



AC susceptibility analysis of coated conductor tapes

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Markus Bauer

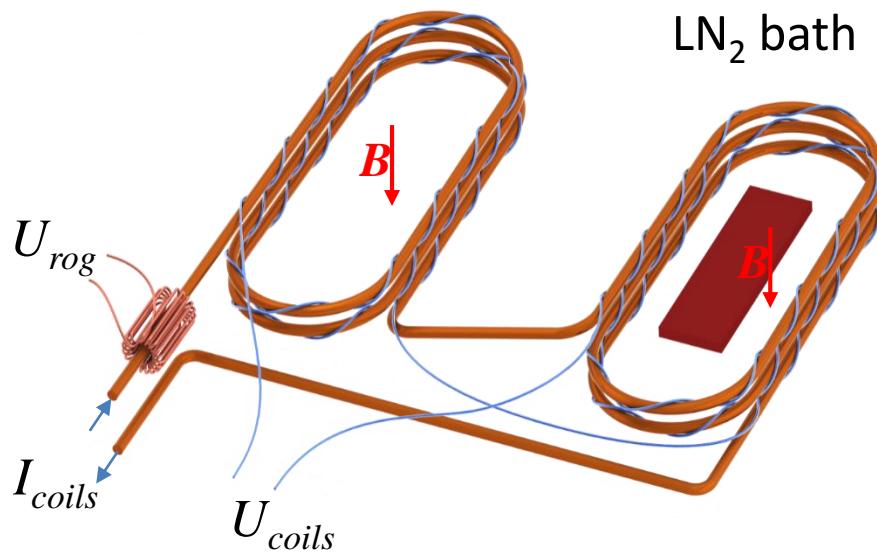
(THEVA Dunnschichttech GmbH, D-85737 Ismaning, Germany)

Martina Falter, Michael Bäcker

(Deutsch Nanoschicht GmbH, D-53359 Rheinbach, Germany)

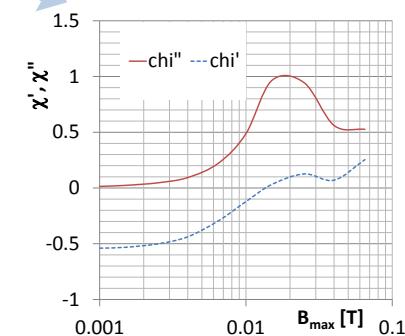
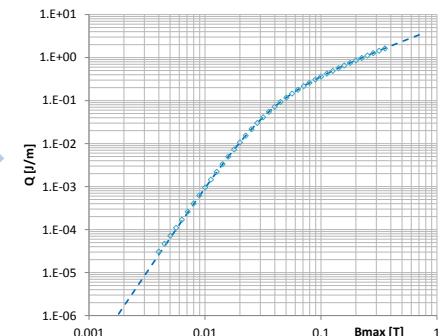
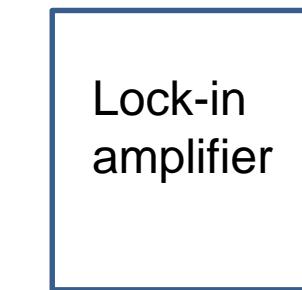
Motivation

Analysis of AC loss behavior of industrially produced CC tapes (sample length ~ 20 cm)



LN₂ bath

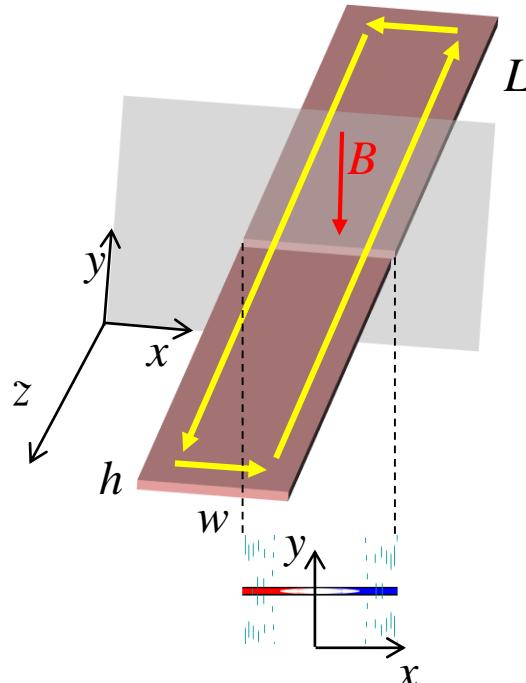
$$B = B_{\max} \cos(2\pi ft)$$



both real and imaginary output channel used

Theory for thin strip

CC tape in perpendicular field \rightarrow thin superconducting strip ($L \gg w \gg h$)

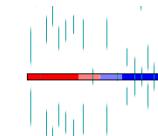


E.H. Brandt, Phys. Rev. B 54 (1996) 4246–4264

magnetic moment (per unit length)

$$\frac{m}{L} = - \int_S j_z x dS_{xy} \quad [\text{Am}]$$

at saturation state:

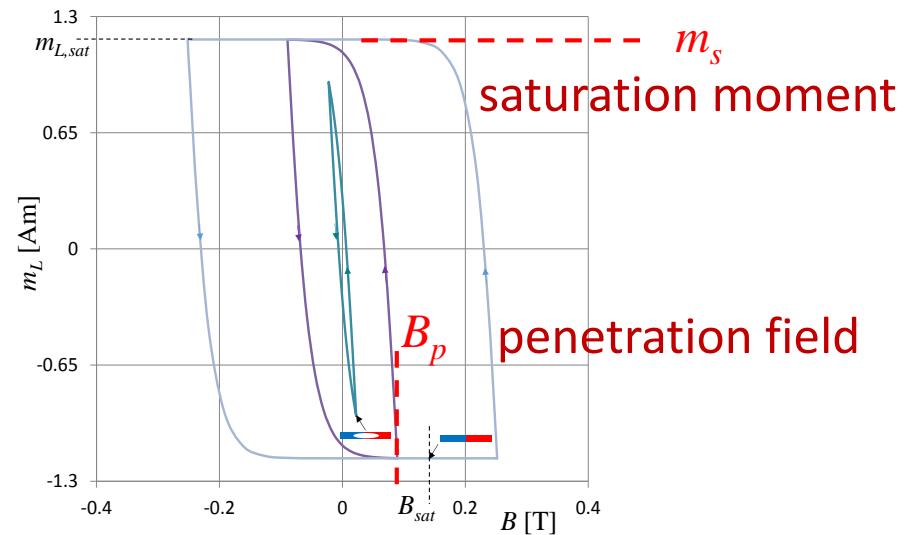


$$\frac{m_s}{L} = \int_S j_c x dS_{xy}$$

useful tool to study the critical current density in contactless way

AC magnetization

magnetization loop(s) $m(B)$:



