Quench antenna development update

MDP Meeting

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US Magnet Development Program

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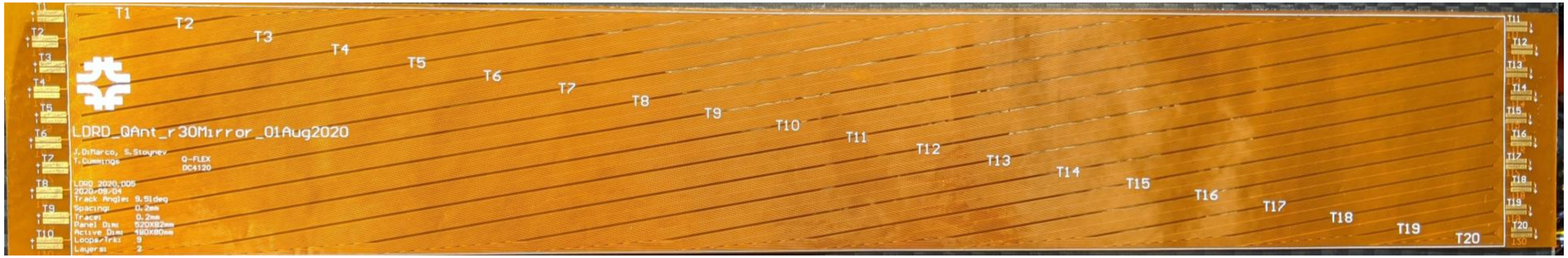
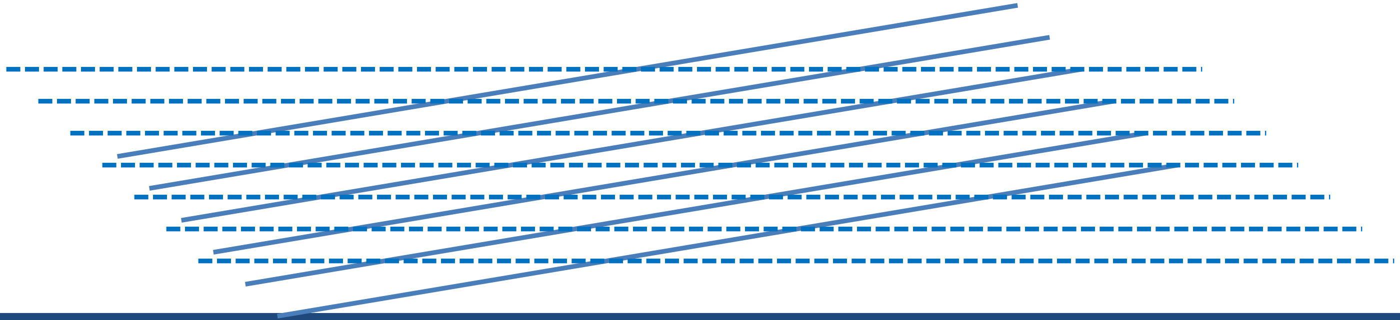
QA arrays used in COMB-STAR-1 (HTS dipole) testing

10 channels, each consists of six identical sections connected in series.
Each section is a bucked signal of two triangular shapes.



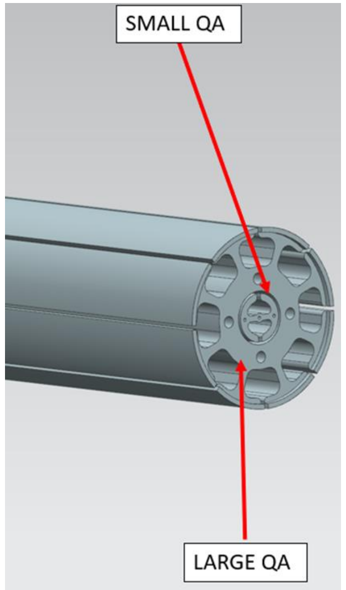
2 x 10 channels (mirroring each other);
each is made of concentric loops.

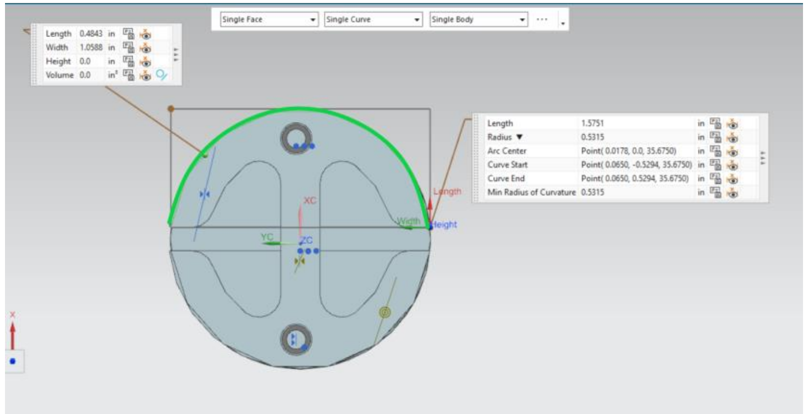
Same panel size (active area): 80 mm x 480 mm; same channel width: 8 mm.
Those were developed in 2020 (LDRD).



When overlayed – channels form a grid which covers ~ 360^{o} (338^{o}) angle in the bore, over the full length of the coils (~ 20 cm).
(for one of the poles, #1, there is ± 11.75^{o} gap along the middle of the pole)

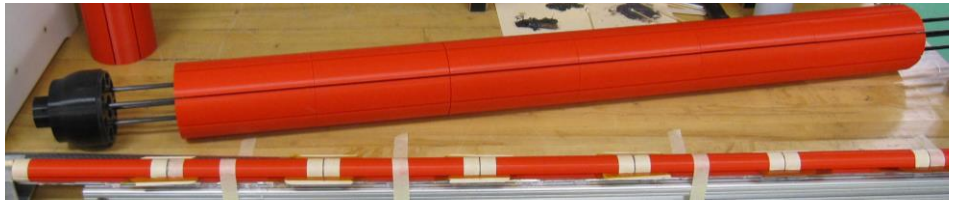
“Warm” QA in-bore support structure



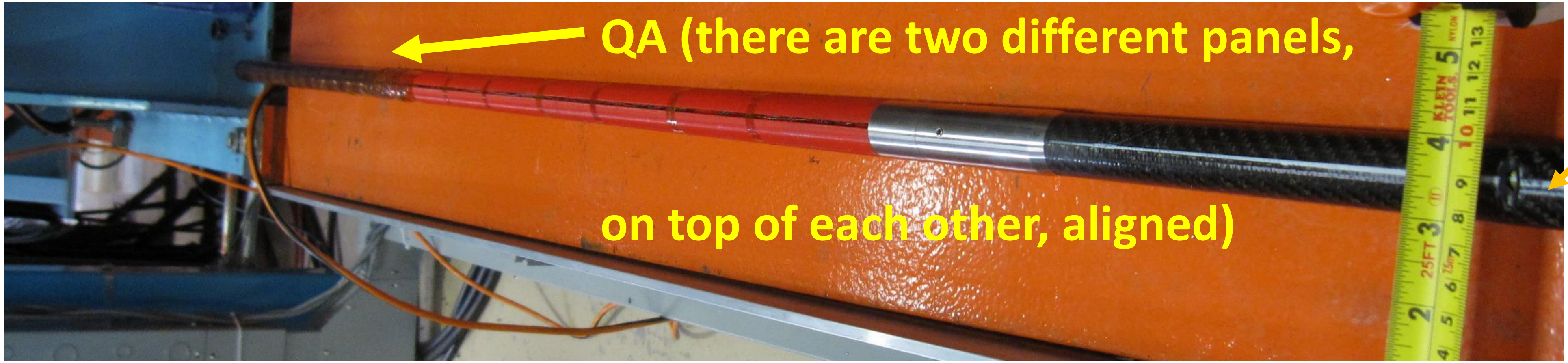


The radius of the small QA support is 0.5315” (or 1.063”dia). The perimeter of highlighted surface in green is 1.5751” The total length of the support is 49.875” (1.26m).

