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2 UPC CommSensLab EXCELENCIA MARÍA DE MAEZTU 2017 - 2020
3 ICMAB INSTITUT DE CIÈNCIA DE MATERIALS DE BARCELONA
EXCELENCIA SEVERO OCHOA
CSIC CONSEJO SUPERIOR DE INVESTIGACIONES CIENTÍFICAS

RF Characterisation of HTS-CC Tapes as Alternative Coating for the FCC-hh Beam Screen

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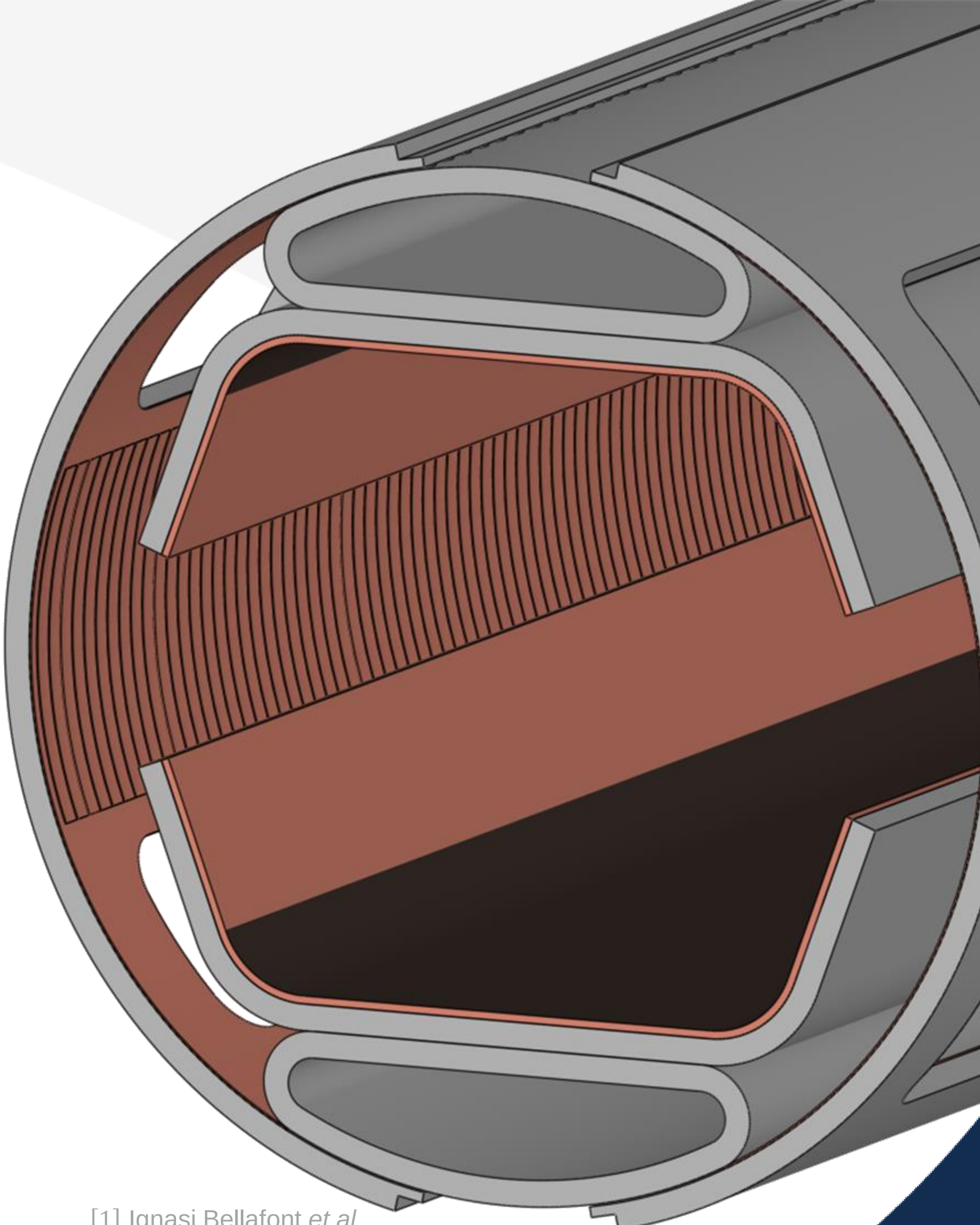
Beam Screen Design FCC-hh

Coated Conductor Coating

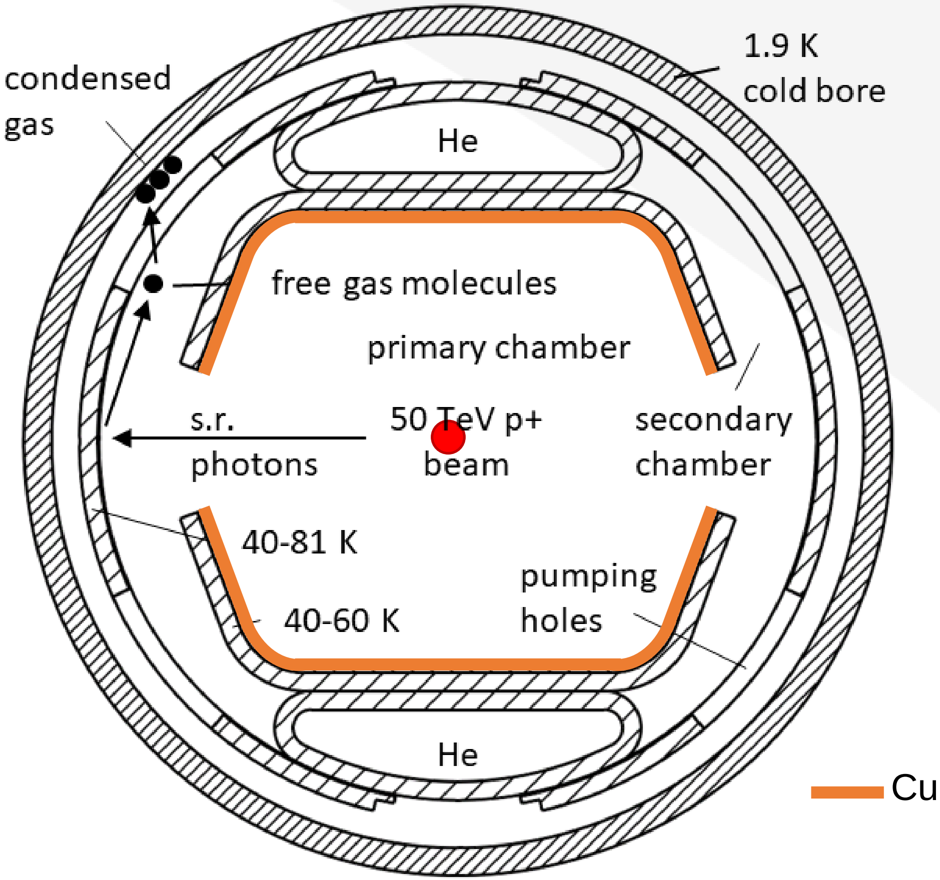


[1] Ignasi Bellafont *et al.*

Beam Screen Design

FCC-hh

- Nominal aperture:
  - H: 28.37 mm
  - V: 24.4 mm
- Slit height:
  - 7.5 mm
- Beam screen:
  - 1.0 mm steel
  - 0.3 mm copper
- Operating temperature
  - 50 ± 10 K

