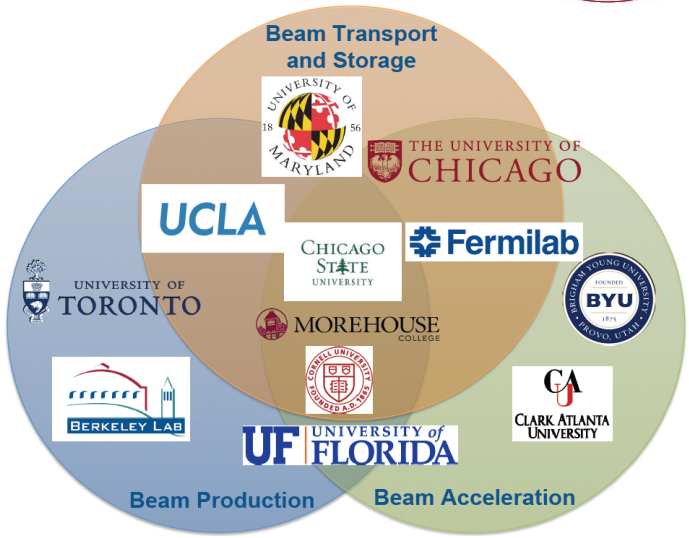
Theoretical estimates of maximum fields in SRF cavities: stability theory, disorder and laminates

Danilo Liarte, Daniel Hall, Matthias Liepe, James Sethna (Cornell), Sam Posen (FNAL), Mark Transtrum (Brigham Young University), Gianluigi Catelani (Peter Grünberg Institut)



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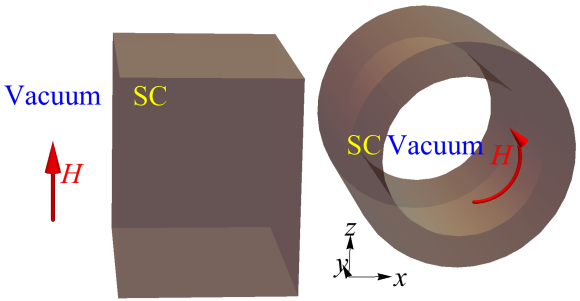
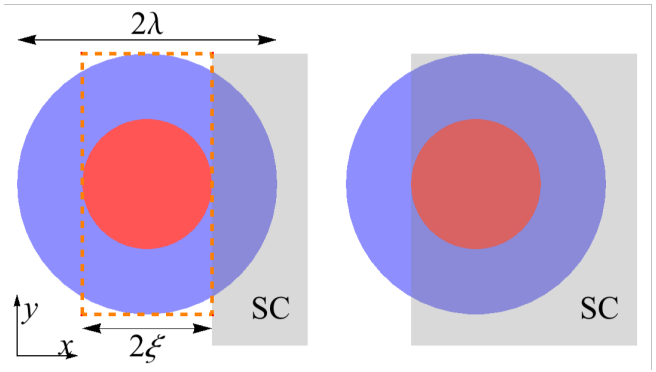
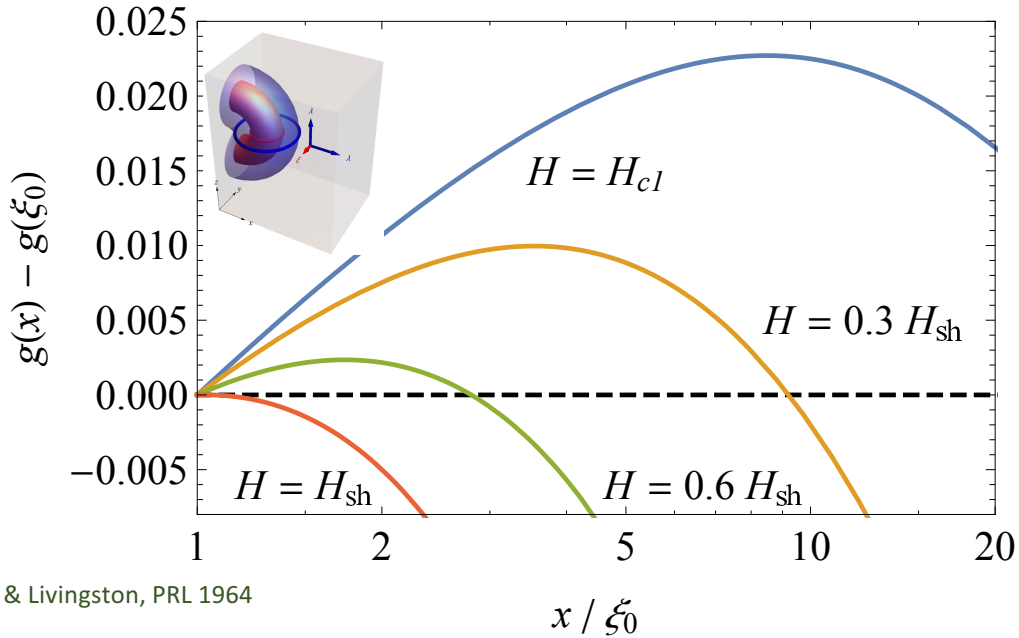
Surface energy barrier & vortex entry fields





