U.S. MAGNET DEVELOPMENT PROGRAM

Instrumentation/Diagnostics topics - status

MDP Meeting

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Milestones

PROGRAM

Diagnostics milestone table

BERKELEY LAB

Milestone #	Description	Target
AIIId-M1	Development of a new generation of self-calibrating acoustic emission diagnostics hardware	December 2020
AIIId-M2	Finalizing software algorithms for acoustic data analysis, completing analysis for the CCTs and 15T dipole	December 2020
AIIId-M3	Development and test of a linear quench localization sensor on a Bi-2212 subscale and/or ReBCO CCT series	March 2021
AIIId-M4	Test of a large-scale Hall array and imaging current distribution in HTS tape stacks and coils	May 2021
AIIId-M5	Completing spot heater studies to improve voltage-based diagnostics and address "silent" quenches	July 2021
AIIId-M6	Demonstration of inverse acoustics-based probing of interfaces in a dedicated small-scale coil	September 2021
AIIId-M7	Development of multi-element and flexible quench antennas and localization of quenches in using flexible quench antenna arrays	September 2021
AIIId-M8	Characterization of training-like behavior in different impregnation materials under load using a Transverse Pressure Insert (TPI) measurement system	December 2021
AIIId-M9	Development and test of a standalone acoustic quench detection and localization FPGA-based system	December 2021
AIIId-M10	Development and test of a non-rotating new magnetic probe prototype	December 2021
AIIId-M11	Demonstration of a programmable fully-cryogenic FPGA "smart" sensor core with digital readout and analog front-end (SQUID) amplifiers	December 2021
AIIId-M12	Calibration of FBG fibers in a small cryostat. Installation on an MDP magnet and strain measurement during a quench. Design a proof of principle experiment for quench 3D spatial detection and coil azimuthal strain mapping and install fiber on MDP magnet. Use fibers for energy spectrum analysis and HTS quench detection.	December 2022

- Next generation acoustic hardware (LBNL)
- Acoustic data analysis completed for 15 T (LBNL), CCT4 and subscale 2 – in progress (LBNL). New ML algorithms for quench precursors (FNAL)
- In progress, new developments (LBNL)
- Hall array hardware built, tested on CORC (LBNL)
- Talks in progress at FNAL for implementing these studies
- TBD (LBNL)
- MQXFA QA built and delivered, warm bore tube QA structures are ready as well (FNAL). CCT subscale antennas (LBNL)
- New tests with matrimid and organic resins mixed with high-Cp ceramics are planned at FNAL
- Non-FPGA portion was built and tested (LBNL, BNL). Upgrade to FPGA TBD towards the target date
- TBD (LBNL, FNAL) – likely early 2022
- New DAQ boards, performance characterized for various cryo-parts. One channel cryo-system to be tested by the end of 2021 (LBNL)
- Progress with early tests. Modifications to vertical test facility to integrate fibers. (FNAL, BNL)

U.S. DEPARTMENT OF ENERGY | Office of Science

Diagnostics & mechanisms
MDP 2021 Collaboration Meeting

M. Marchevsky

"Spot heater array" studies

Flex-QA development

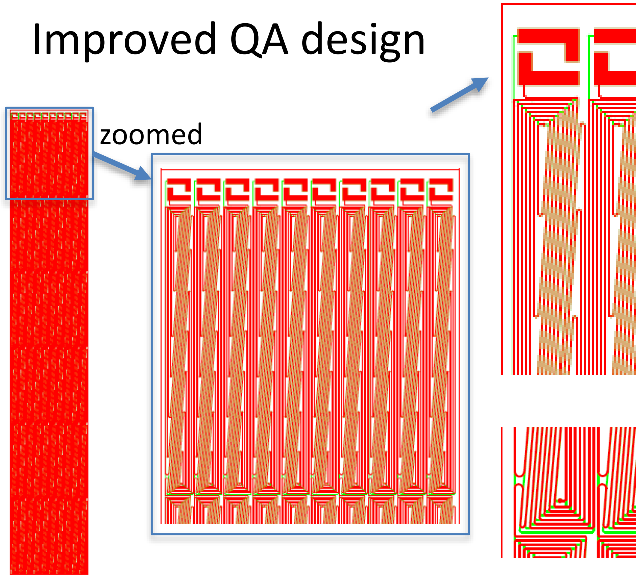
(and I'll give the status of other relevant activities too)