QAs were designed to fit the “smaller diameter” warm bore support.
QA are wrapped around the support body.
The support was developed in 2020-2021 (same LDRD).

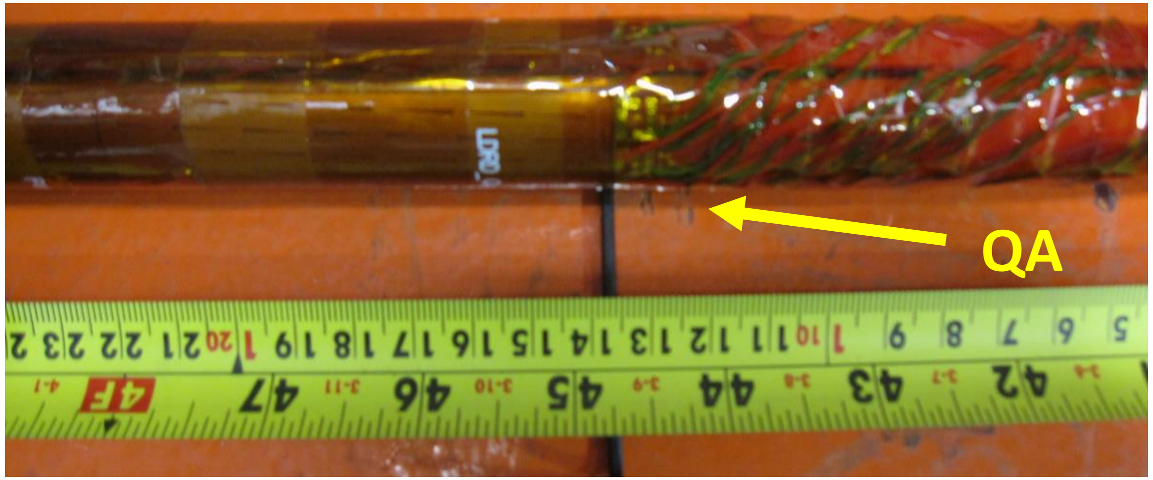


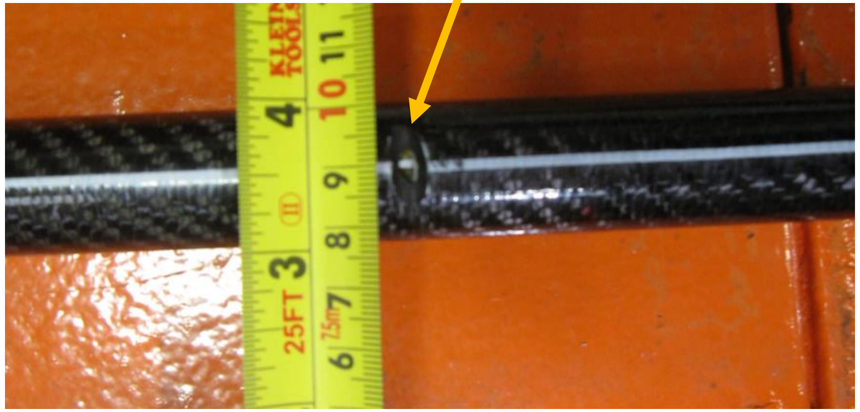
QA set up



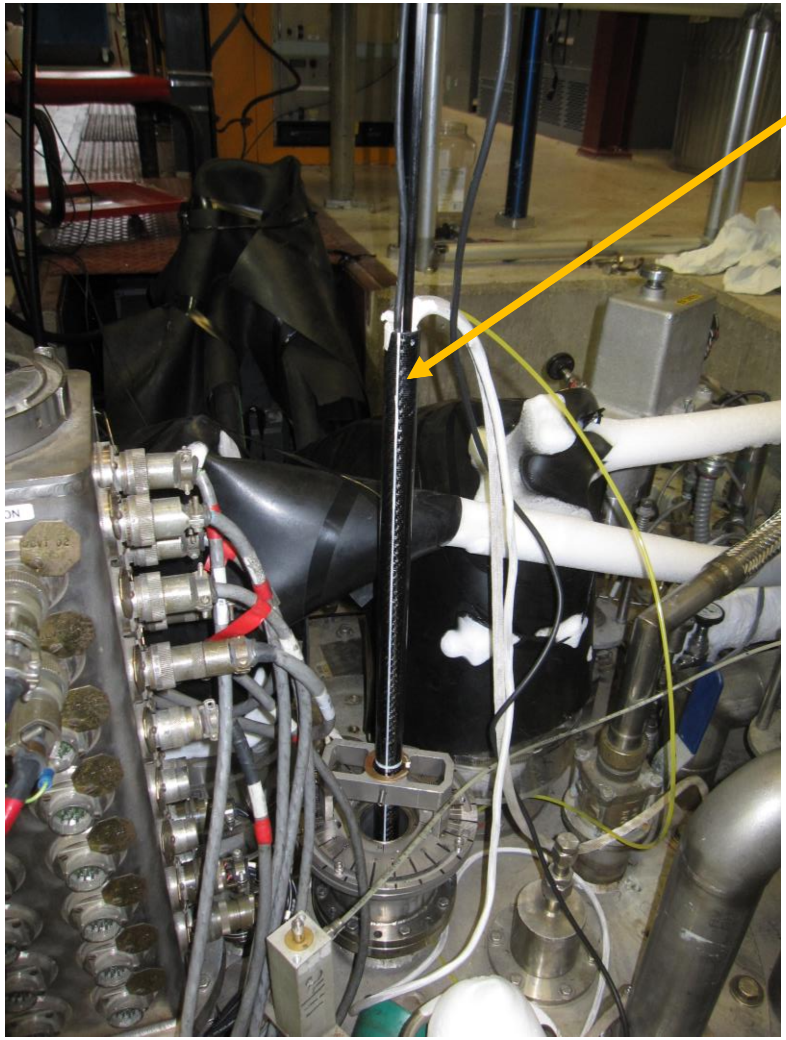
Carbon fiber tube (in black)

