U.S. MAGNET DEVELOPMENT PROGRAM

Recent Test Results

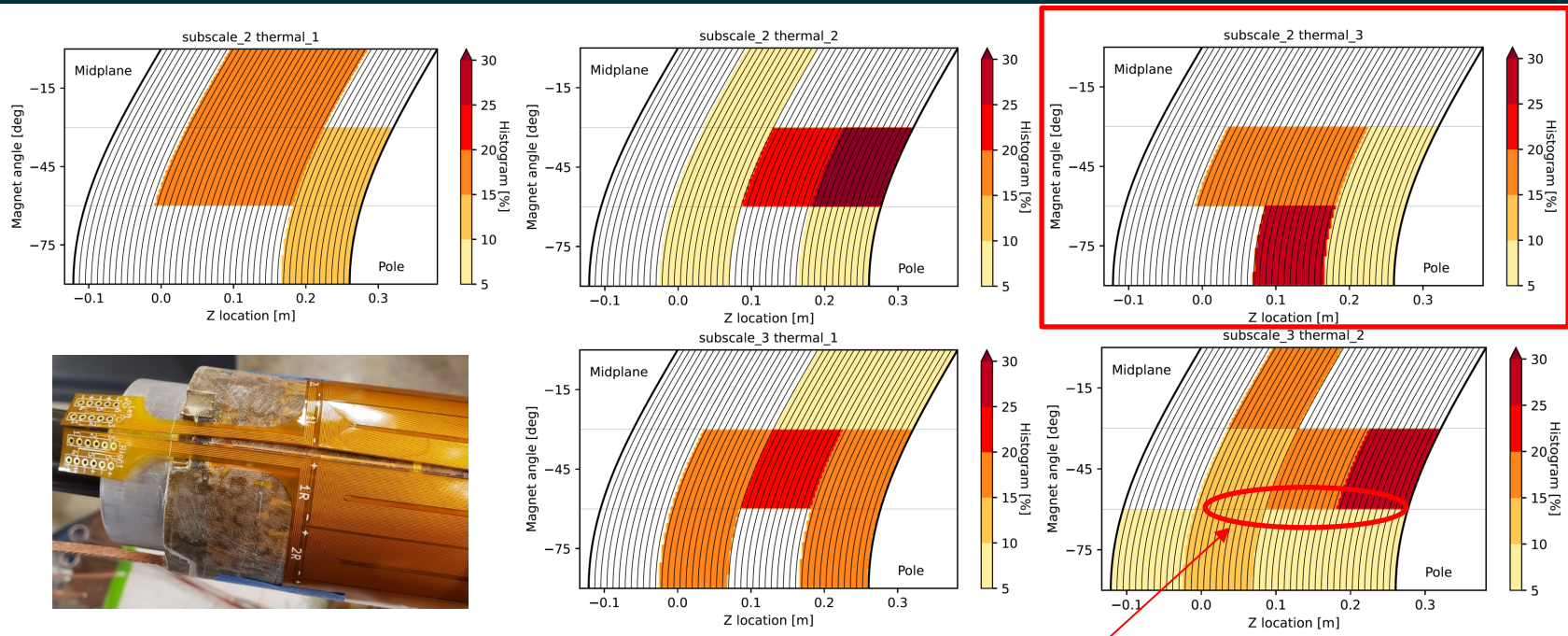
Diego Arbelaez and Reed Teyber on behalf of LBNL Nb_3Sn CCT Team

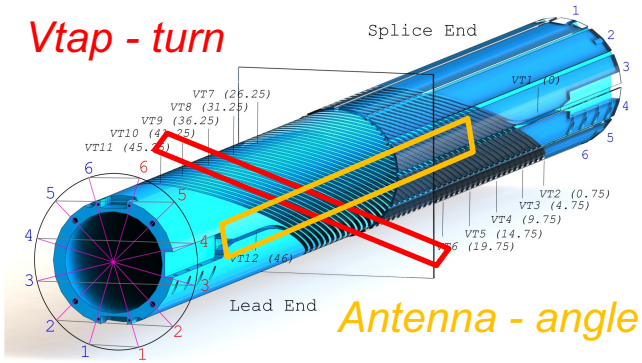
Outline

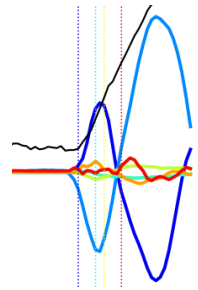
- Improved inter-layer quench antenna localization method
- Test results from wax CCT subscale

Quench Localization Analysis

- Extensive analysis was performed by R. Teyber
  - Combine Vtap and quench antennas to localize quenches
  - Histogram bins to 15, 45 or 75 degrees based on antenna element with largest measured flux
- New method was recently introduced to improve the resolution of angle localization by using correlation between antenna segments







Work by R. Teyber

Improved Quench Localization Method

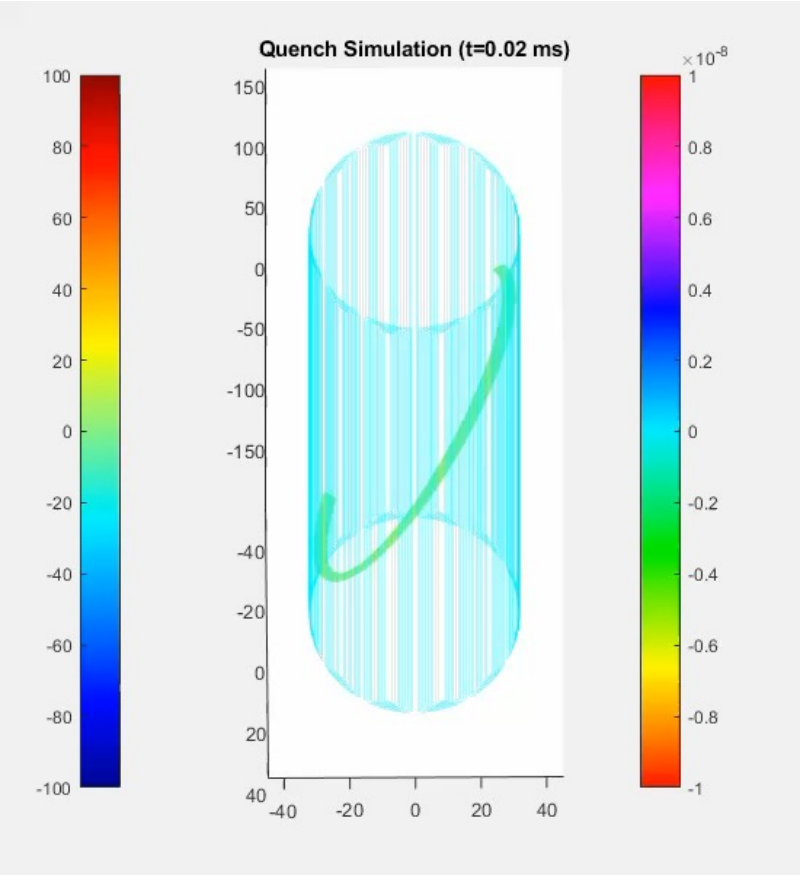
- Define Correlation parameter as $C_{ij} = \int_0^{t_0} |\varphi_i \varphi_j| dt$
- Improve localization by accounting for signals from neighboring antenna elements
  - Cross-Correlation between neighboring antennas
  - Self-Correlation of neighboring antennas
- Use Quench simulations to determine relationship between correlation parameters and quench initiation angle

