

# Work Status Report

## Magnet Controls and Monitoring Systems of Halls A, B, C, and D

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Detector Support Group  
05/01/2019

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- **Conclusions**

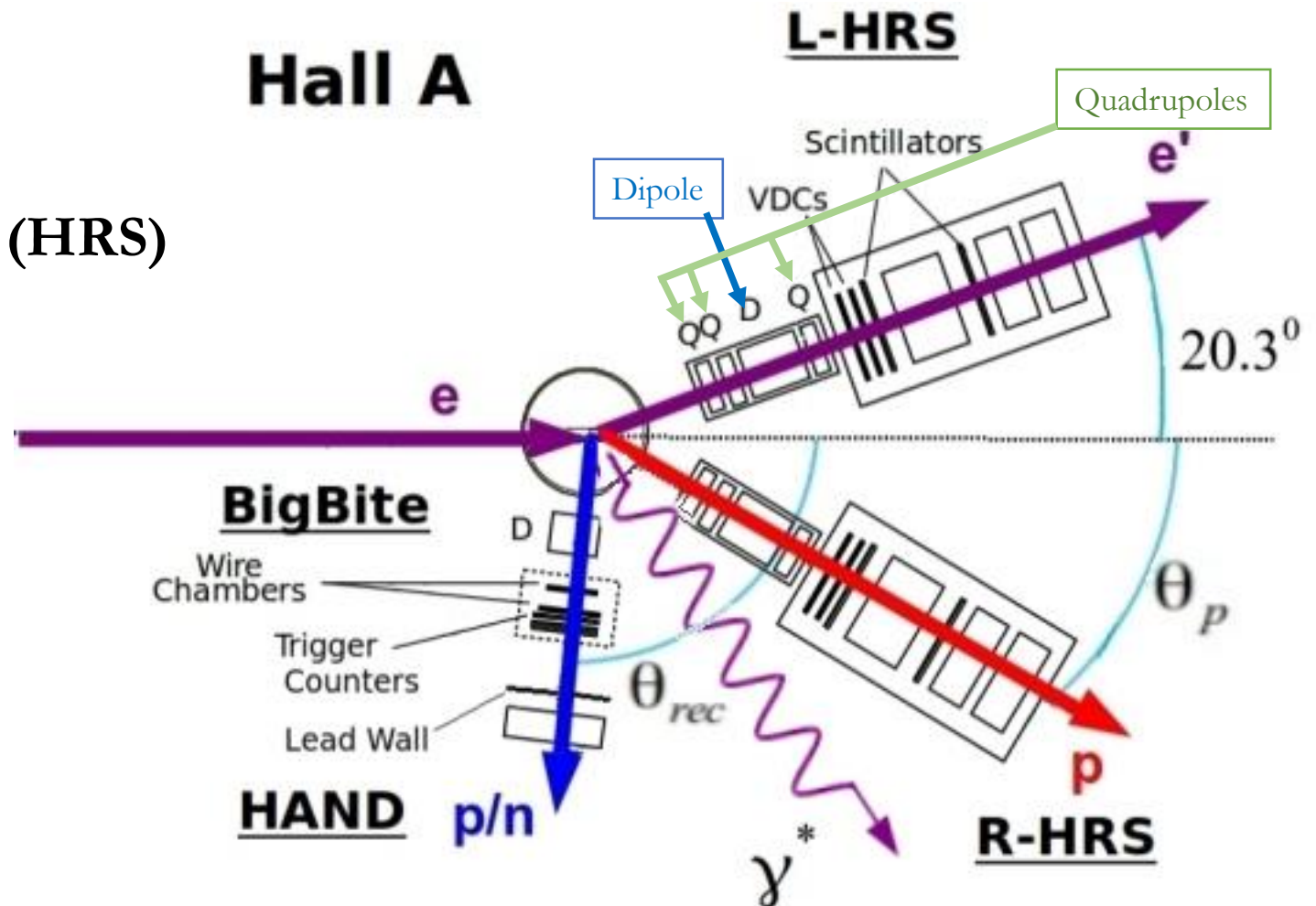
# Hall A – Magnets Overview

- Each High Resolution Spectrometer (HRS)

- Three superconducting quadrupoles
- One superconducting dipole

- Nominal operation parameters

- Q1: 1850 A,  $\nabla B = 9.5$  T/m
- Q2/Q3: 3250 A,  $\nabla B = 3.5$  T/m
- Dipole: 1500 A,  $B = 1.6$  T



Plan view of left and right HRS with the magnets

# Hall A Magnets – Dipole Power Supply Controls



10 V, 2000 A DC Dynapower dipole magnet power supply



DC input modules (x3)

PLC chassis Power Supply

DC output modules (x4)

SCL 500 PLC Controller

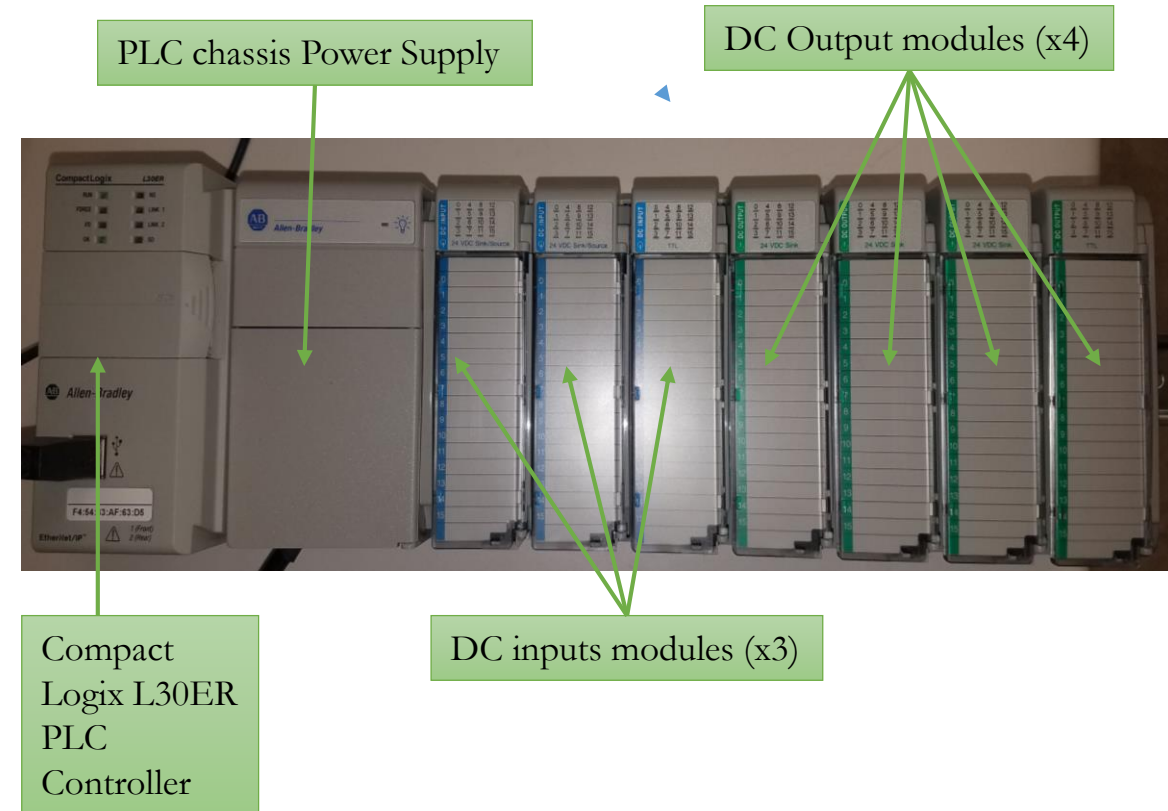
Existing 1747-L511 SCL 500 series PLC on PSU controls of dipoles on right and left arms

