Trapped flux sensitivity studies as a function of: treatment, RF field and frequency

Martina Martinello

9th Nov, 2018

Overview

- Introduction
- Sensitivity studies at low and medium field (5-16 MV/m), as a function of:
    1. Surface treatments (mean-free-path)
    2. RF field
    3. Frequency
- Sensitivity studies at high field (25-49 MV/m), as a function of:
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- Conclusions

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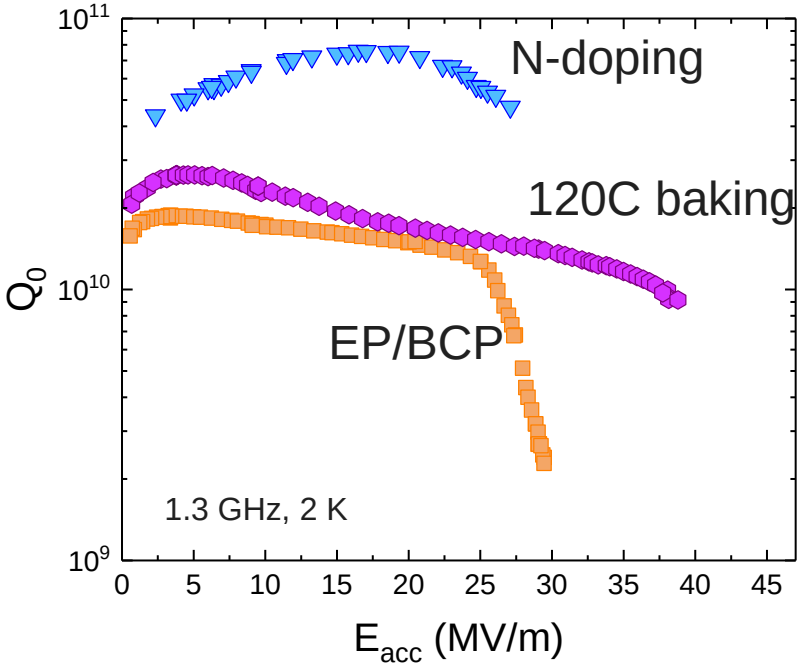
Analyzed Cavities for Sensitivity



	650 MHz	1.3 GHz	2.6 GHz	3.9 GHz
EP	✓	✓	✓	
BCP				✓
120 C baking	✓	✓	✓	✓
2/6 N-doping	✓	✓	✓	✓
120 N-infusion		✓	✓	
75-120C baking		✓	✓	

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Data Analysis

For each cavity:

- Surface resistance decomposition:

$$R_S\,(\,2\,K\,) = R_T\,(\,2\,K\,) + R_{Fl} + R_0$$

1. $R_T\,(\,2\,K\,)$: T dependent surface resistance at $2\,K$
2. R_{Fl}: Trapped flux surface resistance
3. R_0: Intrinsic residual resistance

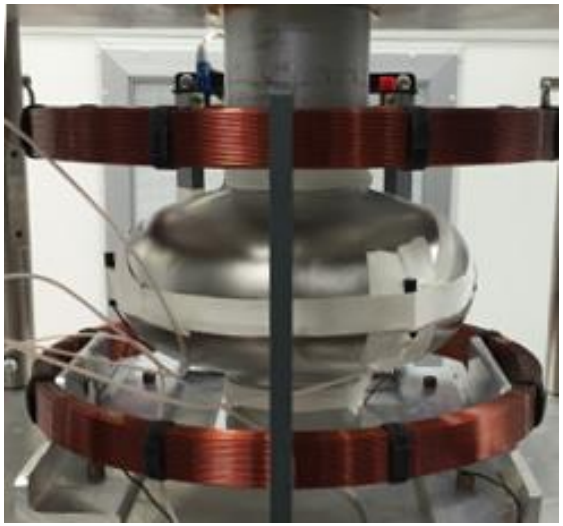
Trapped Flux Surface Resistance

$$R_S\,(\,2\,K\,) = R_{BCS}\,(\,2\,K\,) + R_0 + \boxed{R_{Fl}}$$

R_{Fl} defines the dissipation due to trapped flux during the SC transition:

$$\boldsymbol{R_{Fl} = B_{trap} \cdot S}$$

$$R_S\,(\,1.5\,K, B_{Trap}\,) \sim R_0 + R_{Fl}\,(\,B_{Trap}, l\,)$$



$$\boxed{R_{Fl} = R_S\big(1.5\,K, B_{Trap}\big) - R_0}$$

- $R_S\big(1.5\,K, B_{Trap}\big)$ measured after **slow cooldown** in a known amount of external magnetic field: $B_{ext} = B_{Trap}$
- R_0 measured after **fast cooldown in compensated magnetic field**: $B_{ext} = 0,\ R_{fl} = 0$

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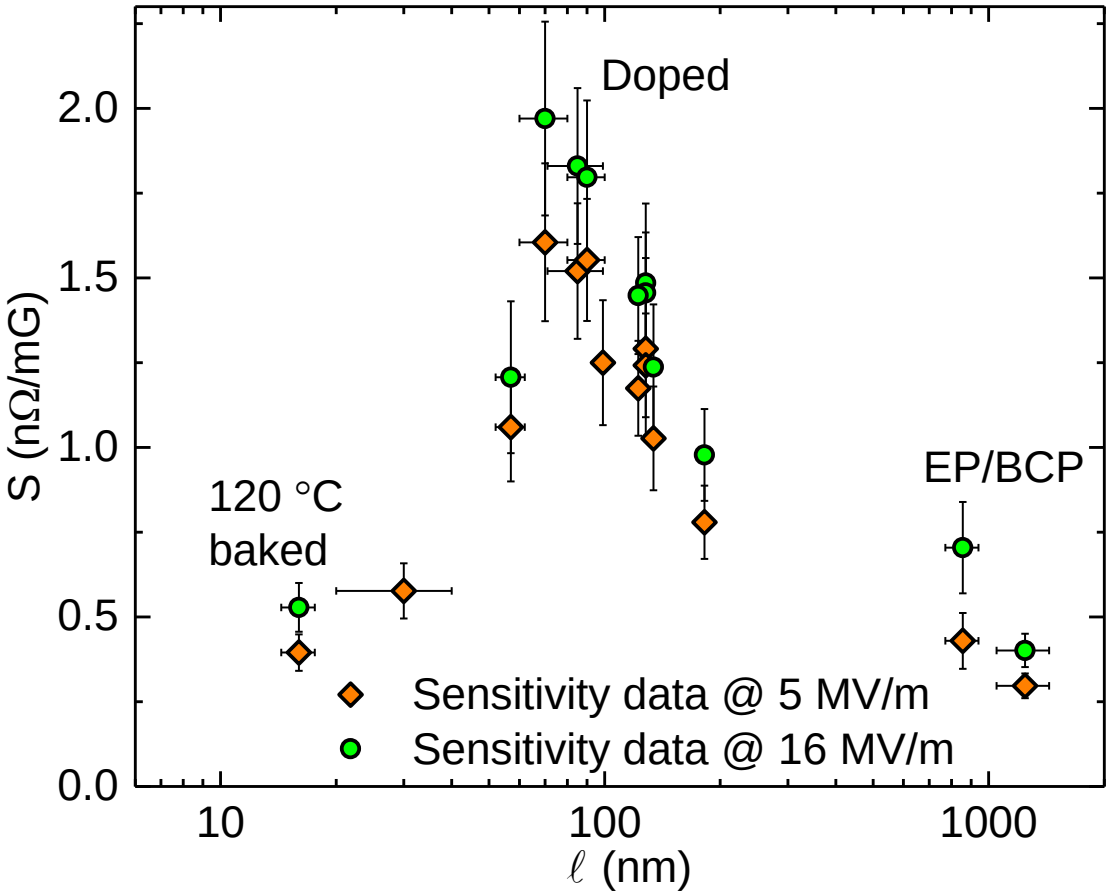
Sensitivity vs mean-free-path

