Statistical Modeling of Peak Accelerating Gradients in LCLS-II and LCLS-II-HE

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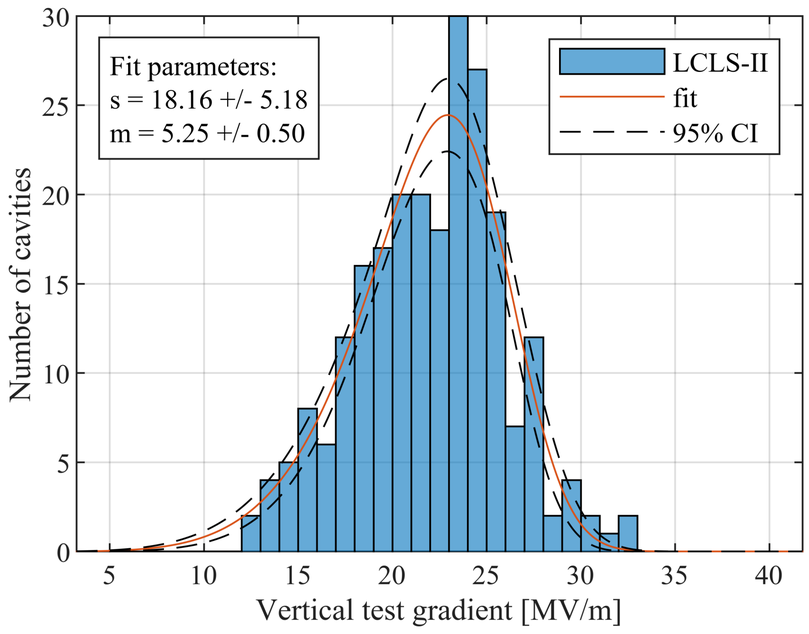
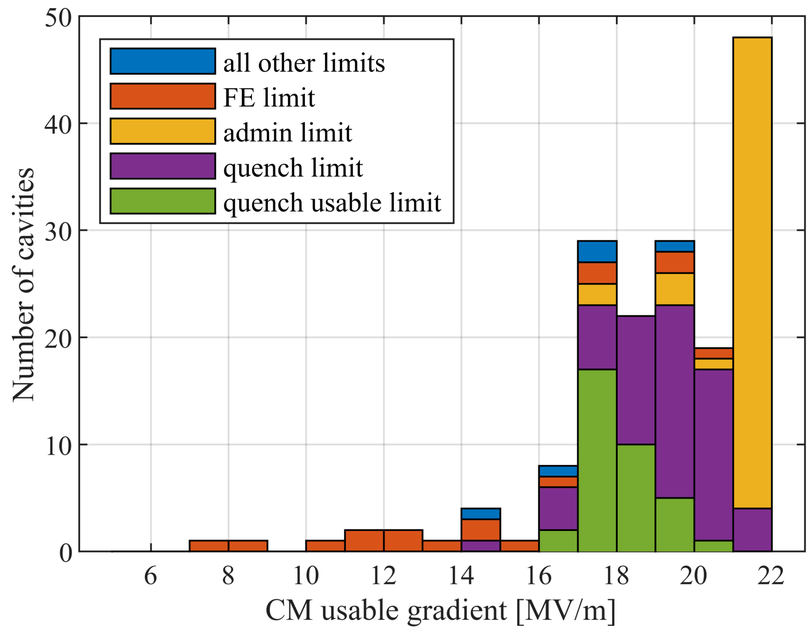
Modeling LCLS-II Cavity Gradient Performance

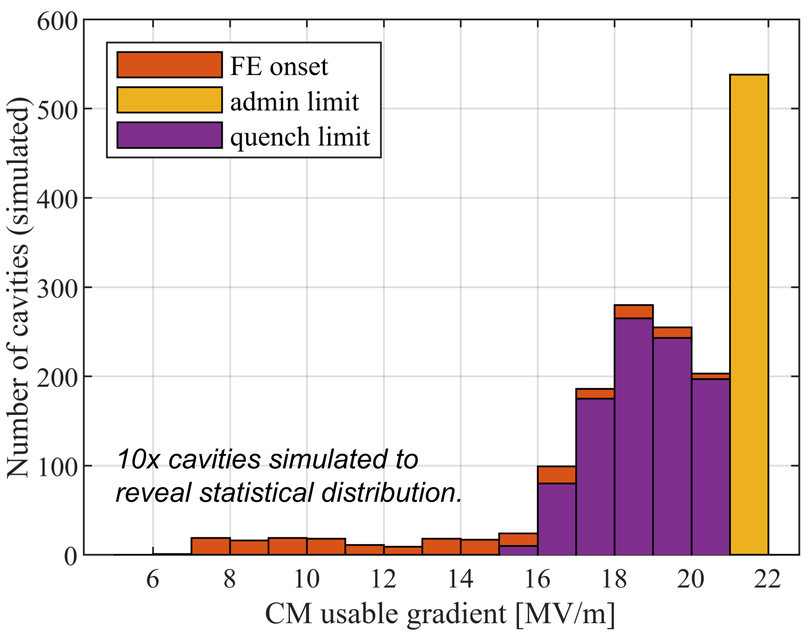


Peak vertical test accelerating gradients of LCLS-II cavities are well fitted by a two-parameter **thermal defect model**.

