Quench Protection Systems

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SS1/SS2 Lessons Learned

- *Will need to retrain after warming*
- *~13 quenches*
- *recool magnet after quench >500l of LHe*
- *4-5 hours to recover and settle*
- *additional quenches w/new forces*
- *~6 seconds for 5 coils to quench*
- *transients ~100μs*

FC2 Lessons Learned

- *few quenches for training*
- *remembers training even after thermal cycle*
- *using cryocoolers to re-cool; ~3 days to recover*
- *additional quenches w/new forces (?)*

Integrated QPS

- *QPS is Quench Protection System*
- *existing systems:*
  - *Fermilab TD – SS*
  - *Daresbury – FC (and DS)*
- *must keep existing QD functionality*
  - *identify similarities and differences*
  - *keep all? reuse parts? completely new?*
- *determine requirements: SS, FC*
- *outline integrated system*

Integrated QPS

For each system:

- *number of voltage taps*
- *signals for quench detection*
- *coupling of these signals*
- *dynamic range of the signals*
- *requisite time resolution for transients*
- *duration of quench*

Existing Systems

Voltage Tap Input
- 3 Voltage taps
- 3 Resistive measurement

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Amplifier
- Central tap amplified
- Outer taps to provide reference

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Isolator
- Signal isolated from magnet

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Comparator
- Window comparator to compare signals

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De–Energizer
- Signal out of range
- System latched in quench state

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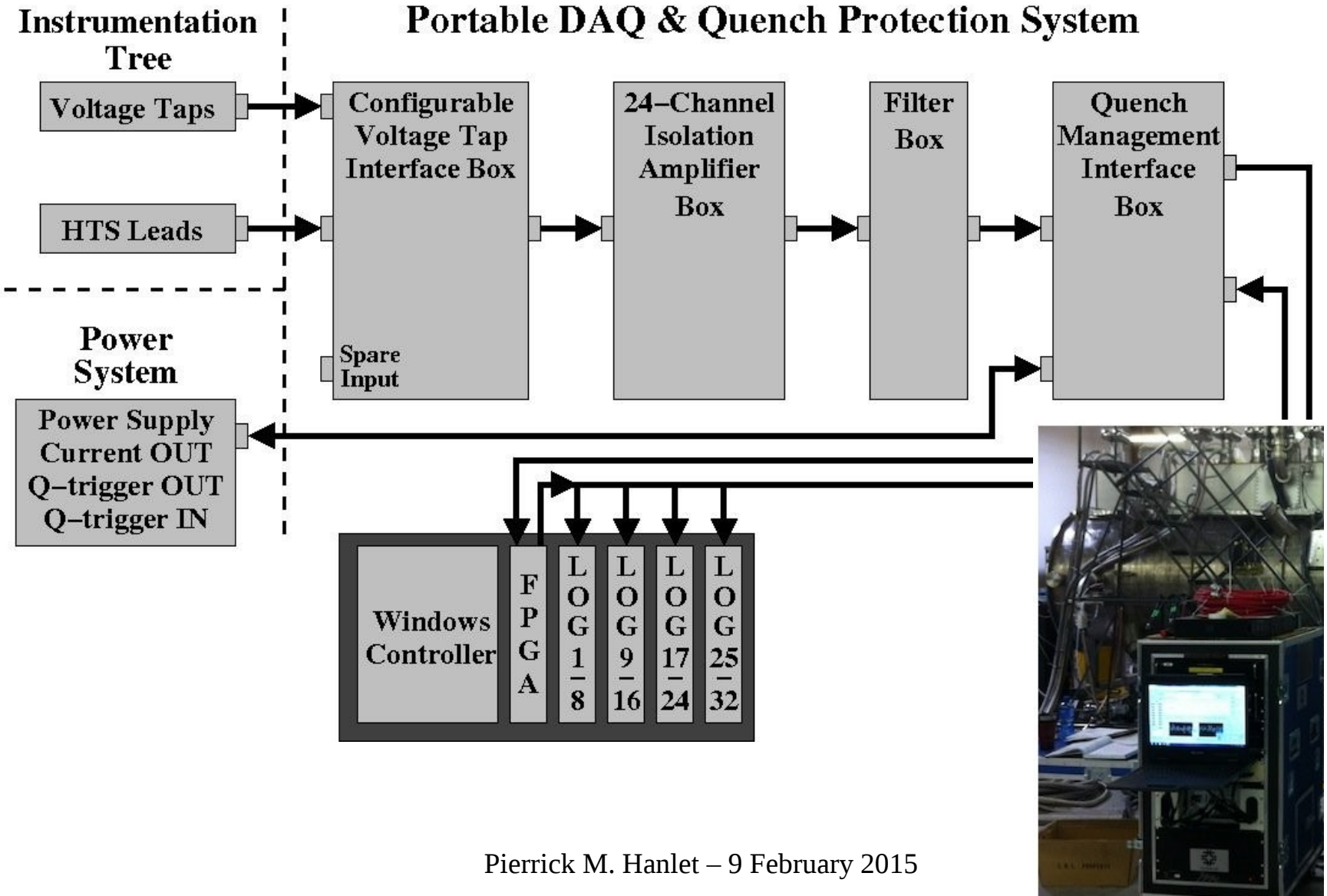
Quench Trigger
- Relay chain commenced
- Magnet contactors opened