Trapped flux sensitivity:

$$S = \frac{R_{Fl}}{B_{Trap}}$$

- Bell-shaped trend of S as a function of mean free path
- **Sensitivity maximum around $\ell = 70$ nm** → N-doped cavities present higher sensitivity than standard Nb cavities
- Light doping is needed to minimize trapped flux sensitivity



M. Martinello et al., App. Phys. Lett. **109**, 062601 (2016)

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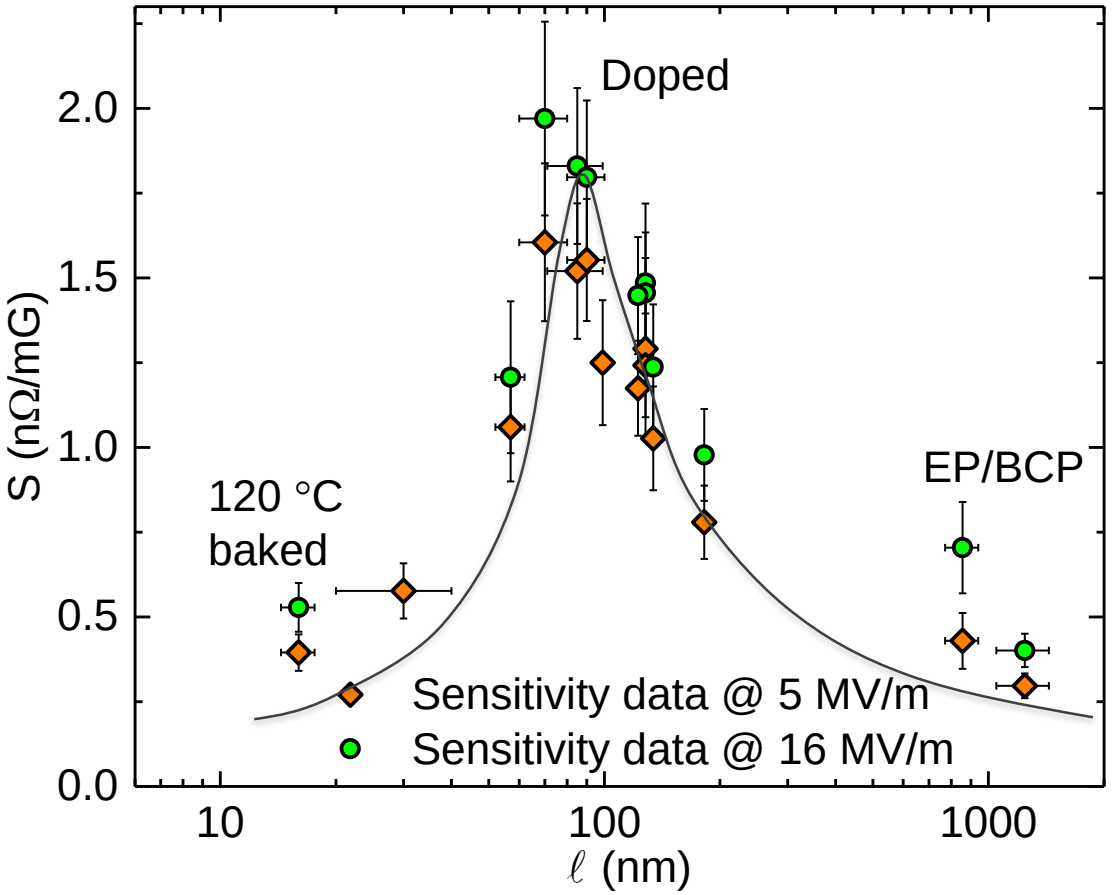

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M. Checchin *et al.*, Supercond. Sci. Technol. **30**, 034003 (2017)

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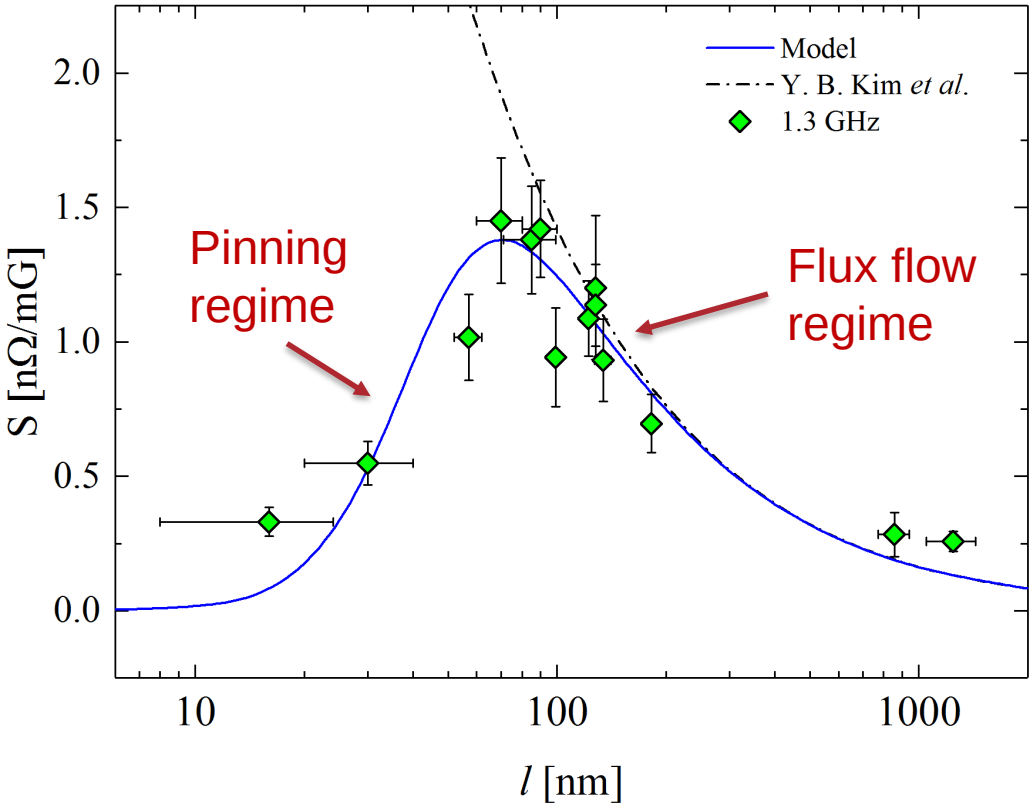

