Spectrometer Solenoid Quench Protection Systems

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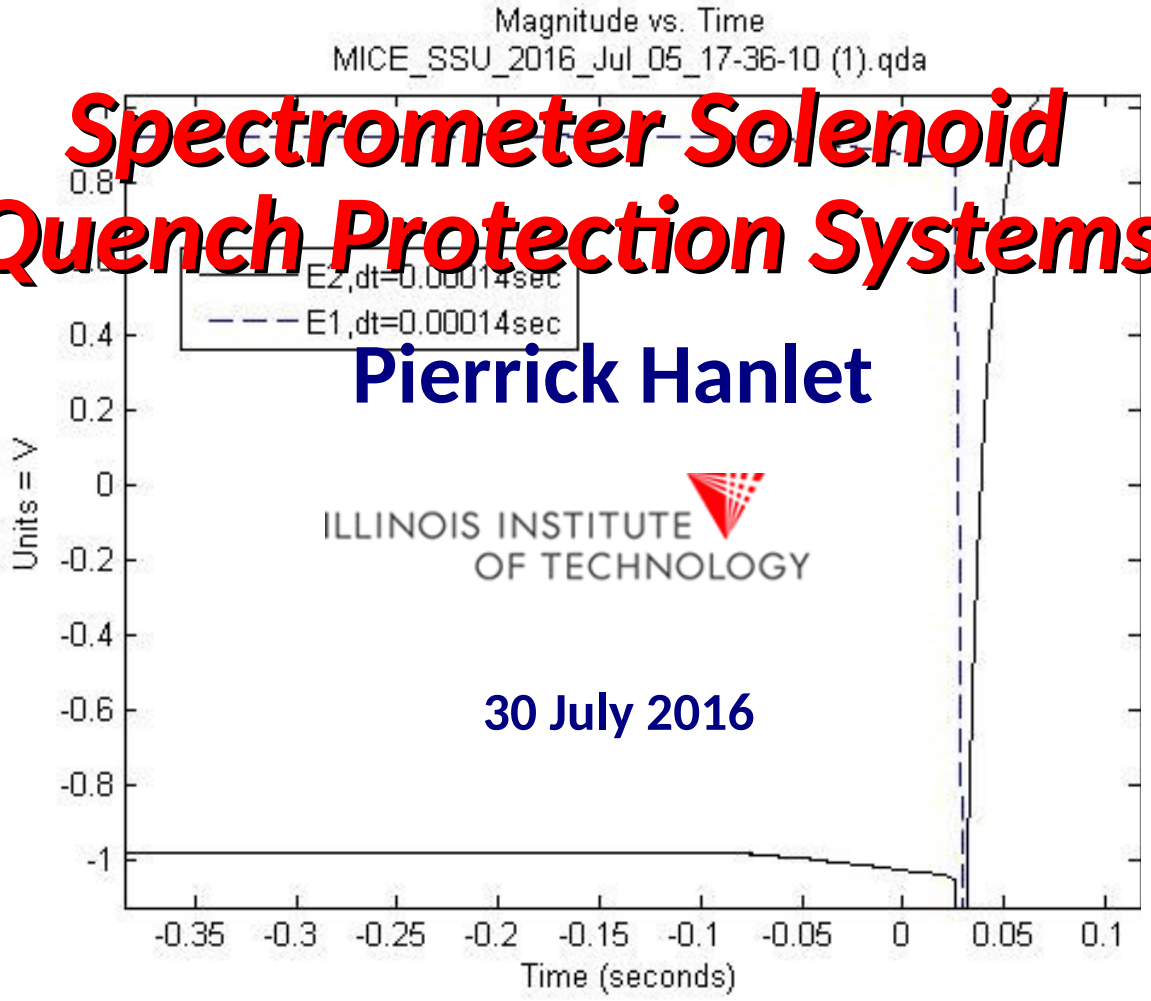
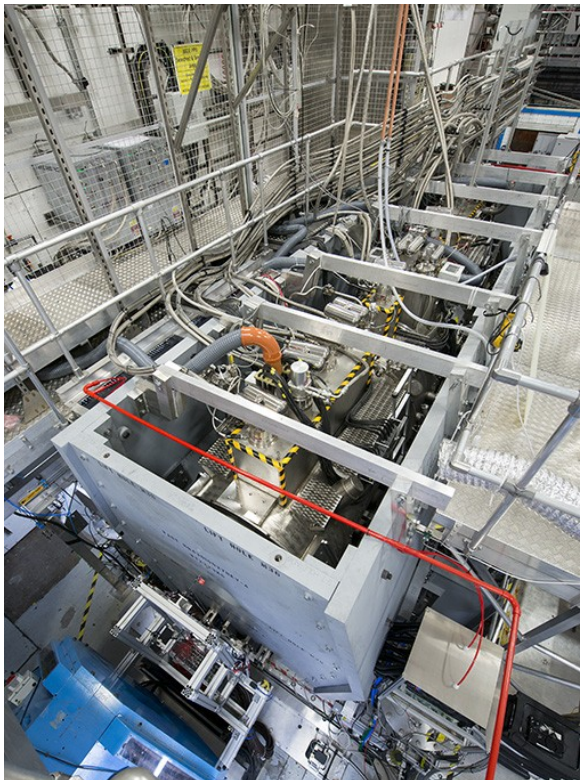


Outline

- Description of system
- Principle of SS QPS (Quench Protection System)
- Upgrades since last CM
- Plots
- What is next?



