U.S. MAGNET DEVELOPMENT PROGRAM

MDP Diagnostics milestones at FNAL

MDP Meeting

August 31, 2022

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US Magnet Development Program

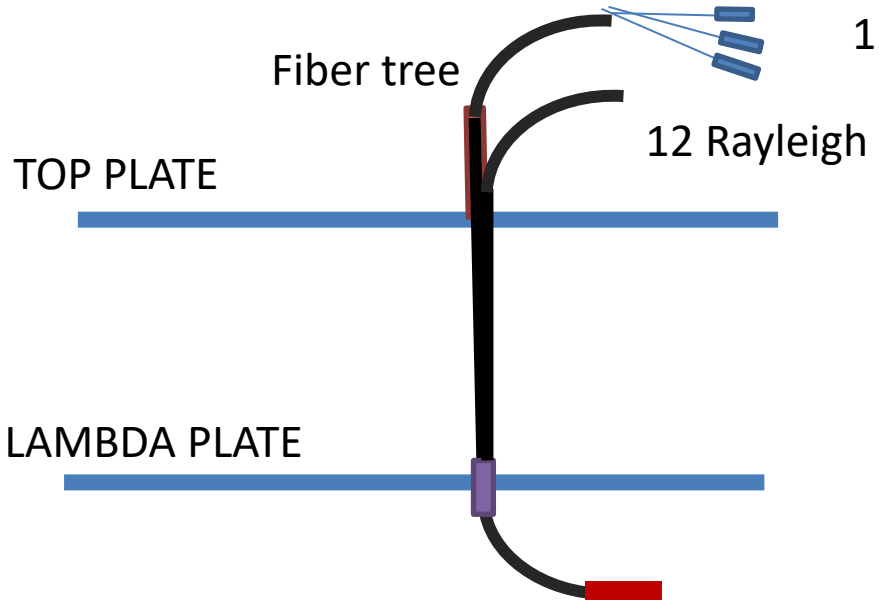
Fermi National Accelerator Laboratory

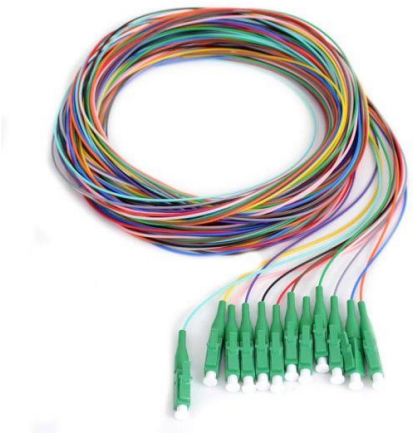
US Magnet Development Program

Optical Fiber work at FNAL (M. Baldini and S. Krave)

MILESTONES

- Calibration of FBG fibers in a small cryostat (2021): completed
- Installation of fibers on an MDP magnet and strain measurement during a quench (2021): completed
- Modification of magnet test facility top plate to accommodate fiber line (2021): completed/improvement ongoing





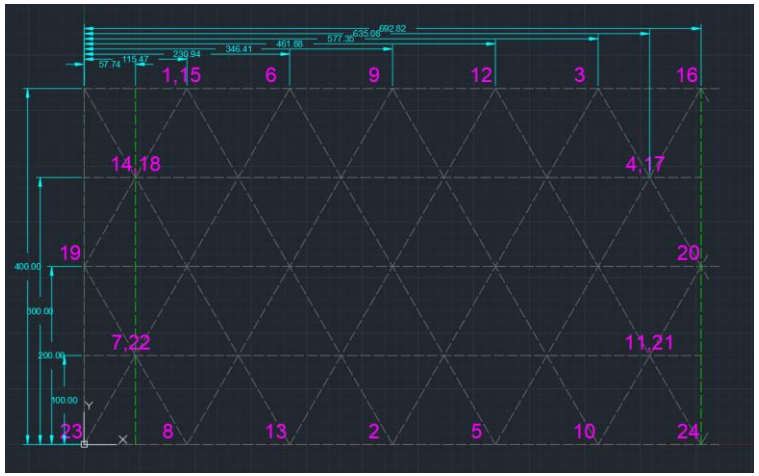
Fiber signal amplitude dropped significantly during cool down. Some work is ongoing to improve the fiber feedthrough layout

