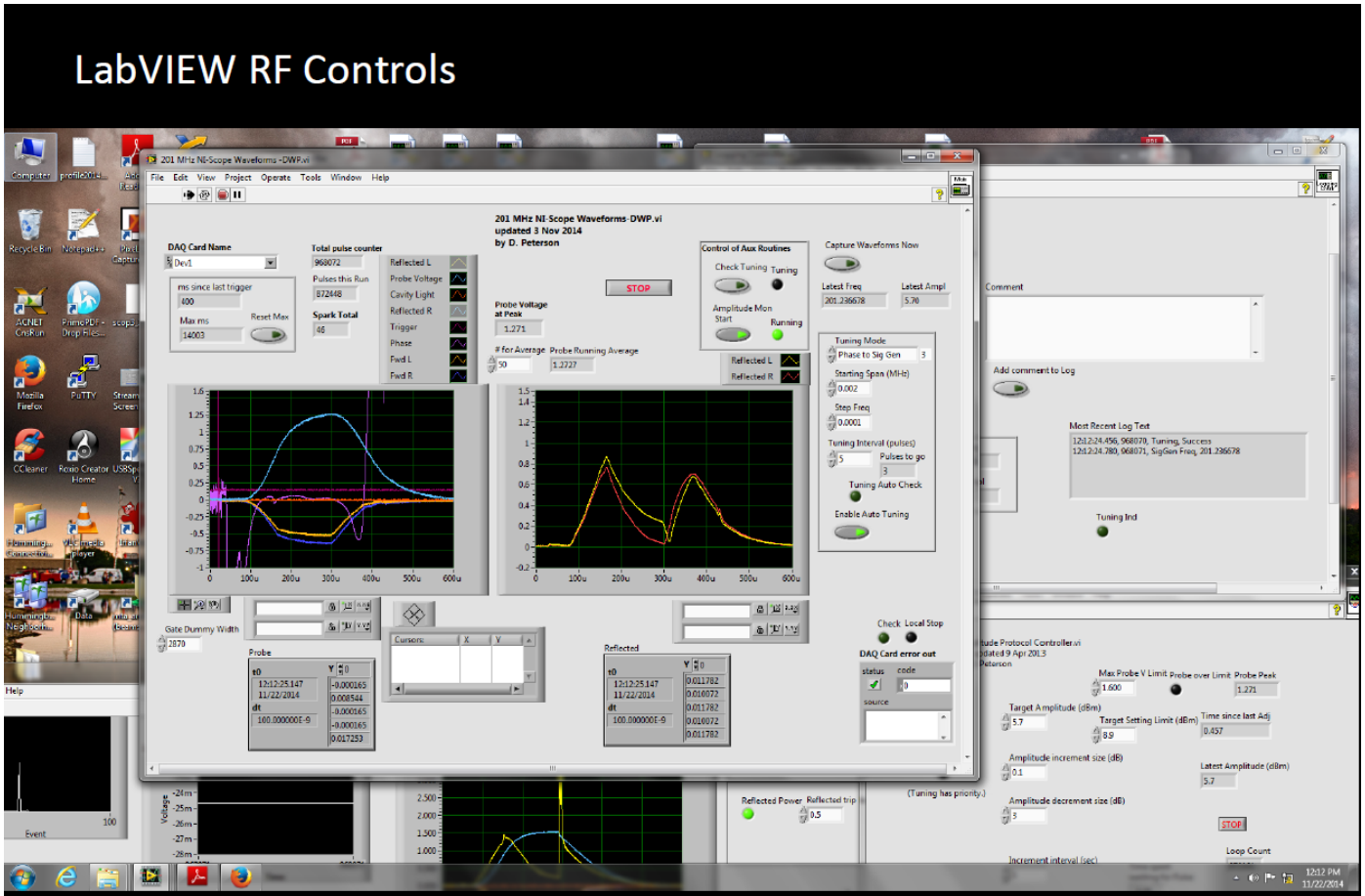
Support Stand

MICE Cavity Commissioning/Operation at MTA

Control room at the Linac Gallery

MICE Cavity Commissioning/Operation at MTA

