Methods in Quench Detection for Advance Superconductive Systems

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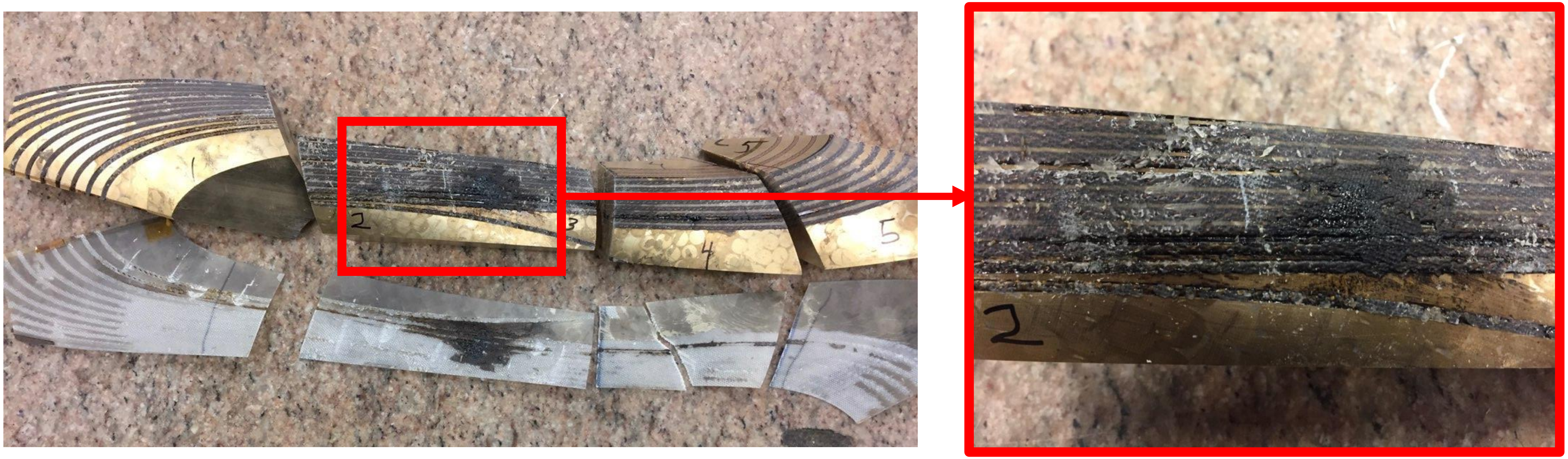
MOTIVATION

