Advances in Nb_3Sn Coating at Fermilab Including Recent World Record Performance Cavity Results

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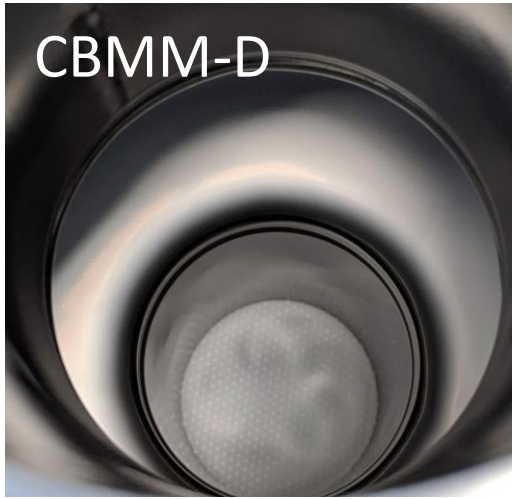
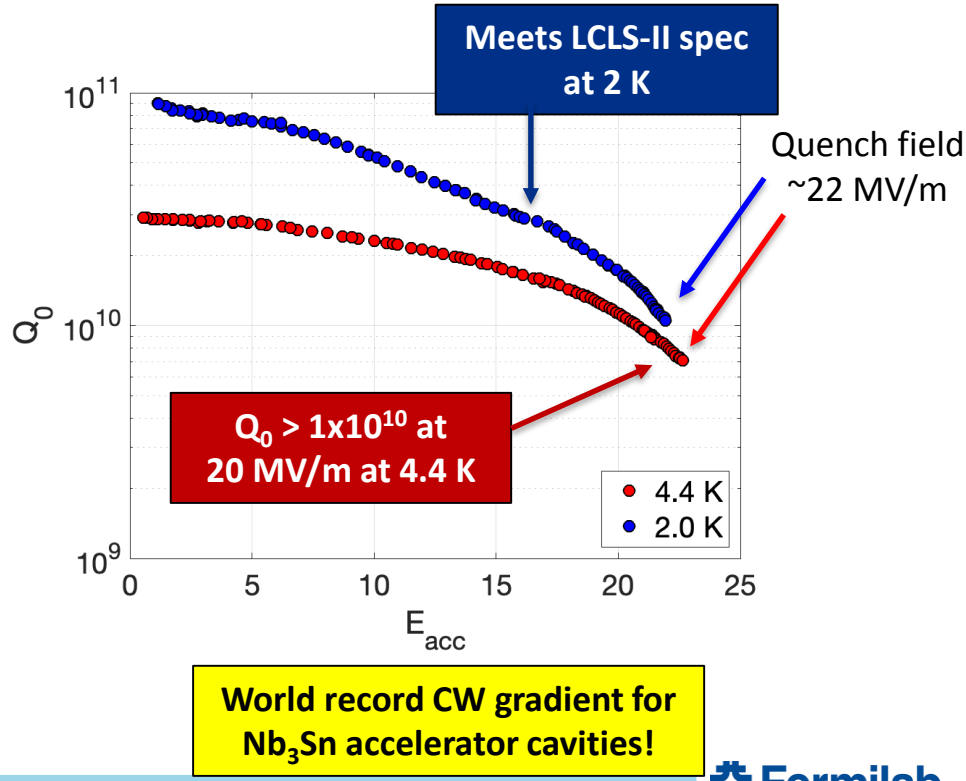
CBMM-D Results Presented at SRF'19

- Single cell 1.3 GHz cavity with shiny surface





World record CW gradient for Nb_3Sn accelerator cavities!

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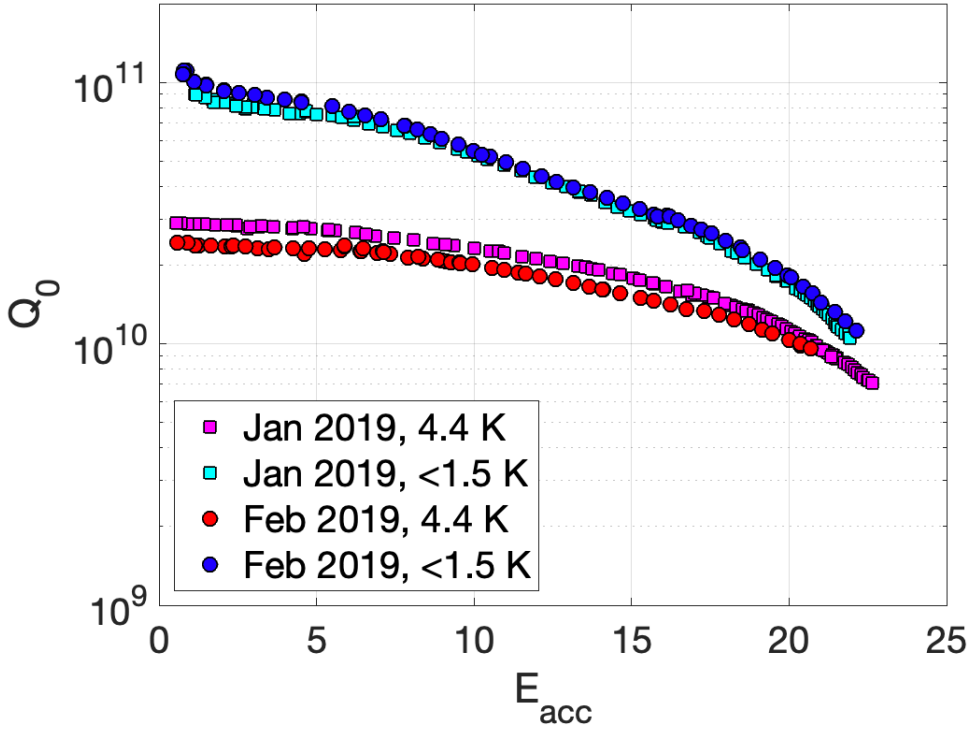
Variation in Quench Field Observed, in Expected MP Band