Control System



From talk by D. Peterson at December 2014 MAP meeting

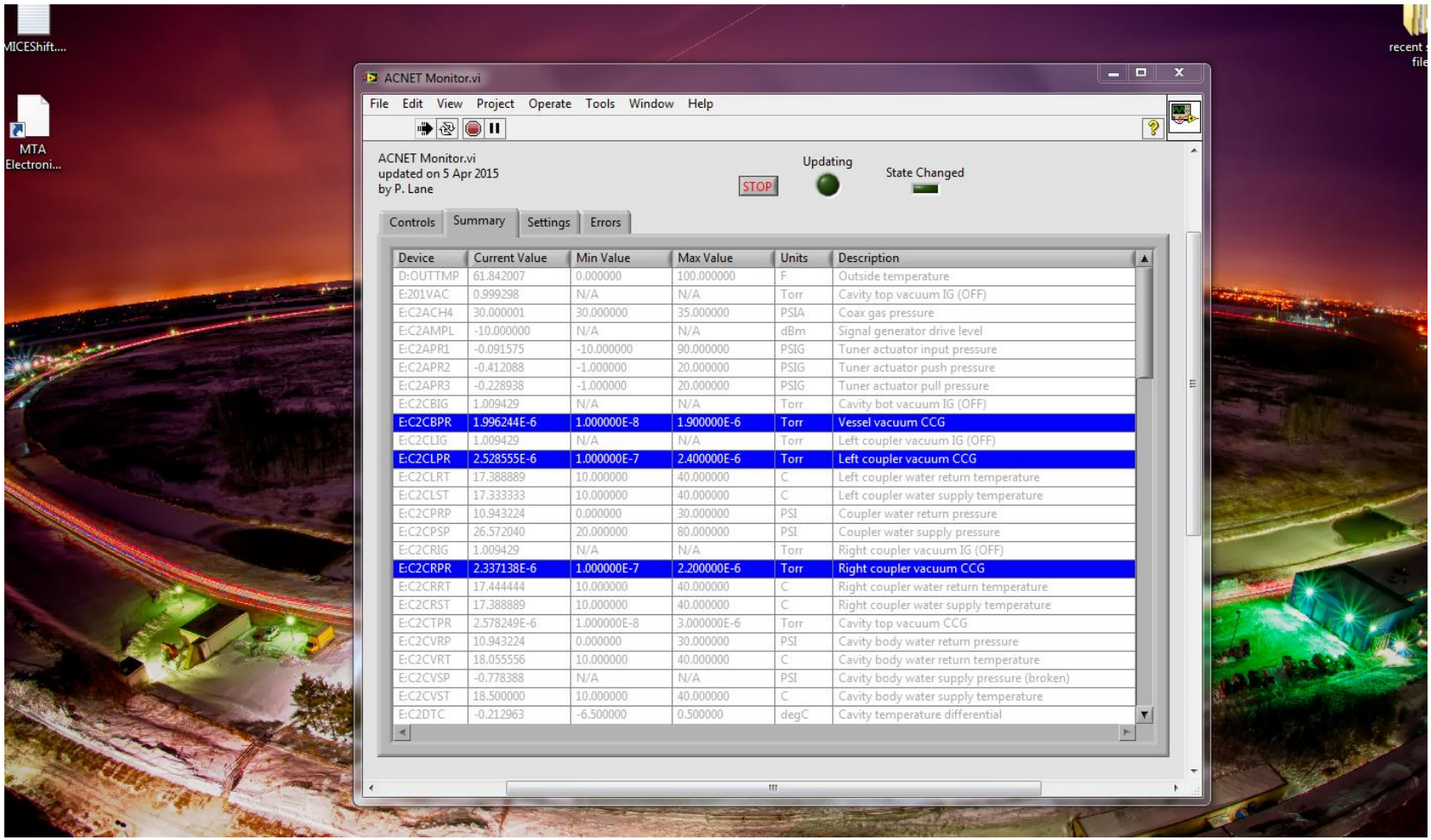
MICE Cavity Commissioning/Operation at MTA

