IEEE-CSC, ESAS and CSSJ SUPERCONDUCTIVITY NEWS FORUM (global edition), Issue No. 63, Mar. 2026. Presentation given at ISS 2025, Nagasaki, Japan, Dec. 2025.

Roma Tre

Physics of superconductors for haloscopes: the cases of NbTi, Nb_3Sn and Fe(Se,Te)

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Group & Collaborations

microwaves

A. Alimenti, A. Magalotti,
N. Pompeo, E. Silva, G. Sotgiu, K. Torokhtii,
P. Vidal Garcìa

Roma Tre

samples, discussions, irradiation…

M. Putti, M. Cialone, V. Braccini, M. Iebole, A. Leverattto, I. Pallecchi, F. Loria, C. Bernini, E. Bellingeri, A. Malagoli …

G. Celentano, A. Mancini, V. Pinto, L. Piperno, A. Augieri, A. Masi, F. Rizzo, A. Vannozzi, L. Muzzi,…

G. Ghigo, L. Gozzelino, D. Torsello, F. Laviano, R. Gerbaldo

C. Pira, V. Garcia Diaz, D. Fonnesu, C. Gatti, C. Ligi, D. Di Gioacchino

S. Posen

T. Tamegai

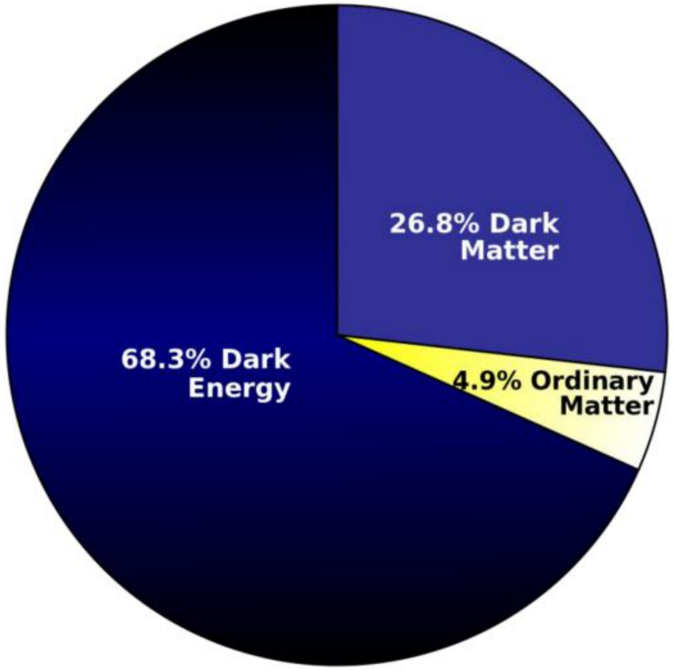
S. Okayasu

Outline

- Introduction: haloscopes and the need for low R_s materials
- Physical background: high frequency vortex motion
- Surface impedance in the mixed state and measurement technique
- Samples:
  - Nb-based: Nb_3Sn, NbTi
  - Fe(Se,Te)
- Results:
  - Pinning regimes
  - Flux flow
- Conclusion: SC haloscopes performance estimation

Dark matter

From astronomical observations: there is a large amount of matter that do not interact with light



Source: Wikipedia, DMPie_2013, https://it.wikipedia.org/wiki/Energia_oscura#/media/File:DMPie_2013.svg

Ipser, J., and P. Sikivie. *Phys. Rev. Lett.* 50.12 (1983): 925.

New gravitation theories

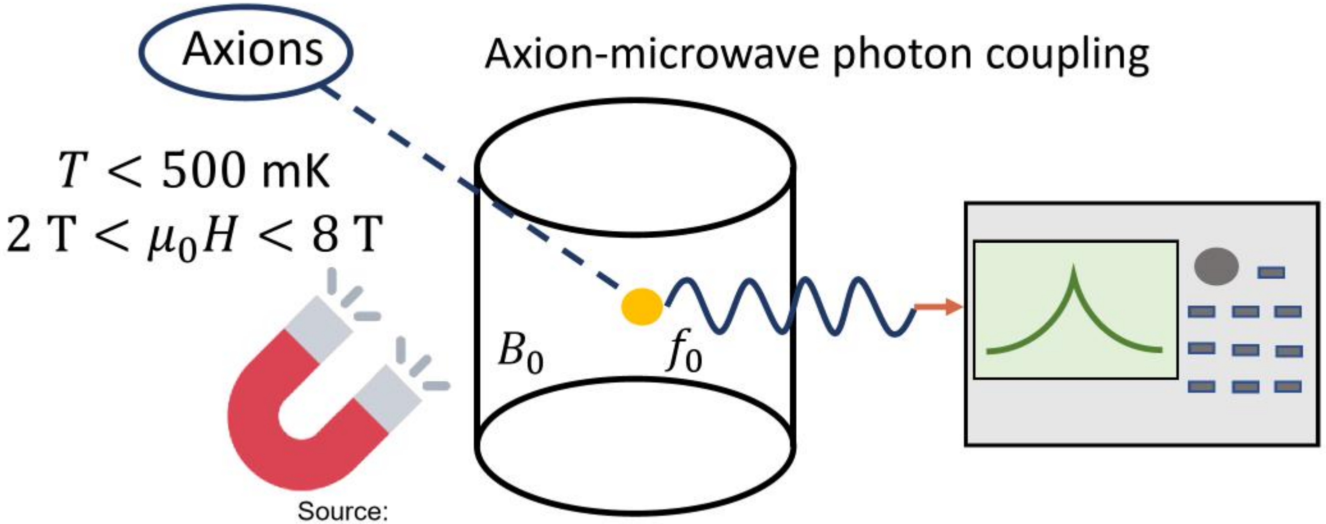
Non-baryonic matter that we currently cannot see:

Possible candidates:

- WIMPs
- MACHOs
- Sterile neutrinos
- Axions

- Why the electric dipole of neutron is zero? (Strong CP-problem)
- Dark matter

Haloscopes: high-Q cavities for axion search



$T < 500$ mK

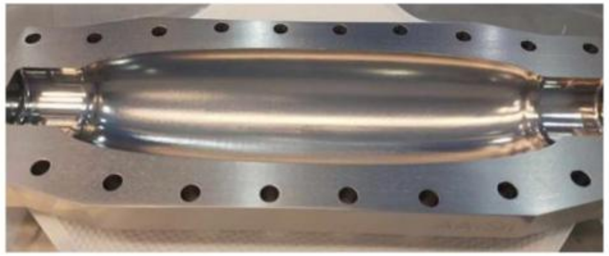
$2\ \mathrm{T} < \mu_0 H < 8\ \mathrm{T}$

Source:
Flaticon, Magnet_361700, https://www.flaticon.com/free-icon/magnet_361700

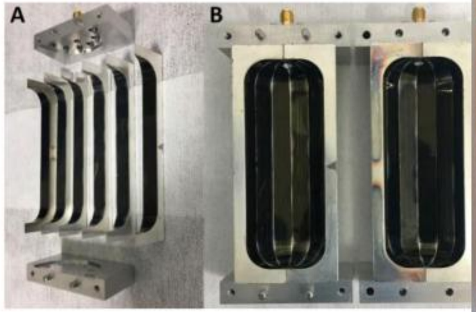
$$P \propto (QB^2V)(g_{a\gamma}^2\rho_a\nu) < 10^{-22}\ \mathrm{W}$$

P: signal power
Q: cavity quality factor
V: cavity volume
B: magnetic field
$g_{a\gamma}$: axion-photon coupling
ρ_a: axion local density
ν: photon frequency

Nb_3Sn *1



YBCO *2

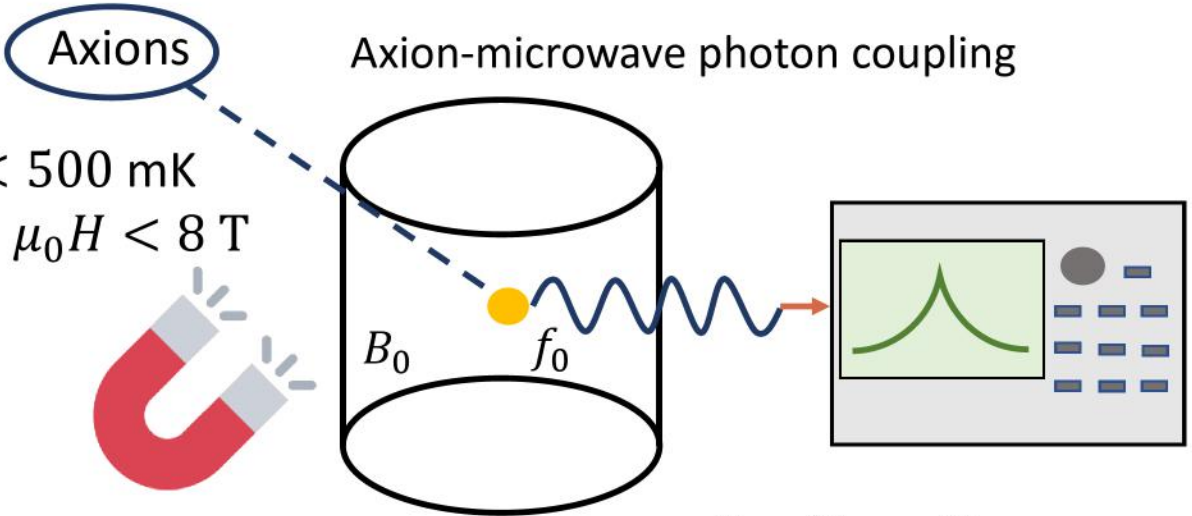


*3

NbTi *4

*Sources:
1. Posen, S. et al., *Phys. Rev. A* 20.3 (2023): 034004.
2. Ahn, D. et al. *Phys. Rev. A* 17.6 (2022): L061005.
3. Ahyoune, S. et al. *J. High Energy Phys.* 2025.4 (2025): 113.
4. Alesini, D., et al. *Phys. Rev. D* 99.10 (2019): 101101.

Haloscopes: high-Q cavities for axion search



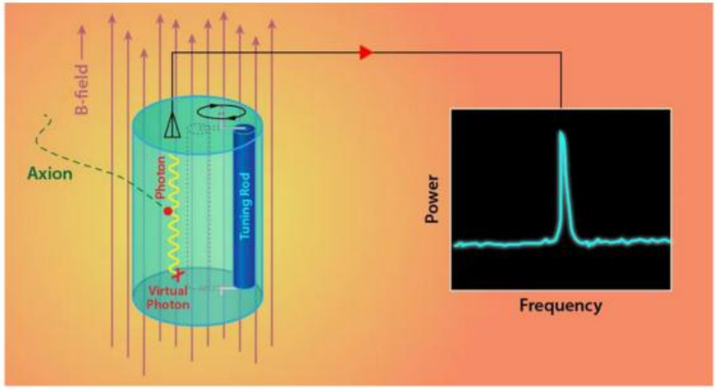
Axion-microwave photon coupling

$T < 500$ mK
$2\ \mathrm{T} < \mu_0 H < 8\ \mathrm{T}$

Source:
Flaticon, Magnet_361700, https://www.flaticon.com/free-icon/magnet_361700

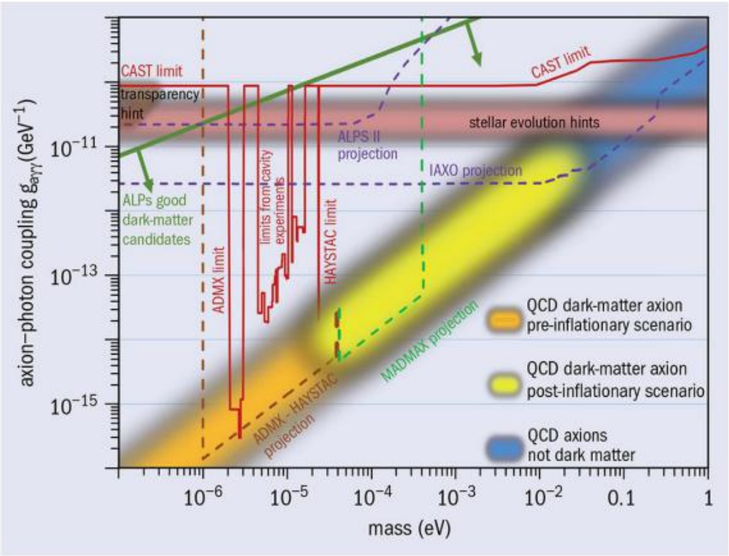
Tunable cavities:

*1



$$P \propto (QB^2V)(g_{a\gamma}^2\rho_a\nu) < 10^{-22}\ \mathrm{W}$$

*2



Haloscopes figures of merit:

- Signal power: $P \propto B^2 Q$
- Frequency scan rate: $\frac{df}{dt} \propto B^4 Q$

*Source:

1. Physics (APS), © Boutan/Pacific Northwest National Laboratory, https://physics.aps.org/articles/v11/34#c1
2. Khatiwada, R., et al. *Rev. Sci. Instrum.* 92.12 (2021): 124502.

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Surface impedance

A «simply» measurable quantity - experiment -

$$Z_s = R_s + \mathrm{i}X_s = \frac{E_\parallel}{H_\parallel} =$$

Bulk:

$$\sqrt{i\omega\mu_0\tilde{\rho}}$$

Thin film:

$$\frac{\tilde{\rho}}{t_s}$$

Thin coated conductor:

$$f(\tilde{\rho}, t_s, substrate)$$

Z_s surface impedance
R_s surface resistance
X_s surface reactance
E electric field
H magnetic field
T_c critical temperature

$\tilde{\rho}$ complex resistivity
ρ_{vm} vortex motion resistivity
ω angular frequency
μ_0 vacuum permeability
t_s film thickness

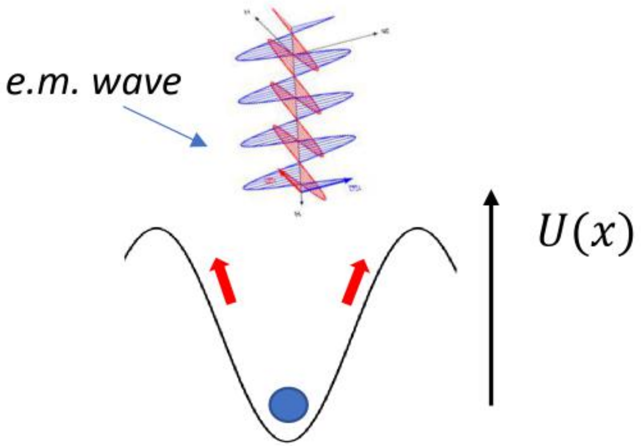
Vortex motion in $\tilde{\rho}$
For T slightly below $T_c(H)$,
$\tilde{\rho} \sim \rho_{vm}$

Full treatment:

Collin, R. E., "Foundation for Microwave Engineering," McGraw-Hill, (1992)
Silva, E. et al., *Supercond. Sci. Technol.* 9.11 (1996): 934-941.