QA and "cold" electronics progress

- Flex-QA (flexible PCB quench antenna) - Joe DM, Stoyan
  - A version of the flex-QA installed ready for testing in a magnet
  - Improved versions of QA being procured, other being drafted
  - Room-temperature test stand being procured

LDRD funds

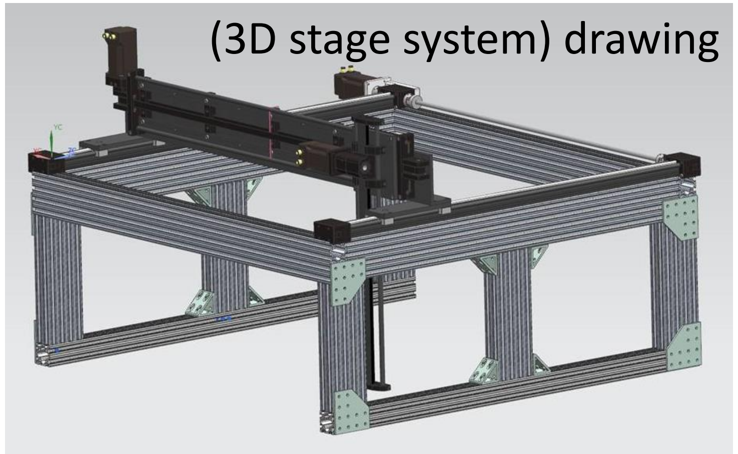
Improved QA design



QA during installation

Test stand

(3D stage system) drawing



MDP Roadmap

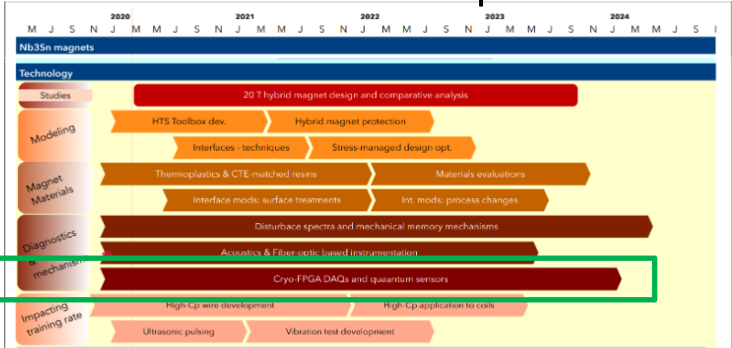


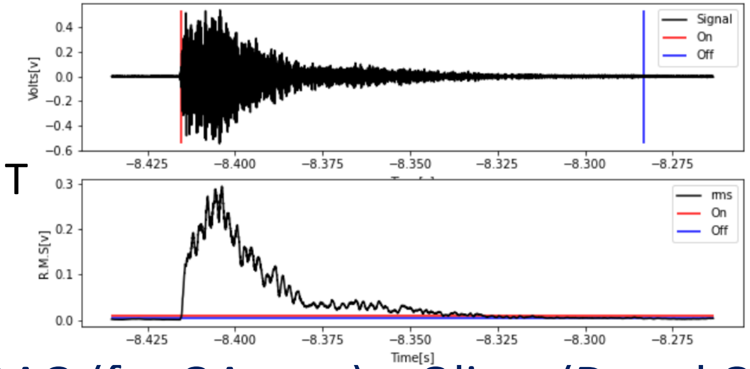
Figure 9. The updated roadmaps for the major elements of the program, including Nb_3Sn Magnets, HTS (Bi-2212 and REBCO) Magnets, and the various Technology areas. The $N_{b3}Sn$ magnet designs will focus on stress-managed structures, motivated by the need to intercept forces in magnets at high field and with large bores compatible with hybrid (HTS/LTS) configurations.

