Theoretical calculations of maximum fields in SRF cavities

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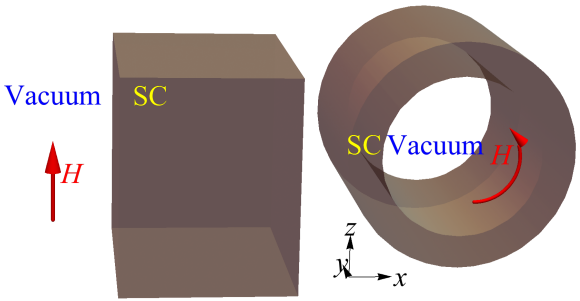
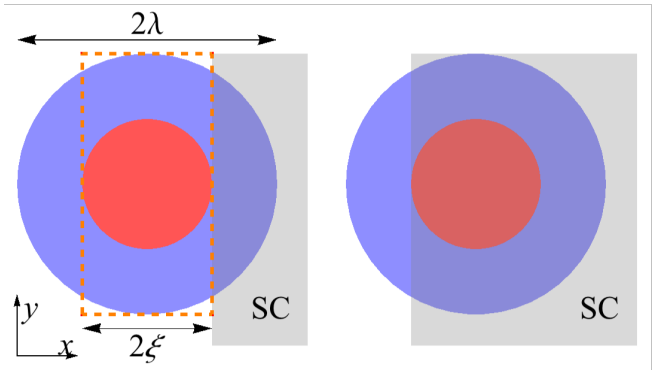
A National Science Foundation Science & Technology Center

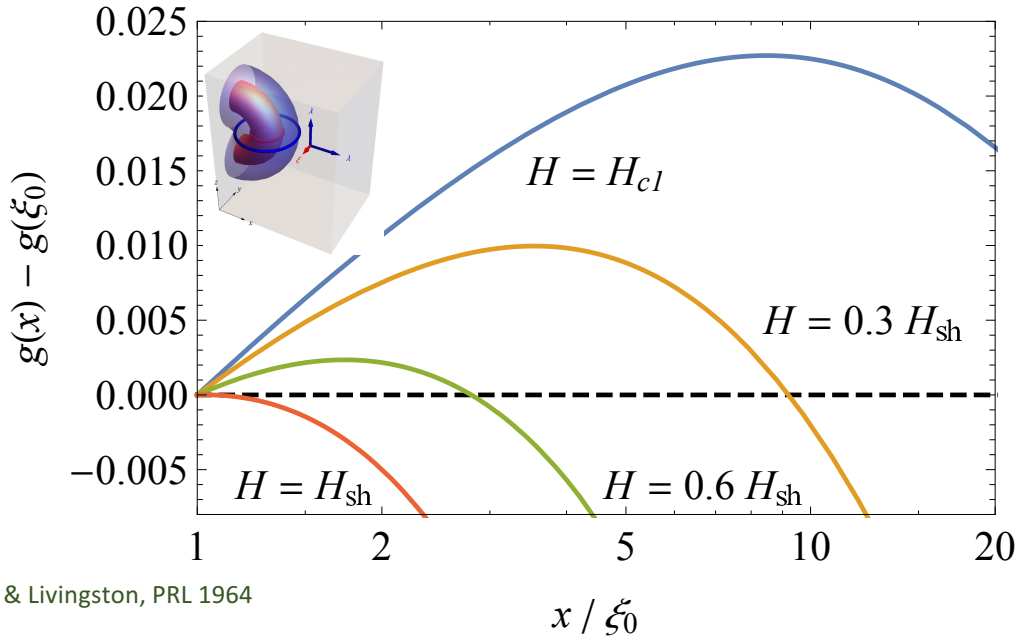
TTC Topical Workshop - RF Superconductivity: Pushing Cavity Performance Limits

