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LCLS-II

TUPP138

Analysis of New High-Q_0 SRF Cavity Tests by Nitrogen Gas Doping at Jefferson Lab

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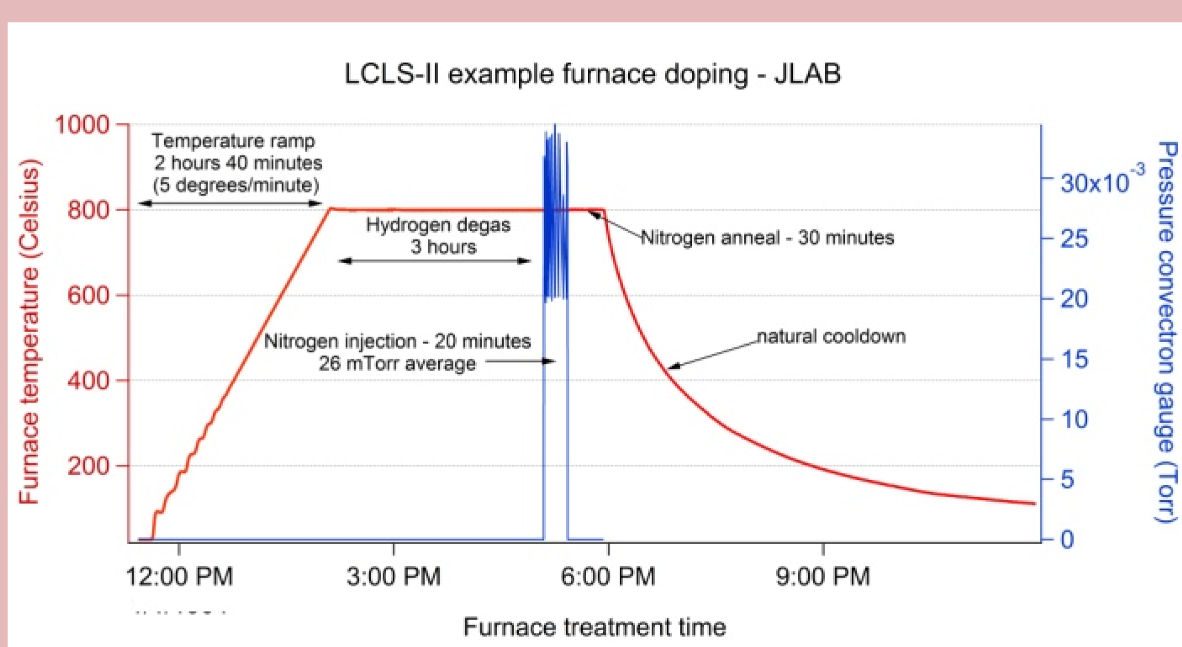
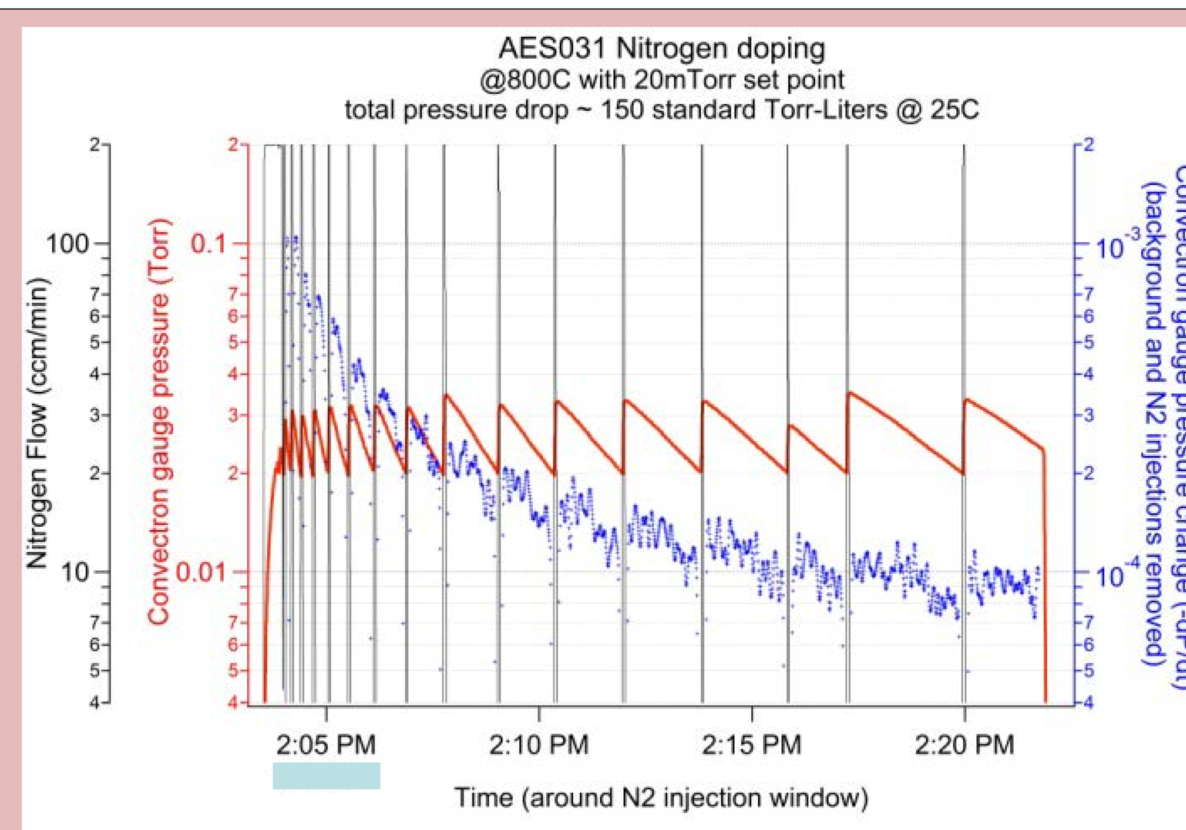
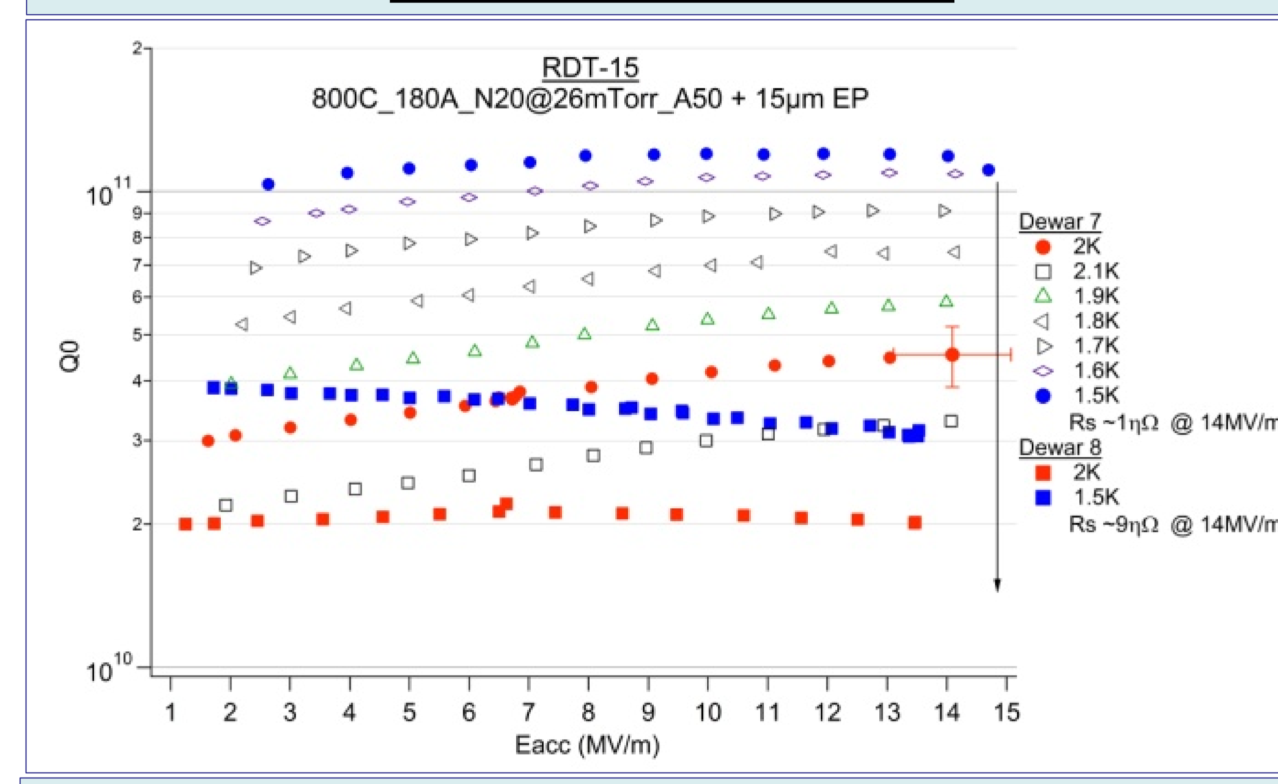
Nitrogen doping during 800˚C heat treatment