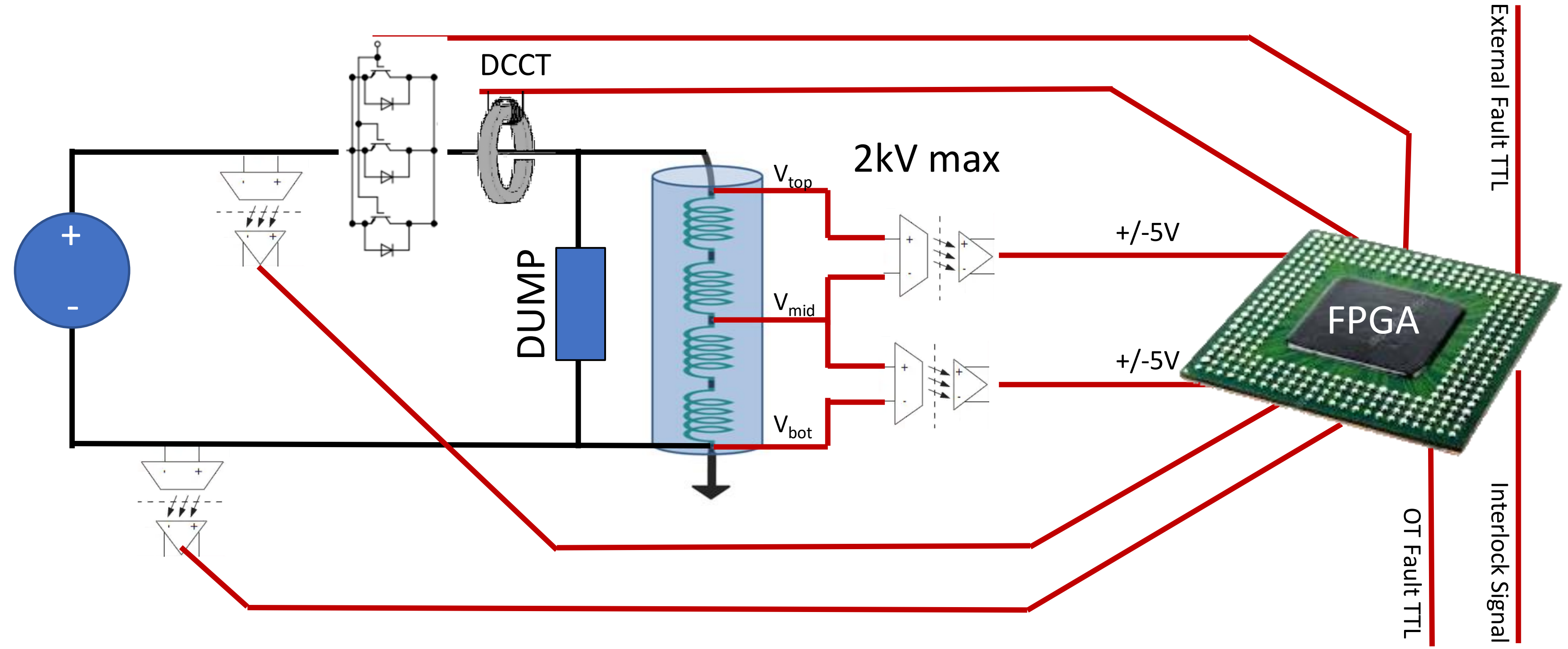
- Early detection of the quench development in superconducting magnets is critical for its protection. Superconducting coils are easily damaged due to hot-spot overheating if active protection is not timely activated resulting in the loss of the magnet;
- This detection must be performed in real time with the minimal possible amount of lag time between the detection and the activation of the protection system;
- Systems design to detect the precursor conditions to the magnet quenching are called quench detection systems (QDS);
- Quench detection characteristics are generally optimized for High Temperature Superconducting (HTS) magnets, and Low Temperature Superconducting (LTS) magnets.

DAMAGE

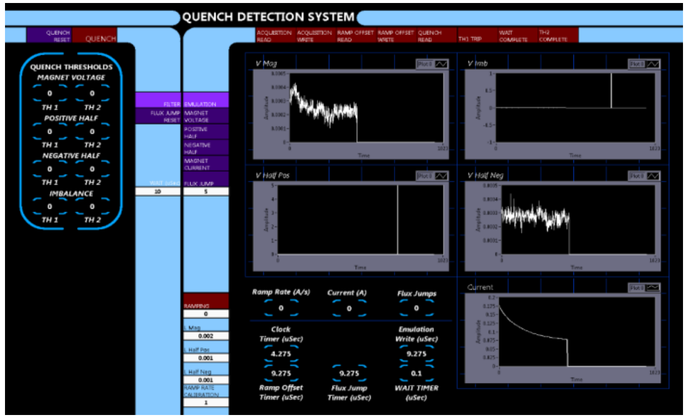


- Pictures of magnet cutout shows damaged due to delayed quench detection;
- Failing to detect a quench don’t necessarily leads the magnet to burn, depending on the magnet it can only cause excessive boiling of the cooling fluid, or reduce the magnets performance.

