Massachusetts Institute of Technology
22.68J/2.64J
Superconducting Magnets

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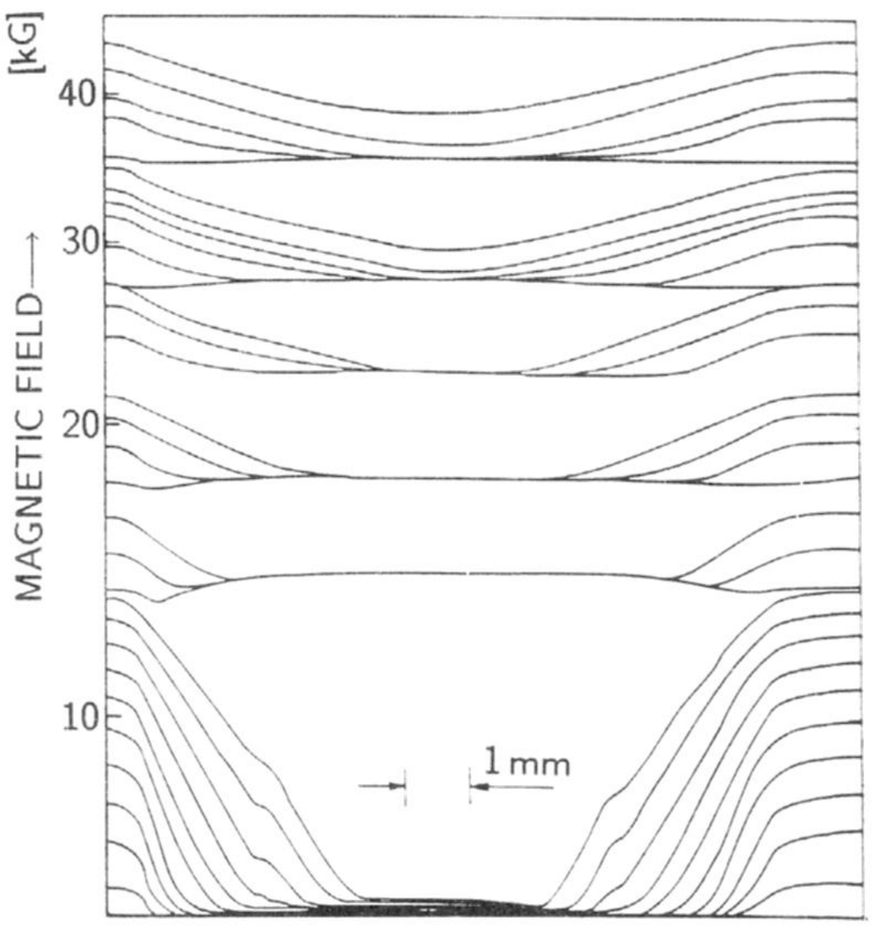
April 10, 2003

- Lecture #7 – Magnetic Instabilities
  - Flux Flow; Bean's Critical State Model
  - Magnetization; Flux Jumping