Cavity, couplers, vacuum vessel and MTA Hall Instrumentation:

- two **Pick Up** loops (PU1 and PU2) to monitor RF fields
- four **Cavity Light** (CL) signals consisting of optical fibers + PMT to detect breakdown in the cavity
- Piezoelectric **acoustic sensors** on cavity body to detect and localize breakdown through acoustic signals
- **Forward and Reflected power** waveforms from directional couplers near cavity on Left and Right Coupler arms, and near Klystron station
- viewports on Left and Right **couplers** to detect **light** signals
- **Field Emission Probes** in Left and Right couplers to monitor coupler conditioning
- **Faraday Cup**
- **Radiation defectors**:
  - ionization chambers for overall dose rate
  - 4 scintillator + PMT counters in the Hall for X-ray rates
  - two small plastic scintillators (SPS): up- and downstream of the cavity, directly on vacuum vessel
  - NaI crystal
- water flow and pressure
- thermocouples on cavity body and infrared sensors to look at Be windows
- gas pressure for tuner actuators
- vacuum pressure at various gages
- Solenoid: current, voltage, temperature, LHe level
- many more

MICE Cavity Commissioning/Operation at MTA

ACNET monitor



Device	Current Value	Min Value	Max Value	Units	Description
D:OUTTMP	61.842007	0.000000	100.000000	F	Outside temperature
E:201VAC	0.999298	N/A	N/A	Torr	Cavity top vacuum IG (OFF)
E:C2ACH4	30.000001	30.000000	35.000000	PSIA	Coax gas pressure
E:C2AMPL	-10.000000	N/A	N/A	dBm	Signal generator drive level
E:C2APR1	-0.091575	-10.000000	90.000000	PSIG	Tuner actuator input pressure
E:C2APR2	-0.412088	-1.000000	20.000000	PSIG	Tuner actuator push pressure
E:C2APR3	-0.228938	-1.000000	20.000000	PSIG	Tuner actuator pull pressure
E:C2CBIG	1.009429	N/A	N/A	Torr	Cavity bot vacuum IG (OFF)
E:C2CBPR	1.996244E-6	1.000000E-8	1.900000E-6	Torr	Vessel vacuum CCG
E:C2CLIG	1.009429	N/A	N/A	Torr	Left coupler vacuum IG (OFF)
E:C2CLPR	2.528555E-6	1.000000E-7	2.400000E-6	Torr	Left coupler vacuum CCG
E:C2CLRT	17.388889	10.000000	40.000000	C	Left coupler water return temperature
E:C2CLST	17.333333	10.000000	40.000000	C	Left coupler water supply temperature
E:C2CPRP	10.943224	0.000000	30.000000	PSI	Coupler water return pressure
E:C2CPSP	26.572040	20.000000	80.000000	PSI	Coupler water supply pressure
E:C2CRIG	1.009429	N/A	N/A	Torr	Right coupler vacuum IG (OFF)
E:C2CRPR	2.337138E-6	1.000000E-7	2.200000E-6	Torr	Right coupler vacuum CCG
E:C2CRRT	17.444444	10.000000	40.000000	C	Right coupler water return temperature
E:C2CRST	17.388889	10.000000	40.000000	C	Right coupler water supply temperature
E:C2CTPR	2.578249E-6	1.000000E-8	3.000000E-6	Torr	Cavity top vacuum CCG
E:C2CVRP	10.943224	0.000000	30.000000	PSI	Cavity body water return pressure
E:C2CVRT	18.055556	10.000000	40.000000	C	Cavity body water return temperature
E:C2CVSP	-0.778388	N/A	N/A	PSI	Cavity body water supply pressure (broken)
E:C2CVST	18.500000	10.000000	40.000000	C	Cavity body water supply temperature
E:C2DTC	-0.212963	-6.500000	0.500000	degC	Cavity temperature differential