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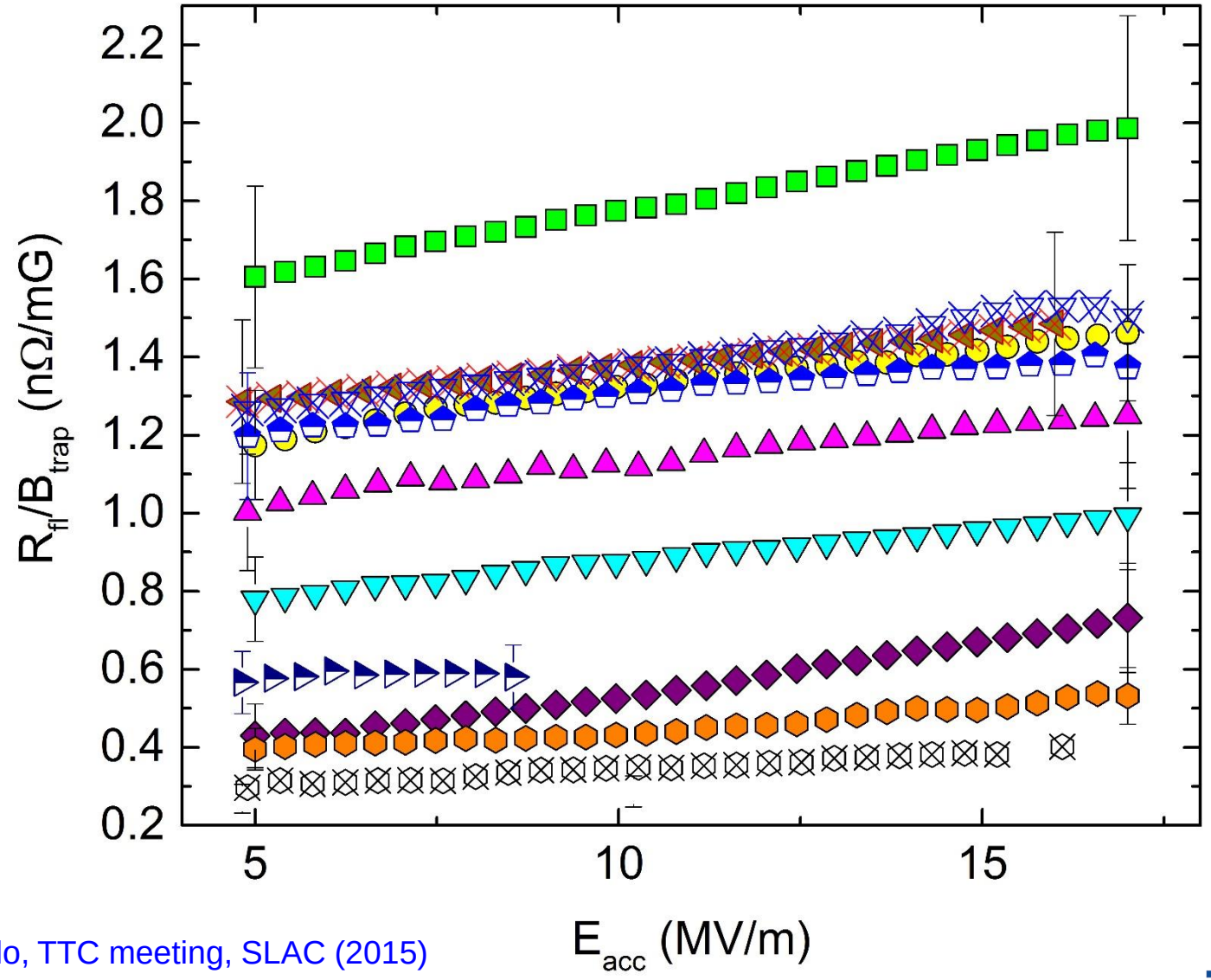
Trapped Flux Sensitivity Field Dependence



M. Martinello, TTC meeting, SLAC (2015)

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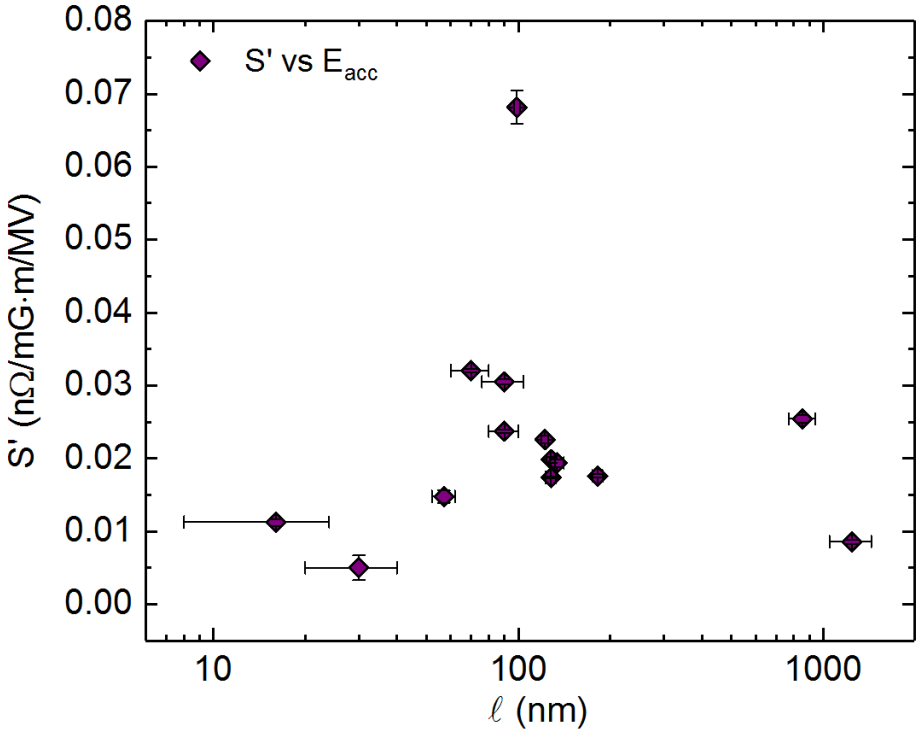
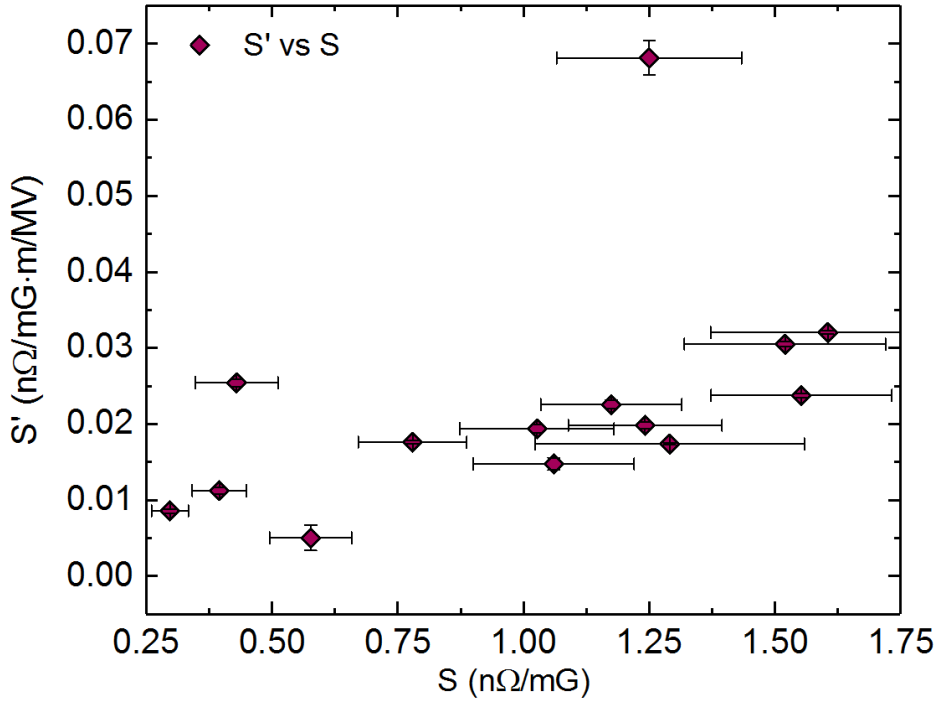
Trapped Flux Sensitivity Field Dependence