Surface energy barrier & vortex entry fields





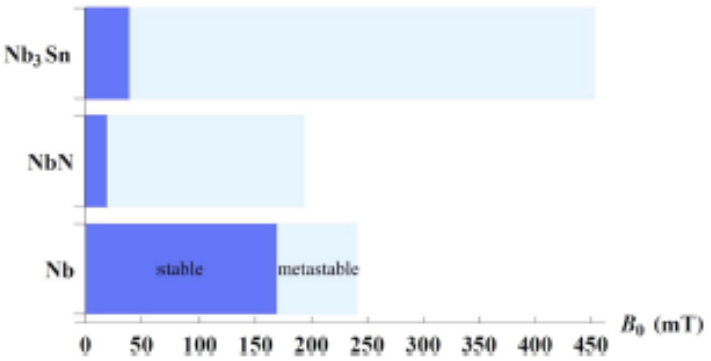
DBL, Posen, Transtrum, Catelani, Liepe, Sethna, SUST 2017



Bean & Livingston, PRL 1964

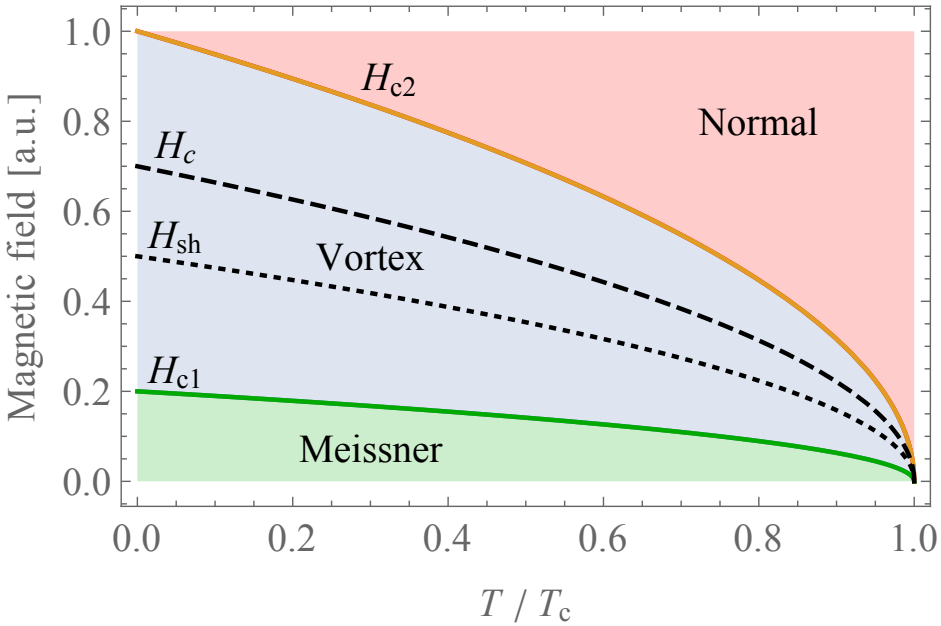
Stability analysis: the superheating field (H_{sh})

- In high-field applications, SRF cavities operate above H_{c1}, at the metastable Meissner state.
- The Meissner state becomes unstable for fields above H_{sh}.