SS2 (SSU) As Built

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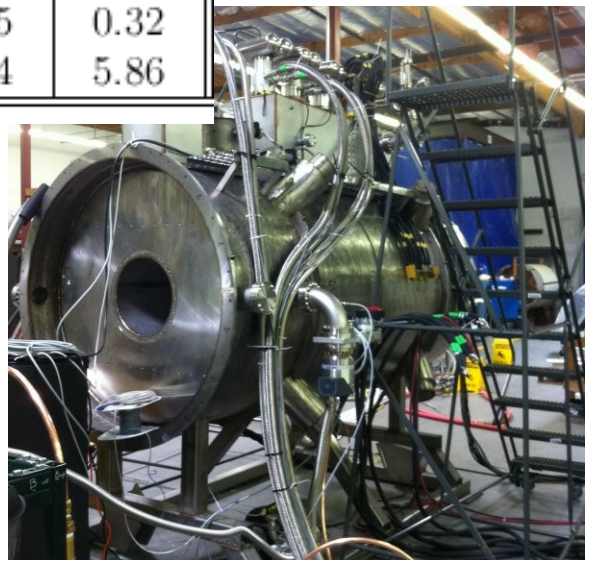
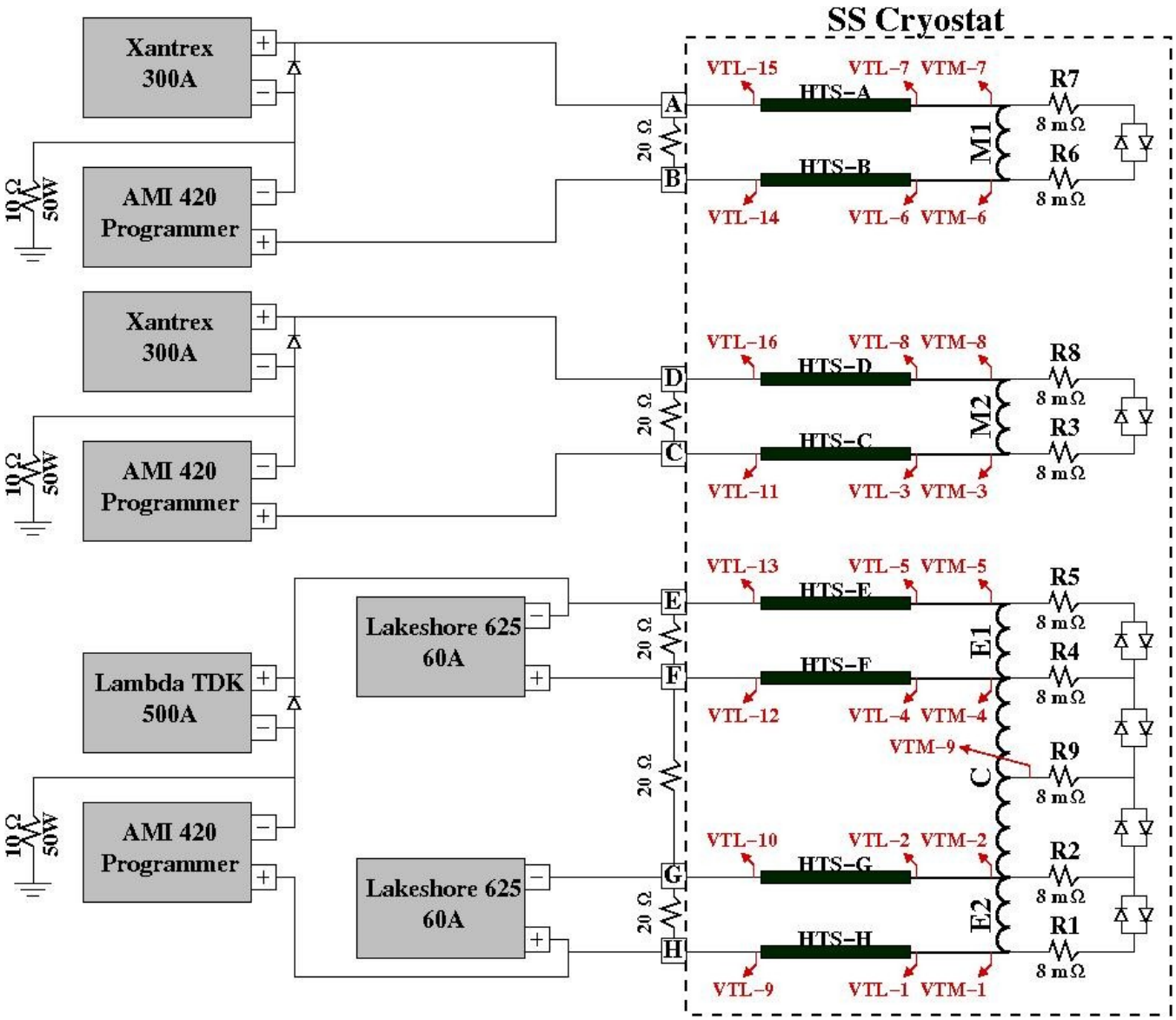
Table 1: Summary of MICE Spectrometer Solenoid Magnet (SS2) Parameters.