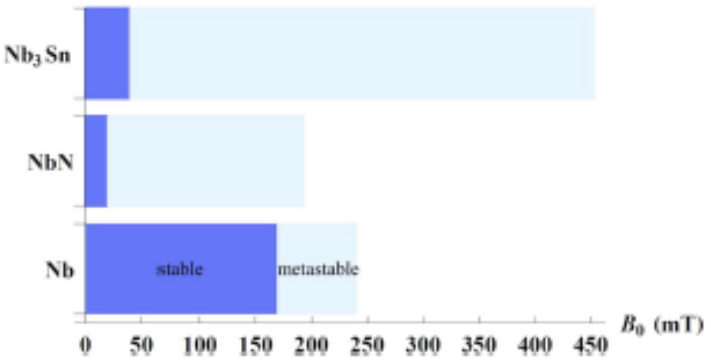
DBL, Posen, Transtrum, Catelani, Liepe, Sethna, SUST 2017



Bean & Livingston, PRL 1964

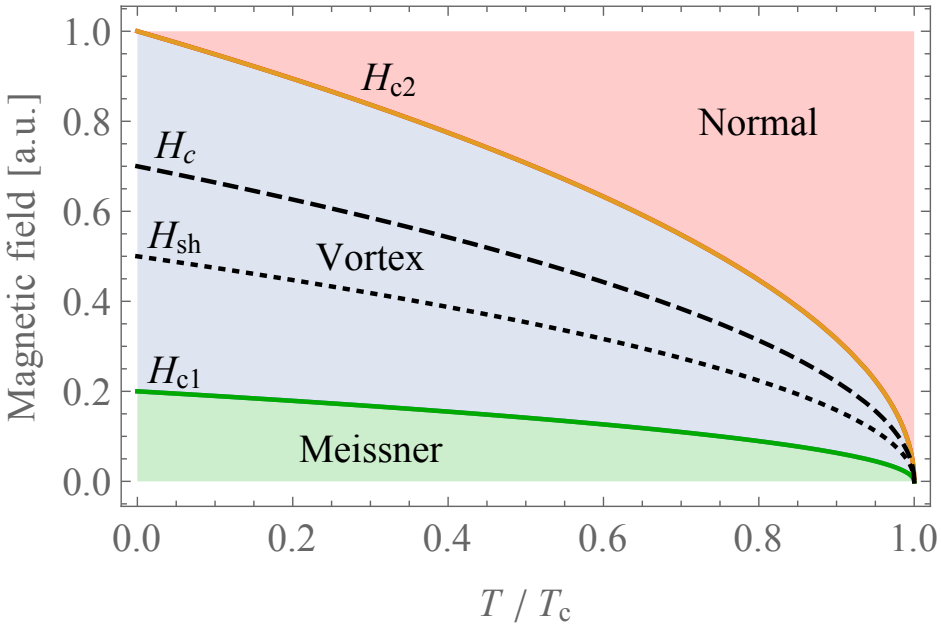
Stability analysis: the superheating field (H_{sh})

- 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}.