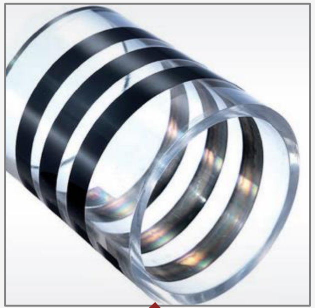


[1] Ignasi Bellafont *et al.*

Beam Screen Design

Coated Conductor Coating

- HTS coated conductor stripes
  - commercially available 2 – 12 mm
- Display on several chosen positions
  - e.g. alternating CC and Cu
  - lower ac losses
- Covered with amorphous Carbon to reduce SEY
- Reducing beam coupling impedance
  - low surface resistance



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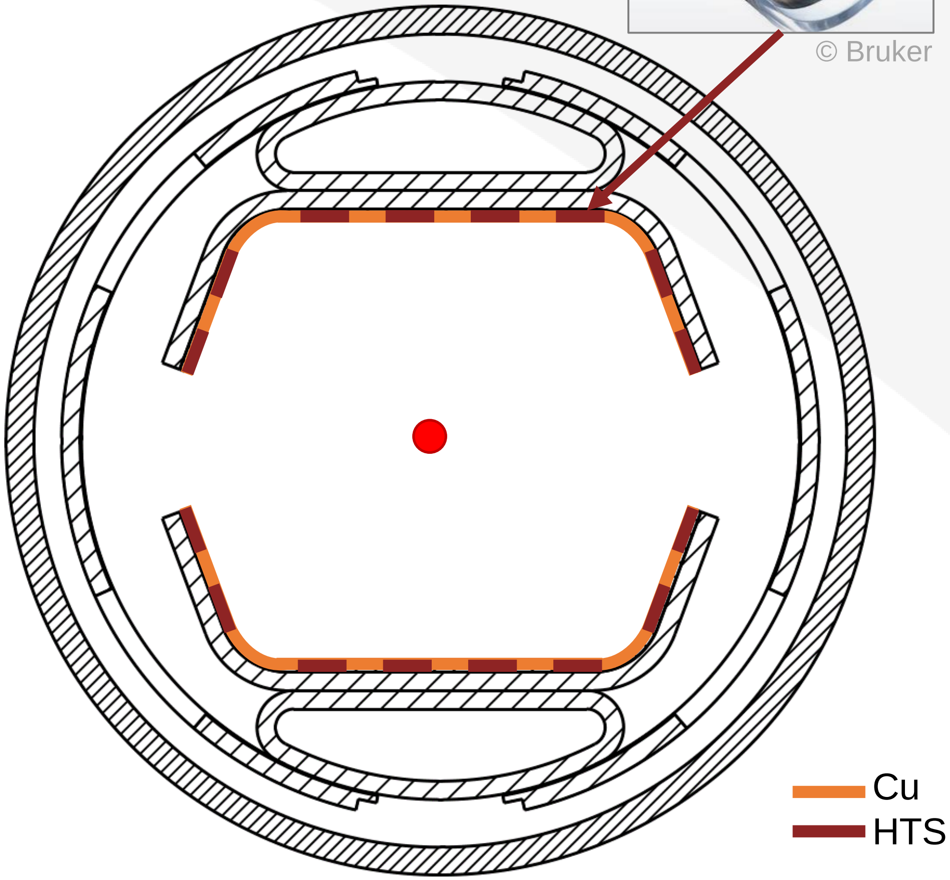
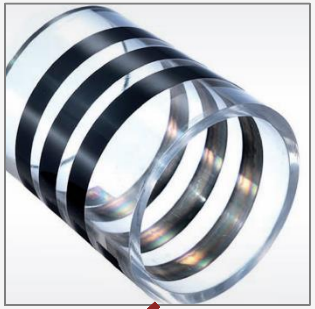


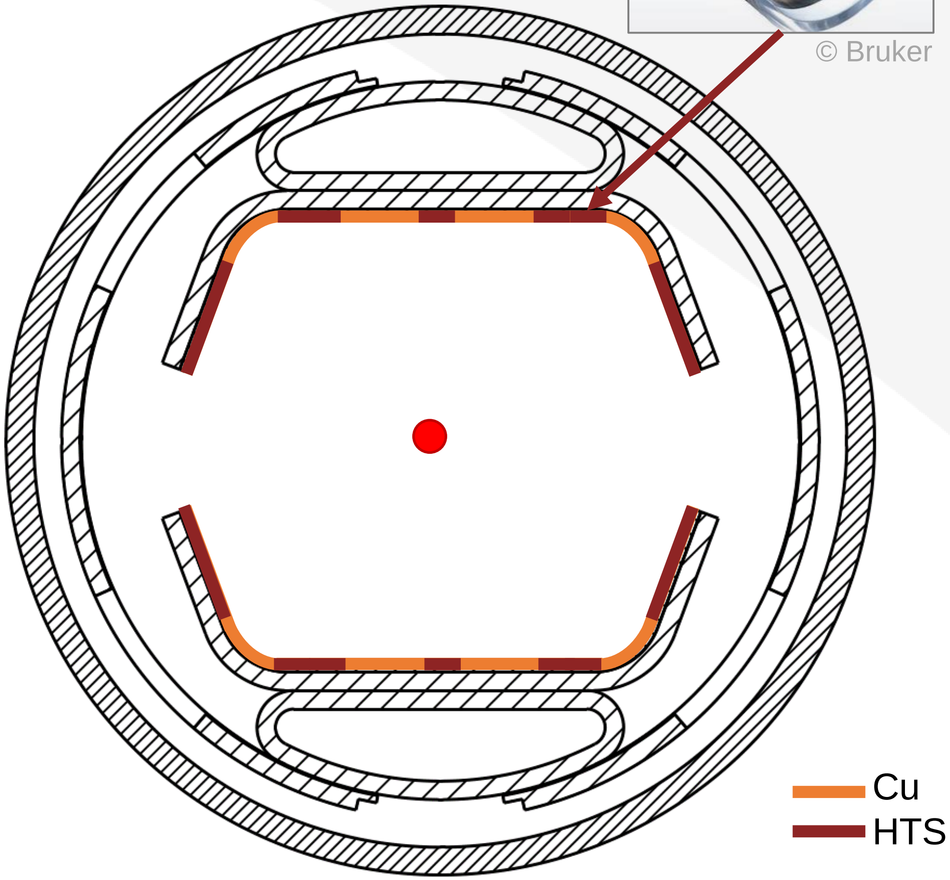
[1] Ignasi Bellafont *et al.*
[2] Patrick Krkotić *et al.*