Parameter	M1	M2	E1	C	E2
Coil inner radius (mm)	258	258	258	258	258
Coil thickness (mm)	46.2	30.9	60.9	22.1	67.8
Coil length (mm)	201.3	199.5	110.6	1314.3	110.6
Current Center Axial Position (mm)	124.0	564.0	964.0	1714.0	2464.0
Number of layers	42	28	56	20	62
Number of turns/layer	115	114	64	768	64
Number of turns	4830	3192	3584	15360	3968
Coil current density (A/mm^2)	137.7	147.8	124.3	147.7	127.1
Coil current (max) (A)	264.8	285.6	233.7	275.5	240.2
Coil self inductance (H)	12.0	5.0	9.0	40.0	11.3
Coil Stored Energy (MJ)	0.42	0.20	0.26	1.55	0.32
Peak Field in Coil (T)	5.30	4.32	5.68	4.24	5.86



- *25 voltage taps*
  - *8 pairs on HTS leads*
  - *8 pairs on LTS leads*
  - *6 across coils*
- *resistively coupled/isolated*

SS Simplified Layout



Principle

- Superconductors have no resistance, $\Delta V = IR = 0$
  - voltage taps (VTs) across each segment
  - HTS (High Temperature SC) from warm external leads
  - LTS (Low Temperature SC) between HTS and coil
  - coils
- When ramping magnets, $\Delta V = -L\, dI/dt$ on coils (not leads)
- Additional $\Delta V = -M\, dI/dt$ from adjacent coils
- Center coil has a center VT
- Each coil has LTS sections without VTs – ***no protection!***
- To protect magnets:
  - monitor voltages across leads, trip on ΔV above threshold
- When thresholds are exceeded, open contactors

Principle

To protect the magnets:

- **LEADS**: monitor lead VTs, trip on ΔV above threshold
  - LTS leads have 10mV thresholds
  - HTS leads have 1mV thresholds
  - QPS sums leads
  - separate contactors for leads (more later)

- **MATCH COILS**: monitor VTs across M1 & M2:
  - threshold set on $\Delta V - L\, dI/dt$, where L is a "balancing" parameter
  - threshold set on $\Delta V - M\, dI/dt$, where M is a "balancing" parameter to account for other coils
  - request dI/dt for FC

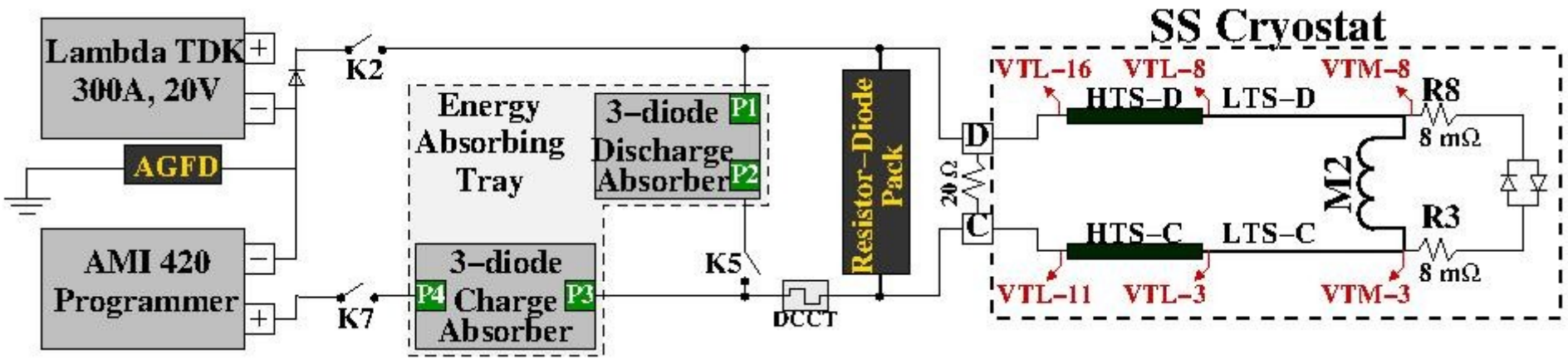
Principle

To protect the magnets – continued:

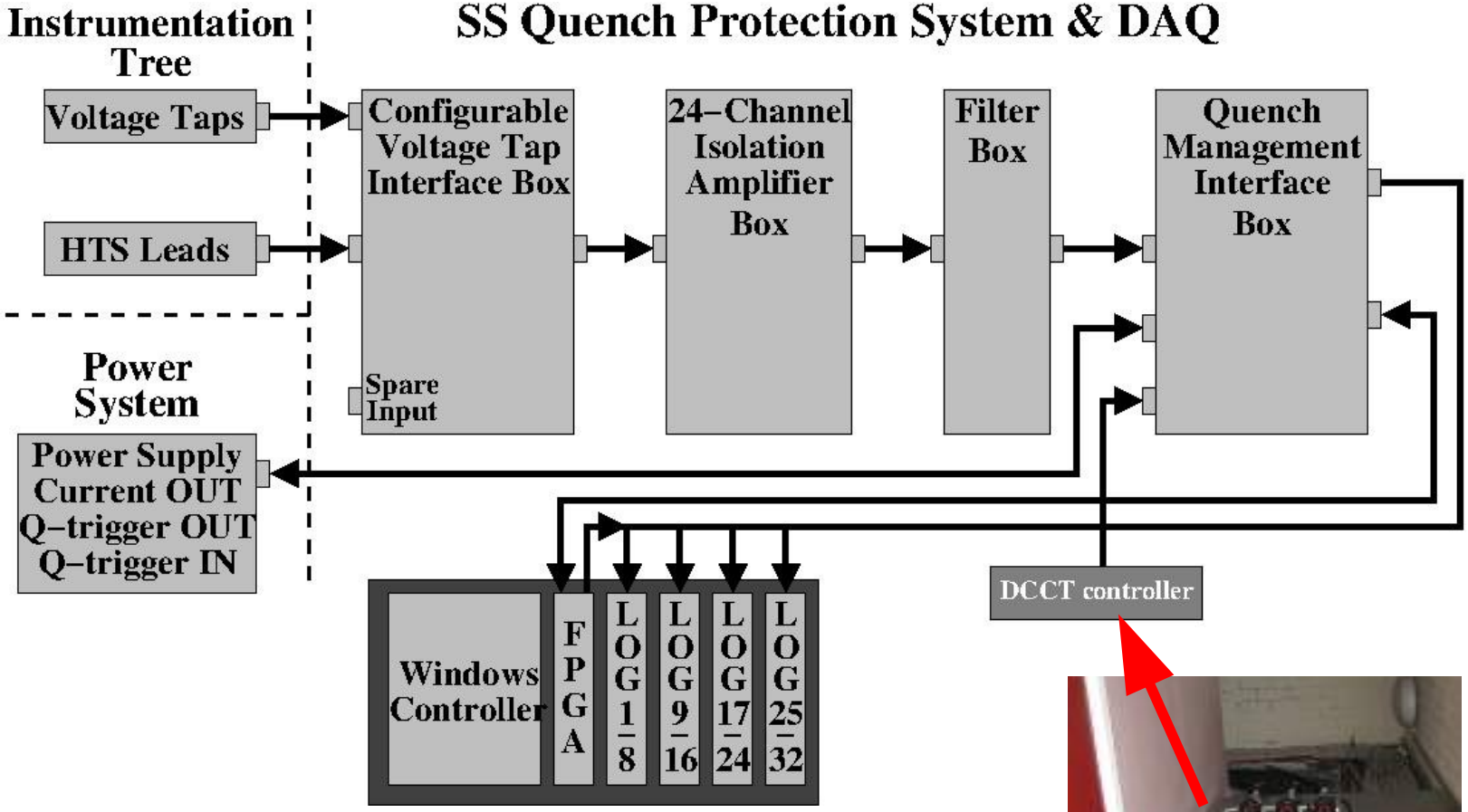
- **CENTER**: monitor VTs across E1+C/2 and E2+C/2, trip on ΔV above threshold
  - E1 – C – E2 are wired in series and have single 300A PSU
  - trim power supplies sink current on E1 and E2
  - since C coil has center VT, can buck the 2 half coil signals
  - threshold is set on (E1+C/2) - L (E2+C/2) where L is a "balancing" parameter

Since last CM

- Alan, Sandor, and I found VTs for both SSD center tap and SSD-M2, this allowed
  - protecting SSD with (E1+C/2) - L (E2+C/2)
  - protecting one of SSD M2 LTS leads
- Updated Power train and QPS
  - added external Resistor-Diode pack
  - added DCCT information for I and dI/dt measurements
  - added to EPICs interface



