U.S. MAGNET DEVELOPMENT PROGRAM

Nb_3Sn CCT Subscale 7 Results

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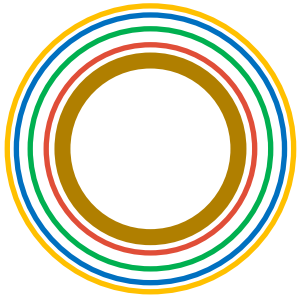
CCT Sub7 (filled wax) Impregnation

- Filled wax is expected to provide low strength properties of wax (desired for minimal training) but with improved bulk modulus for improved stress distribution to conductor
  - PSI transverse pressure test showed similar results for filled wax and epoxy while plain wax showed more Ic degradation
- Process for filled wax impregnation uses same concept as for other subscales but new consumable materials implemented
  - Glass tape wrap with sufficiently large openings for particles used
  - Peel ply with sufficient permeability for particles used
  - Low density flow media replaces hex cell media used for wax / epoxy
- Dispersion of particles in wax is improved by use of high shear mixer and probe sonicator

Impregnation Layers



Mandrel
Glass Tape Wrap
Peel Ply
Flow Media
Vacuum Bag / Shrink Tape

Coil Impregnation

Flow Media

Peel Ply Experiments

Coil after Impregnation

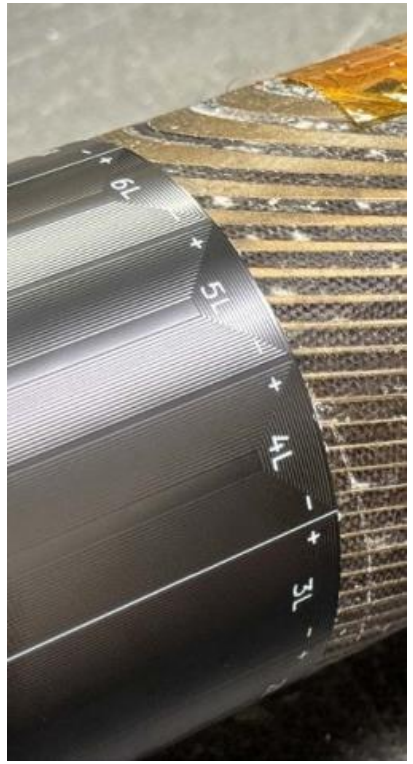
Impregnated Sample

Effort led by Jose Luis Rudeiros Fernandez

CCT Subscale 7 Test

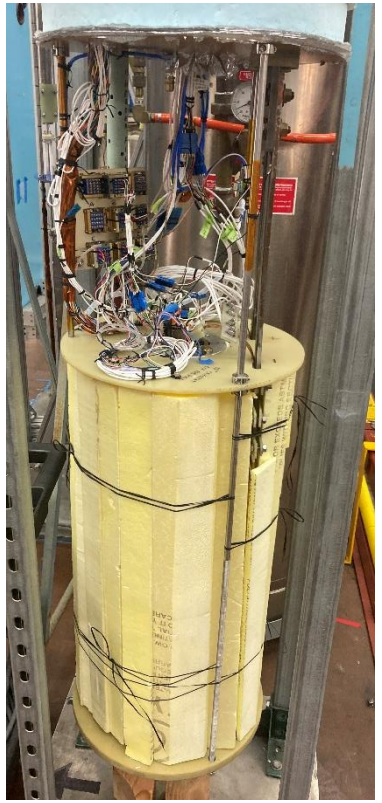
- Magnet assembled with typical Epoxy filled Kapton bladder process
  - Filled wax inner layer
  - Plain wax (no filler) outer layer
  - Outer aluminum shell
- Magnet tested in 15” Cryostat
- Instrumentation includes
  - Voltage taps
  - Flexible quench antennas in between layer 1 and layer 2
  - Acoustic sensors (to be presented at later date)
  - Strain gages on the shell

