Lessons Learned From Nitrogen Doping at JLab

Exploration of Surface Resistance with Varied Interstitial Atom Diffusion on Niobium Cavity Surfaces

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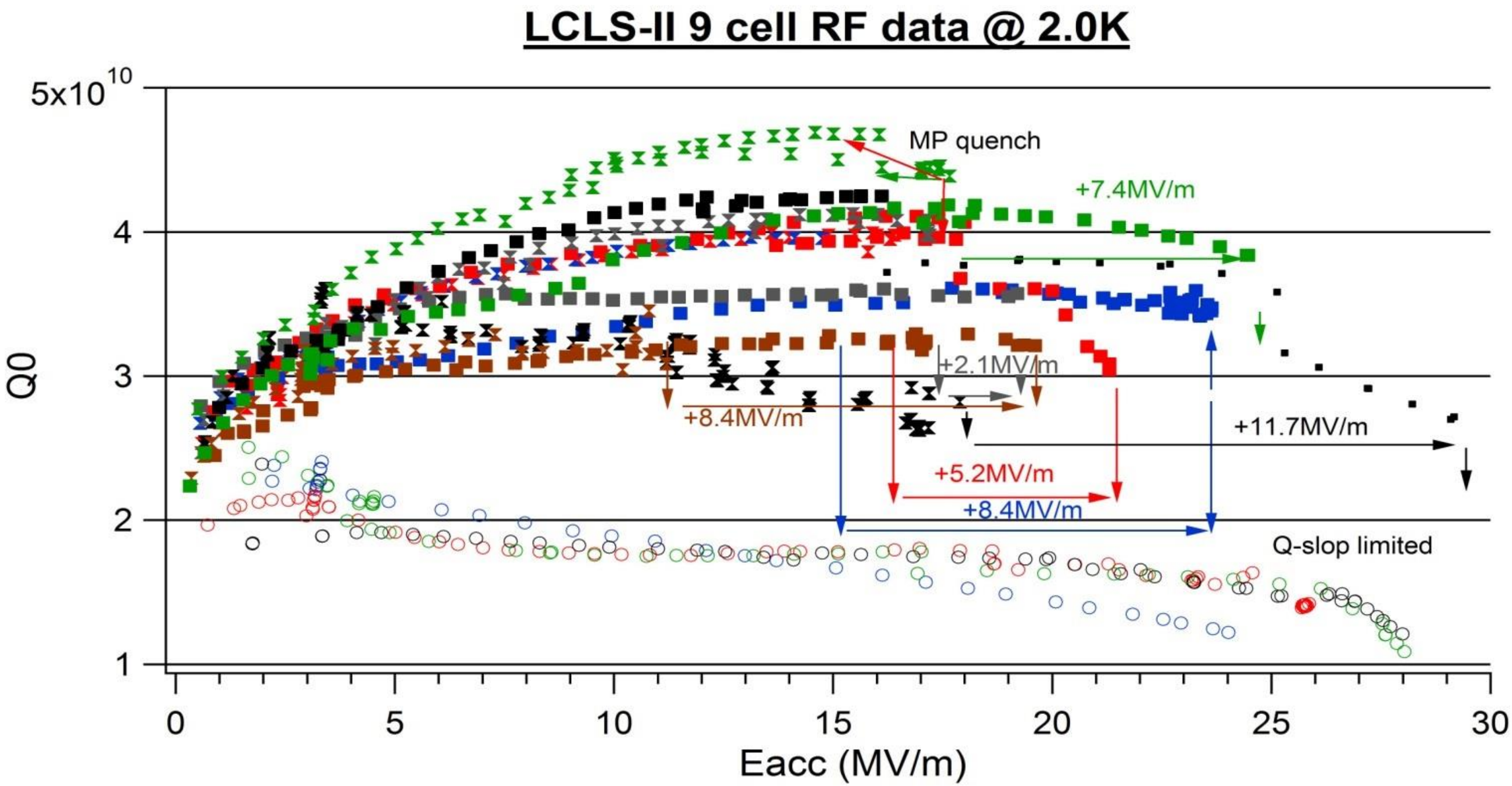
MOBA07

What to remember/what I learned

1) It now seem clear, Nitrogen doping i.e. getting nitrogen into cavity at 800C is the easy part.
2) Controlling the test environments: magnetic field, cooling rate, and test hardware is the hard part. *Environmental monitoring instrumentation is your friend.*

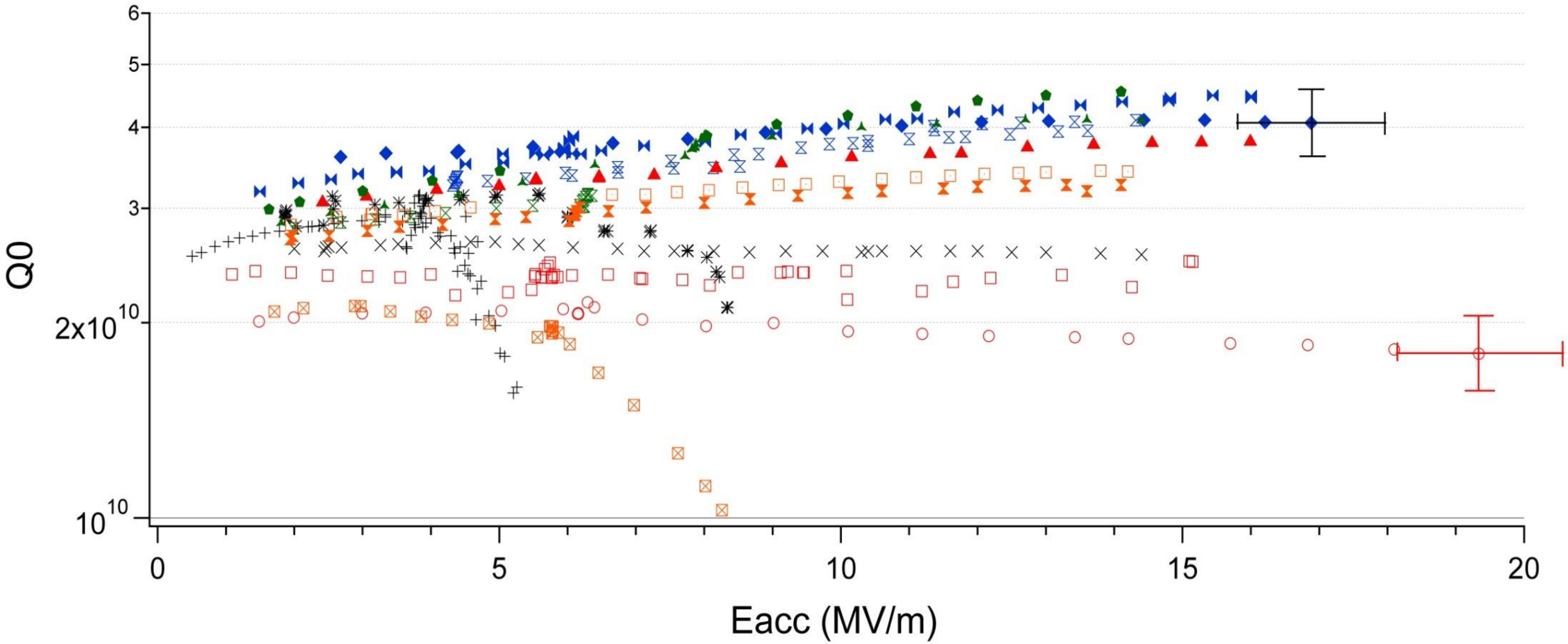
3) Q vs Eacc is not enough, Q vs Eacc vs T in a controlled environment with "surface resistance decomposition" is a must (all data that follows is 1.3GHz @ 2.0K unless noted).
4) What is the nitrogen doing? Where is it going?

Cavity tests to date – 2.0K



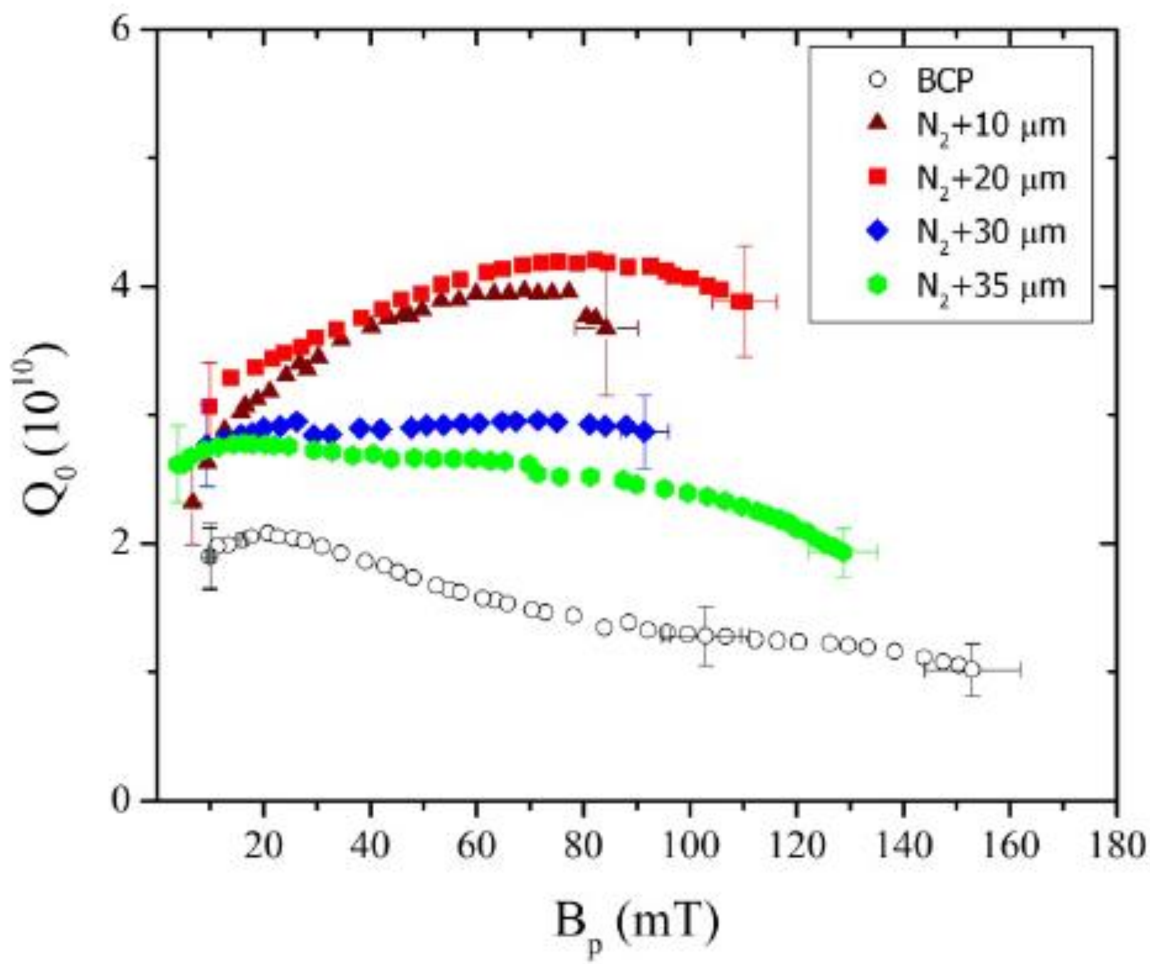
9 cell mini production and re-doping second run