- **Dynapower power supplies**
  - Power L-HRS and R-HRS dipoles
- **Allen-Bradley SLC 500 PLC system**
  - Monitored interlock circuits and controlled switches
- **Issues**
  - PLC faults required access to hall to recover normal operations
  - Controller lifecycle status discontinued
    - Production ended Jan 2017 †

# Hall A Magnets – DSG Contributions

## DSG recommended and procured

- **Allen-Bradley CompactLogix**
  - Standardization across Physics division
  - Nearly all existing modules have direct replacement
  - On-the-fly code changes possible
  - Low cost compared to other systems
    - ~\$4,500/PLC system
  - PLC system comprises
    - L30ER controller (x1)
    - DC input module (x3)
    - DC output module (x4)
- **Three PLC systems**
  - Two for dipole PSUs (left and right arms of HRS)
  - One spare
- **PLC systems received March 2019**

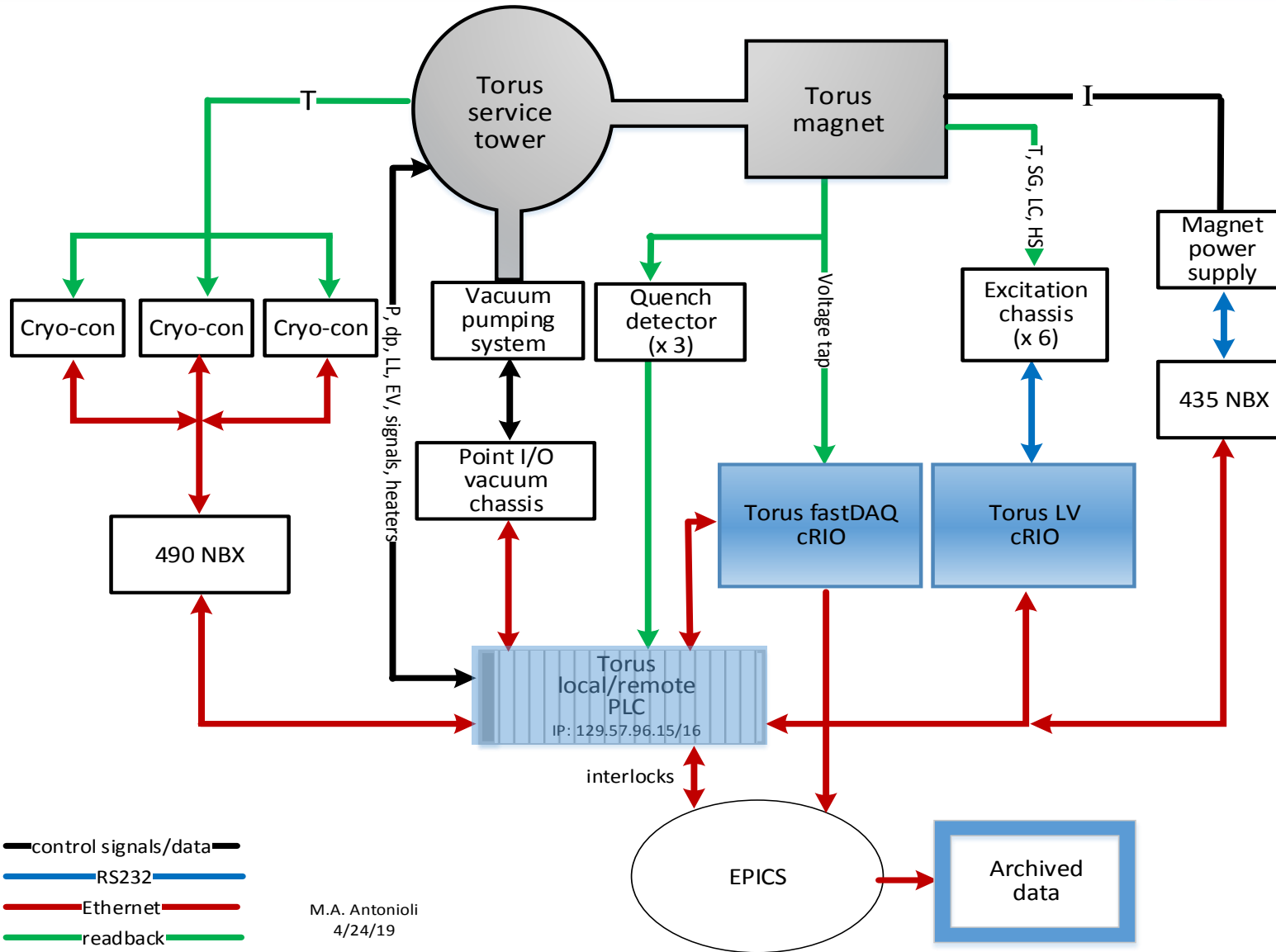


# Hall A Magnets – DSG Contributions

- **Converted code from RSLogix 500 to Studio 5000**
  - PLC code in Studio 5000 V. 28 is compatible with Windows 10
- **Developing**
  - Software tests to verify system's operations before and after PLC replacement
  - Test station to test PLC controllers and IO modules