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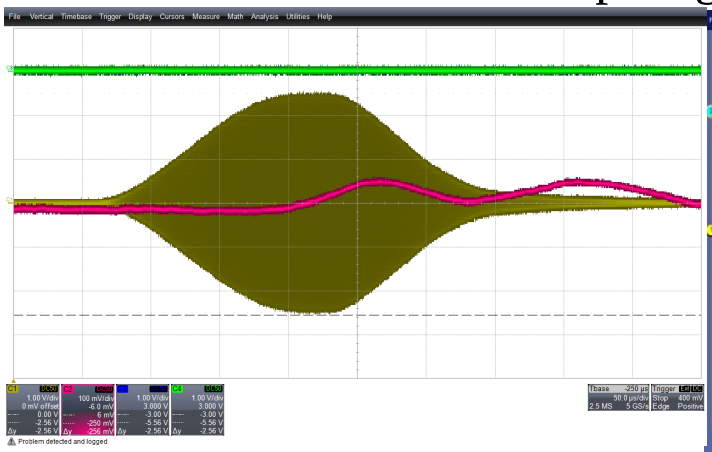
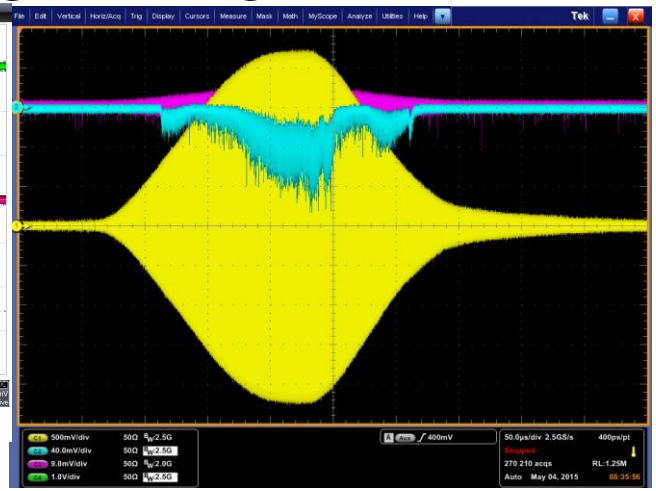
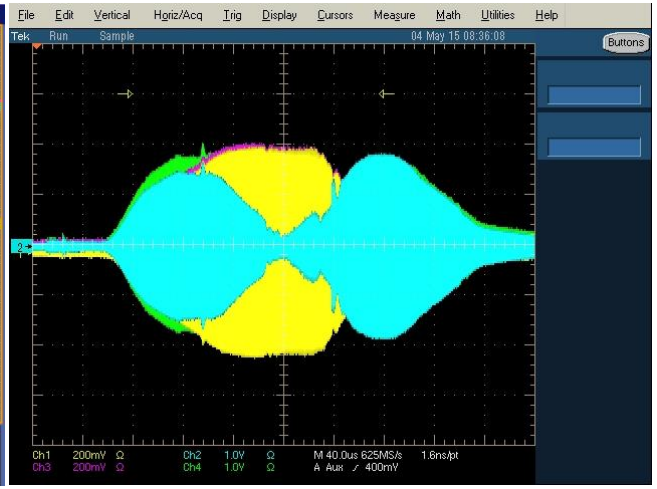
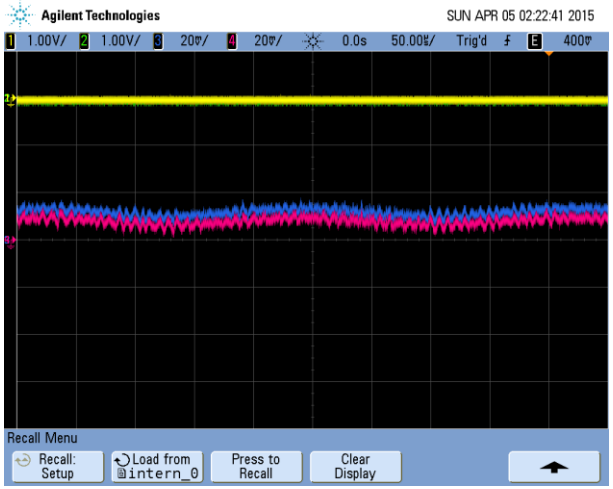
MICE Cavity Commissioning/Operation at MTA