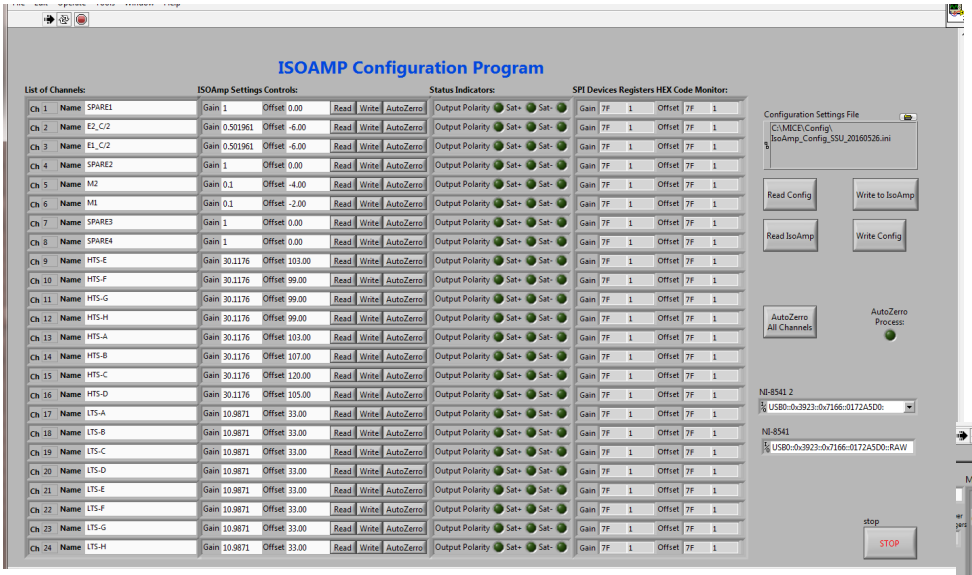
SS QPS Layout



SS QPS Features

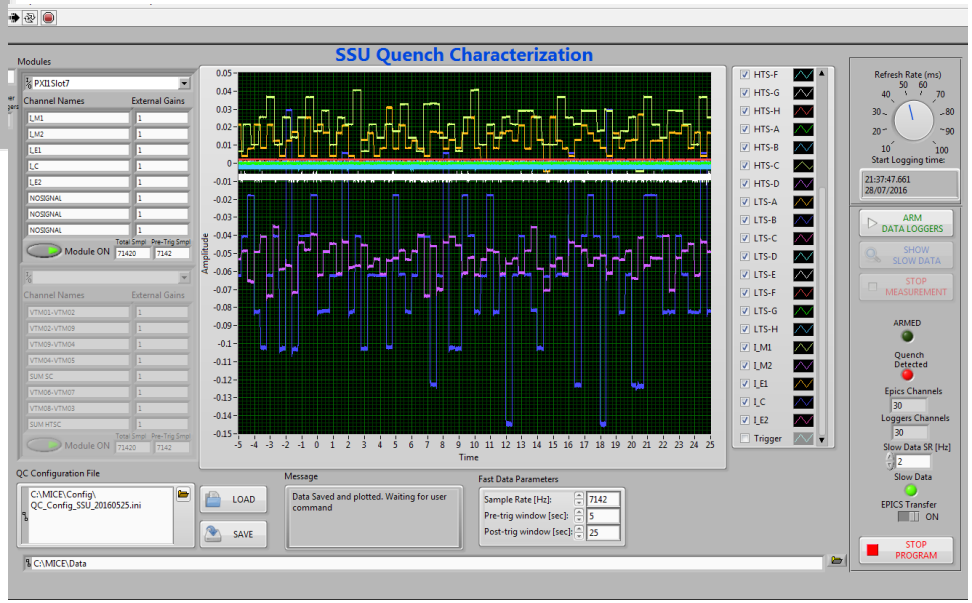
- digital (FPGA) and redundant analog QD
- signals monitored and stored:
  - lead voltages
  - coil voltages
  - currents & dI/dt signals
  - triggers
- open contactors and reports to control system
- data loggers store fast (~7kHz) data in ring buffer
- output signals to EPICS – 5Hz – slow logging