Beam Screen Design

Coated Conductor Coating

- HTS coated conductor stripes
  - commercially available 2 – 12 mm
- Display on several chosen positions
  - e.g. gradually increasing tapes
  - lower ac losses
- Covered with amorphous Carbon to reduce SEY
- Reducing beam coupling impedance
  - low surface resistance



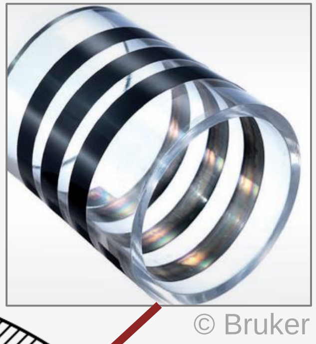


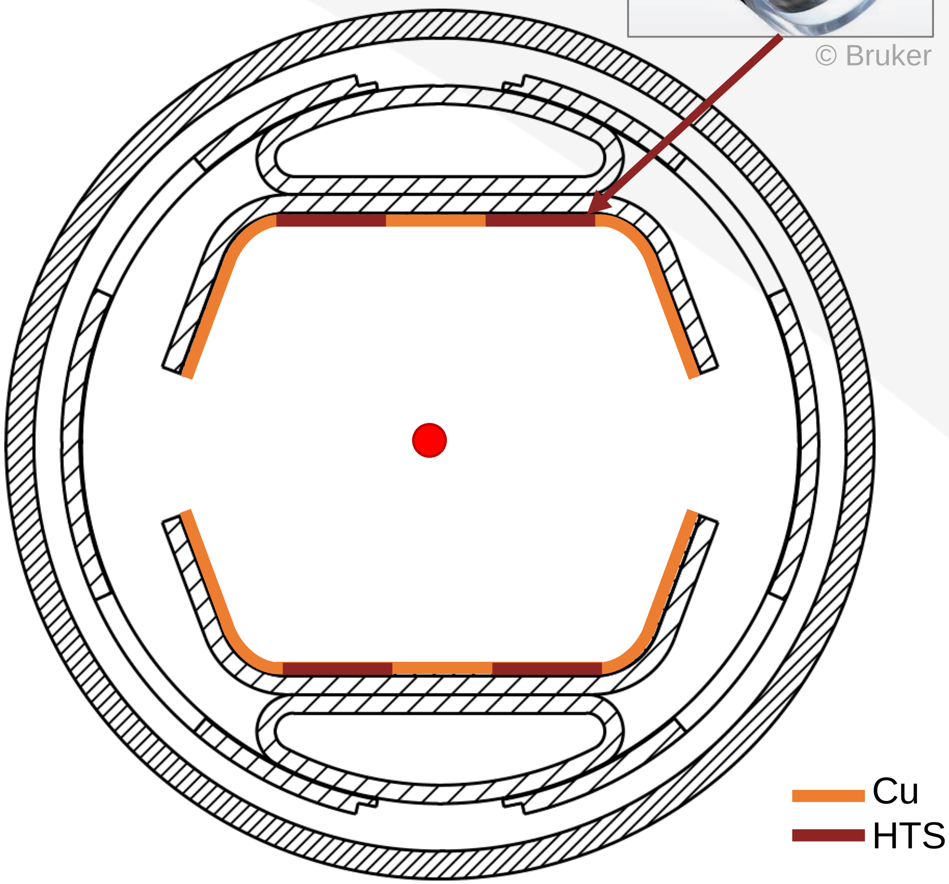
[1] Ignasi Bellafont *et al.*
[2] Patrick Krkotić *et al.*

Beam Screen Design

Coated Conductor Coating

- HTS coated conductor stripes
  - commercially available 2 – 12 mm
- Display on several chosen positions
  - e.g. double track
  - lower ac losses
- Covered with amorphous Carbon to reduce SEY
- Reducing beam coupling impedance
  - low surface resistance





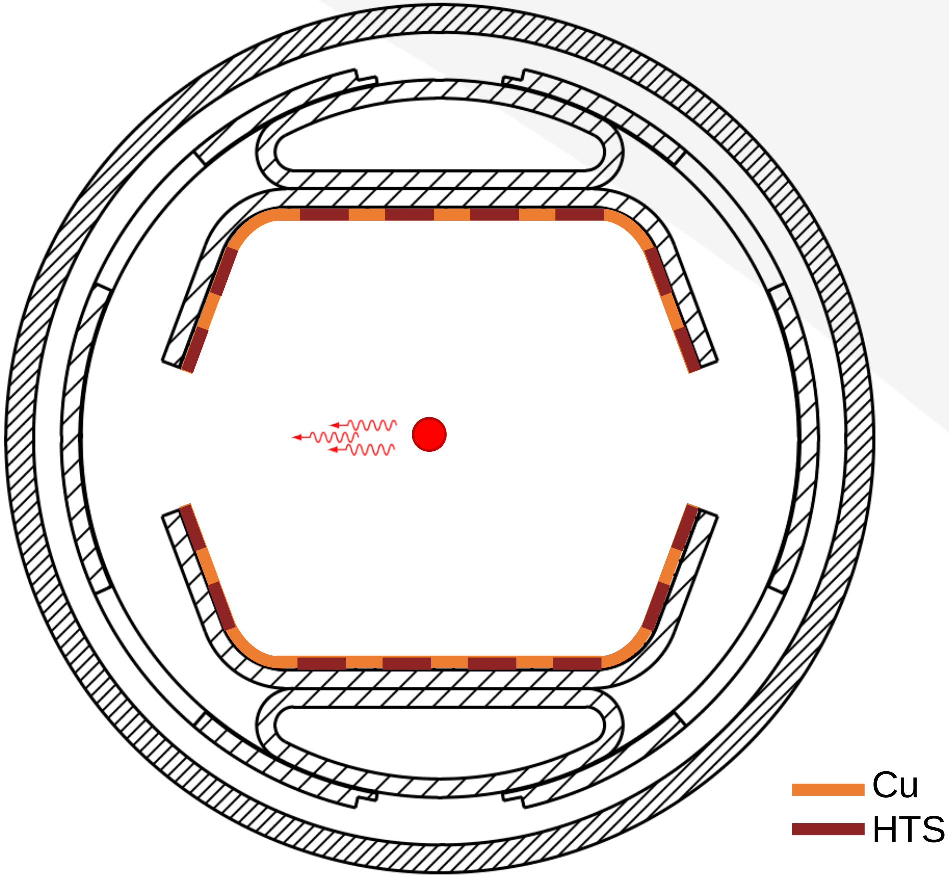
[1] Ignasi Bellafont *et al.*
[2] Patrick Krkotić *et al.*