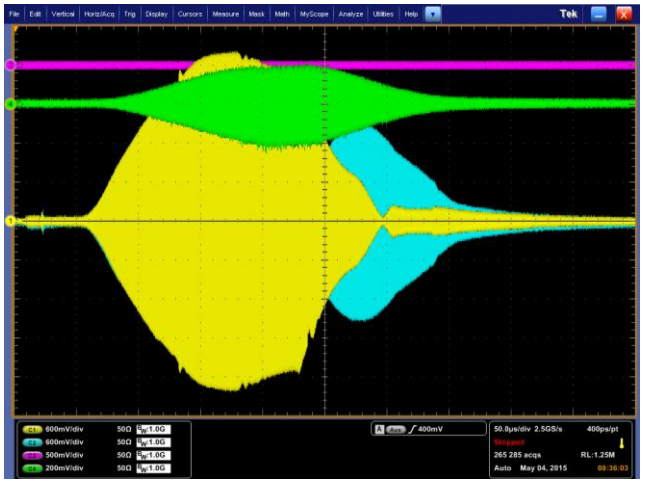
Scope signals during B=5 T run at 11 MV/m.











Top Left: PU1, Faraday Cup, Light #1 and #2;

Top Center: PU2, SPS upstream, SPS downstream, Light#3;

Top Right: Forward and Reflected powers from Right and Left Coupler arms;

Bot. Left: Left and Right Coupler Light and FEP signals;

Bot. Right: Forward and Reflected powers at Klystron, Light #4, NaI crystal.

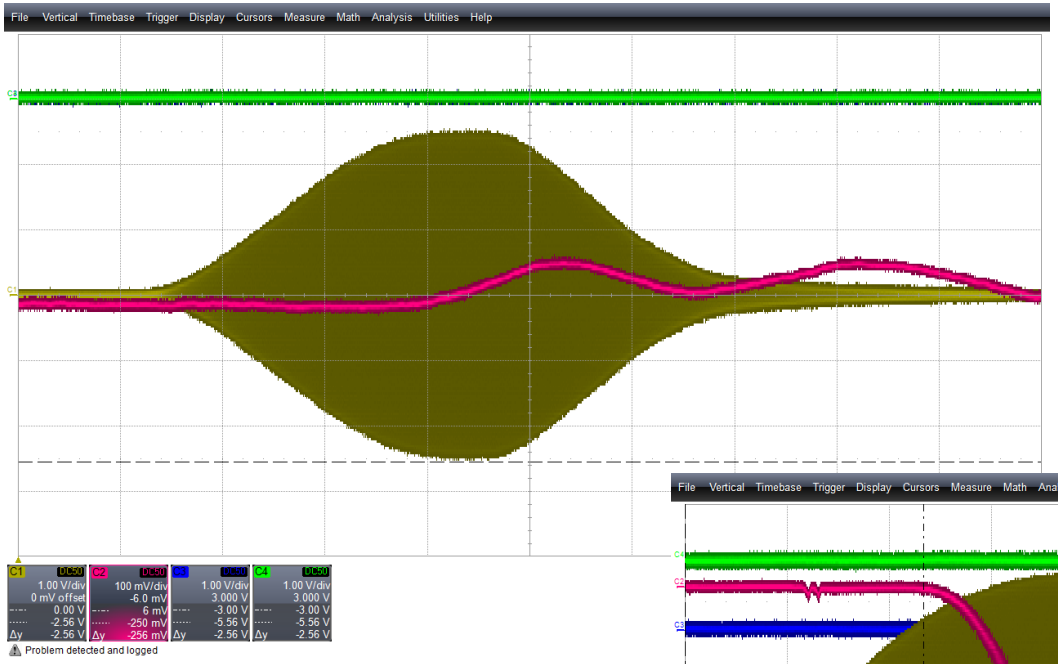
MICE Cavity Commissioning/Operation at MTA