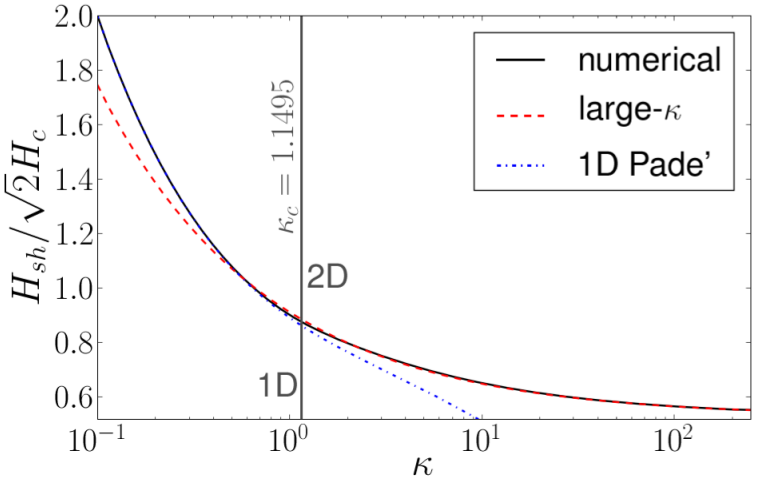
Kubo, SUST 2016

Sketch of a type II superconductor phase diagram



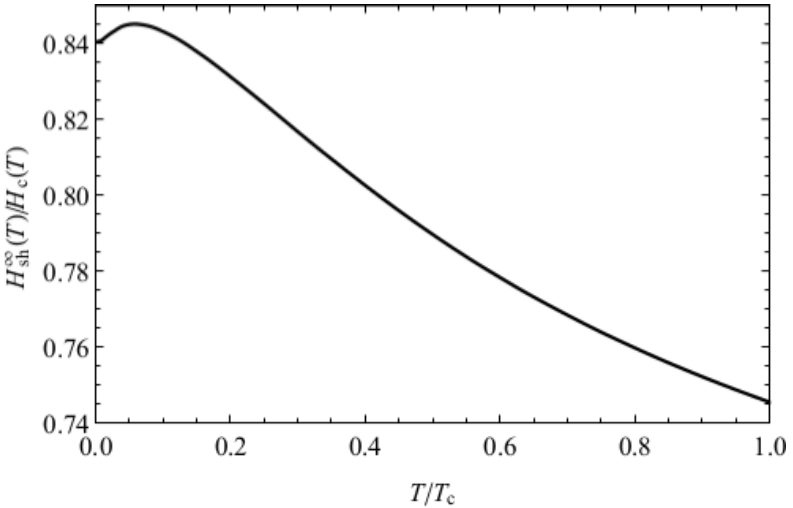
Stability analysis: the superheating field

- As a function of κ (near T_c)
- Ginzburg-Landau theory



Transtrum, Catelani, Sethna, PRB 2011
Kramer, PR 1968, etc…

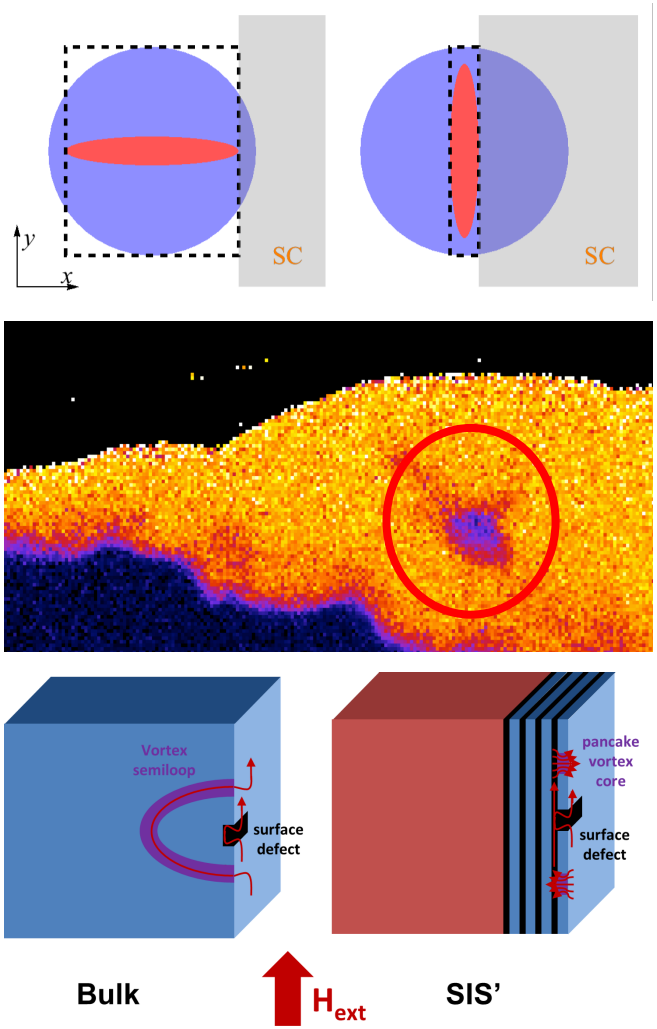
- As a function of T (at high κ):
- Eilenberger theory