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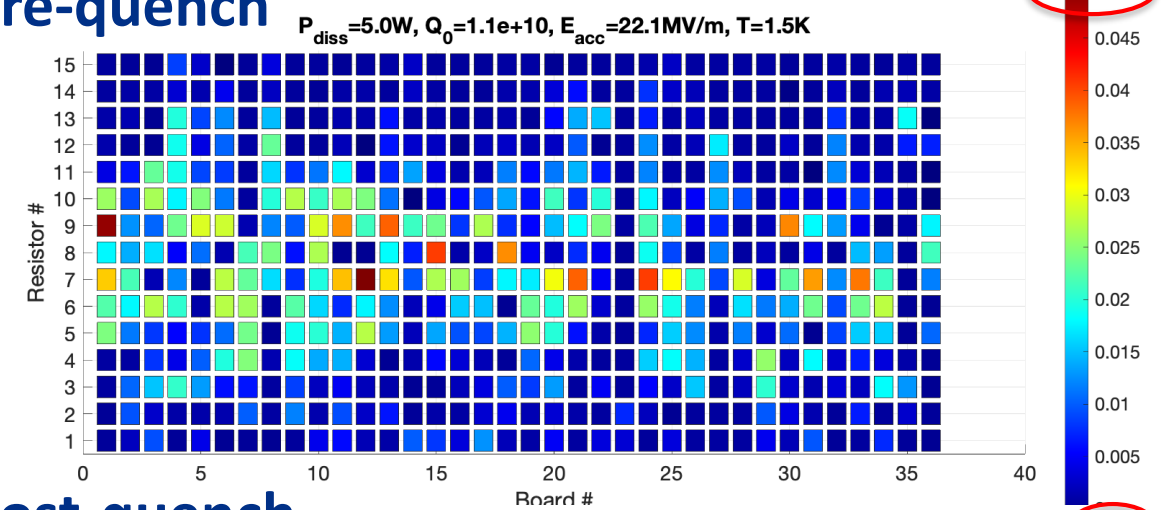
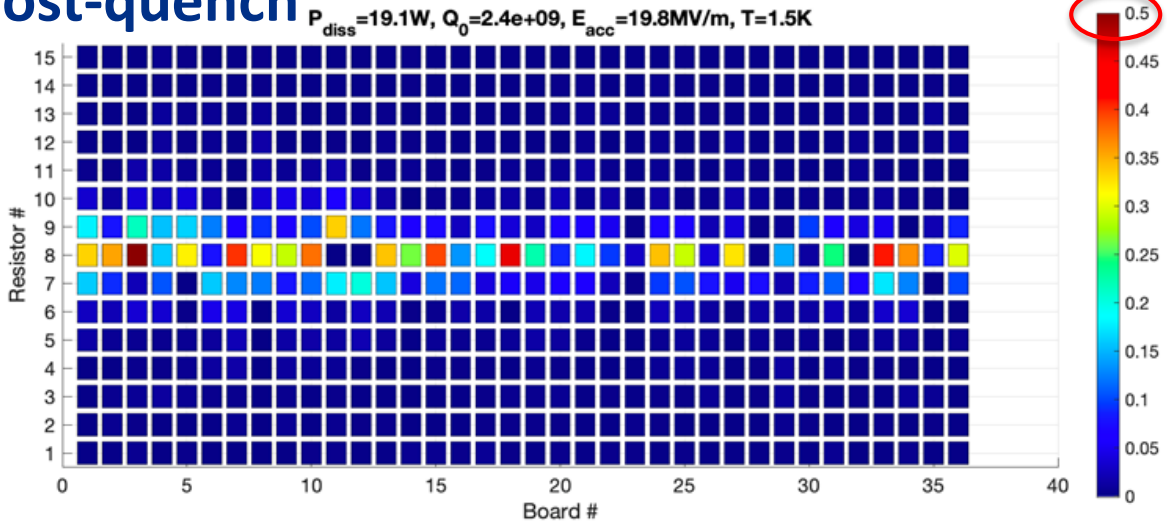
T-Maps

- These are T-maps recorded before and after quench with the cavity in steady state at ~20 MV/m
- Strong heating on the scale of tenths of K is typical after quench for Nb_3Sn due to thermocurrent trapped flux
- However typical distribution is a single spot
- This is widely distributed over the whole equator!
- What effects are highly localized at the equator?