QPS Interface

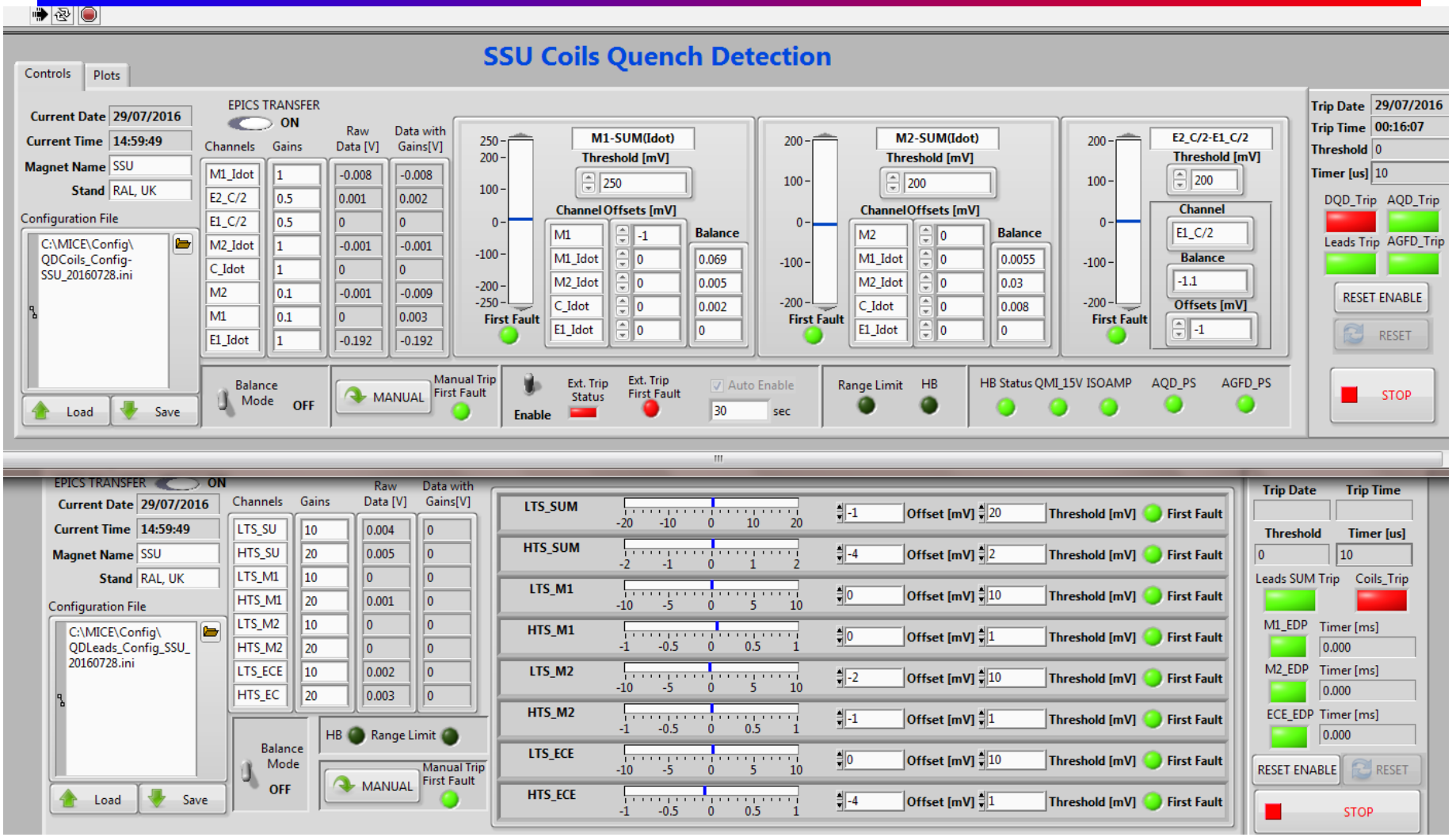


IsoAmp Configuration

Quench Characterization

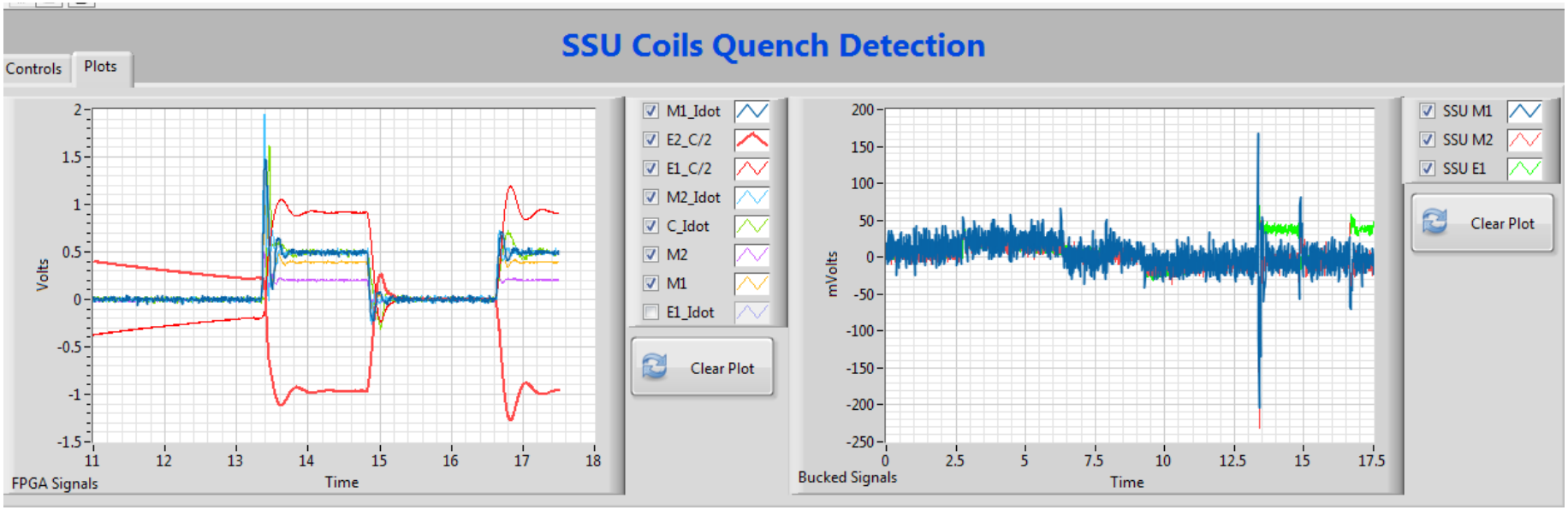


QPS Interface



Coils and Leads QD Configuration

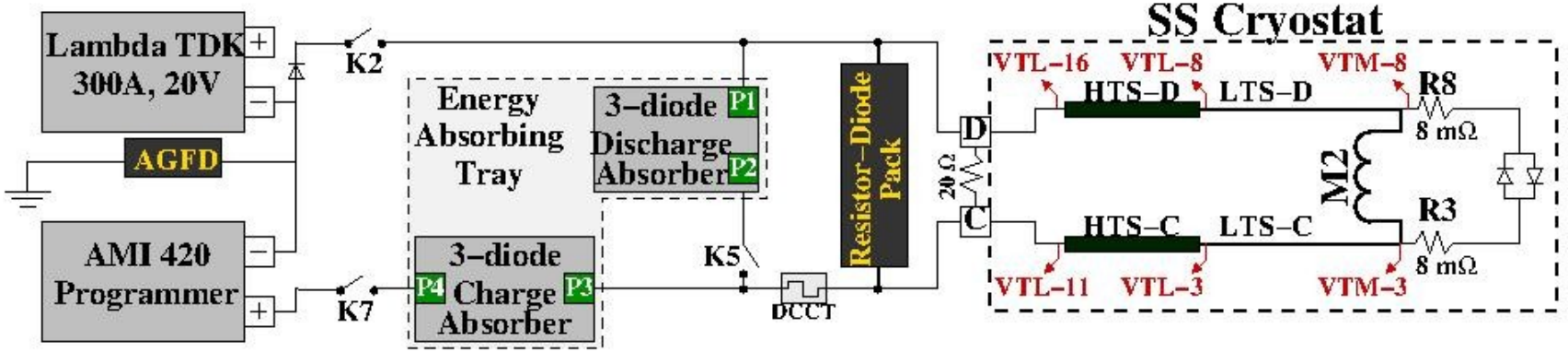
QPS Interface



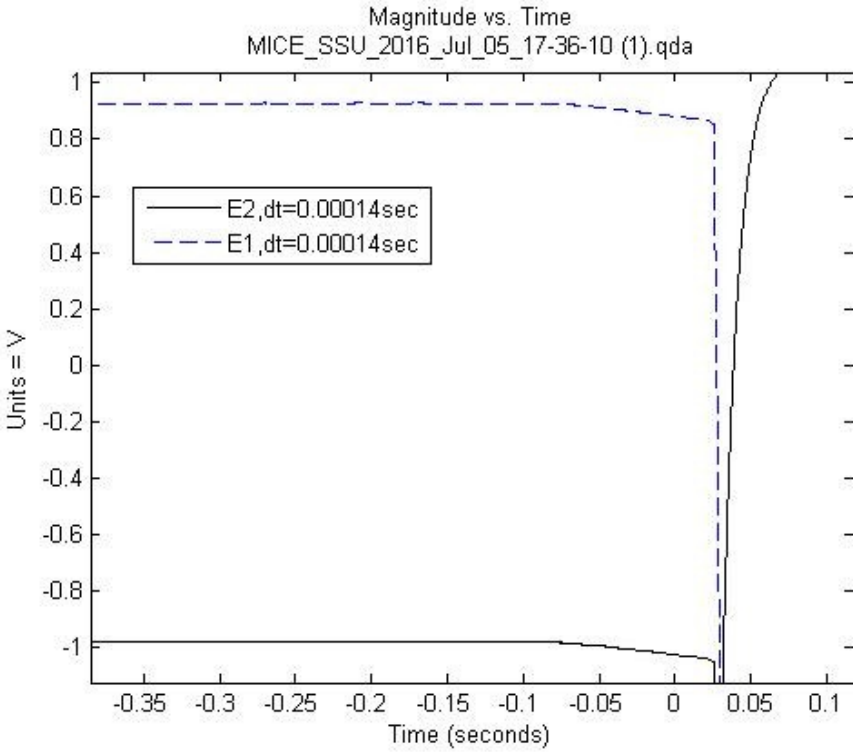
Coils QD Configuration - monitoring

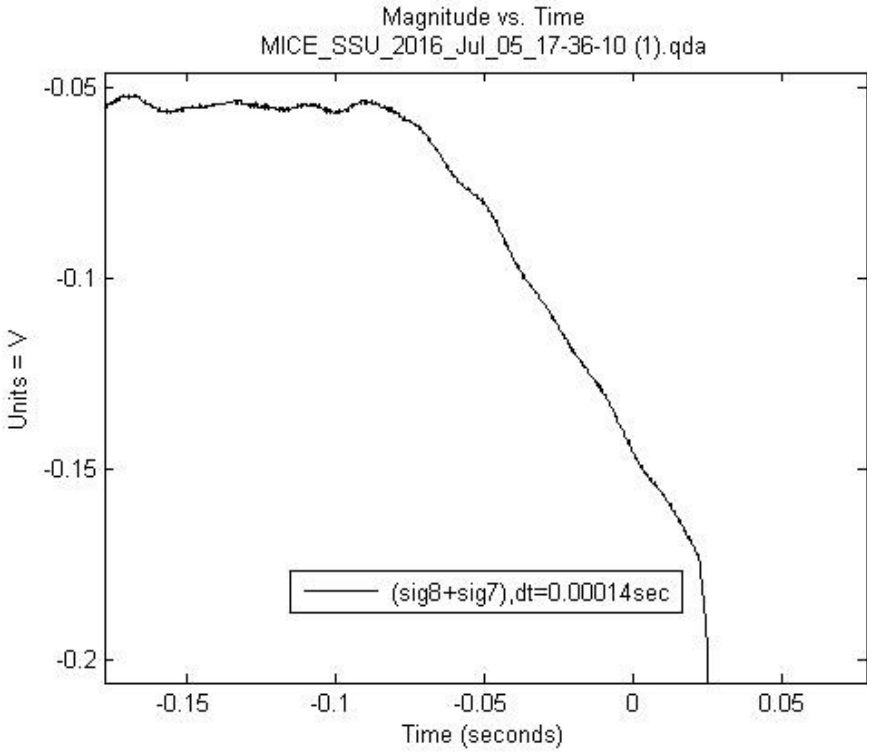
Quench Scenario

- Any quench will first open PSU contactors (K2 & K7)
- To protect internal dump circuit (the LTS section without VTs), energy is extracted through Discharge Absorber
- If HTS or LTS leads show voltage growth, QPS opens K5 to prevent damage to leads => energy is dissipated in internal absorber
- If then, the internal circuit opens, the Resistor-Diode pack will become the energy dump
- Output fast data and Quench signals