Cavity tests to date – 2.0K



Single cell systematic doping

Cavity tests to date – 2.0K



Single cell large grain incremental EP – Dhakal et al, IPAC 2015 WEPWI009

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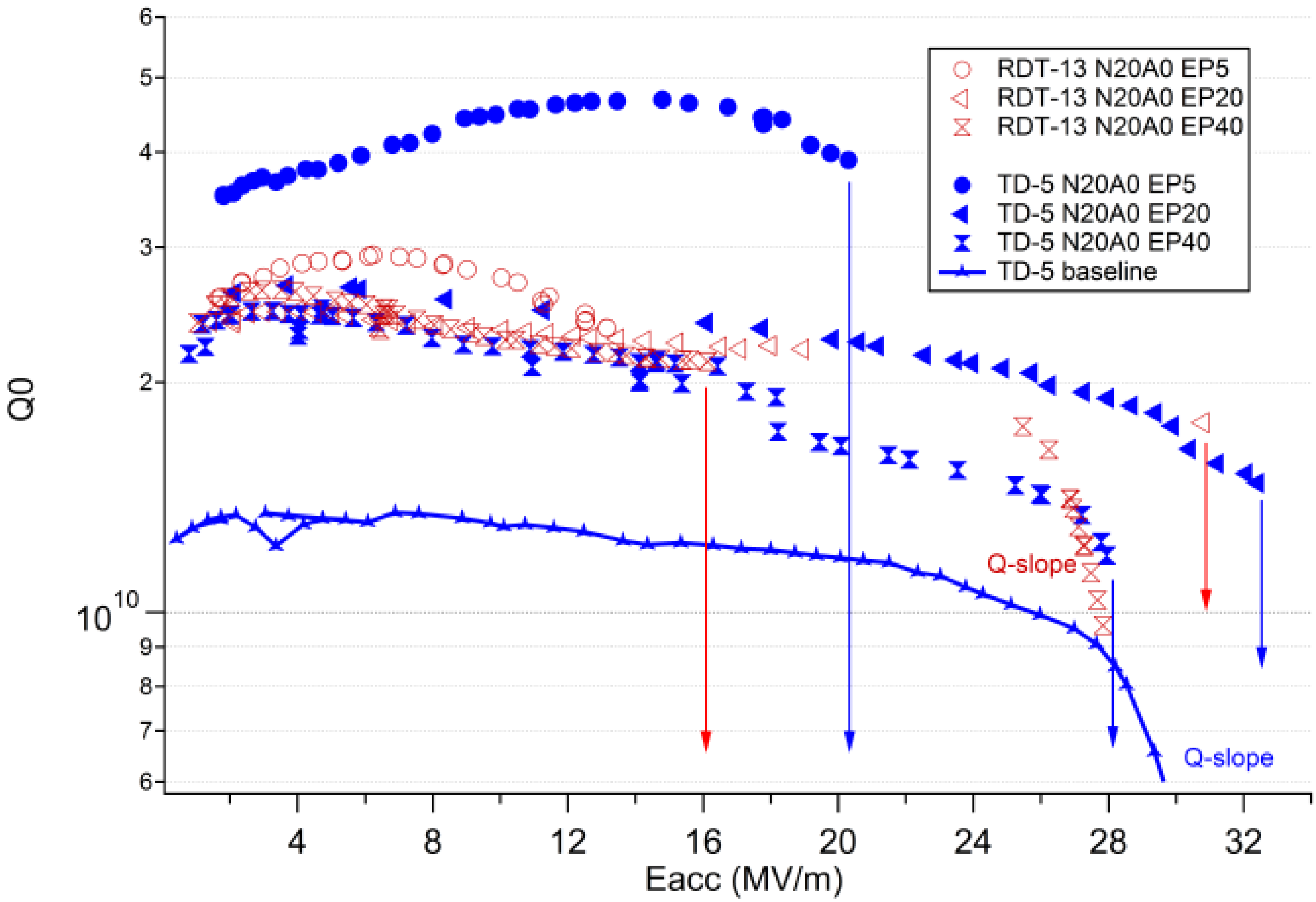
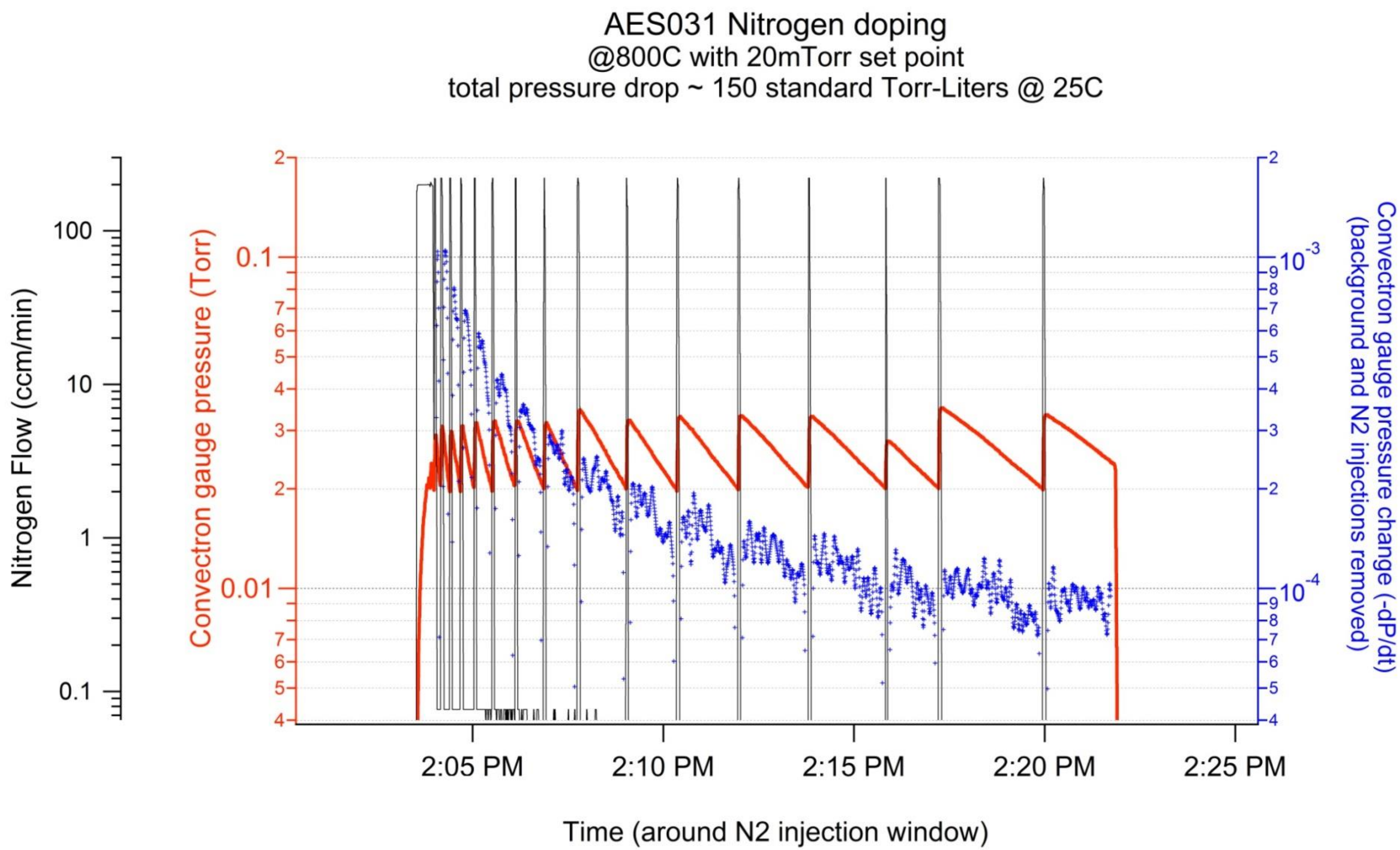


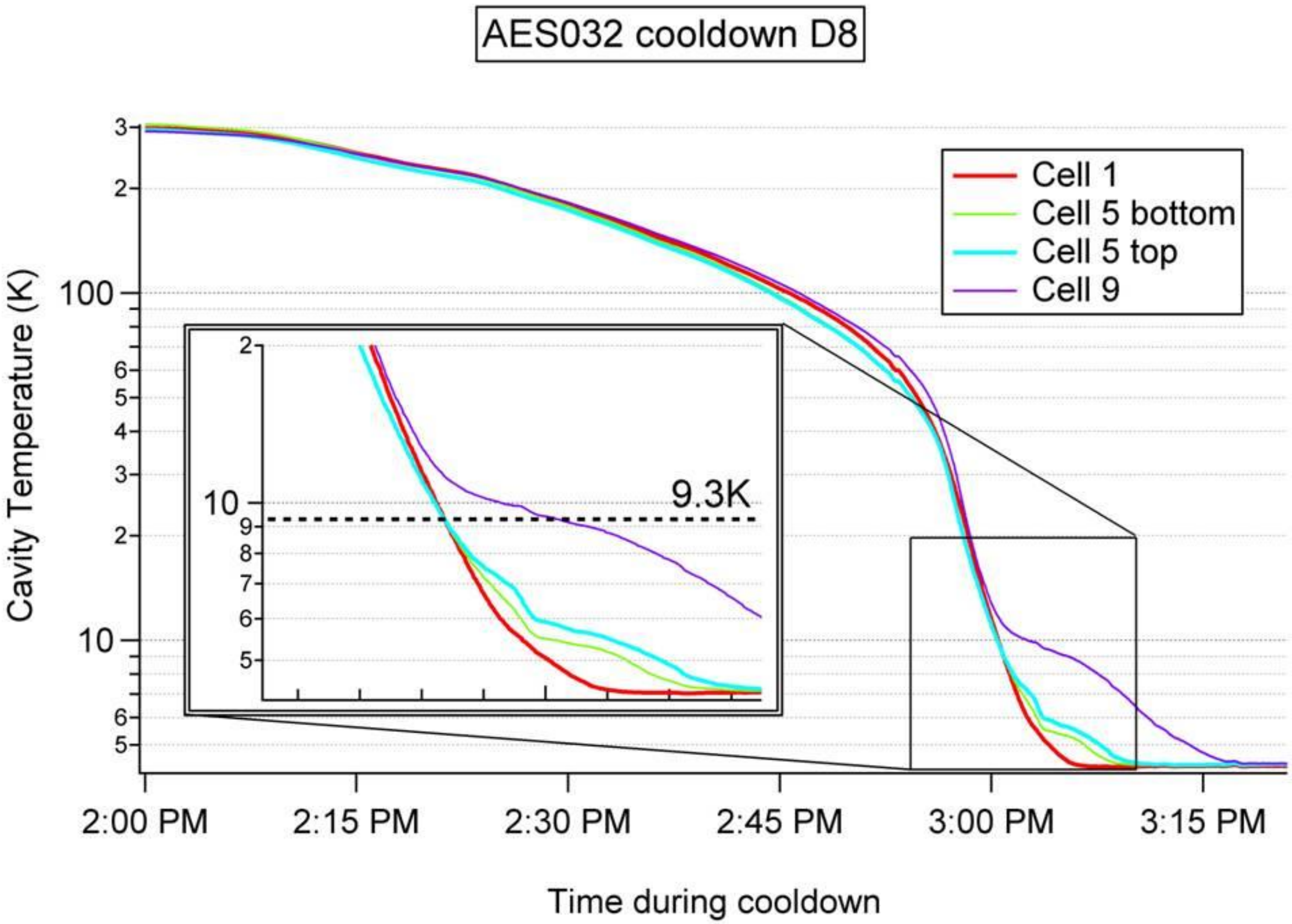
Large grain vs fine grain –systematic removal