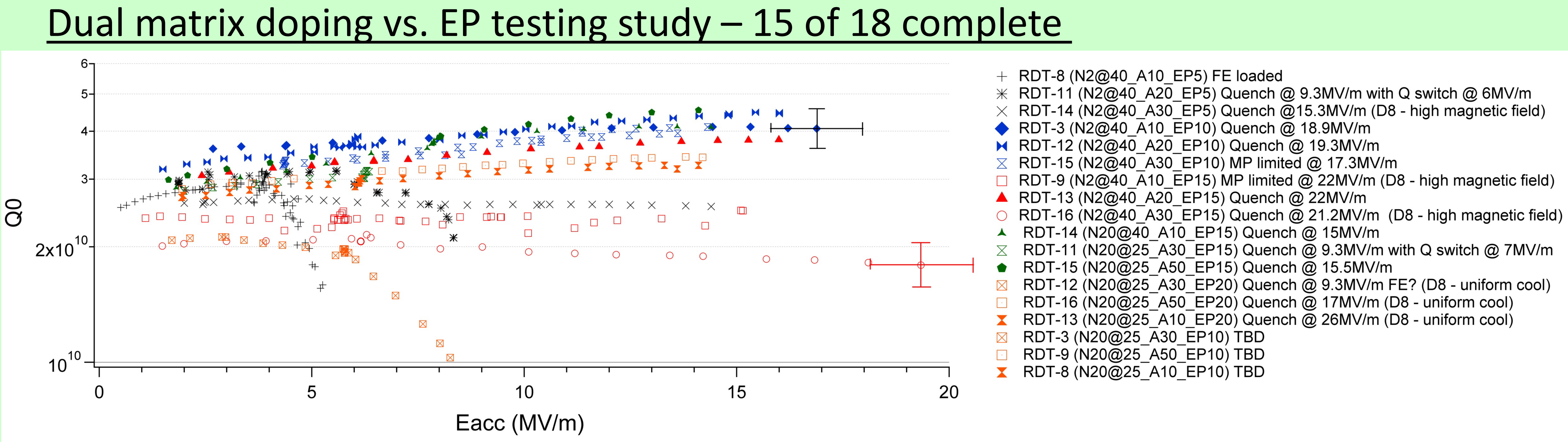
Left: Example of 800°C heat treatment data in JLab's Elnik furnace modified with a Brooks 4850 computer controlled mass flow controller. With 0.2L/min (200ccm/min) orifice. During nitrogen injection all pumping valves are closed. Nomenclature for a furnace run 800°C _A180_N20@26mTorr_A30 (A# is vacuum anneal time, N# is nitrogen time, @#mTorr is calculated average) **Right:** Zoom in on nitrogen doping of 9 cell LCLS-II baseline cavity AES031 during nitrogen injection time. Absorption rate at beginning is at least 10 times faster than at end of doping. Using the flow from the calibrated controller or the Δp/Δt calculation, we have found the amount of nitrogen absorbed is ~150 standard torr-liters of N_2.