Critical current: $I_c = j_c wh$

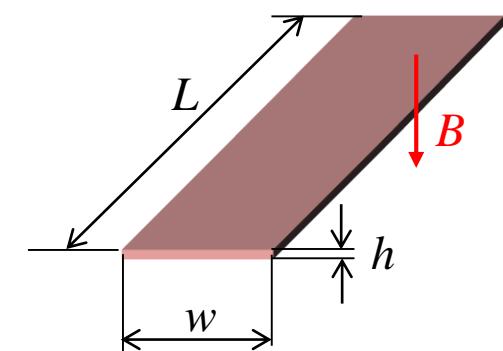
Penetration field:

$$B_p = \frac{\mu_0 j_c h}{\pi} = \frac{\mu_0 I_c}{\pi w}$$

Saturation moment:

$$\frac{m_s}{L} = \frac{j_c h w^2}{4} = \frac{I_c w}{4}$$

$$L \rightarrow \infty$$



AC magnetization

Complex AC susceptibility:

imaginary part (loss):

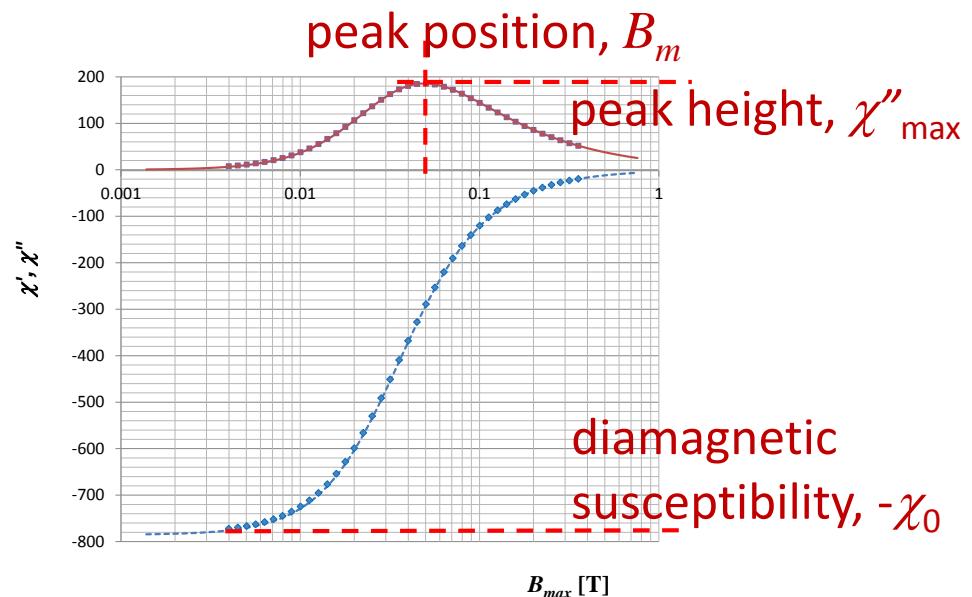
$$\chi'' = \frac{\mu_0}{VB_{\max}^2} \frac{1}{\pi} \int m(t) dB(t)$$

volume

real part (shielding):

$$\chi' = \frac{\mu_0}{VB_{\max}^2} \frac{2}{T} \int_0^T m(t) B(t) dt$$

$$V = Lhw$$



AC magnetization

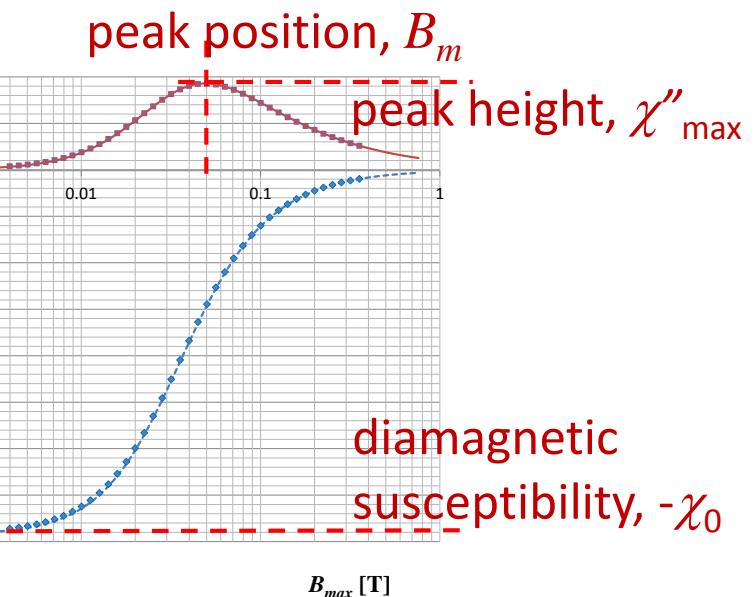
Ideal (uniform) thin strip:

$$\chi''_{\max} = 0.2365 \chi_0 = 0.1857 \frac{w}{h}$$

$$\chi_0 = \frac{\pi}{4} \frac{w}{h}$$

$$0.9711 \frac{w}{h}$$

χ', χ''



$$B_m = 2.465 B_p = 9.86 \times 10^{-7} \frac{I_c}{w}$$



AC magnetization

Ideal (uniform) thin strip:

$$\chi''_{\max} = 0.2365 \chi_0 = 0.1857 \frac{w}{h}$$

$$\chi_0 = \frac{\pi}{4} \frac{w}{h}$$

Experimental susceptibility data:

$$\chi \propto \frac{m}{V} = \frac{m}{Lwh}$$

known L

Comparing theory to experiment:

$$B_m = 2.465 B_p = 9.86 \times 10^{-7} \frac{I_c}{w}$$

arbitrary h

unique w

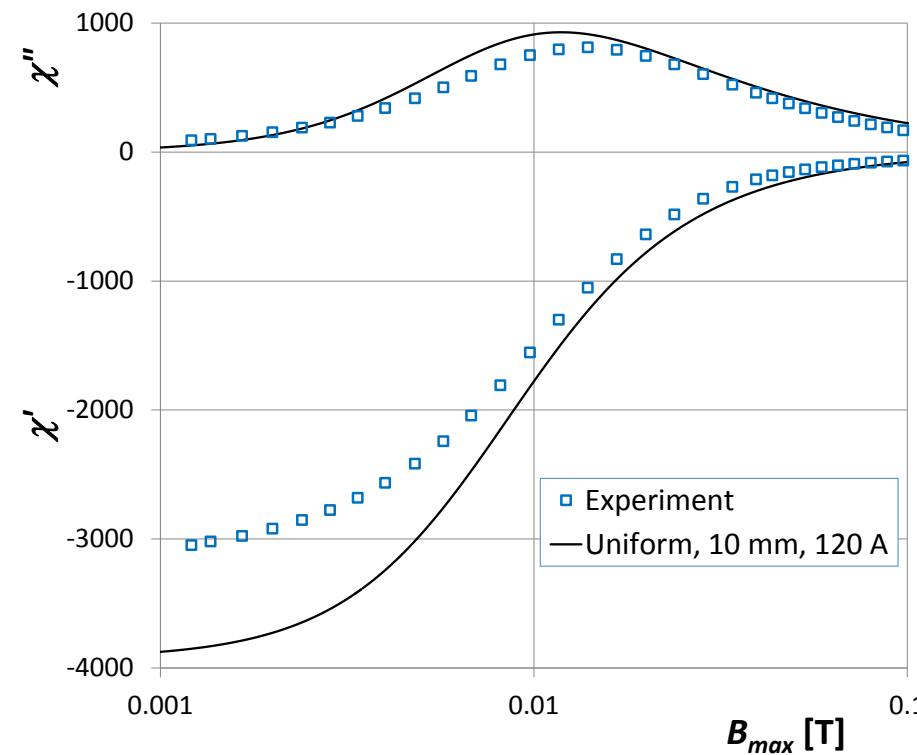
unique I_c

for the ideal strip



CC tape A

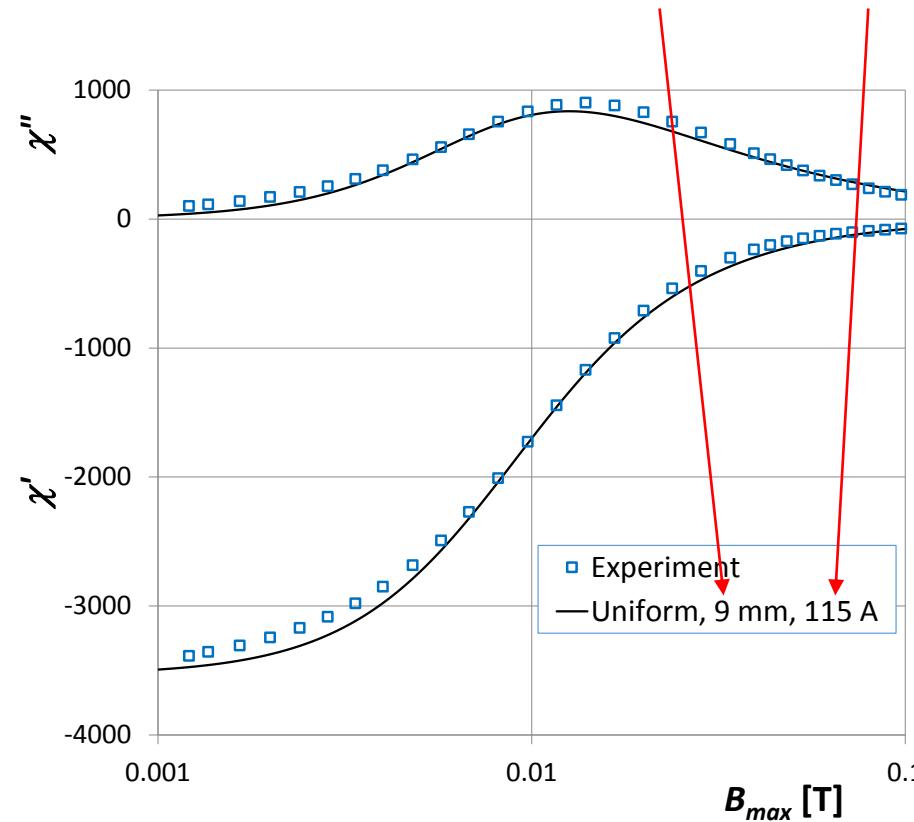
THEVA, (ISD process) $h: 2 \mu\text{m}$, $w = 10 \text{ mm}$, $I_c = 120 \text{ A}$