Beam Screen Design

Requirements

- Operating temperature:
  - 50 ± 10 K
- Magnetic field strength:
  - 1 – 16 T
- Emitted synchrotron radiation:
  - 35.4 W/m/beam
- Beam spectrum frequency:
  - up to 3 GHz
- Image current per bunch:
  - 25 A -> $J_C = 25\ \mathrm{kA/cm^2}$

[Poster Session - Joffre Gutierrez Royo, *'Coating the FCC-hh beam screen chamber with REBa2Cu3O7-x coated conductors'*]



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Experimental Setup

Dielectric Resonator

(compatible with a PPMS system)

Dielectric Resonator

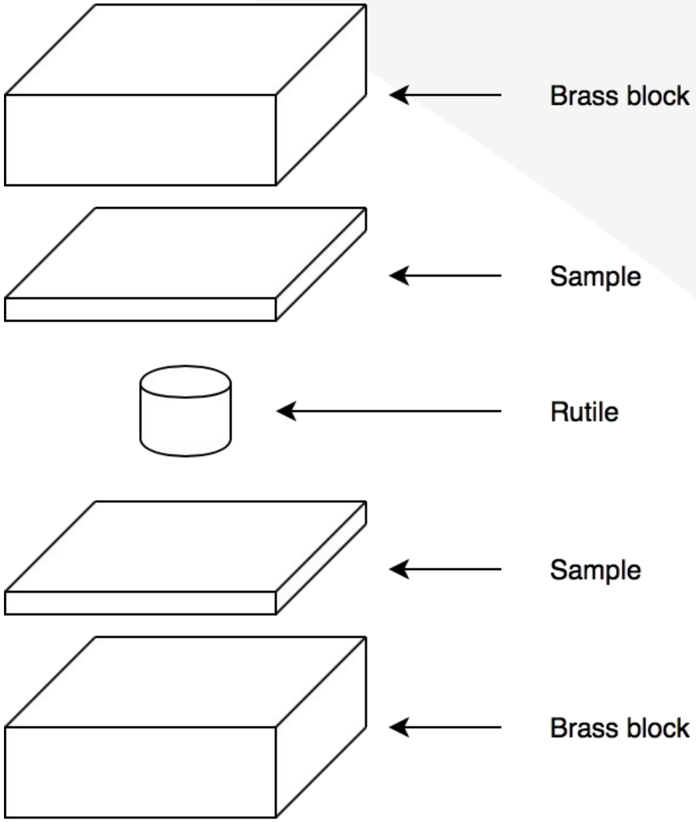
Surface Resistance

- Shielded Hakki-Coleman type
- Samples replace upper and lower plates
- Operating in the TE_{011} mode
  - insensitive to electrical contact of the sample with the metallic enclosure
  - resonance frequency at 50 K is 7.9 GHz
- Surface Resistance is defined as

$$R_S = \frac{G_S}{2}\left(\frac{1}{Q_0} - p \cdot \tan(\delta)\right)$$

$R_S = Surface\ resistance$ $p = Filling\ factor$

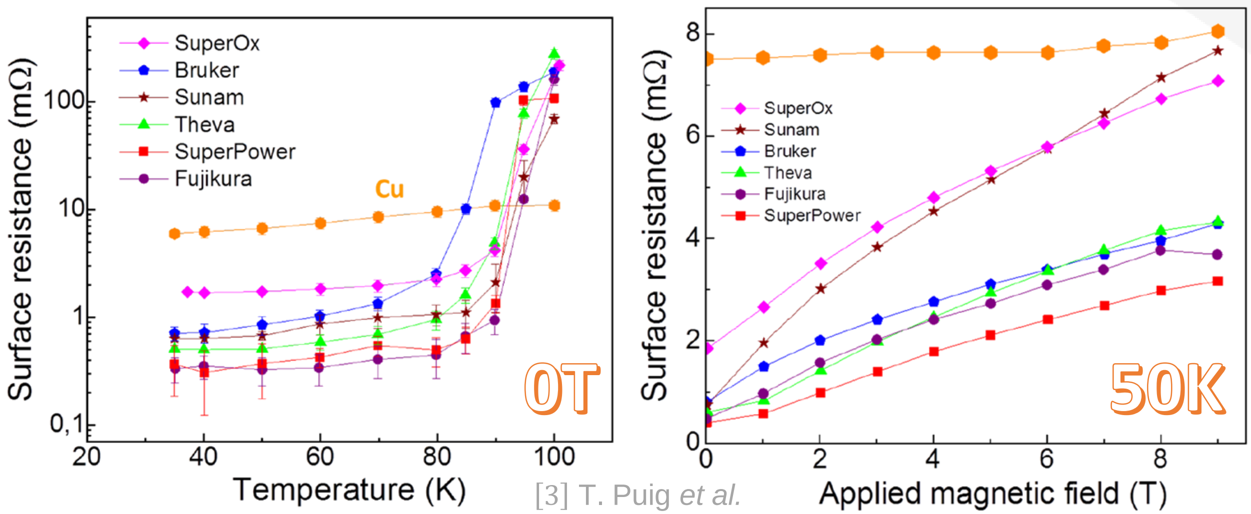
$G_S = Geometrical\ factor$ $\tan(\delta) = Loss\ factor$



Dielectric Resonator

Surface Resistance

We proved that close to FCC conditions (40-60 K, 8 GHz, 0-9 T), HTS surface resistance is lower than that of copper for most manufacturers.