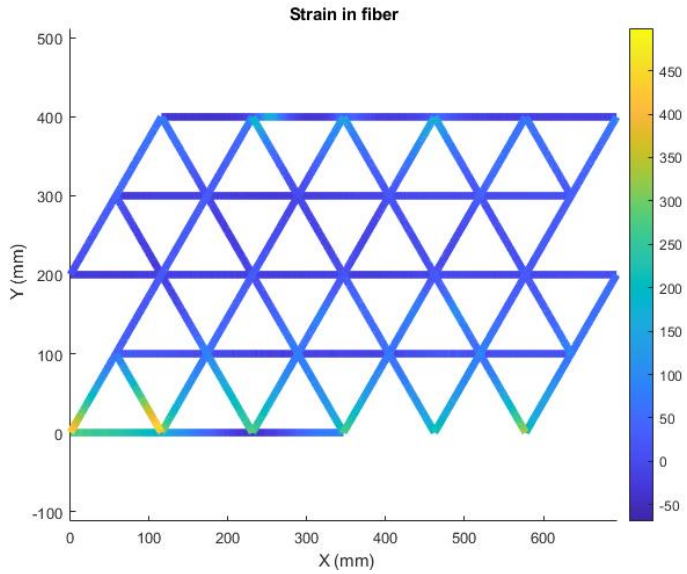
- Reduce number of fiber connectors
- Use G.657 fiber (unsensitive to bending)
- Add fiber lines: 24 fibers (FBG and Rayleigh sensors)
- Use of pigtail cables spliced below the lambda plate
- Cables have been purchased
- Pressure leakage test was performed

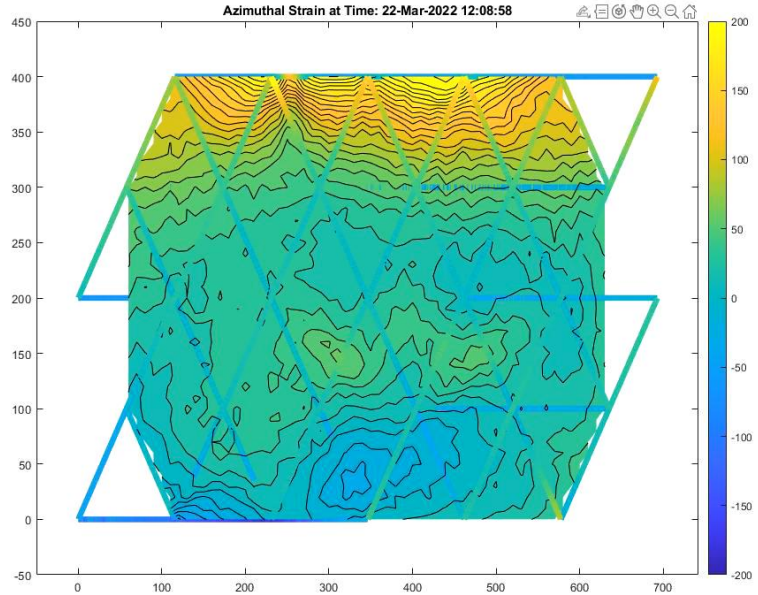
STATUS: work completed by December 2022

Optical Fiber work at FNAL (M. Baldini and S. Krave)

Strain map using Distributed Rayleigh sensors; welding of the stainless steel shell of the AUP cold mass