CC tape A

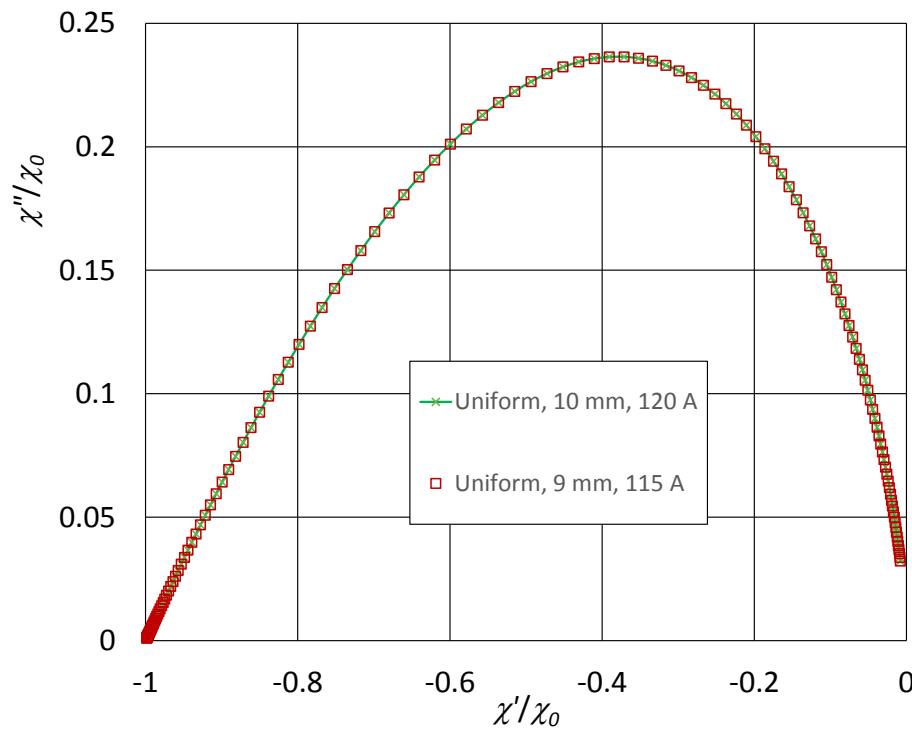
THEVA, (ISD process) $h: 2 \mu\text{m}$, $w = 10 \text{ mm}$, $I_c = 120 \text{ A}$



Could this be correct?

Cole-Cole plot

perfect tool for analysing the form of AC susceptibility dependence



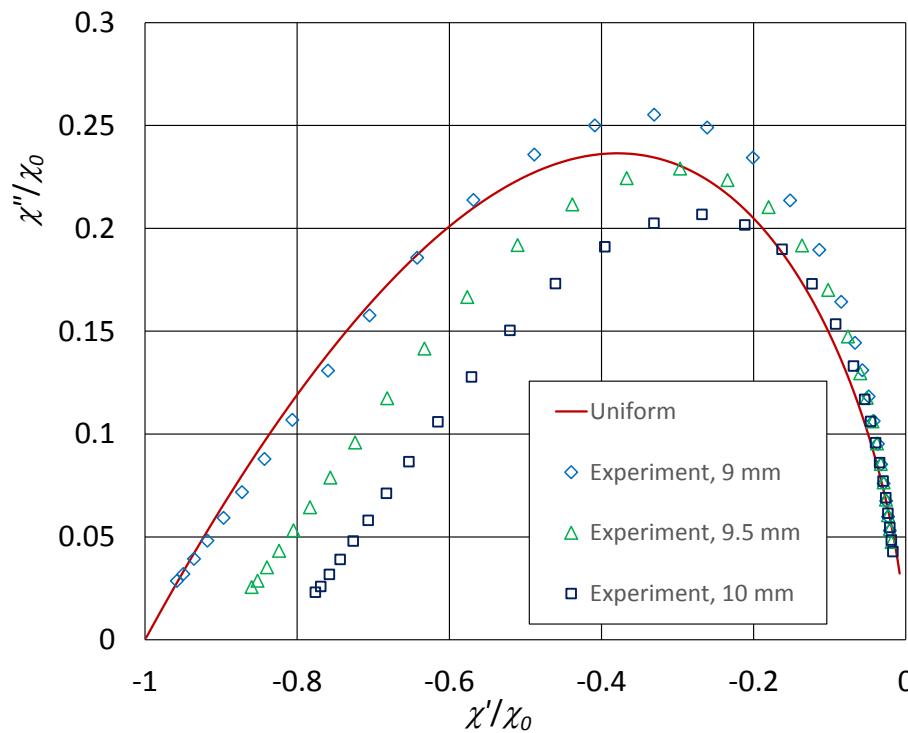
data for all uniform strips
fall on one common curve



CC tape A

THEVA, (ISD process) $h: 2 \mu\text{m}$, $w = 10 \text{ mm}$, $I_c = 120 \text{ A}$