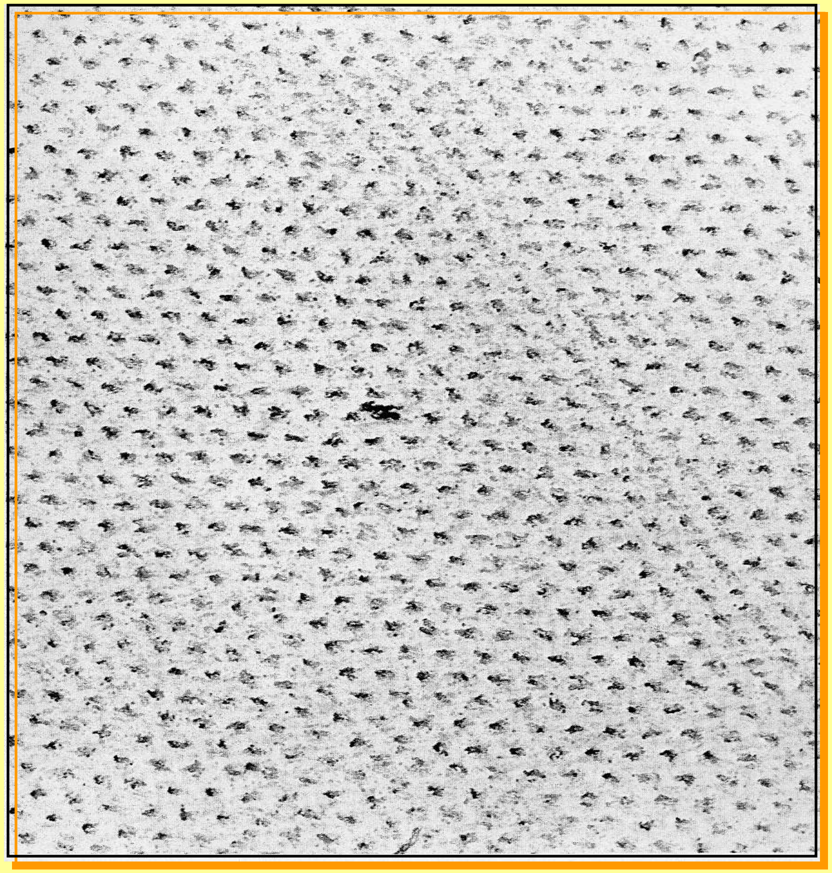
Magnetic Instabilities

- Derive from dissipative nature of flux motion in Type II superconductors
- Flux Flow $\rightarrow$ Flux Flow Resistivity
  - Key to understanding dissipation, local heating, and nature of magnetic instability