Furnace doping - absorption rate



See Report for JLab High Q0 R&D for LCLS-II - FY14,JLab tech note JLAB-TN-15-008

Test environment – accidental uniform cooling D8



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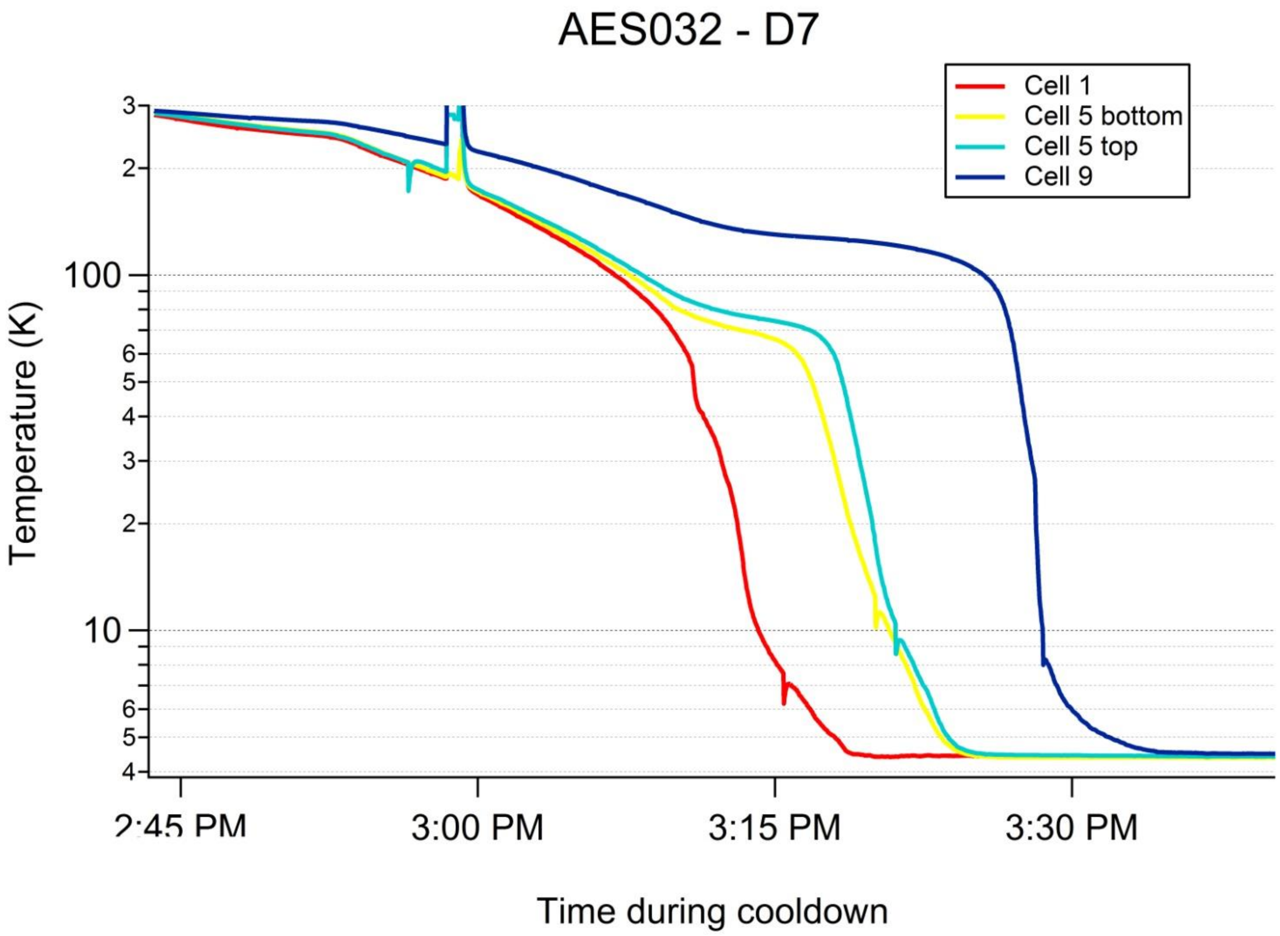

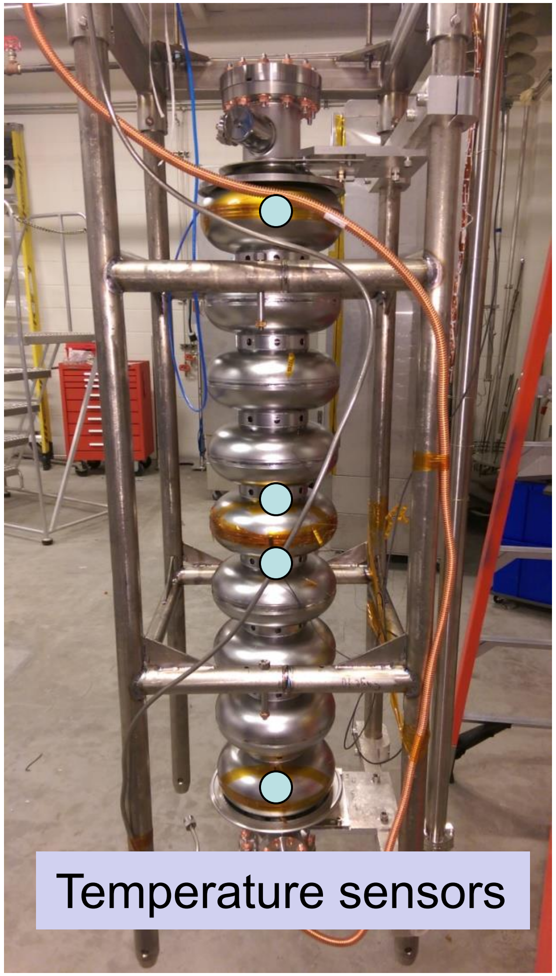

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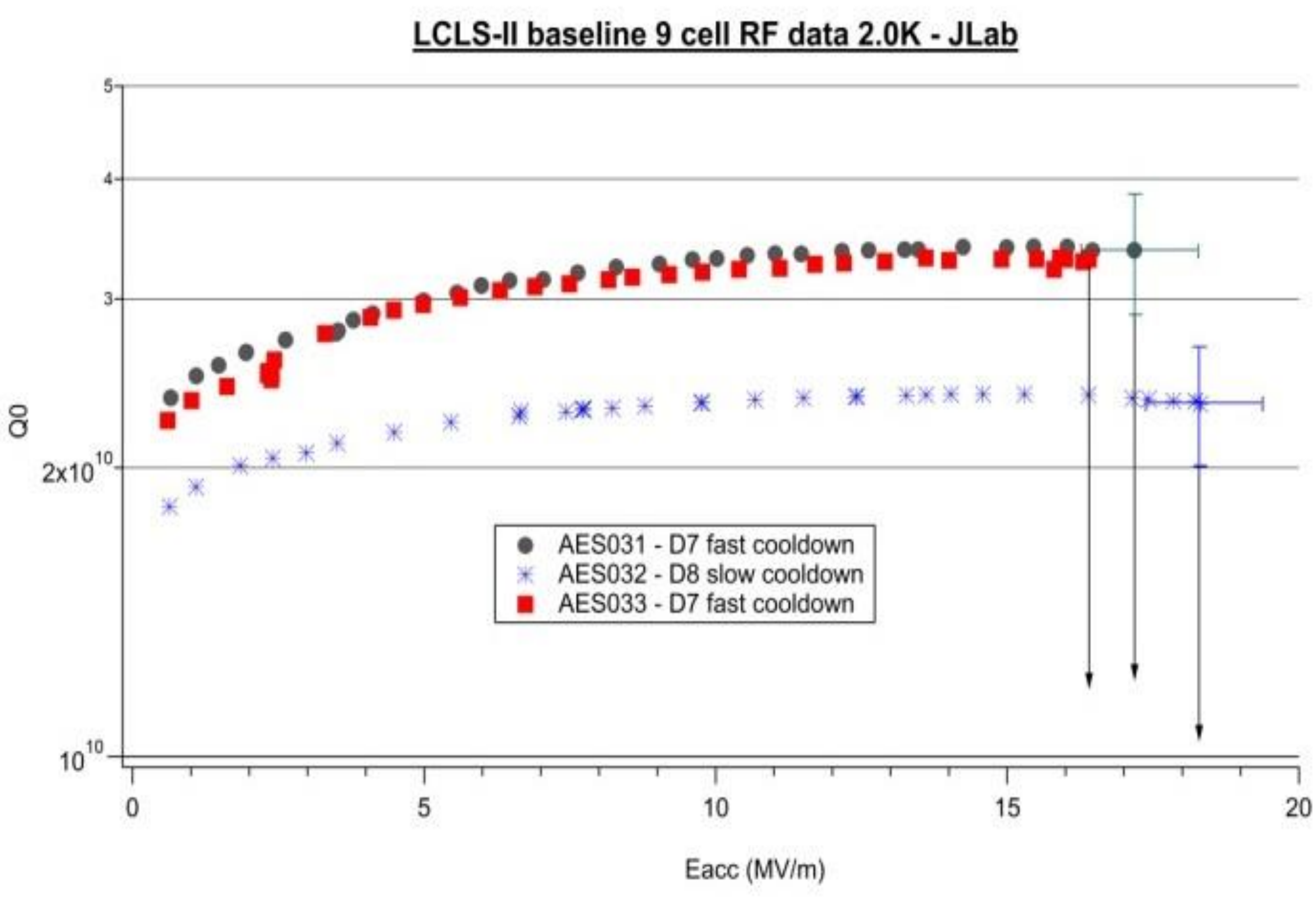
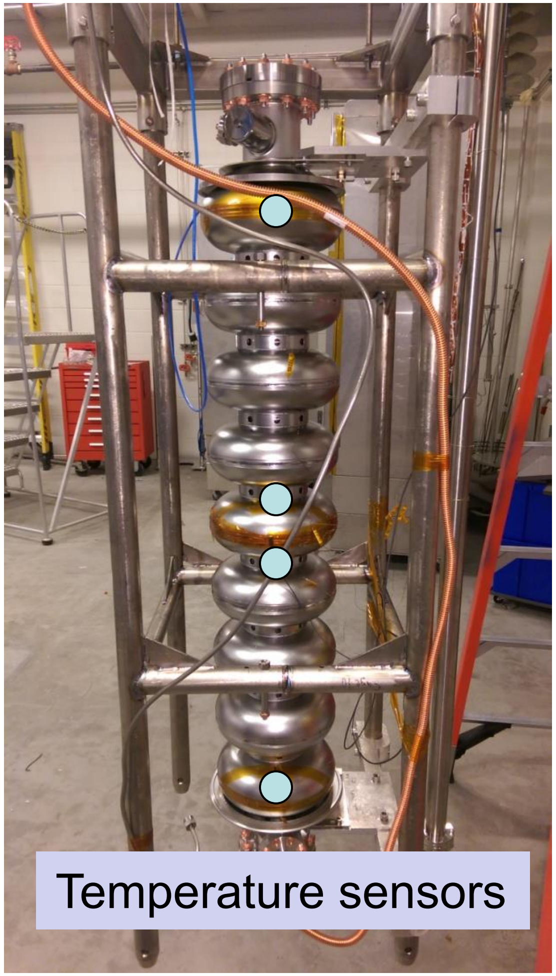
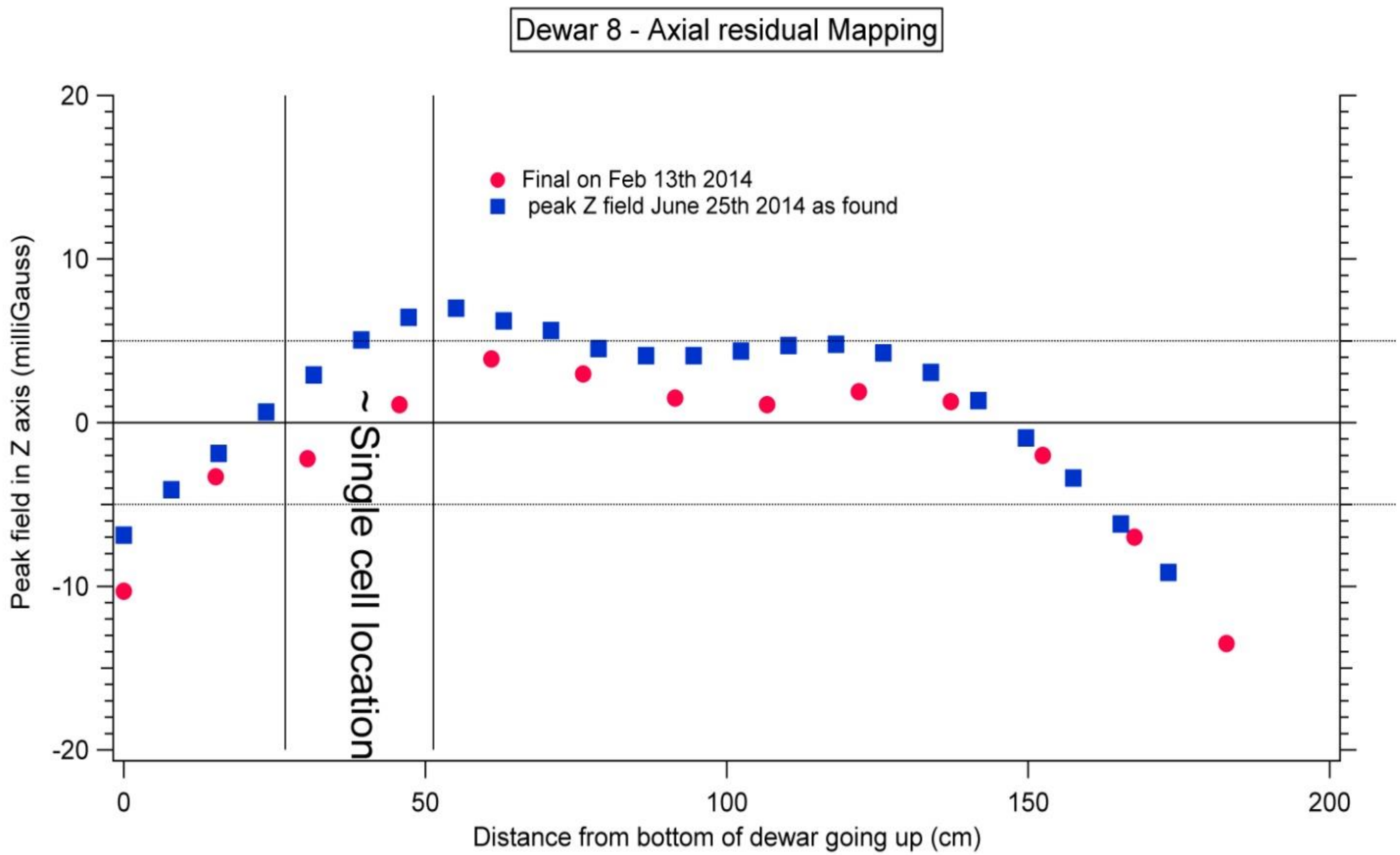