Quench Antenna



Developed by R. Teyber

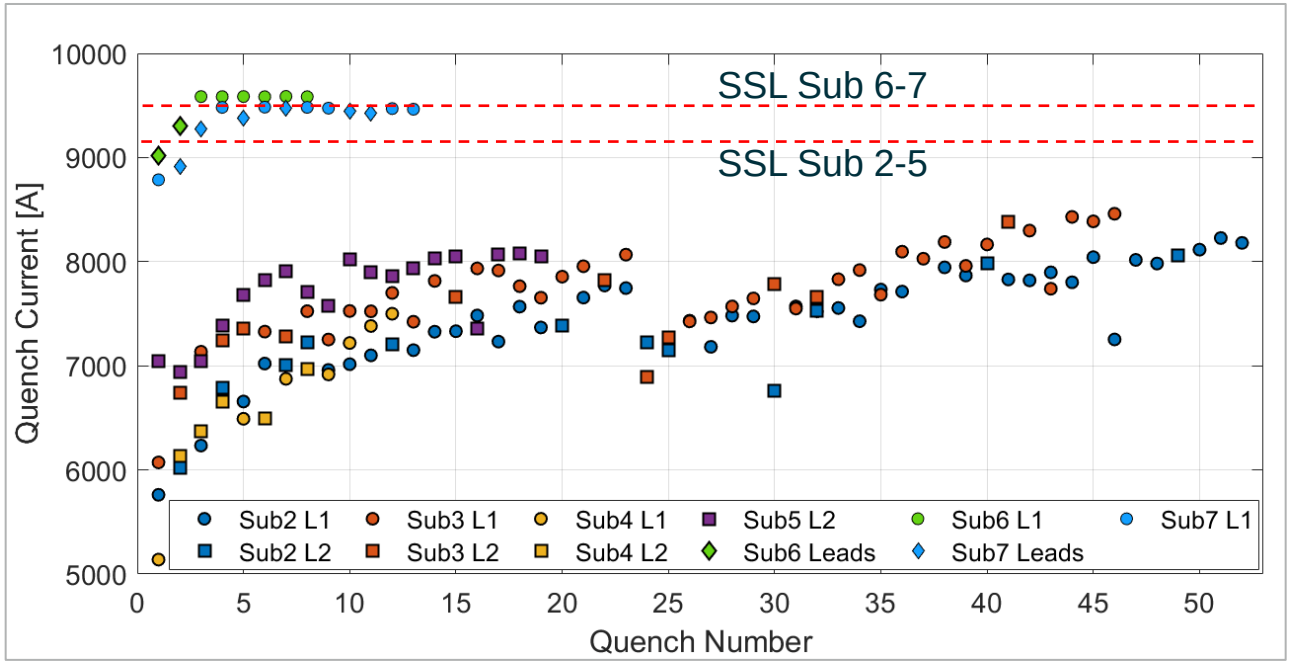
Magnet on Header



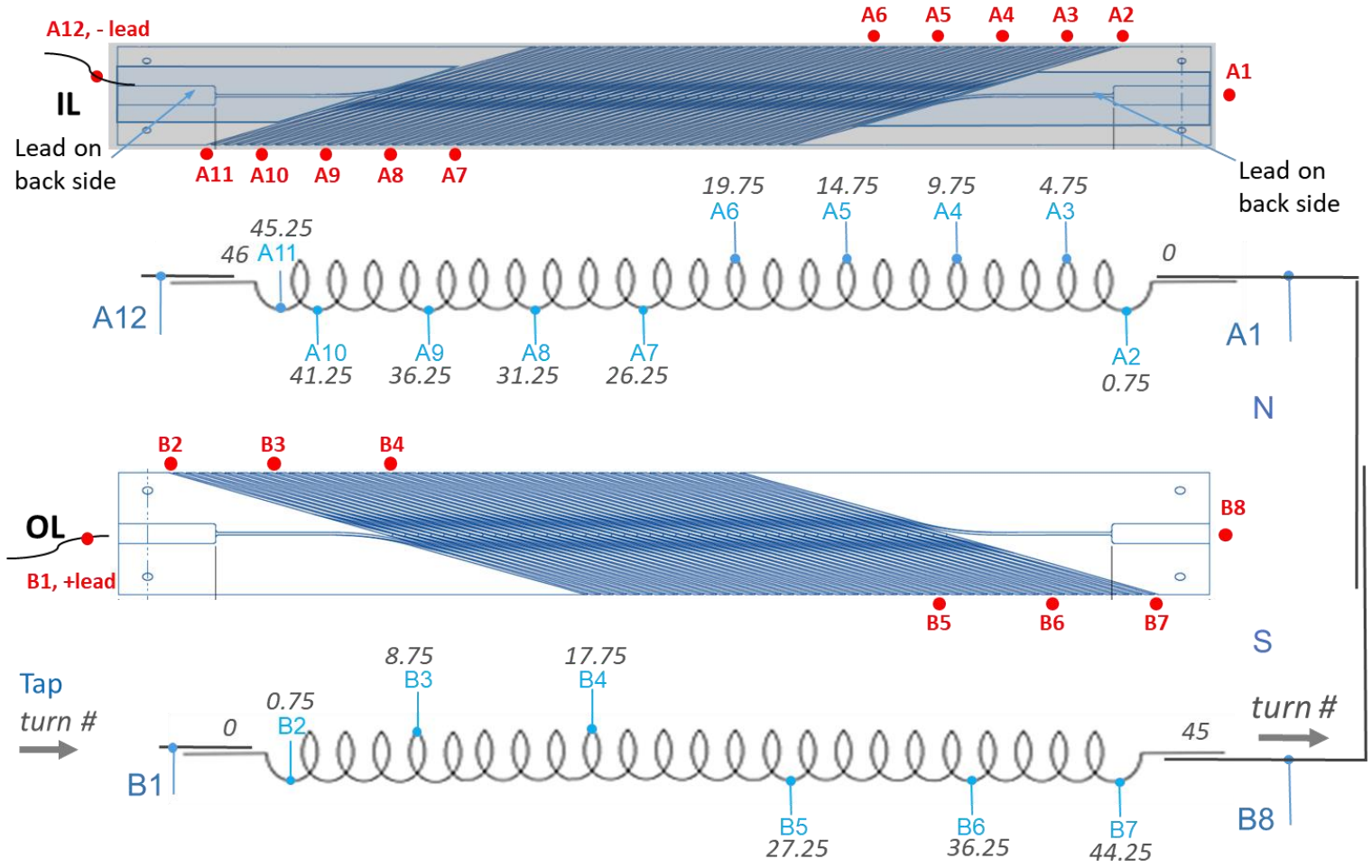
Training Performance of SUB7

- Magnet reaches predicted short-sample limit on second coil quench
  - First quench in L1
  - Second and third quench in leads
  - Fourth quench in L1 at ~ SSL
- Subsequent coil quenches consistently at 9470 A
- More lead quenches were also encountered (suspect liquid level was too low, no more encountered after level was raised further)