**PLCs to be implemented June 2019**

# Hall B Magnets – Torus Instrumentation and Controls Overview



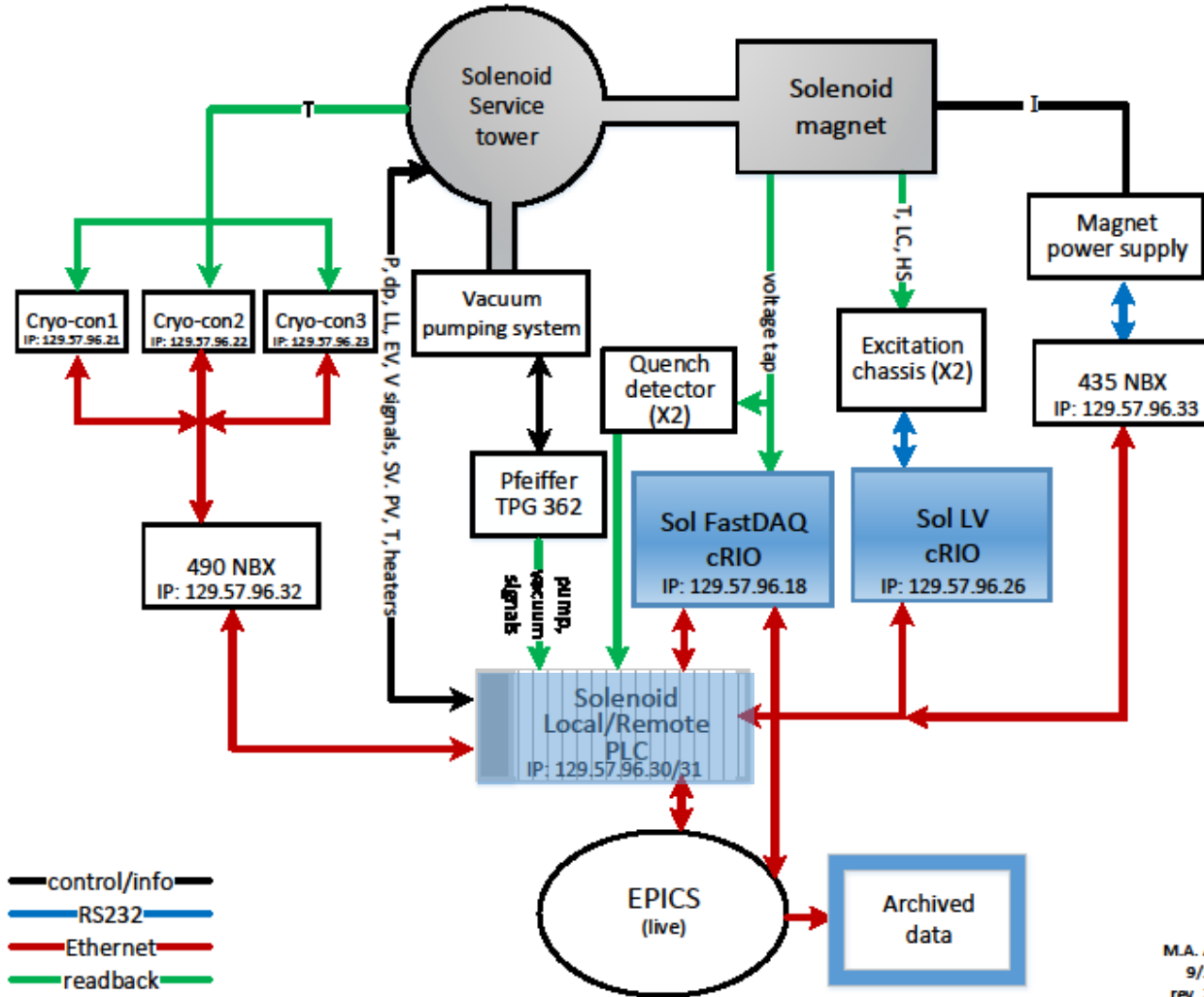
## • Torus

- 6 coils
- Max current 3770 A
- Max 3.58 T

## • DSG developed

- Software
  - PLC and cRIO programs
- Instrumentation
  - Device's firmware upgrade

# Hall B Magnets – Solenoid Controls and Instrumentation Overview



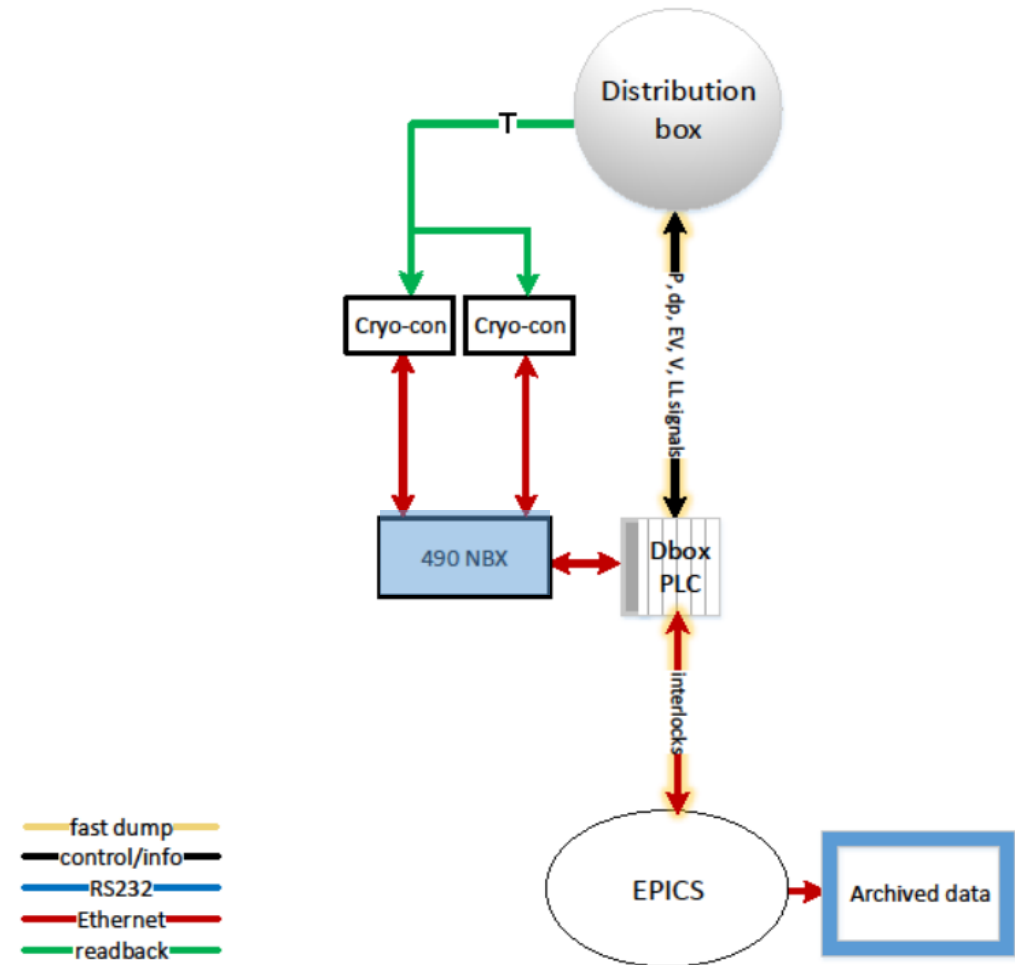
M.A. Antonioli  
9/30/16  
rev. 2/21/17

- **Solenoid**
  - 5 coils
  - Max current 2416 A
  - Max field 5 T
- **DSG developed**
  - Software
    - PLC and cRIO codes
  - Instrumentation
    - Sensor calibration
    - Device's firmware upgrades



# Hall B Magnets – Distribution Box Instrumentation and Controls

- **Distribution Box**
  - Provides common reservoir for torus and solenoid
  - Supplies LN<sub>2</sub> and He for torus
  - Supplies He for solenoid
- **Distribution Box PLC system**
  - Controls and monitors instrumentation
  - Communicates with torus and solenoid PLCs
  - Interlocks cryogenics by closing electric valves
  - Provides inlet temperature monitoring for solenoid and torus PLCs



Distribution Box Controls diagram

M.A. Antonioli  
9/30/16

# Hall B Magnets – DSG Contributions

## Contributions to all aspects of torus and solenoid

### • Controls and Monitoring

— Developed PLC code for solenoid

- Instrumentation and sensors
- Power-up/down (controls Danfysik power supply)
- [Cryogenics operations](#)
- [Interlocks](#)
- Communications with EPICS, power supply, torus, and distribution box PLCs