High frequency vortex motion

One fluxon in a potential well:



Vortex motion due to e.m. impinging wave → Energy dissipation/storage

Very small vortex displacement → No dynamic fluxons interactions - single vortex approx. -

forces balance dynamic equation (per unit length) :

$$\boxed{\eta \boldsymbol{v} + \nabla U = \boldsymbol{J}_{\mu w} \times \hat{\boldsymbol{n}} \Phi_0 + \boldsymbol{F}_{th}}$$

Usually neglected at low enough temperature

- $\eta \boldsymbol{v}$: viscous drag force
- ∇U: pinning force, $U(\boldsymbol{x})$ pinning potential
- $\boldsymbol{J}_{\mu w} \times \hat{\boldsymbol{n}} \Phi_0$: Lorentz force
- $\boldsymbol{F}_{th}$: thermal fluctuations force

Gittleman, J. I. and Rosenblum, B., *Phys. Rev. Lett.* 16.12 (1966): 734–735
Coffey, M. W. and Clem, J. R., *Phys. Rev. Lett.* 67.3 (1991): 386–389
Pompeo, N. and Silva, E., *Phys. Rev. B* 78.9 (2008): 094503
Silva, E. et al., *Phys. Sci. Rev.* 2.7 (2017): 20178004

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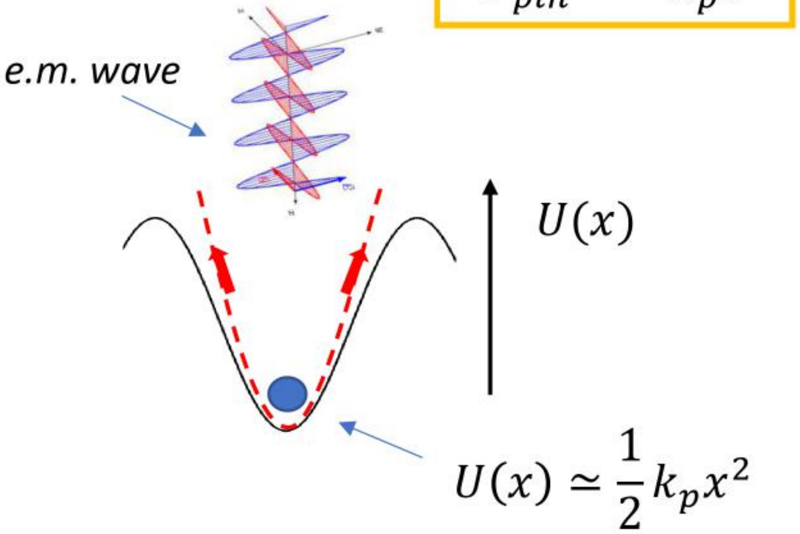
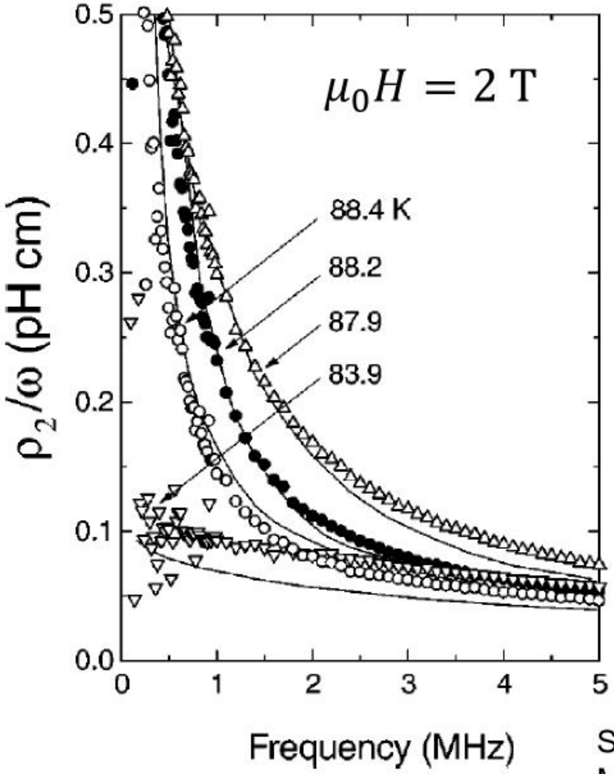
The parameters of interest

$$\boxed{\eta \boldsymbol{v} + \nabla U = \boldsymbol{J}_{\mu w} \times \hat{\boldsymbol{n}}\Phi_0 + \boldsymbol{F}_{th}}$$

- Pinning constant (Labusch parameter) k_p

$$\boxed{\boldsymbol{F}_{pin} = -k_p \boldsymbol{x}}$$





Source:
Matl, P. et al. *Phys. Rev. B* 65.21 (2002): 214514.

- *Low f*: effects of the solid-liquid vortex transition
- *High f*: k_p directly measured
- Imaginary part most sensitive to pinning

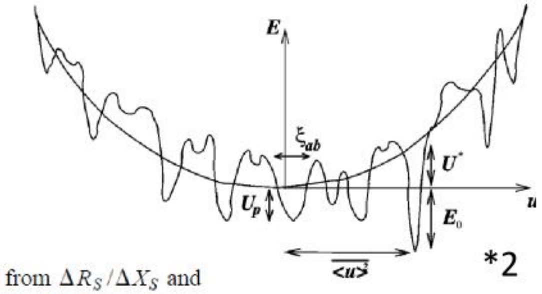
Non-linearities with large oscillations

Calatroni, S. and Ruggero, V.
IEEE Trans. Appl. Supercond. 31.3 (2021): 3500208.

The parameters of interest

$$\eta \boldsymbol{v} + \nabla U = \boldsymbol{J}_{\mu w} \times \hat{\boldsymbol{n}} \Phi_0 + \boldsymbol{F}_{th}$$

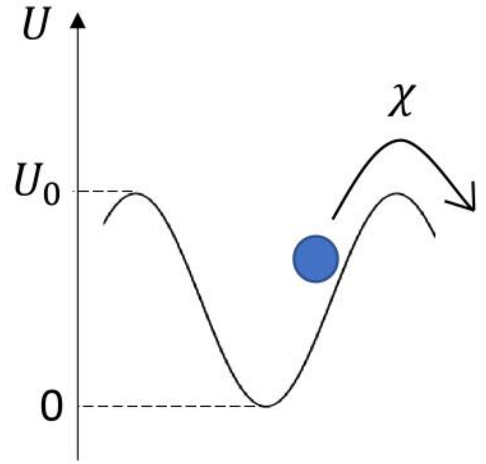
Linear response at microwaves probes secondary small valleys in the pinning potential



*2

- Pinning constant (Labusch parameter) k_p
- Creep factor χ

$0 < \chi < 1$ (adimensional)
$\chi \to 0$: no creep
$\chi \to 1$: no pinning



U_0: creep activation energy
u: normalized energy barrier height
k_B: Boltzmann constant

$$u = U_0(T, B)/k_B T$$

In case of periodic potential:

$$\chi = \left(I_0 \left(\frac{u}{2} \right) \right)^{-2}$$

Coffey, M. W. and Clem, J. R., *Phys. Rev. Lett.* 67.3 (1991): 386–389

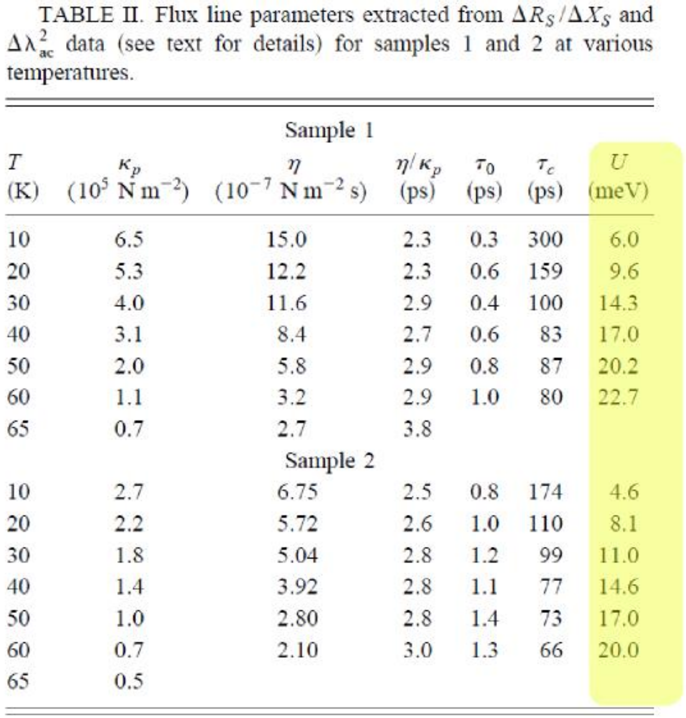


TABLE II. Flux line parameters extracted from $\Delta R_S/\Delta X_S$ and $\Delta\lambda^2_{ac}$ data (see text for details) for samples 1 and 2 at various temperatures.

T (K)	κ_p (10^5 N m^{-2})	η (10^{-7} N m^{-2} s)	η/κ_p (ps)	τ_0 (ps)	τ_c (ps)	U (meV)
Sample 1						
10	6.5	15.0	2.3	0.3	300	6.0
20	5.3	12.2	2.3	0.6	159	9.6
30	4.0	11.6	2.9	0.4	100	14.3
40	3.1	8.4	2.7	0.6	83	17.0
50	2.0	5.8	2.9	0.8	87	20.2
60	1.1	3.2	2.9	1.0	80	22.7
65	0.7	2.7	3.8			
Sample 2						
10	2.7	6.75	2.5	0.8	174	4.6
20	2.2	5.72	2.6	1.0	110	8.1
30	1.8	5.04	2.8	1.2	99	11.0
40	1.4	3.92	2.8	1.1	77	14.6
50	1.0	2.80	2.8	1.4	73	17.0
60	0.7	2.10	3.0	1.3	66	20.0
65	0.5					

*1

*Source:

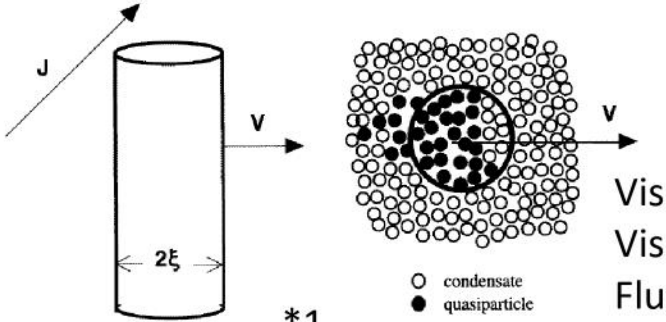
1. Powell, J. R. et al., *Phys. Rev. B* 57.9 (1998): 5474.
2. Kierfeld, J., *Phys. Rev. B* 69.14 (2004): 144513.

The parameters of interest

$$\boxed{\eta \boldsymbol{v} + \nabla U = \boldsymbol{J}_{\mu w} \times \hat{\boldsymbol{n}}\Phi_0 + \boldsymbol{F}_{th}}$$

- Pinning constant (Labusch parameter) k_p
- Creep factor χ
- Flux-flow resistivity $\rho_{ff} = \Phi_0 B/\eta$

«***deep in the vortex solid state***»



*1

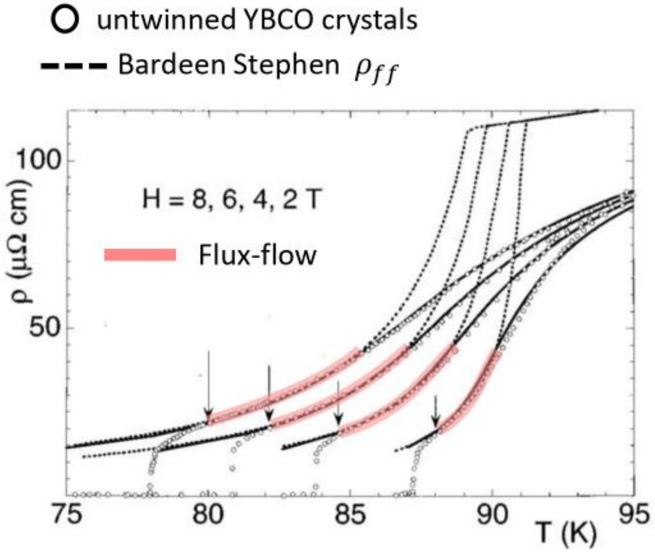
Viscous force: $F_v = \eta v$
Viscous drag coefficient: η
Flux-flow resistivity: ρ_{ff}

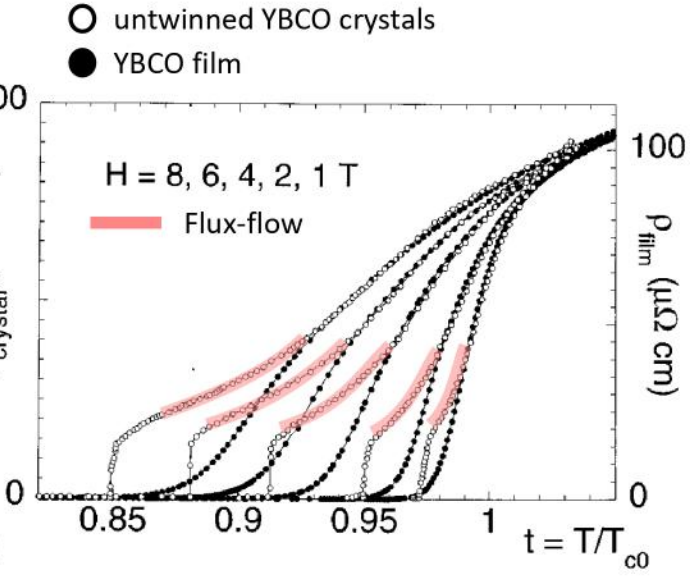
*Sources:

1. Golosovsky, M. et al., *Supercond. Sci. Technol.* 9.1 (1996): 1-15.
2. Sarti, S. et al., *Phys. Rev. B* 56.5 (1997): 2356
3. Liang, M. et al. *Phys. Rev. B* 82.6 (2010): 064502

Flux-flow in dc:

- well discernible in untwinned crystals
- completely masked by pinning in films





*2

Many different specific models for flux-flow:

«all theories for free flux flow are restricted in one way or another (e.g. T close to T_c, B close to H_{c2}, gapless case, etc.)» *3

$$\frac{\sigma}{\sigma_N} - 1 = \frac{1}{\left(1-\frac{T}{T_c}\right)^{0.5}} \frac{H_{c2}}{B}\, \tilde{f}(B/H_{c2})$$

Vortex motion resistivity - frequency dependence

$$\boxed{\eta \boldsymbol{v} + \nabla U = \boldsymbol{J}_{\mu w} \times \widehat{\boldsymbol{n}}\Phi_0 + \boldsymbol{F}_{th}}$$