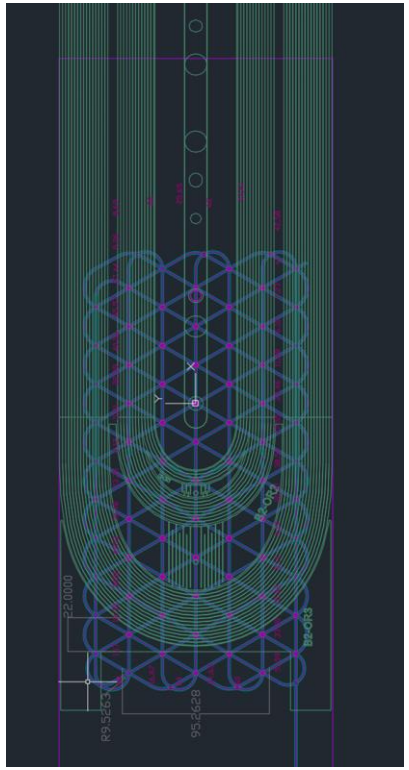


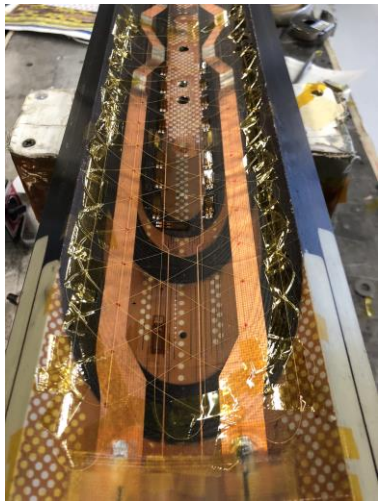
- Weld is at roughly -100 mm
- sample rate was 0.52 Samples/Second for all data
- Spatial pitch is 0.65 mm

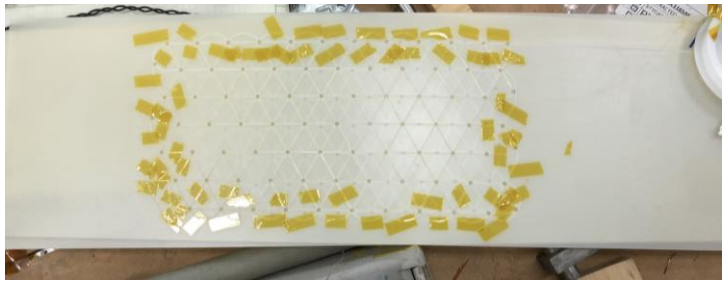
- After obtaining strain measurements in 3 directions, each direction is interpolated onto a rectangular grid
- Interpolation only valid within area bounded by points with all directions measured

Optical Fiber work at FNAL (M. Baldini and S. Krave)

MILESTONE: Coil azimuthal strain mapping:
experiment on coil ten stacks sample made with different epoxy (March 2023): not started yet
install distributed fiber on a mirror magnet for coil strain map (Feb 2023): ongoing







Distributed Rayleigh fibers are going to be installed on the inner and outer radius of an AUP coil to obtained strain maps of the coil ends

- Two 7 m strain sensor fibers were glued on the inner coil radius (completed).
- Two 7 m strain sensor fibers will be glued on the outer coil radius using a 0.5 mm G10 layer (ongoing).

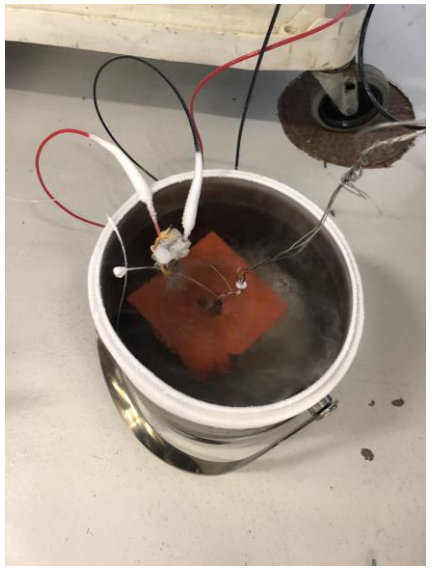
STATUS: A mirror magnet will be assembled by the end of the year and tested at the beginning of 2023

Measurements taken at 100 Hz at 2.6 mm pitch

Optical Fiber work at FNAL (M. Baldini and V. Marinozzi)