TYPICAL QUENCH DETECTION HARDWARE



Signal provided by voltage taps



VOLTAGE TAP SYSTEM AT LBNL

LabVIEW
LabWindows/CVI

Win/Linux

LabVIEW RT
LabWindows/CVI RT

VxWorks

LabVIEW FPGA
Custom VHDL

NI-RIO

Controller

PowerPC

Chassis

FPGA

LBNL QUENCH DETECTION SYSTEM

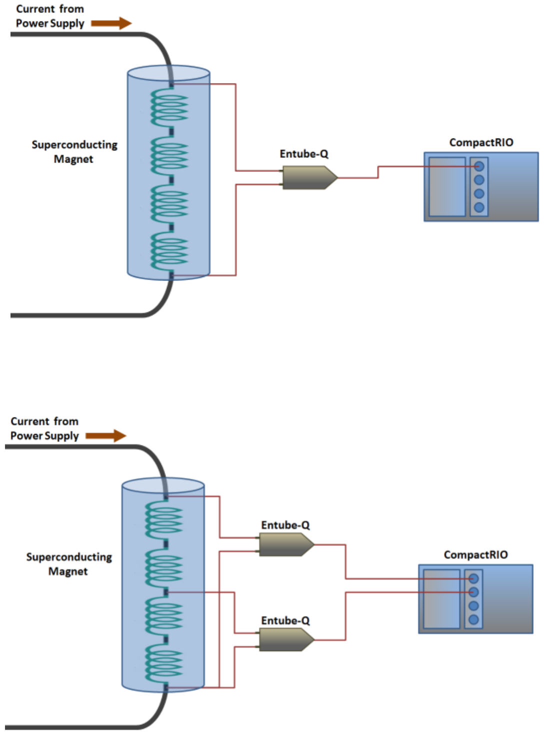
Modules

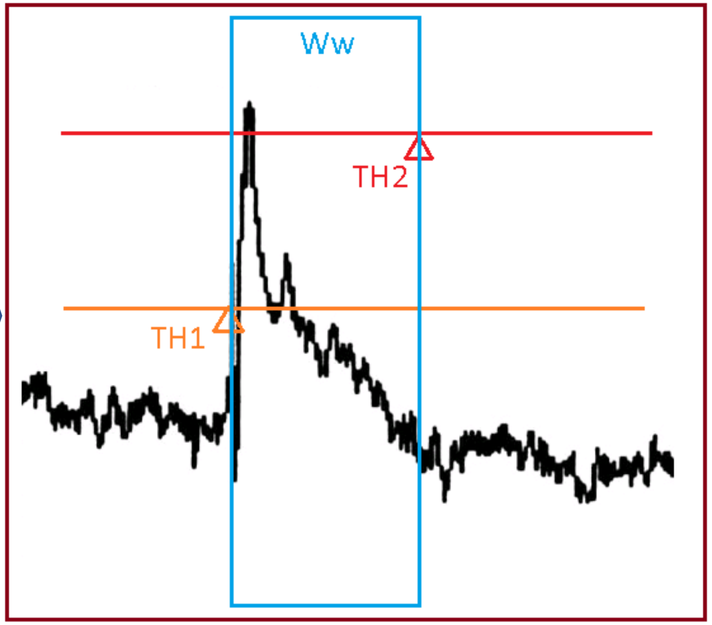
NI-9215
4 ch 100kS/s 16bit