Aligned Hall Probe (for purposes of QA position determination)



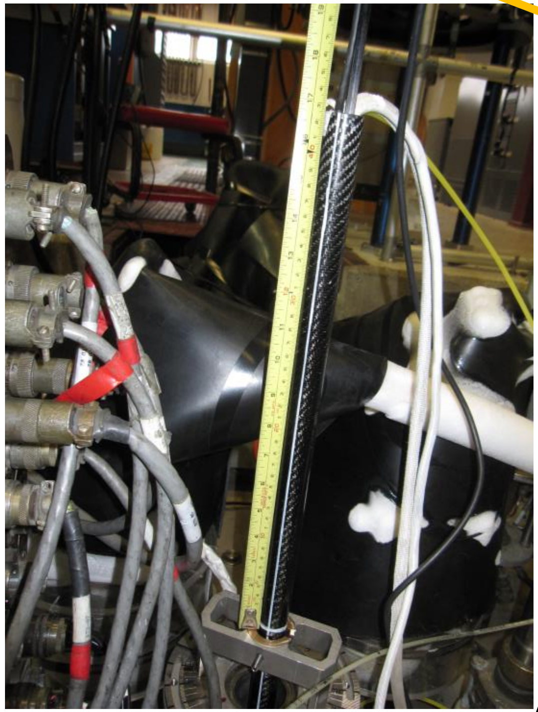


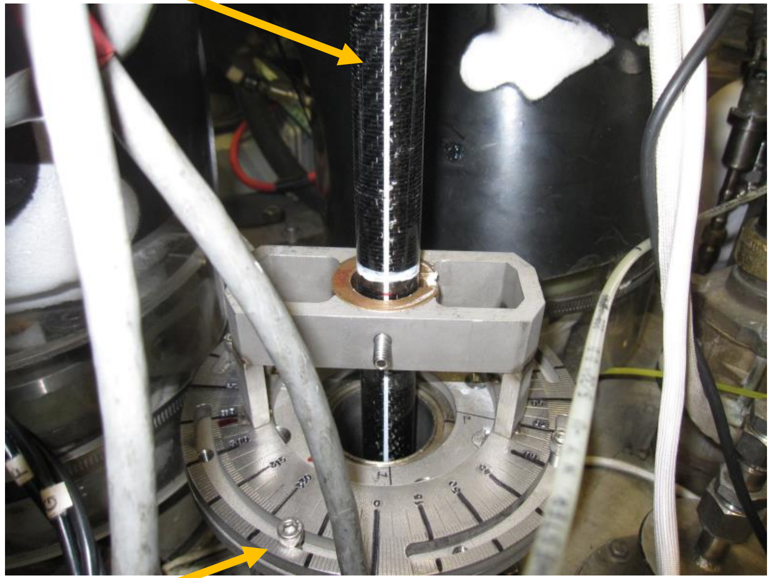
QA positioning (for the HTS dipole measurements)



Carbon fiber tube
(in black)

QA positioning





Angular fixation (within few degree in total)

Magnet

The magnet’s aperture is 60 mm and the support diameter is 27 mm.
Thus, the distance between the QA and the inner coil layer is ~ 16.5 mm (not the best in terms of sensitivity)

Instrumentation deployment

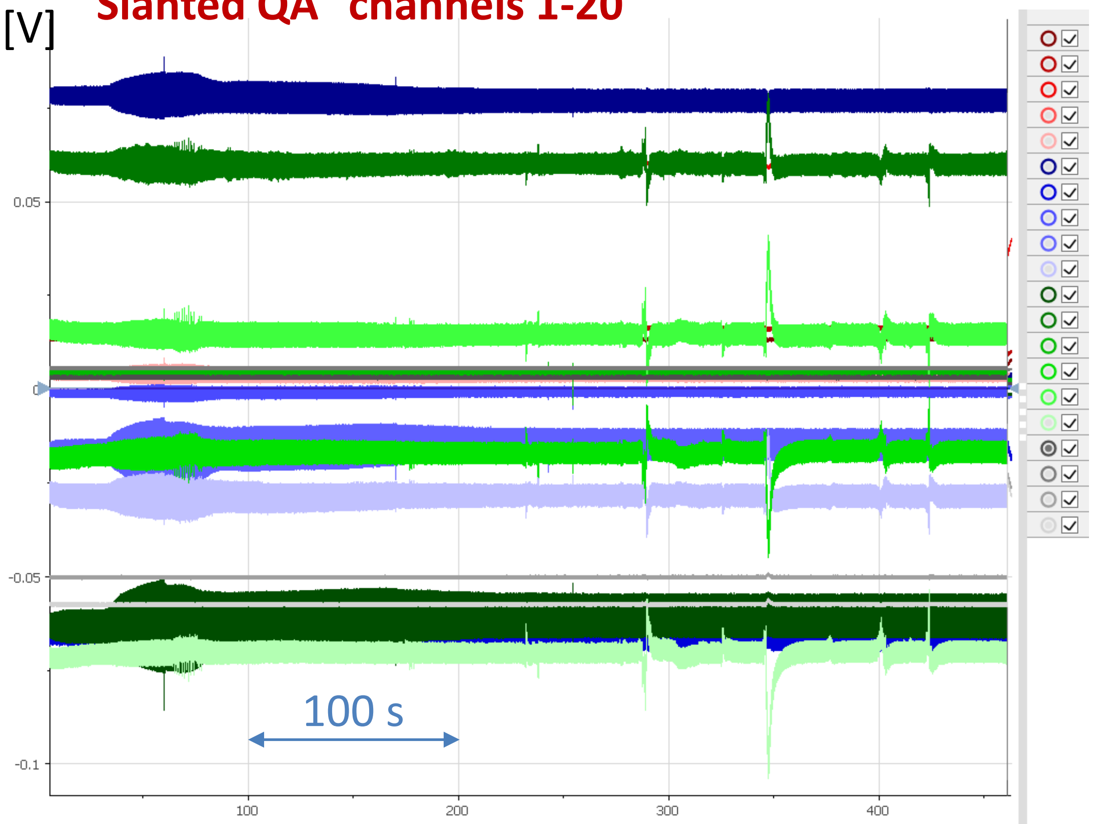
Although the arrays and support were available for several years now,