Example RF data for single-cell studies and change in environmental effect



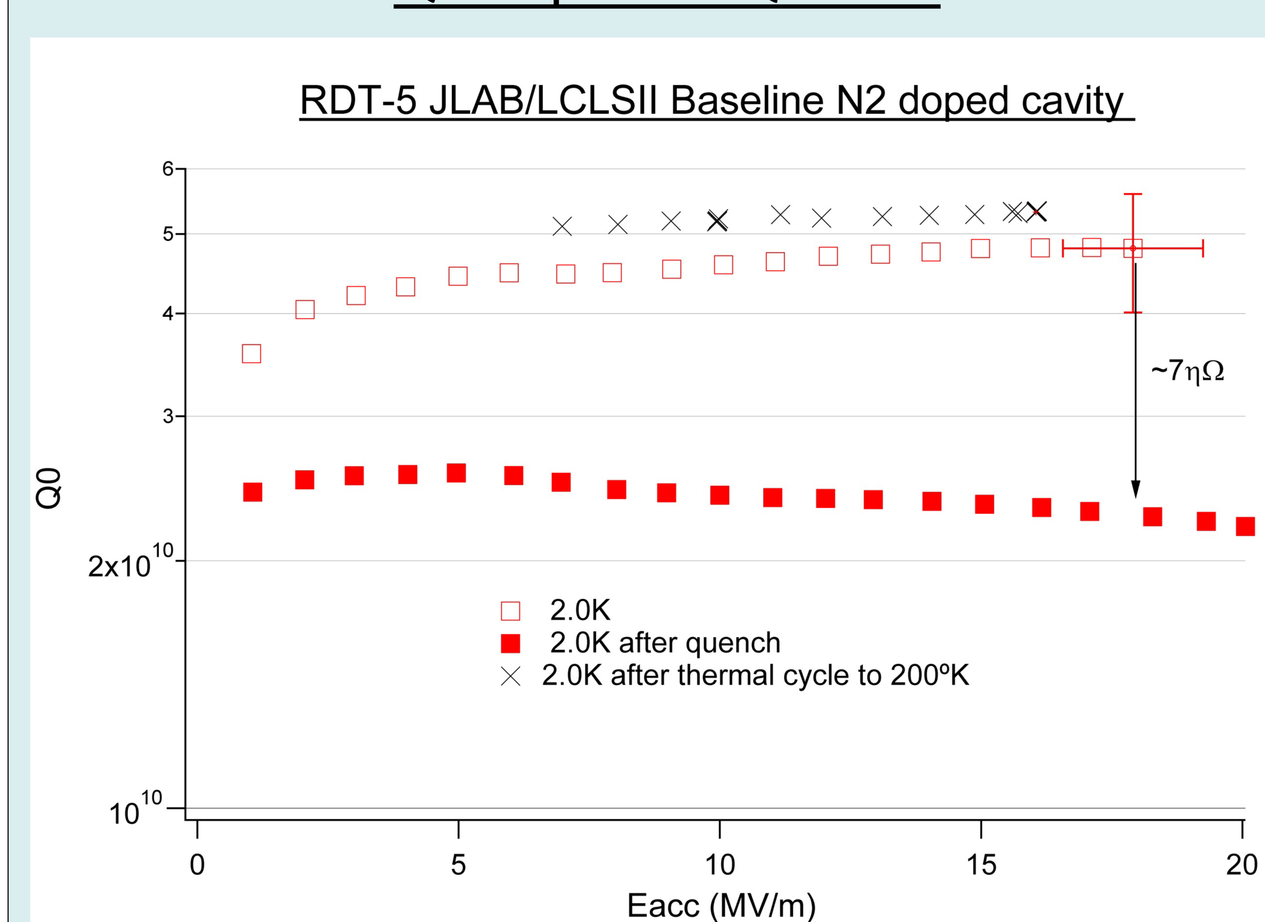
- RF test of single-cell at multiple temperatures; all single-cell cavities tested on left were tested in the same way. Cavities were tested to admin limit (14-16 MV/m) or radiation turn-on at all temperatures before pushing cavity to limits where quench field is found (see *Q*-drop below).
- Two data sets, with a optimal cool down and magnetic field environment (JLab dewar 7 - see 9-cell data bottom left) and high magnetic field environment and uniform cooldown (JLab dewar 8).