CCT Subscale Training



Voltage Tap Layout



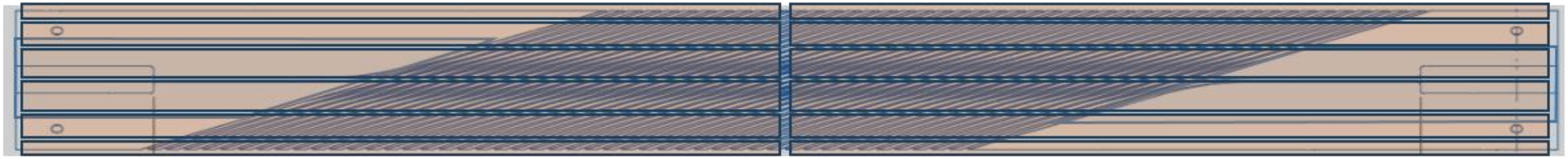
Quench Antenna Layout

Lead End

Return End

QAL1

QAR6

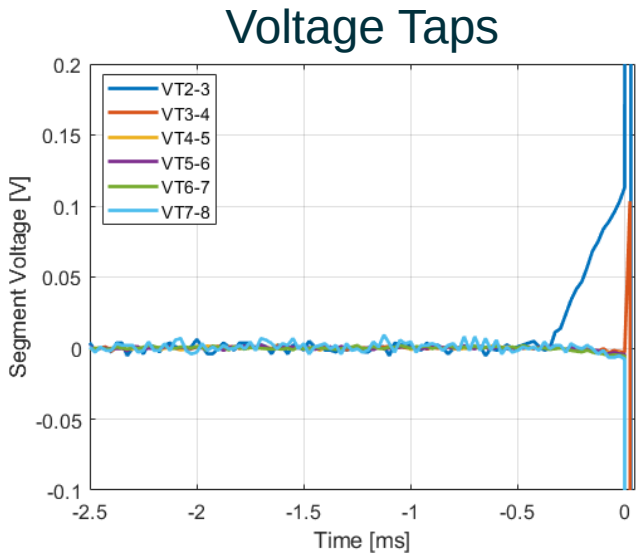


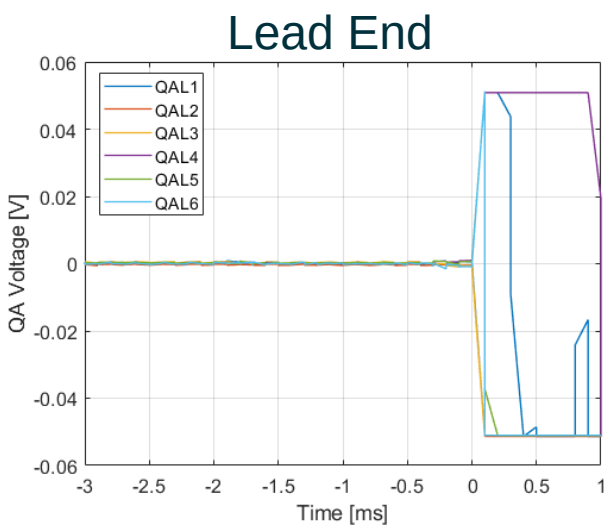
QAL6

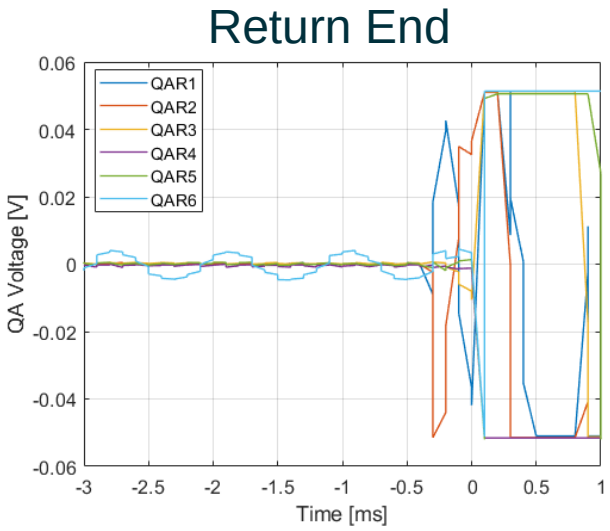
QAR1

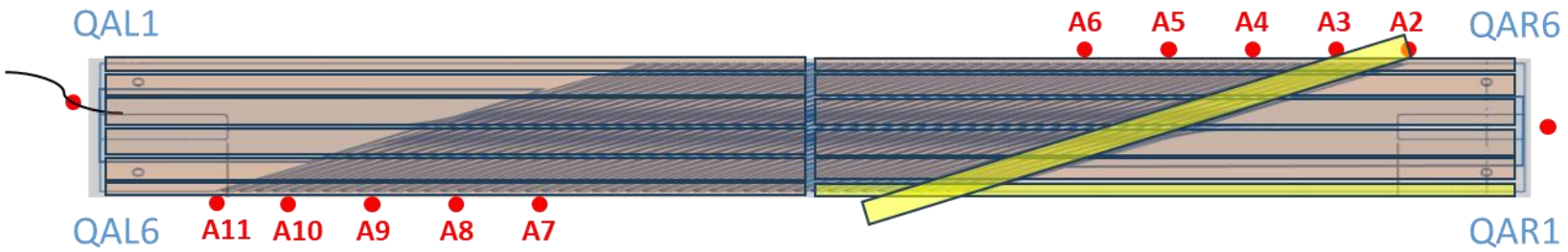
Ramp #1

- Ramp 1 quench in inner layer
  - Segment A2A3
  - Quench antenna QAR1
- Quench is near high field region of first few turns from return end