0º Simulation

	1	2	3	4	5	6
1	0.00032	0.0009468	0.09322	0.09332	0.0006833	0.0003939
2	0.0009468	0.003964	0.336	0.3393	0.002955	0.001192
3	0.09322	0.336	33.1	33.29	0.2314	0.1175
4	0.09332	0.3393	33.29	33.52	0.2337	0.1177
5	0.0006833	0.002955	0.2314	0.2337	0.002383	0.0008524
6	0.0003939	0.001192	0.1175	0.1177	0.0008524	0.0004862

5º Simulation

	1	2	3	4	5	6
1	0.0001387	0.001305	0.07979	0.02255	0.0004082	0.0002941
2	0.001305	0.02232	1.264	0.3669	0.003343	0.003645
3	0.07979	1.264	74.39	21.4	0.2083	0.2177
4	0.02255	0.3669	21.4	6.227	0.05771	0.0627
5	0.0004082	0.003343	0.2083	0.05771	0.001296	0.0008122
6	0.0002941	0.003645	0.2177	0.0627	0.0008122	0.0007119



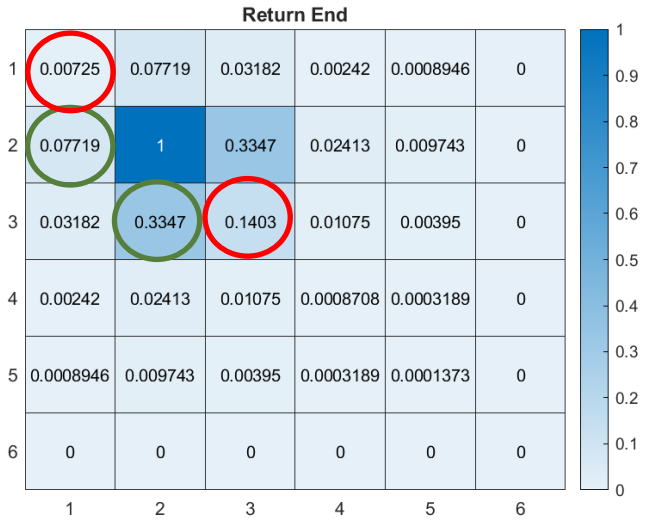
Straight cable simulation performed by Ruben Keijzer & Gerard Willering

Improved Quench Localization Method (cont.)

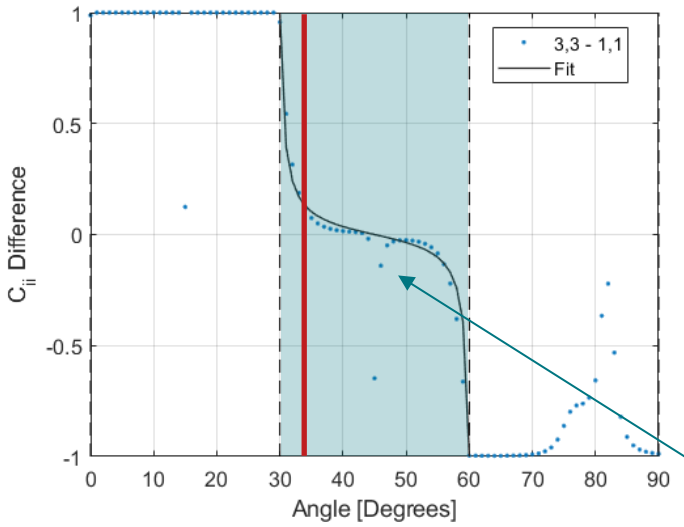
- Find quench location segment by identifying maximum C_{ii}
- Within this segment compare the normalized values of the two neighboring self and cross-correlation values
  - Neighbor self-correlation difference: $\left(C_{i+1,i+1} - C_{i-1,i-1} \right) / C_{i,i}$
  - Neighbor cross-correlation difference: $\left(C_{i+1,i} - C_{i,i-1} \right) / C_{i,i}$
- Use fit function derived from simulations to determine angle for each case (should be consistent)