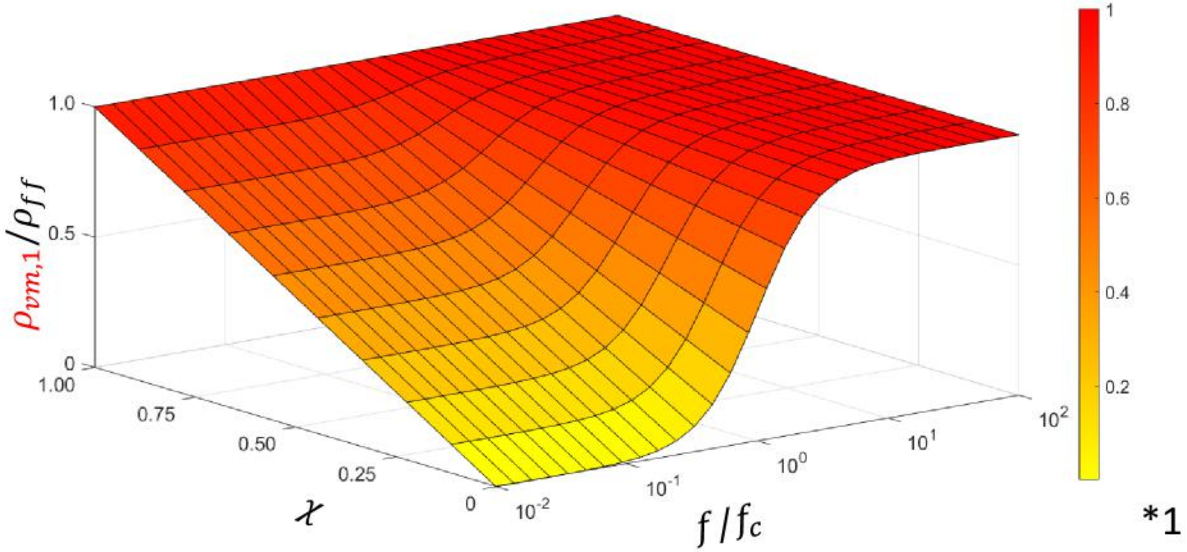
⬇

$$\rho_{vm,CC} = \rho_{vm,1} + \mathrm{i}\rho_{vm,2} = \rho_{ff}\frac{\chi + \mathrm{i}\frac{f}{f_c}}{1 + \mathrm{i}\frac{f}{f_c}}$$

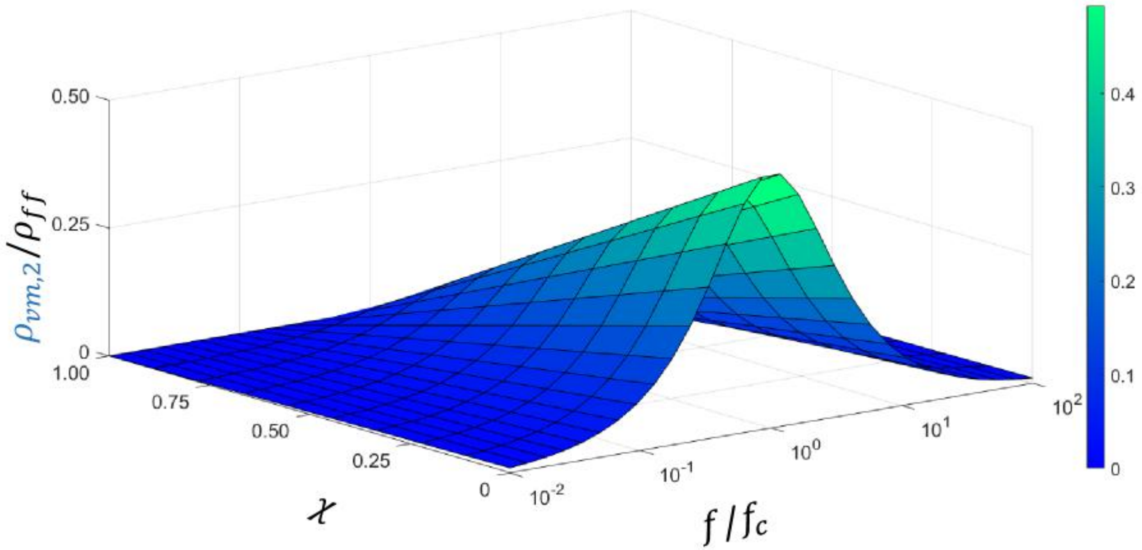
$\rho_{ff} = \Phi_0 B/\eta$: flux-flow resistivity

f_c: characteristic frequency

χ : creep factor



*1



*Source:

1. Alimenti, A. et al. *IEEE Instrum. Meas. Mag.* 24.9 (2021): 12-20.

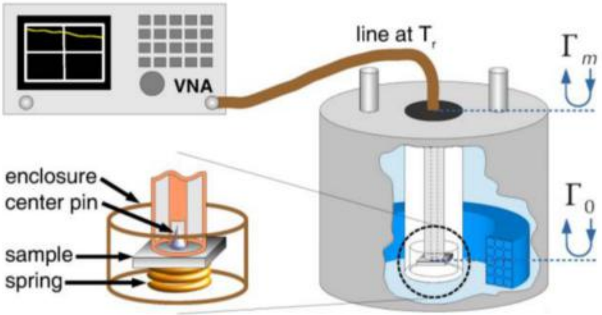
$\rho_{vm,CC}$ experimental validation

Measurement technique:

- Corbino disk
- frequency: 45 MHz < f <50 GHz
- $H \parallel c$ up to 9 T

Samples:

- YBCO – thin film on $LaAlO_3$
- Thickness 100 nm
- Growing technique: PLD
- $T_c = 91.2$ K

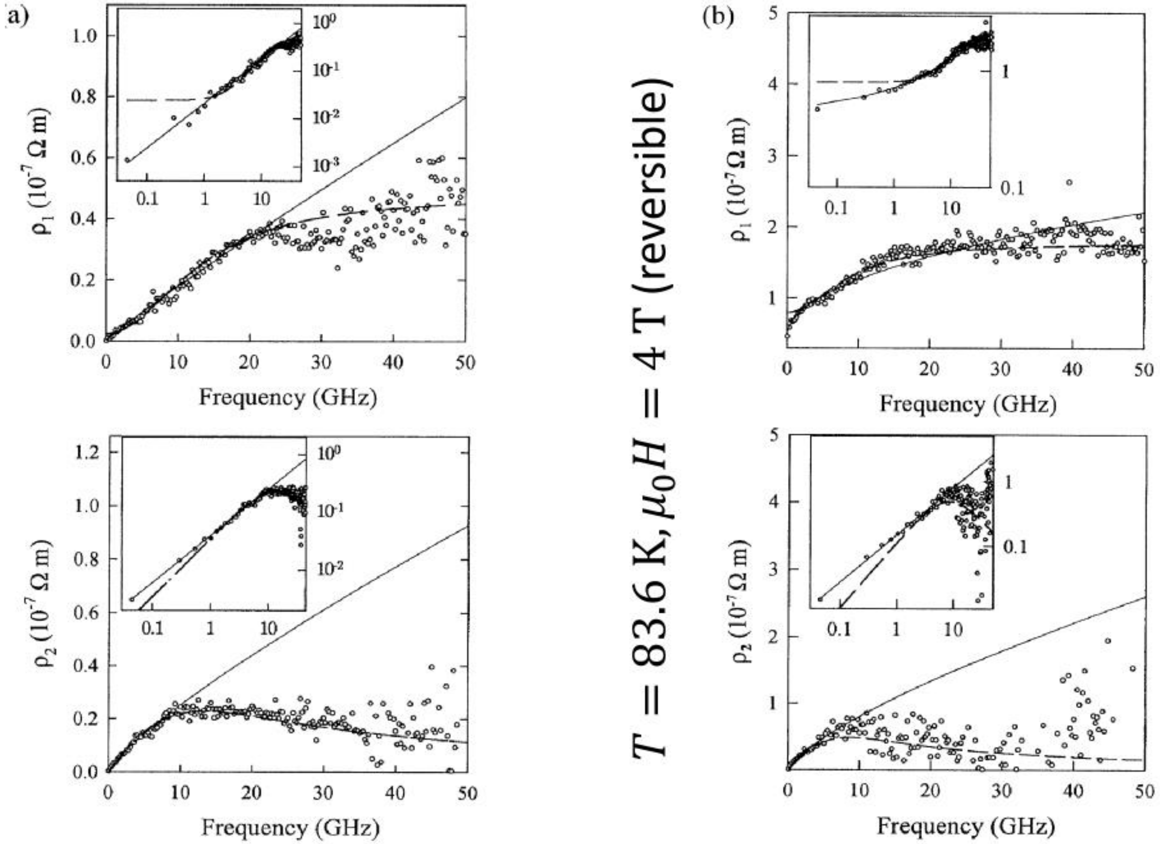


*2

$$\rho_{vm} = \rho_1 + \mathrm{i}\rho_2$$

$T = 80.2$ K, $\mu_0 H = 0.4$ T (irreversible)

$T = 83.6$ K, $\mu_0 H = 4$ T (reversible)



*1

—— $\rho_1 \propto p_0 + \omega^{\alpha_1}$; $\rho_2 \propto \omega^{\alpha_2}$ Low frequency scaling model

– – $\rho_{vm,CC}$ Coffey-Clem model

*Sources:

1. Wu, D. H. et al., Phys. Rev. Lett. 75.3 (1995): 525
2. Silva, E. et al., *IEEE Trans Instrum. Meas.* 65.5 (2016): 1120-1129.

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Dual frequency measurement method

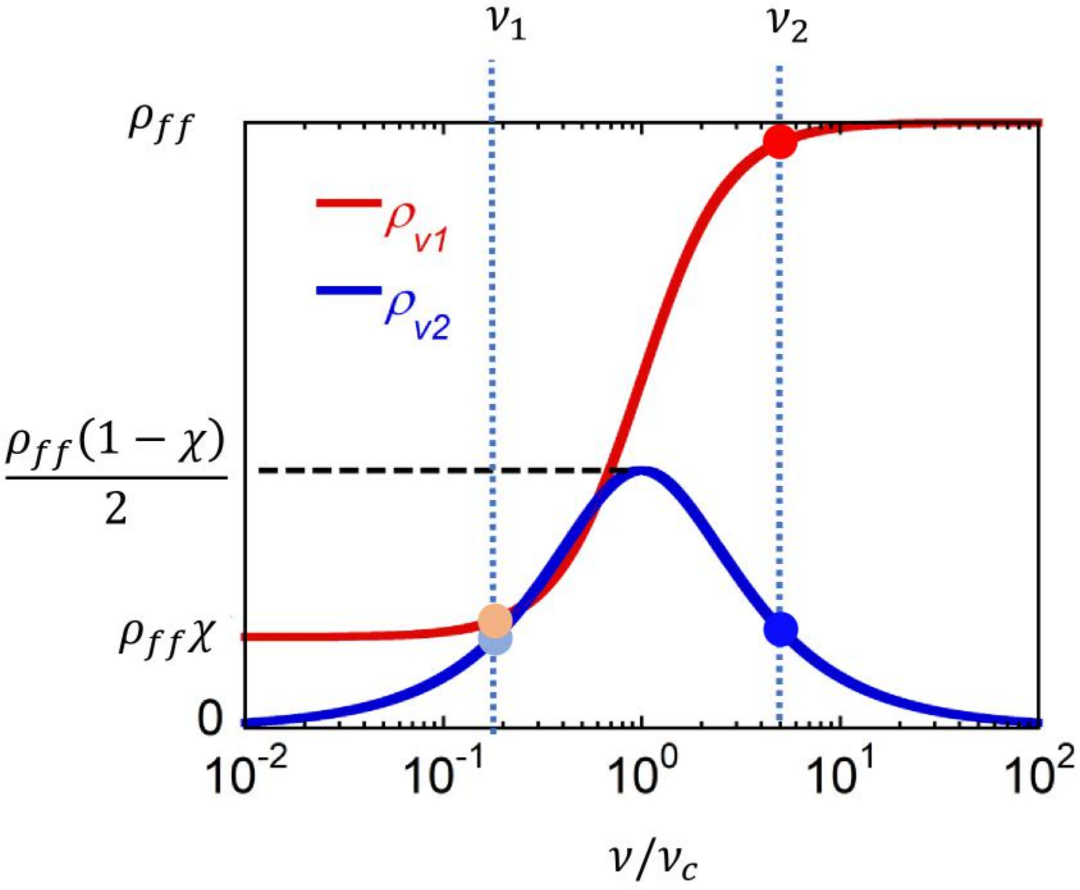
4 independent measurements:

$$\rho_{vm}(\nu_1) = \rho_{v1}(\nu_1) + \mathrm{i}\rho_{v2}(\nu_1)$$

$$\rho_{vm}(\nu_2) = \rho_{v1}(\nu_2) + \mathrm{i}\rho_{v2}(\nu_2)$$

⬇

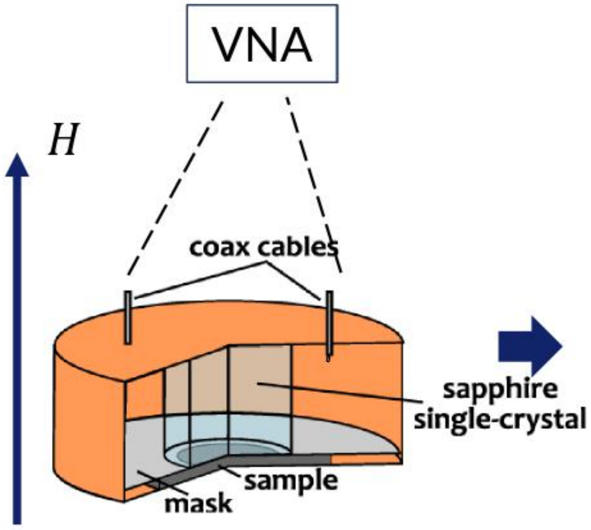
3 parameters (ρ_{ff}, ν_c, χ) + check

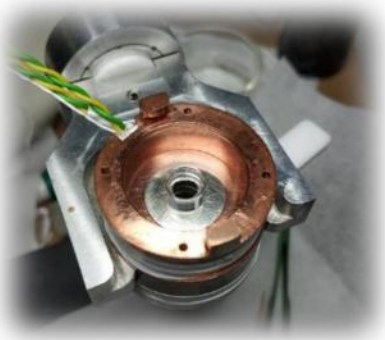


More details on the measurement method:
Pompeo, N. et al. Measurement 184 (2021): 109937.