Pre-quench

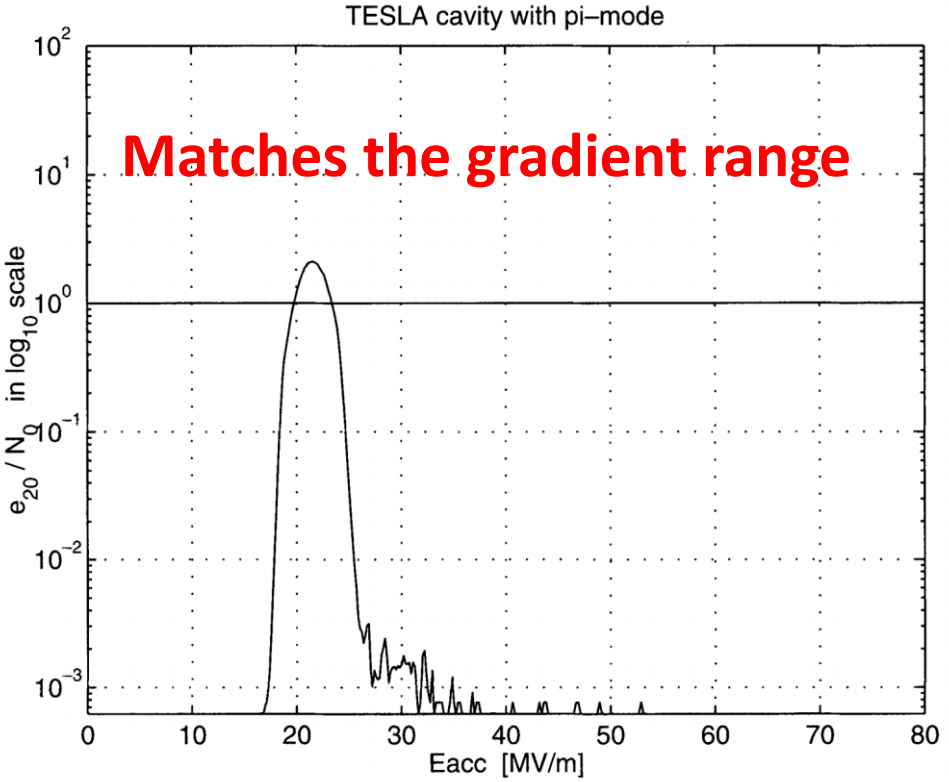


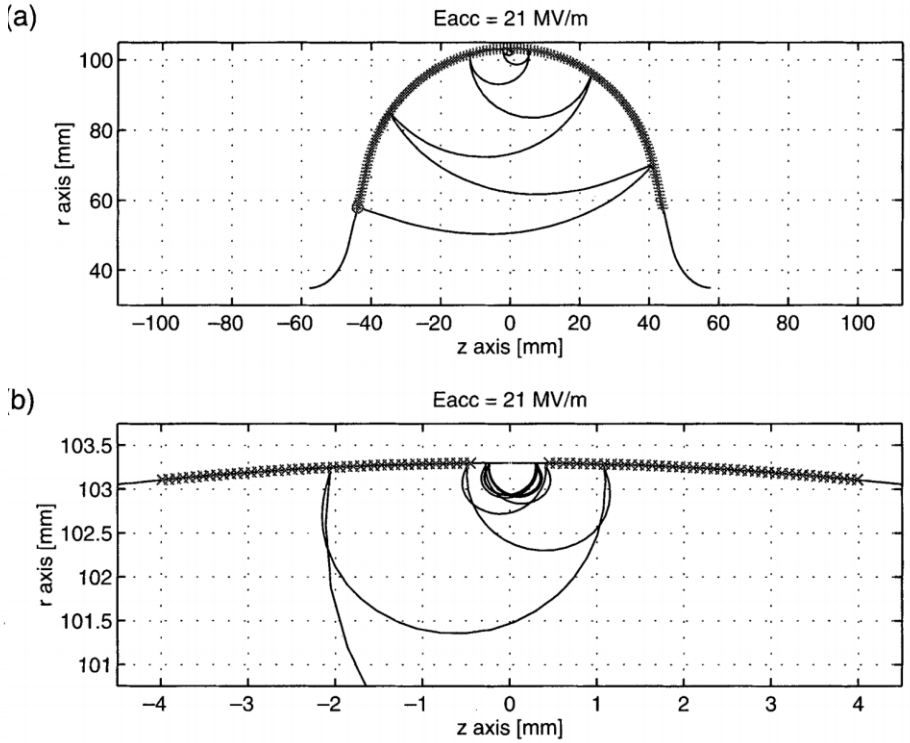
Post-quench



Multipacting in Tesla Shape Cavities

Matches the cavity region



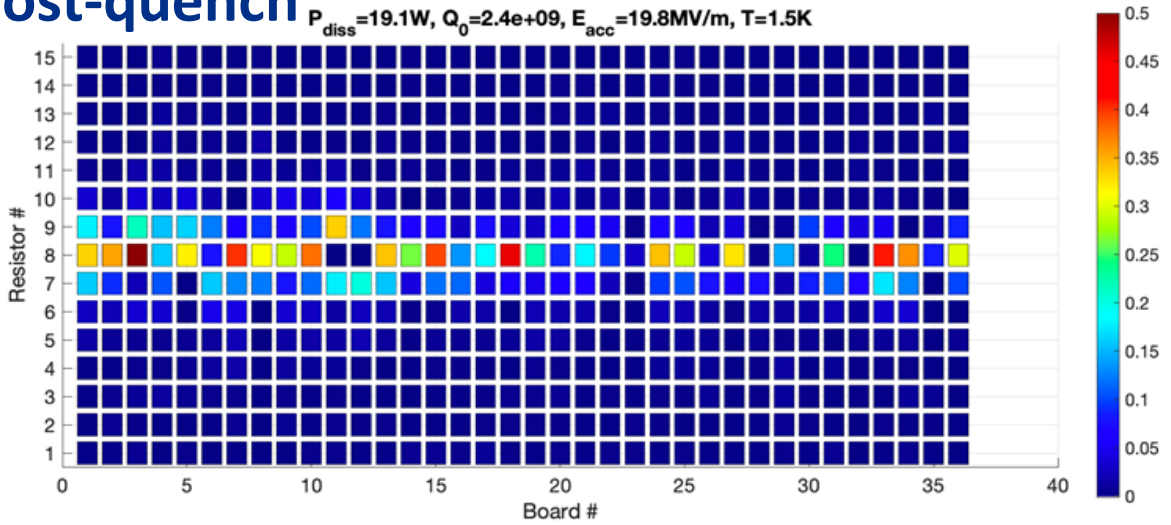