  - Requires understanding of the concept of the "critical state"
  - Leads to understanding of magnetization and hysteresis losses in changing magnetic fields

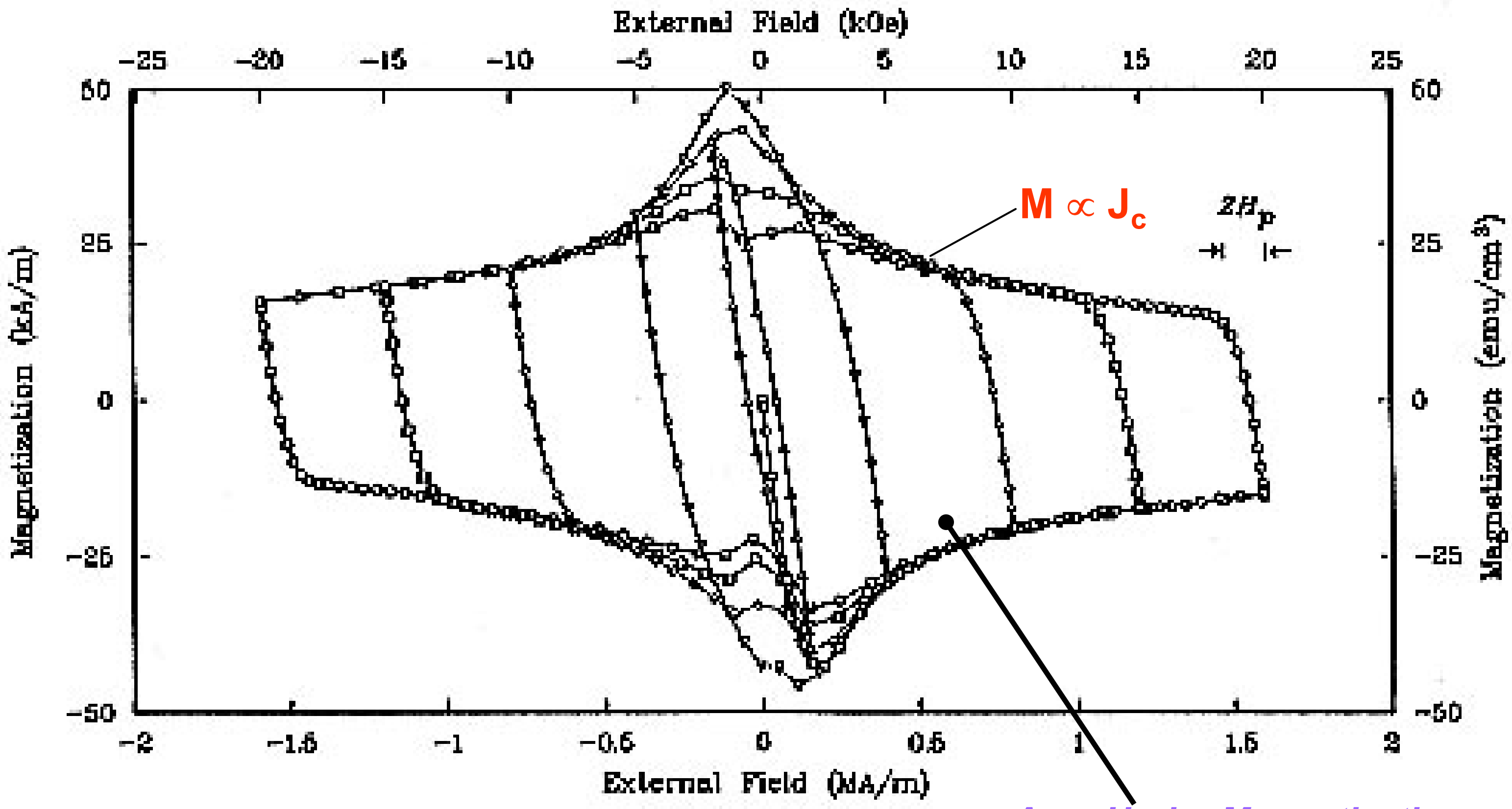
Measured Flux Penetration in a Type II Superconductor