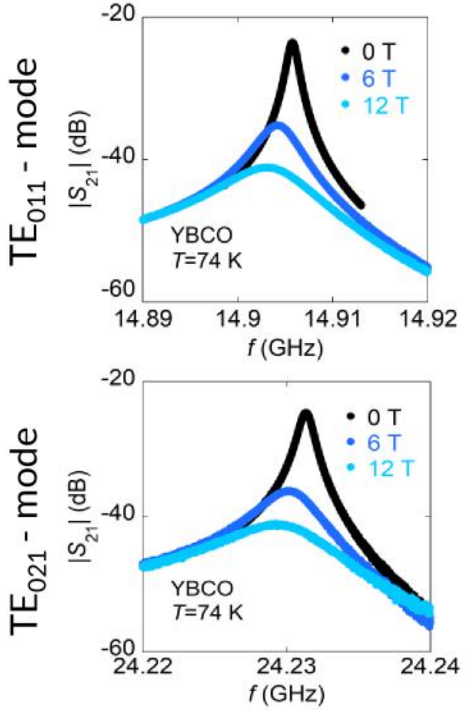
Measurement technique & system

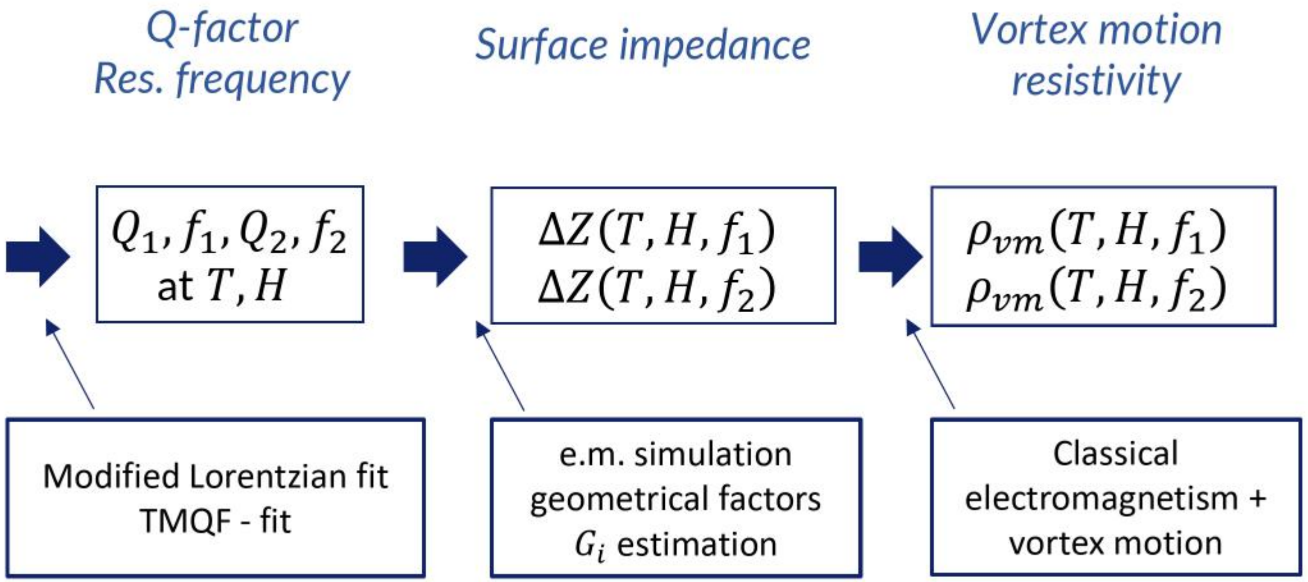
Dielectric loaded resonator





S-parameters





Q-factor Res. frequency

Q_1, f_1, Q_2, f_2 at T, H

Modified Lorentzian fit
TMQF - fit

Surface impedance

$\Delta Z(T, H, f_1)$
$\Delta Z(T, H, f_2)$

e.m. simulation
geometrical factors
G_i estimation

Vortex motion resistivity

$\rho_{vm}(T, H, f_1)$
$\rho_{vm}(T, H, f_2)$

Classical electromagnetism + vortex motion

Pompeo, N. et al., Measurement 184 (2021): 109937
Alimenti, A. et al., IEEE Instrum. Meas. Mag. 24.9 (2021): 12-20
Torokhtii, K. et al., Measurement: Sensors 18 (2021): 100314
Alimenti, A. et al., Meas. Sci. Technol. 30.6 (2019): 065601
Torokhtii, K. et al., Acta IMEKO 9.3 (2020): 47-52
Leong, K. et al., IEEE Trans. Microw. Theory Tech. 50.9 (2002): 2115-2127

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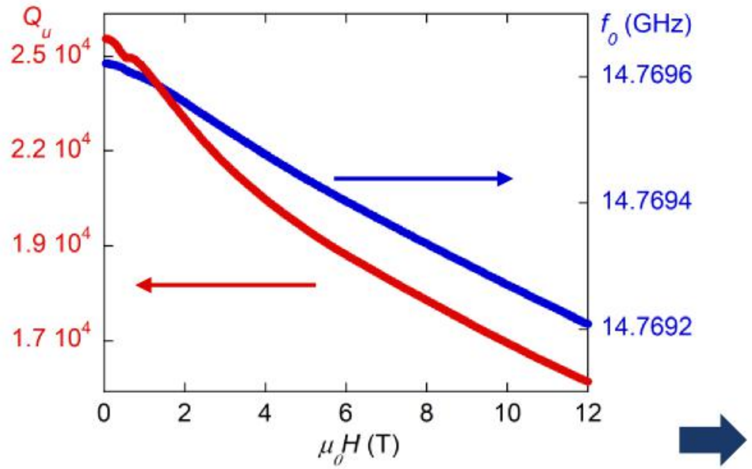
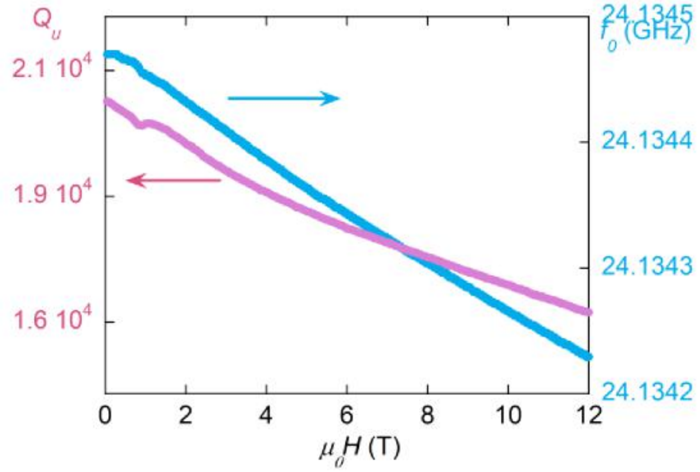
Data elaboration example – REBCO CC 60 K

Q_u & f_0 - 60 K

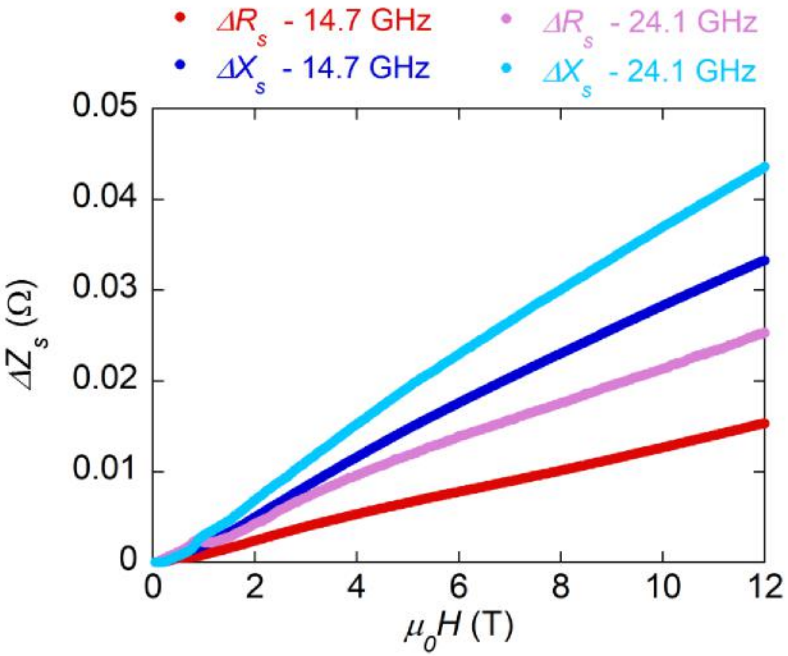
TE_{011}



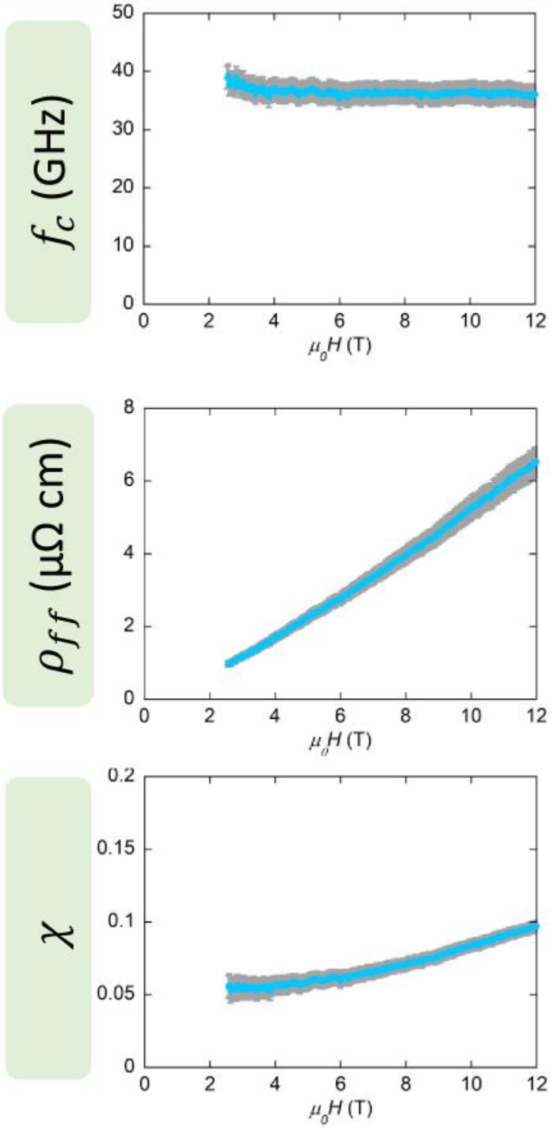
TE_{021}



ΔZ_s - 60 K



Roma Tre group, publication in preparation



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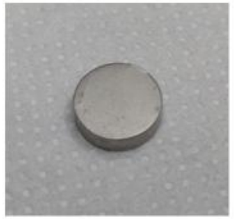
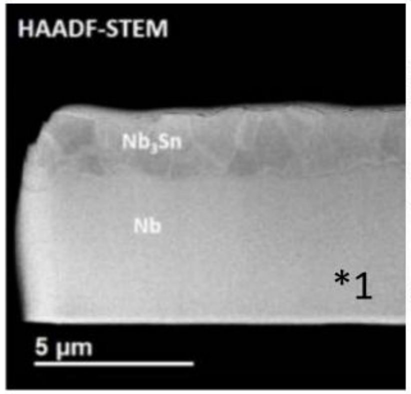
Nb based SCs

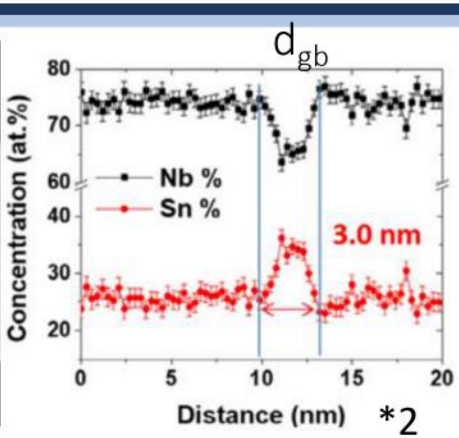
Nb_3Sn and NbTi samples

Nb_3Sn - on - Nb grown by *Vapor Tin Diffusion (VTD)*

- Substrate : large-RRR Nb rolled sheets (≈ 3 mm)
- Coating: polycrystalline Nb_3Sn
  - Thickness d = (2.0 ± 0.6) μm, $d_{gb} = (1.4 \pm 0.6)$ μm
  - Sn - segregation at GBs of $d_{gb} \approx 3$ nm .







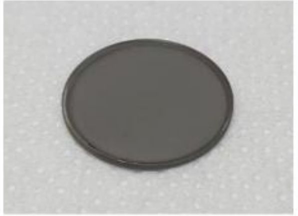
*2

Sources:

1. S. Posen et al., Supercond. Sci. Technol. 34 025007 (2021)
2. J. Lee *et al.*, Acta Materialia, **188**, 155–165 (2020)

Nb_3Sn – on – Cu grown by *DC Magnetron Sputtering* (*DCMS*)

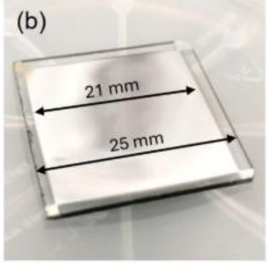
- Substrate : ≈ 2 mm sapphire .
- Coating: polycrystalline
  - Thickness d ≈ 7.5 μm



Fonnesu, D. et al. *Sci. Rep. 16* 3539 (2026)

$Nb_{40}Ti_{60}$ – on – quartz grown by *DC Magnetron Sputtering* (*DCMS*)

- Substrate: ≈ 1.2 mm quartz
- Coating: polycrystalline
  - Thickness d = 2.0 μm



J. Lee *et al., Supercond. Sci. Technol.* **32**, 024001 (2019)
C. Pira *et al.*, “Progress in European Thin Film Activities”, *SRF23’*

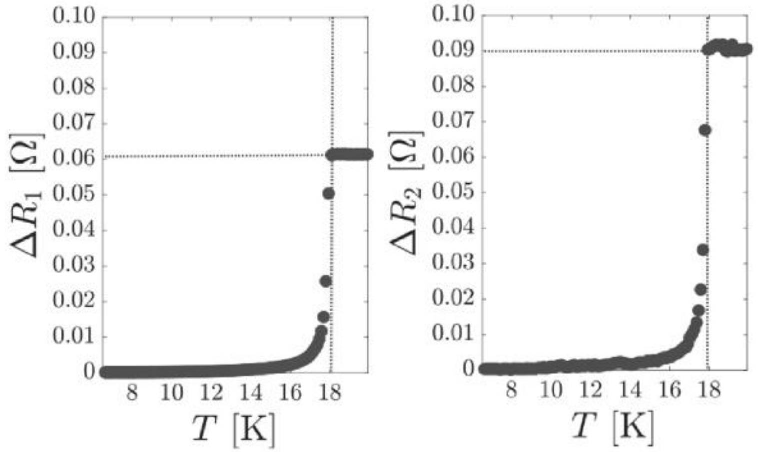
Nb based samples – zero field transitions