Catelani & Sethna, PRB 2008

Summary

- Anisotropy
- Disorder
- Laminates
- Final considerations



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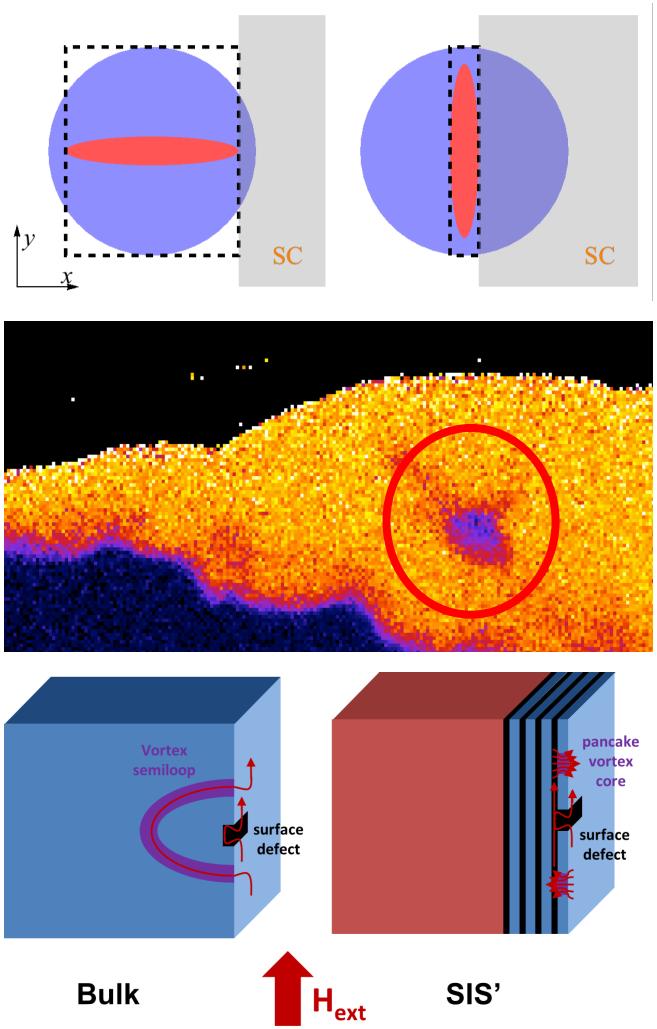
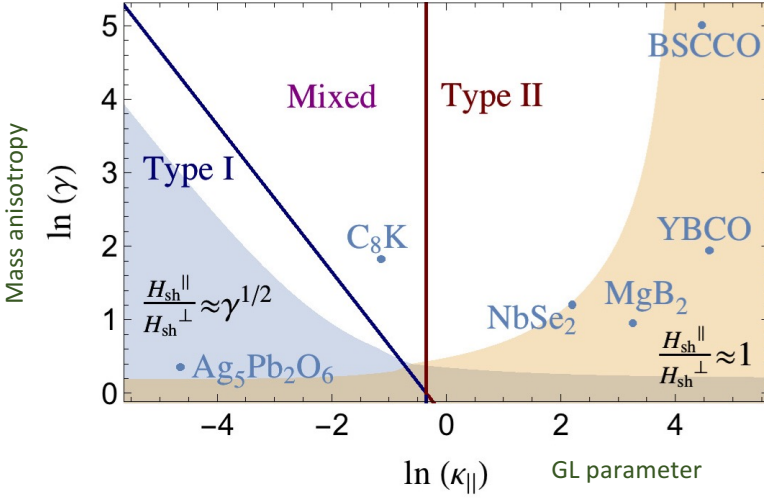
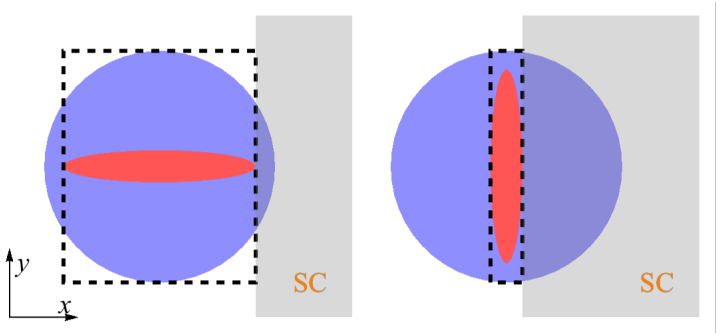


H_{sh} is isotropic (near T_c) for new materials

- Ginzburg-Landau theory: rescaling and change of coordinates map anisotropic systems into the isotropic one.
- H_{sh} is isotropic for high-κ materials (near T_c, including MgB_2).
- MgB_2 is complicated (Bud'ko & Canfield, Phys. C 2015): two gaps, two distinct anisotropies (see bottom right) conflicting estimates.