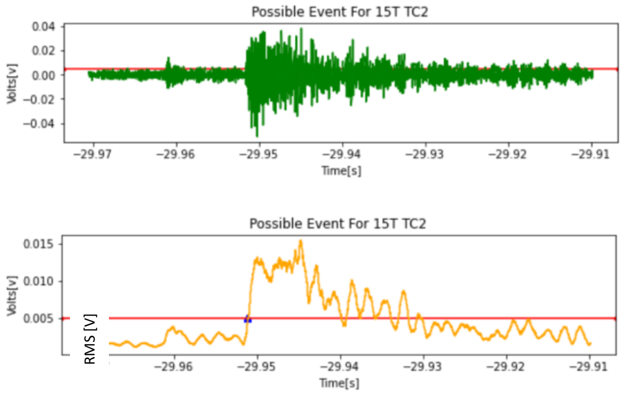
- "Cold" electronics – Ryan R. (group), Steve, Stoyan (just the FNAL side)
  - Collaboration with LBNL (Marcos)
  - Electronics components were tested in LN at APS-TD,
  - established regular activities (~ weekly)
  - Pending results, we'll plan for LHe testing

Acoustics analysis and DAQ developments

- Acoustics (with Steve)
  - Kiernan, a Summer student is working with us on “15 T” acoustics data analysis
  - We are after analyzing/categorizing events of interest

Acoustic data from 15 T





Plots relate to testing of code and algorithms to find “interesting” events

- Multichannel fast DAQ (for QA, etc.) – Oliver (Darryl O.), Steve, Stoyan
  - We upgraded hard-drives which were rate bottlenecks
  - We bought additional cards to get to 64+ differential channels
  - Tested functionality at this stage – all good
  - Software development was started, cabling discussed
  - Work halted for few months due budget constraints, resuming

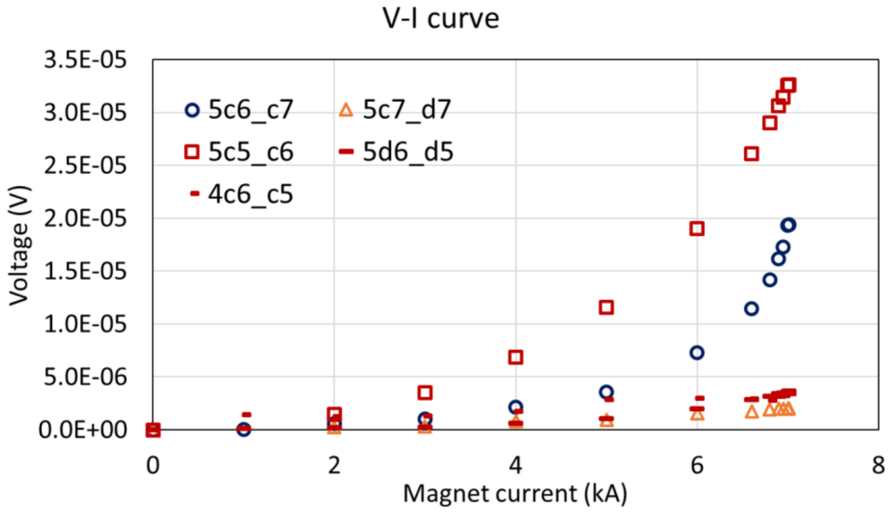
One of two NI-crates

“Spot heater array”, V-I technique - stalled

- “Spot heater array” studies (no progress since last time)
  - It is also a current sharing and other diagnostics experiment
  - An initial proposal (for funding) was sent in January 2020
  - A FNAL note written in November 2020 (as requested/strongly advised earlier)
  - An updated presentation with targets and narrative prepared and given at FNAL (January-April 2021)
  - Discussion on next steps initialized with management
  - Waiting for stated support (and support)