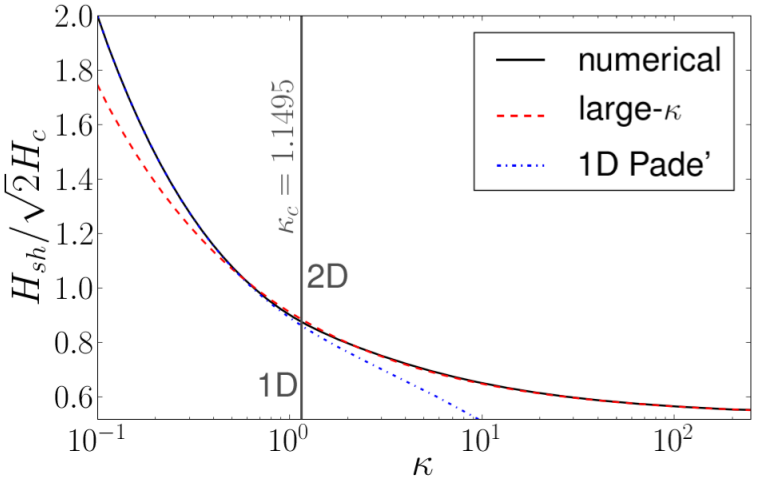
Kubo, SUST 2016

Sketch of a type II superconductor phase diagram



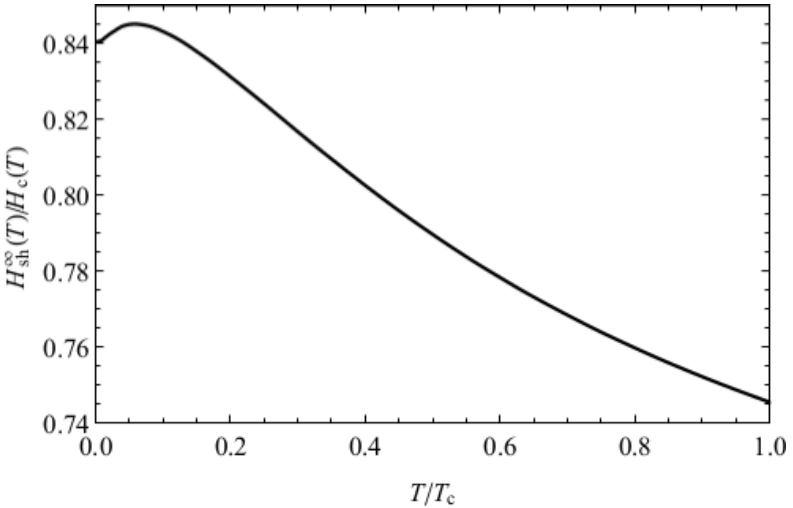
Stability analysis: the superheating field

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



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

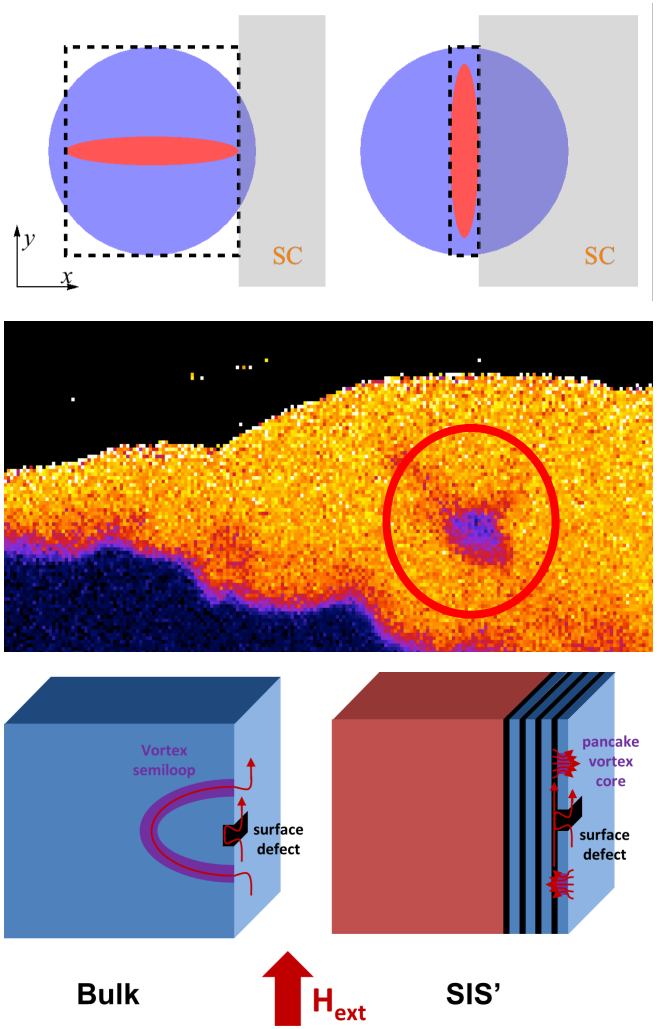
- As a function of T (at high κ):
- Eilenberger theory