[3] T. Puig *et al.*

Surface Resistance

Normal Conductor vs Superconductor

$R_{S_{Cu}} \propto \sqrt{f}$

$R_{S_{SC}} \propto f^2$

Surface Current Density

Magnetic Field Amplitude

- Estimated value of the magnetic rf field for the FCC
  - $H_{max} = 250\ \text{A/m}$ (0.3 mT)

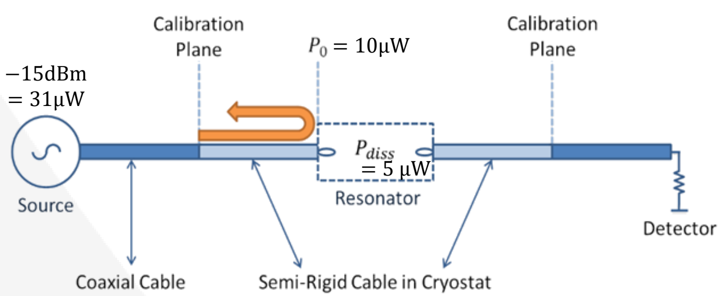
- Magnetic field amplitude:
  - $A \propto \sqrt{\frac{Q_0 P_{diss}}{\omega_0}}$

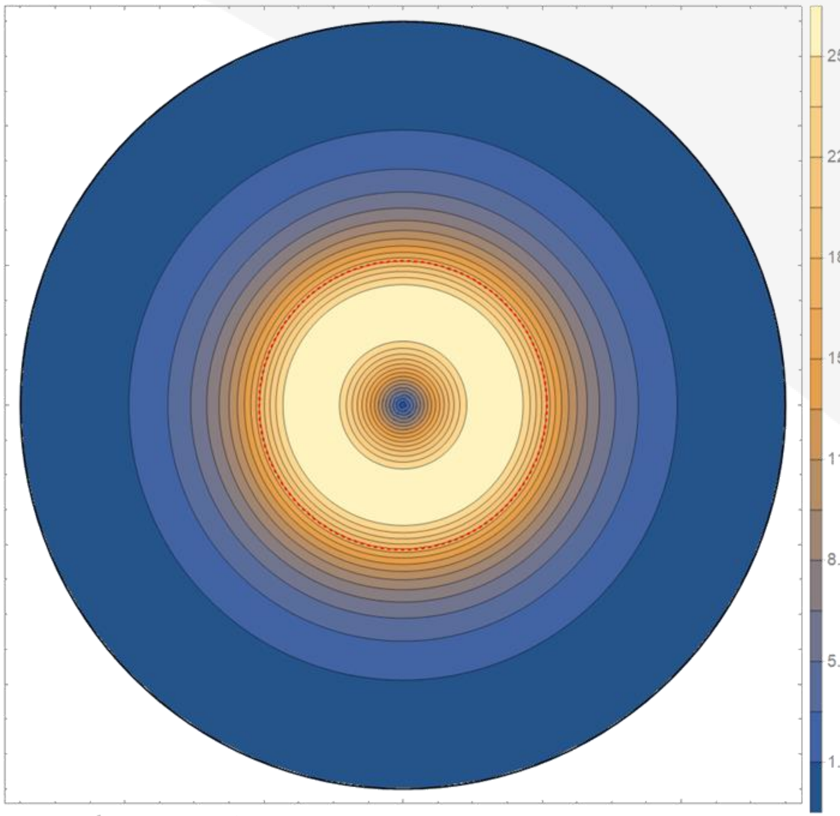
$Q_0 = Quality\ factor$

$P_{diss} = Power\ dissipated$

$\omega_0 = Resonant\ frequency$

- Experimental set-up and losses





Analytical estimation of the distribution of rf magnetic field strength on a sample in the DR

Surface Current Density

Magnetic Field Amplitude

- Estimated value of the magnetic rf field for the FCC
  - $H_{max} = 250\ \mathrm{A/m}$ (0.3 mT)

- Magnetic field amplitude:
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$Q_0 = Quality\ factor$

$P_{diss} = Power\ dissipated$

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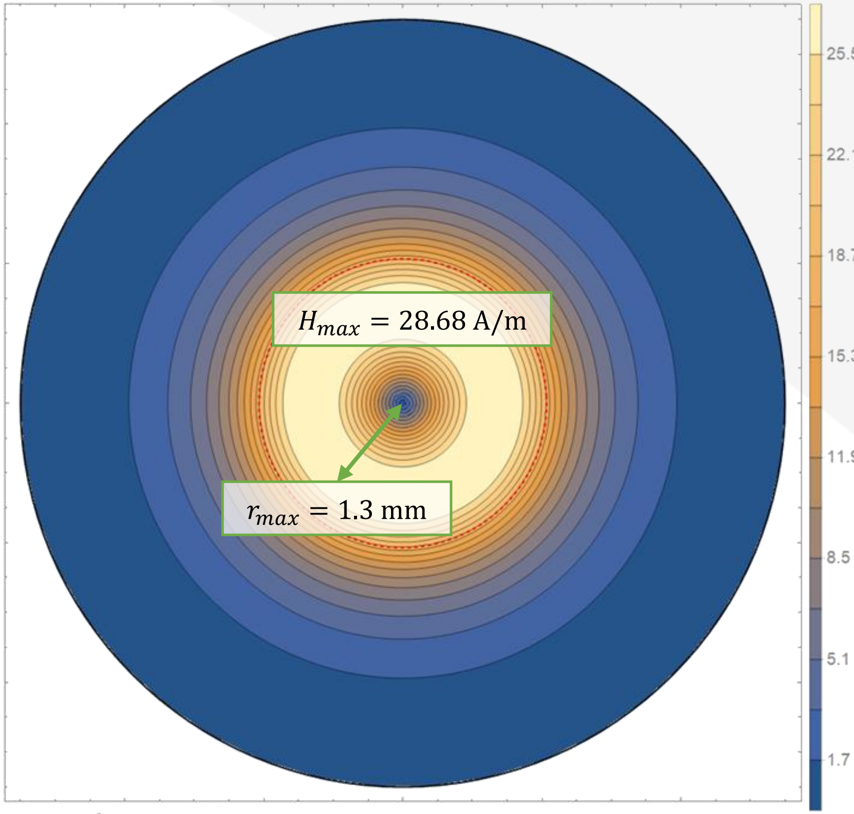
Sample	H_{max}(50 K,0T)	H_{max}(50 K,9T)
SuperPower	29 A/m	7 A/m
SuperOx	13 A/m	4 A/m