Sensitivity field dependence (S') study as a function of mean-free-path and sensitivity (S)





- **Bell-shaped trend** of S' as a function of mean-free-path
- **Linear trend** of S' as a function of S

➢ **The higher is the sensitivity, the higher is its field dependence**

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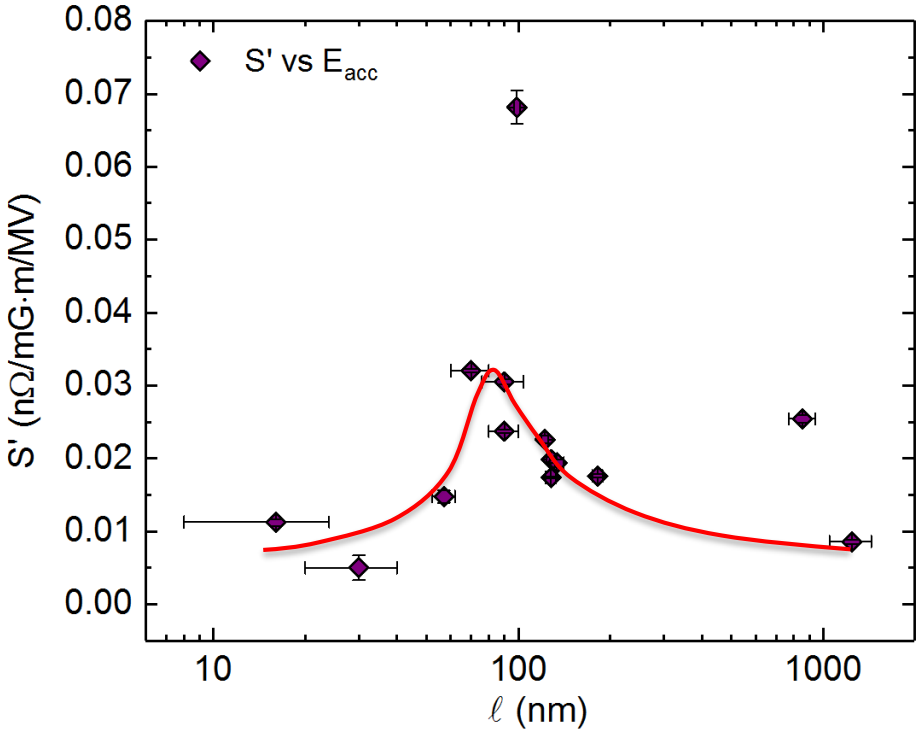

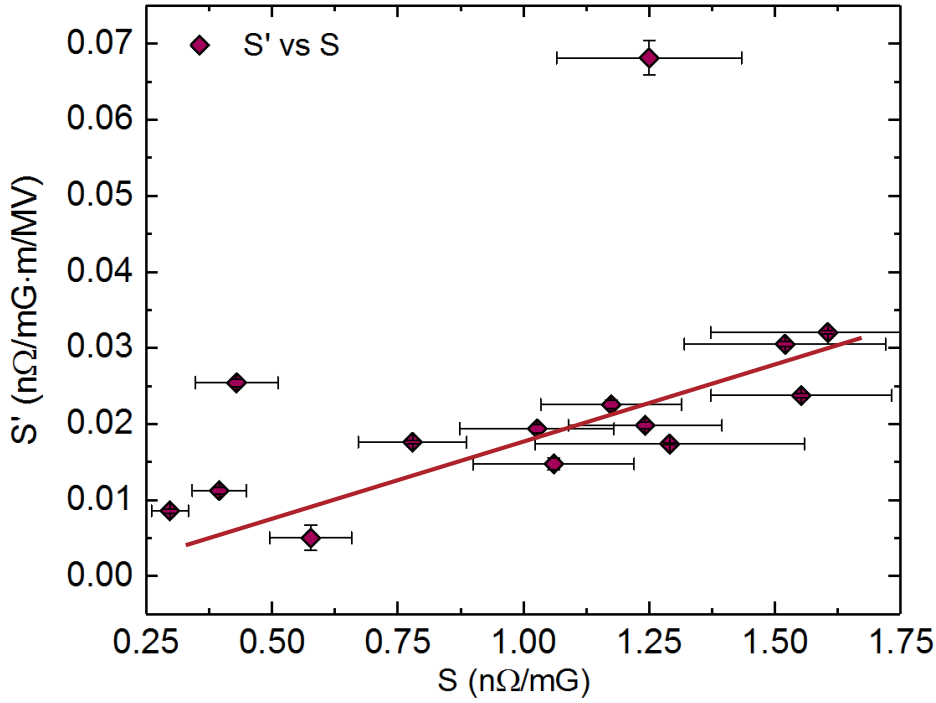

- **Bell-shaped trend** of S' as a function of mean-free-path
- **Linear trend** of S' as a function of S

In agreement with previous measurements on Nb/Cu cavities
[C. Benvenuti *et al.*, *Physica C* **316** (1999) 153-188]

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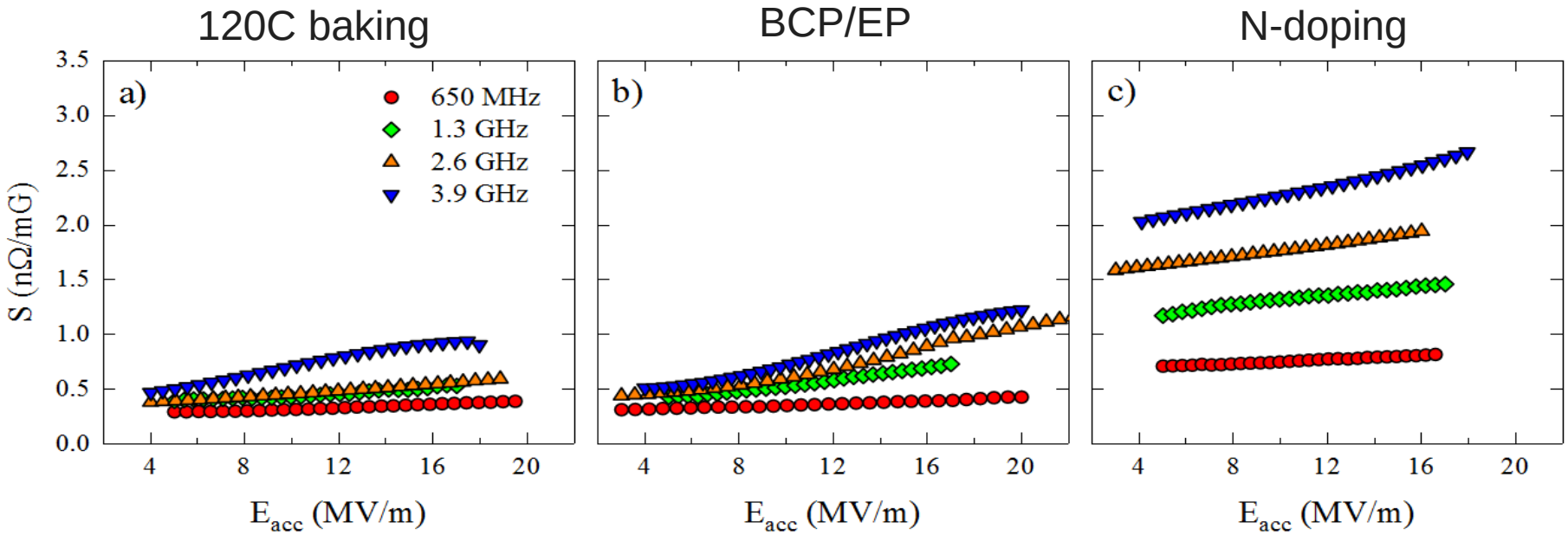
Sensitivity for different frequencies