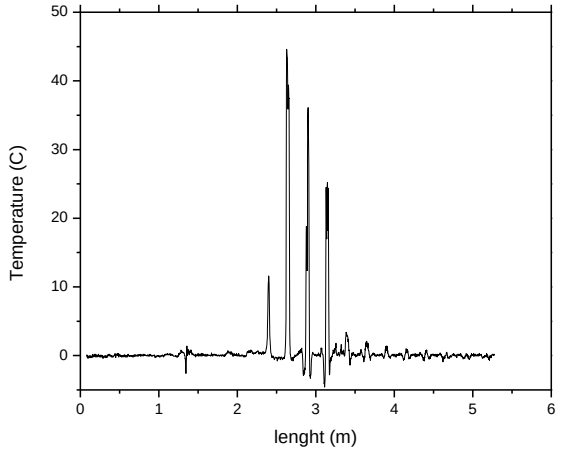
MILESTONE: Design a proof of principle experiment for quench detection (LDRD):

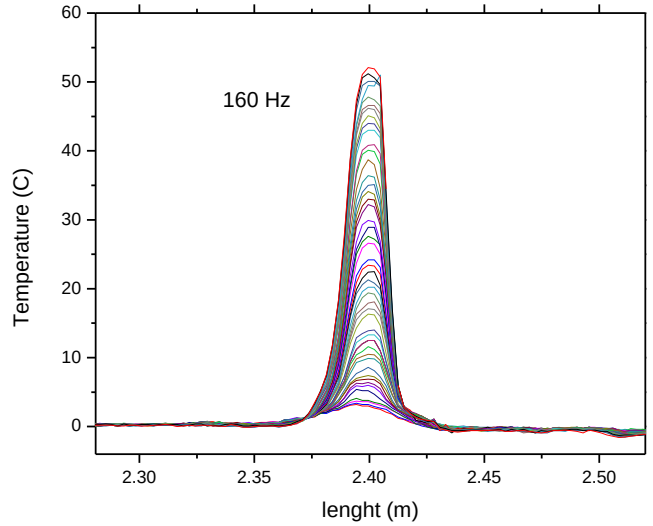
- Small coil fabrication and tests (Dec 2022): ongoing
- Energy spectrum analysis (dec 2023): ongoing



First test in Li Ni has been successfully performed using:

- temperature fiber sensor (5 m fiber encapsulated on a Teflon tube). Sample rate 160Hz, spatial pitch 2.6 mm
- Heater is 5mm wide (3 turns)
- Use capacitor bank with 12 capacitor (27 mF each) to modify the discharge time and deposited energy





STATUS:

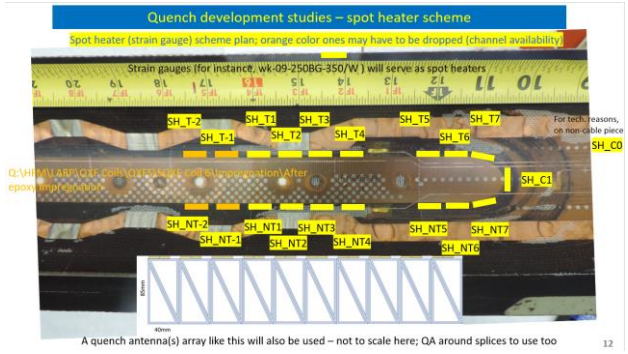
- Analysis of first test results is ongoing
- Test in Li He with 4 coils with wider heaters and strain and temperature fiber sensors by the end of September