— Developed LabVIEW code

- Controls and monitoring of temperature, load cells, hall sensors
- [Fast data acquisition](#) for voltage tap measurements
- Upgraded LabVIEW software for solenoid and torus

— Developed java scripts

- Converts RS-Logix Sequence of Events (SOE) timestamps format to UNIX time
- Implemented SOE timestamp EPICS screen



Local solenoid PLC control systems



Solenoid fast DAQ cRIO

04/19/2019 09:38:12 Solenoid and Torus SOE Timestamps

Solenoid				Torus					
0	VCL_Lead_T	0	0	N/A	0	VCL_Lead_T	0	0	N/A
1	LHe_LL1	0	0	N/A	1	LHe_LL1	0	0	N/A
2	LHe_LL2	0	0	N/A	6	PLC_Fast_Dump	0	0	N/A
3	Splice_T1	0	0	N/A	8	Watchdog	0	0	N/A
4	Splice_T2	0	0	N/A	9	Lead_Water_Flow	0	0	N/A
5	MainContact	0	0	N/A	10	VT_Cable	0	0	N/A
6	PLC_Fast_Dump	0	0	N/A	11	System_Cable	0	0	N/A
8	Watchdog	0	0	N/A	12	QD1_Sum	0	0	N/A
9	Lead_Water_Flow	0	0	N/A	13	QD2_Sum	0	0	N/A
10	VT_Cable	0	0	N/A	14	QD3_Sum	0	0	N/A
11	System_Cable	0	0	N/A					
12	QD1_Sum	0	0	N/A					
13	QD2_Sum	0	0	N/A					
15	DumpContact	0	0	N/A					

EPICS screen shows SOE timestamps to determine the first fault to propagate in solenoid/torus which caused the fast dump

# Hall B Magnets – DSG Contributions

## • Installation

- Torus and solenoid instrumentation
  - Replaced faulty cRIO controllers
- Terminal servers
  - For remote RS232 serial communication with cRIOs

## • Upgrades

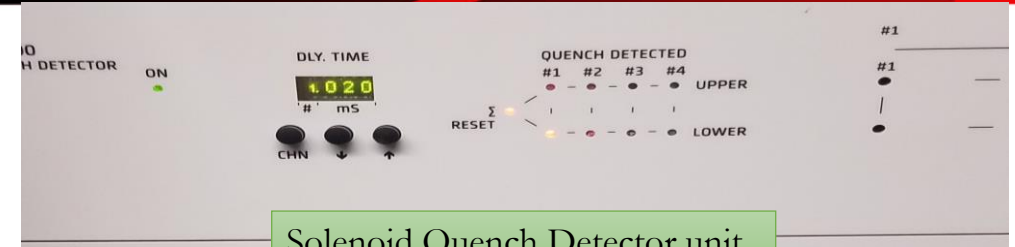
- Control device's firmware
  - Cryo-con temperature monitors

## • Calibration

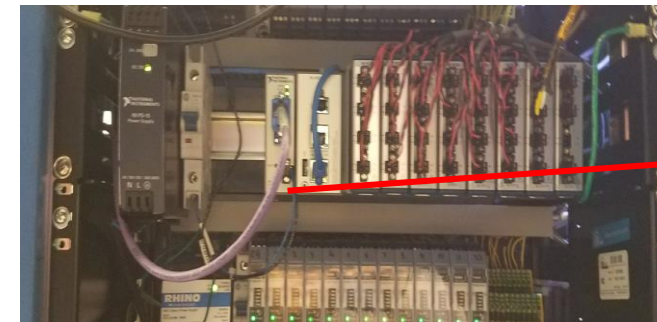
- Temperature, load cell, and hall sensors
- Quench detection units

## • Debugging and repairs

- Magnet power supplies
  - Modified and tested control boards
  - LCW inlet/return lines to avoid differential pressures going over set threshold values in MPS



Solenoid Quench Detector unit



Torus FastDAQ cRIO chassis

Moxa Terminal Server



Flow switches located internally in MPS



Disconnected hoses on SCR at Torus MPS



Cryo-con-18i temperature monitors

# Hall B Magnets – DSG Contributions

- **Analysis**

- Investigation of out of plane forces and [load cell analysis](#)

- **Documentation**

- Reports and notes

- Controls faults during fast dump events for torus and solenoid

- Instrumentation, circuits, and control diagrams

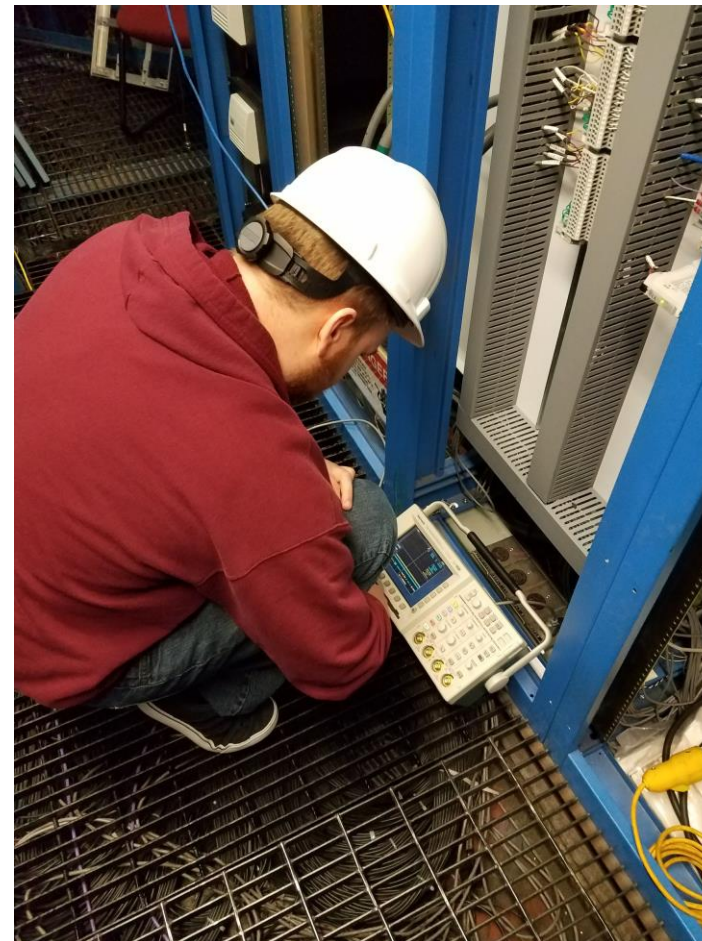
- cRIO and PLC critical components spares list

- Pre-power up interlock test procedures

- **On-call support 24/7**

# Hall B Magnets – Status

- Controls systems running efficiently
- Torus and solenoid are in **good health**



Tyler connecting scope to monitor solenoid voltage tap trips on quench detectors

# Hall B Magnets – Tasks for Summer 2019

- **Perform pre-power-up instrumentation and interlock checkouts**
- **Update firmware for MPS control boards**
  - Verify MPS communications (local/remote) and interlocks for MPS
  - Verify and calibrate MPS set slew, set output, induced fast dumps from EPICS GUI bottom and LHe low level
  - Test low current discharge at 100 A and a medium at 300 A (at different slew rate)
- **Test magnets in reverse polarity**
- **Implement rewiring of PLC watchdog**
- **Move hardwired interlocks from the fast-dump circuit to the slow ramp-down circuit**
- **Upgrade firmware for torus/solenoid and Distribution Box PLC controllers**