$$f(\theta) = -\frac{\tan(b\theta)}{\tan(b\pi/12)}$$

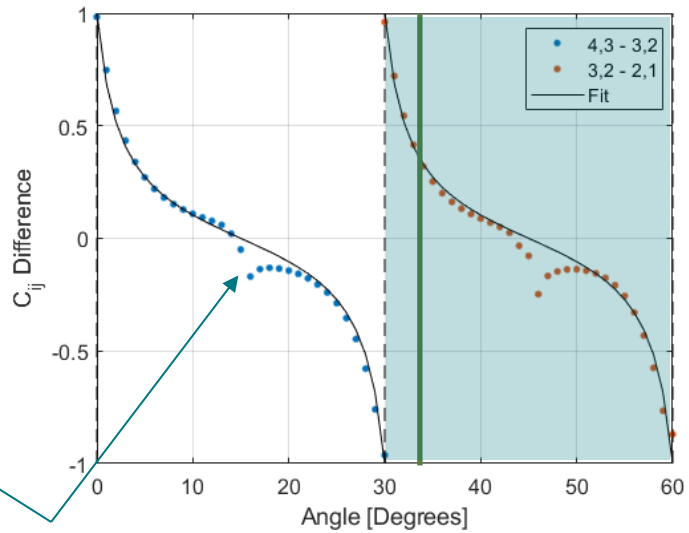
Normalized Correlation Matrix



Self-Correlation Neighbor Difference



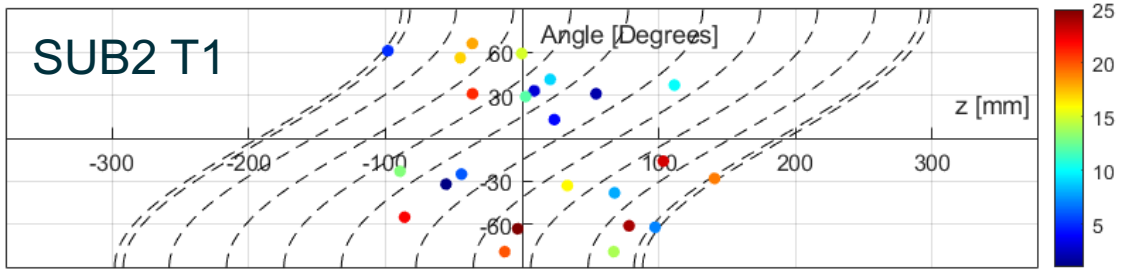
Cross-Correlation Neighbor Difference

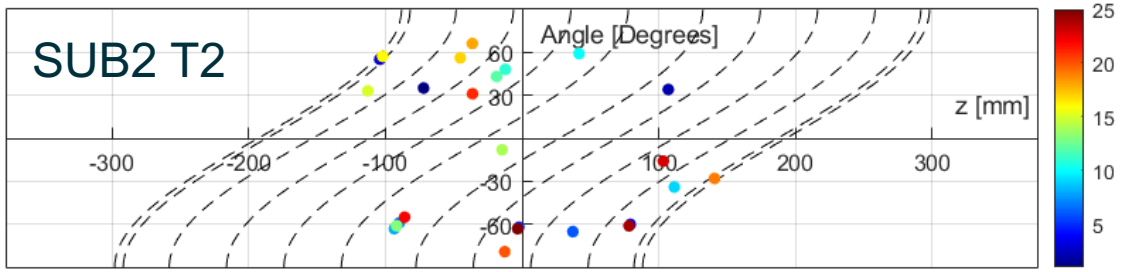


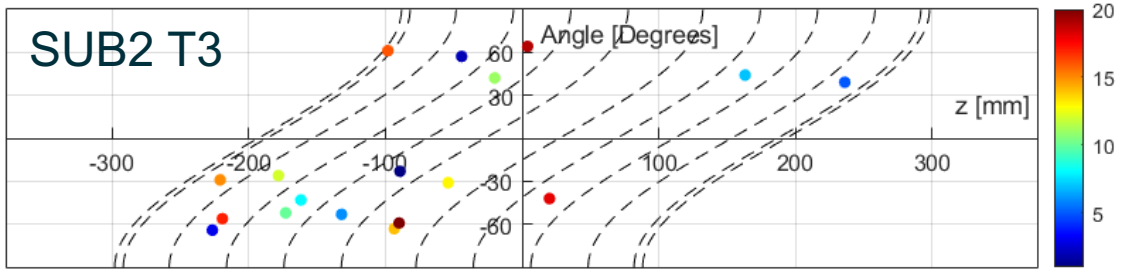
Points are simulation results (deviations near “dead” zones)