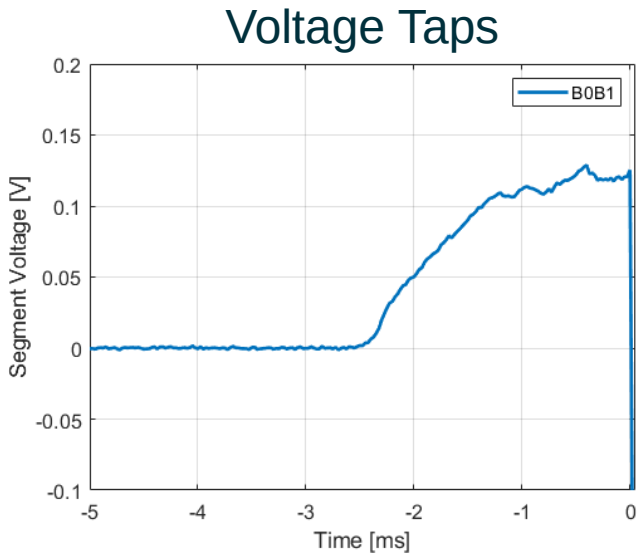


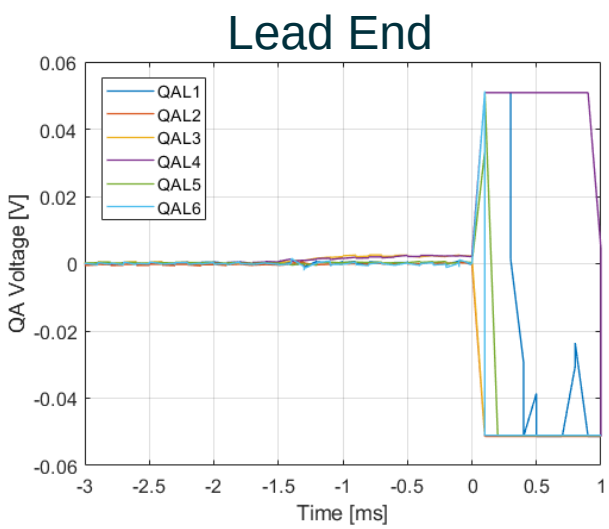




Ramp #2

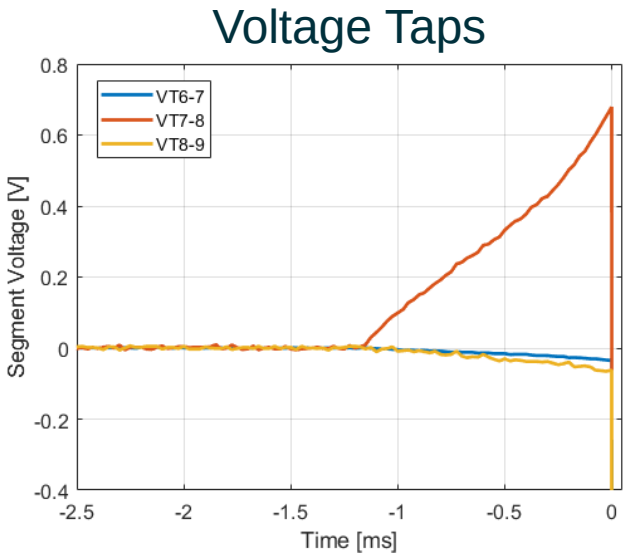
- Ramp 2 quench in positive lead
- Quench antenna shows small response in lead location
- Other lead quenches show similar response