Test environment - magnetic field drift



Report for JLab High Q0 R&D for LCLS-II - FY14
JLab tech note JLAB-TN-15-008

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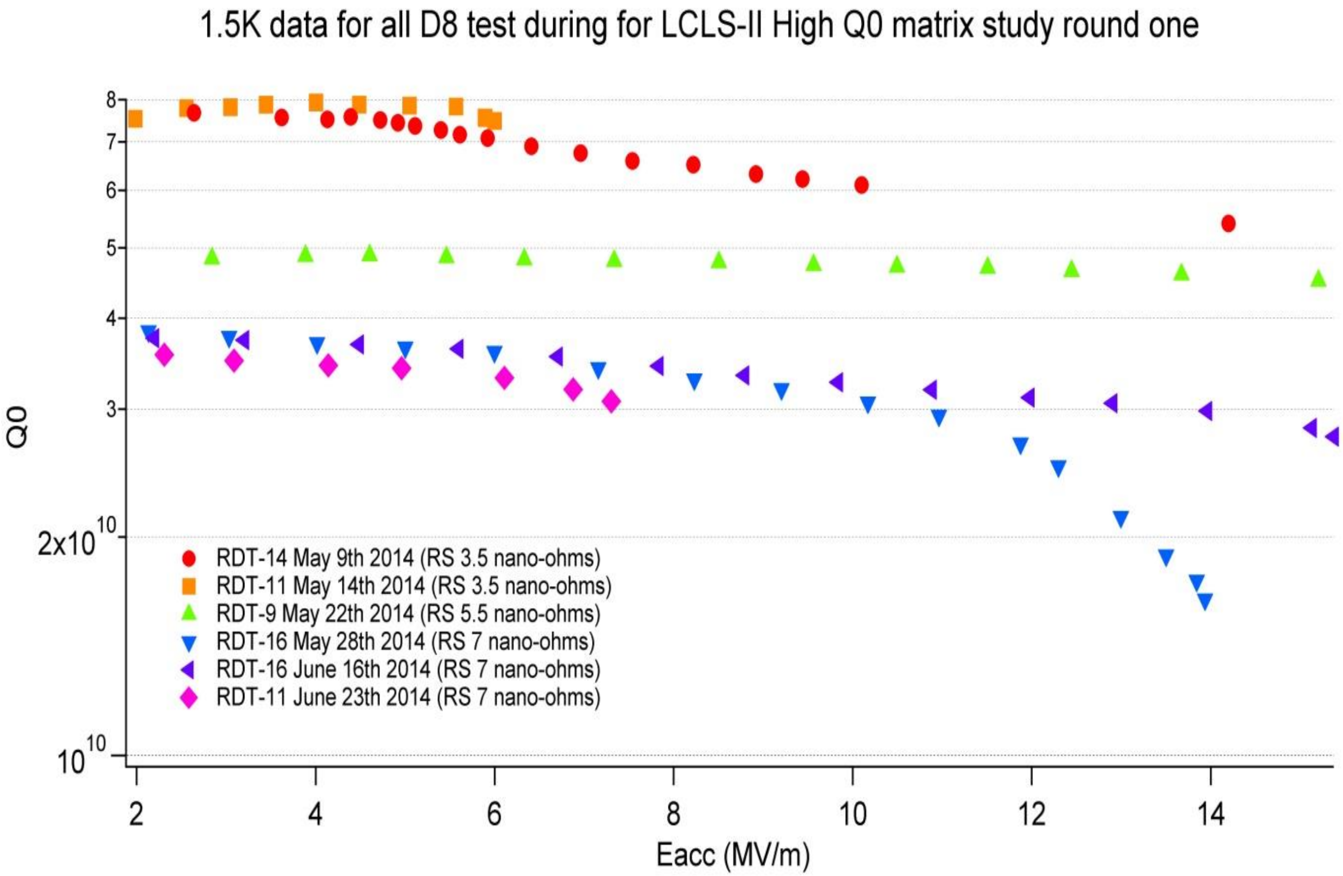

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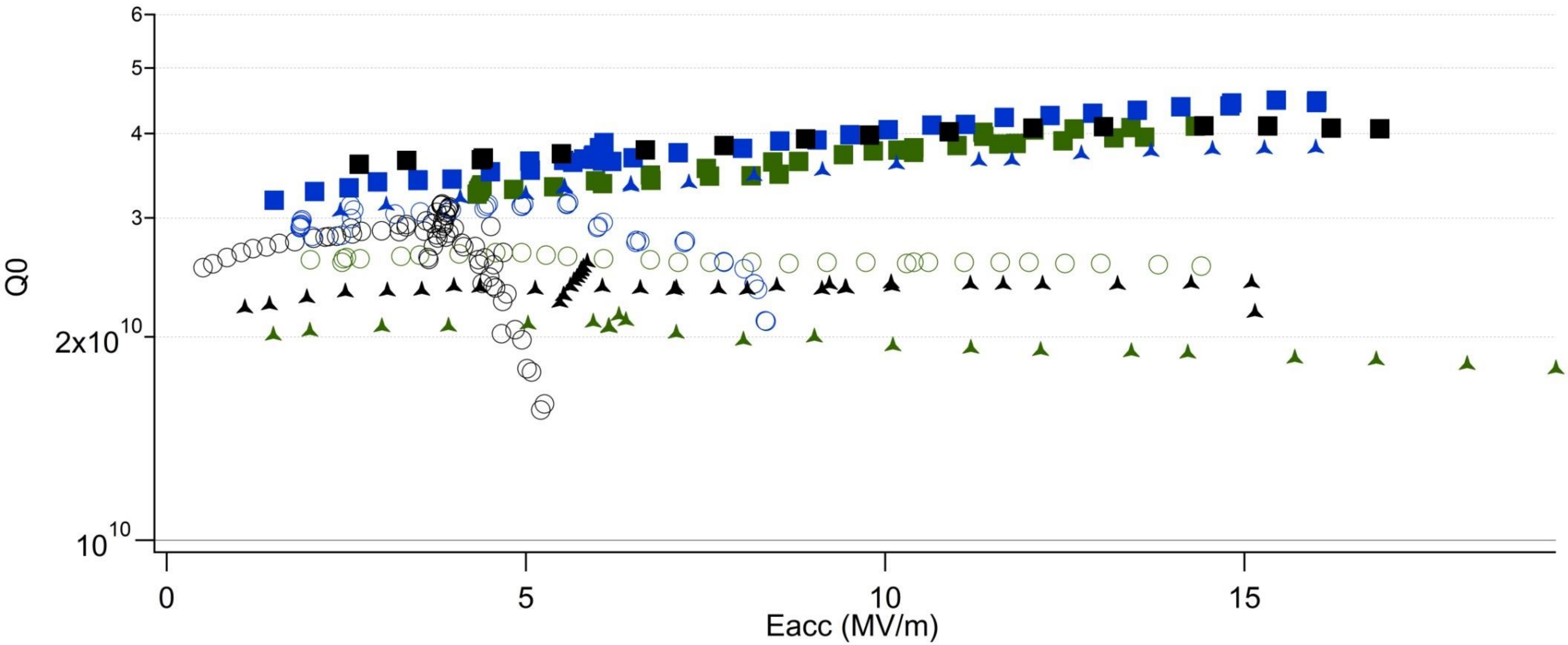
Surface decomposition is essential - Qo vs. Eacc vs. T



All single cell cavities, all with now know good doping, all should easily have Q0 > 3.5e10 @ 16MV/m

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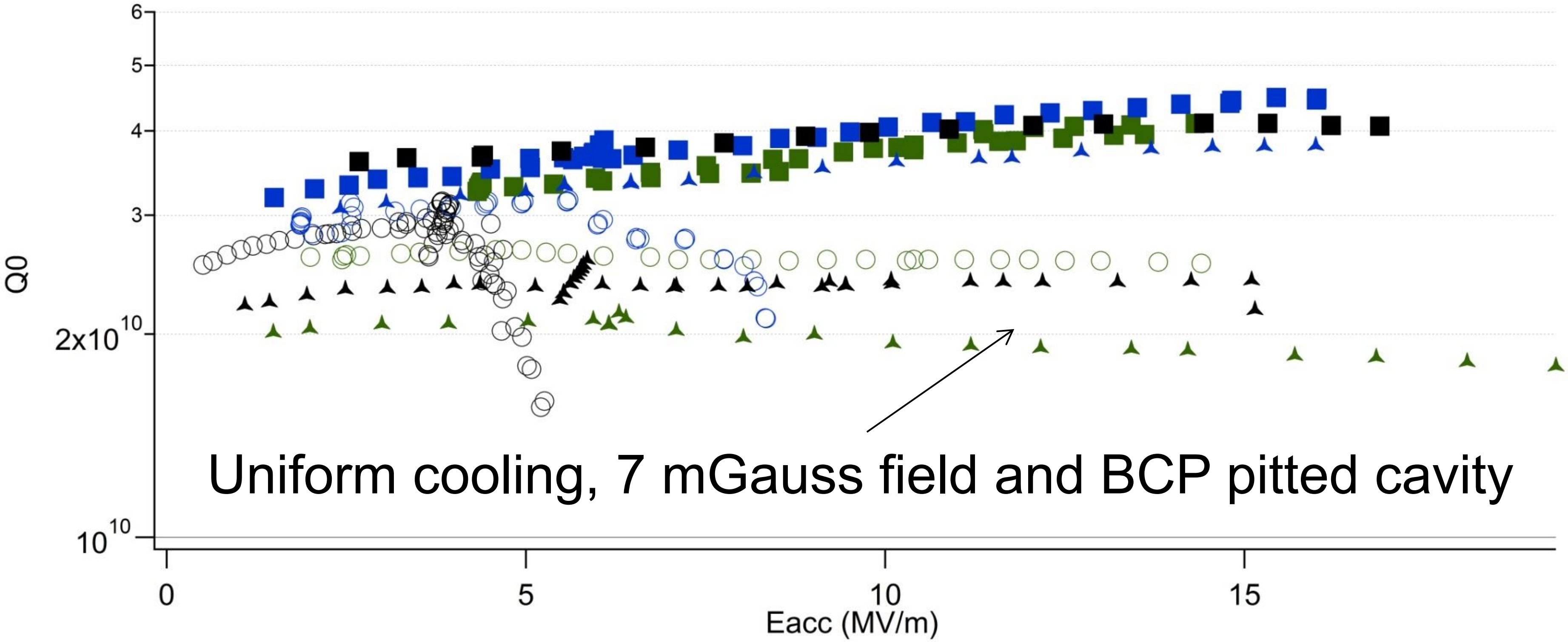