Catelani & Sethna, PRB 2008

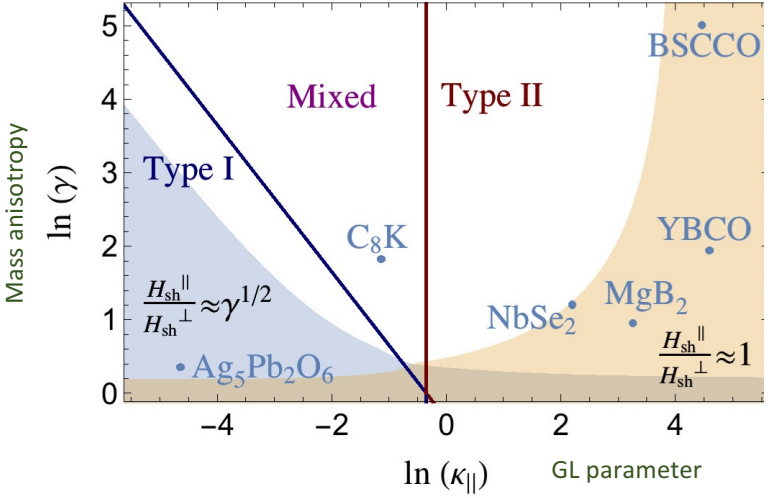
Summary

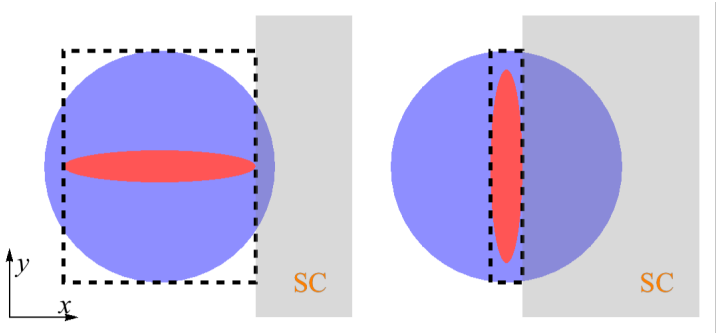
- Anisotropy
- Disorder
- Laminates
- Final considerations