DBL, Transtrum, Sethna, PRB 2016

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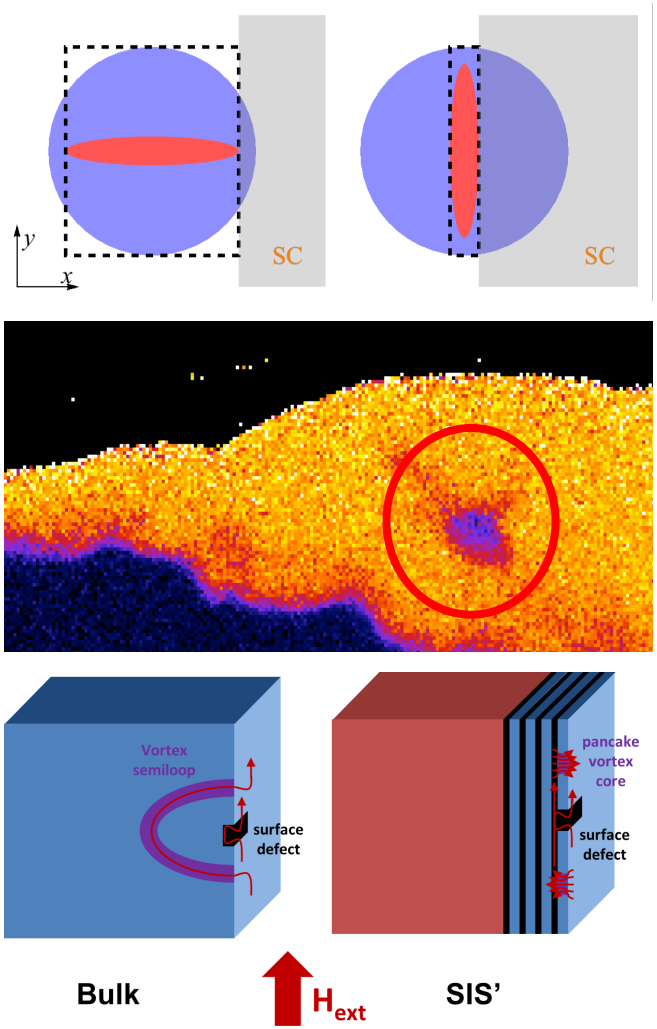
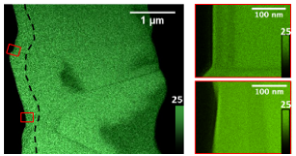
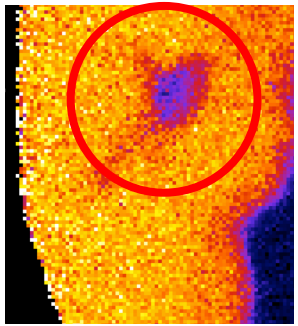