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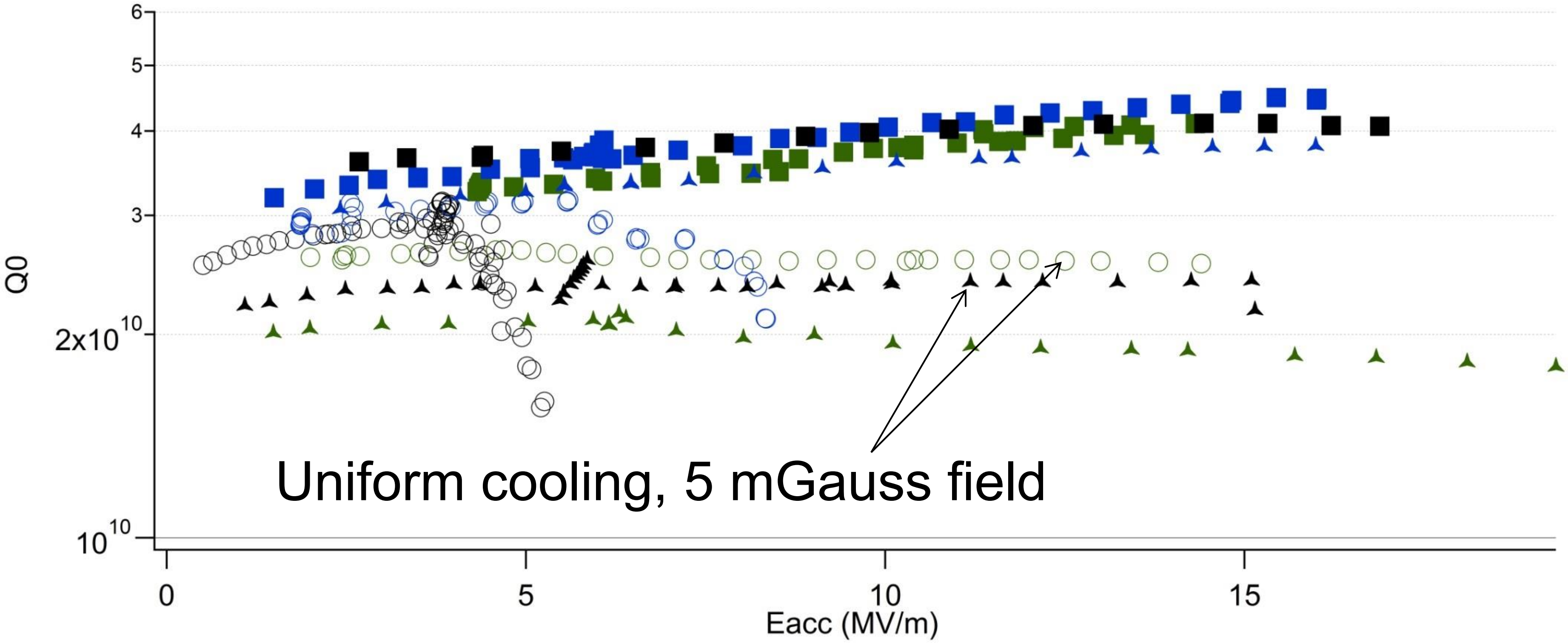

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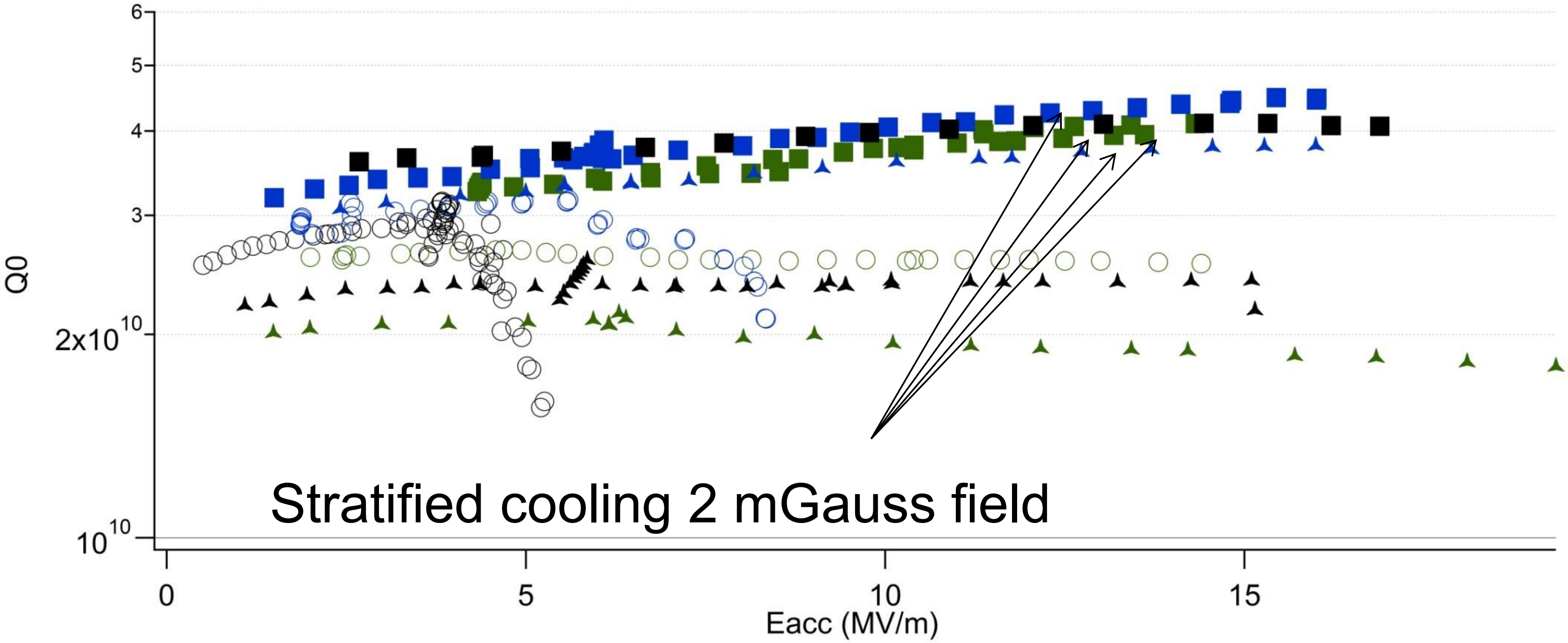

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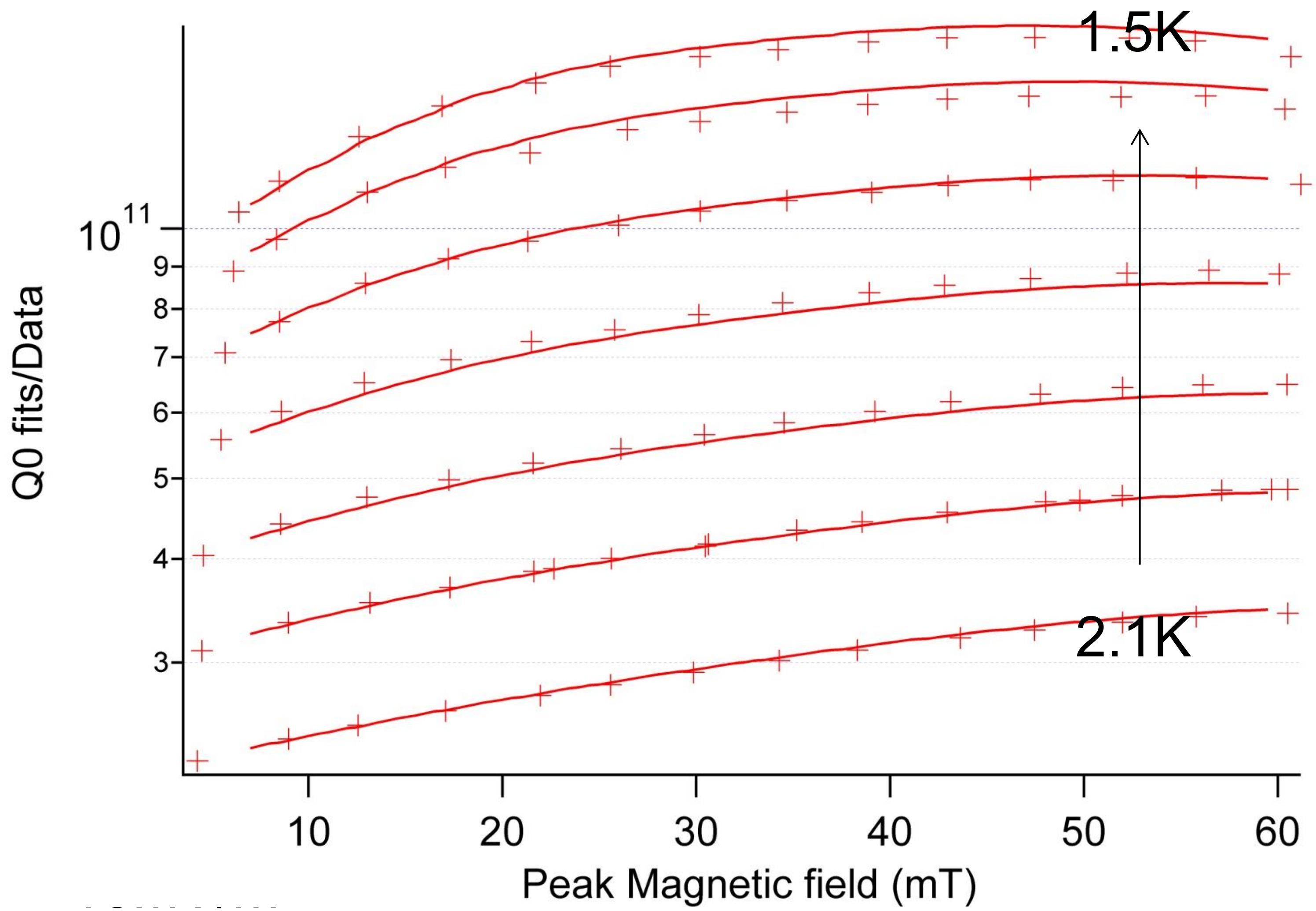