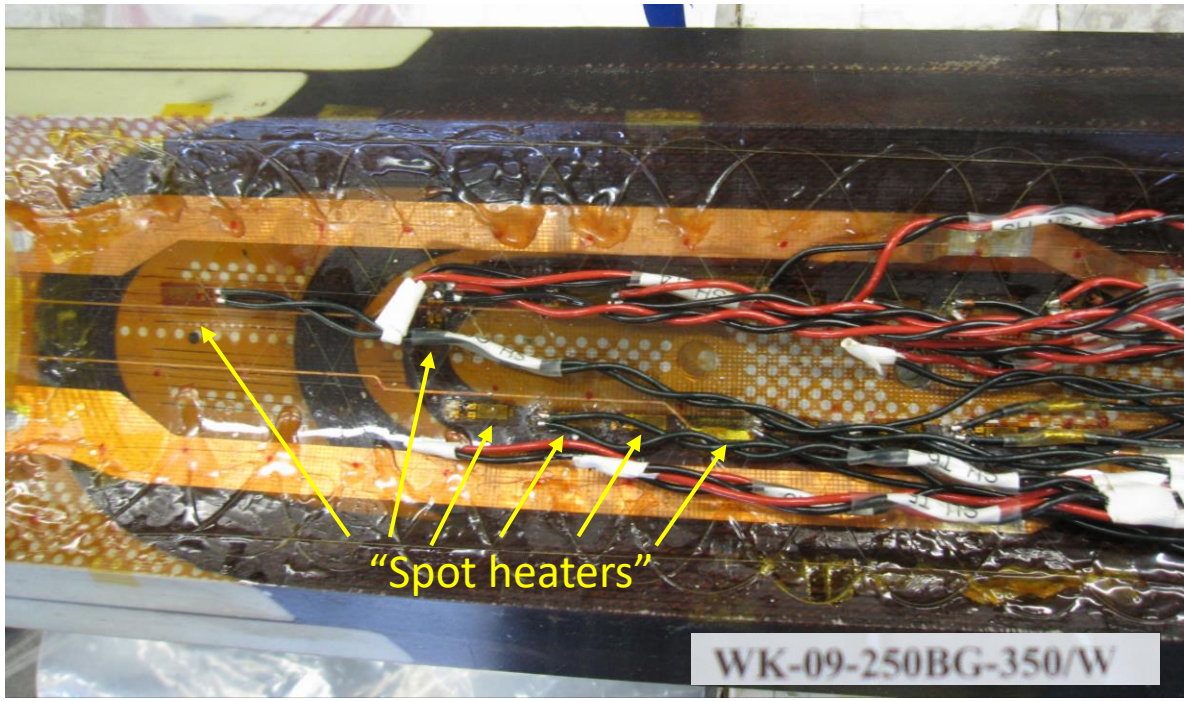
Spot heaters, quench voltage development

				New date	
AIIId-M5	Completing spot heater studies to improve voltage-based diagnostics and address "silent" quenches	Jul-21	Not started	Jul-23	S. Stoynev

A mirror magnet called MQXFSM3 is being assembled as a "diagnostics vessel". Part of Diagnostics are strain gauges to be used as spot heaters.

After September 6th we have insufficient technical personnel or priority to plan in detail, but work will continue (coil instrumentation finalization and then magnet assembly lead by two of our engineers as parallel support).
July 2023 should be a relatively safe deadline for magnet testing.