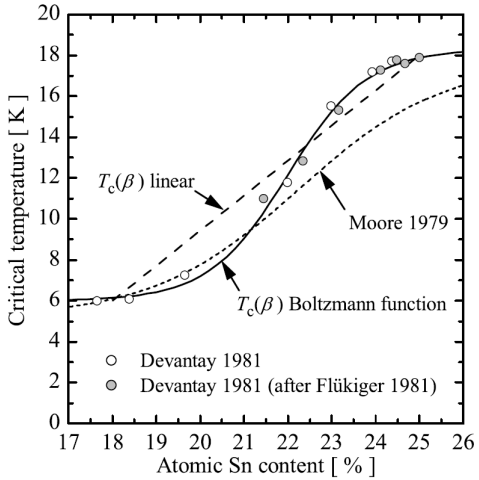
Sn depleted regions and Nb3Sn quenches



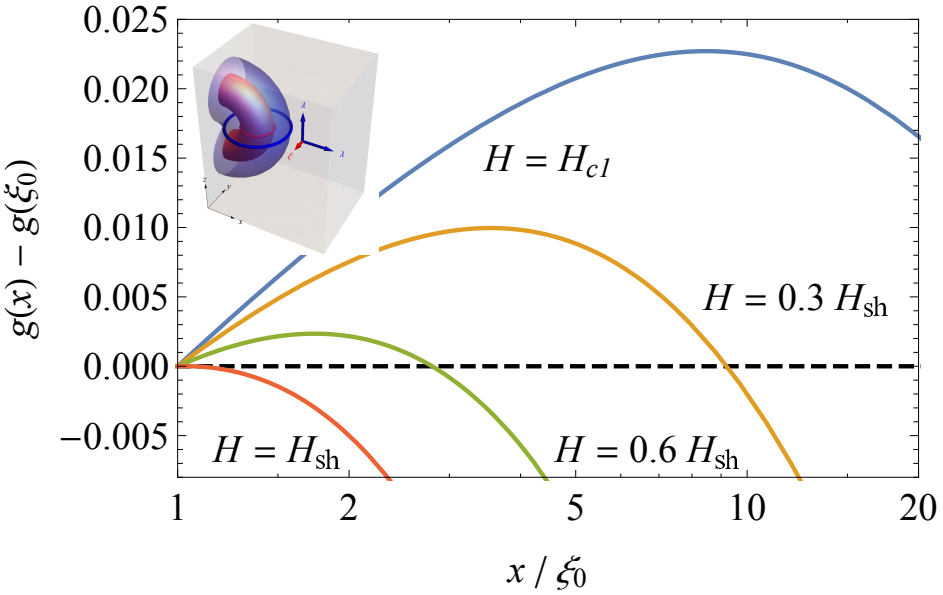
Thomas Proslier
(Argonne)



Muller Group
(CBB)



A. Godecke: SUST 2006



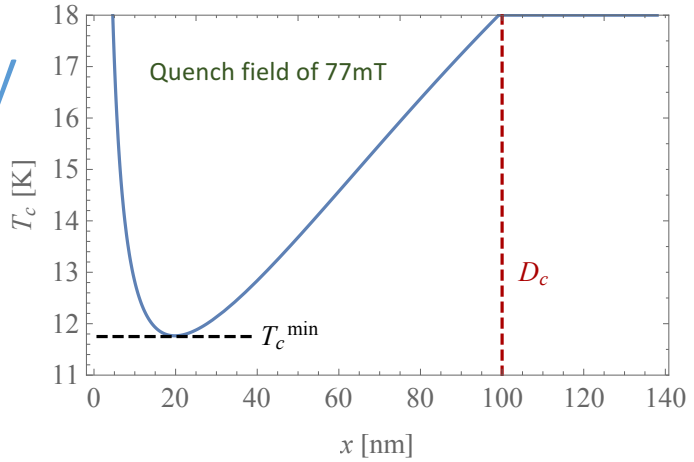
Can the tin depleted regions (or something else) facilitate vortex nucleation?

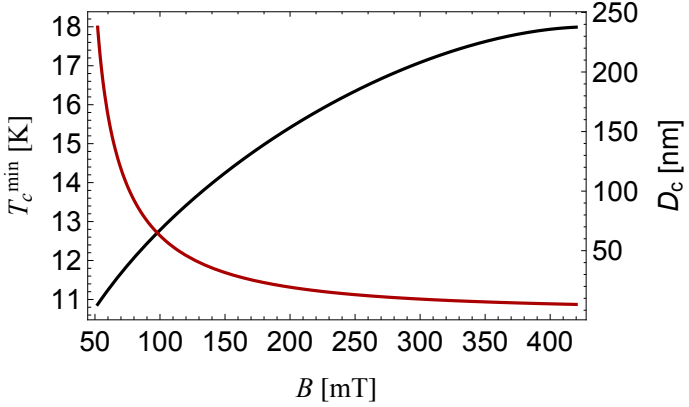
Critical temperature profile that allows vortex nucleation in Nb_3Sn

Cavity quenches and reliability

- We predict a relation between critical temperature drop, defect sizes, and quench fields that is ‘consistent’ with experiments.

- Gaussian disorder model: High-κ materials are (almost) as ‘reliable’ to vortex nucleation by disorder as low-κ materials.
- The proximity to H_{sh} is dangerous.