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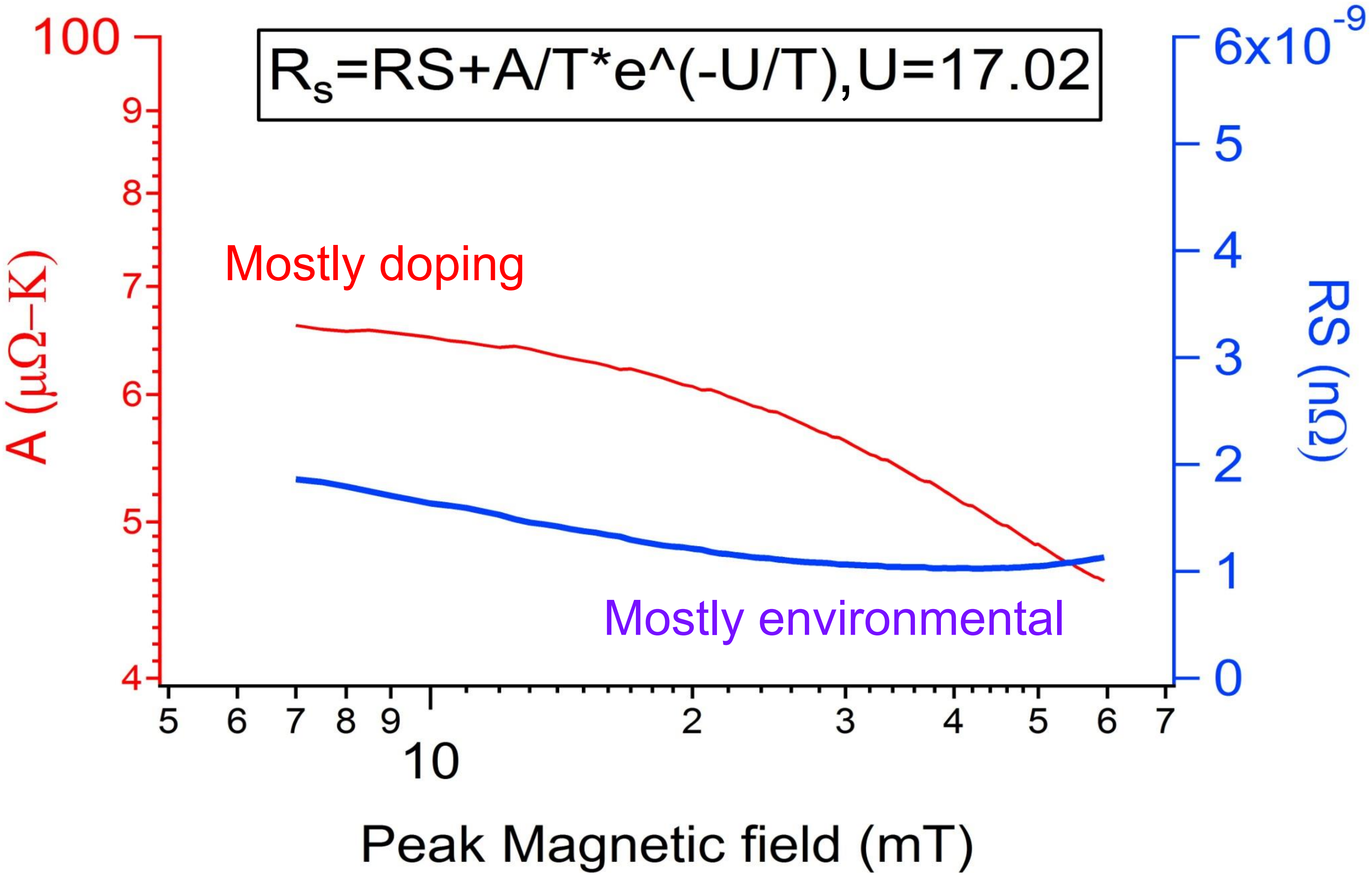
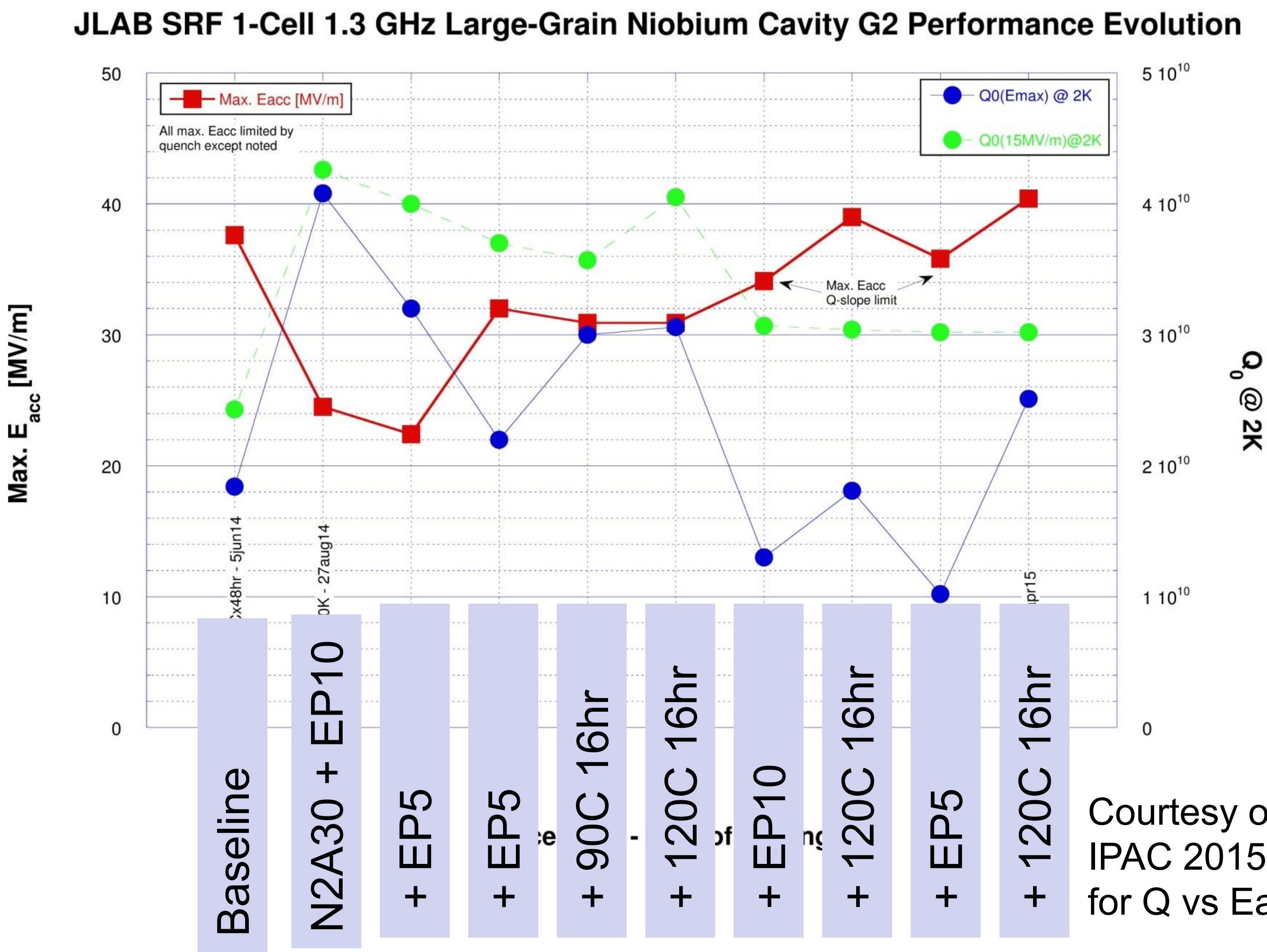
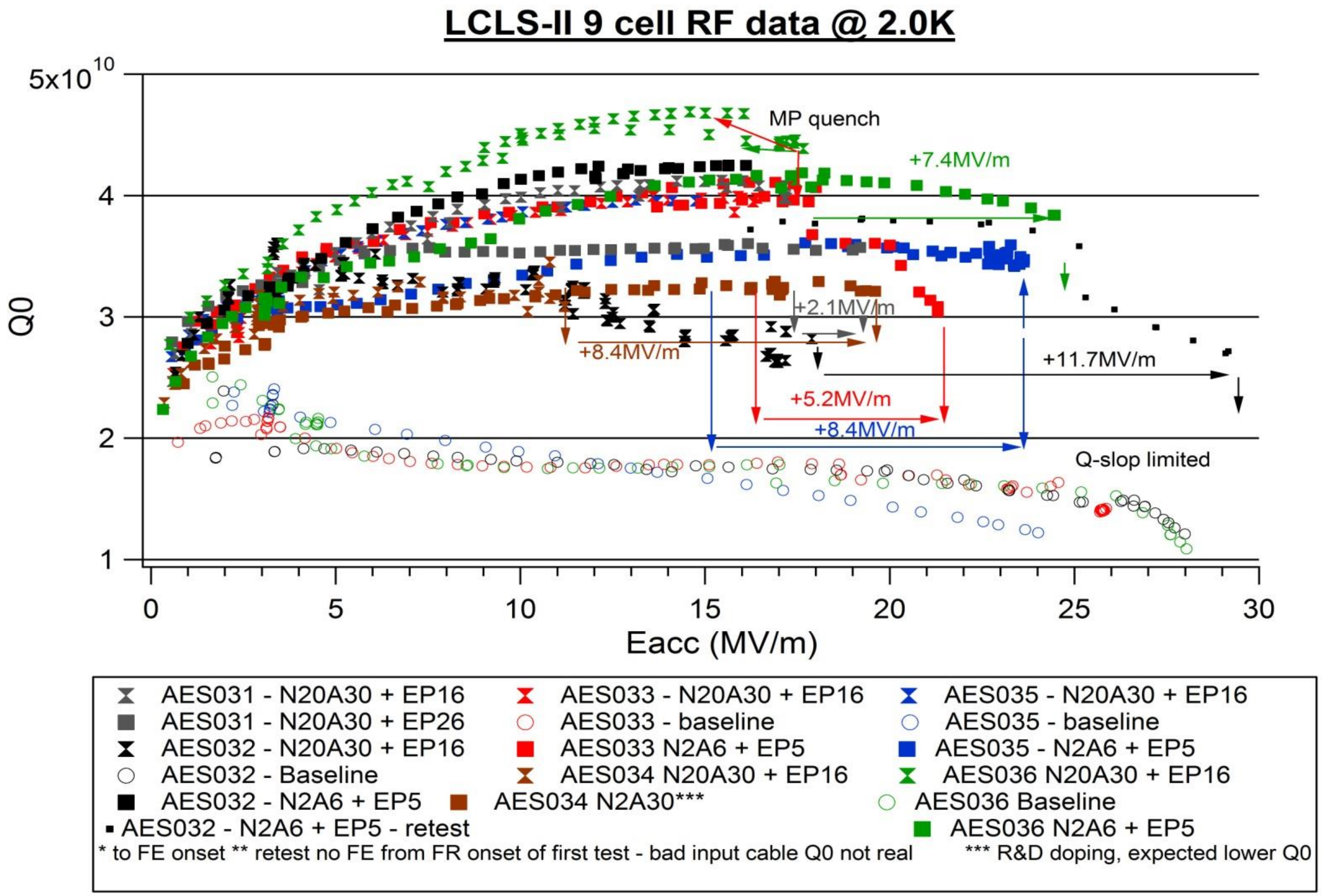