Existing Systems



SS2 As Built

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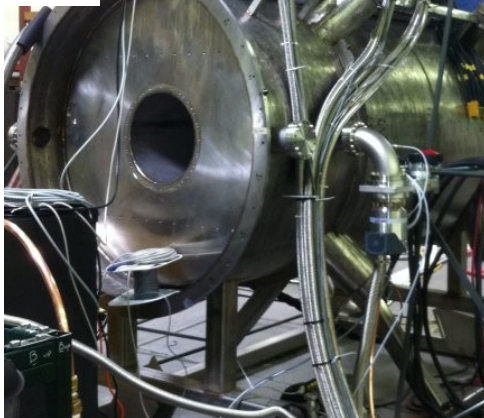
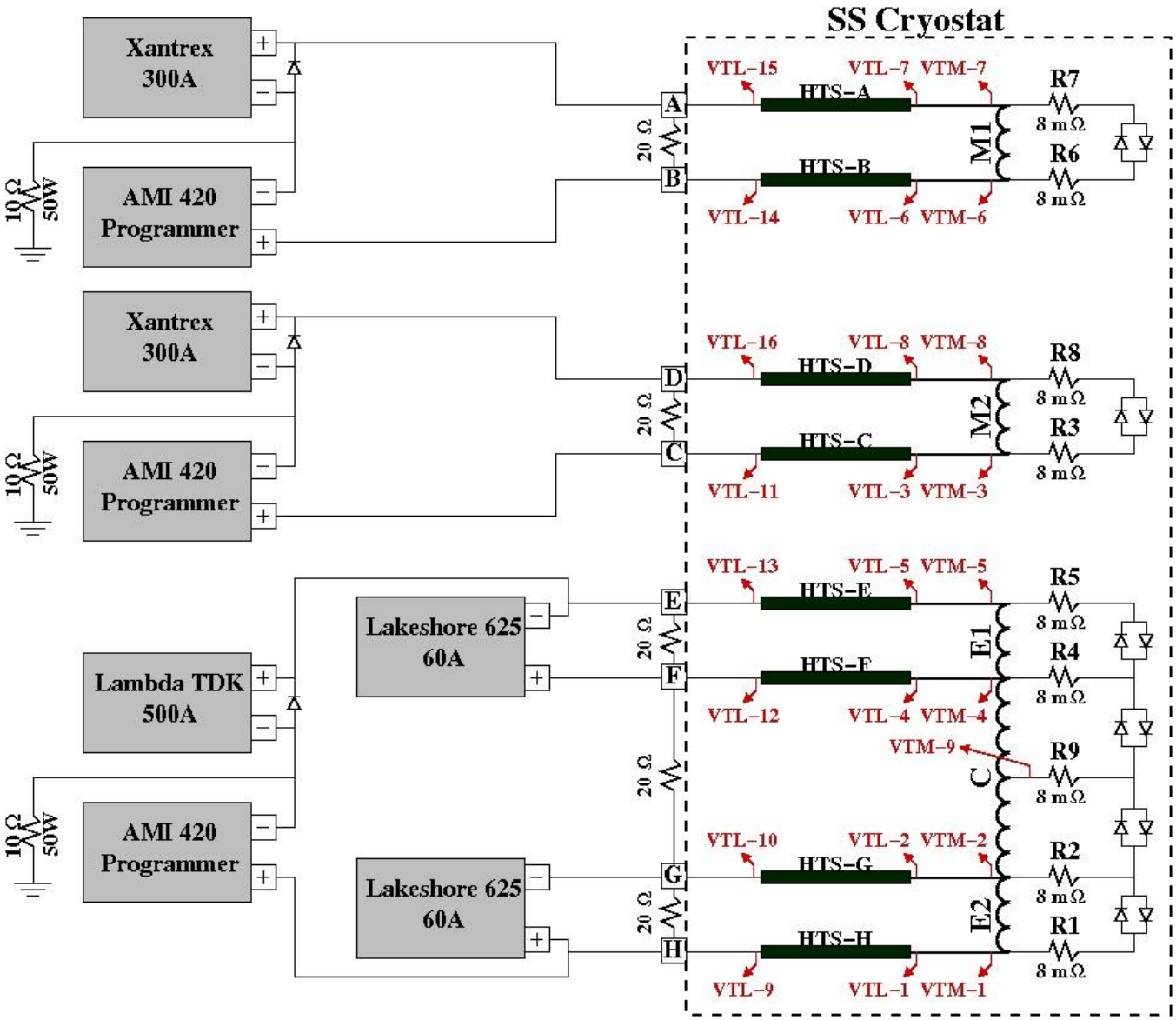
Table 1: Summary of MICE Spectrometer Solenoid Magnet (SS2) Parameters.