Quench Localization SUB2 and SUB3

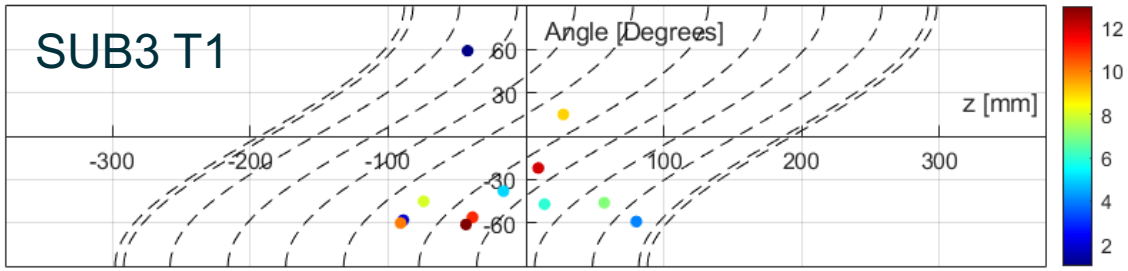
CCT Subscale 2

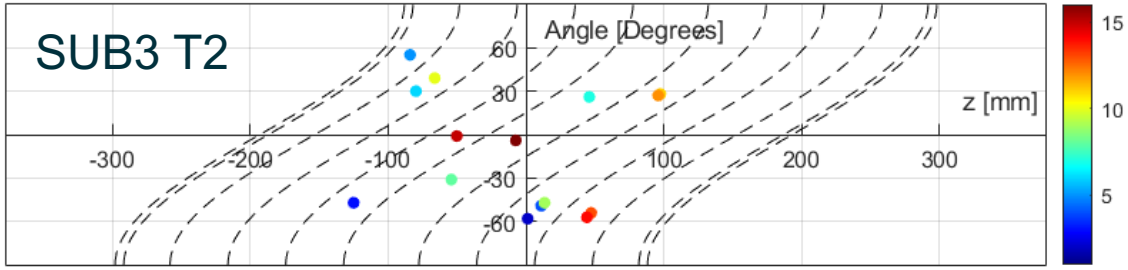






CCT Subscale 3



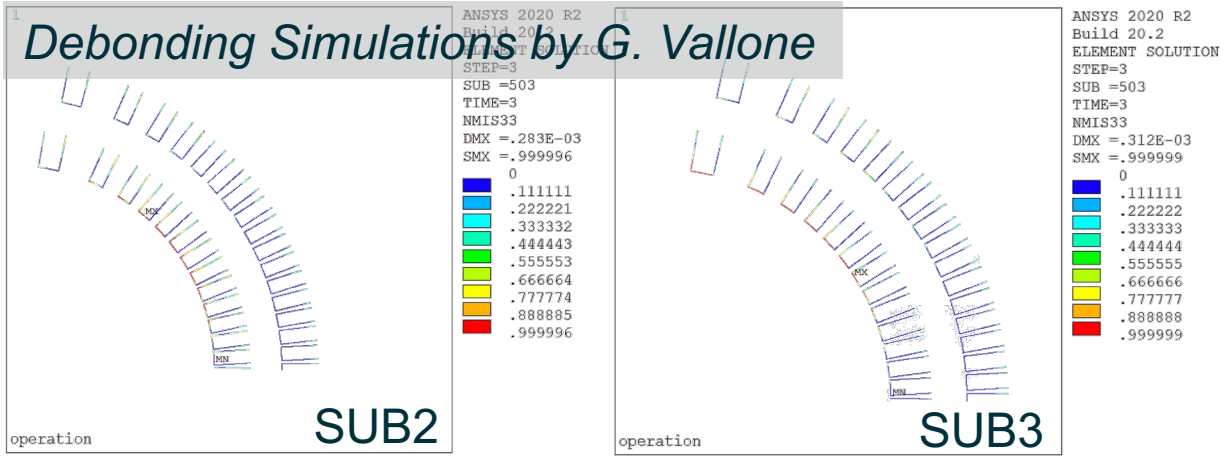


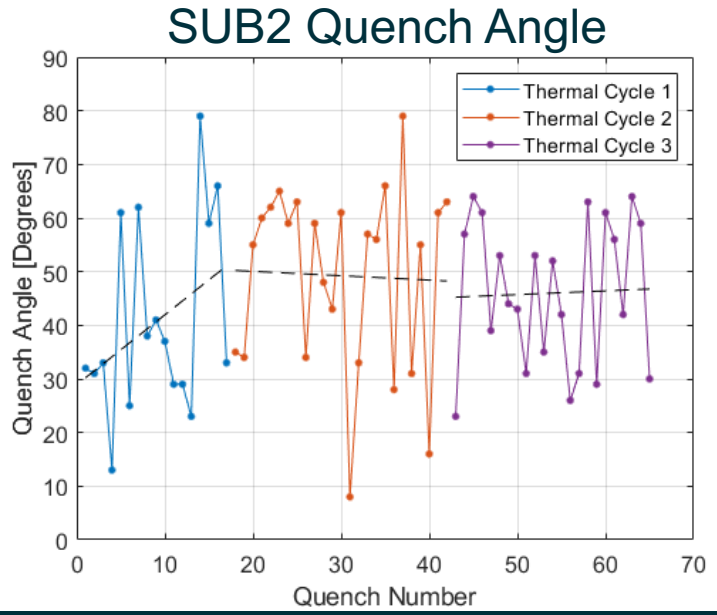
- Dashed lines represent Vtap segment
- Color represents quench number

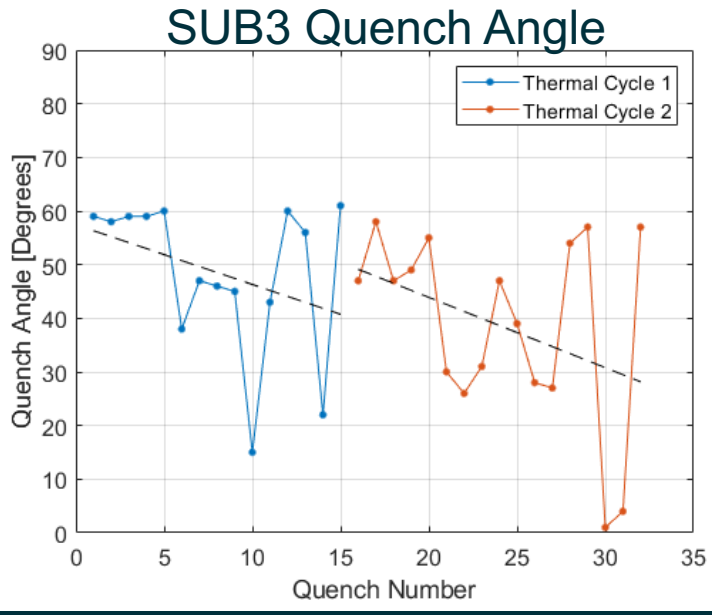
Quench Angle Localization Summary and Next Steps

- General trends for quench angle on thin and thick spar magnets have been established
- Simulations of debonding and training in CCT magnets are being performed by G. Vallone
- Will continue to use available information and tools to improve understanding of training mechanisms in these magnets