G2 – Large grain incremental EP



Courtesy of R.L. Geng
IPAC 2015 WEPWI013
for Q vs Eacc

Quench analysis on 9 cell cavities



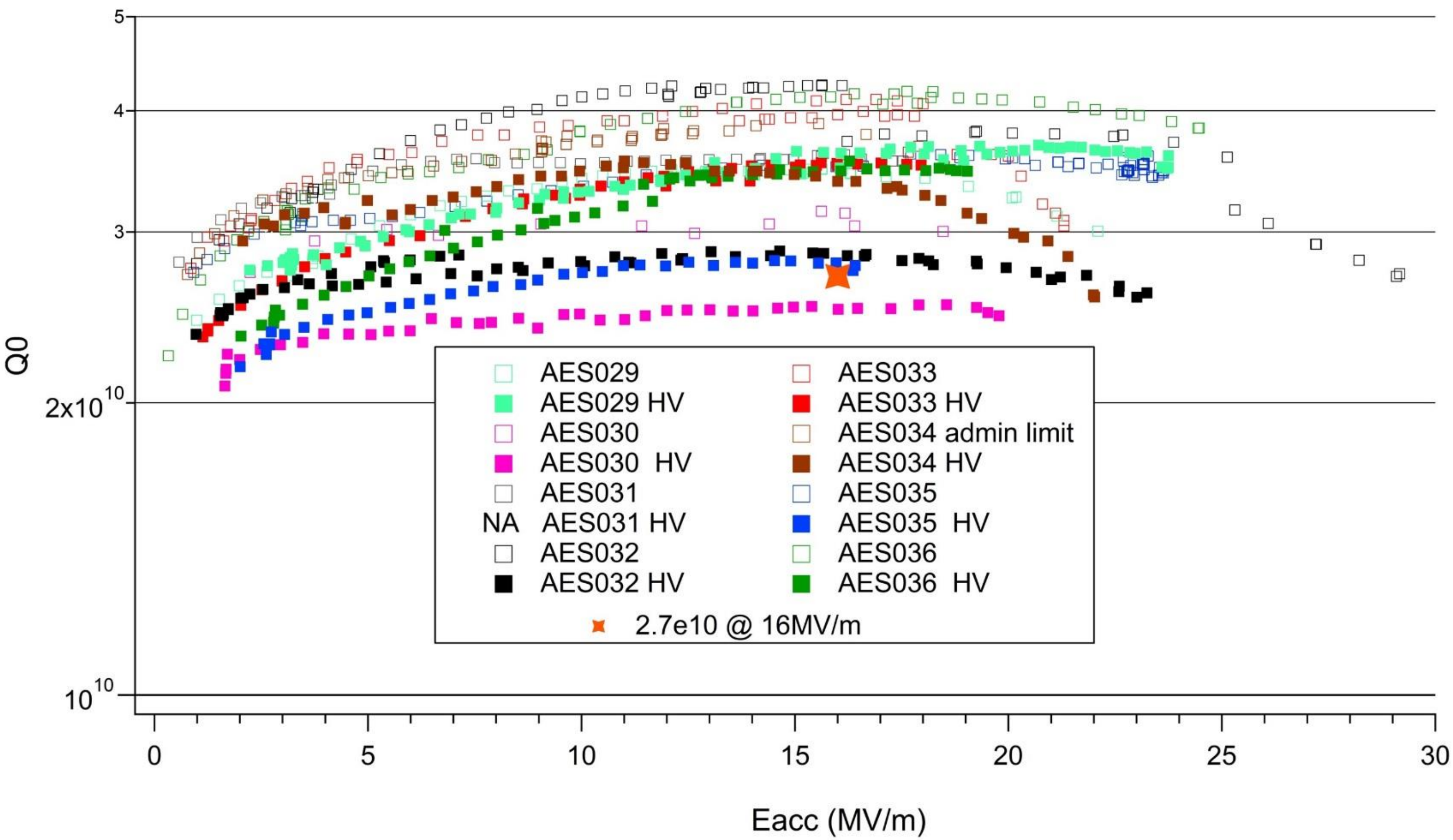
N20A30 +EP 16μm
Average quench field – 16.8MV/m

N2A6 + EP 5 μm
Average quench field – 23MV/m

lower Q0 @ 16MV/m With lower N2?

Palczewski et al. – IPAC2015 WEPWI019 QUENCH STUDIES OF SIX HIGH TEMPERATURE NITROGEN DOPED 9 CELL CAVITIES FOR USE IN THE LCLS-II BASELINE PROTOTYPE CRYOMODULE AT JEFFERSON LABORATORY

LCLS-II prototype results before and after HV welding

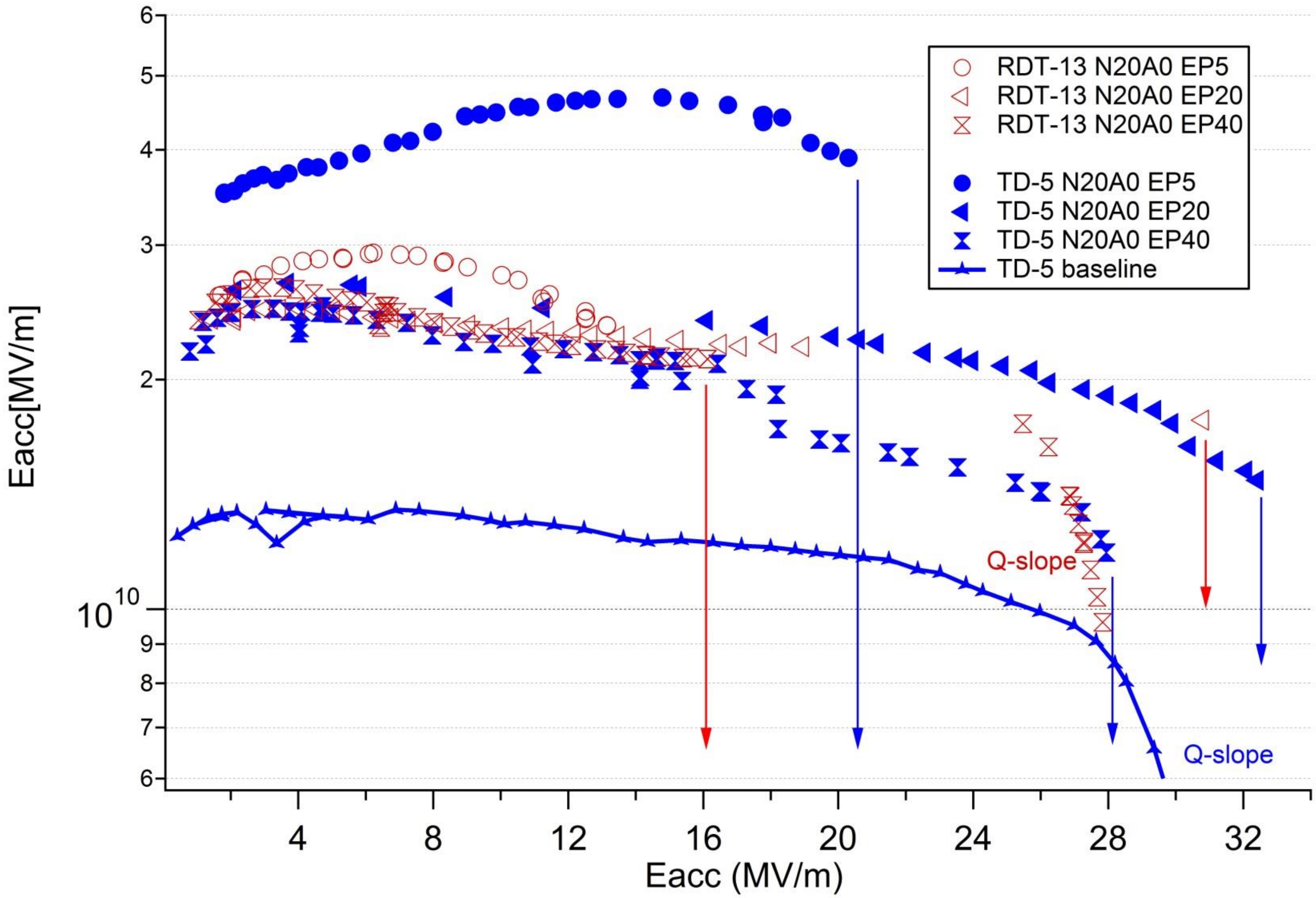


Average Q_0 is lower after HV welding by ~10% or 1.25nΩ

Current data suggest environmental effects are the major cause of Q_0 degradation after HV welding.

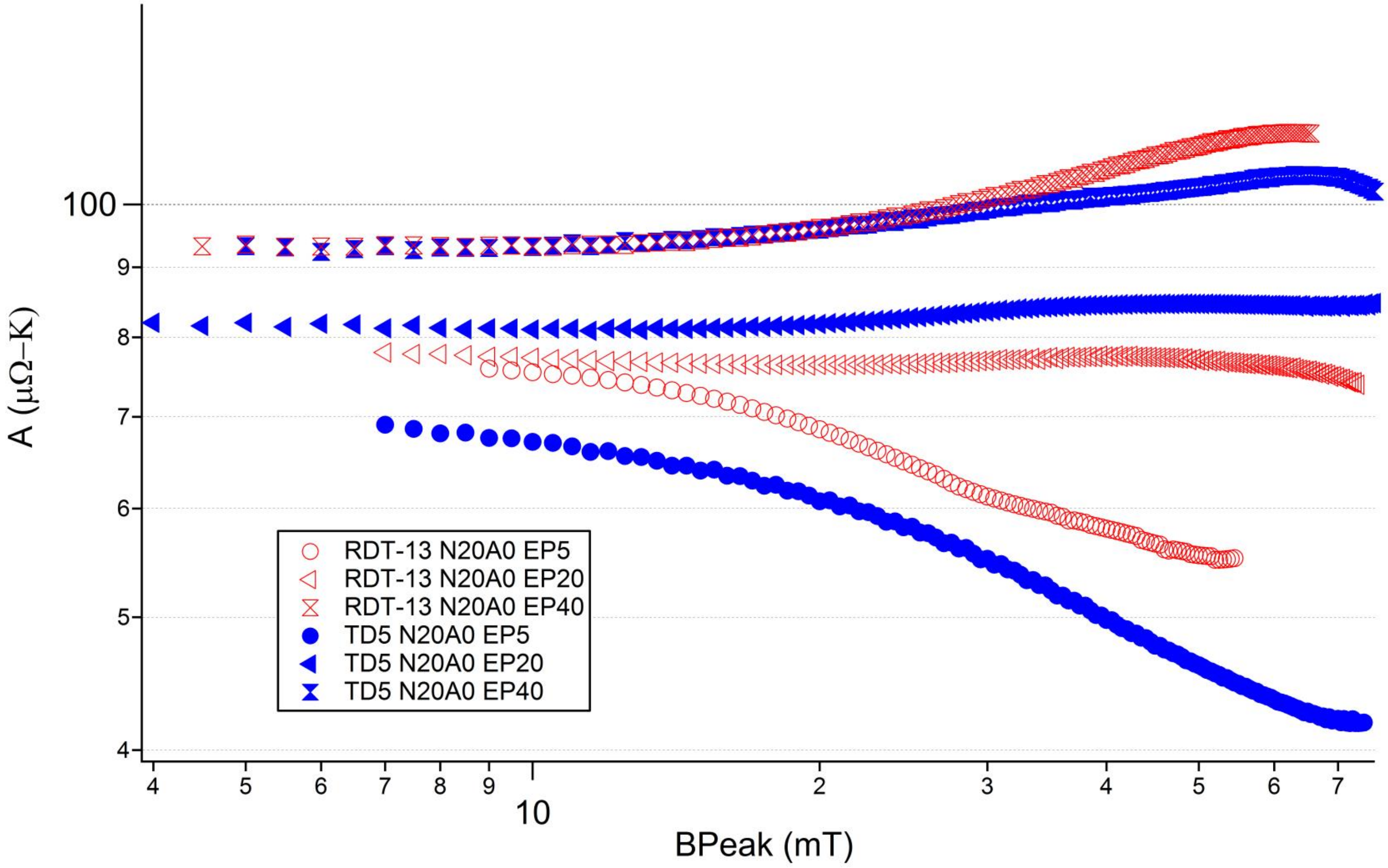
Palczewski et al. – this conference MOPB040 today

Systematic doping vs. EP (FG and LG)



Systematic doping vs. EP (FG and LG)