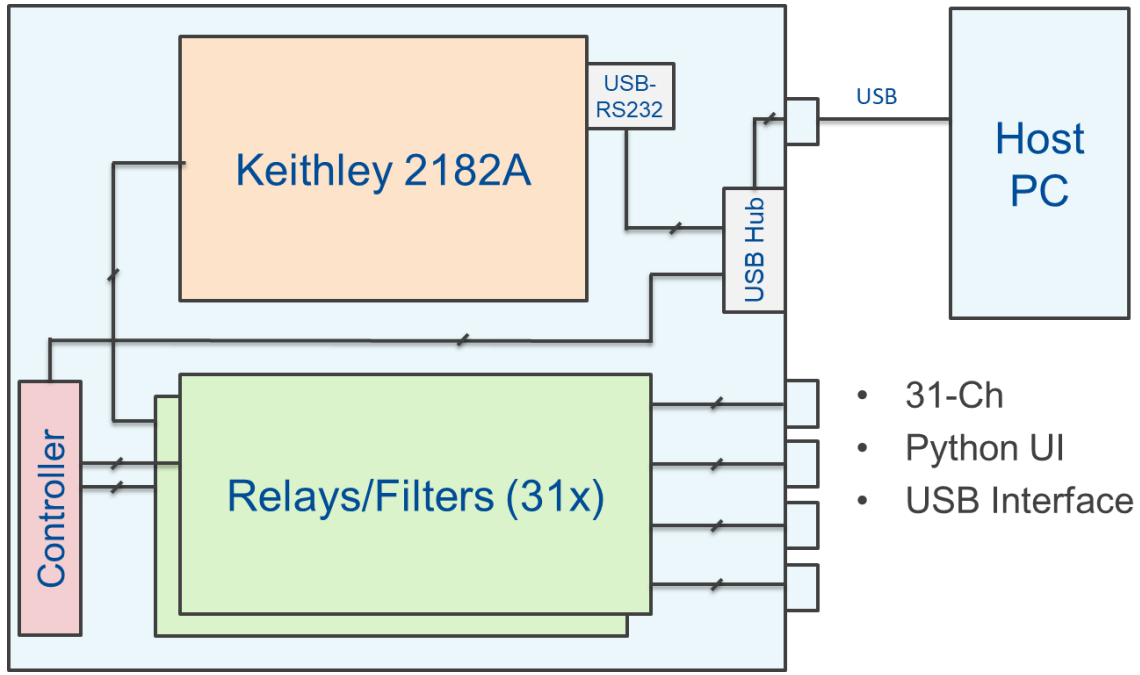
The main goals and reasoning regarding this development are found in https://www.osti.gov/biblio/1769393 (since 2020)

V-I system (Tom Cummings, Stoyan S.)

AIIId-M5a	Development and comissioning of a dedicated V-I measurement system (multichannel nanovoltmeter) for superconducting magnets	Jan-00	In progress	Mar-23	S. Stoynev

The V-I system design is ready, parts are procured; there was a long period where the key engineer was not available for personal reasons. We also had issues with technician availability, seemingly resolved very recently. We still think that by December we'll have a functional tester (limited number of channels at this point of time).
The rest should be straightforward.

This architecture differs by the existing 20-channel unit (input/output mainly)



- 31-Ch
- Python UI
- USB Interface

(as of June)

- Develop Python UI: Complete
- Develop USB Interface: Complete
- Develop Controller Firmware: Complete
- Design/Order/Receive Controller PCB: Complete
- Order/Receive Controller Components: Complete
- Order/Receive Chassis Components: Complete
- Chassis Panel Drawings: IP (95%)
- Chassis Schematics: IP (95%)
- Controller Assembly: Not started
  - 20hrs technician
- Assemble Chassis: Not started
  - 100hrs technician

Flex-QA arrays (Stoyan S., Joe DiM.)

New date

AIIId-M7	Development of multi-element and flexible quench antennas and localization of quenches using flexible quench antenna arrays	30-Sep-21	Completed		S. Stoynev,
AIIId-M7a	Characterization of different quench antenna designs for use in superconducting devices		In progress	Jan-23	S. Stoynev,

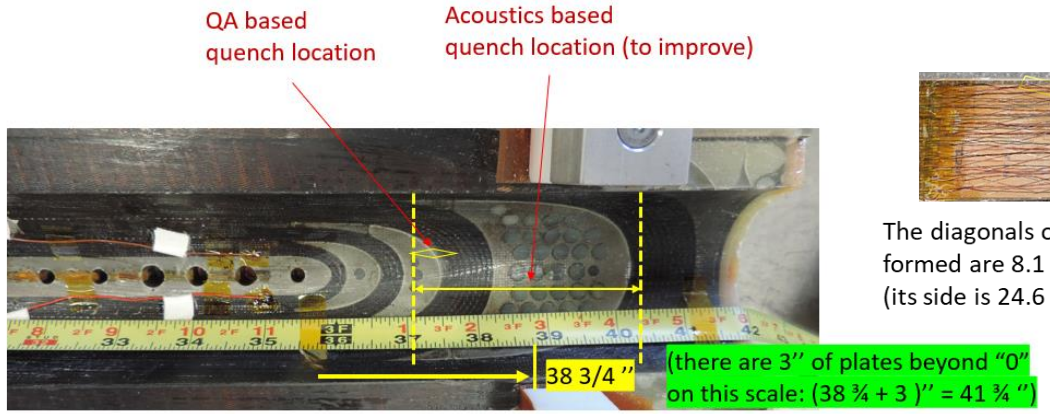
Multiple QA designs, QA warm bore supports, and a "warm" test stand (WTS) were designed/procured.