Pasi Yla-Oijala, "Electron multipacting in TeSLA cavities and input couplers," *Particle Accelerators*, Vol. 63, pp. 105-137 (1999)

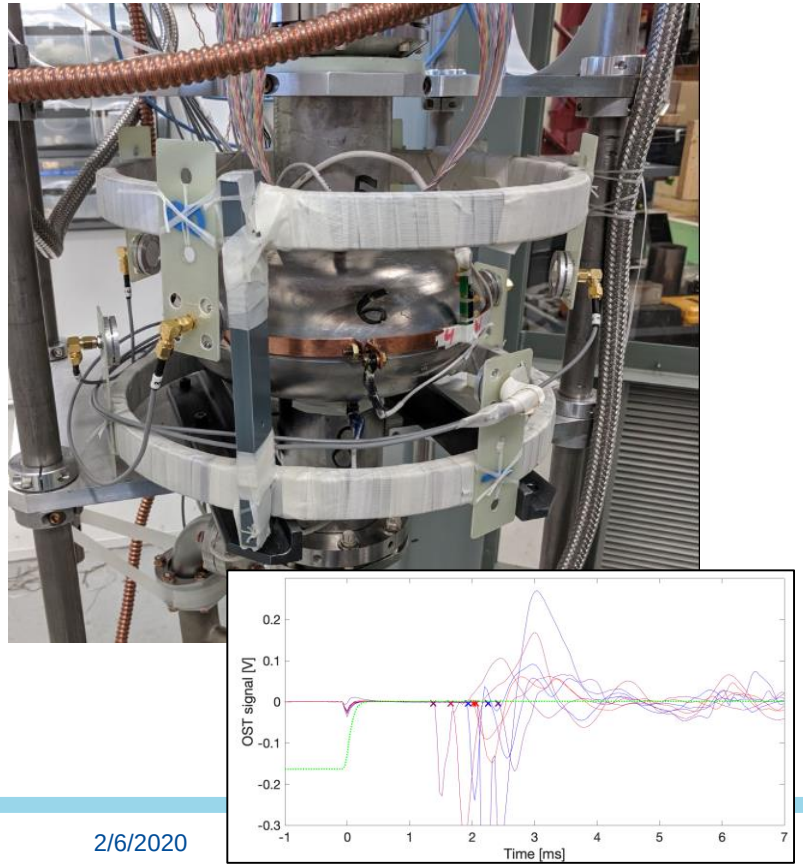
Question: How Could the Entire Equator Have Trapped Flux?