- **B = 0 "shakedown" run with Cu windows (Sept. 15 – Nov. 26 2014)**
  We had achieved gradients of **13.5 MV/m** with breakdown probability **~ 10^{-6}**.
  Recorded **32 breakdown** events
  Had issues with modulator stability (~ 400 trips)

- **B = 0 run with Be windows (March 18 – April 6)**
  0.5M+ pulses at >**11 MV/m** (~1.6 MW input power)
  Dose rate comfortably below tracker damage threshold
  No breakdown events
  Up to 14 MV/m for short periods
  No issues with the cavity or services (vacuum, water)
  All instrumentation and DAQ worked well

- **B = 5 T run with Be windows (April 24 – ongoing)**
  Detectors and other components moved, rebuilt as needed.
  1M+ pulses at >**8 MV/m** (~1 MW input power)
  3M+ pulses at >**11 MV/m** (~1.6 MW input power)
  Dose rate comfortably below tracker damage threshold
  No issues with the cavity or magnet operation
  No breakdown events
  Up to 14 MV/m; held at **13.5 MV/m** for 3M+ pulses

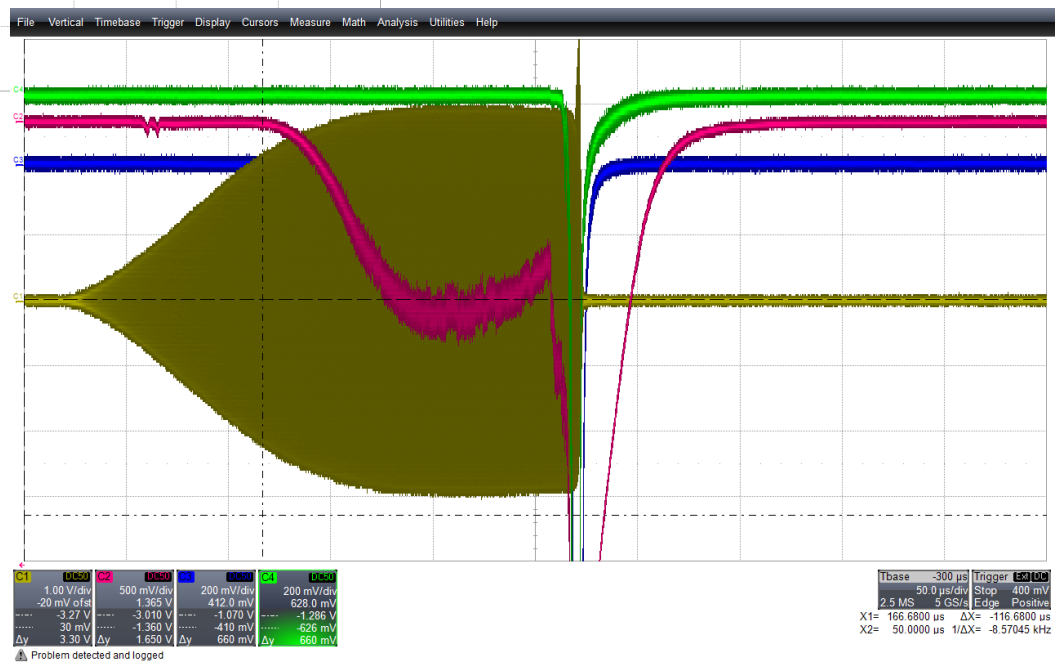
MICE Cavity Commissioning/Operation at MTA



11 MV/m

Example of Breakdown event

13.5 MV/m



MICE Cavity Commissioning/Operation at MTA

- **Conclusions:**

  We have successfully demonstrated that the RF Cavity Module can be operated in MICE channel at gradient of **10.3 MV/m** in presence of magnetic field.

- **Plans:**

  - Tuner System Test at MICE operation frequencies, collecting 0.25M+ pulses at ~ 1MW power, and 0.5M+ pulses at ~2MW power.

  - We also plan to have “physics runs” to observe dependencies of various signals on magnetic field.