# Hall C Magnets – Overview

- **High Momentum Spectrometer (HMS)**
  - Three superconducting quadrupoles
  - One superconducting dipole
- **Super High Momentum Spectrometer (SHMS)**
  - Three superconducting quadrupoles (Q<sub>x</sub>)
  - One superconducting horizontal bender (HB)
  - One superconducting dipole

System	Magnet	Values at Maximum Momentum		
		Momentum [GeV/c]	Current [A]	Field or Gradient
HMS	Q1	7.4	980	2.03 T
	Q2	7.4	830	
	Q3	7.4	370	
	Dipole	7.4	3000	
SHMS	Q1	11	3930	2.56 T
	Q2	11	2455	7.9 T/m
	Q3	11	3630	11.8 T/m
	Dipole	11	2480	7.9 T/m
	HB	11	3270	3.9 T

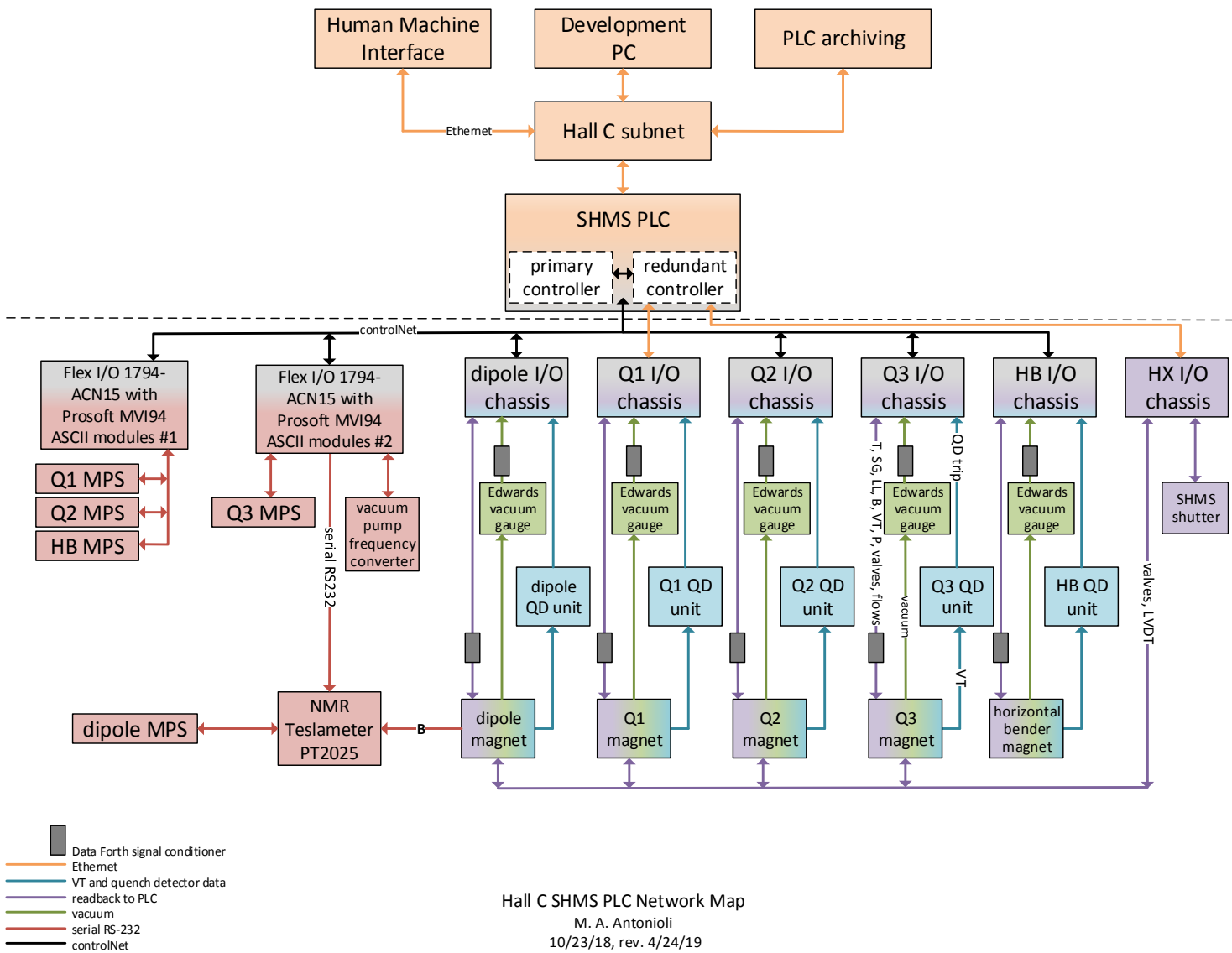


Hall C HMS magnets – side view



Hall C SHMS magnets – side view

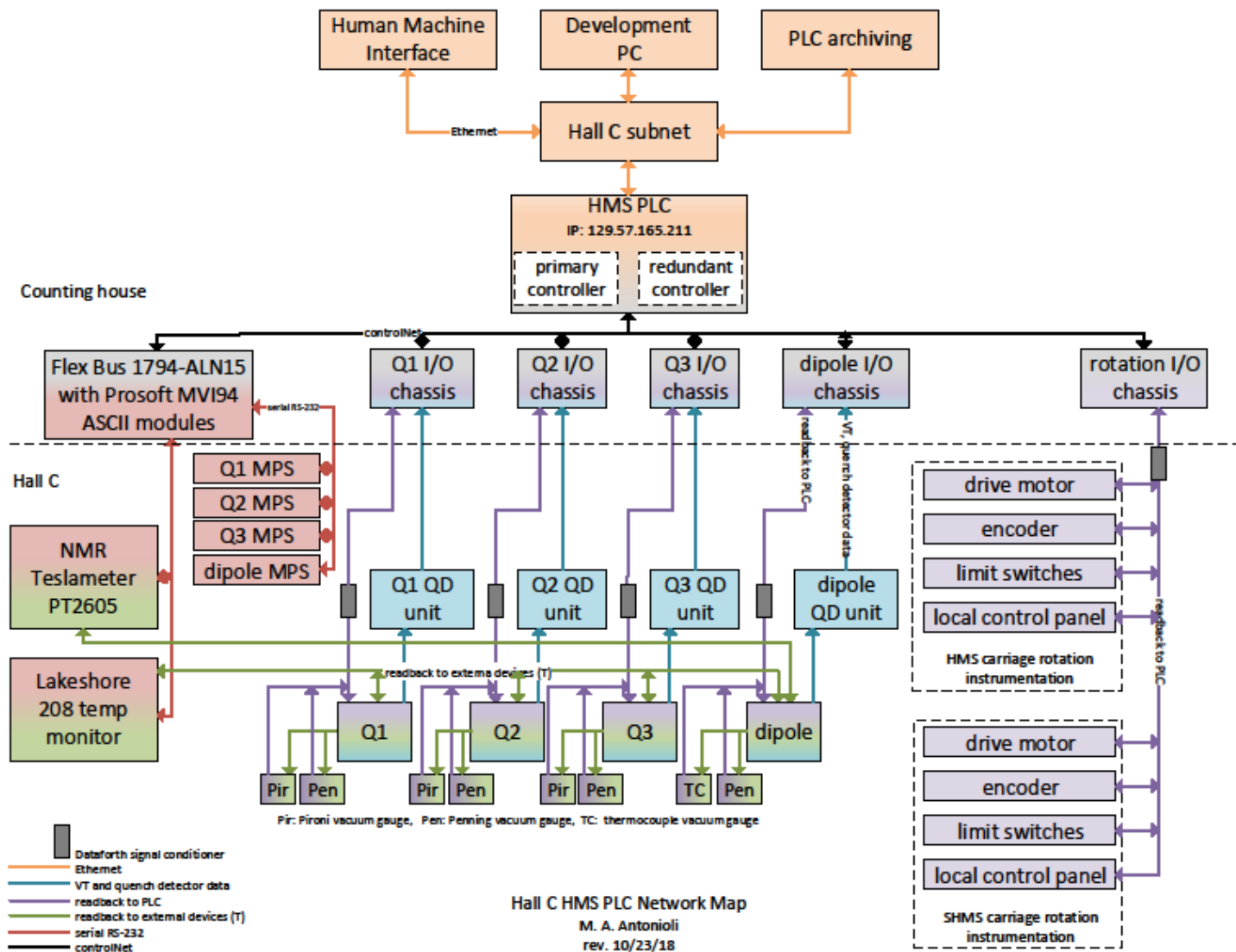
# Hall C Magnets – SHMS Controls and Instrumentation