Cole-Cole plots: sensitive to w because of scaling with χ_0



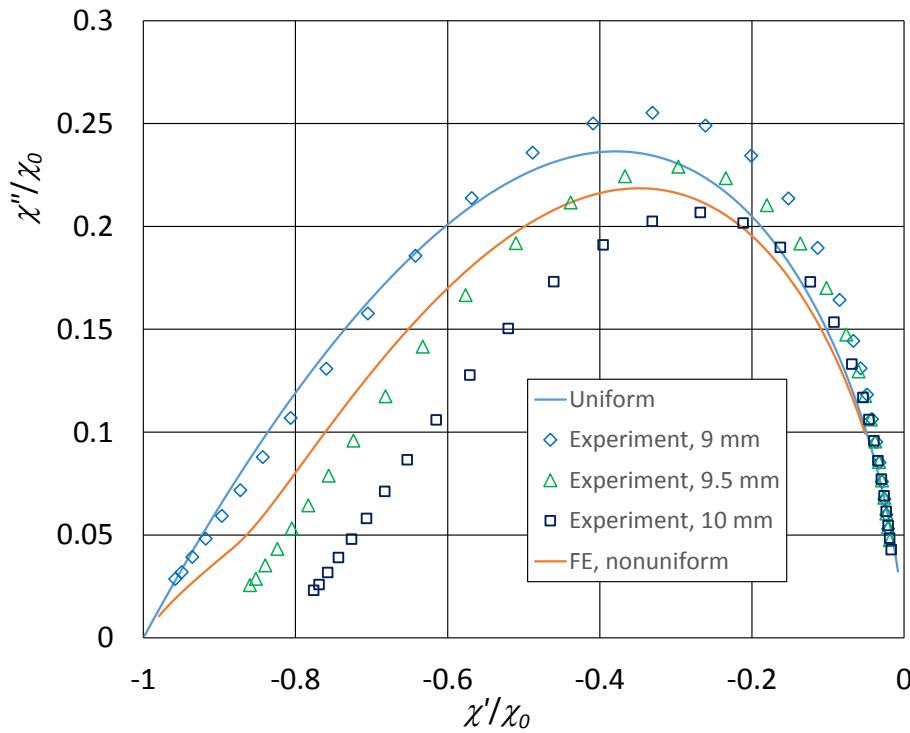
$$\chi_0 = \frac{\pi}{4} \frac{w}{h}$$



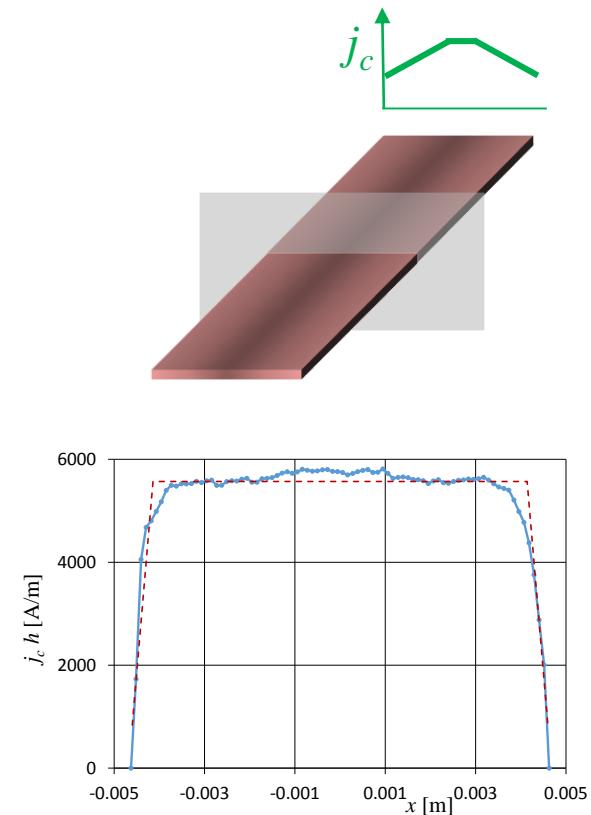
CC tape A

THEVA, (ISD process) $h: 2 \mu\text{m}$, $w = 10 \text{ mm}$, $I_c = 120 \text{ A}$

Cole-Cole plots: form of the AC dependence



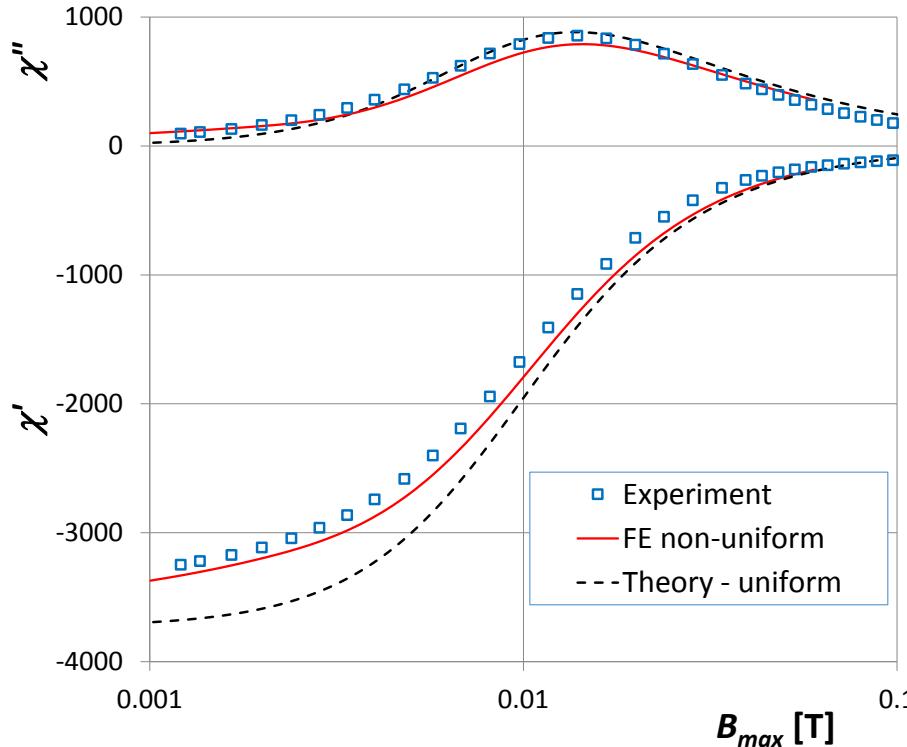
non-uniformity confirmed by Hall mapping



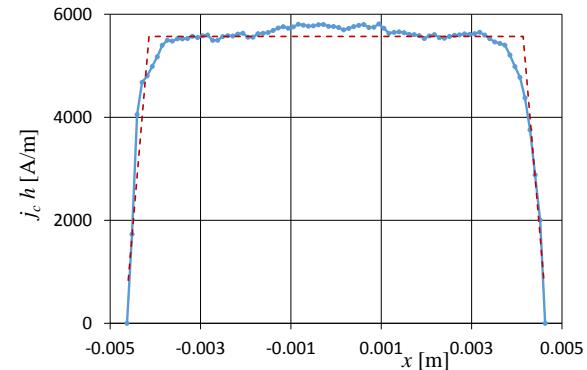
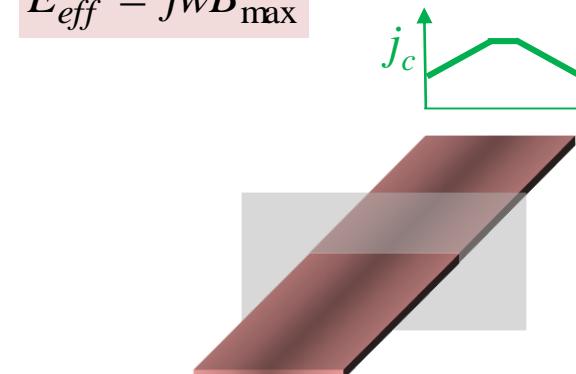