Nb_3Sn *(VTD)*

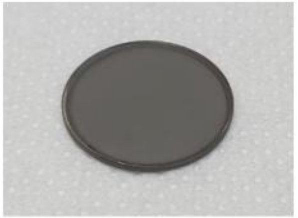
$T_c \simeq$ **18.0** K

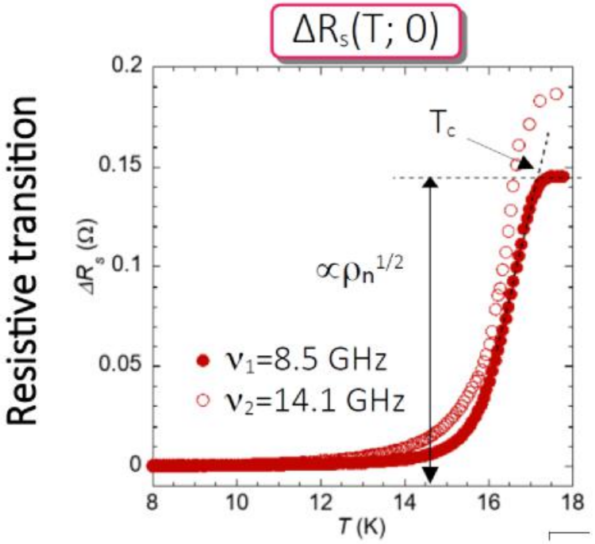
ν_2=14.4 GHz

ν_1=8.5 GHz

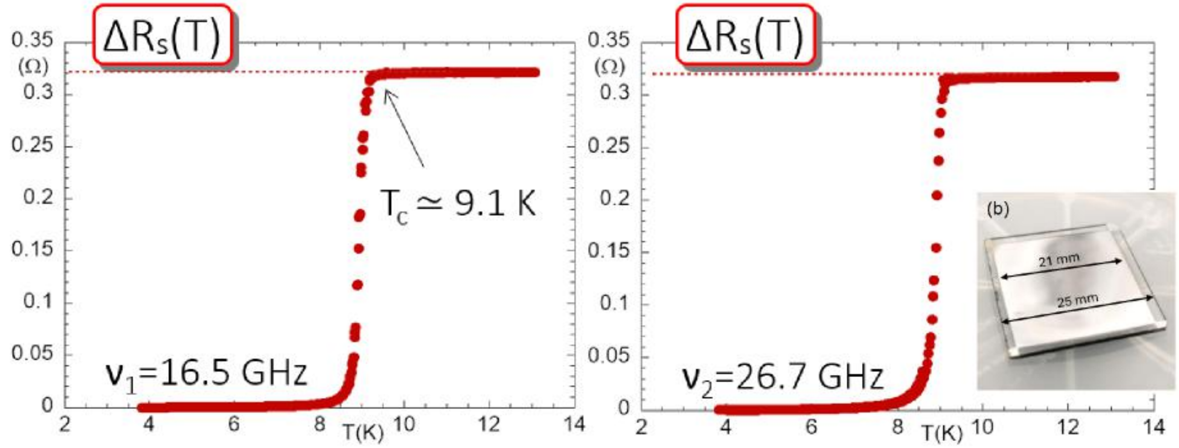


Nb_3Sn (DCMS)

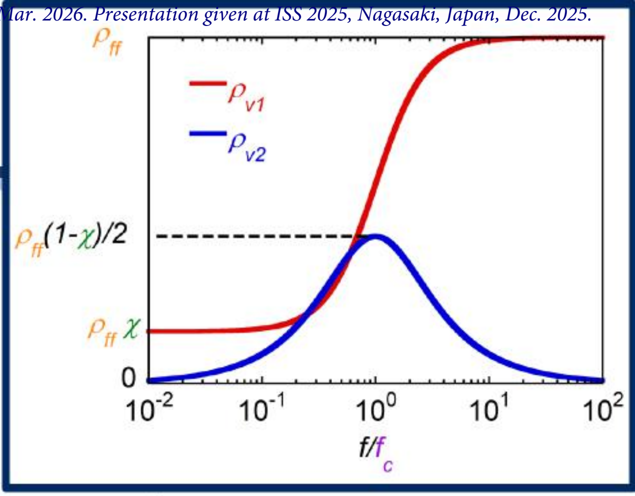




NbTi*(DCMS)*



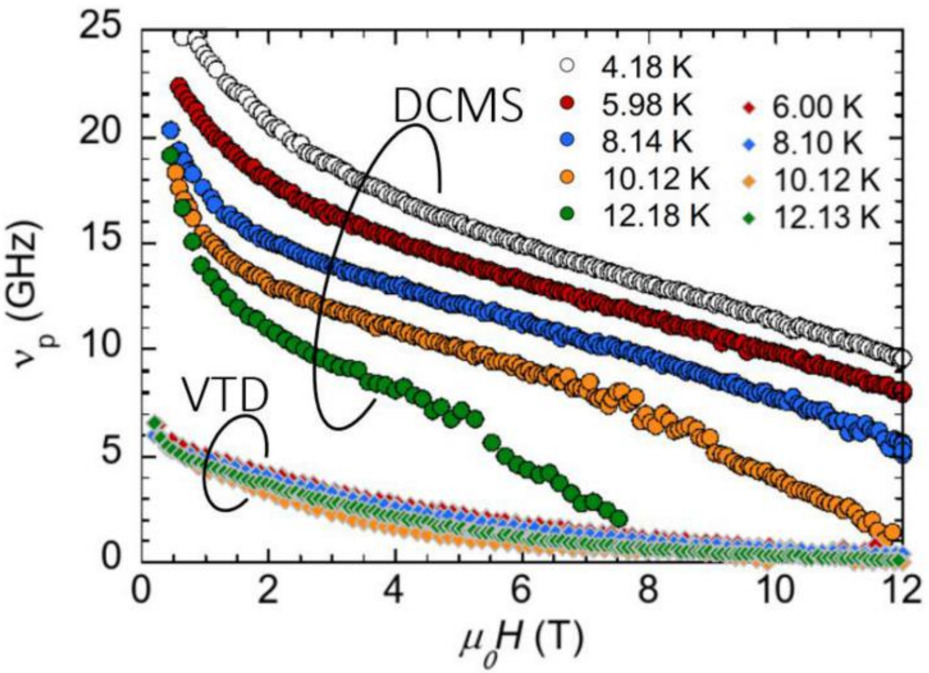
Characteristic frequency



Nb$_3$Sn, DCMS&VTD samples

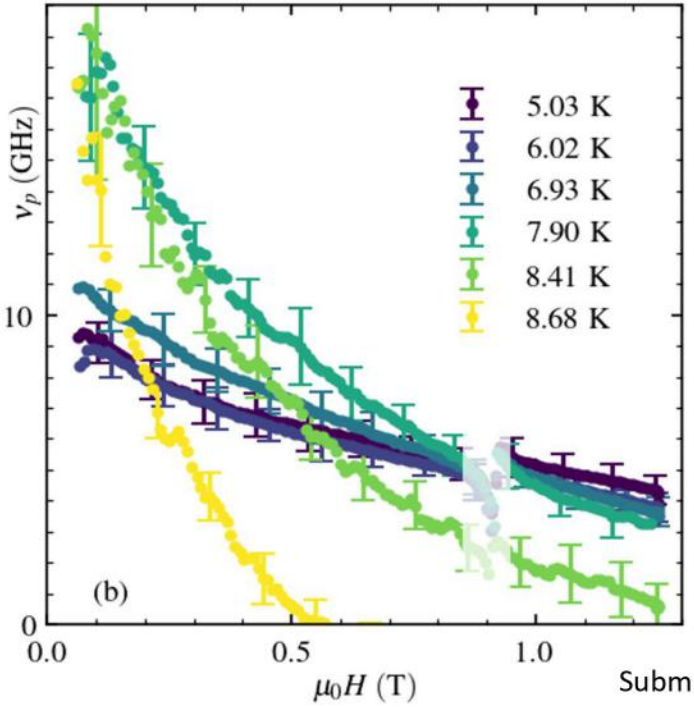
ν_p much larger in DCMS sample
→ significantly improved pinning?
→ dissipation actually reduced?

$$\nu_p \propto k_p \rho_{ff}$$



Data partially available in: Vidal Garcìa, P. et al. , *IEEE Trans. Appl. Supercond*. 36.5 (2026): 3500705

NbTi - DCMS sample



Submitted for publication

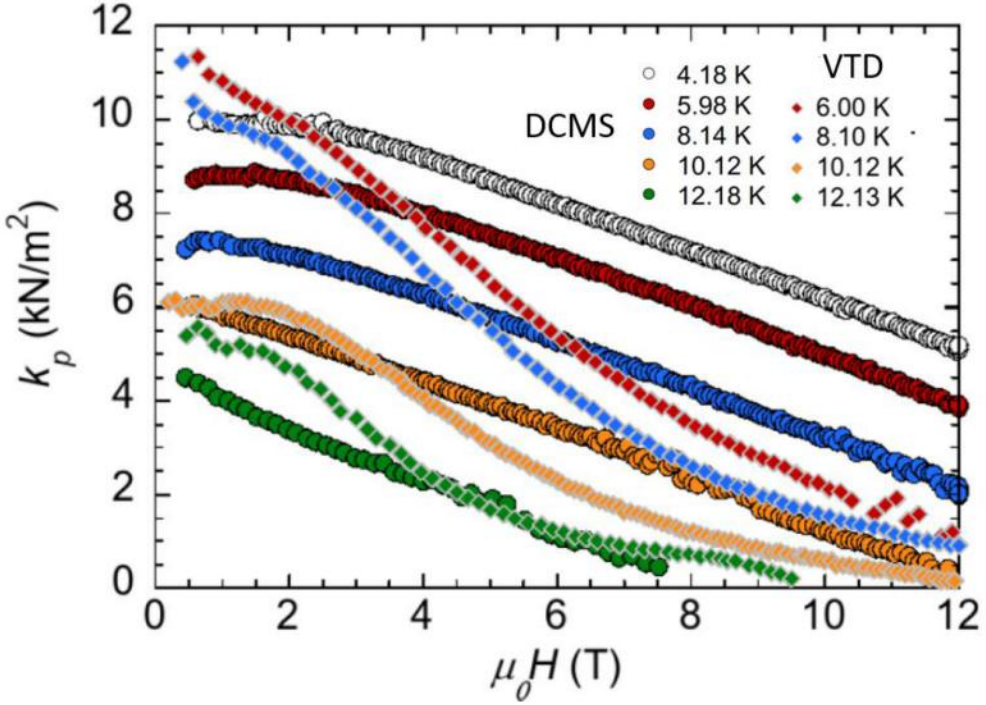
Pinning constant

Nb_3Sn, DCMS&VTD samples

$$k_p\ (DCMS) > k_p(VTP)$$

At medium/high fields

→ promising for high field regimes



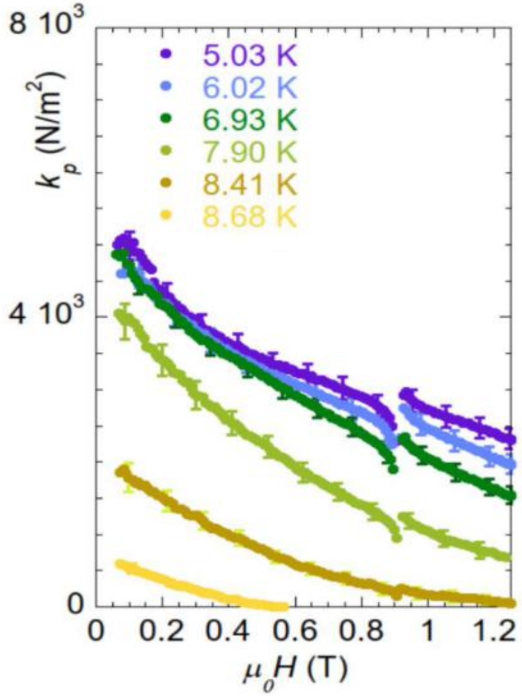
Roma Tre group, publication in preparation