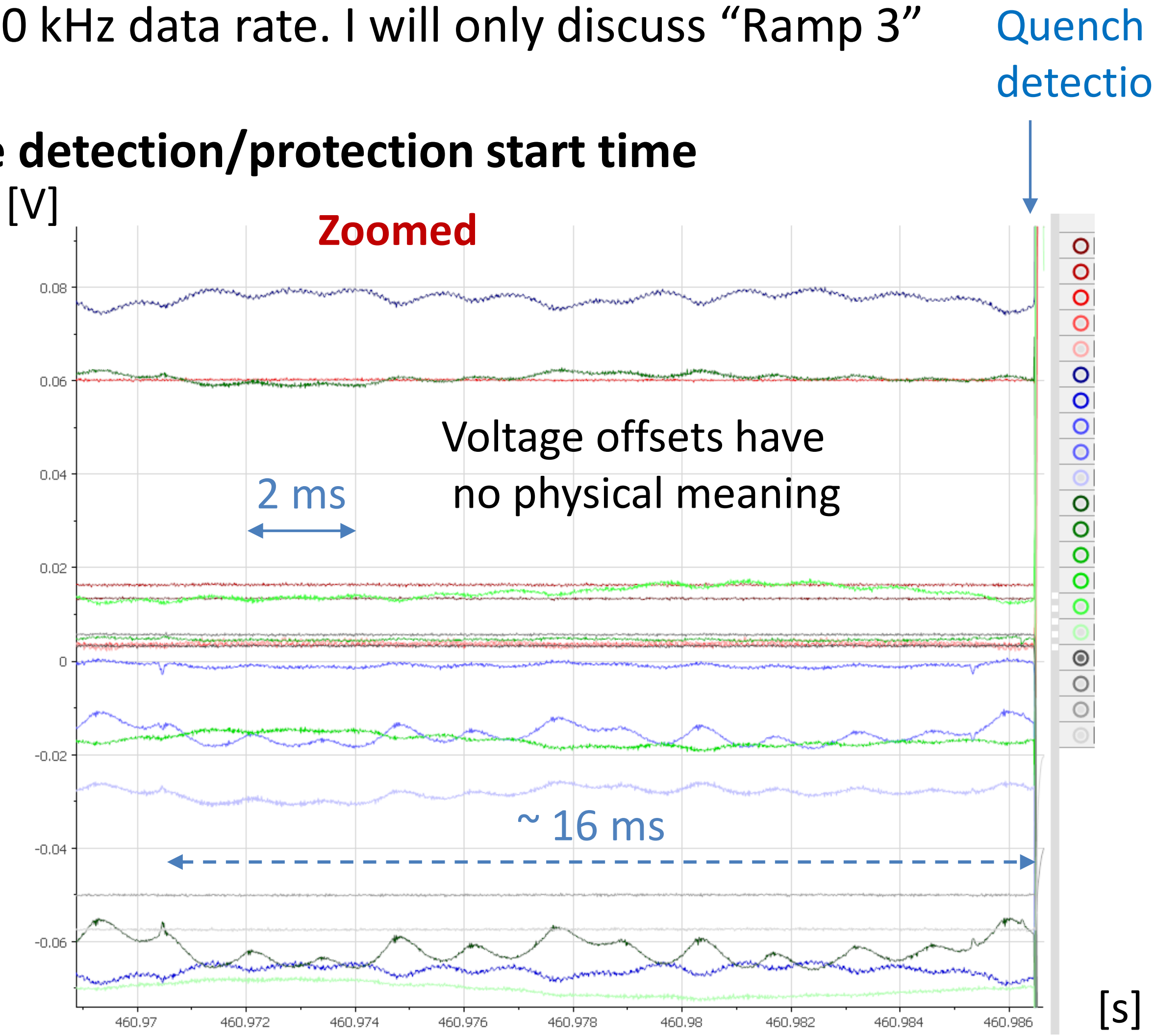
- This is the first in-magnet test for one of the QA array types (bucked QA)
- This is the first real magnet test of the two different QAs together
- This is the first use of the QA support in a real magnet test

Snapshots of data and quick analysis

Data (30 channels) are recorded over most ramps, 100 kHz data rate. I will only discuss “Ramp 3” (one of highest currents reached, I = 3273 A, 1.83 K),

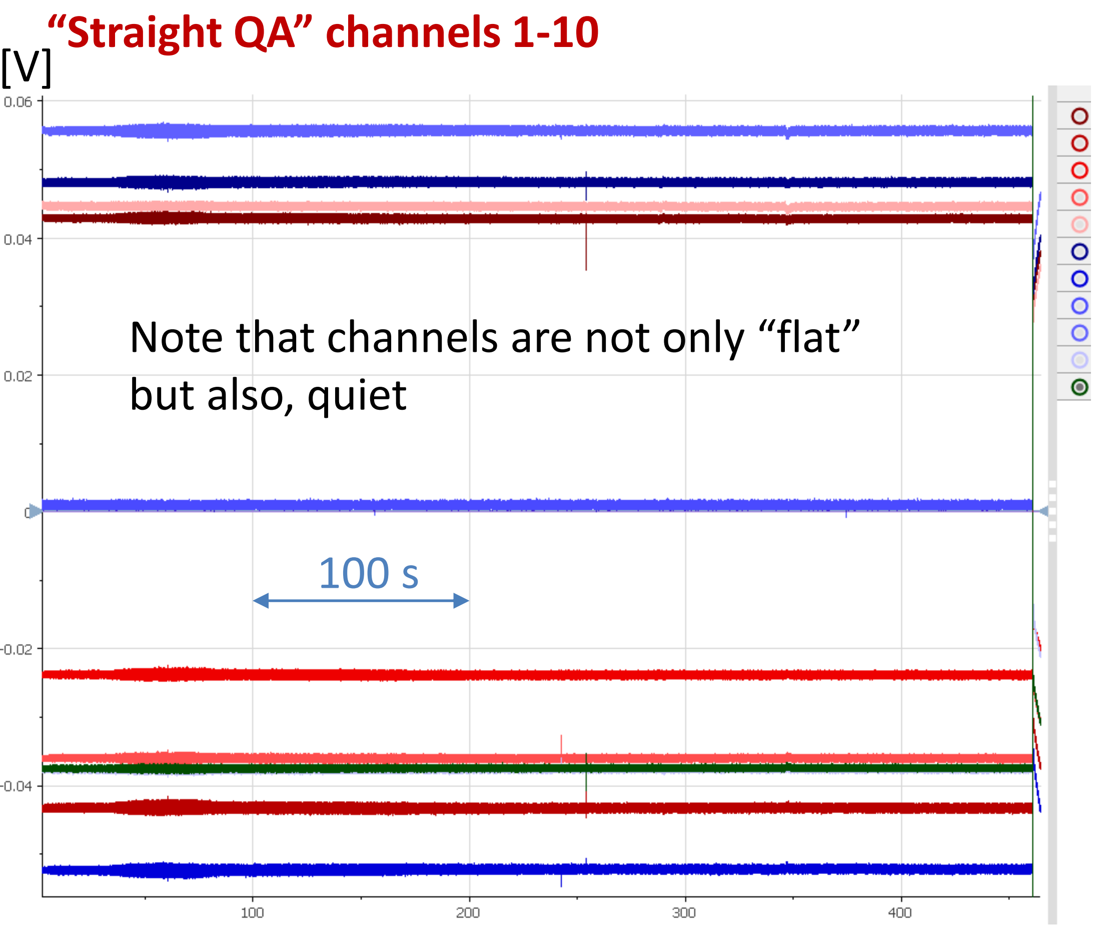
VT segments point to quench start at ~ 20 ms before detection/protection start time