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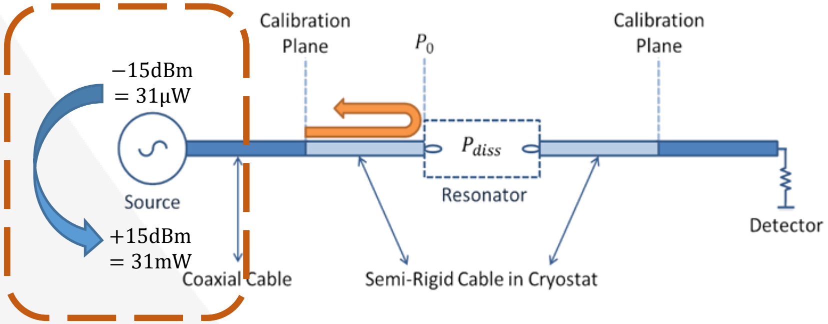
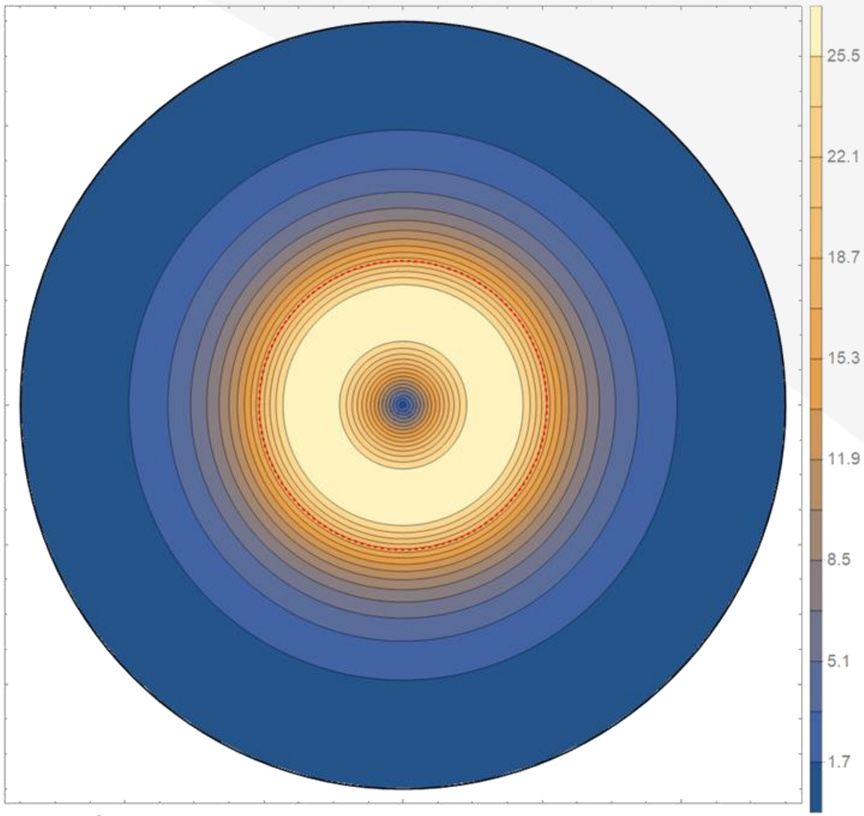




Analytical estimation of the distribution of rf magnetic field strength on a sample in the DR

Surface Current Density

Power

- Estimated value of the magnetic rf field for the FCC
  - $H_{max} = 250$ A/m (0.3 mT)

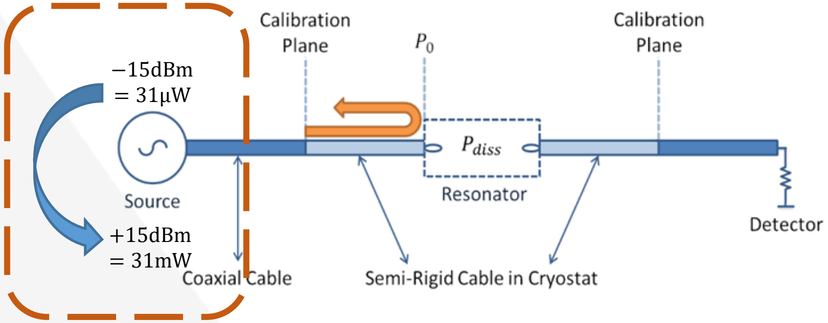
- Magnetic field amplitude:
  - $A \propto \sqrt{\frac{Q_0 P_{diss}}{\omega_0}}$