- Trapped flux sensitivity increases with frequency
- The increment strongly depends on the surface treatment, i.e. on the mean free path
- Higher frequencies seem to have a larger field dependence

M. Checchin et al., App. Phys. Lett. 112 072601 (2018)

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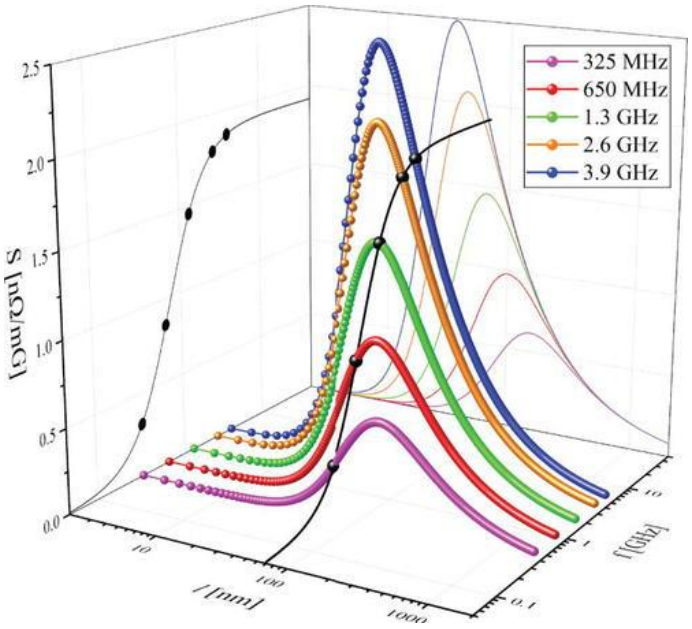
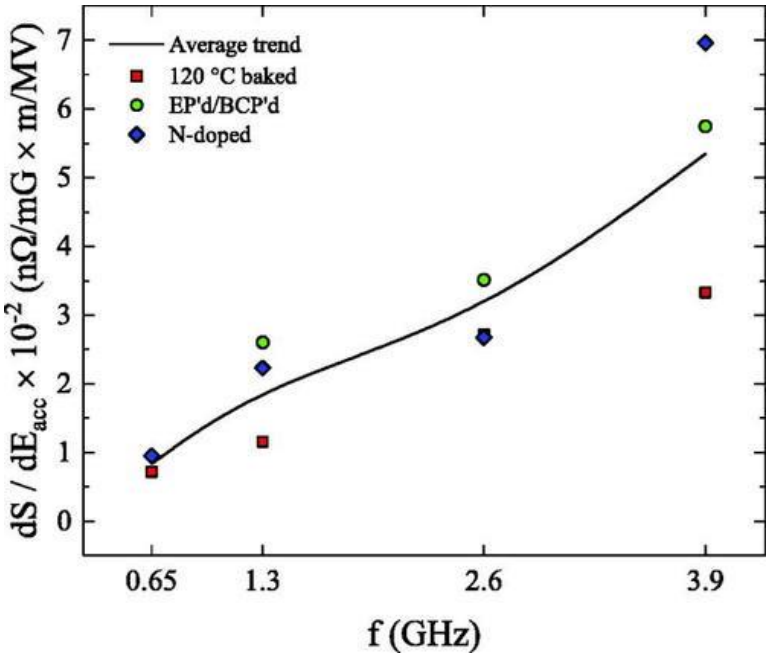
Trapped Flux Sensitivity Field Dependence

Sensitivity field dependence study as a function of the frequency

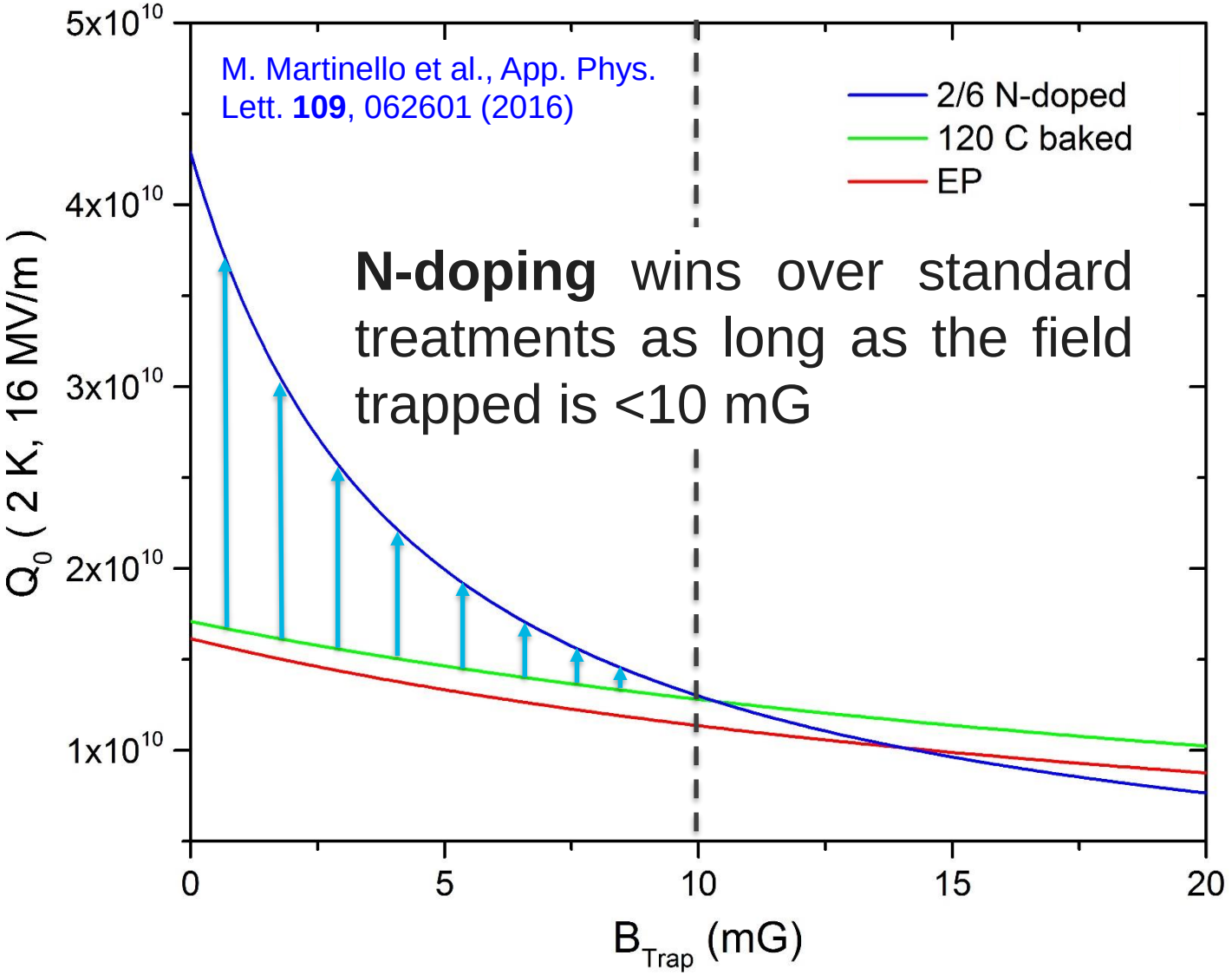




- Both the sensitivity and its field dependence (dS/dE_{acc}) **increase with the frequency**