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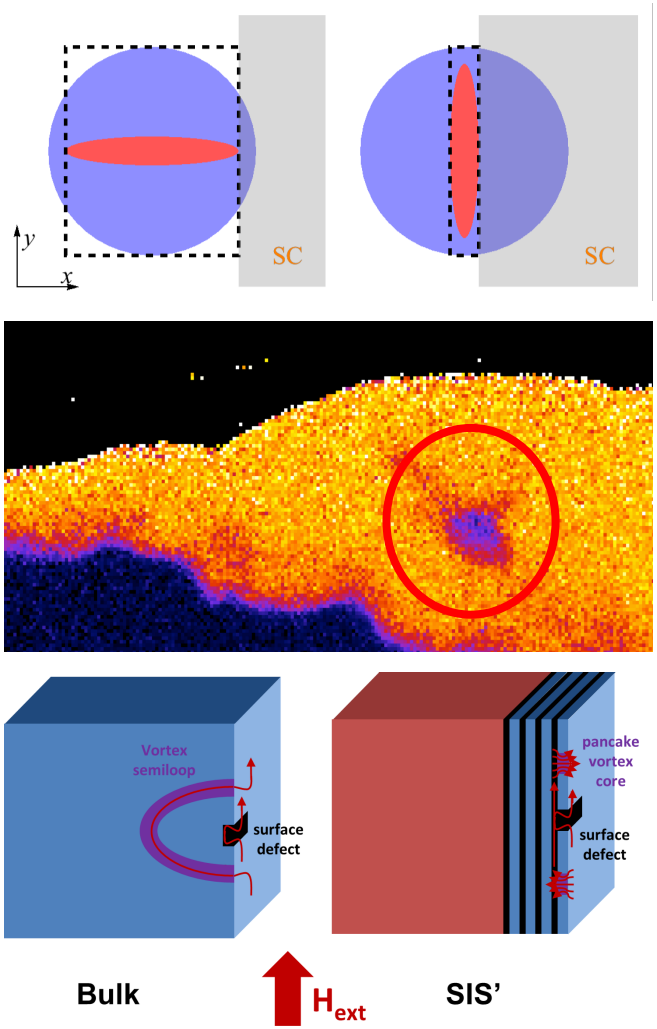
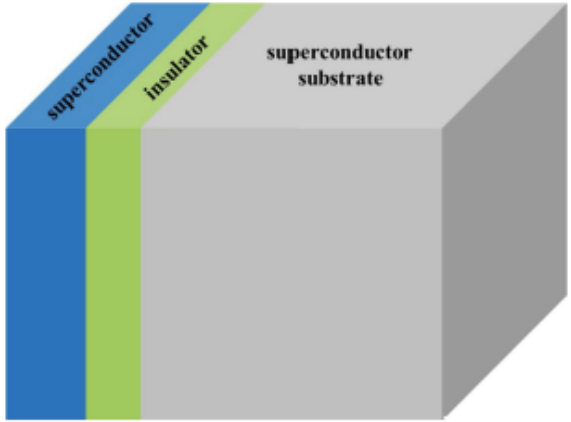
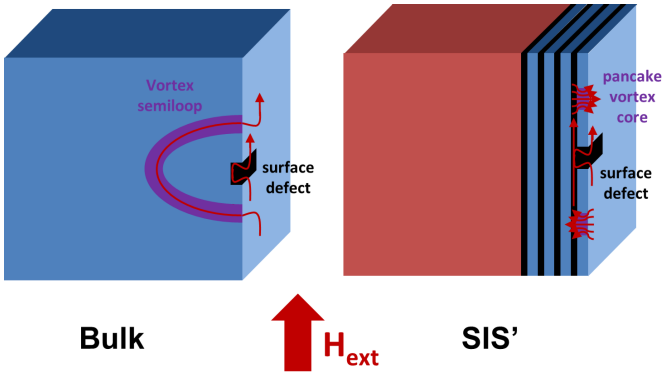


Laminates

Kubo, SUST 2016

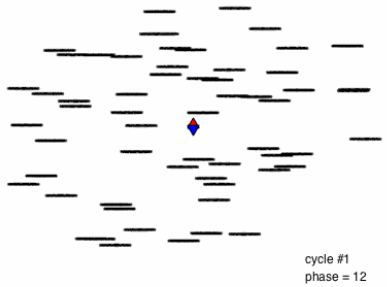


- Kubo's review (SUST 2016): multilayer coating. Advances in optimizing thickness and materials assessment.
- Gurevich's proposal (Appl. Phys. Lett. 2006): Can we use SIS structures to increase H_{sh}, and reduce the effects of flux penetration?