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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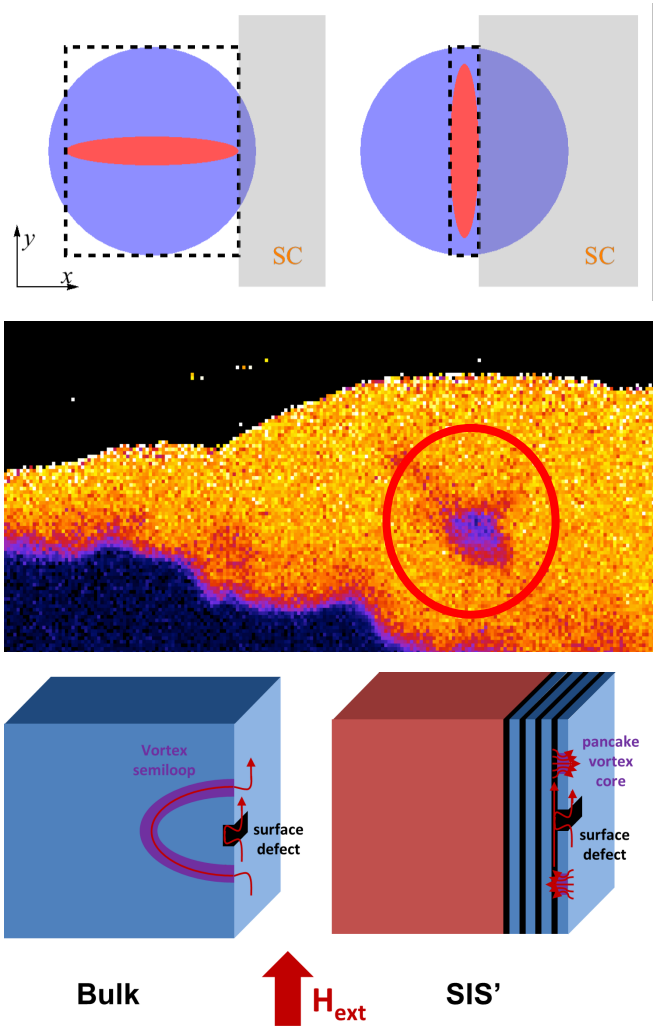
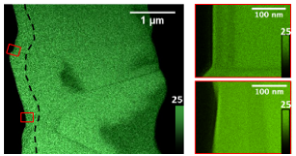
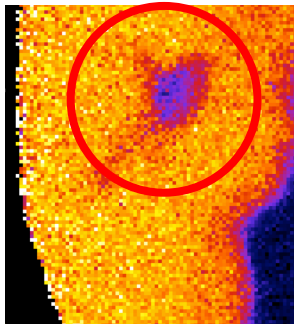


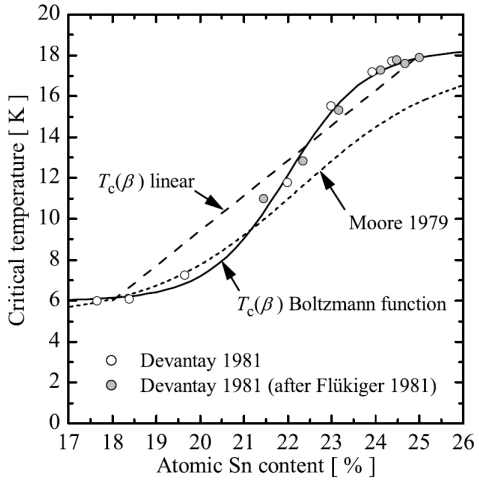
Sn depleted regions and Nb3Sn quenches



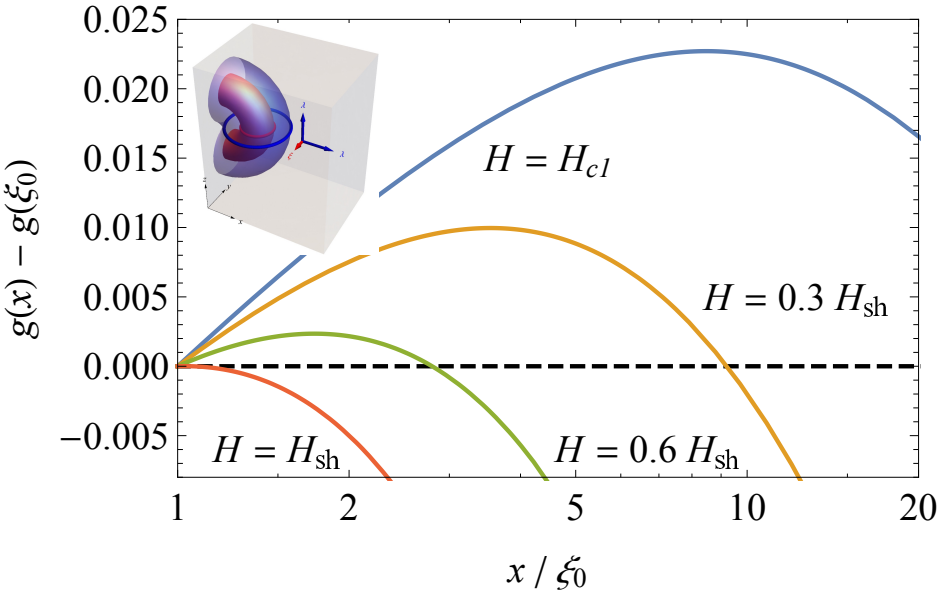
Thomas Proslier
(Argonne)