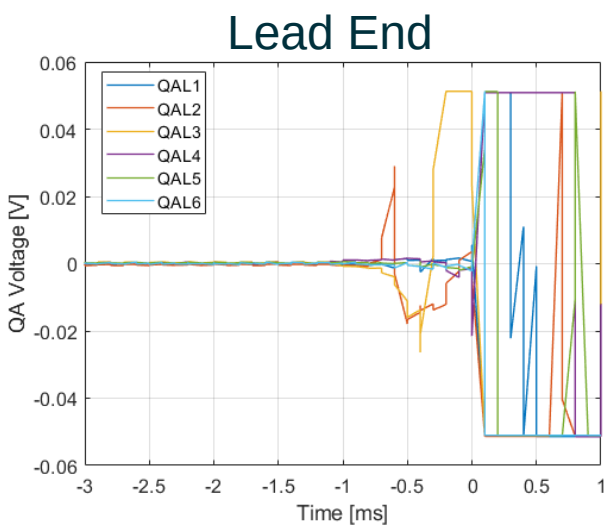


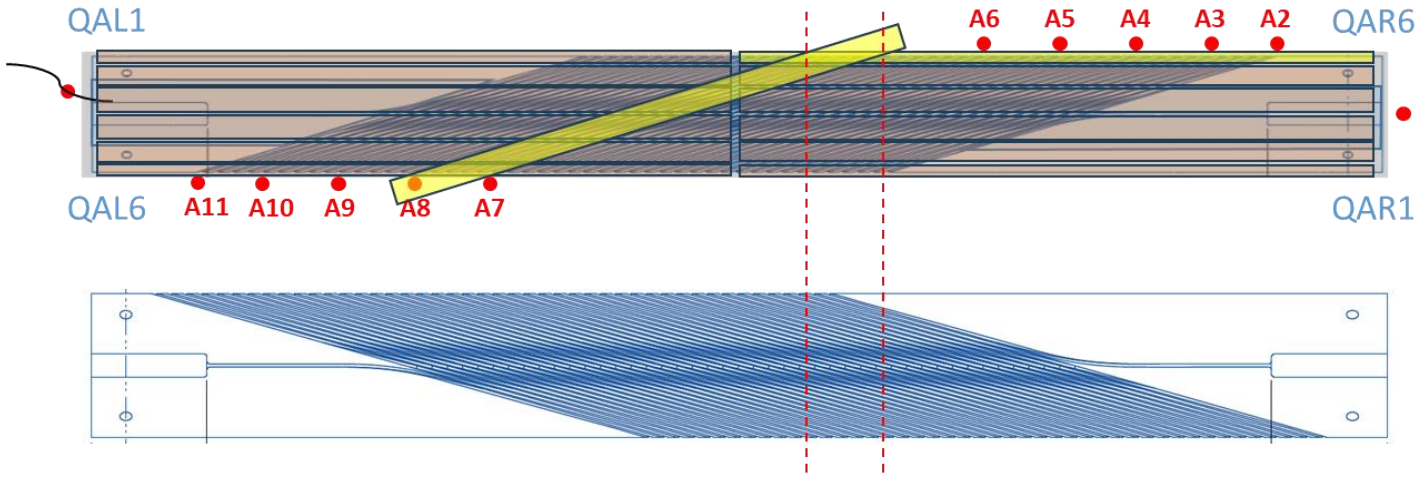


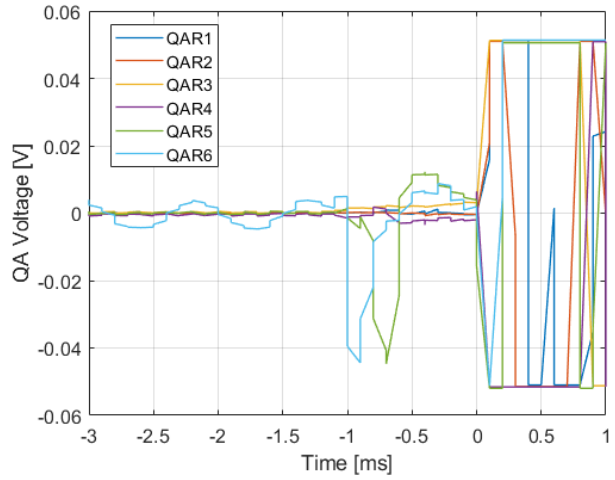
Ramp #4

- First quench at plateau
- Ramp 4 quench in inner layer
  - Segment A7A8
  - Quench antenna QAR6
- Quench is at high field region