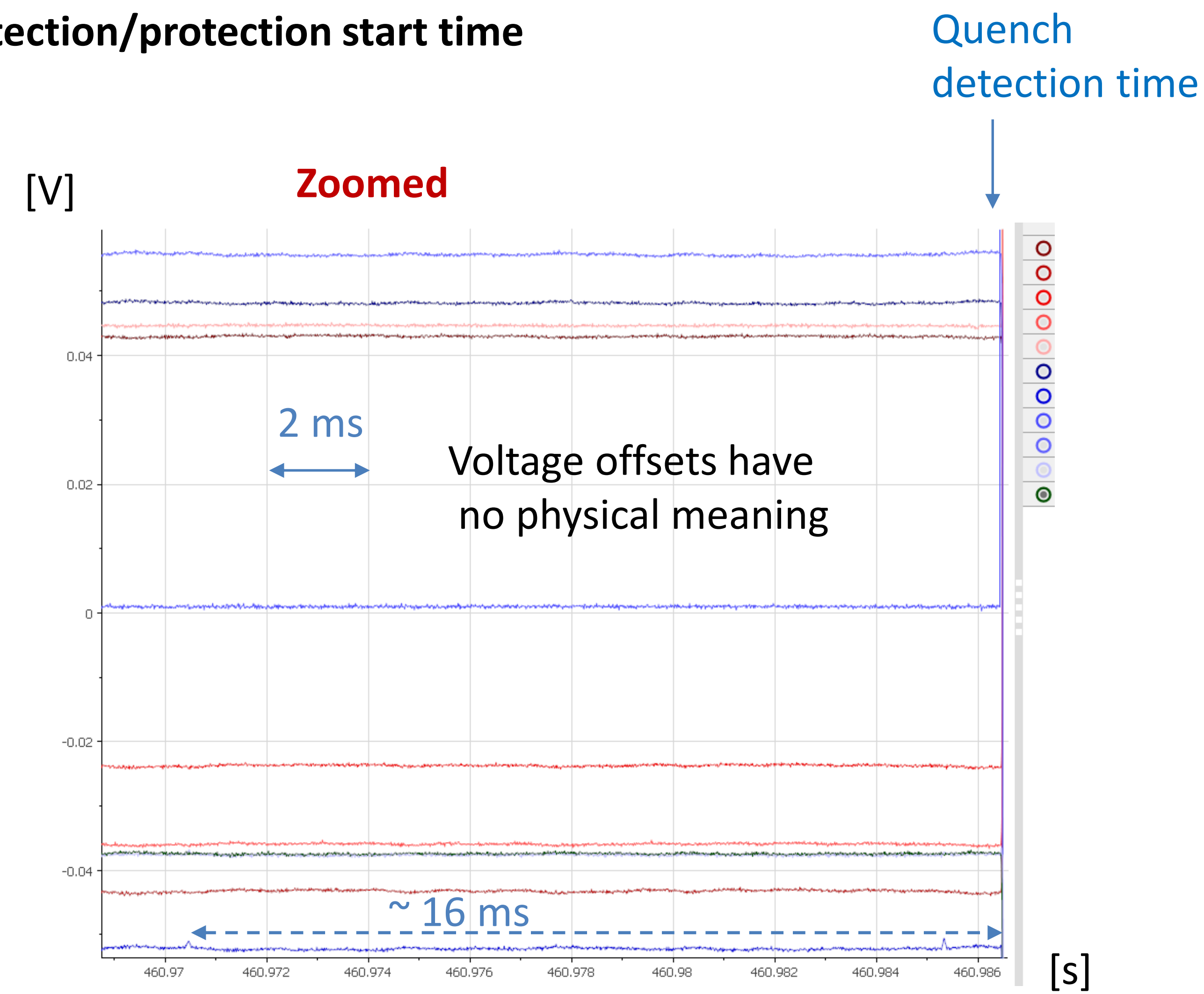




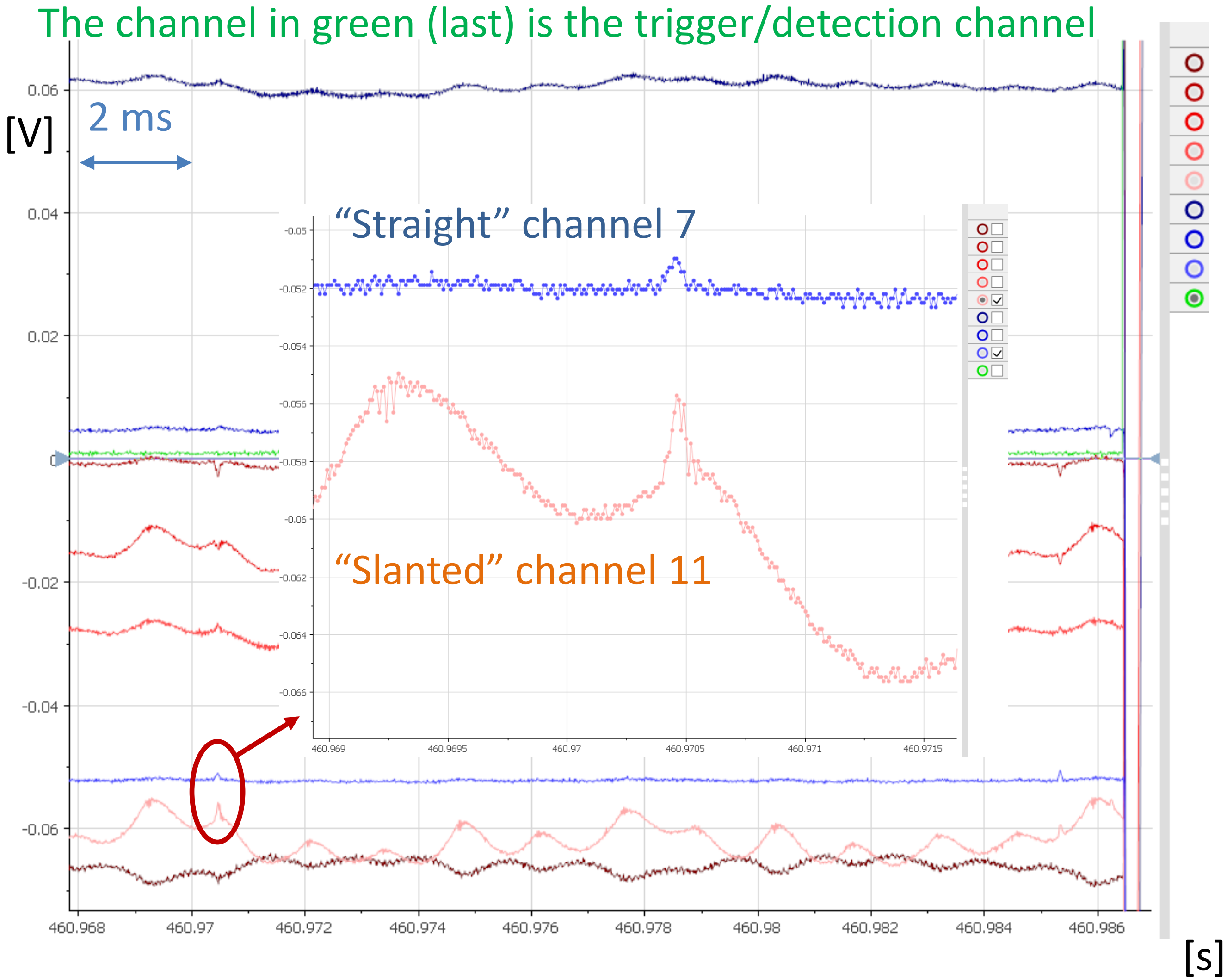
Snapshots of data and quick analysis

VT segments point to quench start at ~ 20 ms before detection/protection start time