m describes defect size distribution
s describes overall defect prevalence

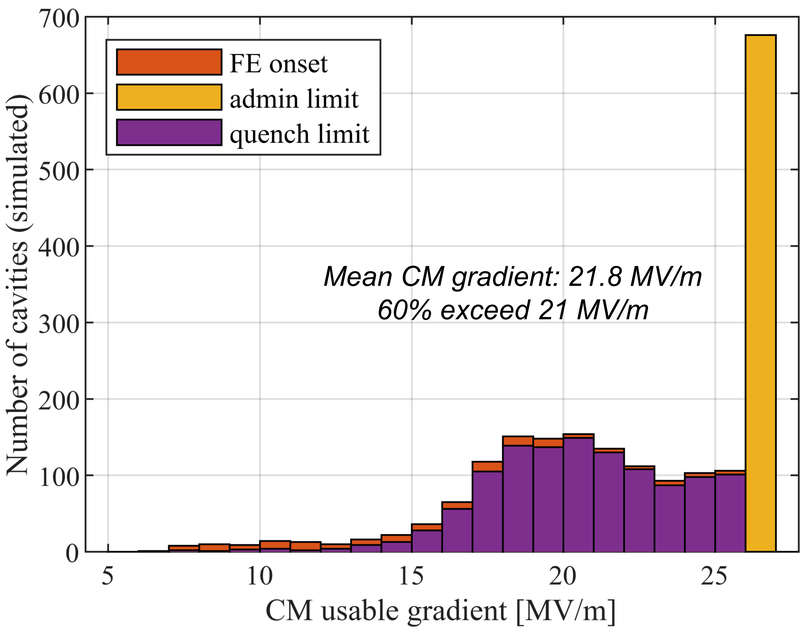


LCLS-II gradients in cryomodule test were often limited in the 17-21 MV/m range, corresponding to the multipacting band for TESLA cavities. The performance of these cavities was consistent with **multipacting**. A smaller number of cavities were limited by **field emission**.



Numerical simulation of cavities using the thermal defect model and simulations of gradient degradation by multipacting (50% of cavities) and field emission (10% of cavities) yields results **consistent with LCLS-II performance**.

Modeling LCLS-II-HE

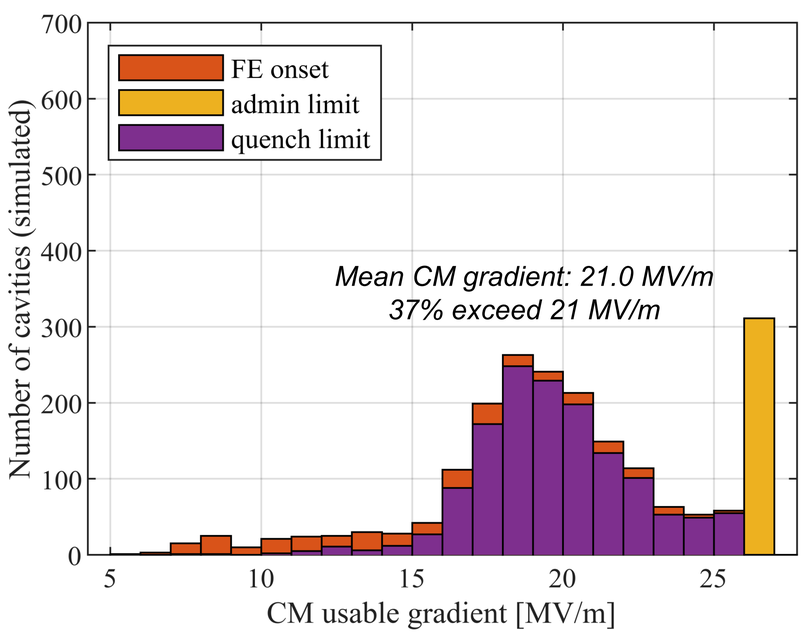


Simulation of LCLS-II-HE cryomodule gradients with improved vertical test gradients and rates of multipacting and field emission decreased by 50%

Results from R&D program and vCM test indicate that LCLS-II-HE cavities will have **improved ultimate gradient limits** as well as **reduced rates of limitation** by multipacting and field emission.

If the improvements to multipacting and field emission mitigation are not as dramatic as indicated by the vCM, our simulation results indicate that gradient degradation may adversely impact the ability of HE to reach the target gradient of **21 MV/m**.

The administrative limit on gradient has been increased to 26 MV/m, allowing the high-performing cavities to compensate for any low-gradient cavities.



Simulation of LCLS-II-HE cryomodule gradients with improved vertical test gradients but the same multipacting and field emission rates as in LCLS-II

Variable Acceptance Threshold for Accelerating Gradient

LCLS-II-HE has chosen an acceptance threshold for peak gradient in vertical test of **23 MV/m**, a value that accounts for measurement uncertainty and that has been confirmed effective by the vCM test.

If cavity performance deviates from the expected behavior, the cavity technical board (CTB) may choose to implement a **variable acceptance threshold**.

Example 1: cavities routinely exceed performance spec in cryomodule; CTB allows lower-performing cavities to minimize unnecessary rework costs while still meeting average gradient target

Example 2: field emission more prevalent than expected; CTB increases acceptance threshold to compensate for low-performing cavities already in cryomodules

The CTB will over the course of production:

- Closely monitor vertical test performance and cryomodule gradient degradation
- Evaluate the simulation to forecast cavity performance based on known results
- Optionally adjust the gradient acceptance threshold to minimize cost and risk

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