Flux Enters in Quantized Vortices

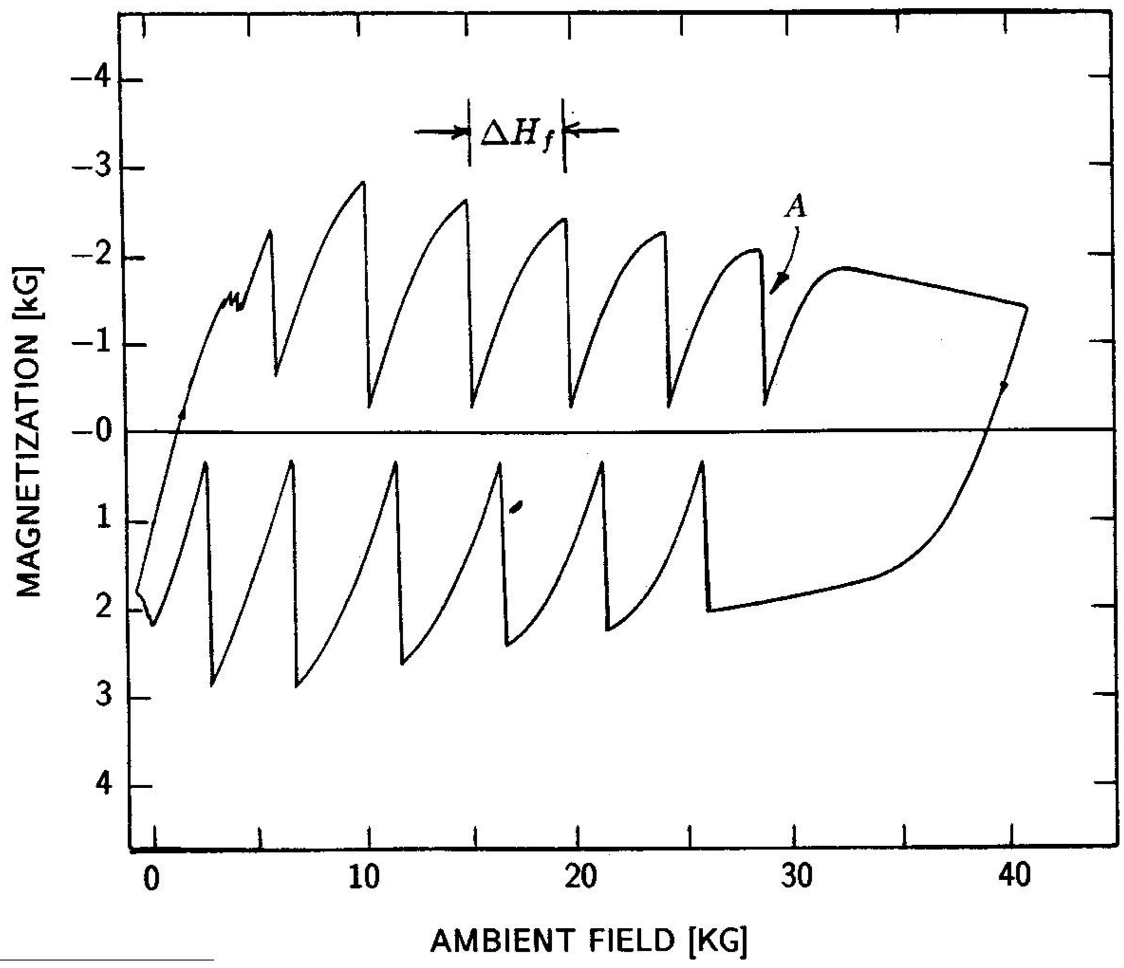


Technical Type II Superconductors Display a Magnetic Hysteresis

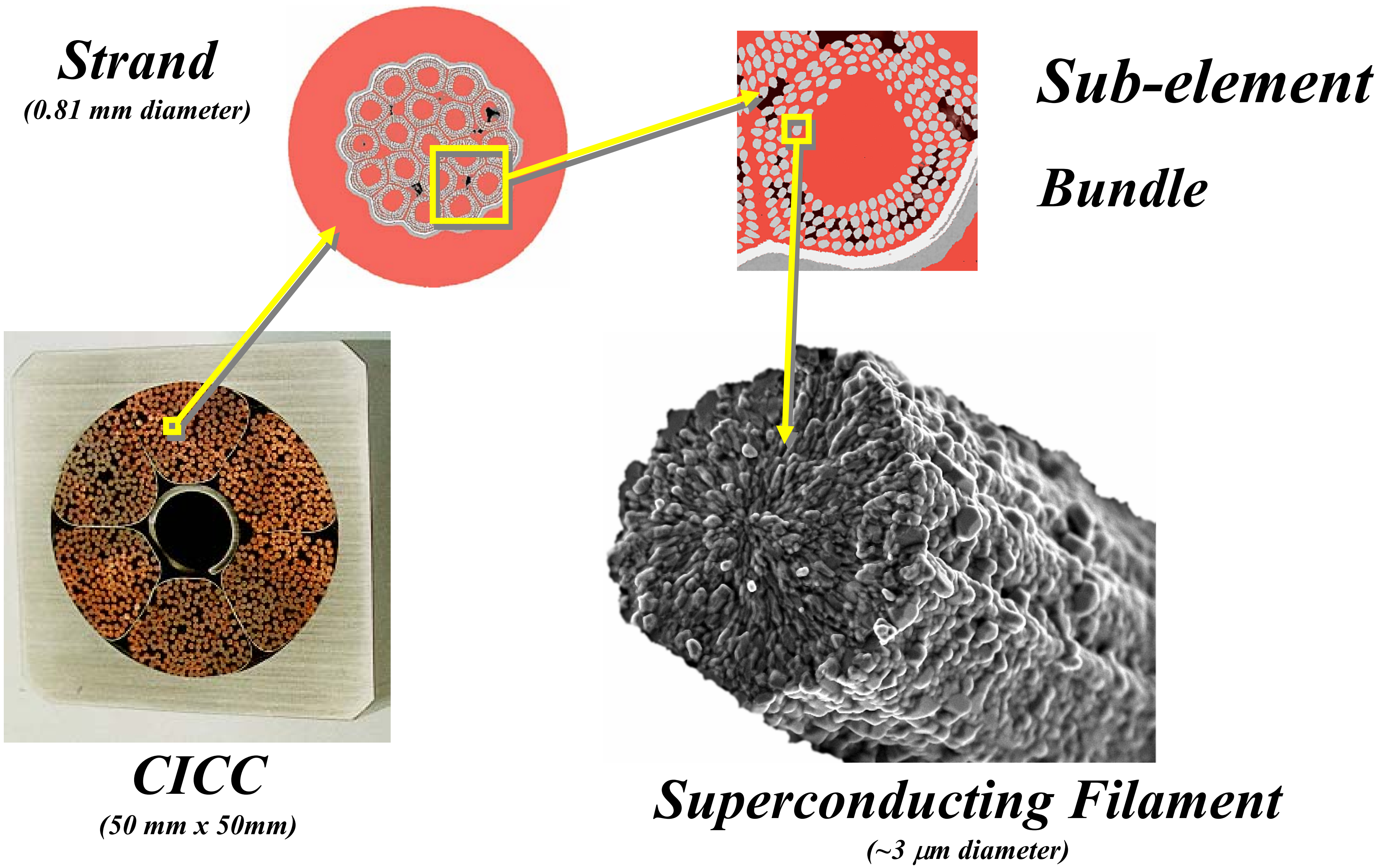