Dual matrix doping vs. EP testing study – 15 of 18 complete



15 of 18 vertical test results from matrix study undertaken for the LCLS-II project. All cavities which show a lower than expected Q_0 were either inadvertently in a non-ideal magnetic field, or the cooldown was slow and uniform (see example RF testing in upper right and environmental effect). One cavity, RDT-11 , has large manufacture defects which produce an early quench and Q-switch. Data above is from initial power rise before Q-drops, quench field defined after all temperature data taken. All good cavities quench 15 MV/m-25 MV/m (lower than expected). There is no clear sign of doping dependence/EP vs *Q* as originally envisioned. Environmental effects dominate the variations between tests.

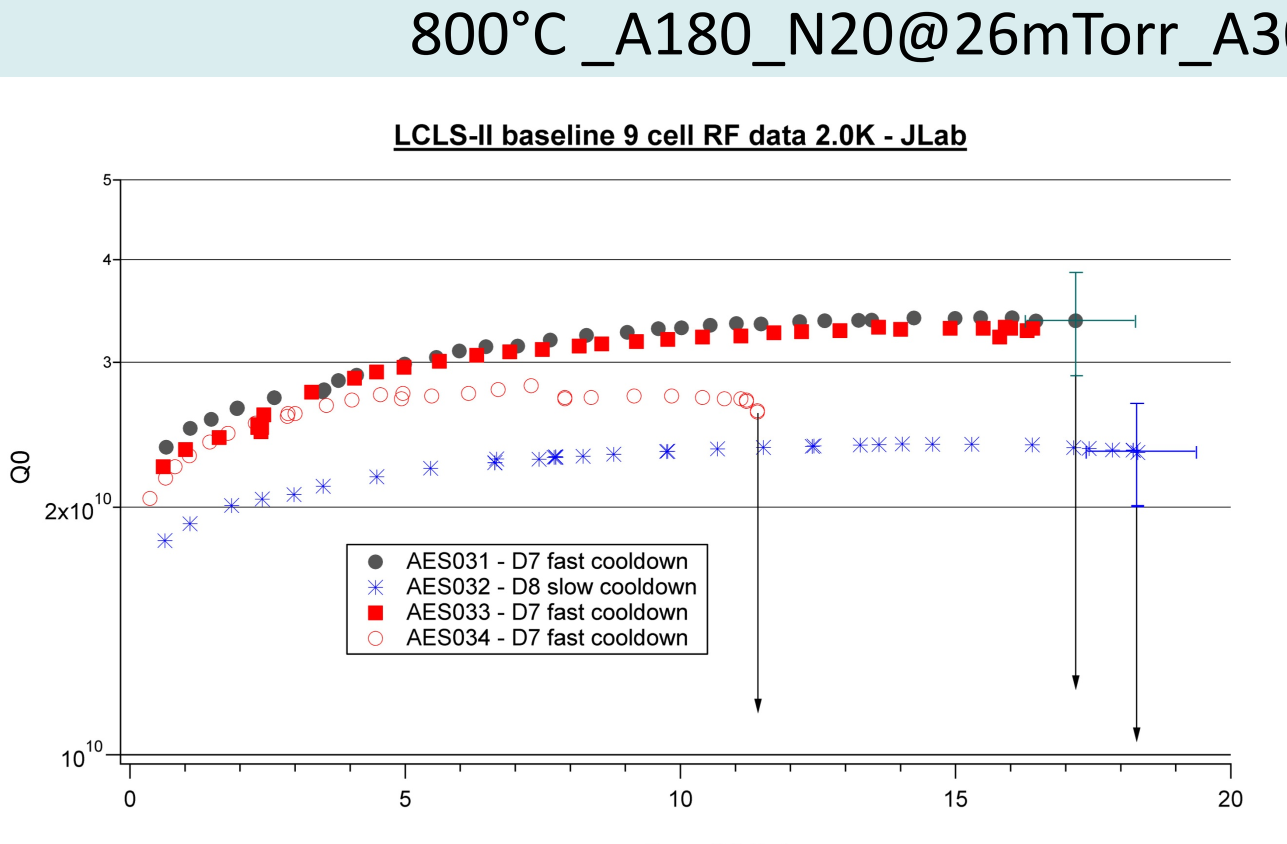
Q-drop with Quench

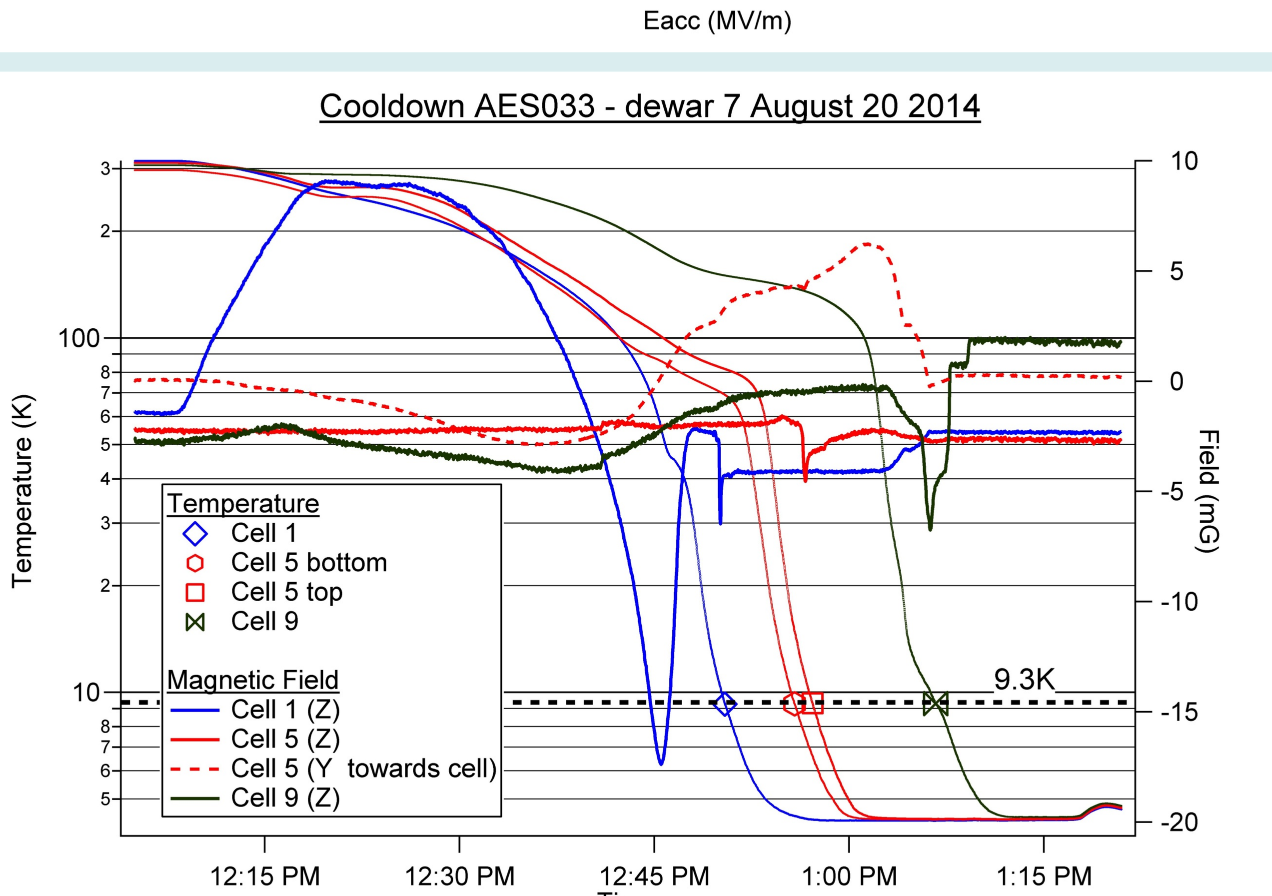


A dramatic example of *Q*-drop with a single quench - RDT-5 800°C_A180_N2@40mTorr_A6 recipe and then received a 5 µm EP. The change in the total resistance from a single quench was 7 nΩ, @ 18 MV/m yielding a *Q* change from 5×10^{10} to 2.2×10^{10} @ 2.0 K. Thermal cycling to 200 K and re-test returned the Q_0 to its original value. Other cavities quenched hundreds of times without a *Q* drop. Many others are somewhere in-between.