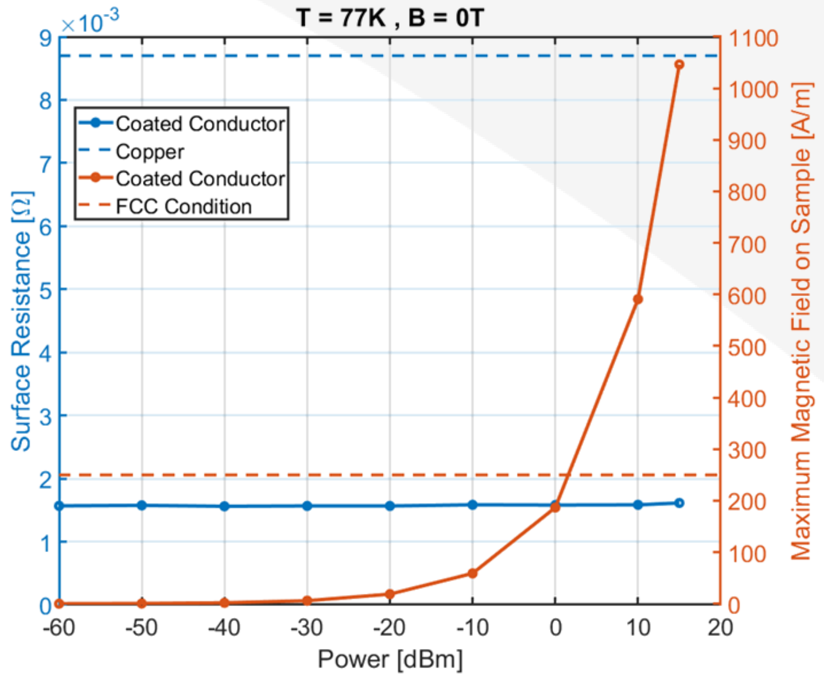
$Q_0 = Quality\ factor$

$P_{diss} = Power\ dissipated$

$\omega_0 = Resonant\ frequency$

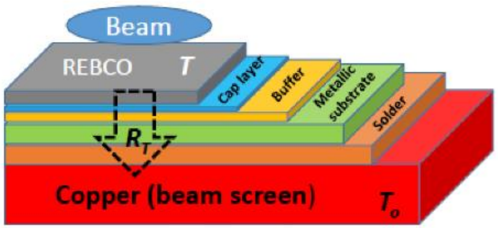
- Experimental set-up and losses





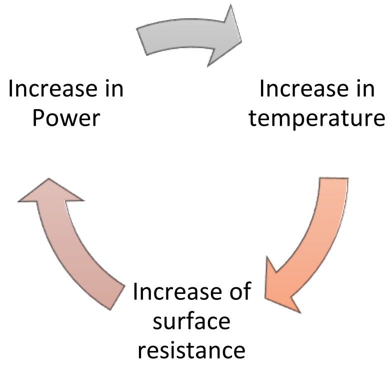
Surface Current Density

Thermal Runaway – R. Vaglio & S. Calatroni



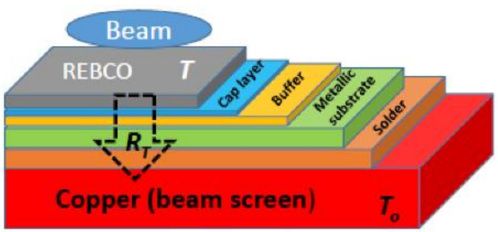
[4] Ruggero Vaglio *et al.*

- Transversal thermal resistance is the sum of individual thermal resistances



Surface Current Density

Thermal Runaway – R. Vaglio & S. Calatroni



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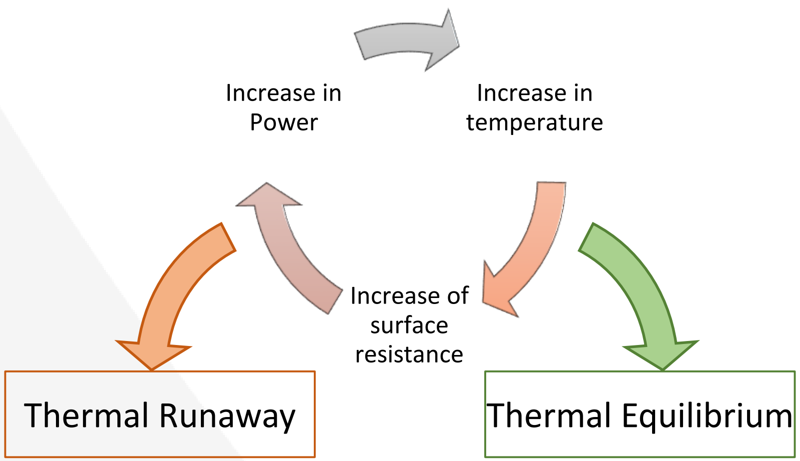


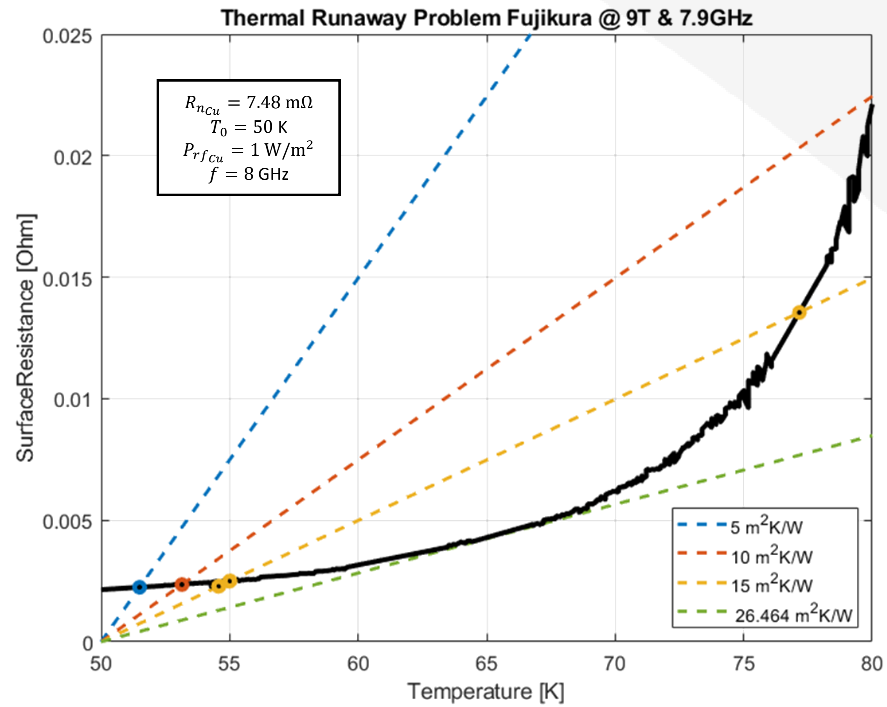
- Linear relationship

$$R_S(f,T) = \frac{T - T_0}{R_T} \frac{R_{n\,Cu}}{P_{rf\,Cu}}$$

$R_S = R_n = Surface\ resistance$

$R_T = Thermal\ resistance$

$P_{rf} = RF\ power\ dissipated$



Surface Reactance

Magnetic Field

- A perturbation in temperature or/and magnetic field produces a relative change in resonant frequency according to

$$-2\frac{\Delta f_0}{f_0} = \frac{\Delta X_S}{G_S} + \frac{\Delta X_m}{G_m} + p\frac{\Delta \varepsilon_r}{\varepsilon_r}$$

[5] Pompeo *et al.*

$f_0 = Resonant\ frequency$ $X_m = Surface\ reactance\ of\ Brass$

$X_S = Surface\ reactance\ of\ SC$ $\varepsilon_r = Permittivity\ of\ dielectric$

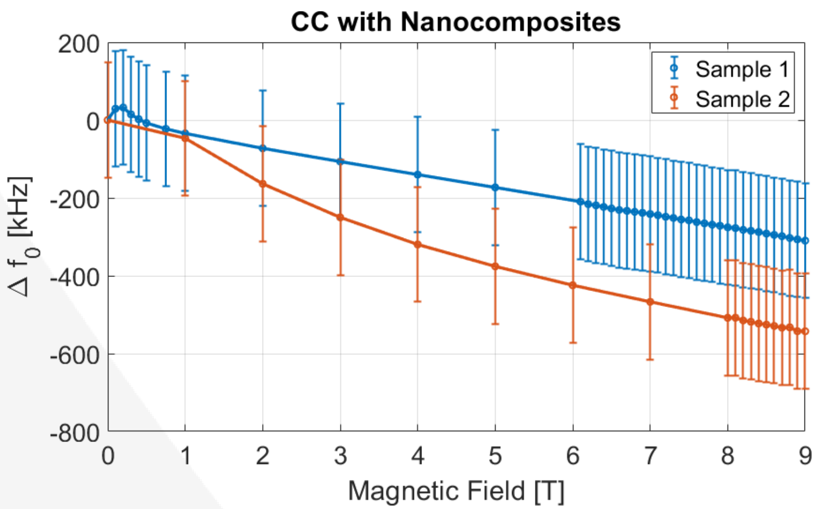
Surface Reactance

Magnetic Field

- A perturbation in temperature or/and magnetic field produces a relative change in resonant frequency according to

$$-2\frac{\Delta f_0}{f_0} = \frac{\Delta X_S}{G_S} + \frac{\Delta X_m}{G_m} + p\frac{\Delta \varepsilon_r}{\varepsilon_r}$$