NbTi, DCMSsample

→ k_p depends on fluxon density

→ fluxons are NOT individually pinned by defects

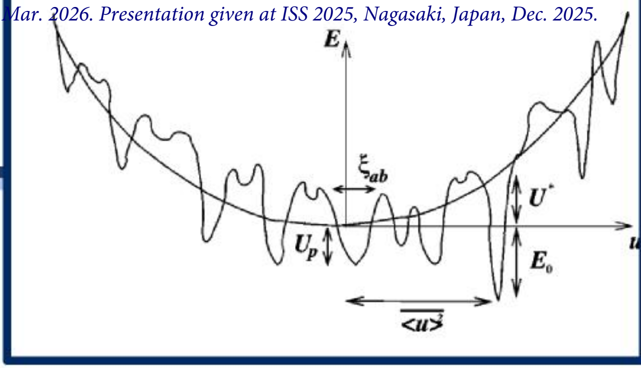
→ collective pinning regime



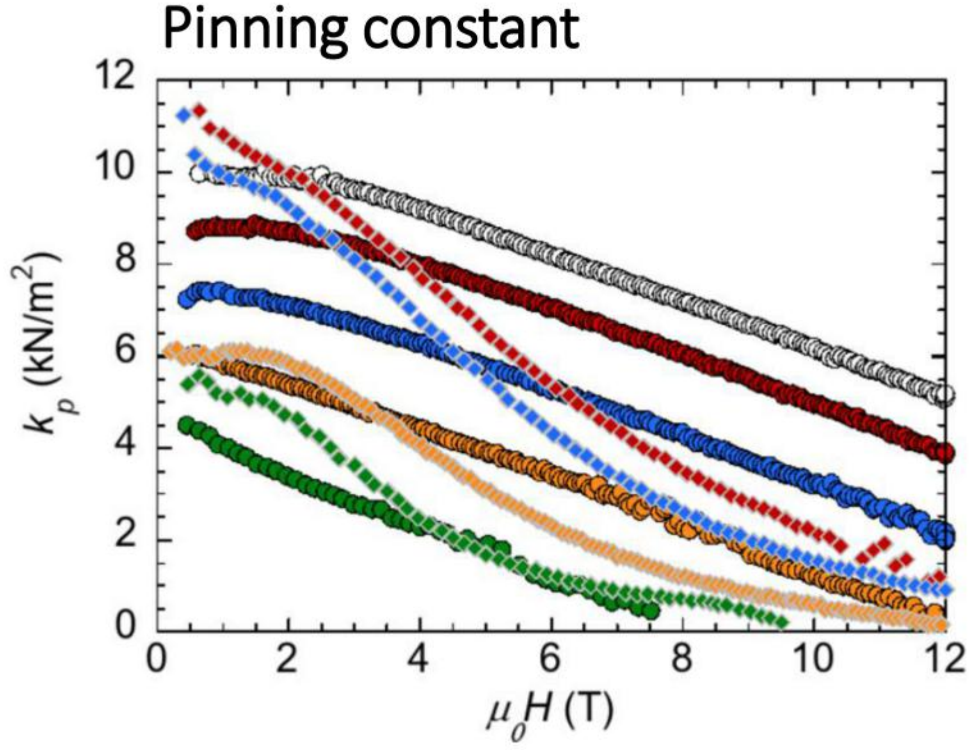
Submitted for publication

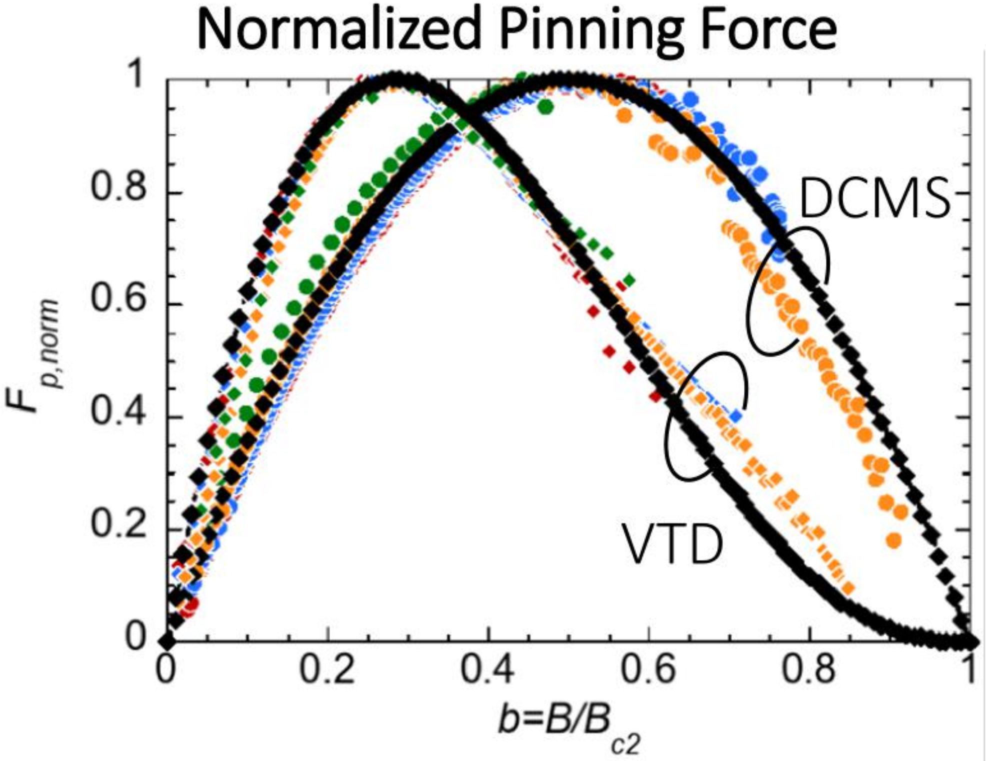
Why the different in field behaviour?...

Pinning force



Source: Kierfeld, J., *Phys. Rev. B* 69.14 (2004): 144513.

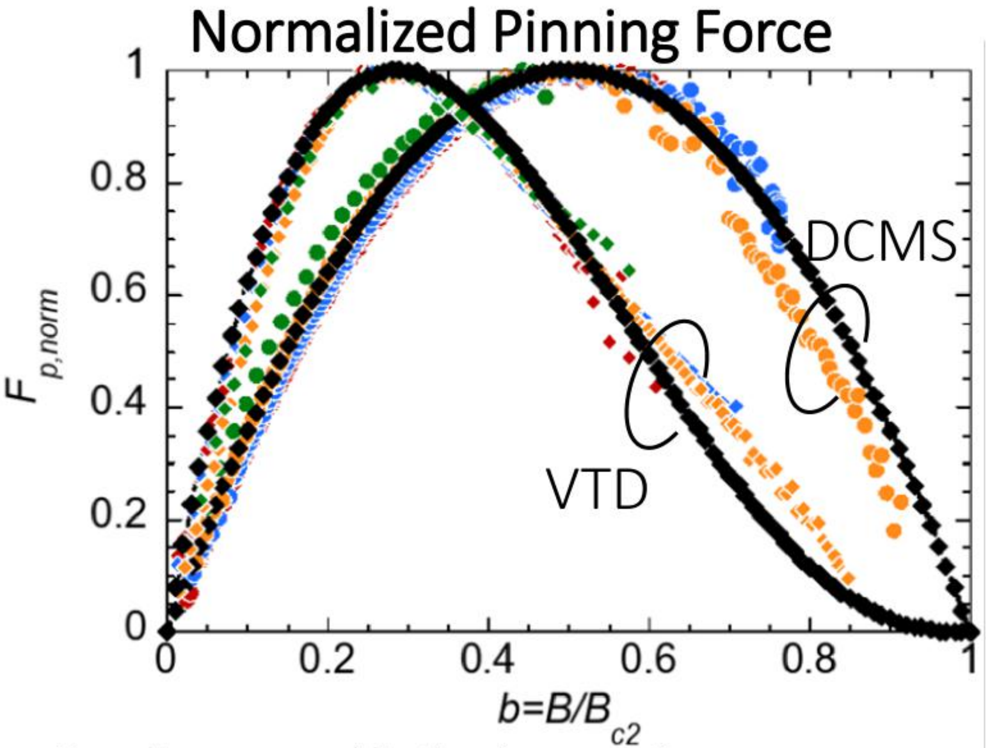




$$F_p = k_p B \xi / \phi_0$$

Roma Tre group, publication in preparation

Nb_3Sn DCMS vs VTD – pinning force comparison



Roma Tre group, publication in preparation

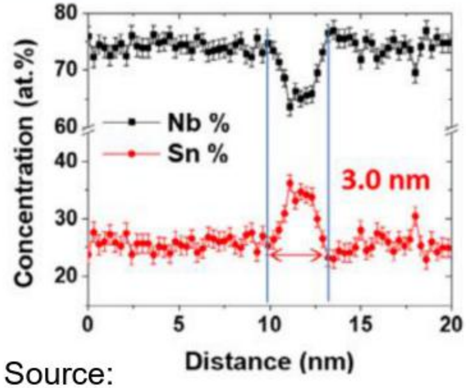
[1] Blair & Hampshire, Phys. Rev. Res. 4, 023123 (2022)

[2] J. Lee et al., Acta Mat. 188, 155 (2020)

[3] D. Dew-Hughes, J, Theor. Experim. and Appl. Phys. 30, 293(1974)

VTD

- DH scaling analysis: $F_p(b)=b^p(1-b)^q$
- Good fit with p=1, q=2.5: weak pinning by normal and thin GB according to computational results for Nb_3Sn [1]
- Consistent with results for GB from APT [2]



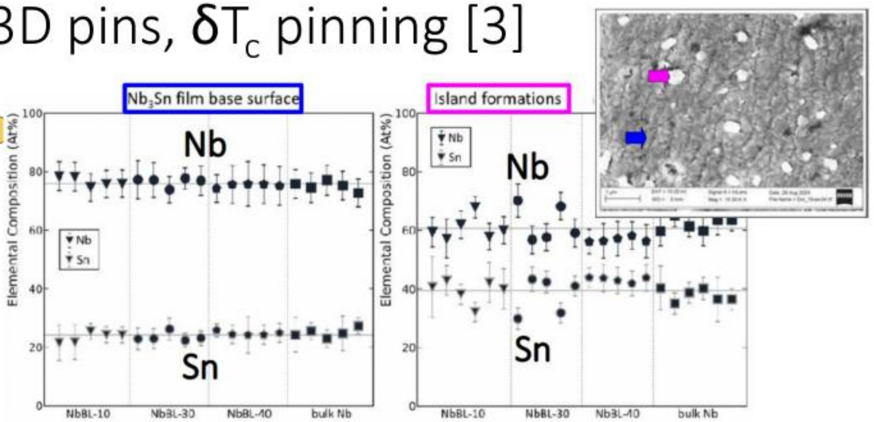
Source:
J. Lee et al., Acta Mat. 188, 155 (2020)

weakly pinning GB, consistent with $\xi_{GL}>d_{gb}$

DCMS

- DH scaling: p=1, q=1 → 3D pins, δT_c pinning [3]

Consistent with Sn-rich islands observed in similar samples



Source:
Fonnesu, D. et al. *Sci. Rep. 16* 3539 (2026)

NbTi – Dew-Hughes pinning analysis

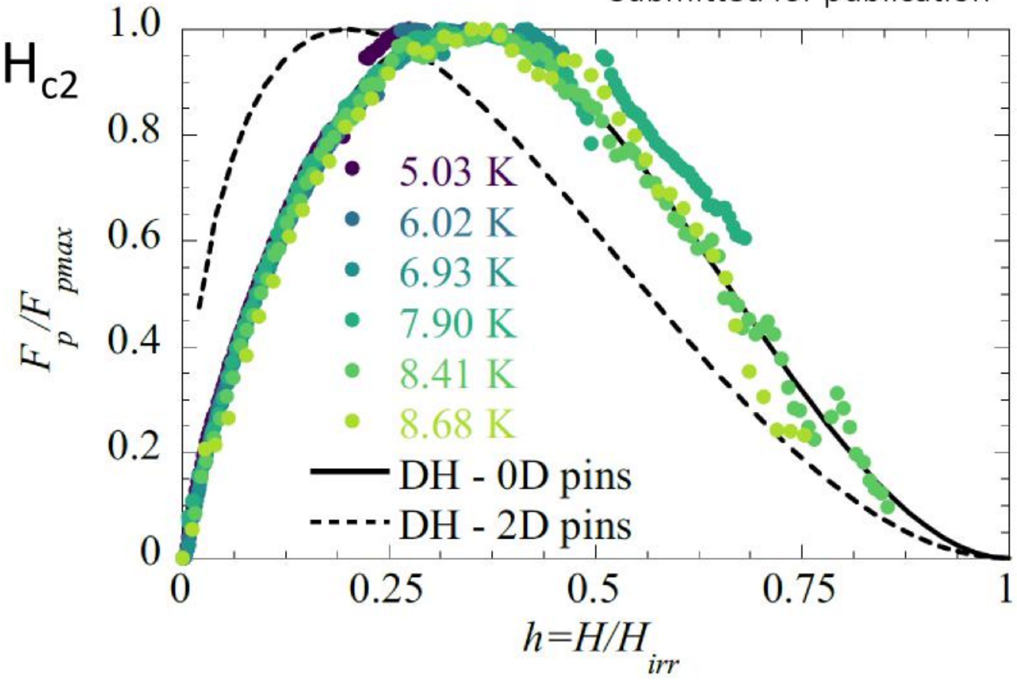
- data satisfactorily scale with a reduced field $H_{irr} \sim 0.6\ H_{c2}$
- Theory: q = 2; p = 0.5 (2D pinning), p = 1 (0D pinning)

- Result: q = 2; p = 1

⇒ point pinning dominates

- Consistent with findings in samples with similar composition

Submitted for publication



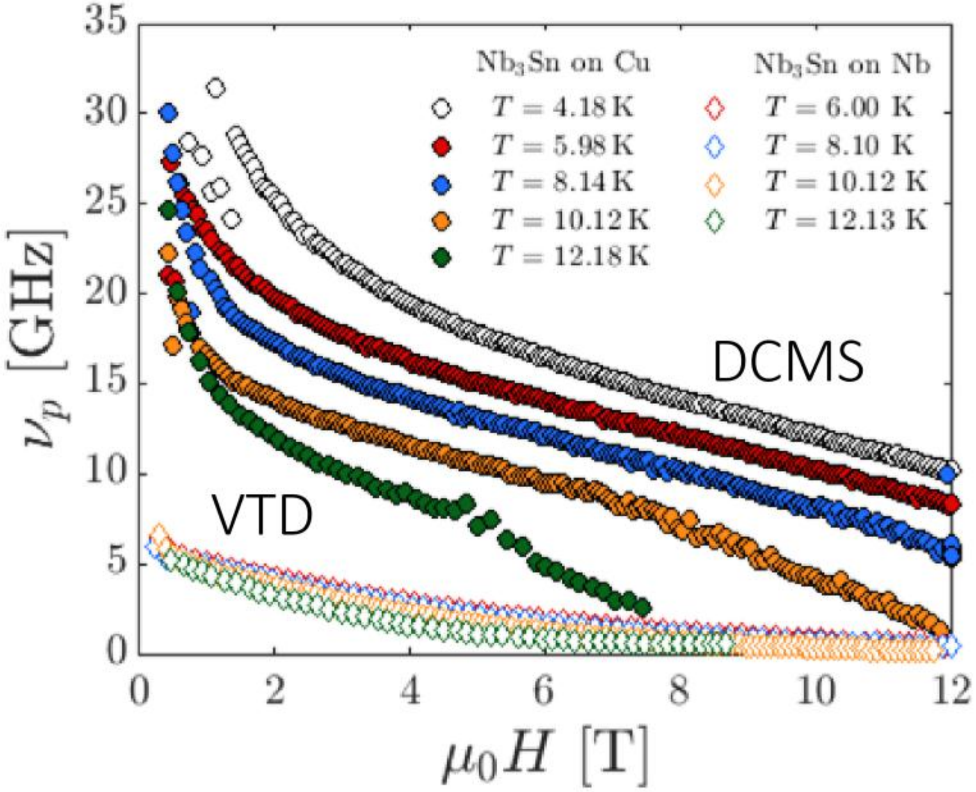
DH analysis: $F_p/F_{p,max} = h^p(1-h)^q$

G, Ghigo et al., Sci. Rep. 13:9315 (2023)