Area Under Magnetization Loop is Proportional to Dissipated Energy/cycle $\propto \Delta B\ J_c\ d_{eff}$

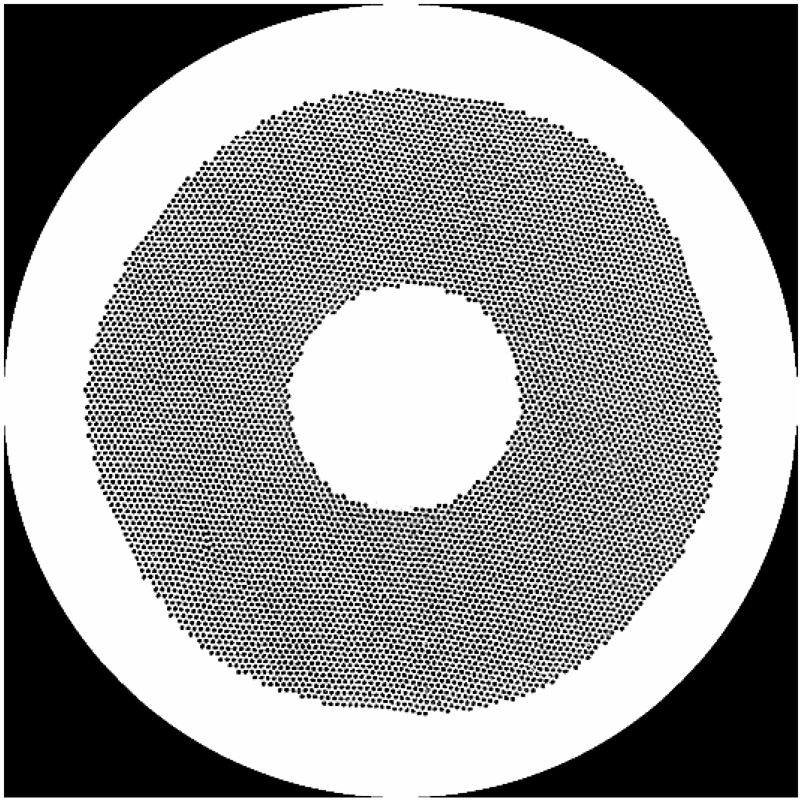
Measured Flux Jumps in a Magnetization Loop