Muller Group
(CBB)



A. Godecke: SUST 2006

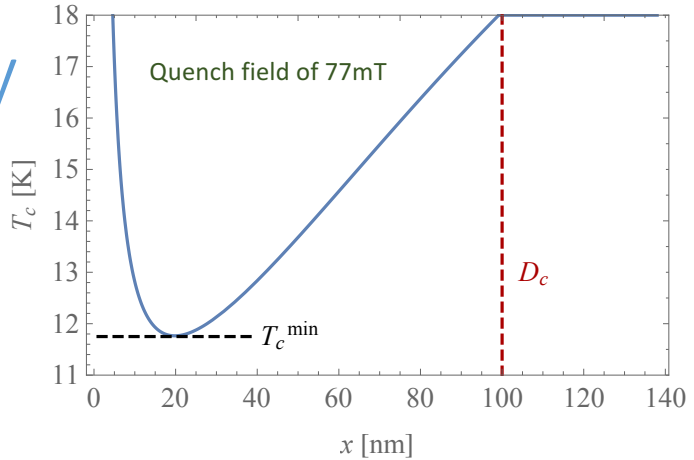


Can the tin depleted regions facilitate vortex nucleation?

Critical temperature profile that allows vortex nucleation in Nb_3Sn

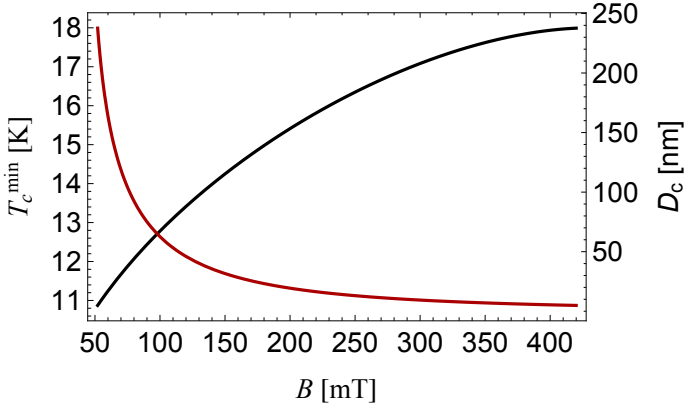
Cavity quenches and reliability

- We predict a relation between critical temperature drop, defect sizes, and quench fields that is ‘consistent’ with experiments.
- Talk to Daniel Hall. (THPB041)



- 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.