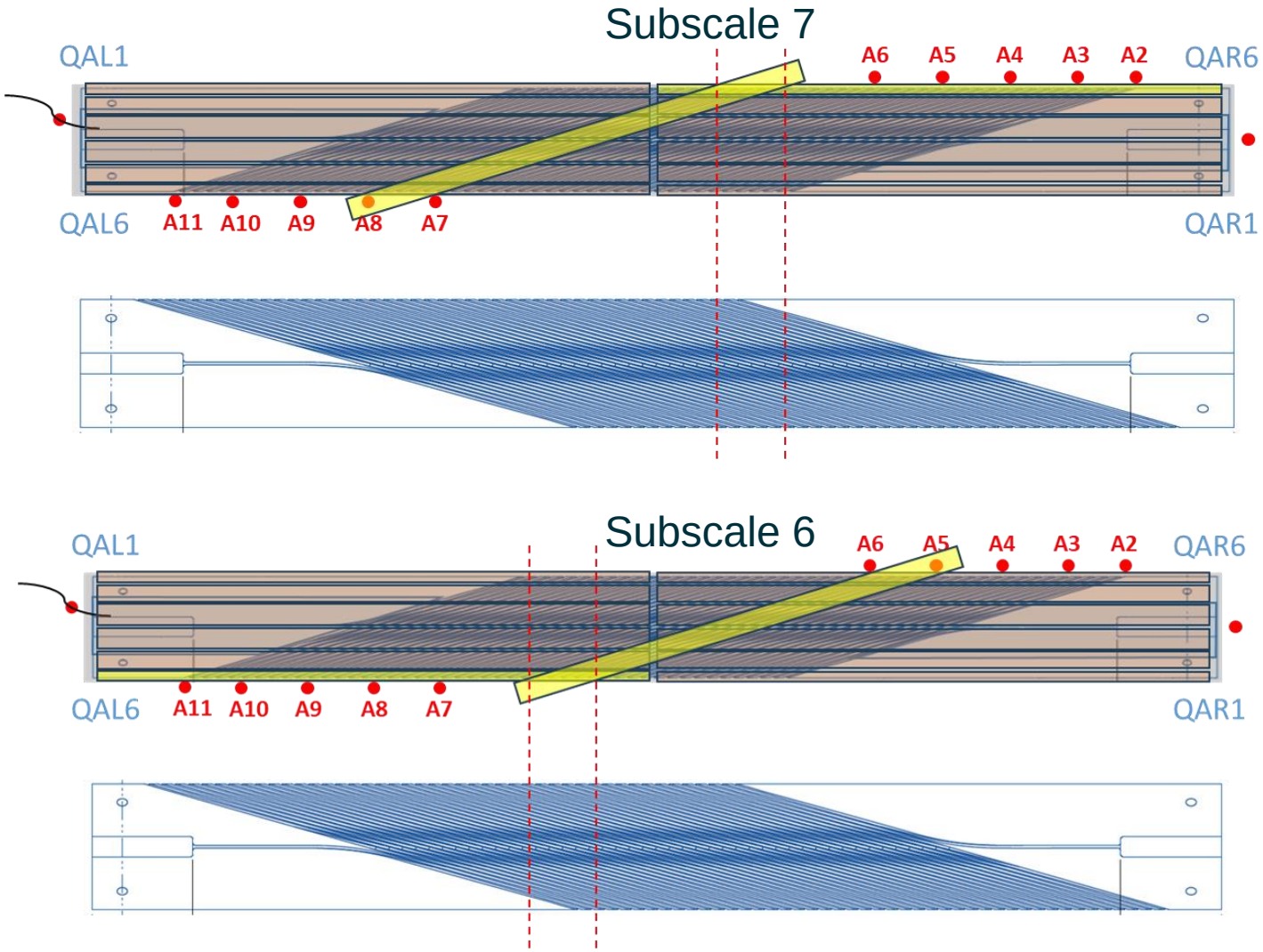






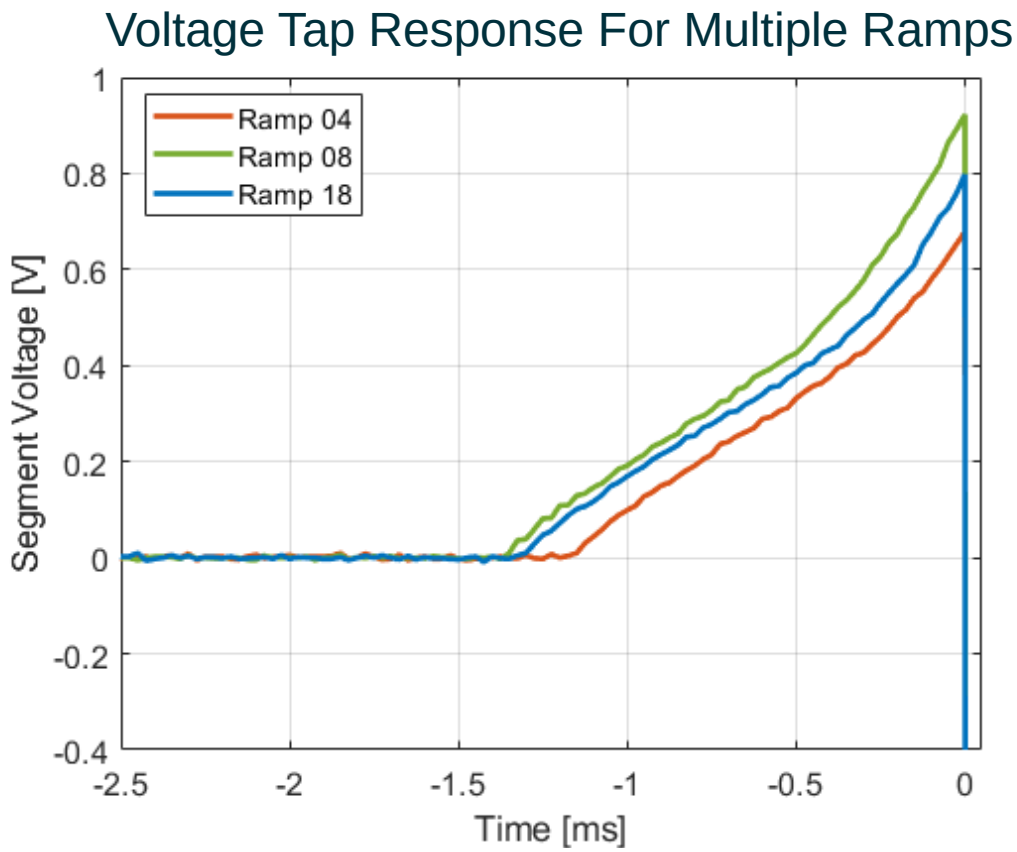


Comparison Between Sub6 and Sub7



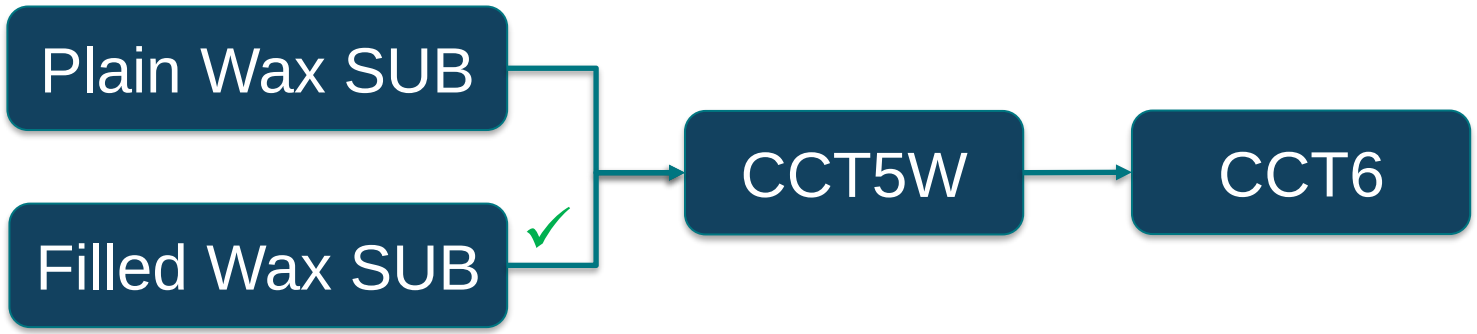
Quench Voltage is Consistent after Quench 4

- Quench response for coil quenches looks the same after plateau



CCT5-W (Wax Impregnated) Motivation

- Desire to operate close to the conductor limit with minimal training for CCT6
- Wax subscale has been completed without training and we are currently working on filled wax subscale magnet
- Have started work on building a wax impregnated CCT5 @10T (CCT5-W) as a stepping stone towards CCT6
  - Average radial stress of CCT5 at 10 T is representative of CCT6 at ~12 T. Subscale stresses are significantly lower
  - The cost and effort to build CCT5W is only slightly more than for a subscale magnet since the process is the same, the machining cost is only slightly higher, and cable is available