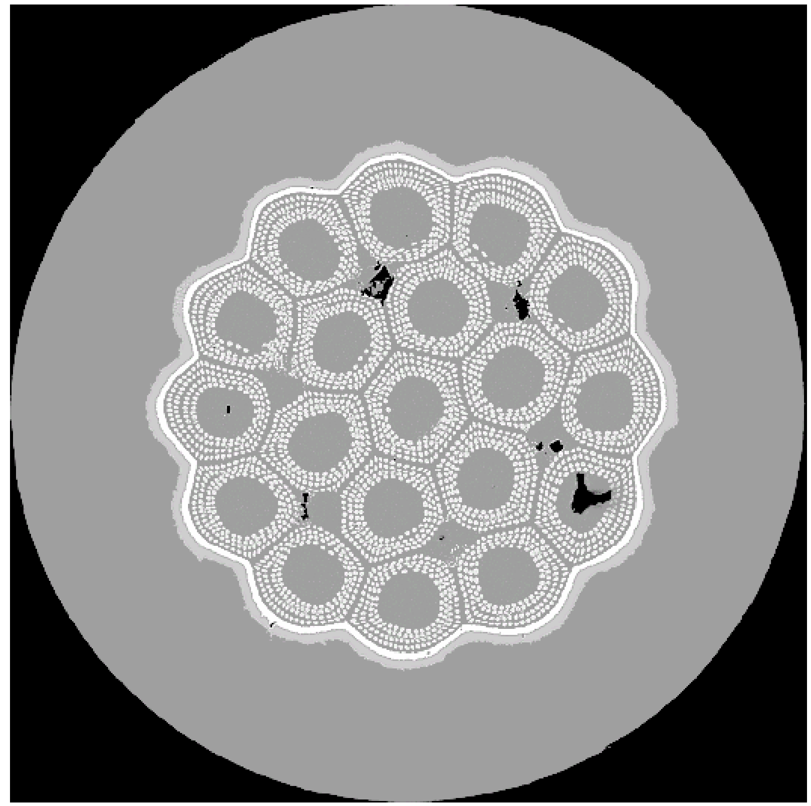
Fine Filaments in Nb_3Sn



Relevant Superconducting Wires are Complex Composites



Typical SSC Nb-47wt.%Ti strand (OST manufacture).



Typical reacted ITER Nb_3Sn strand (IGC manufacture).

Flux Jump Stability of High Temperature Superconductors

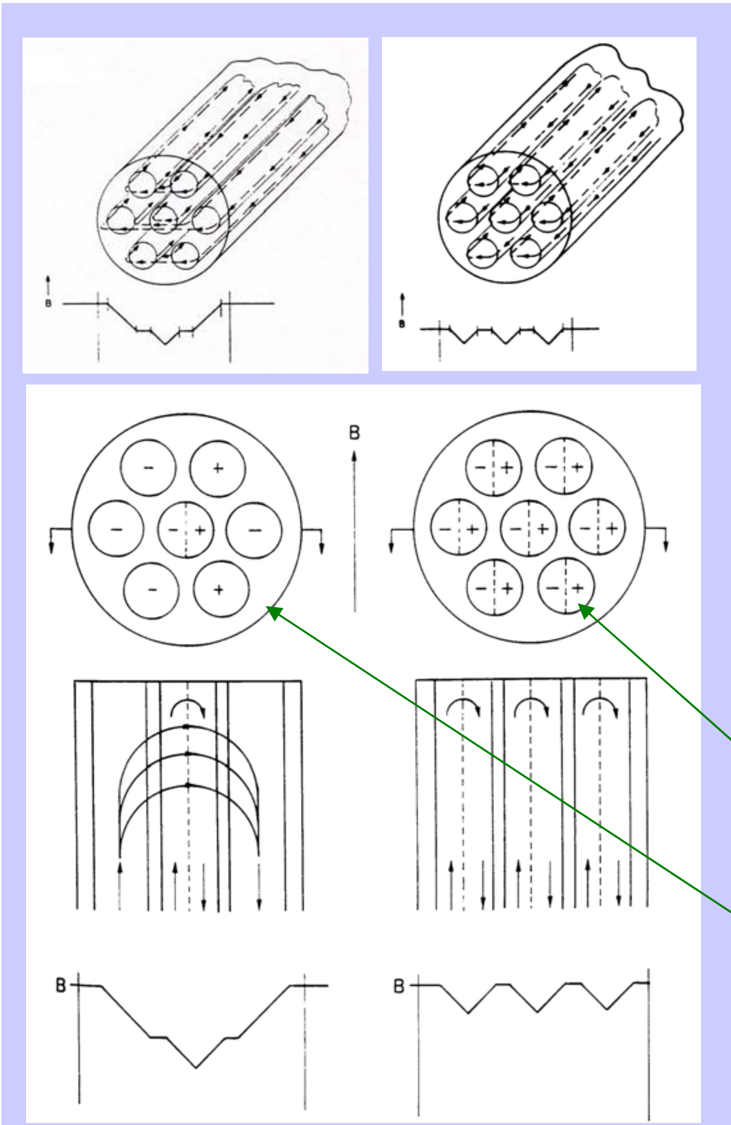
Table 5.2: Critical Size *vs* Temperature