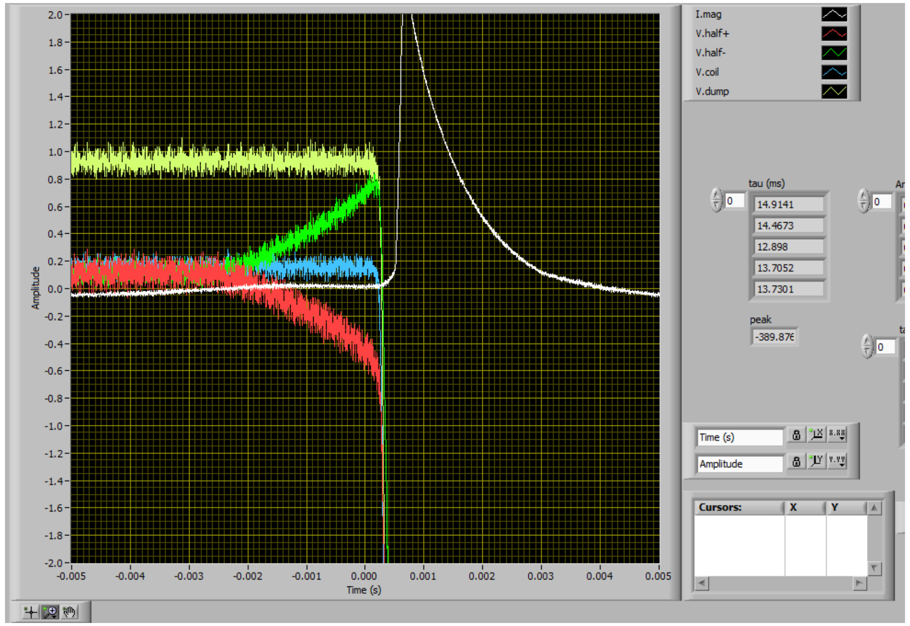
NI-9401
8ch 100ns TTL

REAL TIME DETECTION

SIGNAL ORIGIN



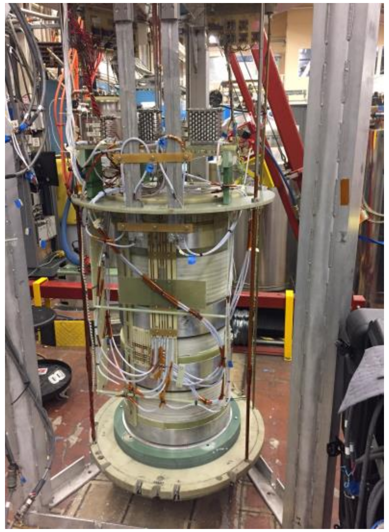


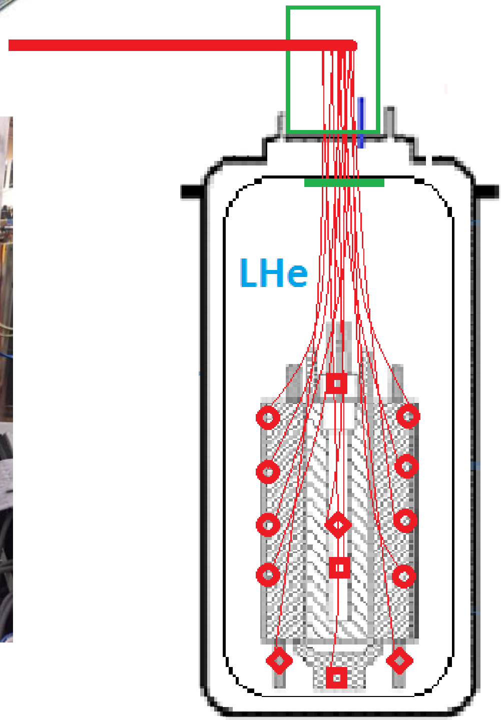


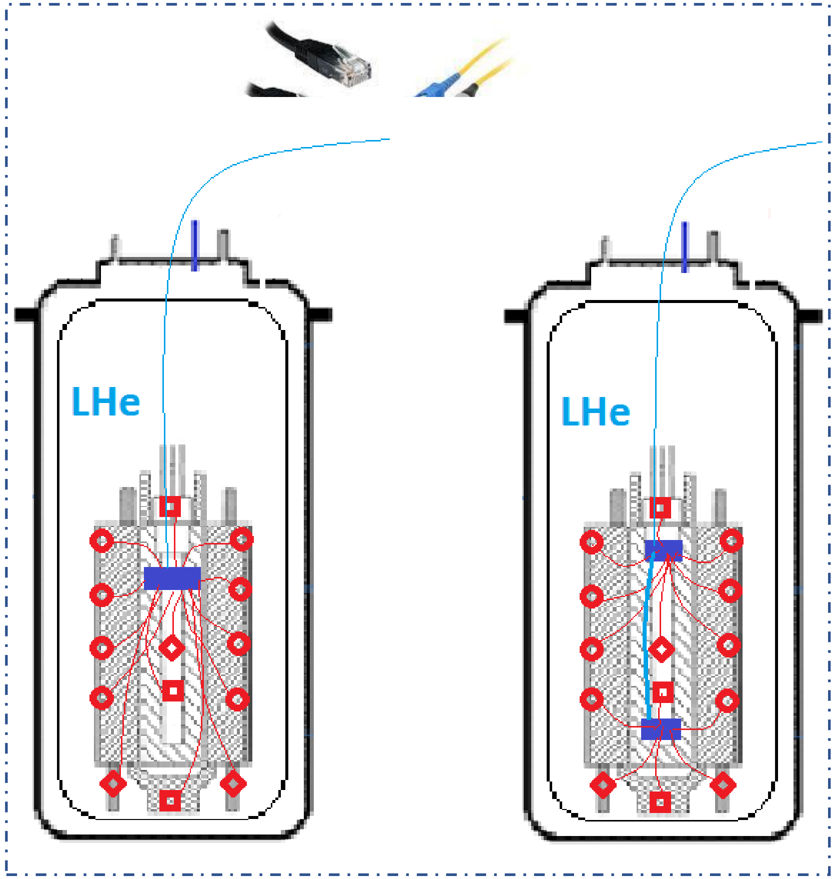
Ww – Window width 2us- 100ms
TH1 – Trigger Threshold
TH2 – Action Threshold

PROTECTION ACTIVATION

MULTIPLE SENSORS



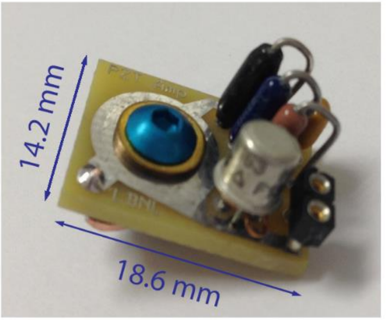