D. Dew-Hughes, Philos. Mag. A J. Theor. Exp. Appl. Phys. 30, 293 (1974)

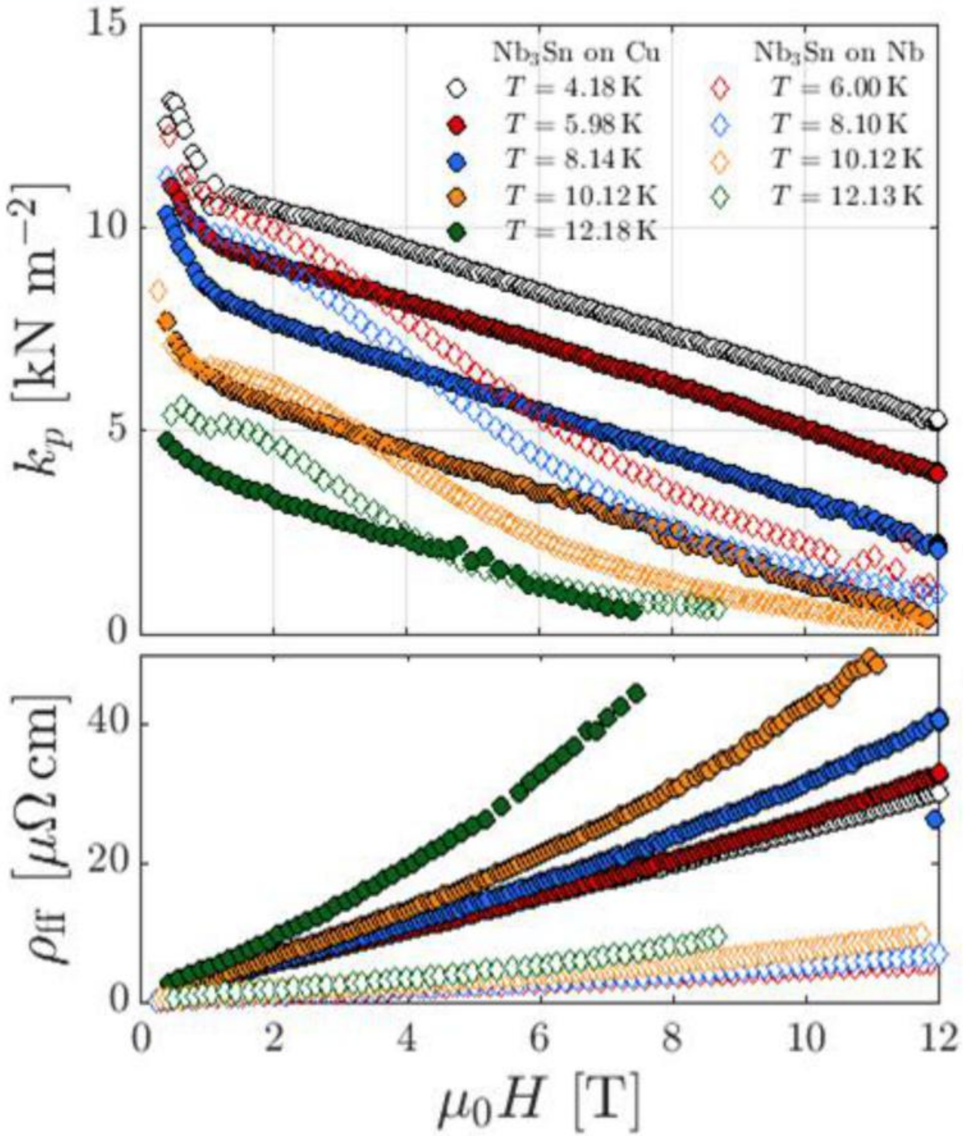
Nb_3Sn DCMS vs VTD– vortex parameters comparison

Pinning frequency



Roma Tre group, publication in preparation

ν_p much larger in DCMS sample



Pinning constant

- Low H: comparable
- High H: improved in DCMS

Flux flow resistivity

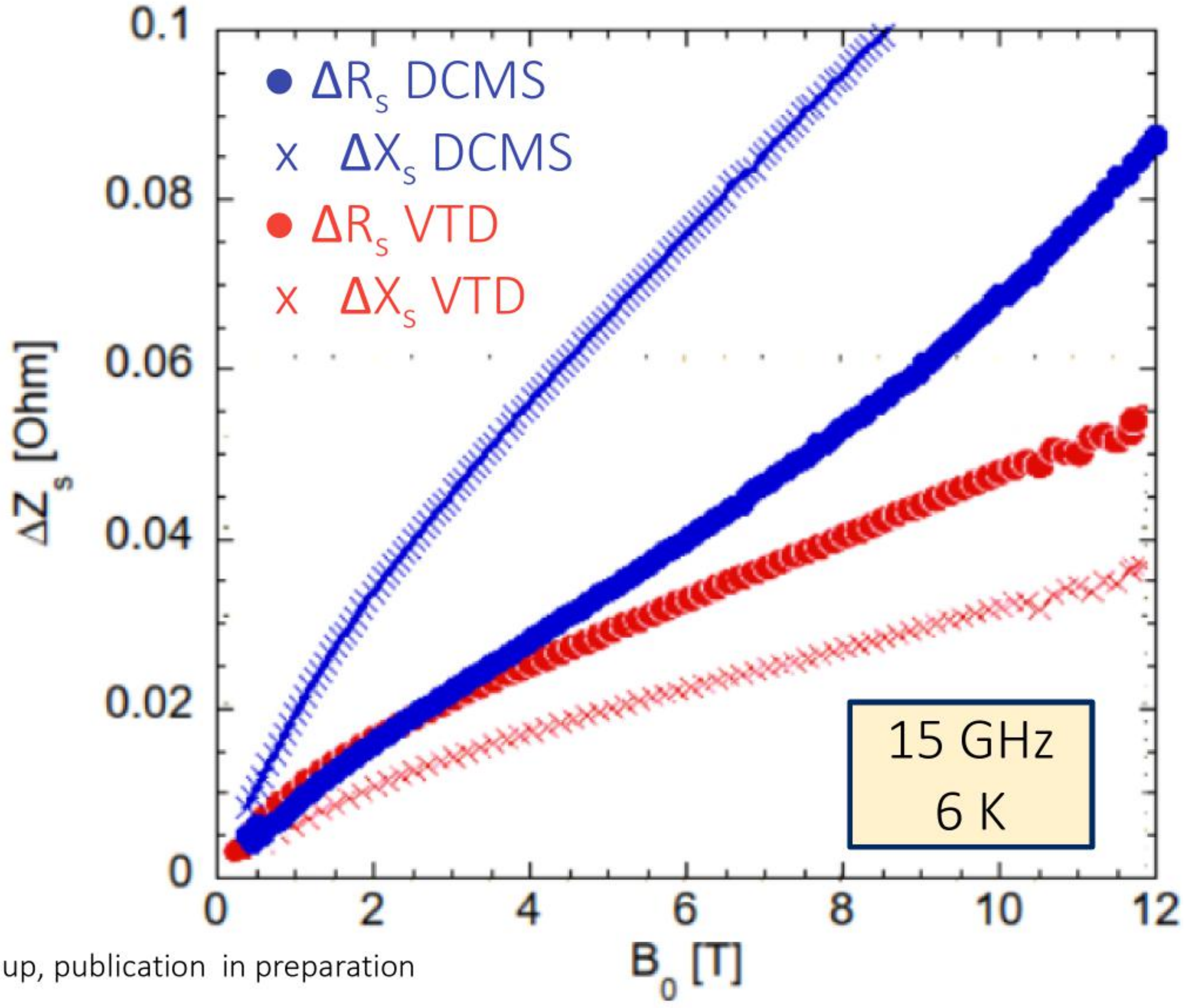
- Pronounced
- increase in DCMS

⇓

GB in DCMS with increased pinning and scattering times?

IEEE-CSC, ESAS and CSSJ SUPERCONDUCTIVITY NEWS FORUM (global edition), Issue No. 63, Mar. 2026. Presentation given at ISS 2025, Nagasaki, Japan, Dec. 2025.

Nb_3Sn DCMS vs VTD – ΔZ_s comparison



Roma Tre group, publication in preparation

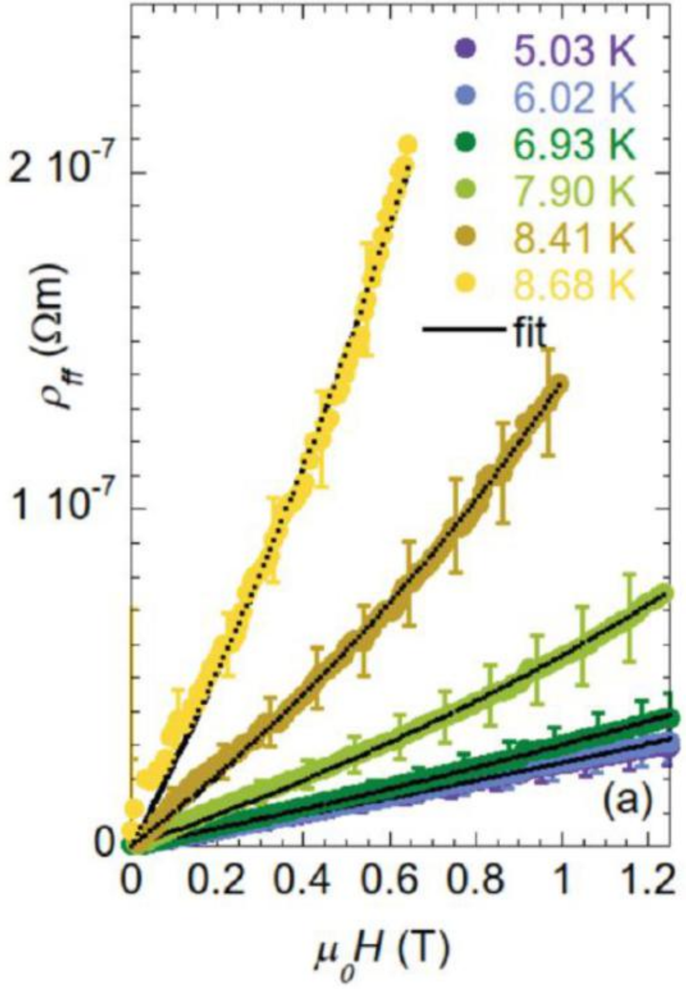
Surface resistance
(dissipation level)
- DCMS > VTD
- → need to reduce flux flow resistivity

Surface reactance
- DCMS >> VTD
- → stronger pinning in DCMS

need to optimize deposition process on Cu by DCMS to retain pinning but reduce scattering times/flux flow resistivity

IEEE-CSC, ESAS and CSSJ SUPERCONDUCTIVITY NEWS FORUM (global edition), Issue No. 63, Mar. 2026. Presentation given at ISS 2025, Nagasaki, Japan, Dec. 2025.

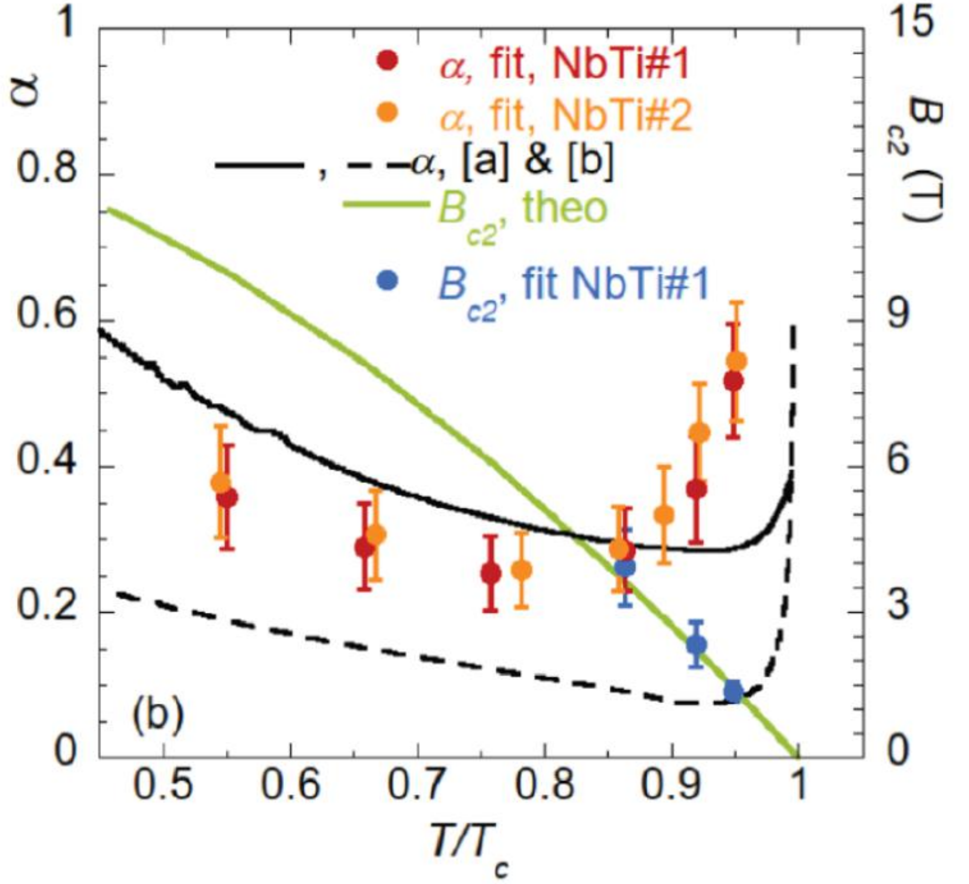
Flux flow resistivity in NbTi



Submitted for publication

$$\rho_{ff} = \rho_n \frac{\alpha B}{(\alpha - 1)B + B_{c2}}$$

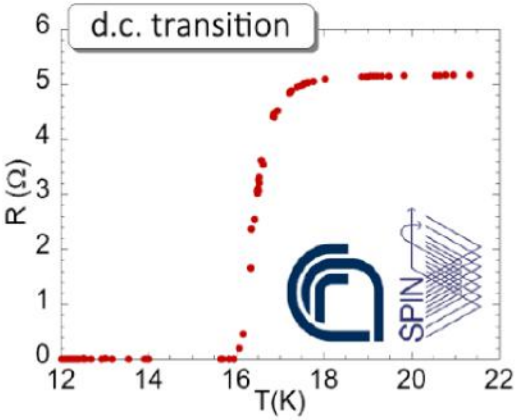
TDGL in excellent agreement with the experimental data



[a] A. Vargunin and M. A. Silaev, PRB 96, 214507 (2017)
[b] N. Kopnin, Theory of Nonequilibrium Superconductivity (2001)

Fe(Se,Te)

Fe(Se,Te) samples

	$Fe(Se_{0.5},Te_{0.5})$ - pristine
T_c	18 K
thickness	240 nm
ρ_n	~ 300 µΩ·cm
Deposition	PLD
ref.	A. Palenzona et al., SuST 25 115018 2012 V. Braccini et al., APL 103 172601 2013
	

$T_{onset} - T_{zero} = 0.6$ K

RRR=1.1

+EELS: cluster with different stoichiometry (Tc)

Fe(Se,Te): high field single-to-collective-pinning crossover

High field measurements, H//c-axis

- increases with H up to a few tesla

- decreases at high H
 → pinning strength depends on vortex density, vortex-vortex interactions affect the dynamics

High fields - collective pinning:

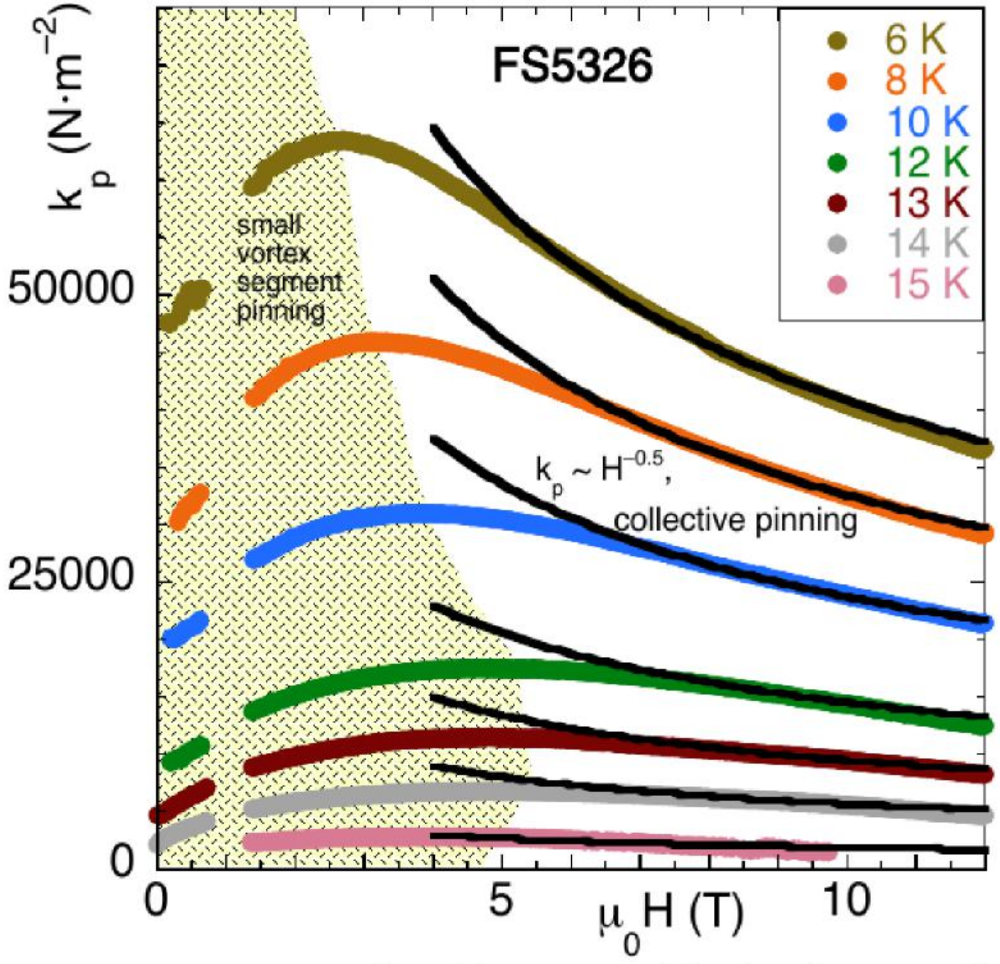
- vortex bundles interacting with weak pins

Golosovsky et al., Supercond. Sci. Technol. 9 1 1996
Campbell, J. Phys. Condens. Matter 4 3186 1971

Crossover from single to collective pinning
(observed also at few T through d.c. resistive transitions)

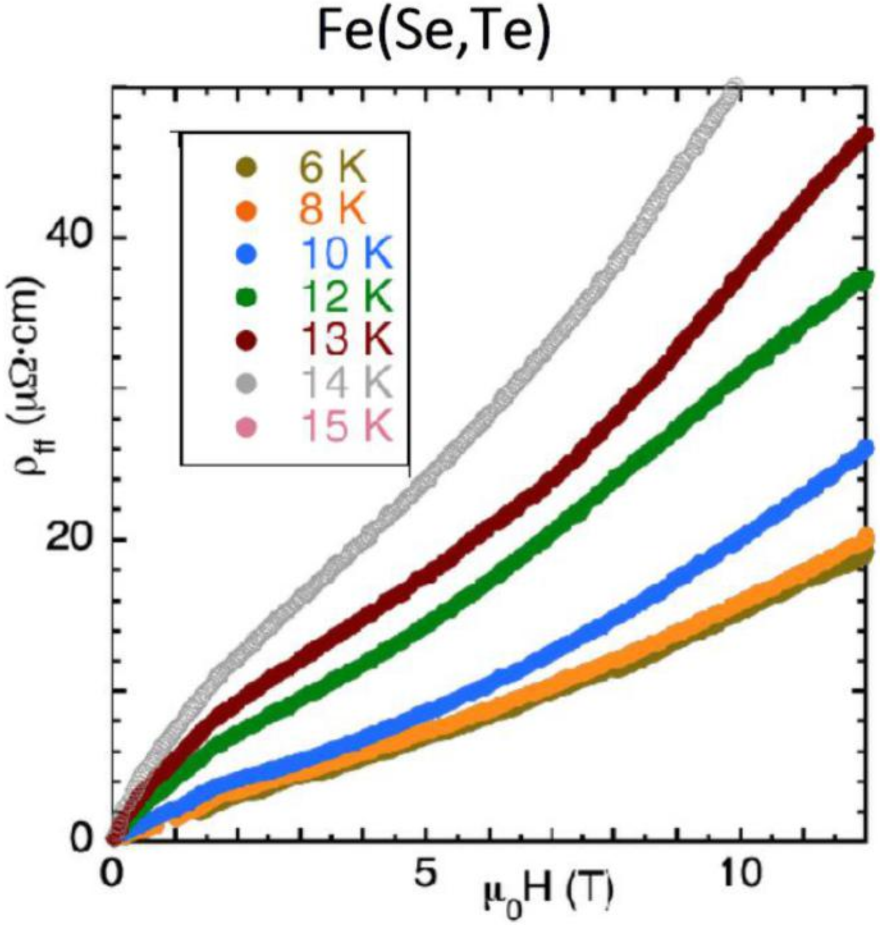
Leo et al., Supercond. Sci. Technol. 28 125001 (2015)
M. Scuderi et al., Sci. Rep. 11 20100 (2021)

pinning constant k_p vs H



Roma Tre group, publication in preparation

Flux-flow in Fe(Se,Te)



Anomalous behavior

$$\rho_{ff} \simeq \phi_0 B / \eta$$

$$\eta = \pi \bar{h} n \omega_c \tau$$

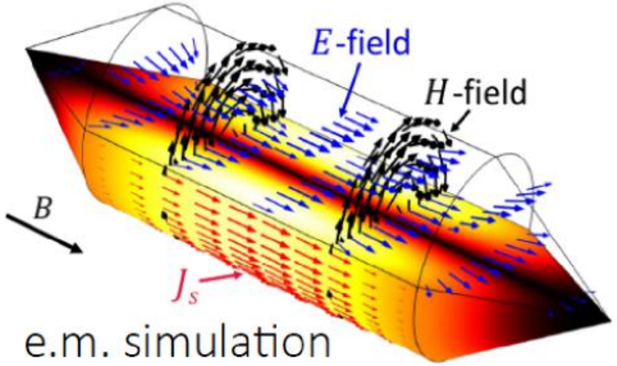
Golosovsky, Supercond. Sci. Technol. 9 (1996)

τ: QP scattering time in the vortex cores
ω_c: cyclotron frequency

Roma Tre group, publication in preparation

SC haloscope performance - model

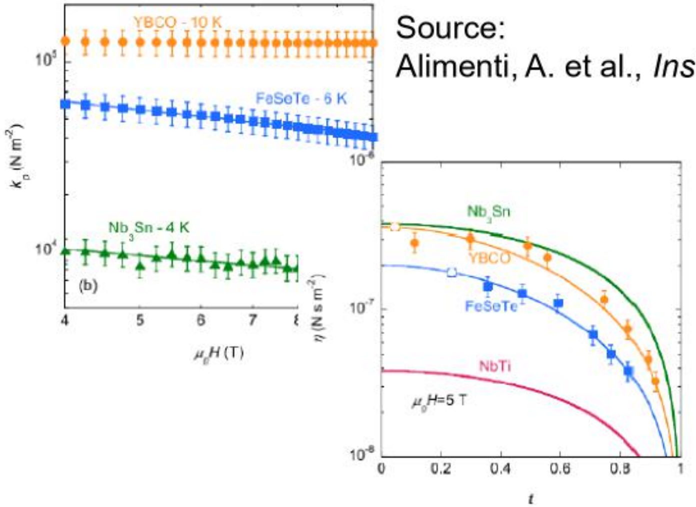
Real structure*



e.m. simulation

$$\frac{1}{Q} = \frac{R_{s,cyl}}{G_{cyl}} + \frac{R_{s,cones}}{G_{cones}}$$

Haloscope Q factor



Source:
Alimenti, A. et al., *Instruments* 6.1 (2021): 1.

Input: measured Vortex parameters

$$\rho_{vm} = \rho_{ff} \frac{1 + \mathrm{i}\frac{\nu_p}{\nu}}{1 + \left(\frac{\nu_p}{\nu}\right)^2}$$

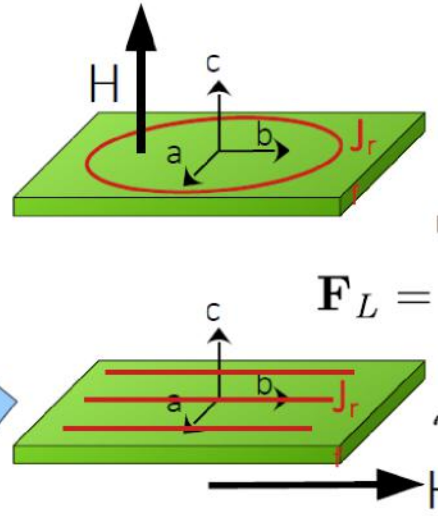
$$\tilde{\rho} = \frac{\rho_{vm} + \mathrm{i}\frac{1}{\sigma_2}}{1 + \mathrm{i}\frac{\sigma_1}{\sigma_2}}$$

$$\Downarrow$$

$$R_{s,cyl} = \mathrm{Re}\left(\sqrt{\mathrm{i}2\pi\nu\mu_0\tilde{\rho}}\right)$$

Surface resistance model

Alimenti et al, Instruments 6 1 (2022)



measurement
setup
max. Lorentz force

$$\mathbf{F}_L = \mathbf{J}_{rf} \times \mathbf{\Phi}_0$$

Haloscope
“force free” config.

Field H orientation wrt
J_{rf} & crystallographic axes

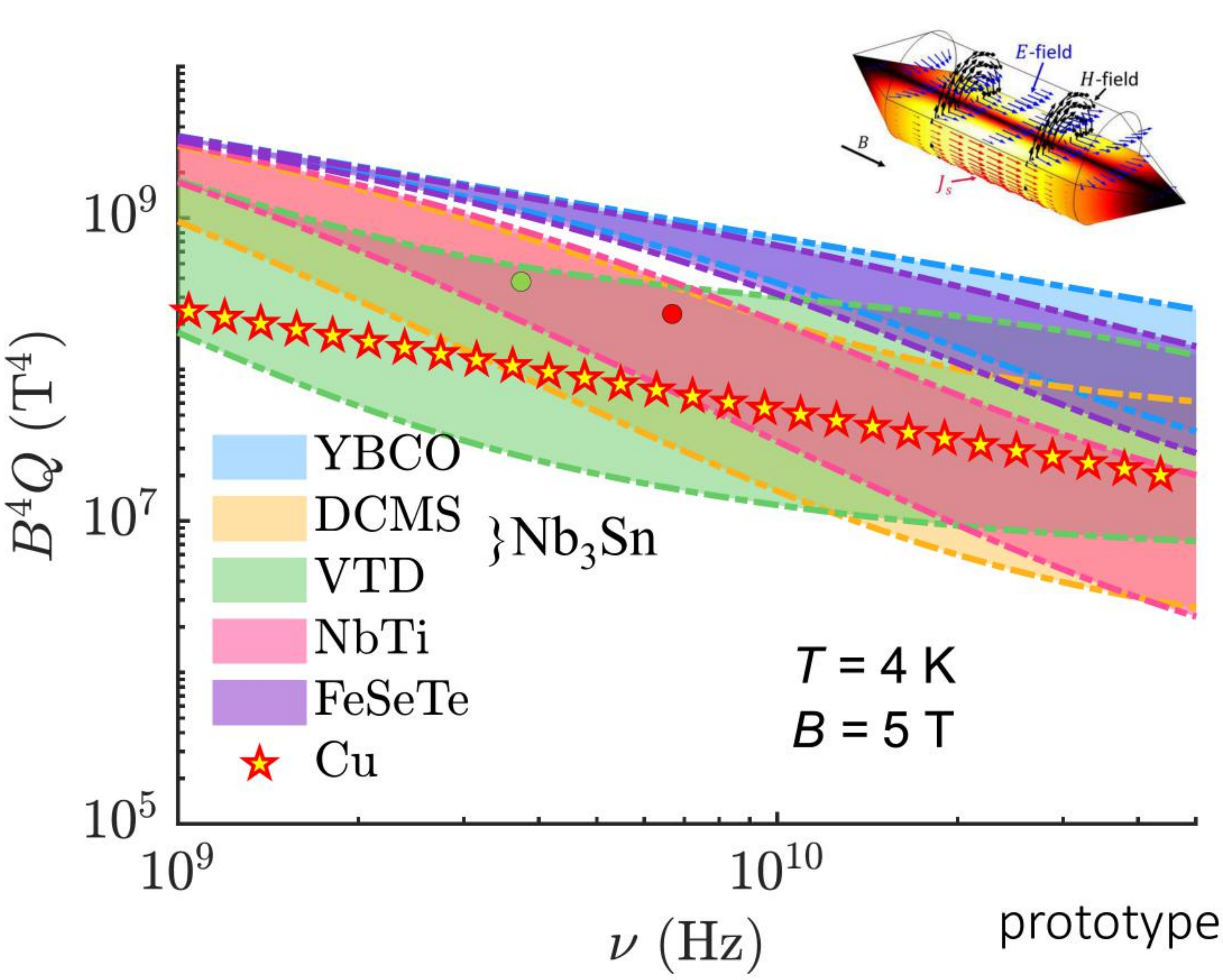
* D. Alesini et al., PRD 99, 101101 (2019)
D. Gioacchino et al., IEEEtas 29, 3500605 (2019)
G. Marconato et al., IEEETas 34, 0600706 (2024)

IEEE-CSC, ESAS and CSSJ SUPERCONDUCTIVITY NEWS FORUM (global edition), Issue No. 63, Mar. 2026. Presentation given at ISS 2025, Nagasaki, Japan, Dec. 2025.

Outline

- Introduction: haloscopes and the need for low R_s materials
- Physical background: high frequency vortex motion
- Surface impedance in the mixed state and measurement technique
- Samples:
  - Nb-based: Nb_3Sn, NbTi
  - Fe(Se,Te)
- Results:
  - Pinning regimes
  - Flux flow
- Conclusion: SC haloscope performance estimation

SC haloscope performance estimation



The front runners: NbTi, Nb_3Sn

- ✅ Established technology for $H=0$
- ✅ Microwave physics: currently explored
- ⚠️ Coating for high H to be optimized

The outsider: Fe(Se,Te)

- ✅ Possible direct deposition
- ⚠️ Microwave vortex physics: beginning

The high Tc competitor: RE-BCO tapes

- ✅ Established technology (for dc)
- ⚠️ Microwave physics known
- ✅ Delaminated and gluing CC tapes

(updated) A. Alimenti et al., Instruments 6 1 (2021)

prototypes

● Nb_3Sn - S. Posen *et al.*, Phys. Rev. App. **20**, 034004 (2023)

● NbTi - G. Marconato *et al.*, IEEE Trans. Appl. Supercond. **34**, 0600706 (2024)

Roma Tre

Physics of superconductors for haloscopes: the cases of NbTi, Nb3Sn and Fe(Se,Te)

THANK YOU FOR THE ATTENTION!

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