Debonding Simulations by G. Vallone



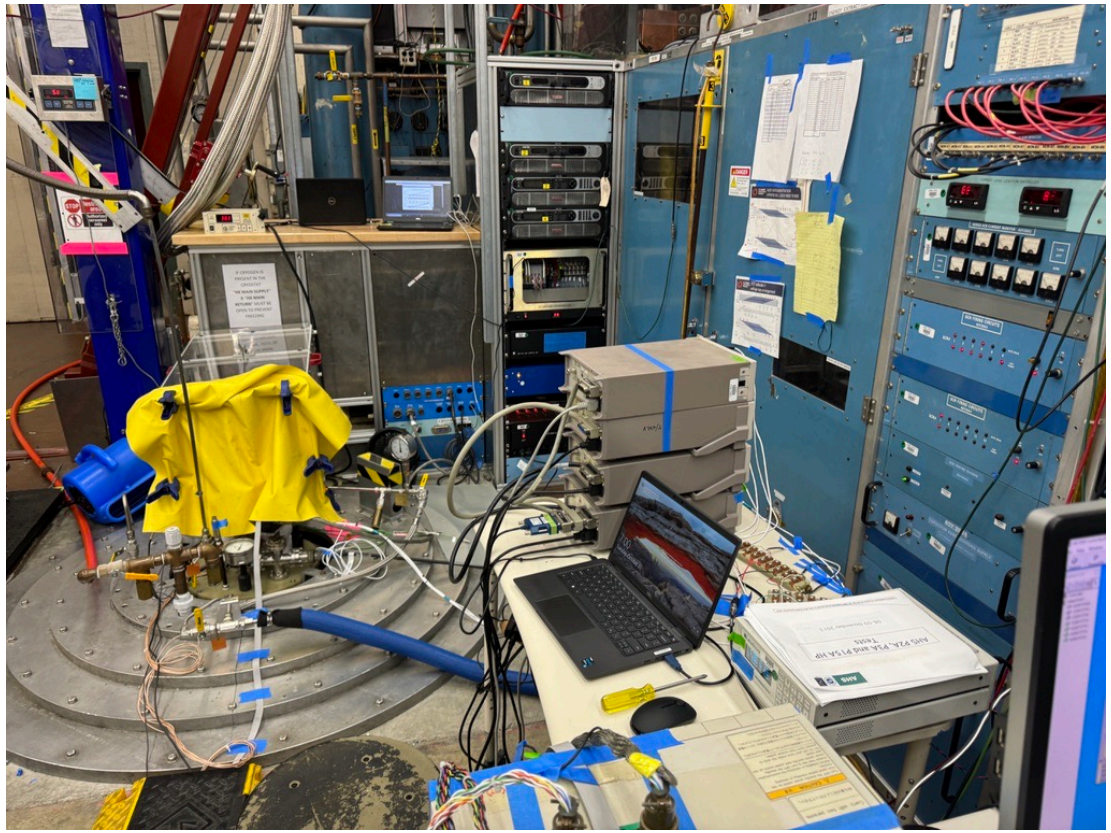


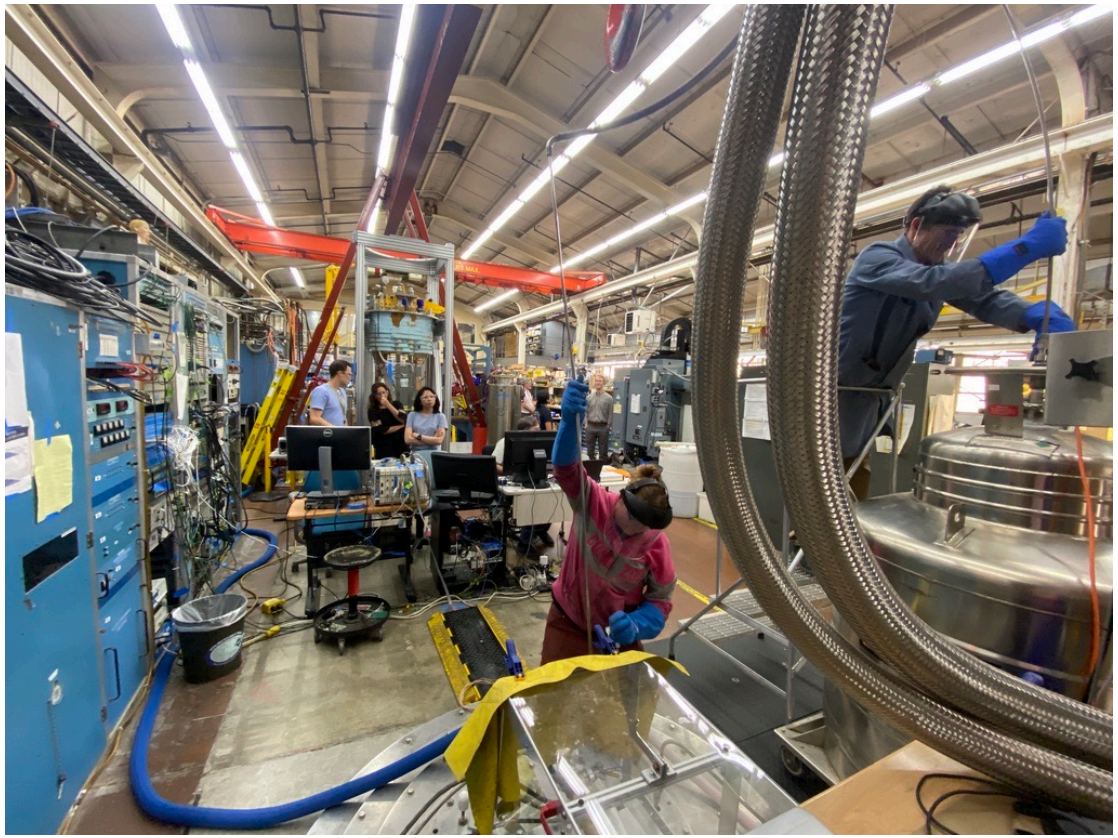


Subscale 6 Test Results

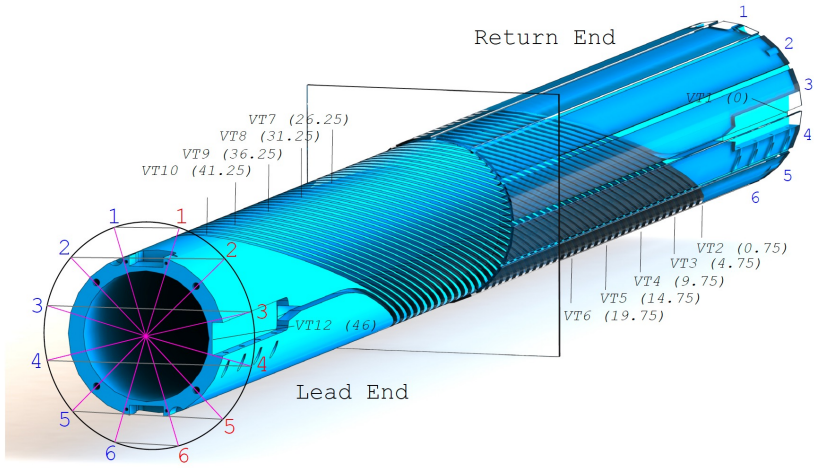
Subscale 6 – Thermal 1 + 2

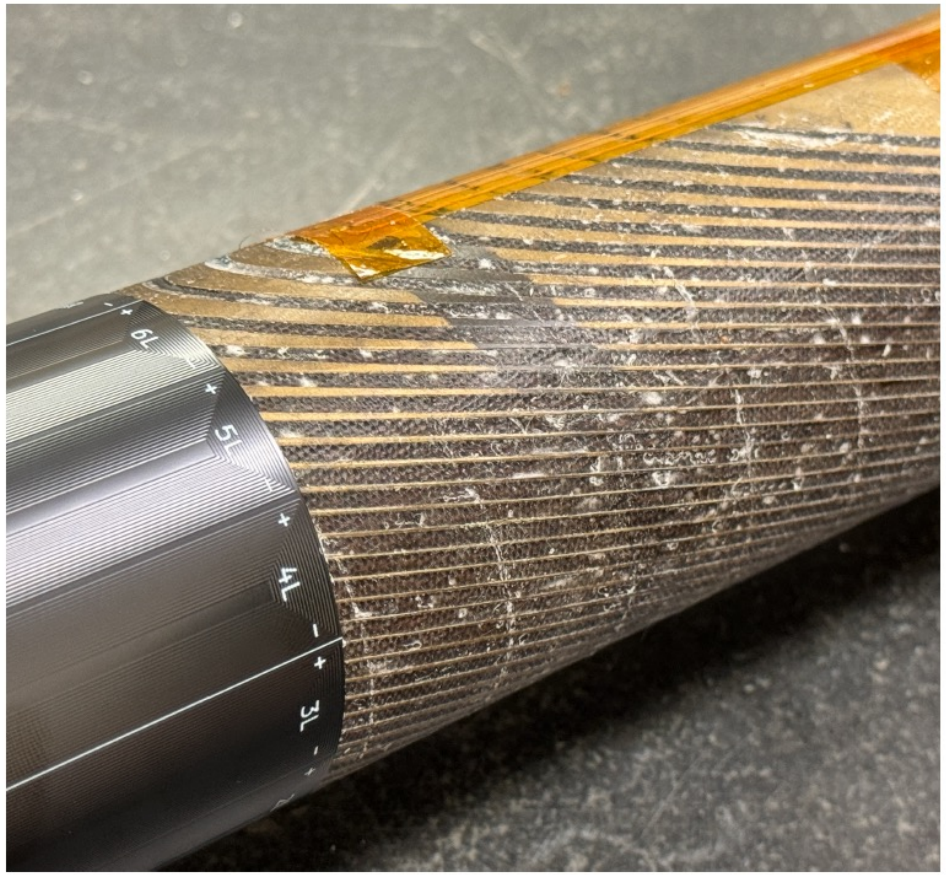
- Full wax subscale tested august (T1), october (T2) 2023

