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Thermal and magnetic flux dynamics in superconducting niobium cavities: implications for the threshold field limit

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While the fabrication technology superconducting Niobium cavities is advanced, a wide gap exist between the theoretical threshold field H_{sh} and the observed values. The reasons behind this discrepancy continue to pose intriguing questions, highlighting the need for further investigation. While material properties undoubtedly influence performance, we believe that the intricate dynamics of thermal and magnetic flux diffusion play a crucial role in limiting H_{sh}.

A notable peculiarity arises from the boundary conditions imposed on the niobium sheet used to fabricate accelerator cavities. The magnetic field is applied at the inner surface, while the outer surface is maintained at a constant temperature. Near the inner surface, the magnetic field can be formally expressed as: $B_a exp(-x/\lambda_e)$, where λ_e, the effective complex penetration depth, is derived using the two-fluid model: $\lambda_e = \lambda_L(1 - in_n\omega\tau_n/n_s)^{-1/2}$, where, $n_n(n_s)$ is normal (superconducting) carrier density, ω and τ_n are field frequency and scattering time of normal carriers, respectively. To further explore this phenomenon, we will present our calculations by self-consistently solving the steady-state heat diffusion equation: $\nabla^2 T(\vec{r}) = -Q(\vec{r})/k$. $T(\vec{r})$ is fixed at the outer surface of the cavity, $Q(\vec{r})$ - the local heat generated by the RF fields, k - thermal conductivity of niobium in its superconducting state.

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Footnotes

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