Sam Posen's simulations (SUST 2017): If there is a mechanism to prevent annihilation after each oscillation, one would expect large losses.

Sam Posen (FNAL)



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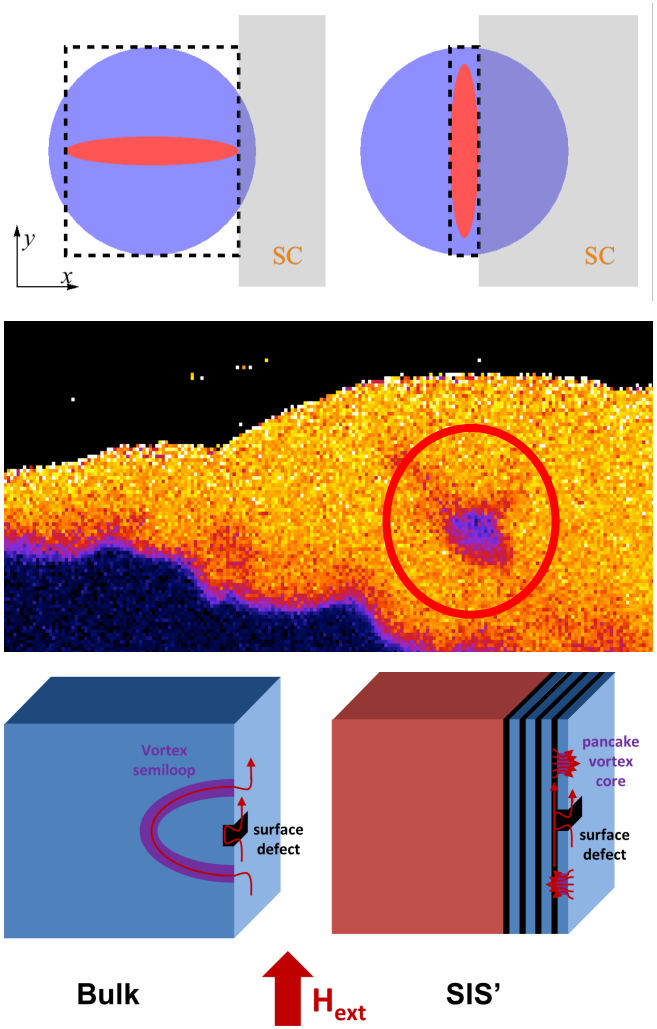
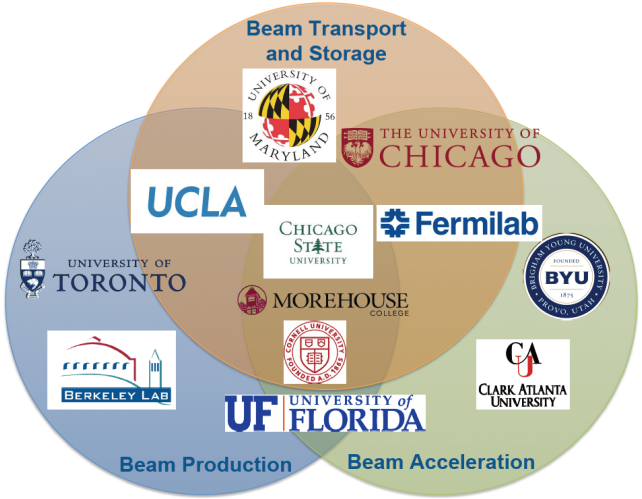


Acknowledgments

- TTC Topical Workshop Committee, for the invitation.
- The Sethna and the Liepe groups in Cornell.
- The Center for Bright Beams SRF team.
- Prof. Alex Gurevich, for useful consultation.
- Financial support from the Center for Bright Beams.



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