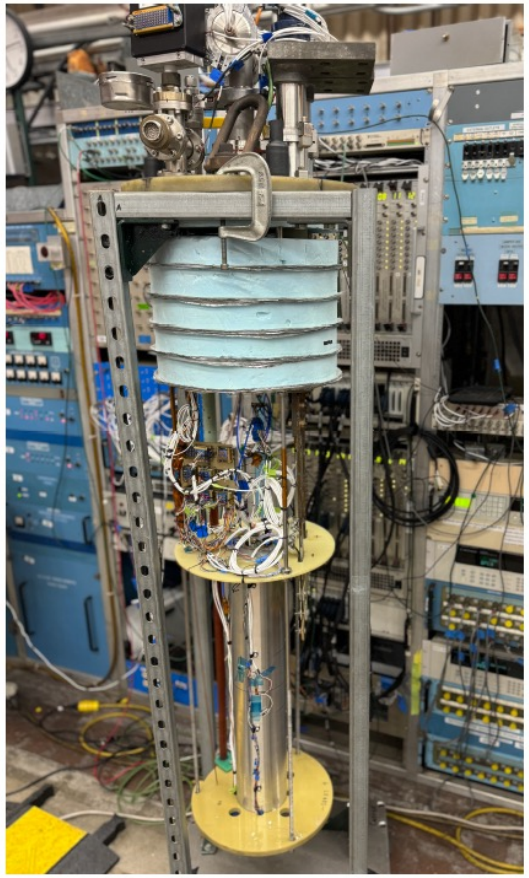




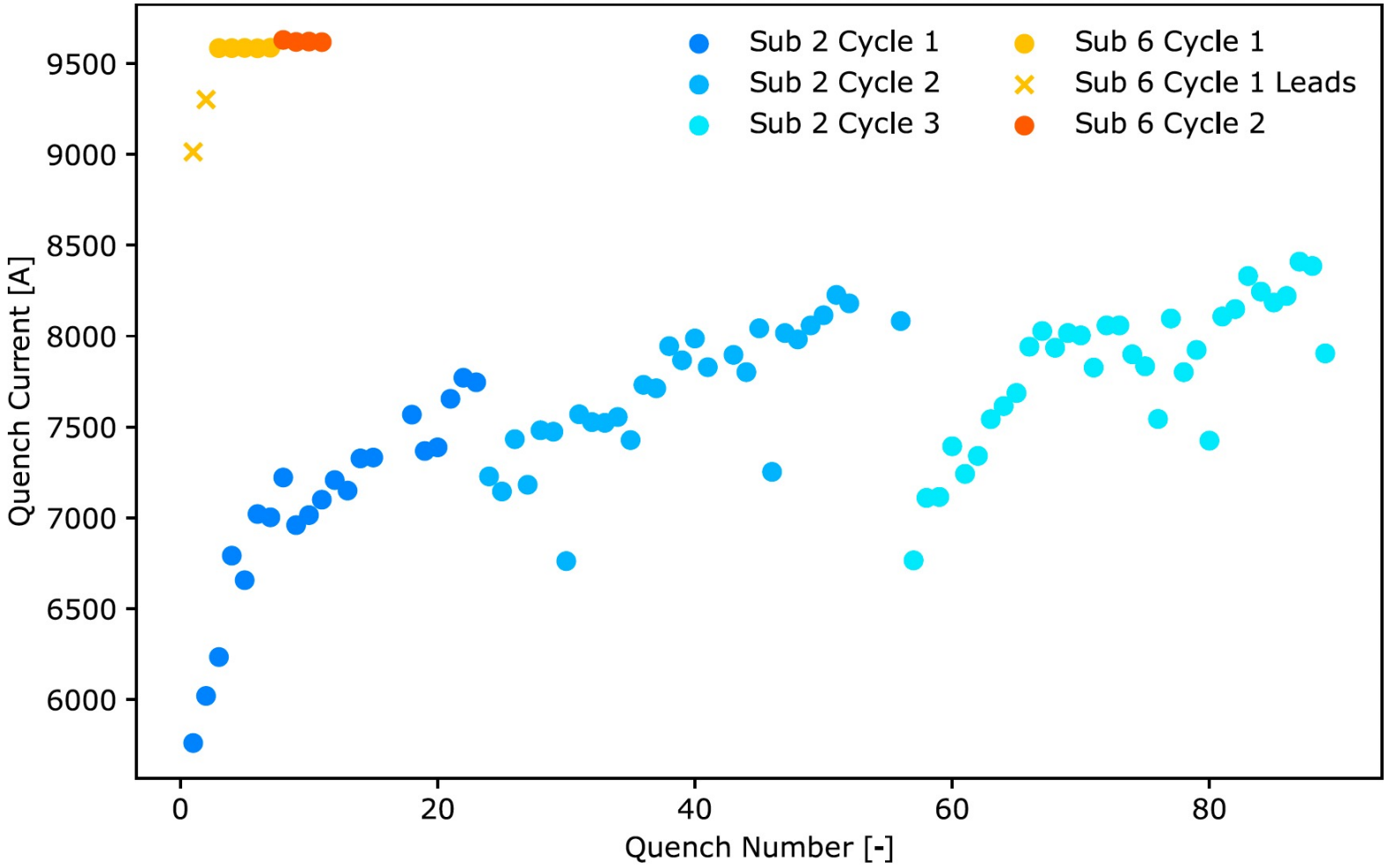
Subscale 6 – Thermal 1 + 2







Subscale 6 – Thermal 1 + 2



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