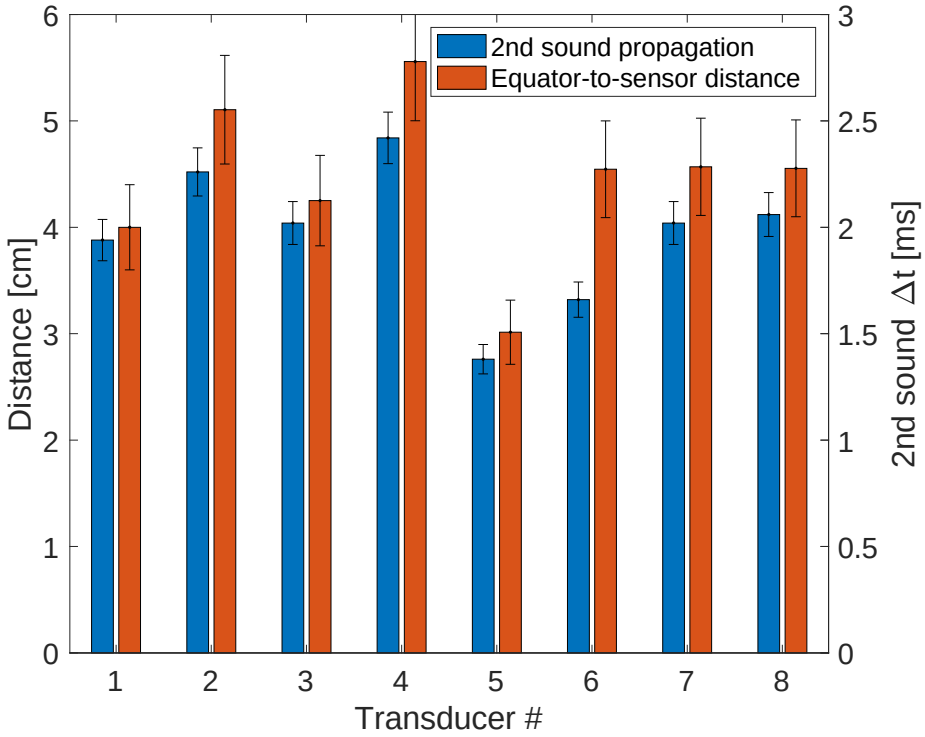
- For multipacting to be the cause of this distribution, the entire equator would have to become normal conducting during the quench to allow flux to be trapped
- Can we see this?
- 2nd sound investigation

Post-quench



Second Sound Investigation





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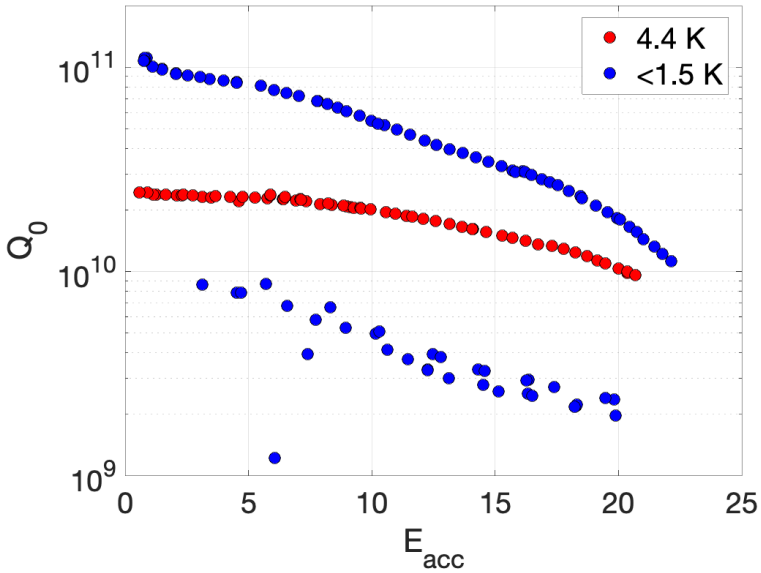
Question: If This is Multipacting, Can We Process it?

- If this were multipacting, we would expect to be able to process it
- However, we could only quench 2-3 times during a test due to Q0 degradation after quench resulting in poor coupling – we'd run out of power
- Solution? Reassemble with stronger coupling
- Original Q_{ext}: ~4e10
- New Q_{ext}: ~1e9