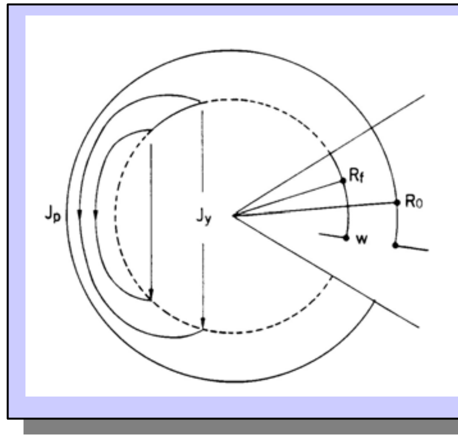
T [K]	I_c [A]	J_c [MA/m^2]	C_s* [kJ/m^{3}K]	a_c [mm]
4	228	1932	0.8	0.2
10	217	1839	7.7	0.7
20	194	1644	68.5	2.4
30	163	1381	240	5.5
40	135	1144	534	9.8
50	108	915	881	16
60	80	678	1219	25
70	53	449	1540	43
80	24	203	1825	103

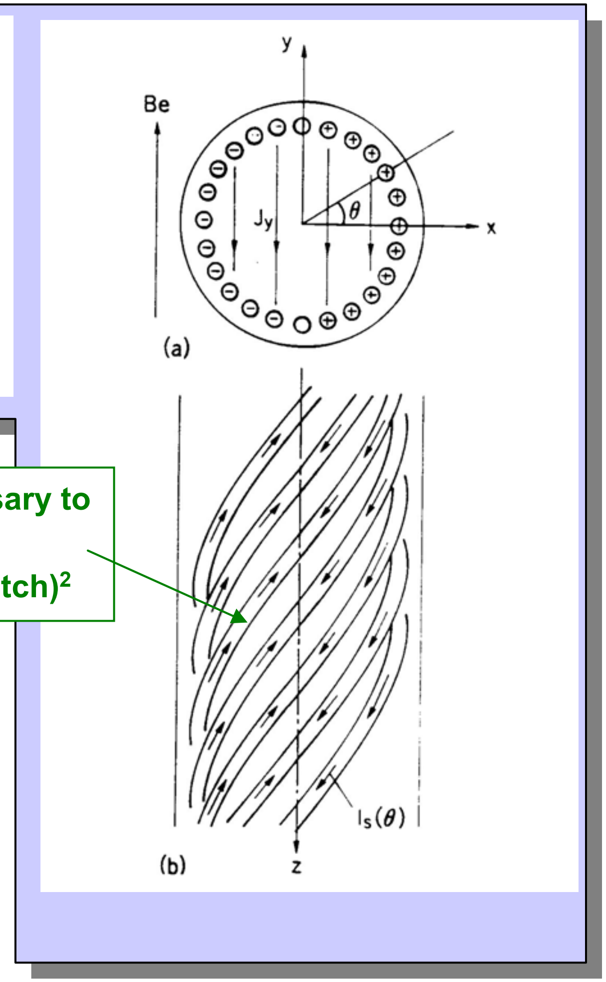
* Copper heat capacity.