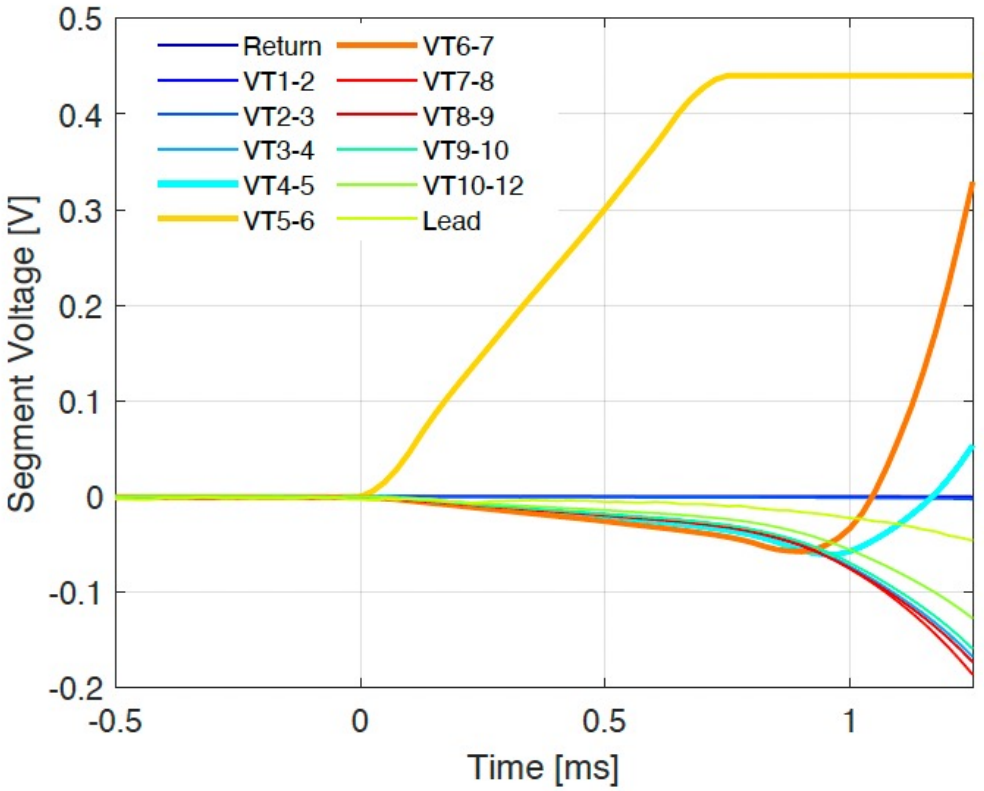

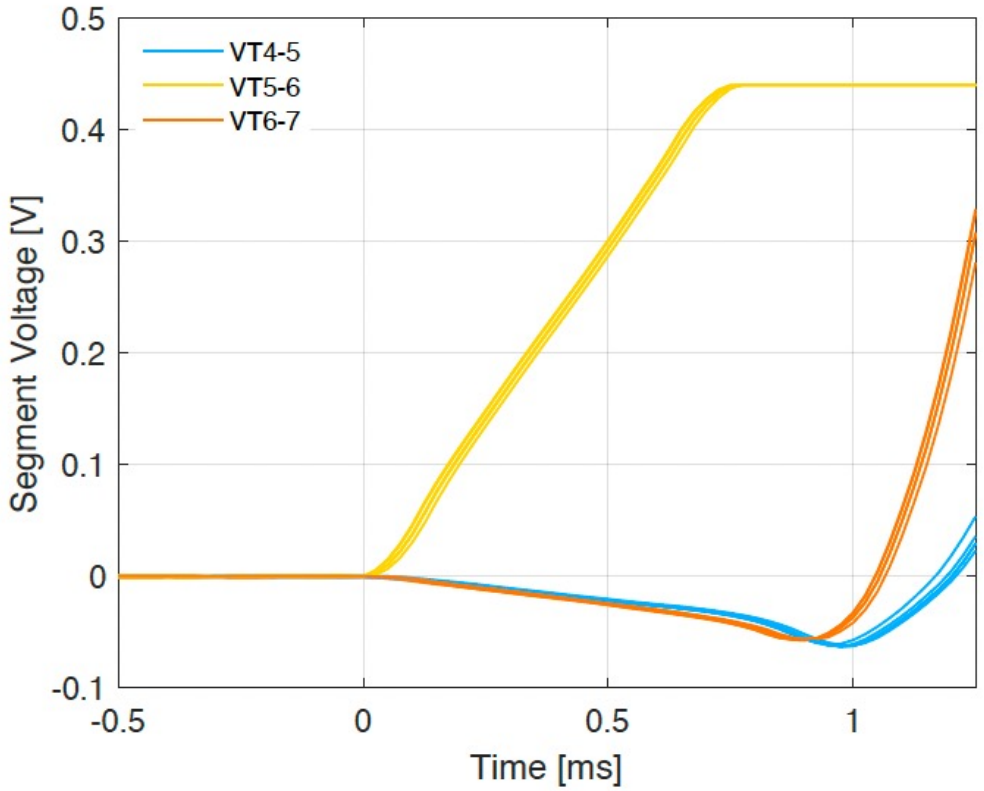

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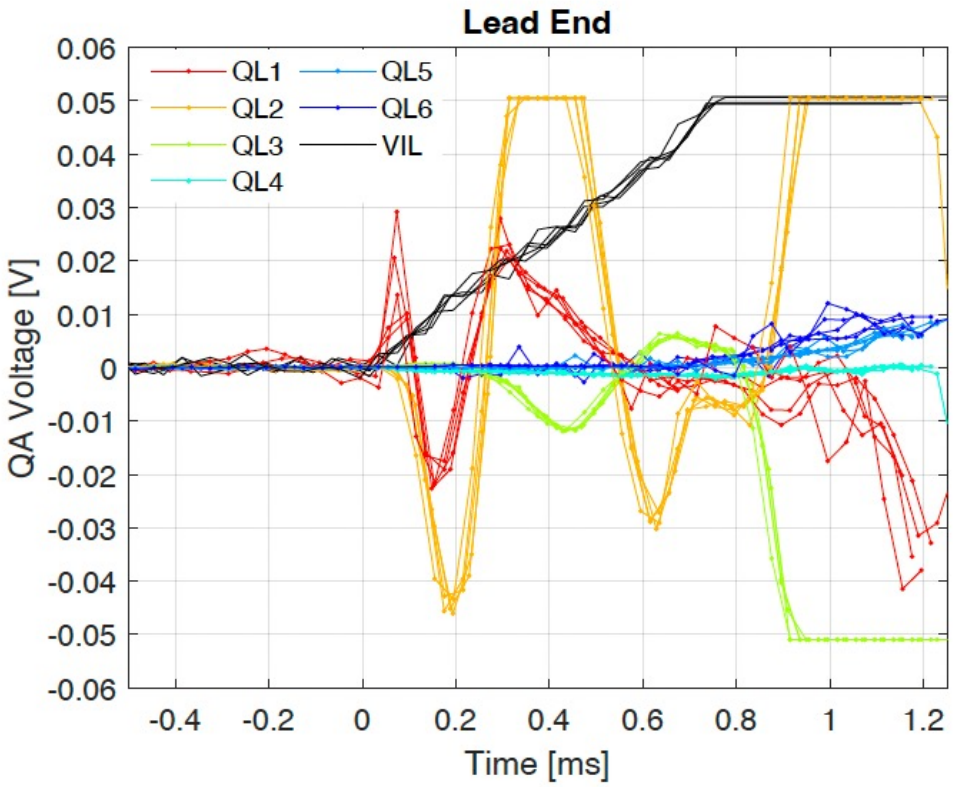