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



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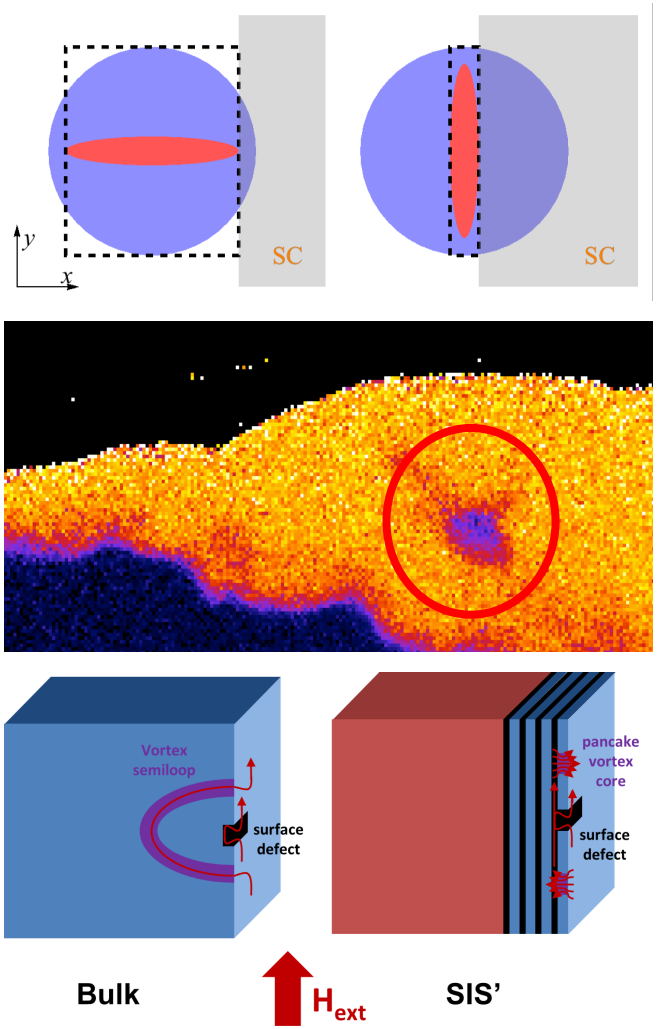
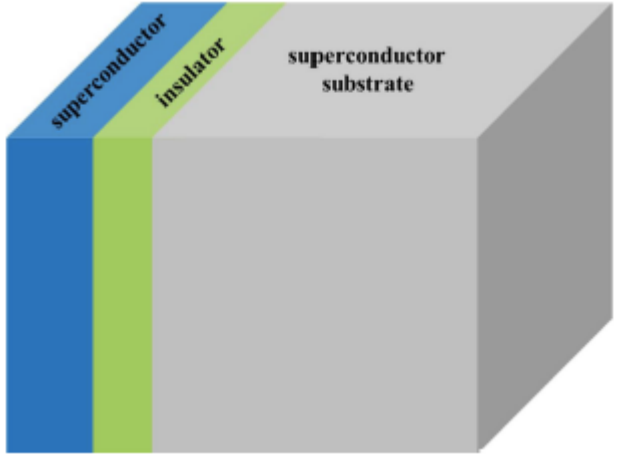


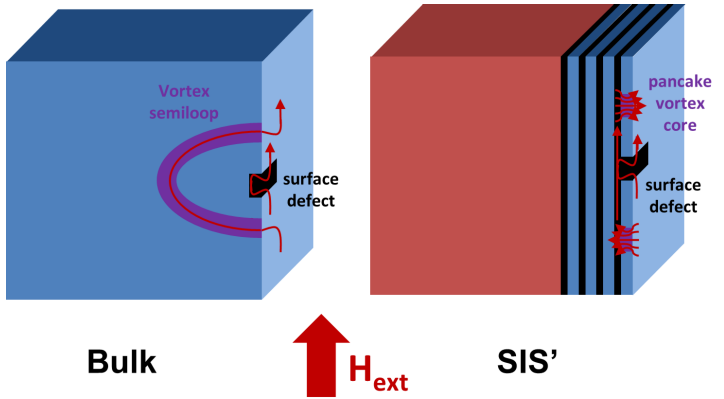
Laminates

- Read Kubo's review (SUST 2016): multilayer coating. Advances in optimizing thickness and materials assessment.
- Talk to Sam Posen, Fermilab.
- Gurevich's proposal (Appl. Phys. Lett. 2006): Can we use SIS structures to increase H_{sh}, and reduce the effects of flux penetration?
- SIS films with thickness d small compared to the penetration depth λ are more susceptible to vortex penetration than bulk films.
- Dangerous vortices in thin films do not typically reside parallel and inside the films, but penetrate in and out of the film via pancake vortices (see figure on right), whose motion dissipates heat.