Snapshots of data and quick analysis



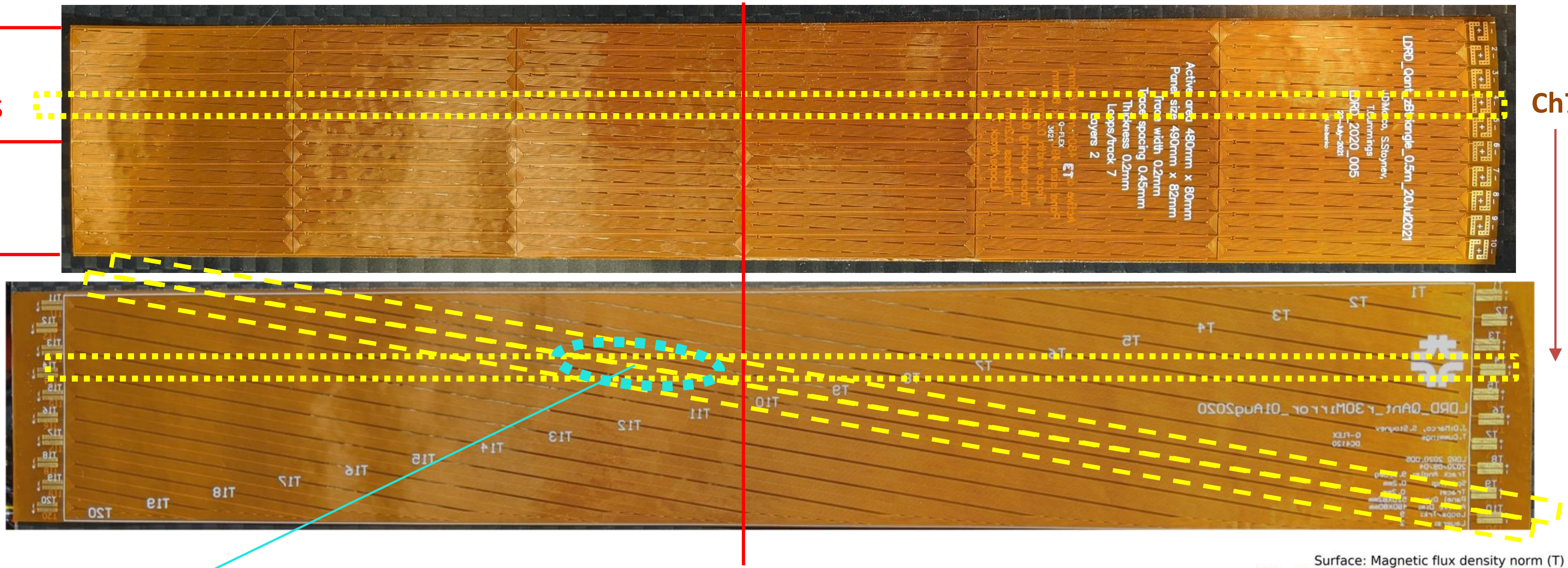
Channels 7 to 13 of the "slanted QA" array give the most prominent signals with clear ones at channels 8-9-10-11; the sign changes between channels 9 and 10 : **very likely the origin of the signal is at channels 9-10**
(we may be able to pin-point location better later)

The only channel with signal from the "straight" array is **channel 7**.

The "straight QA" is less noisy due to internal bucking although it has similar to the "slanted QA" "intrinsic" noise (see the "line" thickness/local RMS).

The "straight" channels have larger effective area across channel width (limited insensitive regions) and in average should generate higher signal.

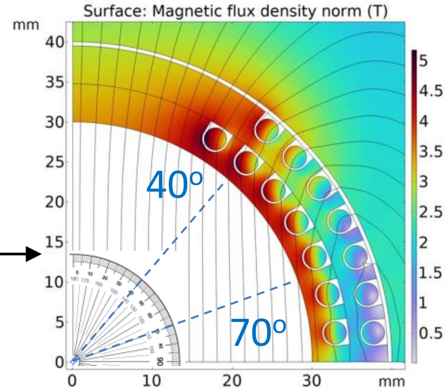
Snapshots of data and quick analysis



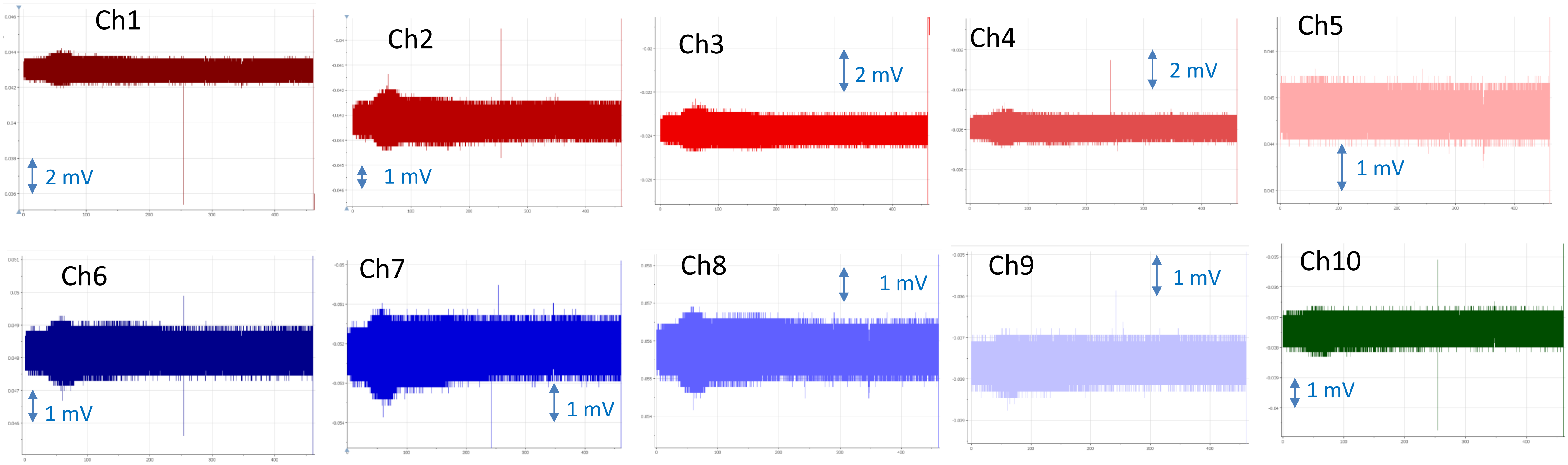
Quench azimuthal location is at 35°-70° from the pole
Quench axial location is 40 mm from the center (toward return-end), within ± 30 mm