CC tape A

THEVA, (ISD process) $h: 2 \mu\text{m}$, $w = 9.5 \text{ mm}$, $I_c = 130 \text{ A}$



$$E_{eff} = fwB_{max}$$

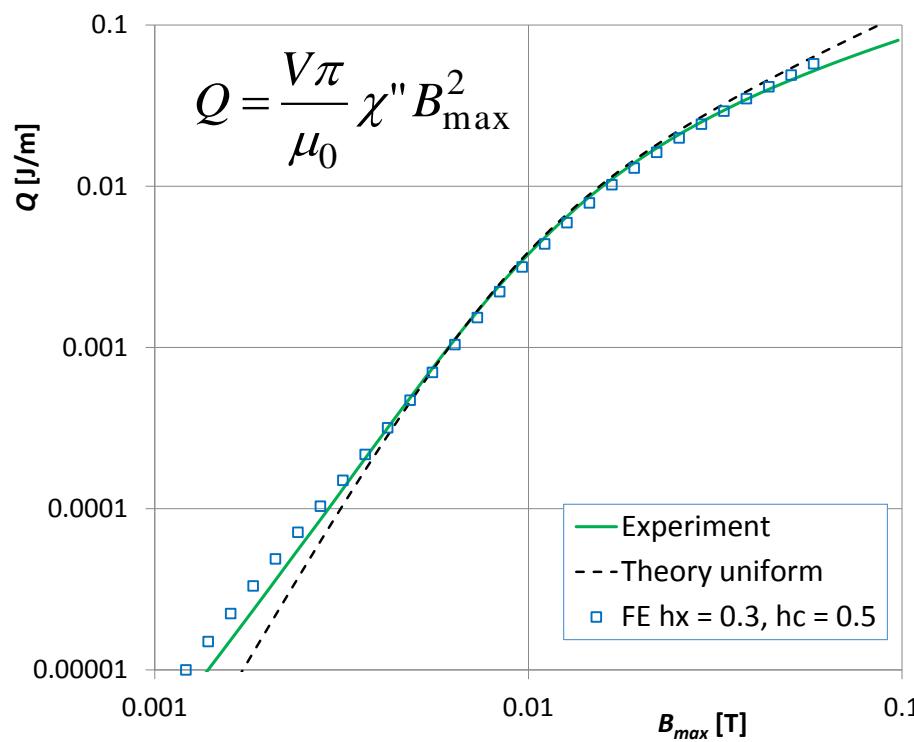


still some discrepancy in the real part

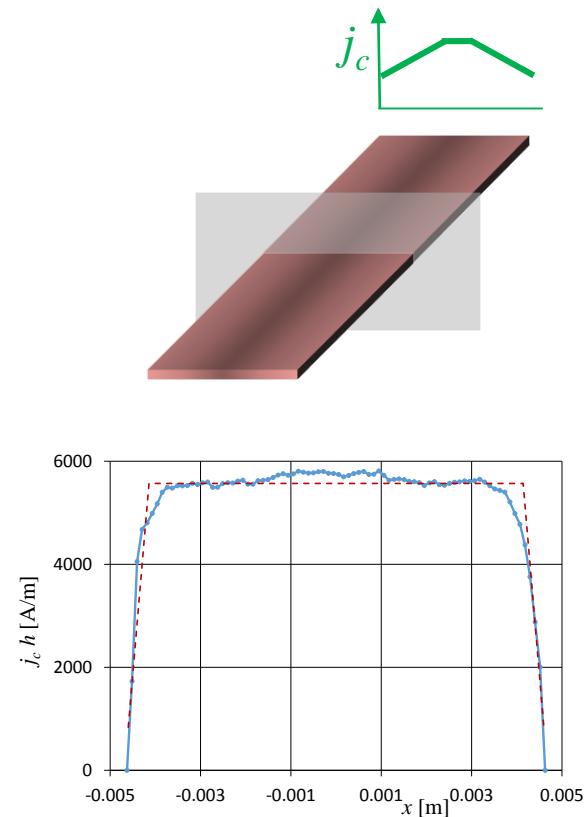


CC tape A

THEVA, (ISD process) $h: 2 \mu\text{m}$, $w = 9.5 \text{ mm}$, $I_c = 130 \text{ A}$, degraded edges



AC loss representation: good agreement

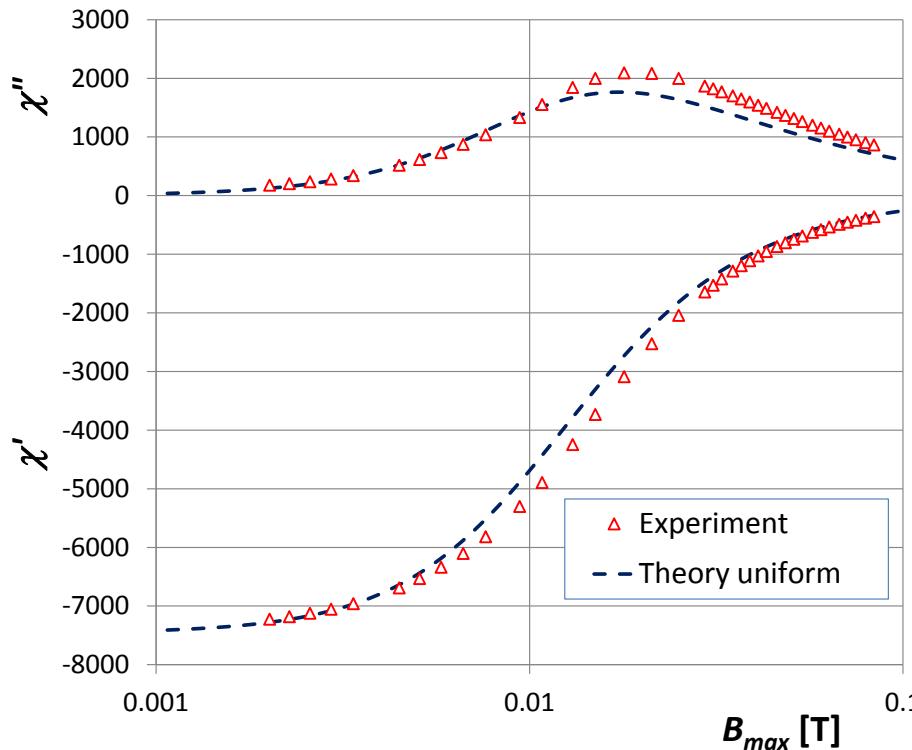




CC tape B

DNano, (CSD process) $h: 1 \mu\text{m}$, $w = 9.5 \text{ mm}$, $I_c = 143 \text{ A}$