M. Checchin et al., App. Phys. Lett. 112 072601 (2018)

The advantage of N-doping at 1.3 GHz



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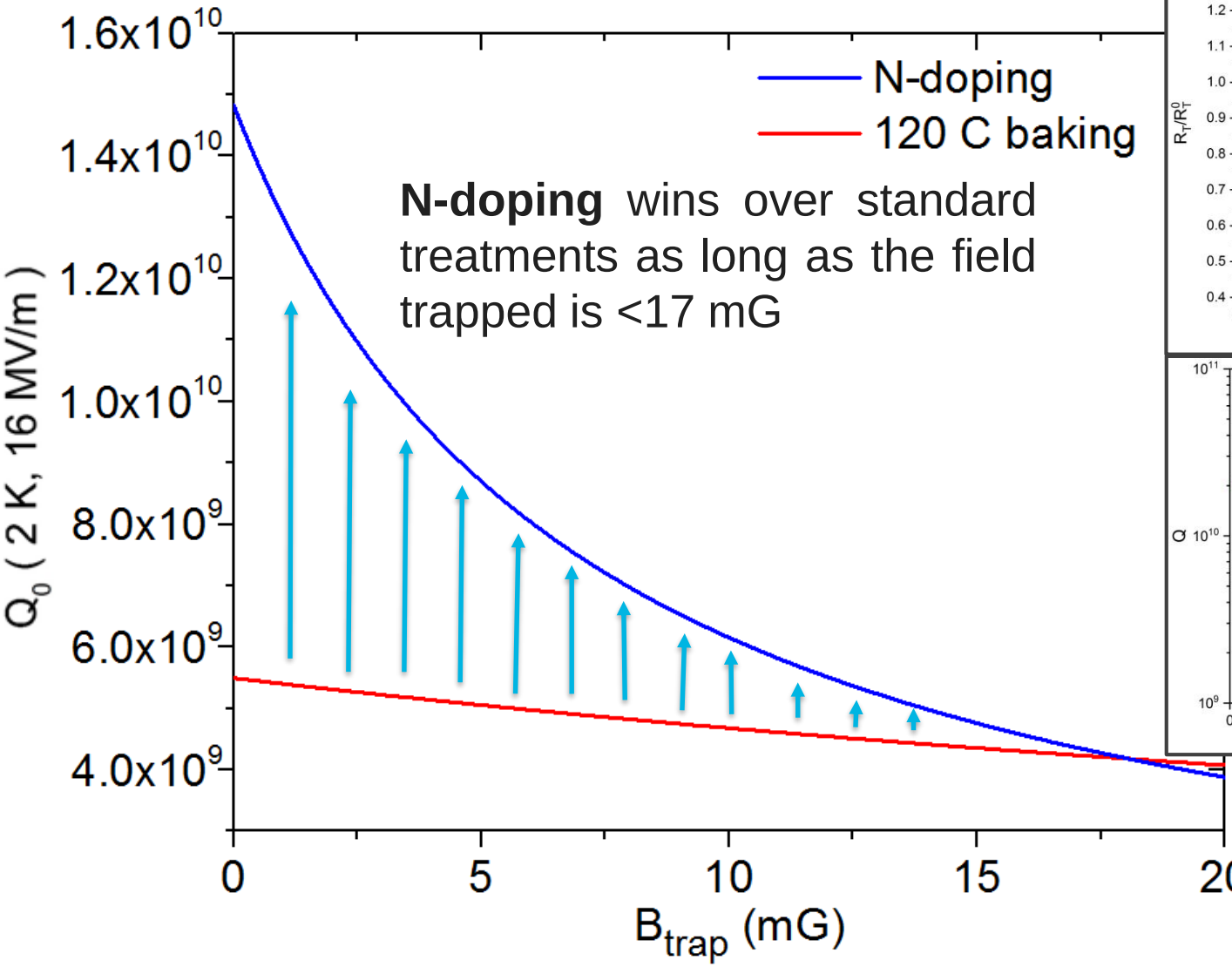
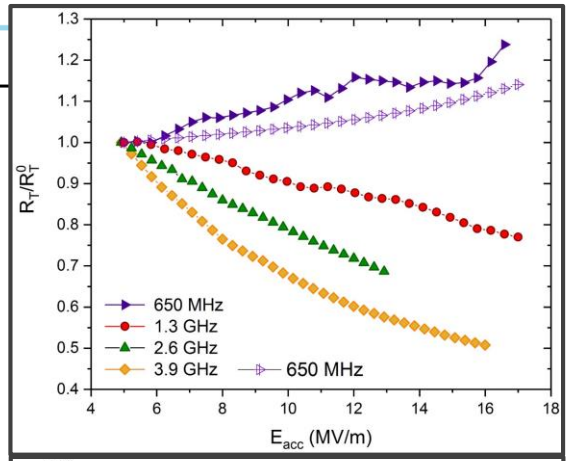
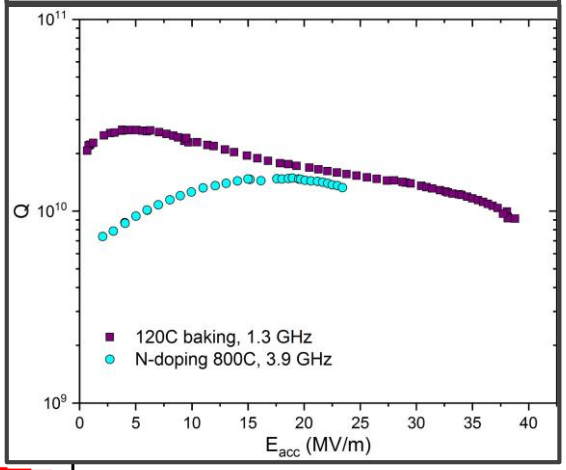
The advantage of N-doping at 3.9 GHz