9-cell serial testing of 6 cavities with LCLS-II heavy doping baseline recipe

800°C _A180_N20@26mTorr_A30 + 15µm EP

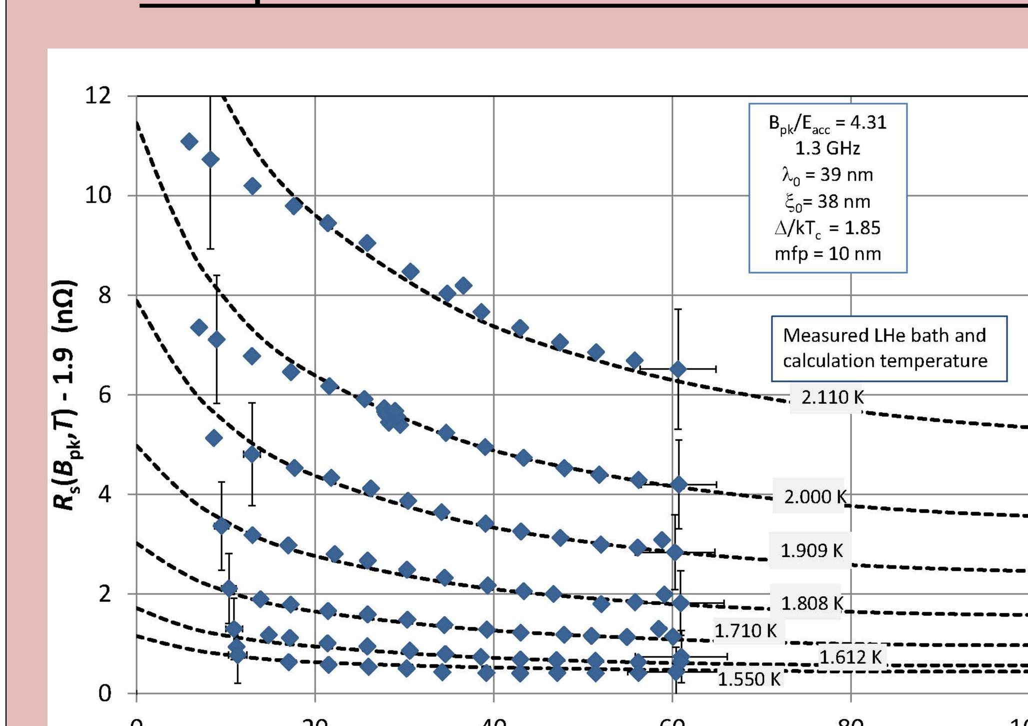




All 9-cell tests have 8 thermal sensors (Lakeshore - Cernox CX-1050-SD-HT-1.4L) located on the bottom, and top flanges, cell 1,3,7,9 and top/bottom cell 5) and 6 flux gate magnetometers (Bartington MAG-F) location on the bottom flange (Z), on cell 1(Z) ,5 (X,Y and Z), and 9(Z)

Four of 6 vertical RF tests at 2K of the serial testing of the LCLS-II baseline heavy doping recipe, the remainder cavities AES0335 and AES036 will be completed by mid September, along with a retest of AES032 in dewar7 with a fast cool down. All cavities received a 115 µm EP prior to heat treatment. Select sensor signals show the temperature difference between cell 1 and cell 9 @ T_c of cell 1 is ~150 K and the temperature difference across cell 5 is 6 K (10 cm). Larger thermal gradients are prevalent on the cell 1 magnetic probe, and all probes show a jump in field as sensor location transitions through T_c.

Comparison with theoretical calculations: $R_s(B_{pk},T)_{BCS}$



Experimental surface resistance from test of RDT-15 above and calculation of BCS surface resistance with electron mfp = 10 nm, using Xiao code[1].

Nitrogen doping yields near "ideal" Nb RF surface resistance

[1] B. P. Xiao, *et al.*, Physica C: Superconductivity, 2013. **490**(0): p. 26-31

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