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



FC1 As Built

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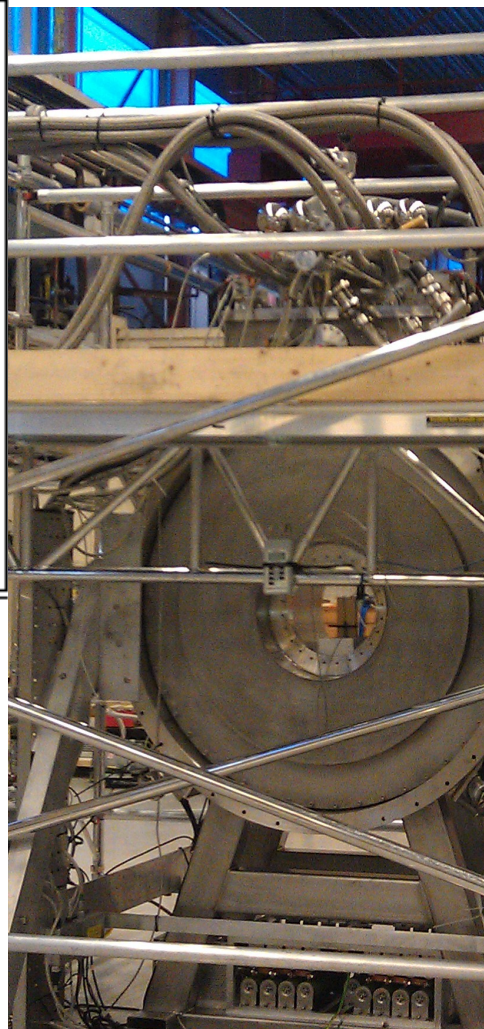
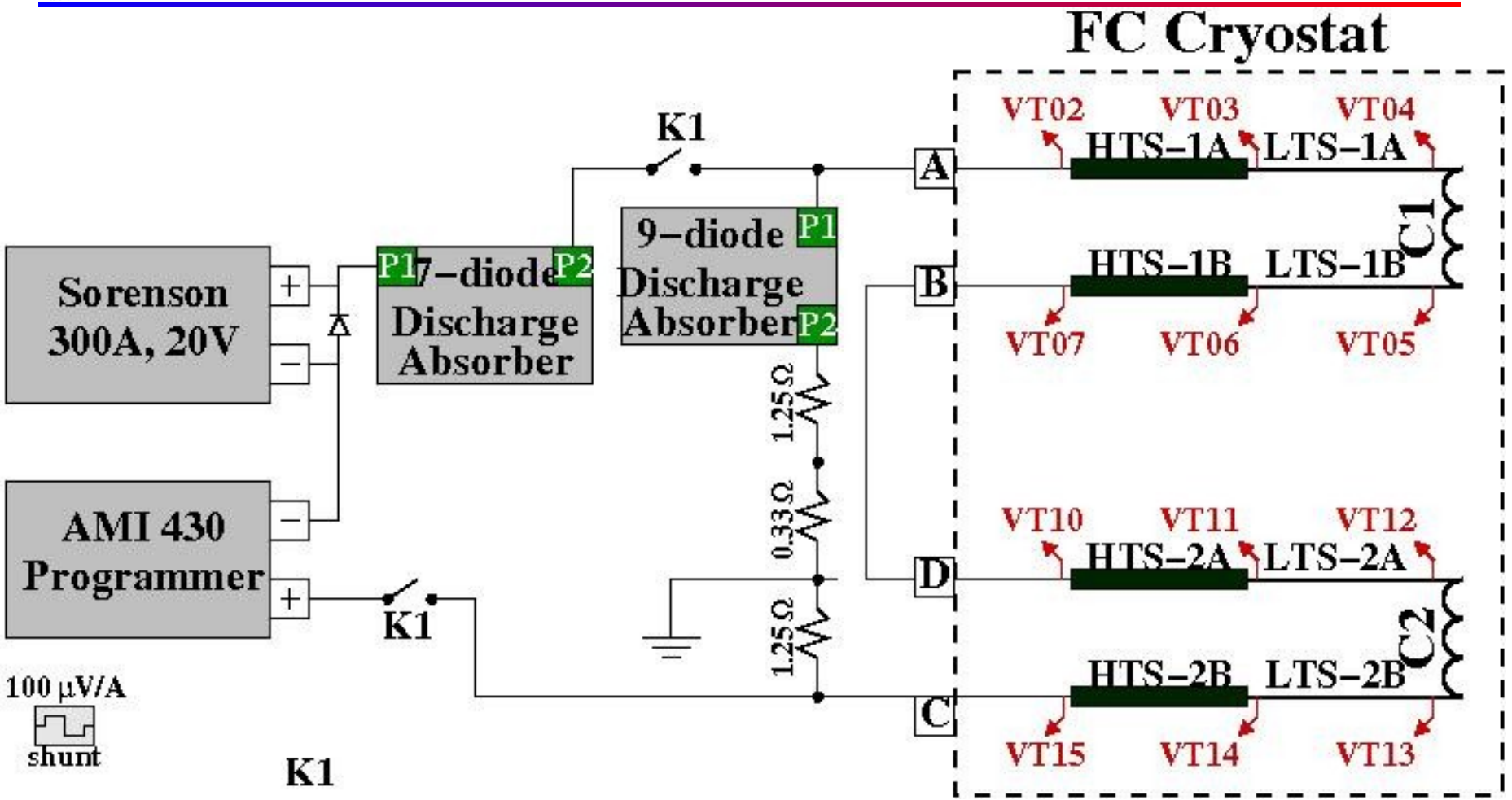
Table 1: Summary of MICE Focus Coil Solenoid Magnet (FC) Parameters.