M. Martinello *et al., Phys. Rev. Lett.* 2018 – in press







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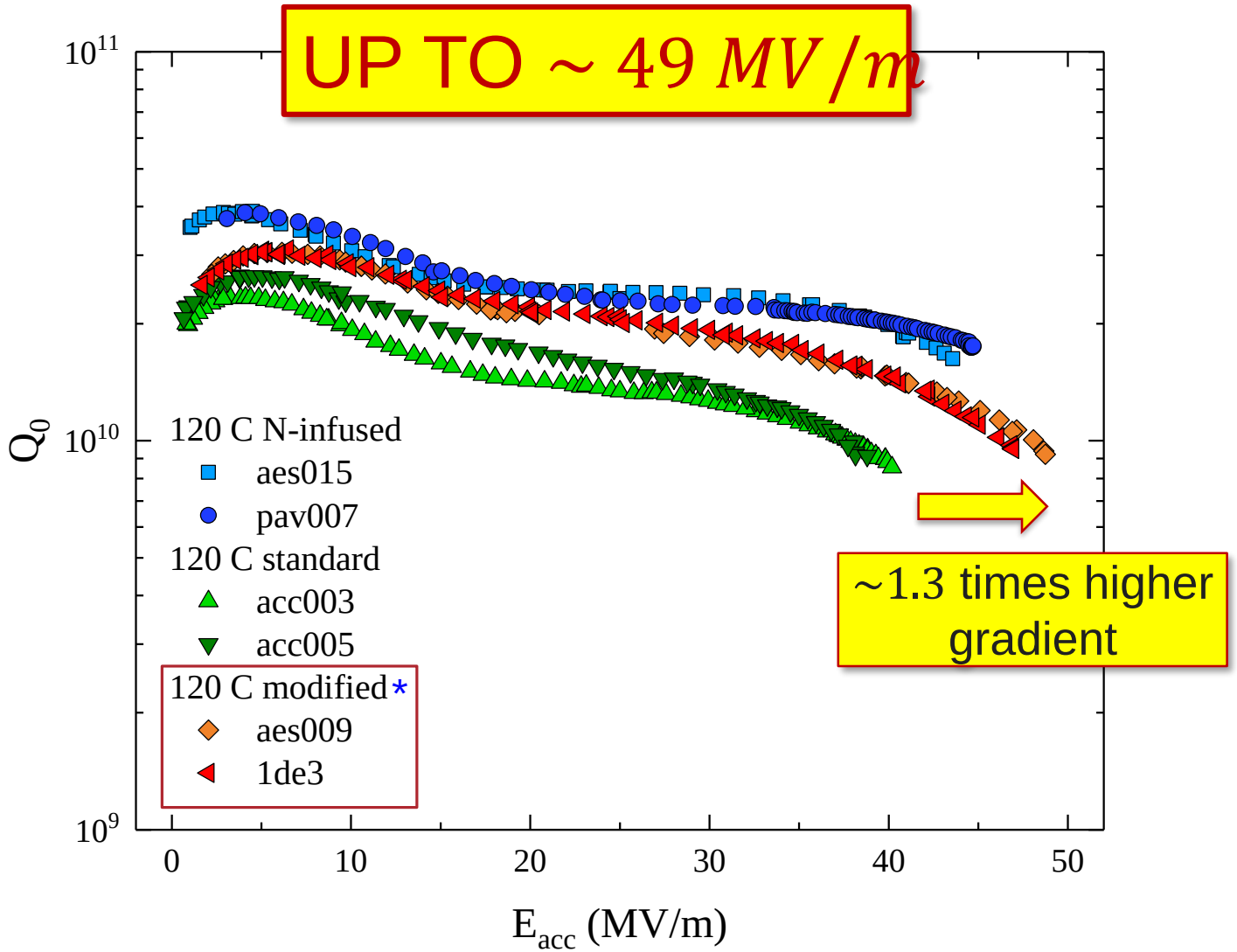
Surface treatments for high gradients



*A. Grassellino *et al.*, to be published (2018) - arXiv:1806.09824

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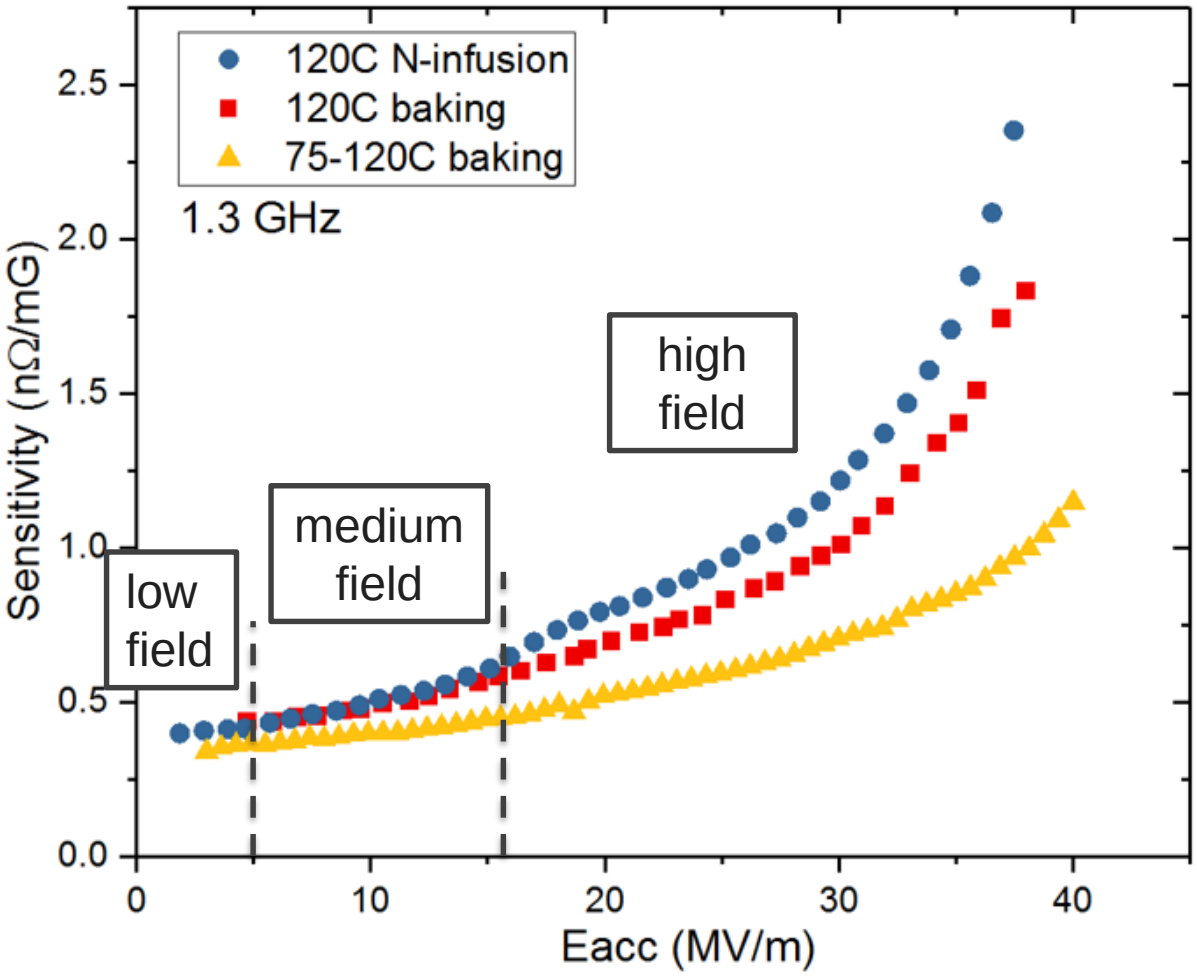
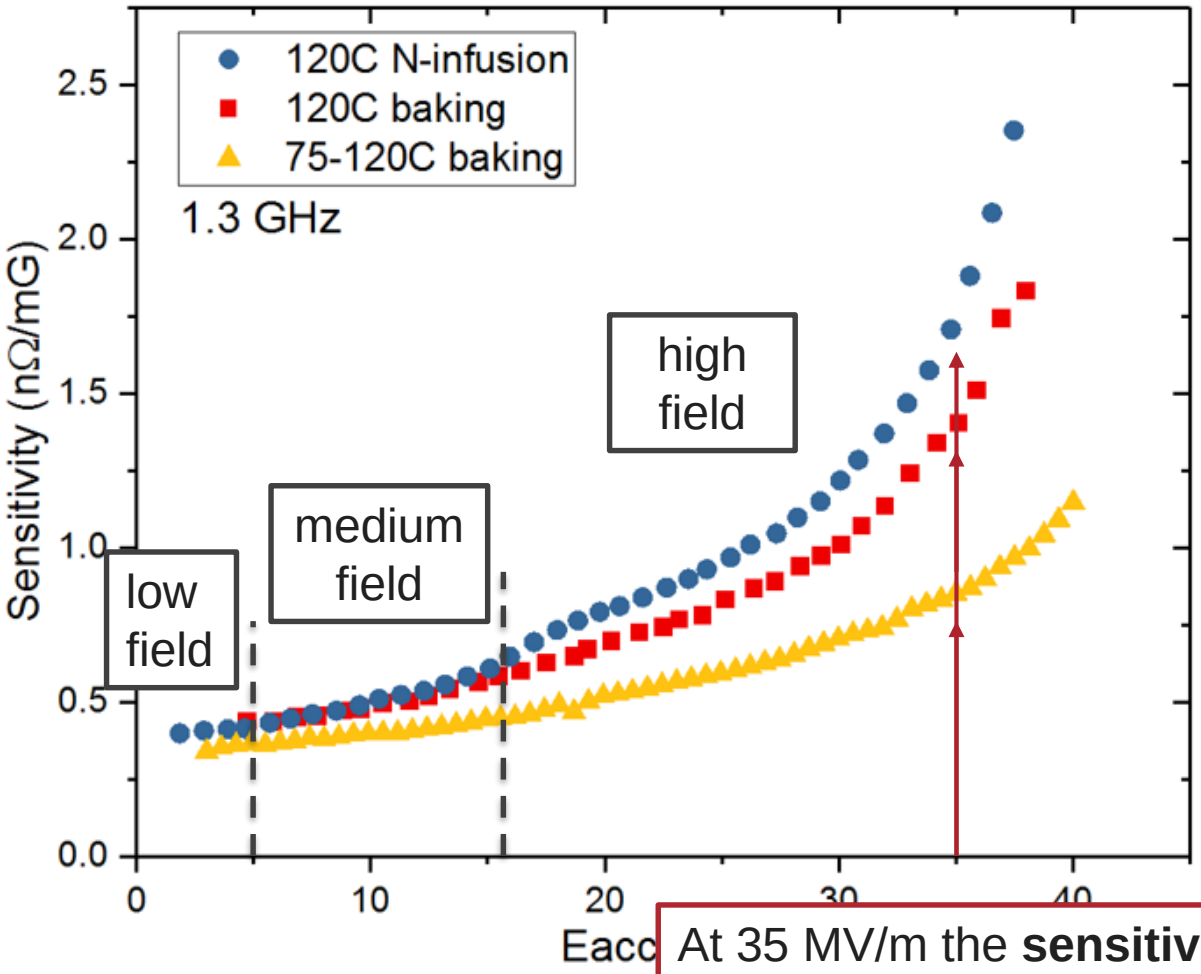
Sensitivity at high field (1.3 GHz)