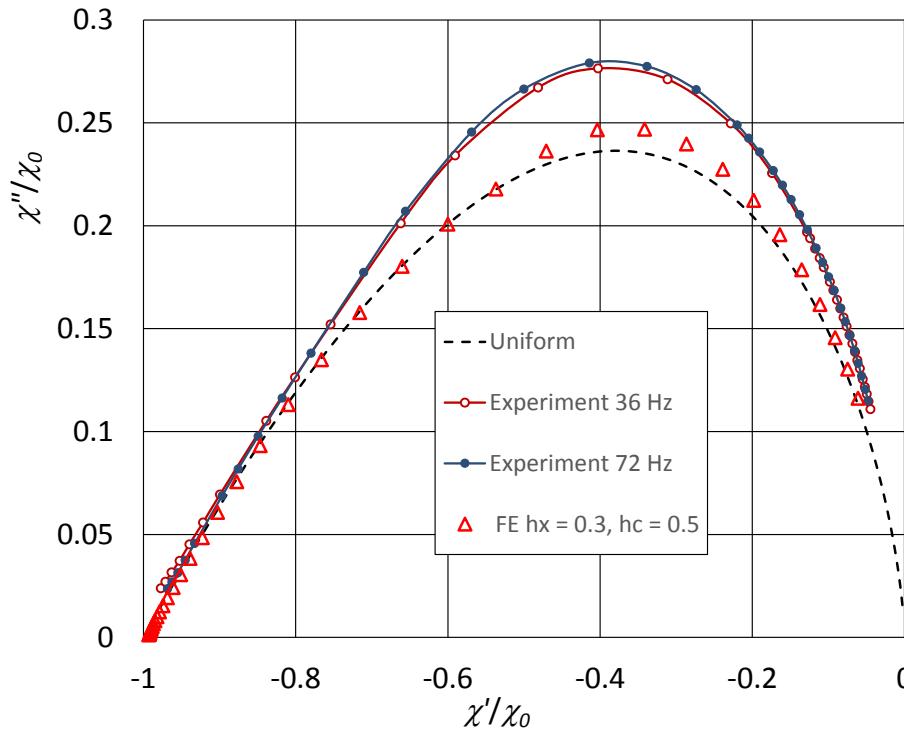
↓
167 A at 72 Hz



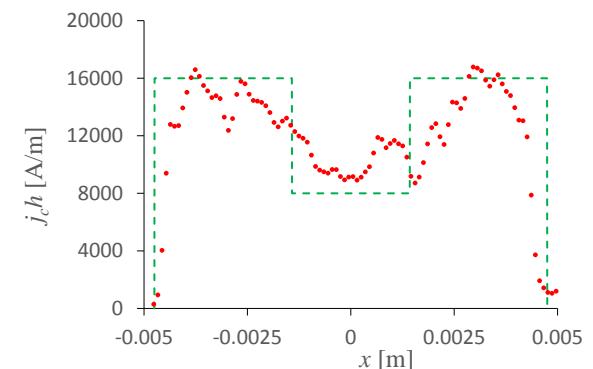
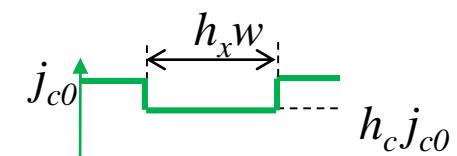


CC tape B

DNano, (CSD process) $h: 1 \mu\text{m}$, $w = 9.5 \text{ mm}$, $I_c = 143 \text{ A}$



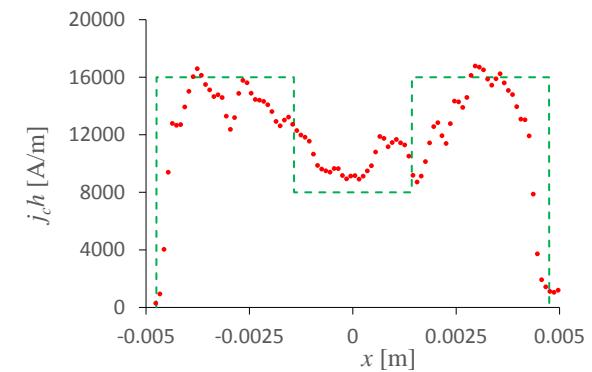
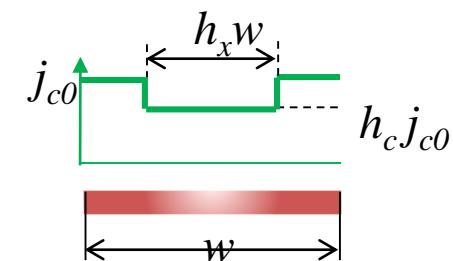
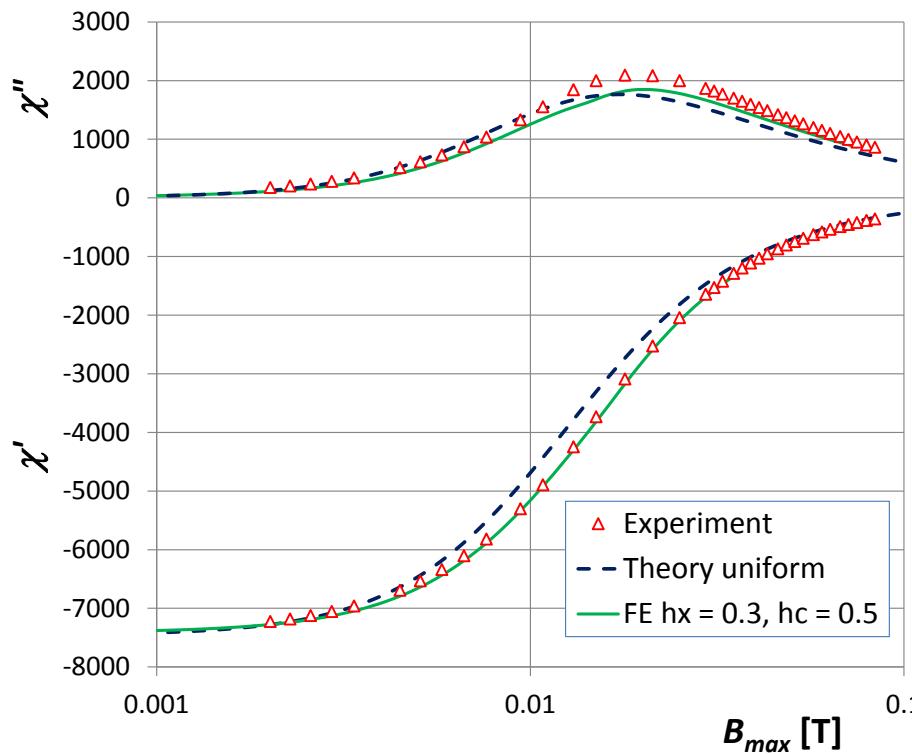
↓
167 A at 72 Hz