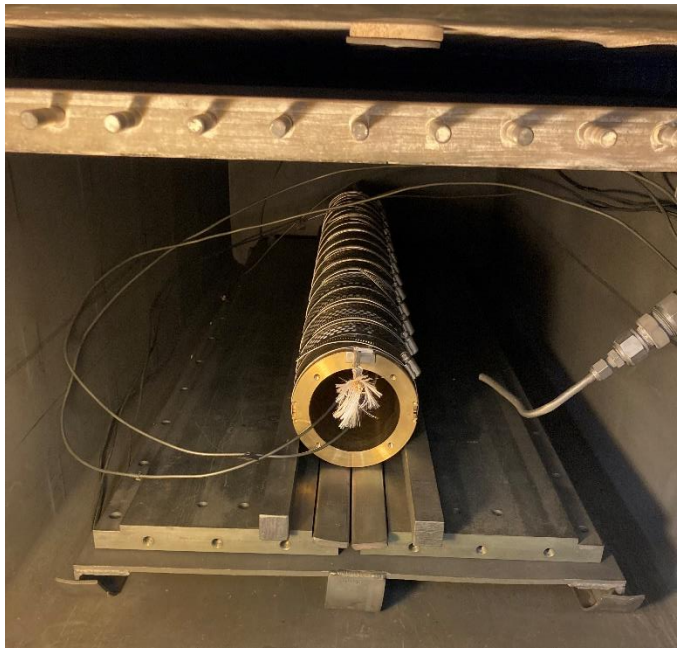
Stress on Turn from Lorentz Force

			2D FE - Magn	
Magnet	**Current**	**Field**	**srr_em**	**stt_em**
	kA	T	MPa	MPa
Subscale	9.5	5.3	15	10
CCT5	17.8	**10.0**	**71**	3
CCT6	10.67	**12**	**85**	5
CCT6	14.22	16	152	9

Analysis performed by G. Vallone and M. Juchno

CCT5-W Status and Next Steps

- Fabrication of inner layer and shell are complete
- Inner layer has been wound and is ready for reaction
- Outer layer at main shop for machining – expected within ~2 weeks



Summary

- Subscale with filled wax tested with minimal training (1 coil quench)
- Moving forward with CCT5W with filled wax to determine feasibility of filled wax impregnation for higher field magnets
- Next Susbscale magnets planned
  - Telene impregnated magnet
  - Filled epoxy / other resin impregnated magnet (not clear which resin to use yet)