- These treatments have similar mfp, and similar sensitivity values at low field
- In the medium field range the sensitivity increases almost linearly with the field
- At high field the sensitivity increases almost exponentially

Sensitivity at high field (1.3 GHz)



- These treatments have similar mfp, and similar sensitivity values at low field
- In the medium field range the sensitivity increases almost linearly with the field
- At high field the sensitivity increases almost exponentially

At 35 MV/m the **sensitivity of 75/120C baked cavities is much smaller** than 120C baked/N-infused cavities

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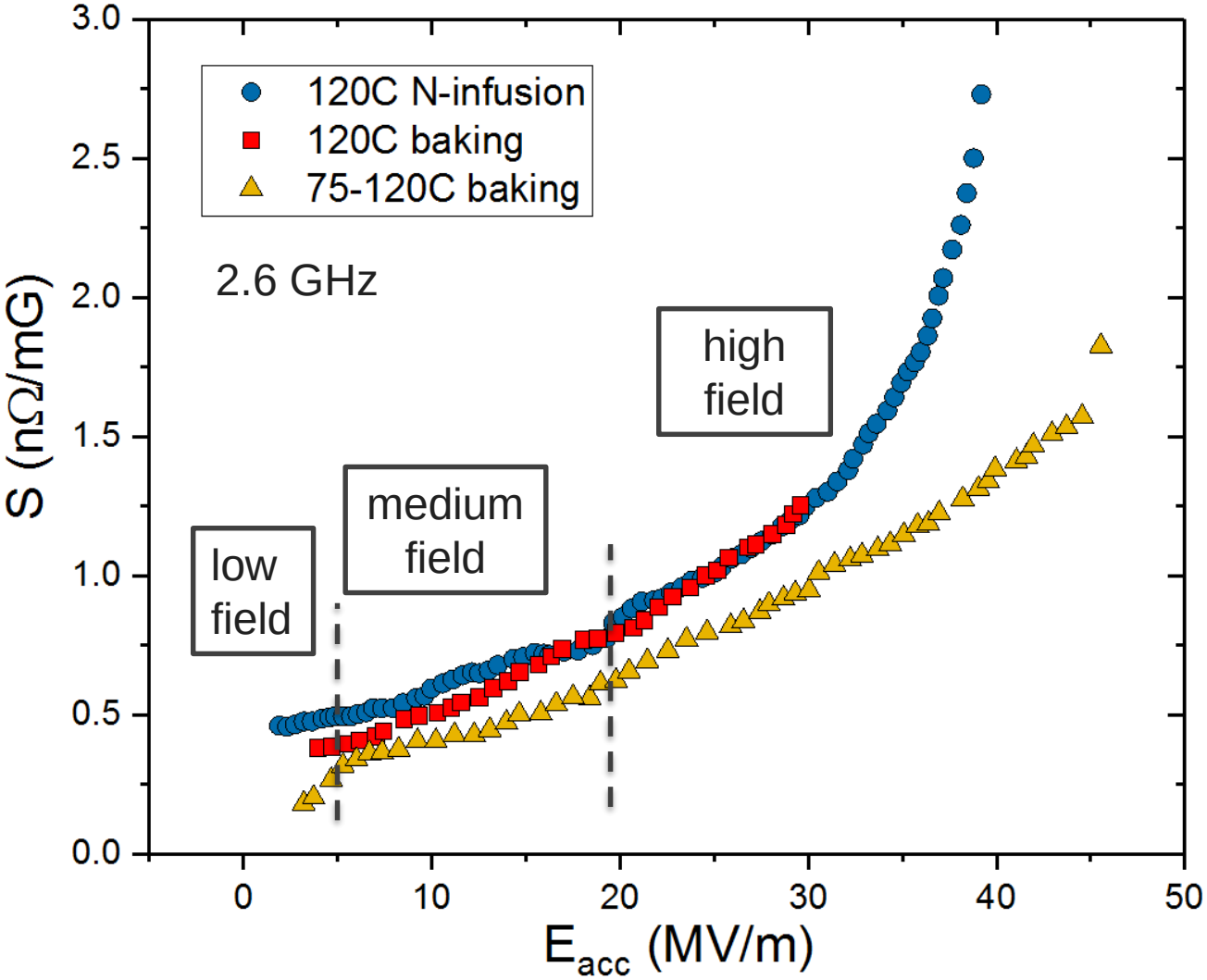
Sensitivity at high field (2.6 GHz)



Similarly to 1.3 GHz:

- Similar sensitivity values at low field
- The sensitivity increases almost linearly with the field in the medium-field range

Differently to 1.3 GHz:

- Only for the 120C N-infused at high field the sensitivity increases almost exponentially

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Conclusions

- Bell-shaped trend of sensitivity vs mfp, maximum at around 70 nm, region of N-doped cavities

- Strong field dependence of sensitivity as a function of the RF field

  - The field dependence is almost linear for the low/medium field range and become more sever at high field, i.e. at high field sensitivity might be pretty large even for surface treatment characterized by low sensitivity at low field (i.e. 120C baking)

  - Cavities with higher sensitivity shows larger field dependence

- Higher frequency cavities show larger sensitivity and also larger field dependence compared to low freq cavities