CC tape B

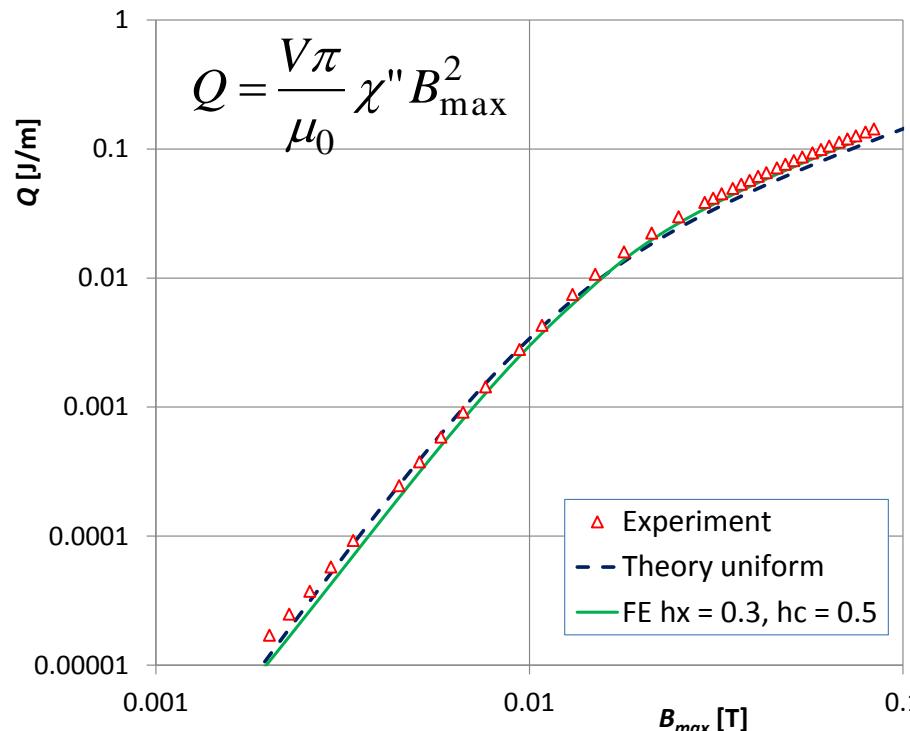
DNano, (CSD process) $h: 1 \mu\text{m}$, $w = 9.5 \text{ mm}$, $I_c = 143 \text{ A}$



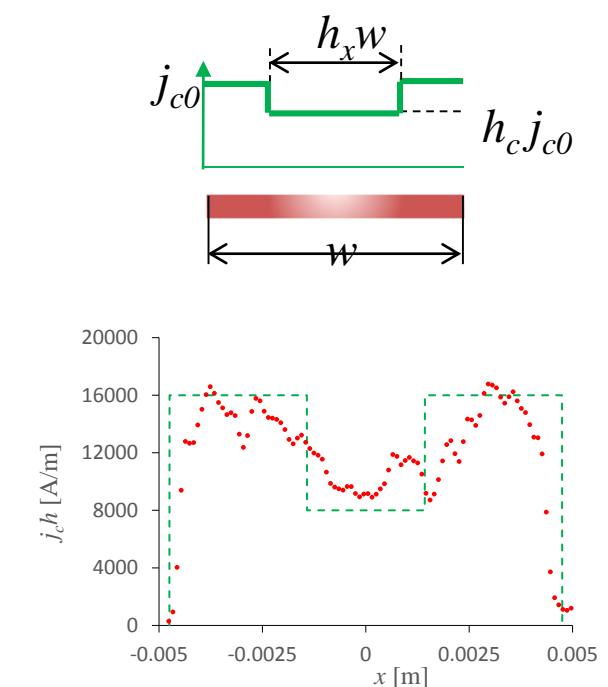


CC tape B

DNano, (CSD process) $h: 1 \mu\text{m}$, $w = 9.5 \text{ mm}$, $I_c = 143 \text{ A}$, better edges



better agreement also for AC loss





Conclusions

AC susceptibility is a powerful tool in revealing the non-uniformity appearing across CC tape width

Cole-Cole plot are extremely suitable in the analysis

For a uniform tape the AC susceptibility allows contactless determination of superconductor width and critical current

AC susceptibility dependence on B_{max} is more sensitive to deviations from ideal behavior than the usually reported AC loss data