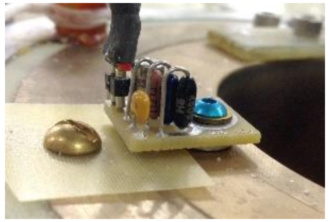


- Acoustic
- Voltage Taps
- Antenna

ALTERNATIVE READOUT SCHEMES

ACOUSTIC DETECTION





CCT2

HD3b

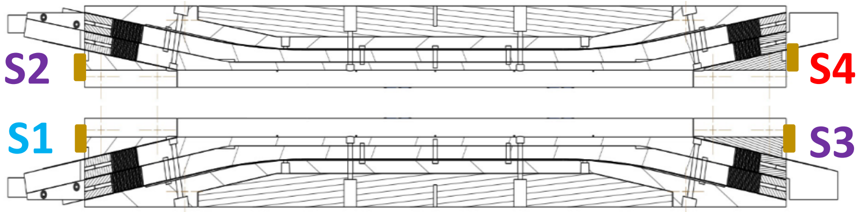
HQ01

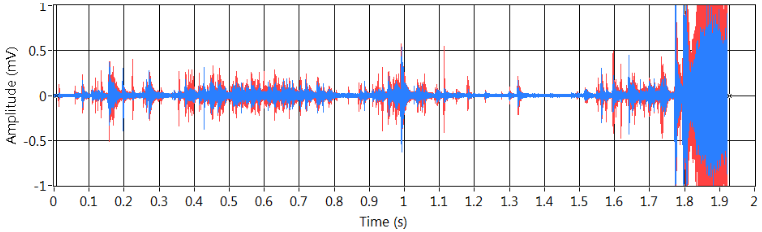
- In-house developed GaAs MOSFET amplified cryogenic acoustic emission sensors (1.9 - 300 K)
- Bandwidth up to ~300 kHz Location triangulation (~ 5 cm accuracy)