Kubo, SUST 2016



Sam Posen (FNAL)



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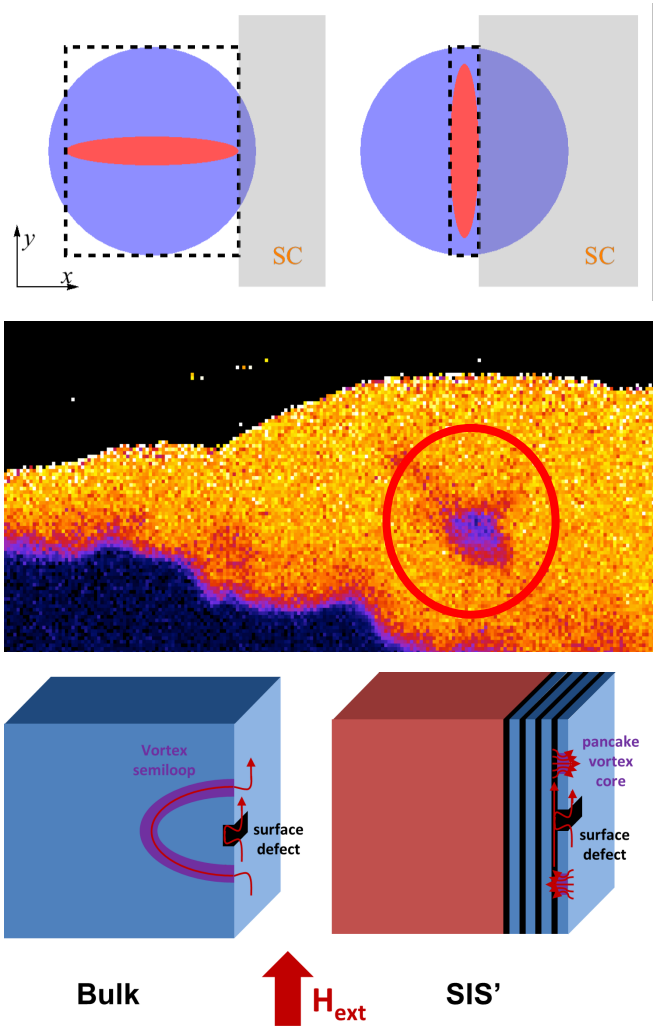
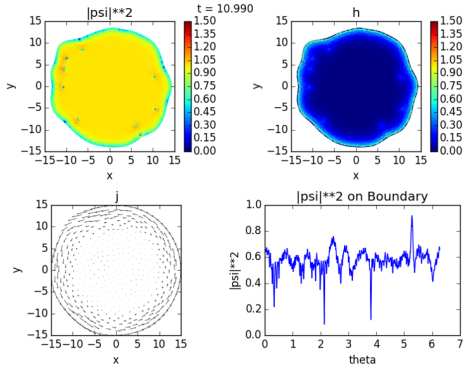


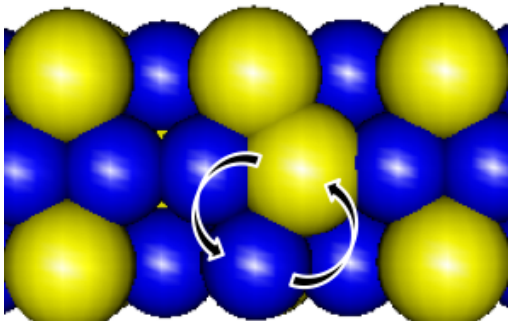
Final comments

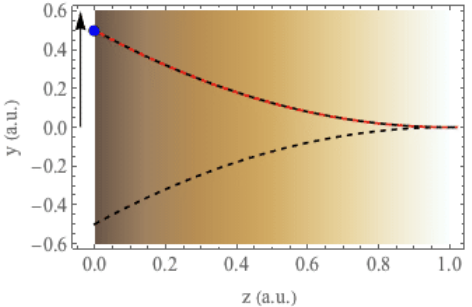
- Spatial inhomogeneity in time-dependent Ginzburg-Landau theory (Transtrum, BYU).
- DFT calculations (Arias, Cornell)
- Surface resistance and collective weak pinning (with Hall & Liepe).

THURSDAY AFTERNOON POSTER SESSION

- CBB theory poster: THPB040
- Cavity quenches: THPB041
- Trapped flux: THPB042







Acknowledgments

- SRF 2017 Committee, for the invitation.
- Sethna's and Liepe's groups.
- CBB-SRF team.
- Alex Gurevich, for useful conversations.