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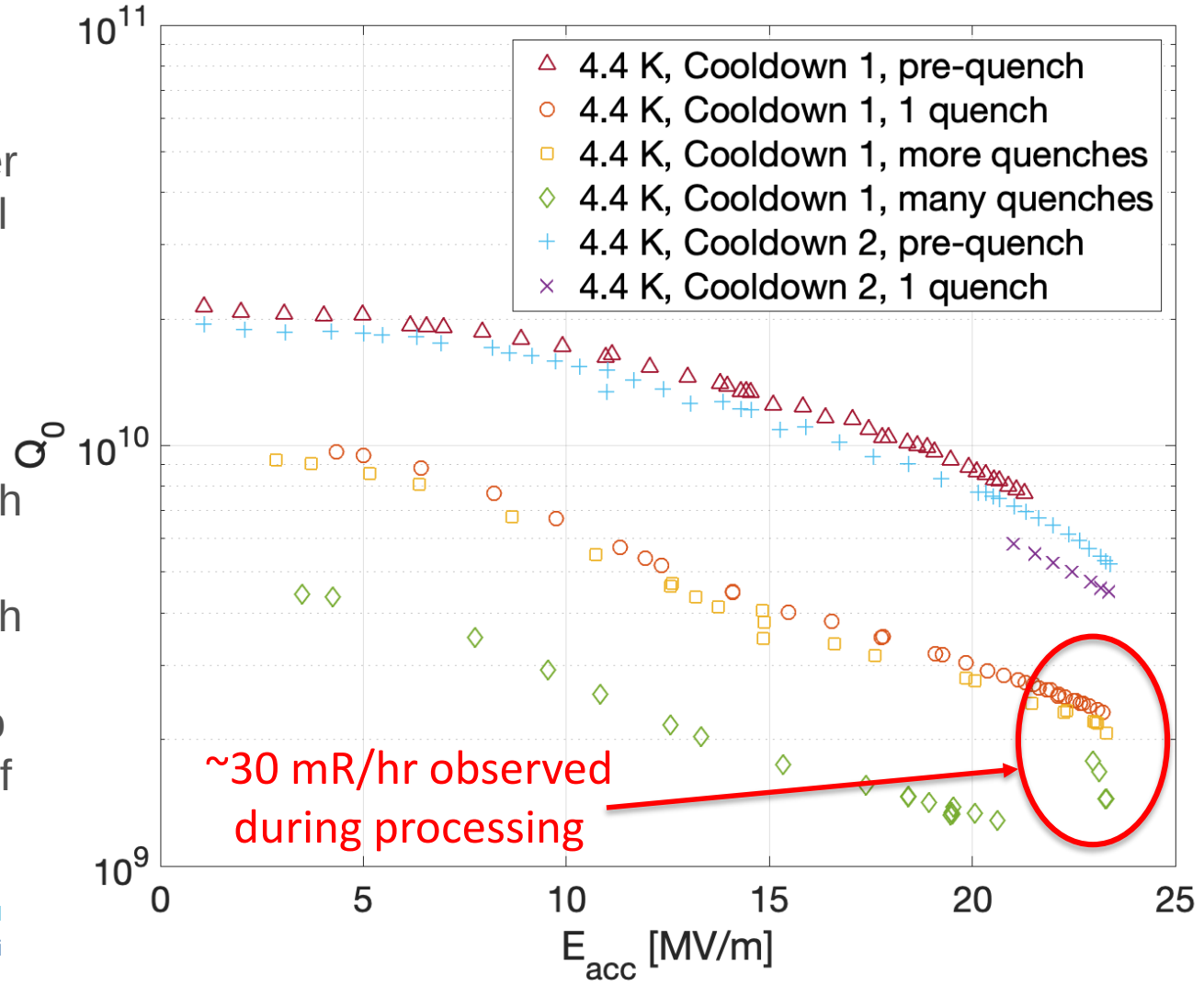
Processing

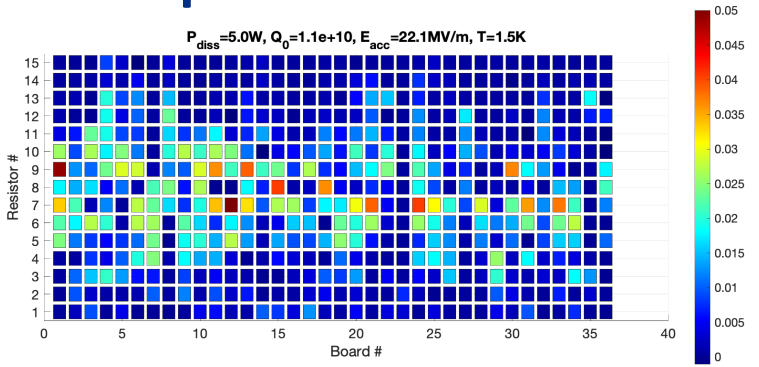
- Processing with stronger coupling was successful
- Maximum gradient increased to 24 MV/m!!
- Thermal cycling was required to reverse Q0 degradation post-quench
- Interestingly Q0 degradation post-quench was much smaller after processing compared to before – different type of quench?



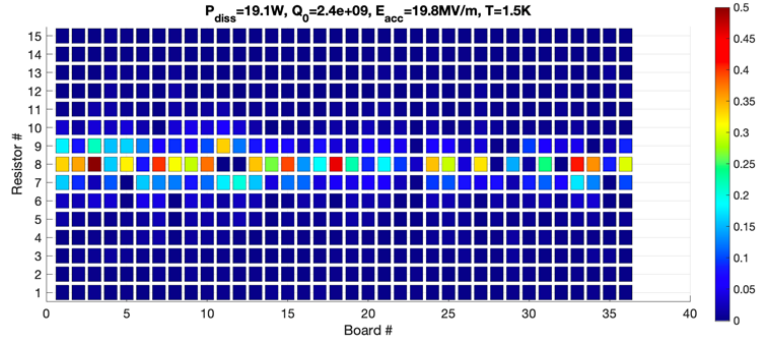
Question: Why no pre-heating?