- **Developed Software**
  - PLC programs
- **Implemented hardware**
  - Swapped network modules
  - Installed power supply relay cards



# Hall C Magnets – HMS Controls and Instrumentation



- **Developed Software**
  - PLC programs
- **Implemented hardware**
  - Redundancy and communication modules
  - NMR PT2606

# Hall C Magnets – DSG Contributions

## List of PLC work done

Item	Description	Status	Comments
1	HMS and SHMS dipole field regulation routine	Completed	Completed on 09/13/2018
2	New NMR communication through PLC to PSU	Does not work as expected	Issues to lock PT2026 when field > 1.4 T
3	Test Ethernet vs Controlnet interface	Completed	Completed on 06/13/2018
4	Swapping of Controlnet by Ethernet modules in SHMS	Completed	Completed on 7/13/2018
5	Add spectrometer rotation electric break control	Completed	Completed on 08/03/2018
6	Add HMS Spectrometer vacuum to controls	Completed	Completed on 07/23/2018
7	Data logging upgrade, install, and make operational	EPICS task	Will be completed in EPICS MYA Archiver
8	Develop "on loop" current regulation routine for quads PSU	Completed	Completed on 08/06/2018
9	Wire UPS status to controls	Completed	Completed on 09/13/2018
10	Modify SHMS shutter not in place status	Completed	Completed on 08/03/2018
11	Add HMS shutter controls and status	Completed	Completed on 08/03/2018
12	Alarm notification to on-call staff	EPICS task	Will be completed in EPICS
13	Add HMS quadrupoles hall probe readouts to PLC	Completed	Completed on 08/29/2018
14	End of life for Windows 7 upgrade to Windows 10	Completed	Completed on 10/02/2018
15	Upgrade SHMS PLC from version 16 to version 20	Completed	Completed on 7/13/2018
16	Upgrade HMS PLC from version 16 to version 20	Completed	Completed on 01/18/2019

# Hall C Magnets – DSG Contributions

- **Development of PLC program for SHMS and HMS**

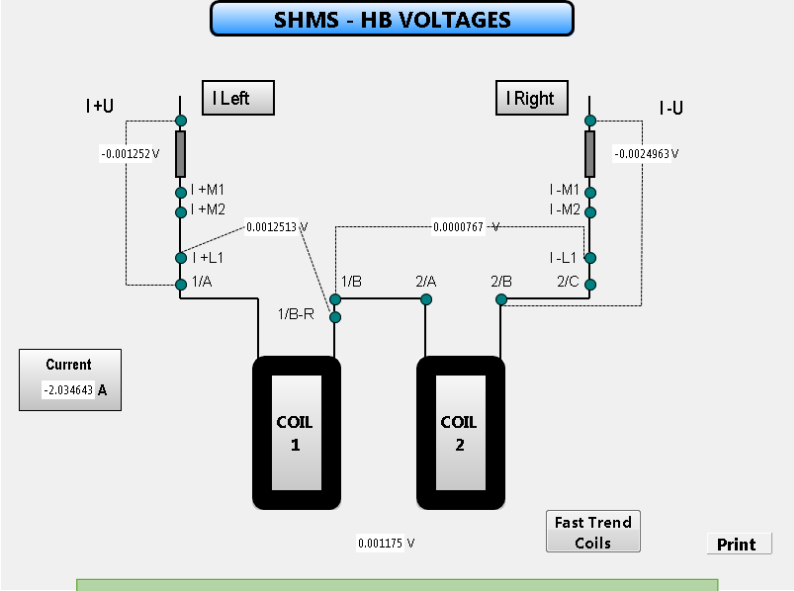
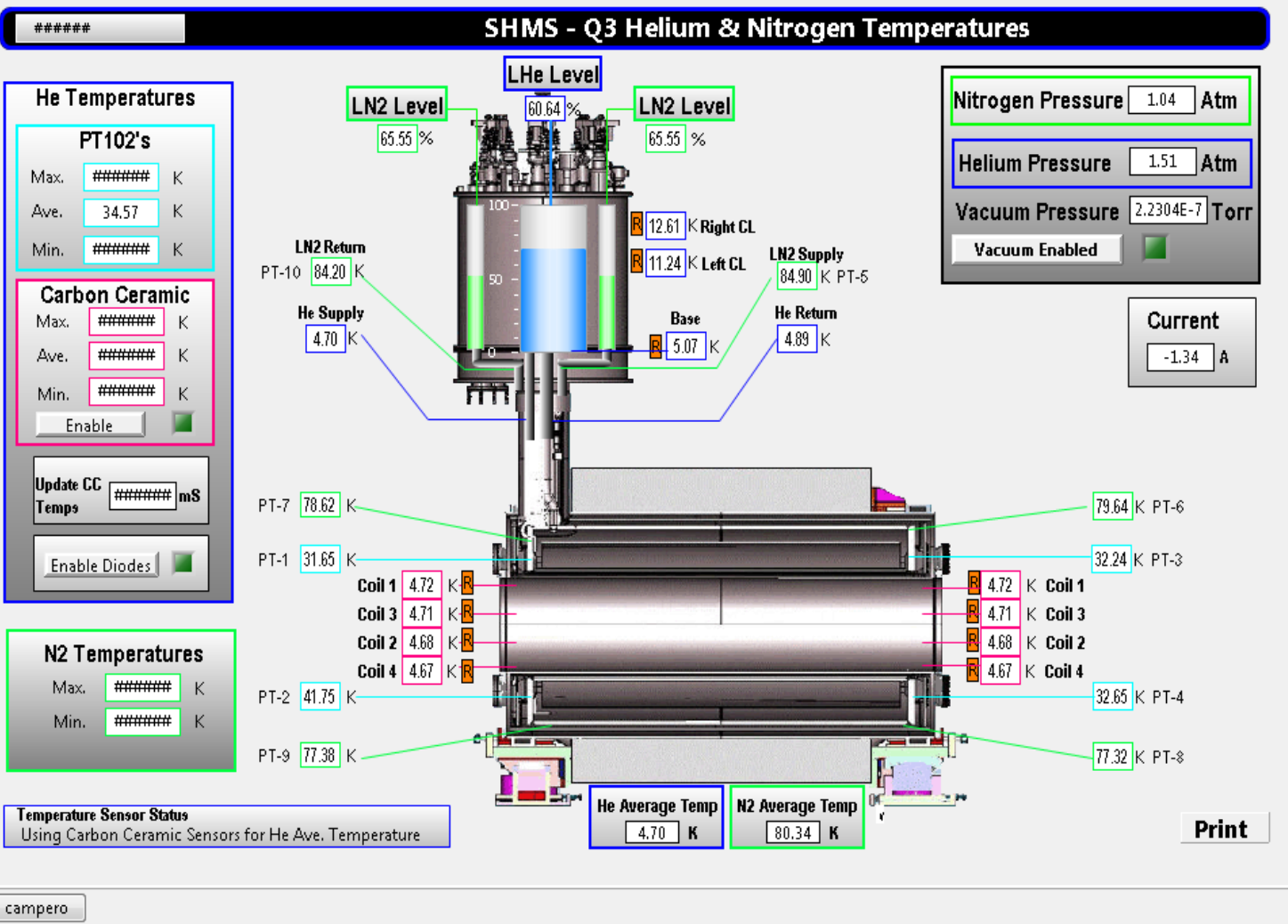
- Dipole field regulation
- Monitoring of UPS backup power supply
- HMS spectrometer vacuum controls
- Quadrupoles current regulation
- PLC heartbeat