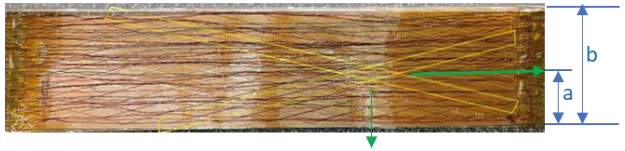
One QA was tested "cold", some of the results were presented.

IEEE TRANSACTIONS ON APPLIED SUPERCONDUCTIVITY 9500205

Flex-PCB Quench Antenna Developments at FNAL

Stoyan Stoynev and Joe DiMarco





The diagonals of the rhombus formed are 8.1 mm and 48 mm (its side is 24.6 mm).

Analysis of signals, including from the outer coil layer, continue; additional testing on channel reduction was performed, analysis still in progress

Details in ASC 2022

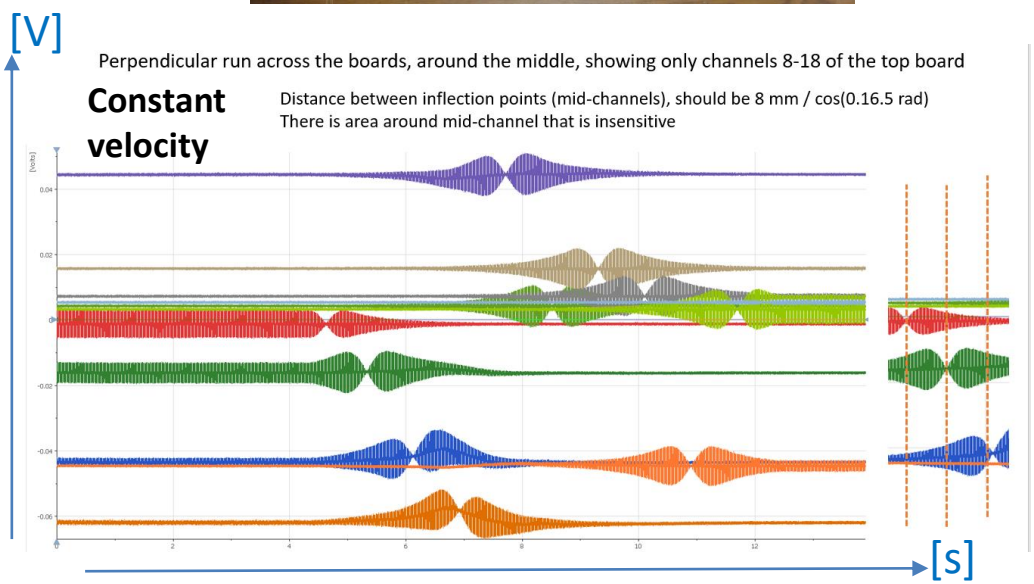
Flex-QA arrays (Stoyan S., Joe DiM)

New date

AIIId-M7	Development of multi-element and flexible quench antennas and localization of quenches using flexible quench antenna arrays	30-Sep-21	Completed		S. Stoynev,
AIIId-M7a	Characterization of different quench antenna designs for use in superconducting devices		In progress	Jan-23	S. Stoynev,

We continue with QA characterization on WTS, all different designs. Main work will be completed for ASC publications.

Flex-QAs prepared for "warm" testing or for installation in MQXFSM3



Tests were performed on the "warm" test stand

Data from the same QA used in the mirror magnet shown

Details in ASC 2022