- If the cavity was multipacting strongly enough to quench the cavity, why didn't it show up on the Tmap until after the cavity had quenched?
- I propose that this is a new case of what I'm calling "sudden-onset multipacting quench"
- This is observed in LCLS-II cavities: stay at fixed CW gradient in MP band, then suddenly quench with pulse of x-rays; processing helps
- Proposal: SEY is sufficiently high for MP, but not triggered for several seconds/minutes, but once it occurs it is strong enough to cause quench; RF period is short enough relative to tau that MP electrons can spread all over equator azimuthally

Pre-quench



Post-quench



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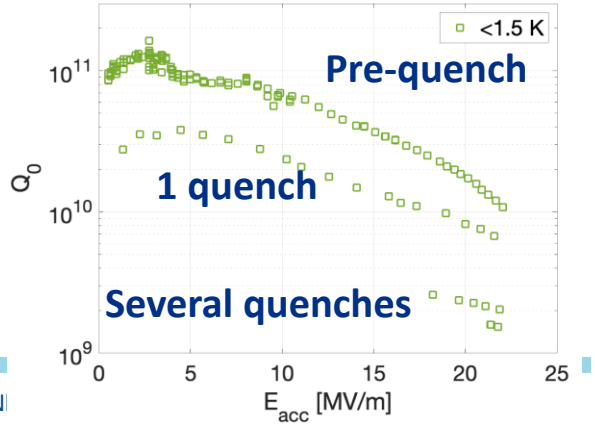
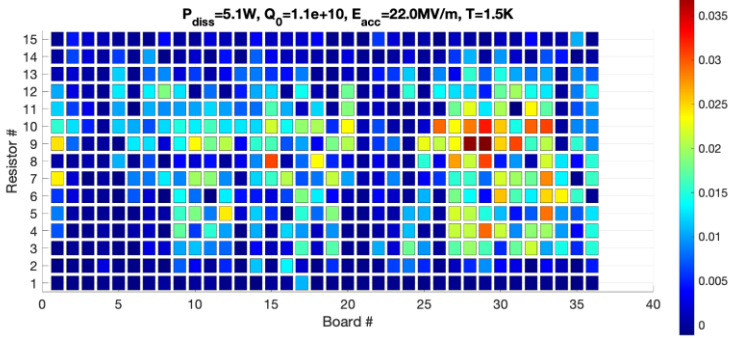
T-Maps In Additional Test

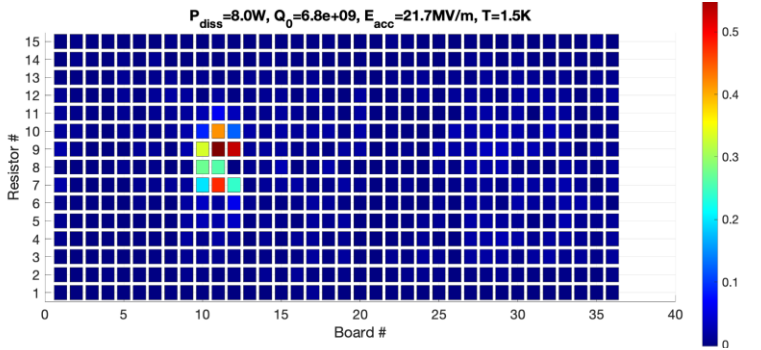
- Cavity was tested an additional time, this time with Tmap installed (still with Q_{ext} ~ 1e9)
- Similar pre-quench heating
- After first quench, Tmap shows typical localized quench pattern
- After several quenches, there is a sudden large Q-drop – T-maps now show equatorial heating
- Additional investigation shows that cavity will quench after staying at same gradient ~20 MV/m for several minutes