(if we account for inefficiency zones, azimuthal location may be 45°-60°)

Actual radial extend of the QA



“Straight” channels during current ramping

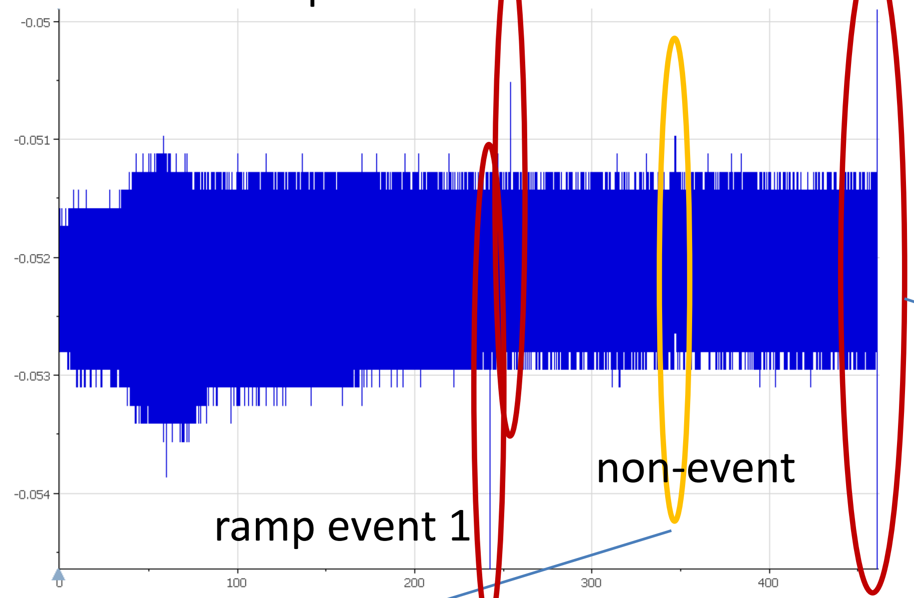


Before quench (trip) time – there is very little activity those bucked channels see, a couple of “events” or so each.
If QA sees all quench events and we can distinguish them from ramp events,
it will mean that QA alone can be used for **HTS quench detection**.

“Events”

Ch7 – the channel which saw the quench

ramp event 2



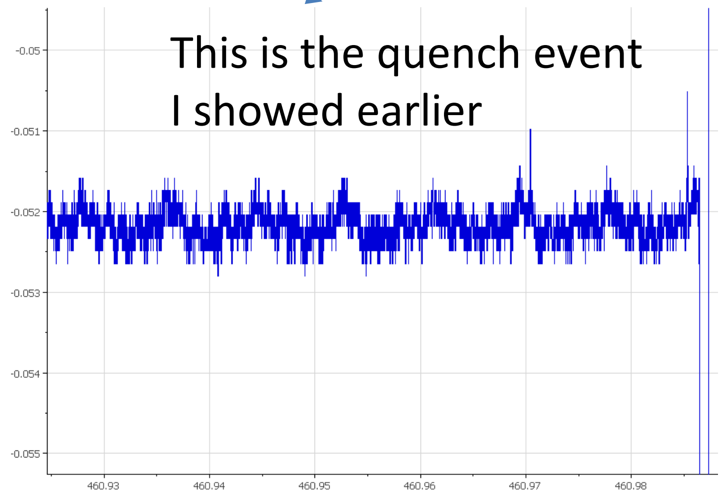
non-event

ramp event 1

This happens to be an overall slight up-change in the signal level lasting for ~1.5 s + a couple of single point spikes reaching “-0.051 V” absolute level (comparable to the level at quench)