✓ Non-intrusive

✓ Immunity to magnetic fields

✓ Inexpensive, portable and easily adaptable to various magnet configurations





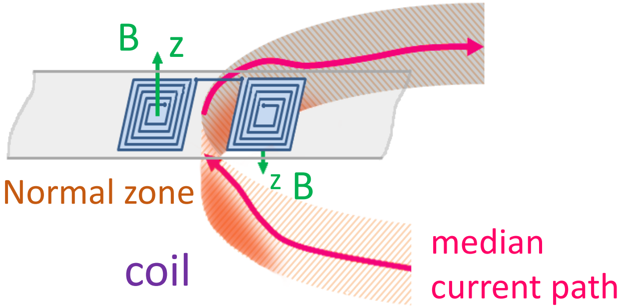
Ramping to a quench (slowed down 10x)

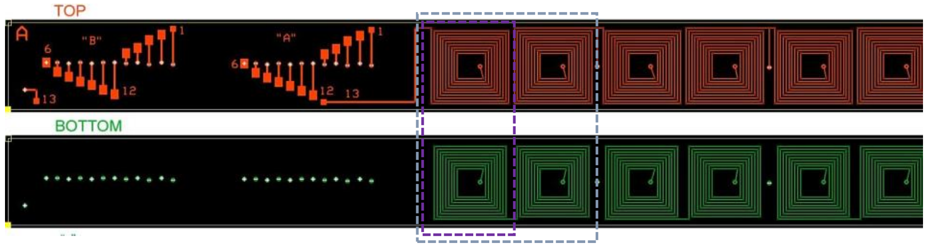
Tested on HQ series, HD3b, Mu2e solenoid, SCU, CCT series and HTS sub-scales Adopted by LARP for MQXF-S and CERN for main dipole and HTS "Feather 2" dipole.

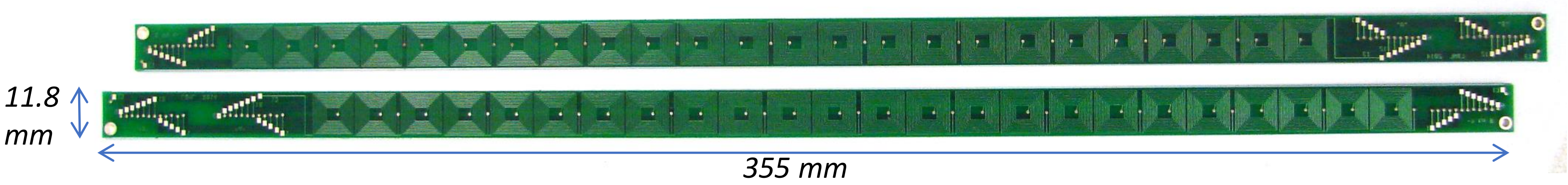
Courtesy Maxim Martchevskii

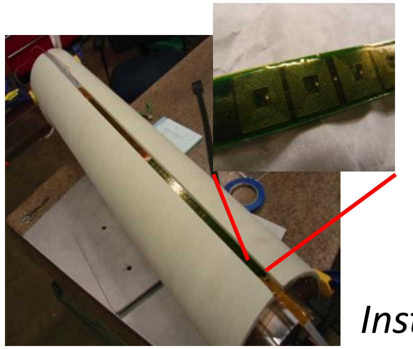
ELECTROMAGNETIC DETECTION

CCT magnet geometry requires a special antenna design: a linear coil that can be placed on top of the coil winding, or in-between the layers.









Installation on the outer layer of CCT2

- 24 printed square coils (each is 2 layers, ~20 turn total, ~1 cm side). Coils are dipole-bucked thus forming 12 independent sensors per array.
- PCB is 1.4 mm thick; Flex circuit can be as thin as 0.28 mm
- Two arrays can be further “stacked” linearly with a flat ribbon cabble

Courtesy Maxim Martchevskii