Programs to be implemented during summer 2019 shut down

- **Development of CSS EPICS screens**

- Magnets cryogenics
  - SHMS and HMS magnets nitrogen and helium temperatures screens (X9) completed
- Horizontal bender voltage tap screen completed
- PLC-EPICS communication test
- Simulation of PLC-EPICS data transfer screen

# Hall C Magnets – DSG Contributions



SHMS-horizontal bender voltage taps screen

OPC Server - Client Test

DATA TYPE	PLC TO EPICS		EPICS TO PLC	
	SET PLC TAG	READ PLC TAG	SET PV	READ PV
BOOLEAN	0	<input checked="" type="checkbox"/>	ON	<input checked="" type="checkbox"/>
STRING	Test in Progress	progress	Writing on PLC	Writing on PLC
SINT	21	21	125	125
DINT	21210000	21210000	36555	36555
REAL	1632.308	1632.308	36555.121	36555.121

CSS screen developed to simulate PLC tag to EPICS data transfer

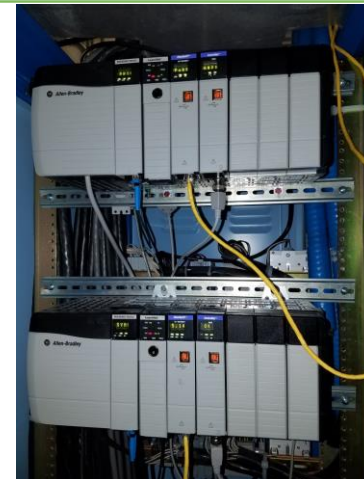
SHMS – Q3 helium and nitrogen temperatures CSS screen developed by DSG

# Hall C Magnets – DSG Contributions

- For phased upgrade of SHMS PLC communication modules
  - Tested compatibility and performance of PLC system running with Controlnet and Ethernet communication modules
- Swapped Controlnet modules with Ethernet modules
  - SHMS Quadrupole 1 PLC chassis
  - Heater Exchanger PLC chassis
    - On several occasions, Controlnet modules lost communication with Local PLC, affecting cryogenics in Hall C and other Halls that uses same helium supply (ESR)
- Upgraded
  - PLC software and firmware for HMS and SHMS control systems to run in Windows 10 environment
  - PLC software for Skylla7 and Controls7 Hall C computers/laptops
  - SHMS PLC controls systems to V20, compatible with Windows 10



Stand-alone PLC setup used for Ethernet/Controlnet compatibility test



SHMS primary and secondary PLC chassis with PLC controller, redundancy, Ethernet, and Controlnet modules

# Hall C Magnets – DSG Contributions

- **Installed NMR** unit and hall probe in HMS dipole



Hall probe installed inside central area of the HMS dipole



Hall probe



ROC-RK3328-CC SBC card implemented on Hall C control systems

- **Implemented ROC-RK3328-CC SBC card**
- **Set up Metro-Lab PT2026 NMR unit**
- **Documented**
  - Instrumentation and network diagrams
  - PLC layouts for HMS and SHMS
- **On-call support 24/7**



Metro-Lab PT2026 NMR unit

# Hall C Magnets – Status and Upcoming Task

- PLC upgrades completed
- Developed PLC programs to be implemented during summer 2019 shutdown
- Developing CSS-BOY screens for magnets