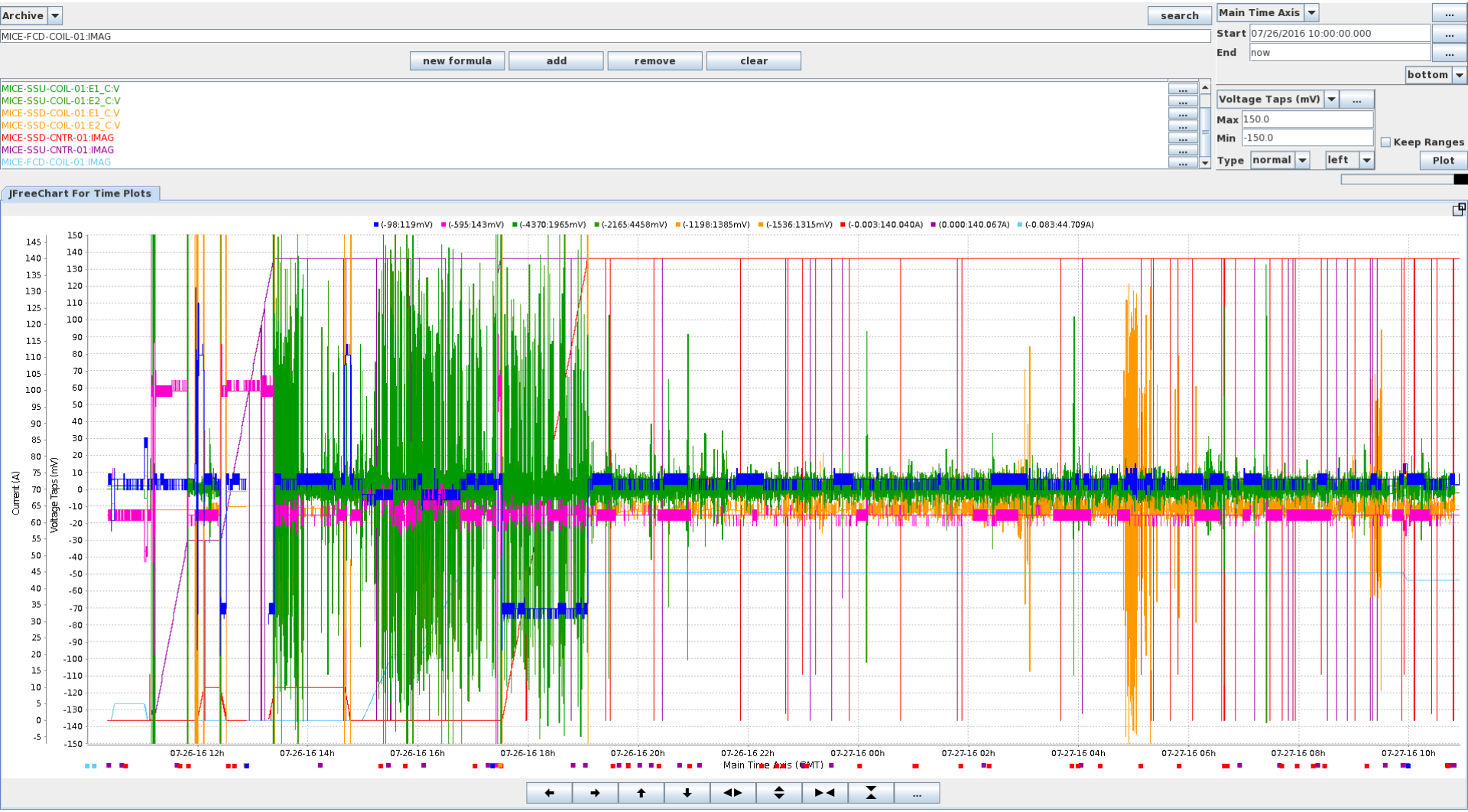
Quench Fast Data Plots



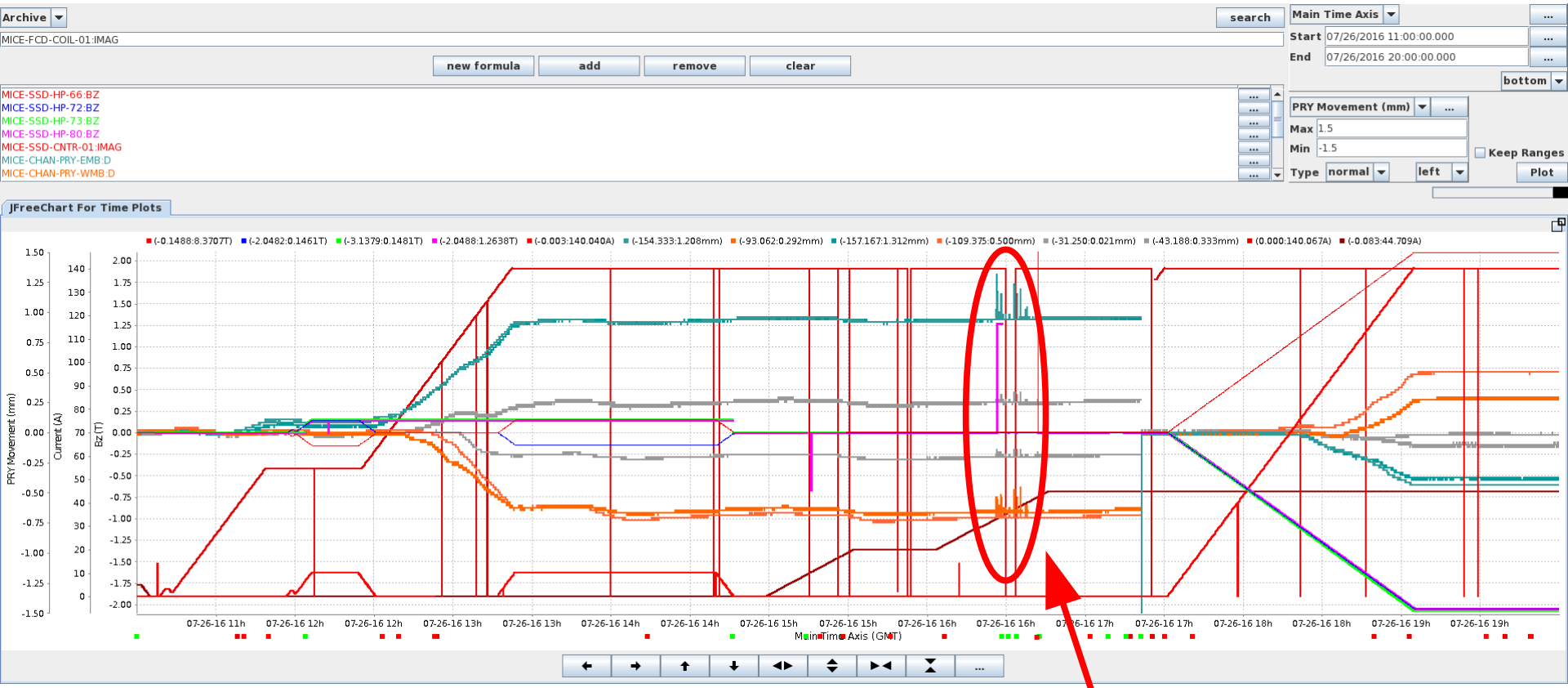


Quench Slow Data Plots

Quench Slow Data Plots



Quench Slow Data Plots



PRY Movement

What's Next

Biggest remaining issue is the noise – note that the coil thresholds are now set to 50X lower than when the magnets were first trained at Wang, NMR

- try to find source, then decide to fix or live with it
- add FC DCCT
  - use to remove mutual inductance contribution
  - will serve as independent current measurement – fixes AMI430 communication problem when system trips
- software modifications
  - QD signals to EPICS
  - inhibit threshold adjustments from live screen
  - additional information from AGFD