- V-I technique development – Tom C. (Darryl O.), Stoyan /no progress/
  - First tests with borrowed multi-channel nano-voltmeter (“MUX”) were successful in the “15 T”
  - We need much improved version of the MUX to accommodate our needs
  - Development of MUX started – virtually all hardware procured
  - Further development halted due to lower priority status (we don’t have an imminent magnet coming for testing) and insufficient resources

V-I measurements for “15 T”



SBIR/STTR sub-topic proposals sent to DOE

SUPERCONDUCTING TECHNOLOGIES FOR PARTICLE ACCELERATORS & MAGNETS

Quench detection systems

(after some feedback)

Grant applications are sought to develop quench detection systems based on machine learning techniques and FPGA electronics. While the test bed can be low temperature superconducting (LTS) magnets the goal is to have such systems suitable for high temperature superconducting (HTS) magnets. A potential system should be able to utilize multiple input sources, be at least 99% efficient without using coil voltage rise (resistance growth) and give less than 0.1% fake triggers. If used in LTS, it should be at least twice faster than standard quench detection based on differential voltage signals alone. If used in HTS, it should demonstrate fast enough quench detection to avoid burning out of the superconductor. It is understood that quench detection should cover the whole range of magnet currents up to at least the design current for the specific magnet.

References:

Hoang, Duc & Tran, Nhan & Boffo, Cristian & Marinozzi, Vittorio & Krave, Steven & Kazi, Sujay & Stoynev, Stoyan. (2021). Intelliquench: An Adaptive Machine Learning System for Detection of Superconducting Magnet Quenches. IEEE Transactions on Applied Superconductivity. PP. 1-1. 10.1109/TASC.2021.3058229.

Wielgosz, Maciej, Skoczeń, Andrzej, & Mertik, Matej (2017). Using LSTM recurrent neural networks for monitoring the LHC superconducting magnets. Nuclear Instruments and Methods in Physics Research Section A, Accelerators, Spectrometers, Detectors and Associated Equipment, 40-50. doi:101016/jnima201706020

Marchevsky, Maxim. Thu. "Quench Detection and Protection for High-Temperature Superconductor Accelerator Magnets". Switzerland. https://doi.org/10.3390/instruments5030027.

SBIR/STTR sub-topic proposals sent to DOE

HIGH ENERGY PHYSICS DETECTORS AND INSTRUMENTATION

Cryogenics electronics

Grant applications are sought to develop electronics working at liquid helium temperatures (a.k.a. “cold” electronics). The main application is bringing signal channels from liquid helium to room temperature by digitizing the signals and transmitting them through large bandwidth connections. The main target parameters are 1 Gbps data rate, at least 14 (better 16) bits per channel and sampling rates above 200 kHz. Use of amplifiers is recommended. The power consumption should be less than 100 mW per channel and less than 30 W total, and the system should be able to start and operate in super-fluid liquid helium.

References:

Turqueti, Marcos & Taylor, Jordan. (2018). Implementation and Cryogenic Operation of FPGA Based n-bit Analog to Digital Converter. 1-2. 10.1109/NSSMIC.2018.8824580.

Braga, Davide & Li, Shaorui & Fahim, Farah. (2021). Cryogenic Electronics Development for High-Energy Physics: An Overview of Design Considerations, Benefits, and Unique Challenges. IEEE Solid-State Circuits Magazine. 13. 36-45. 10.1109/mssc.2021.3072804.

Ray, Biswajit & Gerber, Scott & Patterson, Richard & Myers, Ira. (1995). Power control electronics for cryogenic instrumentation.