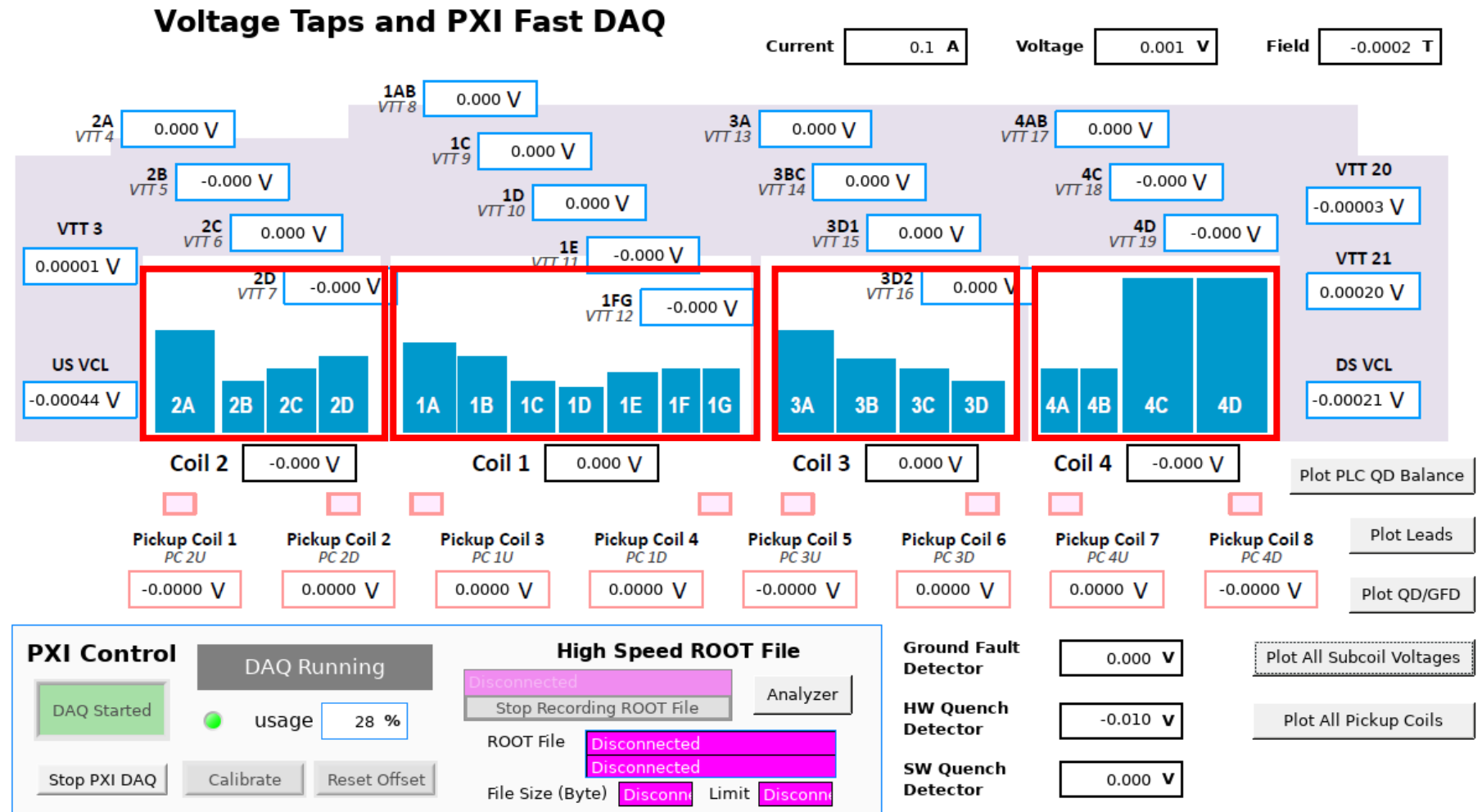
# Hall D Magnet - Overview

- GlueX spectrometer's superconducting solenoid

- # of coils: 4
- Max current: 1350 A
- Field: ~2 T in bore



solenoid

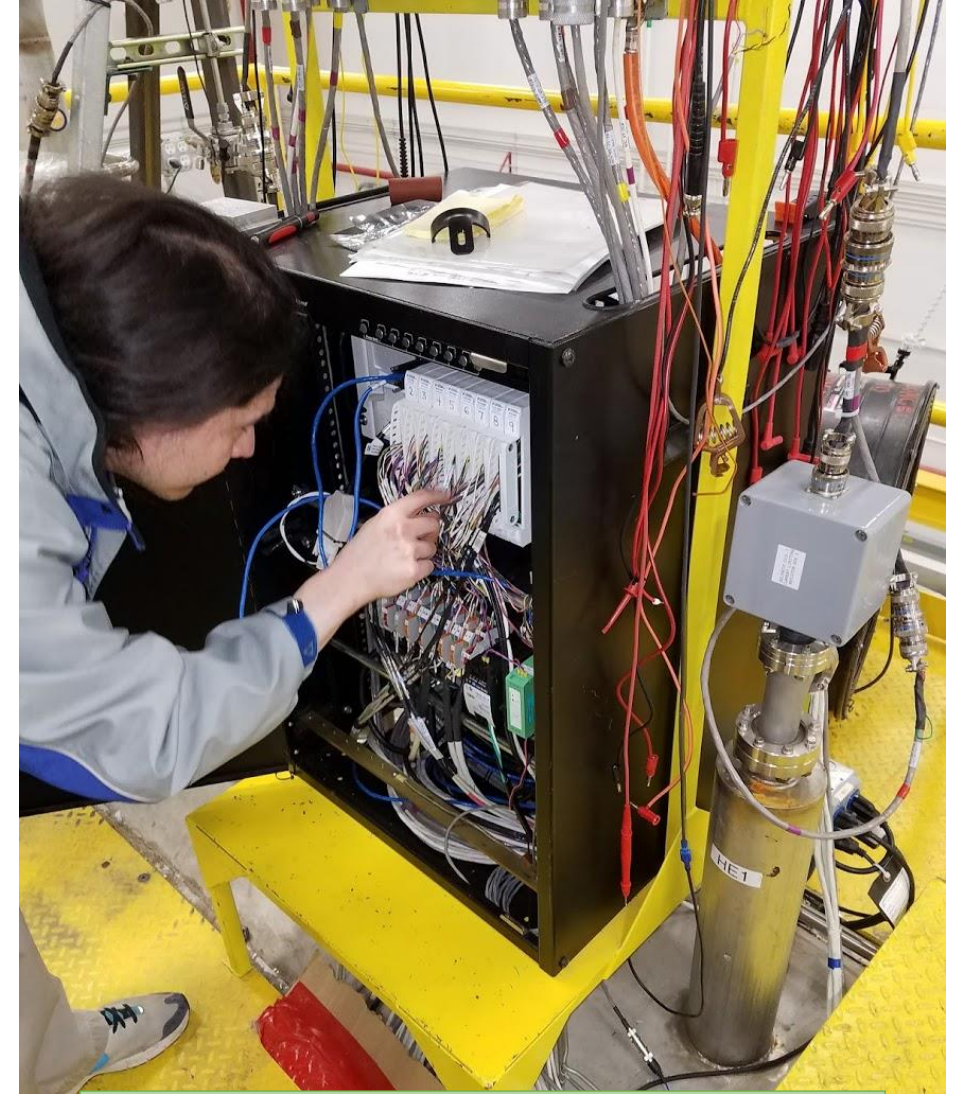


Voltage taps and PXI fast DAQ EPICS screen for solenoid



# Hall D Magnet – DSG Contributions

- **Development**
  - PXI control systems LabVIEW program
    - PXI control systems used for fast DAQ of solenoid voltage taps
  - Interlock HMI screen
  - SQL program for voltage tap analysis
- **Calibrated PXI ADC input modules**
  - Modules read solenoid voltage taps
- **Tested faulty PXI controllers**
- **Specify and procure**
  - New PXI controller e-8840
- **Generated PLC layouts**
- **Provide on-call support 24/7**



Brian checking ADC input modules

# Hall D Magnet – Upcoming Task

- **Replace old PXI controller by new PXI controller**

- Old NI-PXI e-8135 controller

- Allows data transfer rate to EPICS up to 10 KHz
- Loss communication several times
- Needed hardware reboot to bring controller back to normal operations

- New PXIe-8840 controller

- Current ADC input modules installed allows data transfer with PXIe-8840 controller at a rate up to 250 KHz
- Testing required after the PXI controller implementation



New Solenoid PXIe-8840 controller

# Conclusions

## DSG contributes to all aspects of magnet controls and monitoring systems across the Physics division

- Develops software
- Implements instrumentation
- Tests and debugs
- Investigates and solves
- Performs maintenance
- Specifies and procures
- Develops documentation
- Provides on-call support

# Thank You

DSG staff involved

Mary Ann Antonioli, Peter Bonneau, Pablo Campero,  
Brian Eng, Amanda Hoebel, and Tyler Lemon