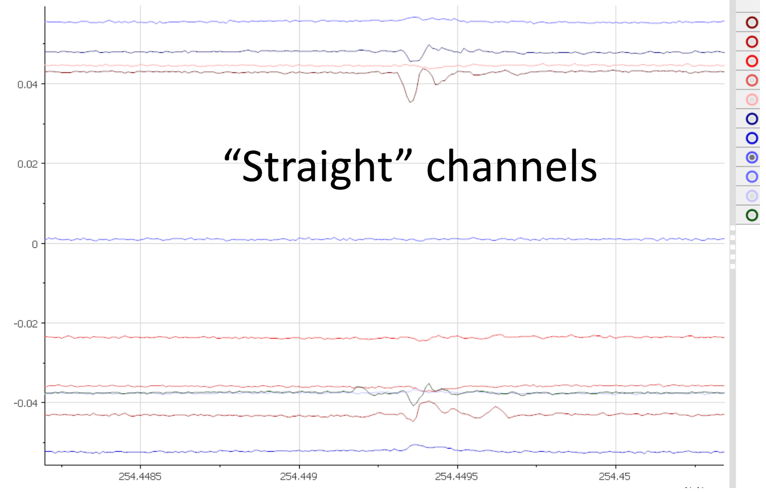
Zoom-in

This is the quench event I showed earlier

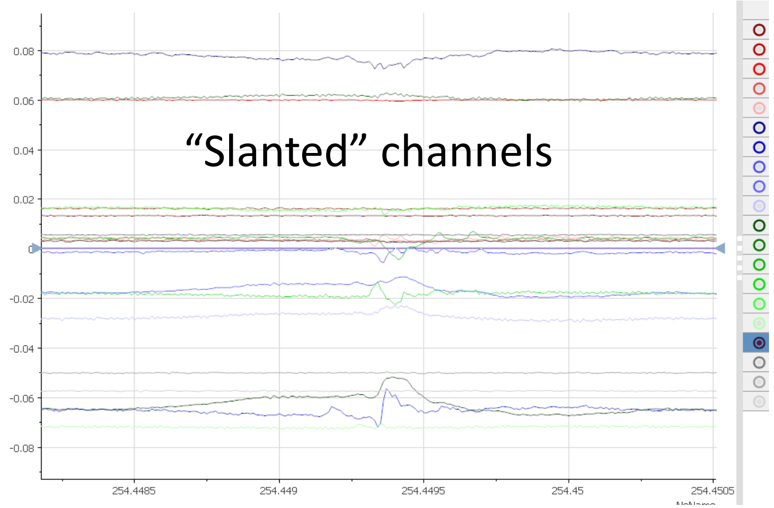


Zoom-in

“Straight” channels



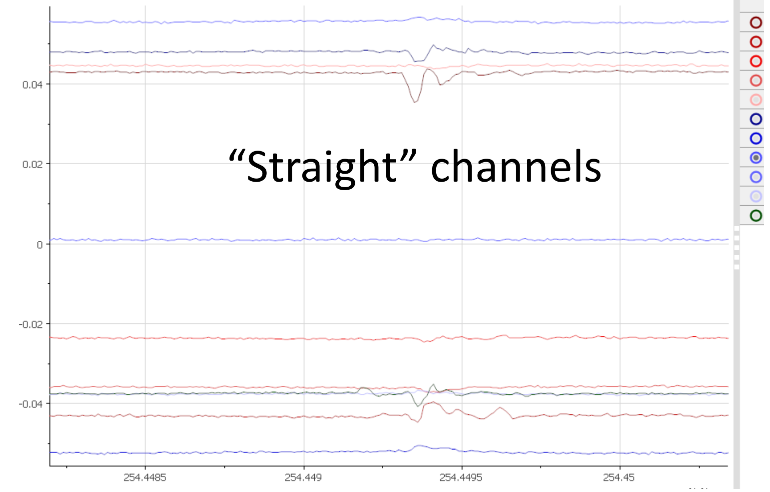
“Slanted” channels



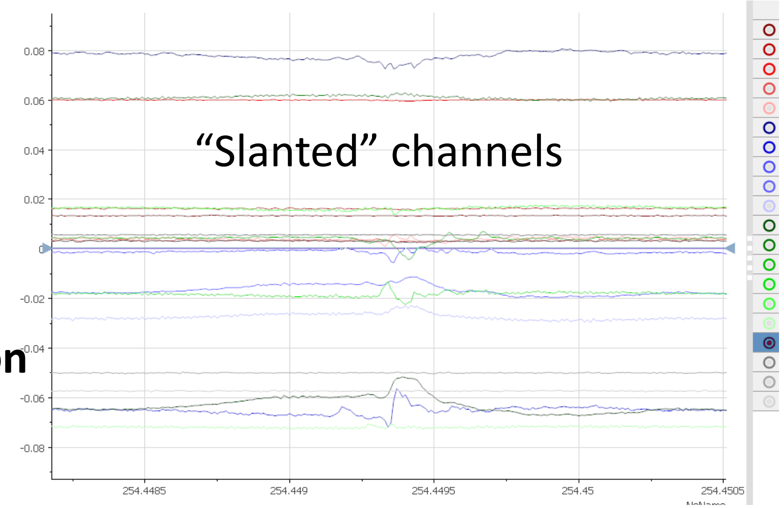
Ramp event 2

Zoom-in

All “straight” channels see this event but the highest signal is in Ch1 (then Ch2 and Ch10; and also Ch6 + Ch5 ?) – those are the two pole areas.



“Slanted” channels which saw this event are Ch5 to Ch16, with highest magnitudes not centered around a channel.
The “event” lasted more than 1 ms but different channels reacted differently.

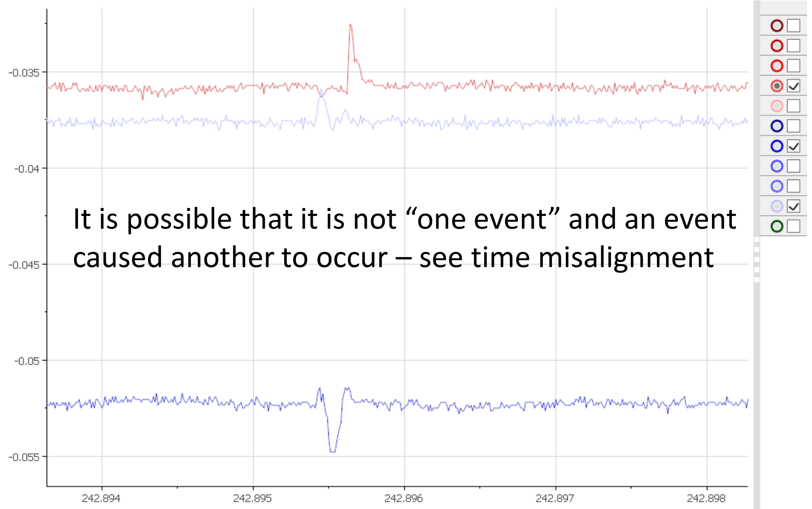


Indications are that this was a complex response with (likely) current redistribution occurring in both coils.

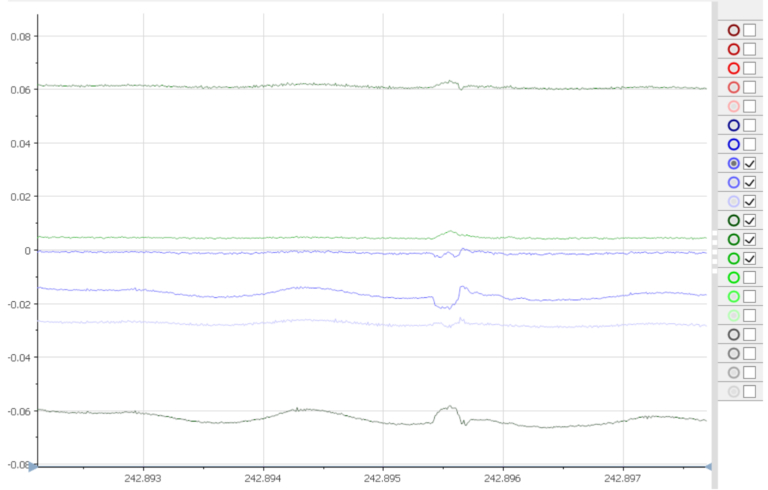
This is not a localized event

Ramp event 1

"Straight" channels Ch4, **Ch7** and Ch9 see it, with channels in between showing harder to distinguish signal – **those are different coils.**



"Slanted" channels Ch8 to Ch13 see it; at Ch10 the sign of the signal changes (this is likely the "central" channel), the adjacent channels are with highest amplitude.

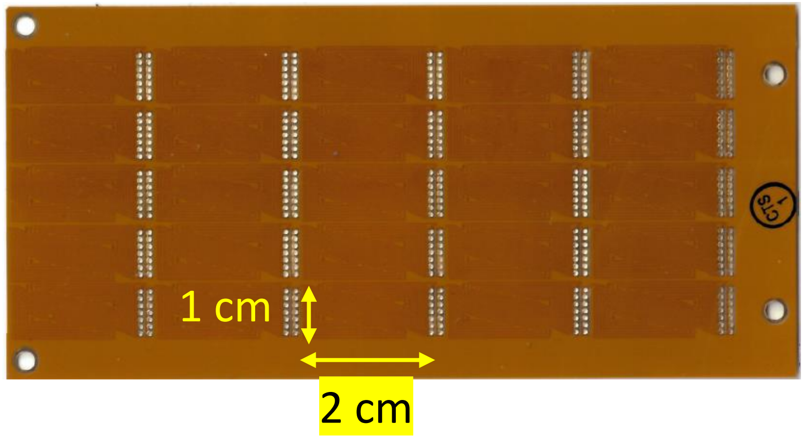


This is not a localized event

Data analysis is ongoing

Much more to analyze /and feed to ML/
including data from other sensors (acoustic, power supply current changes) taken simultaneously

So far, a strong message is that the bucked-QA is nearly free from fake triggers and sees HTS quenches
(there is more to this, not all clear, but it is not the time now to discuss)



The "pixelized" QA is another candidate with bucked-channels which may provide even better signal/noise ratio and less fake triggers (sensor dimensions may need to be tuned in future)