Temperature stability



Surface Reactance

Magnetic Field

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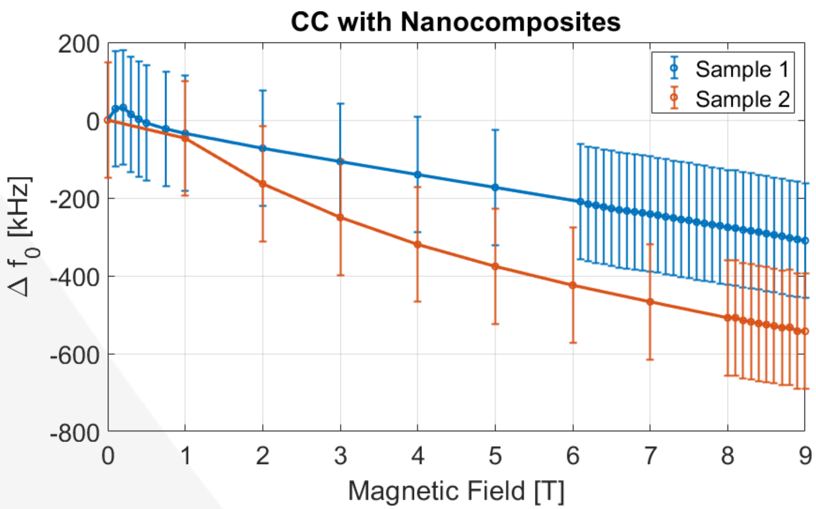

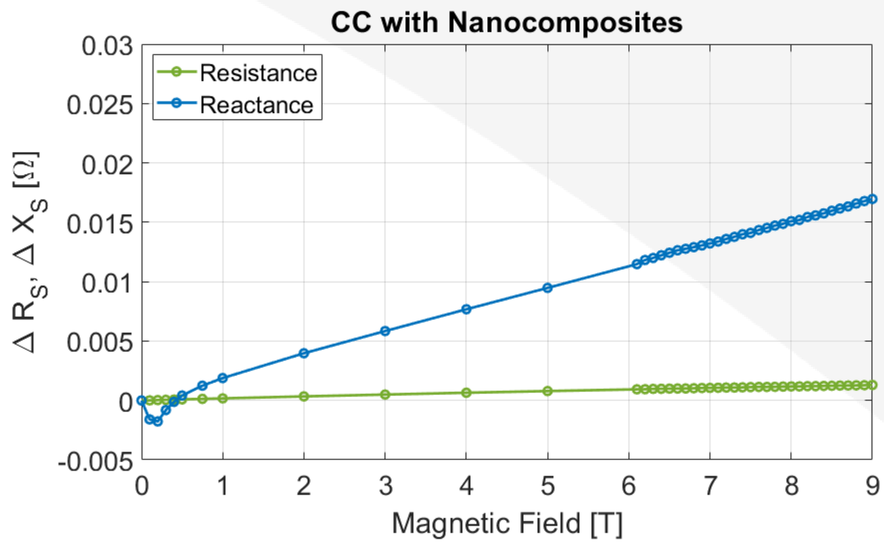

- Study the different influences of the real and imaginary part of beam coupling impedance on the beam stability.

Surface Reactance

Magnetic Field

- A perturbation in temperature or/and magnetic field produces a relative change in resonant frequency according to

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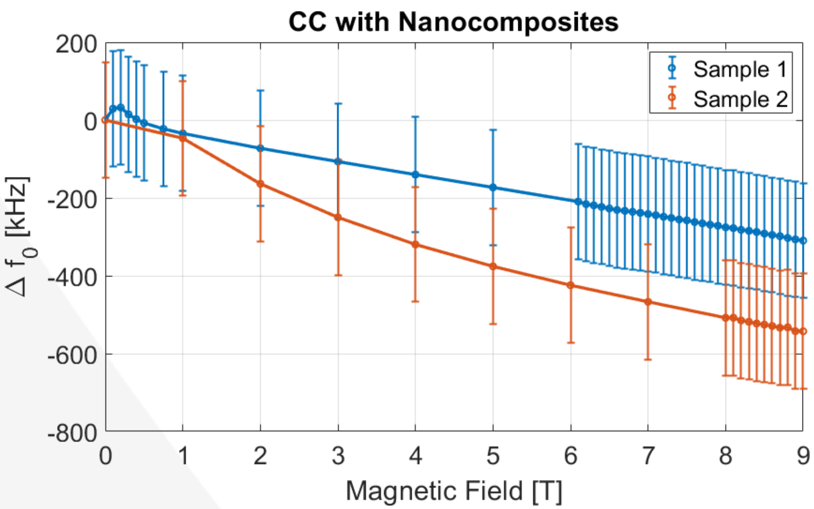

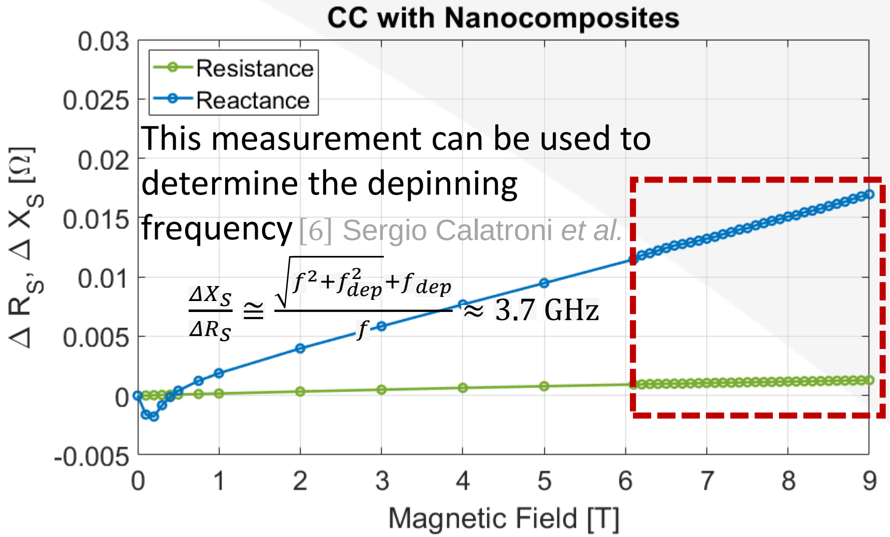

- Study the different influences of the real and imaginary part of beam coupling impedance on the beam stability.

Conclusion & Outlook

- Surface Resistance in all samples is significantly lower than that of copper at 8 GHz up to 9 T
- RF magnetic field strength on the sample at FCC condition does not significantly change the surface resistance value
- Extrapolation to FCC working conditions is favourable for Coated Conductors
- First tests showed that the thermal runaway is no problem
  - Continue studies
- Investigation of the depinning frequency
  - Beneficial for surface impedance to operate below depinning frequency
- Getting closer to FCC conditions
- Improving resonator configurations to lower frequencies, temperature stability
- HTS behaviour under synchrotron irradiation
  - *'HTS REBaCuO coated conductors for the FCC-hh beam screen: Performance under photon irradiation at the ALBA Synchrotron Light Source'*

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