Parameter	C1	C2
Coil inner radius (mm)	267.6	267.6
Coil thickness (mm)	94.3	94.3
Coil length (mm)	213.3	213.3
Current Center Axial Position (mm)	239.3	405.4
Number of layers	84	84
Number of turns/layer (average)	134	134
Number of turns	11256	11256
Coil current density (A/mm^2)	125.8	125.8
Coil current (max) (A)	224.8	224.8
Coil self inductance (H)	80.3	80.3
Coil Stored Energy (MJ)	2.03	2.03
Peak Field in Coil (T)	7.52	7.52



- *12 voltage taps*
  - *4 pairs on HTS leads*
  - *4 pairs on LTS leads*
  - *2 across coils*
- *resistively coupled/isolated*

FC Simplified Layout



Other Considerations

- *Considerations*
  - *common mode*
  - *ground loops*
  - *cable inductance*
- *Testing plan must be properly detailed*
- *Run Control and State Machine key components of operation*
- *MICE note 435*

History

- Summer 2013 – S.Griffeths/T.Hartnett/P.Hanlet discussed QPS integration document
- November 2013 – Sandor Feher (FNAL TD) joined effort to identify needs of SS QPS
- February 2014 – Wang NMR, task force determined plan and needs for overlap of both SS & FC systems
  - leave QPS as is
  - add active ground(earth) (AGF) fault detection for SS and FC
- Sandor led effort to develop QPS requirements document
- SS Specifications document followed
- September 2014 – specifications agreed and plan made to build QPS racks at FNAL TD
- Beginning January, sent DL style rack to US for build

Present Status

- DL system
  - No significant changes from acceptance runs
  - 2 QPS in single rack
  - All parts in hand
- FNAL system
  - minor changes – additional channels for HTS/LTS leads
  - 2 QPS in single rack
  - FNAL to provide AGF for all magnets
  - DL style rack being populated at FNAL, ready in early March
  - commissioning in early March
  - shipping shortly after
- All racks to be installed in RR2
- 3rd rack to house AGF and transformer

FNAL QPS

Present Status

- Each QPS is independent
- Each QPS generates its own trigger
- Data logging
  - each system has own LabView based data logging (fast logging)
  - LabView VI to fill slow data logging (average and rms) to archiver
  - want to standardize pre and post trigger times
  - will create OR of QPS triggers to force logging of all systems regardless of source
  - after post trigger, all data for quench to be written to disk
- Will pre-commission QPS systems in spring by running power supplies into short

Summary

- Independent QPS for each MICE Channel magnet
- DL/FNAL systems fully vetted during acceptance operations
- Minor modifications to each system for final integrated system
- FNAL system due mid-late March
- DL system due mid March
- Pre-commissioning planned after installation
- Triggering/Data logging plans in hand