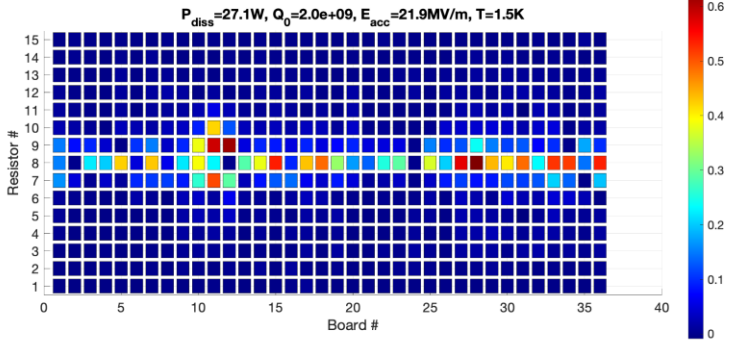
Pre-quench



1 quench



After Q drop

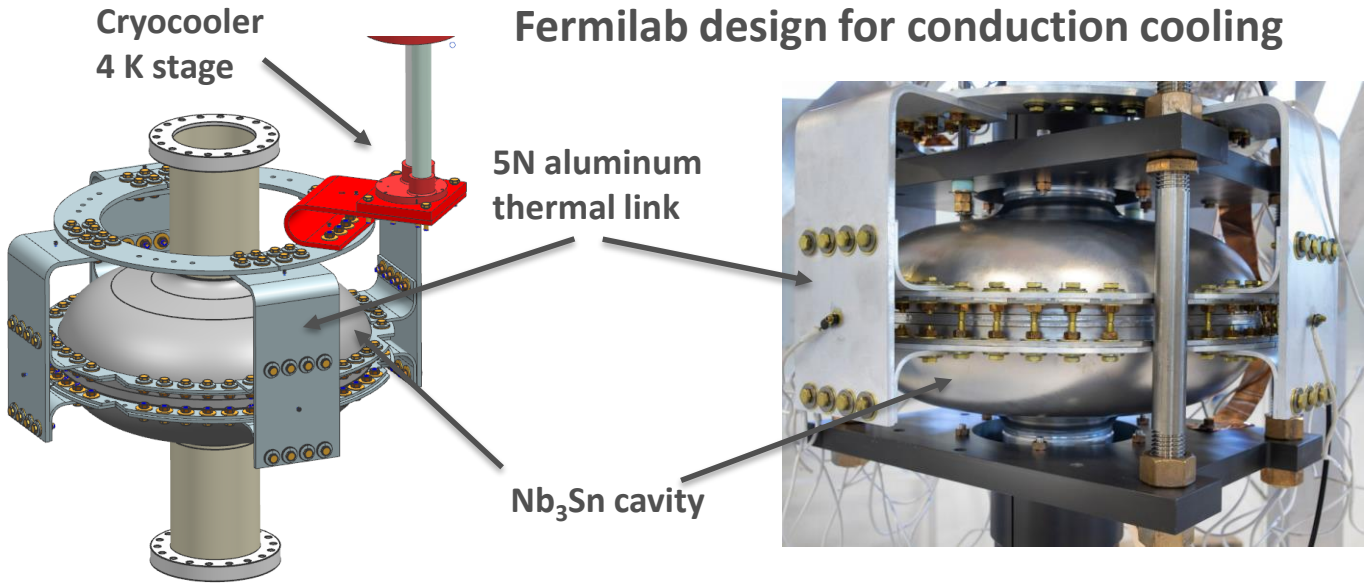


Summary

- Nb_3Sn cavity was originally limited at 22.5 MV/m
- After processing, it now reaches 24 MV/m – new record cw accelerating gradient for Nb_3Sn
- Several observations suggest multipacting as cause for previous limit:
  - Localized heating along equator in Tmap
  - Signal distributed over equator measured with 2nd sound
  - Processing improved max gradient
  - X-rays measured during processing
- Proposed “sudden-onset multipacting quench” to explain lack of preheating and quench occurrence after waiting at fixed gradient

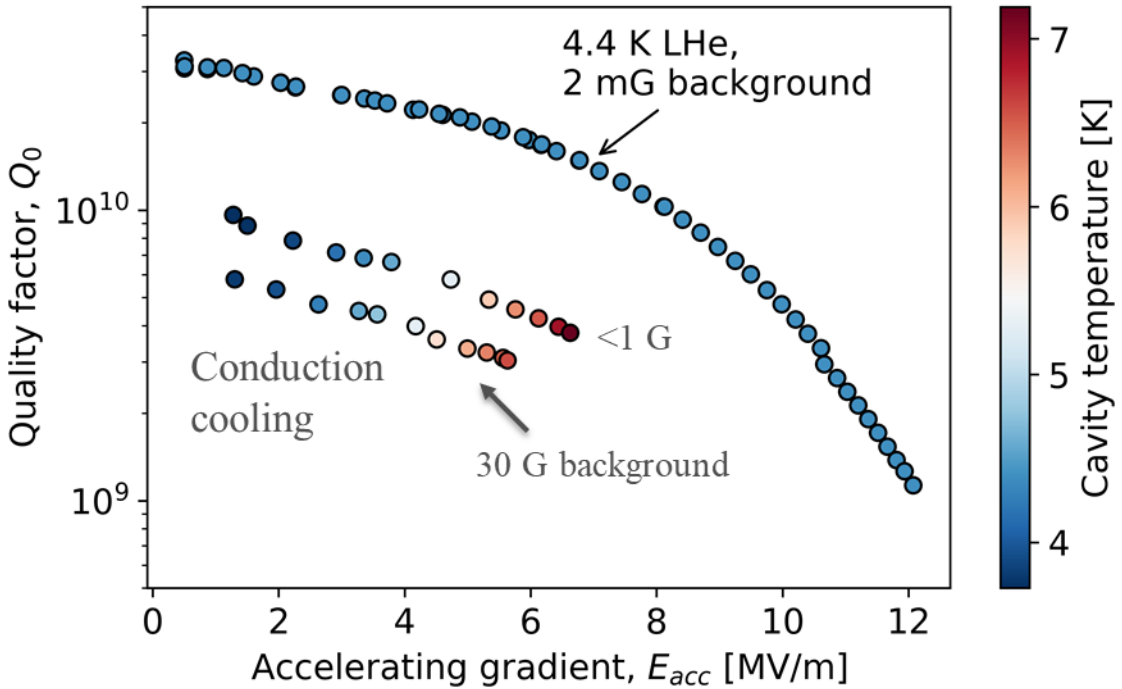
Cryocooler conduction cooling for SRF cavities

- A technique to simply SRF cryogenics that can lead to compact e-beam SRF accelerators for industrial applications
- Fermilab has recently developed a design for cryocooler conduction cooling and demonstrated 6.6 MV/m cw on a single cell 650 MHz Nb_3Sn cavity



First results for a conduction cooled Nb_3Sn 650 MHz cavity

R.C. Dhuley, S. Posen, *et al.*, (under review) https://arxiv.org/abs/2001.07821



More details:
Talk by Dhuley in WG 4,
5 PM Wednesday