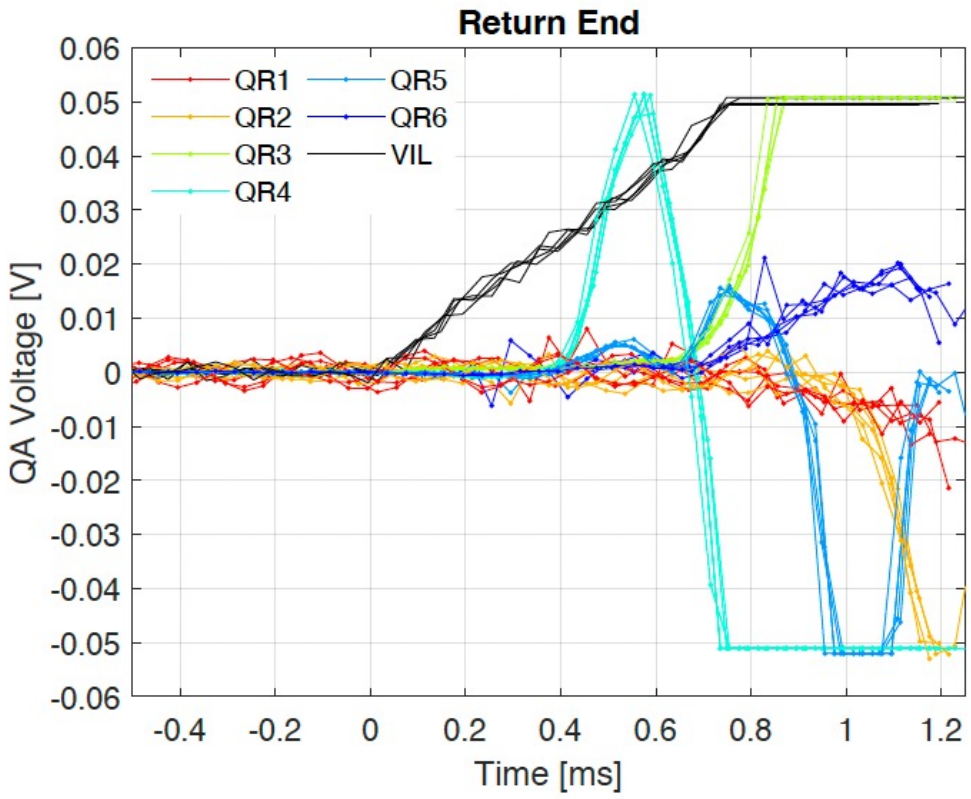

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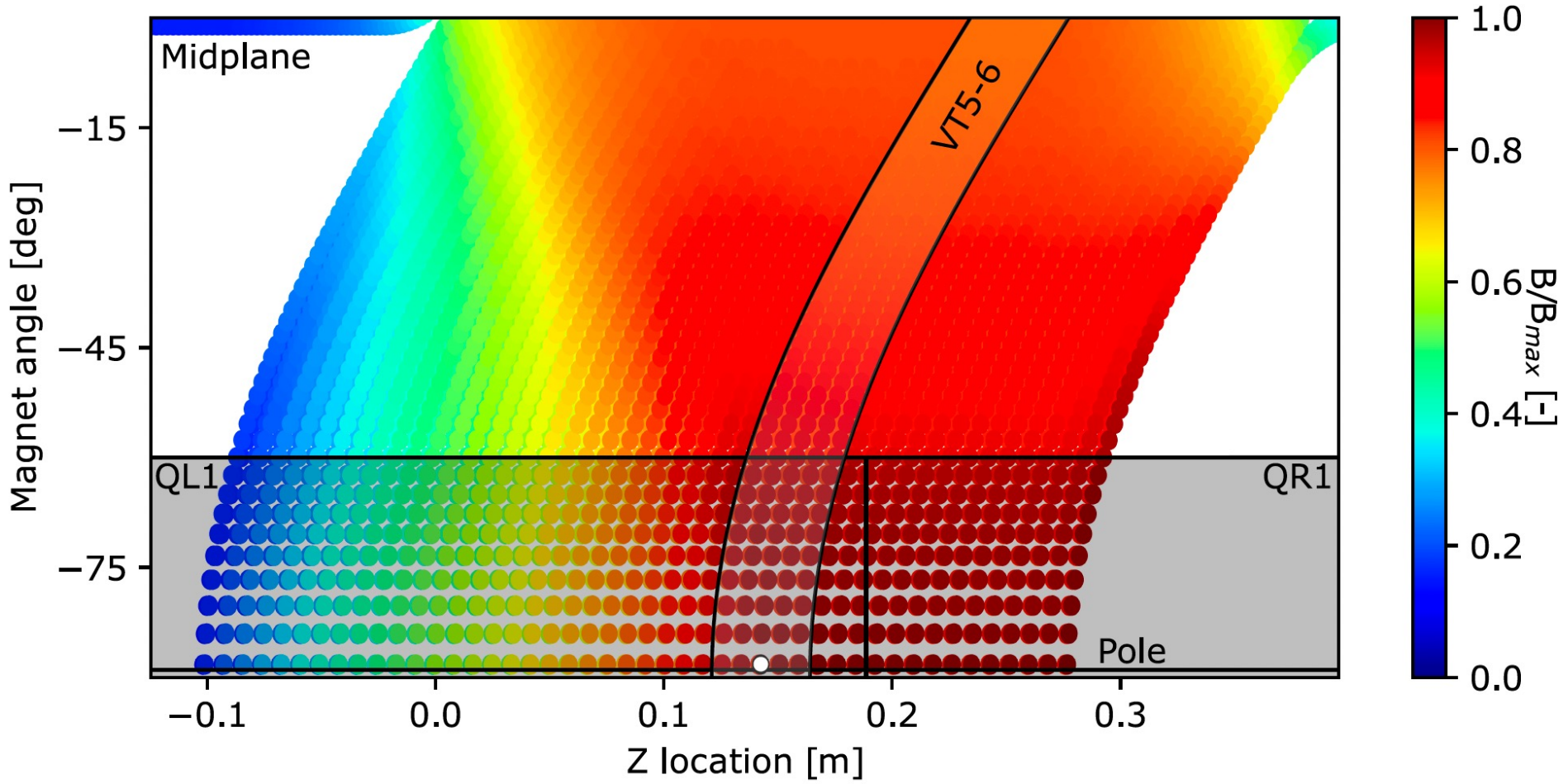

Subscale 6 – Thermal 1 + 2

- The wax subscale test results were just published by Diego, just accepted by Superconductor Science and Technology

Training-Free Demonstration of a 5.4 T Nb_3Sn Canted-Cosine-Theta Accelerator Dipole Impregnated with Paraffin Wax

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