AC Losses

Twisting the superconducting filaments in the composite wire is necessary to electrodynamically decouple them







Twisting filaments also necessary to reduce coupling losses

Power dissipation ∝ (Twist Pitch)^2

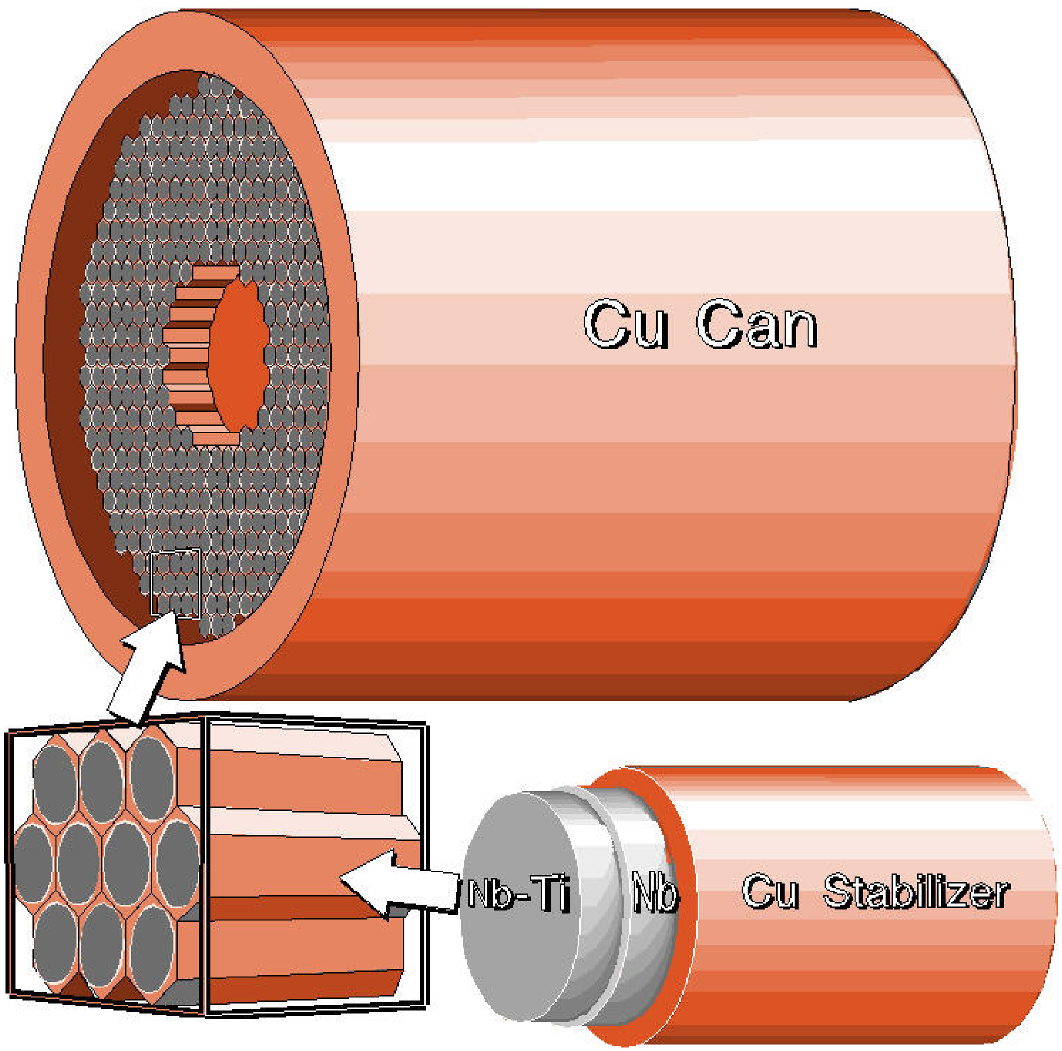
Hysteresis losses

∝ filament diameter (~1 μm)

Hysteresis losses

∝ strand diameter (~1 mm)

NbTi Billet Assembly



HTS Tape
(BSCCO)