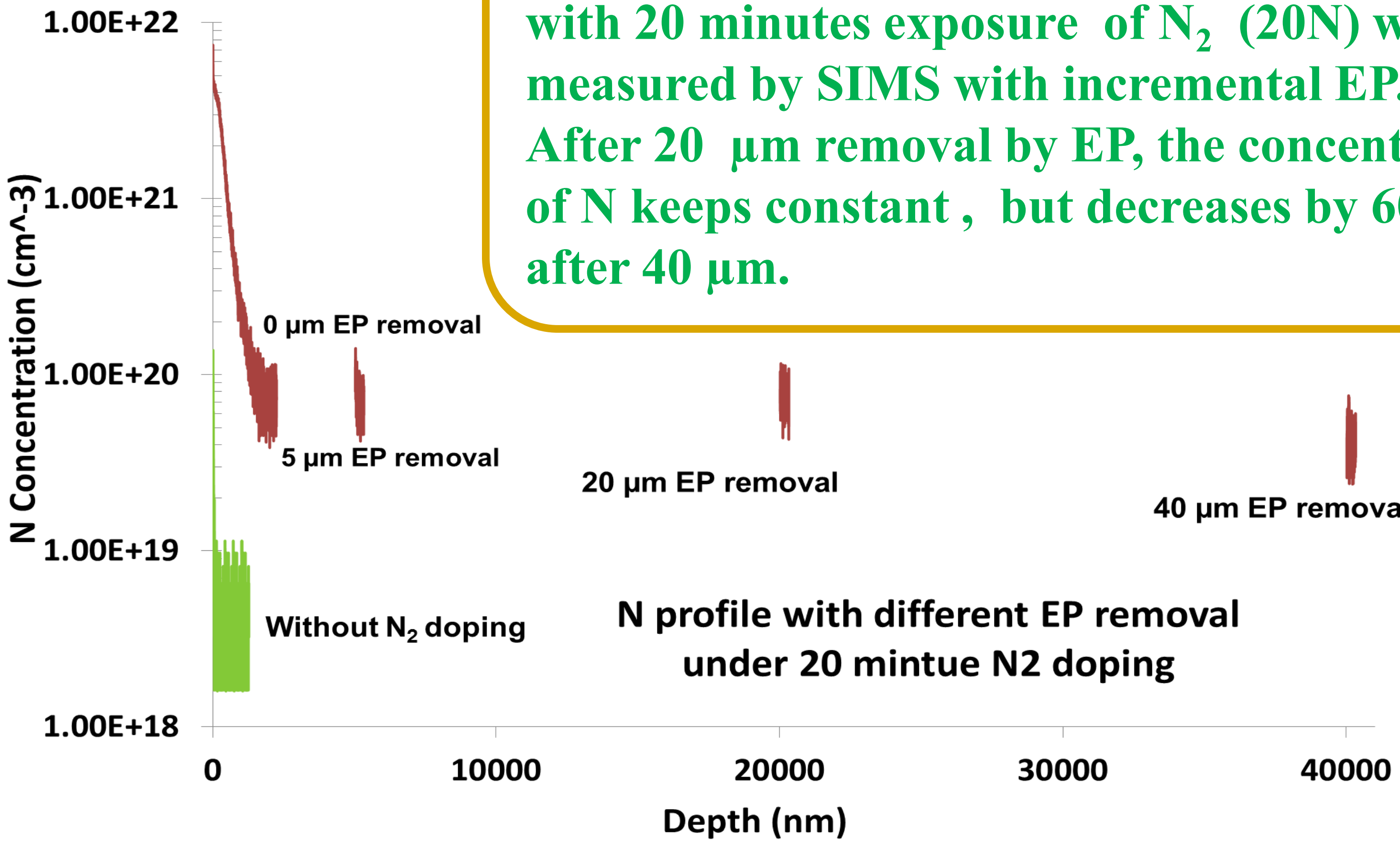
Fitting results remove environmental effects



Palczewski et al. – this conference MOPB039 today

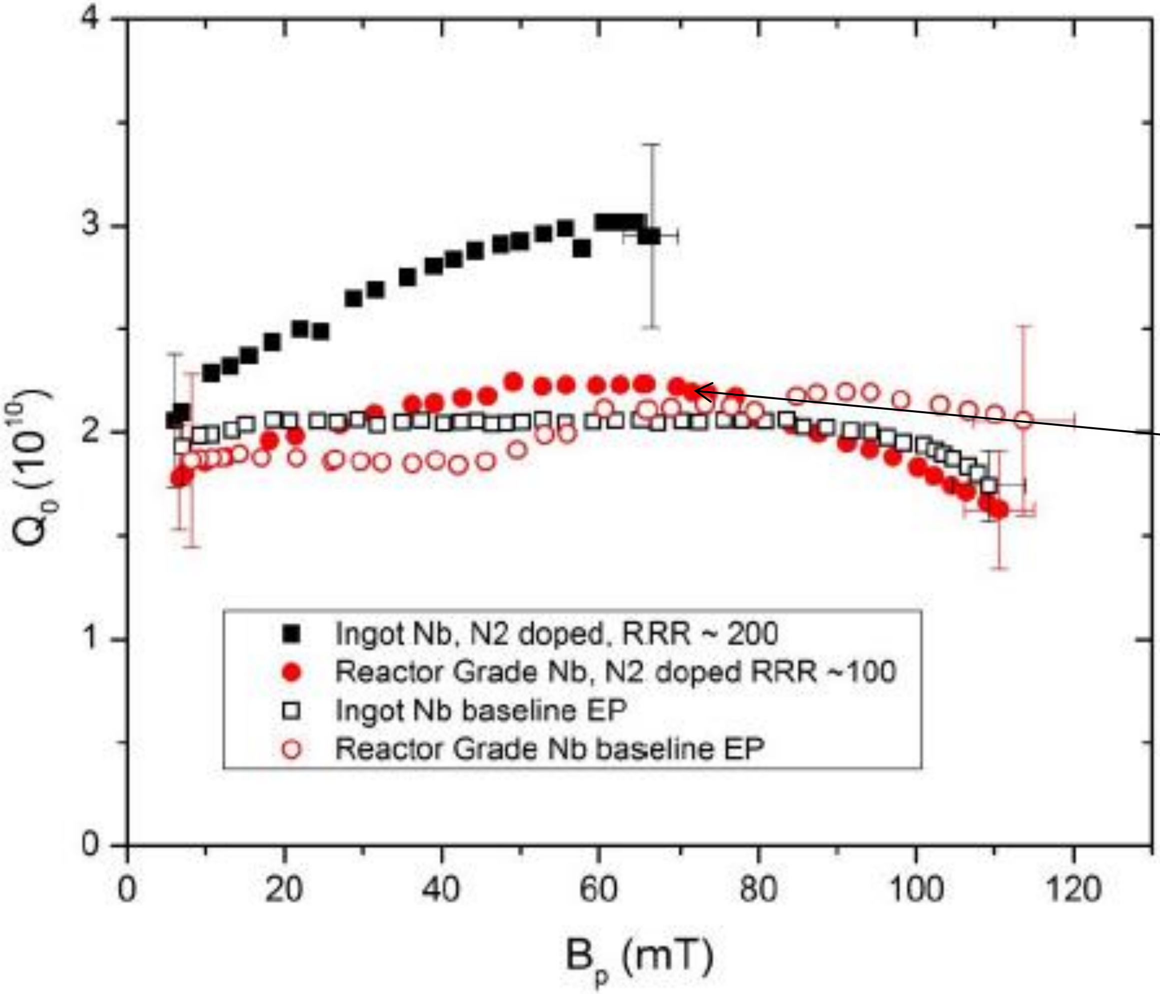
Sample analysis High resolution – from previous slide

The near surface N concentration of Nb sample with 20 minutes exposure of N_2 (20N) was measured by SIMS with incremental EP. After 20 µm removal by EP, the concentration of N keeps constant , but decreases by 60% after 40 µm.



H. Tian et al. – this conference MOPB107 today

Effectiveness of doping vs niobium RRR



No significant signature of doping @ 2.0K on low RRR FG cavities

These are 1.5Ghz @ 2.0K

Pashupati Dhakal et. al ASC'14 1LOr1B-05

Questions?

Contributing Data
C. E. Reece
Pashupati Dhakal
Grigory Eremeev
Hui Tian
R.-L. Geng

Making nitrogen doping work is not that easy but can be done – off to the cryomodules.

Funding
Special thanks to LCLS-II, especially for taking chance on Nitrogen doping
-Initial single cell studies and all 9 cell work

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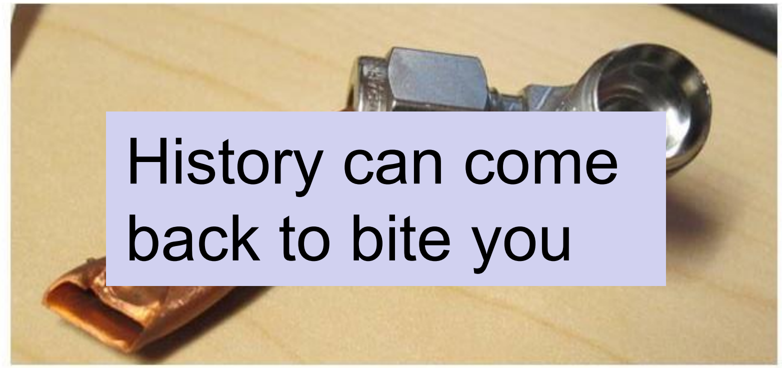

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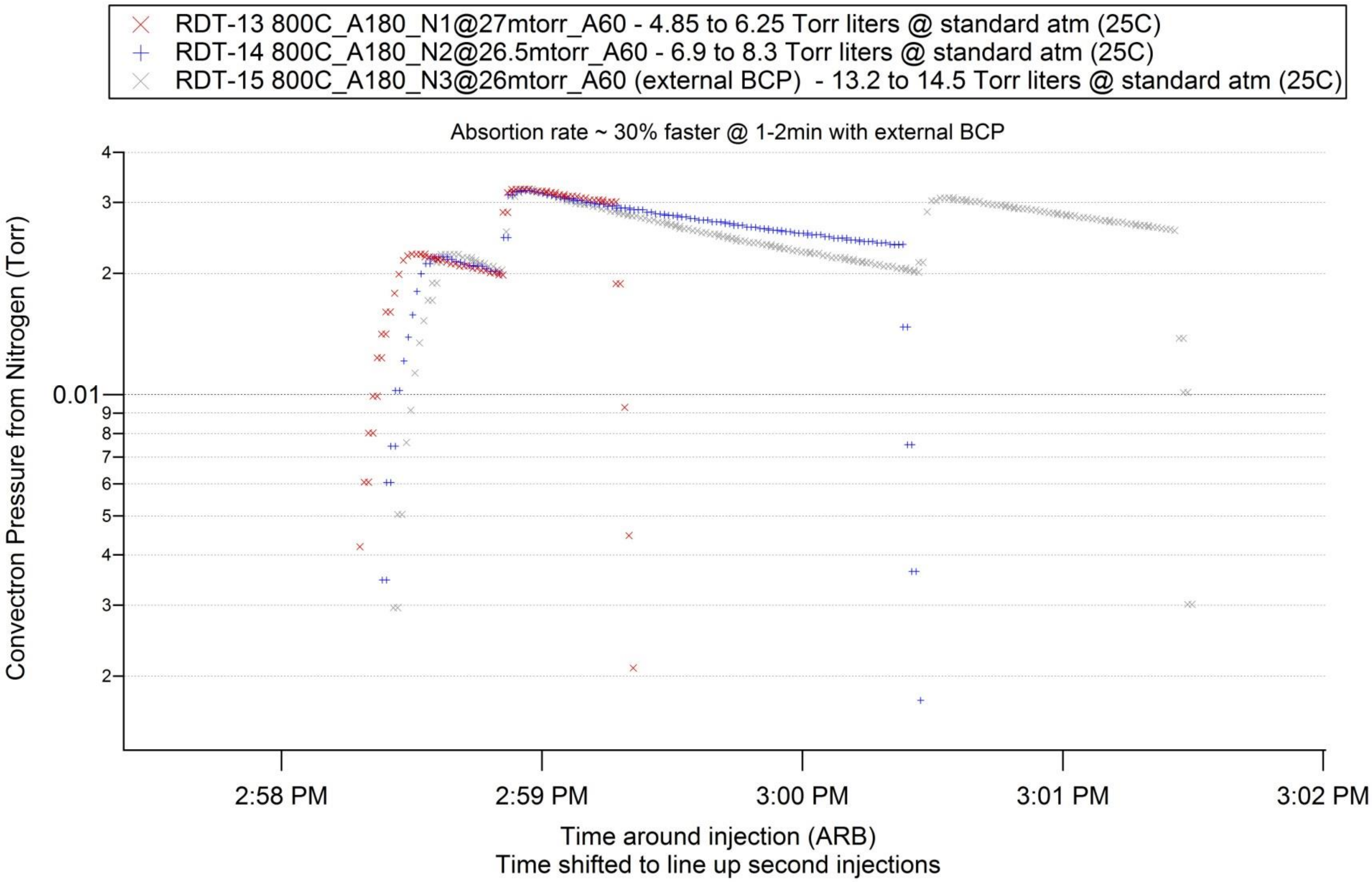
Backup

Furnace doping - redoping

Short injection - Long anneal single cell absorption compare



Re-doping with external chemistry changes total absorption rate