

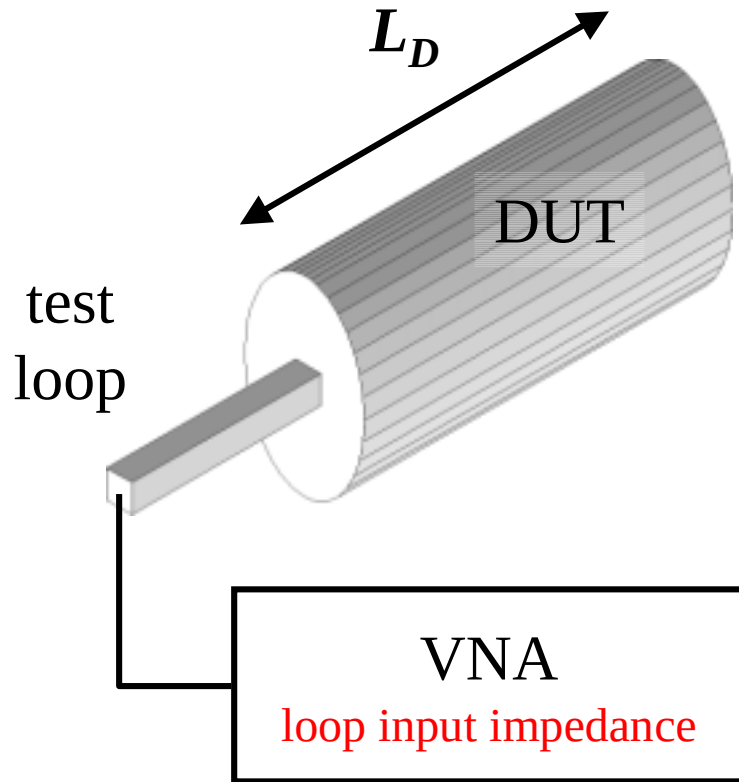
Status of the LHC dump kicker low frequency impedance evaluation

**F. Caspers, A. Mostacci, PS-RF
L. Vos, SL-AP**

- Transverse impedance measurement set-up.
- A reference case: circular steel pipe.
- Dump kicker: bypass effect on the long. imp.
- Dump kicker: trans. imp. coil measurements.
- Dump kicker: displaced wire.

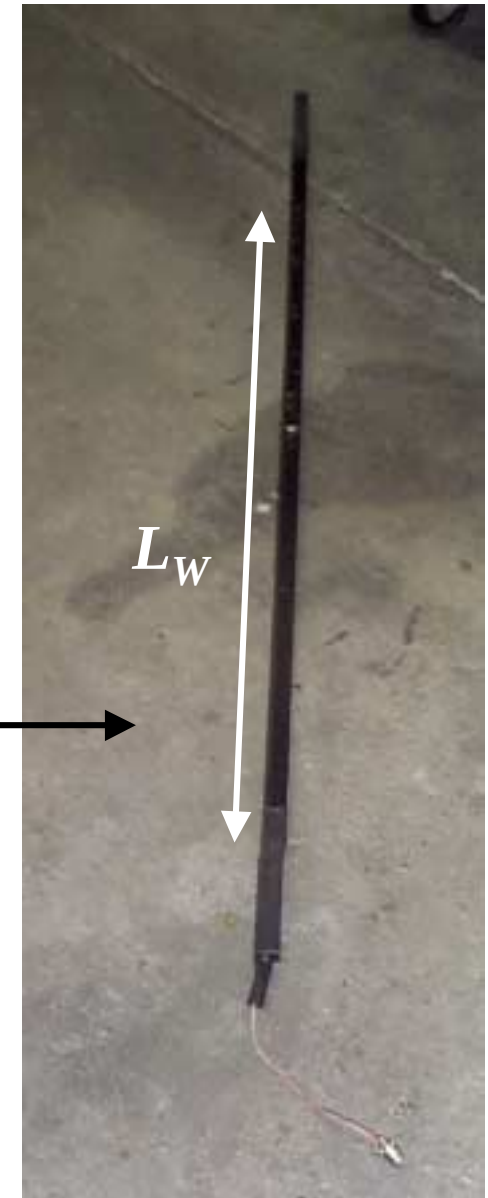


Measurement set-up



Δ loop width
 N # turns

$L_W = 1.25$ m
 $\Delta = 22.5$ mm
 $N = 10$



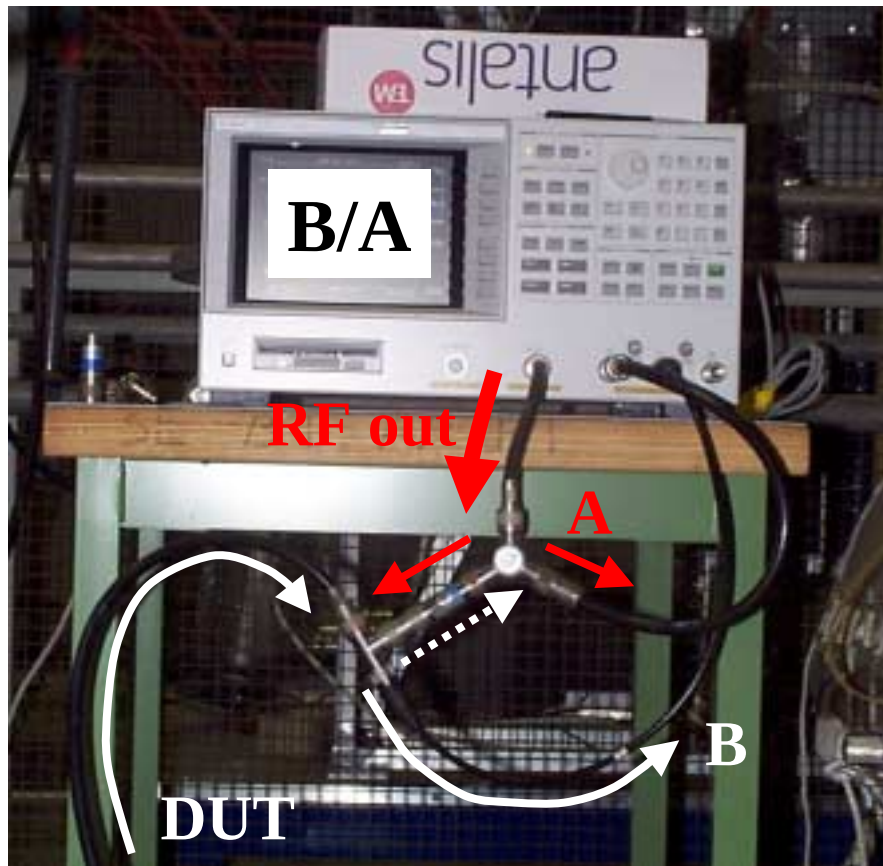
$$Z_T = \frac{c}{\omega} \frac{Z^{DUT} - Z^{free}}{N^2 \Delta^2}$$

added loop
impedance



Two different network analyzer set-ups

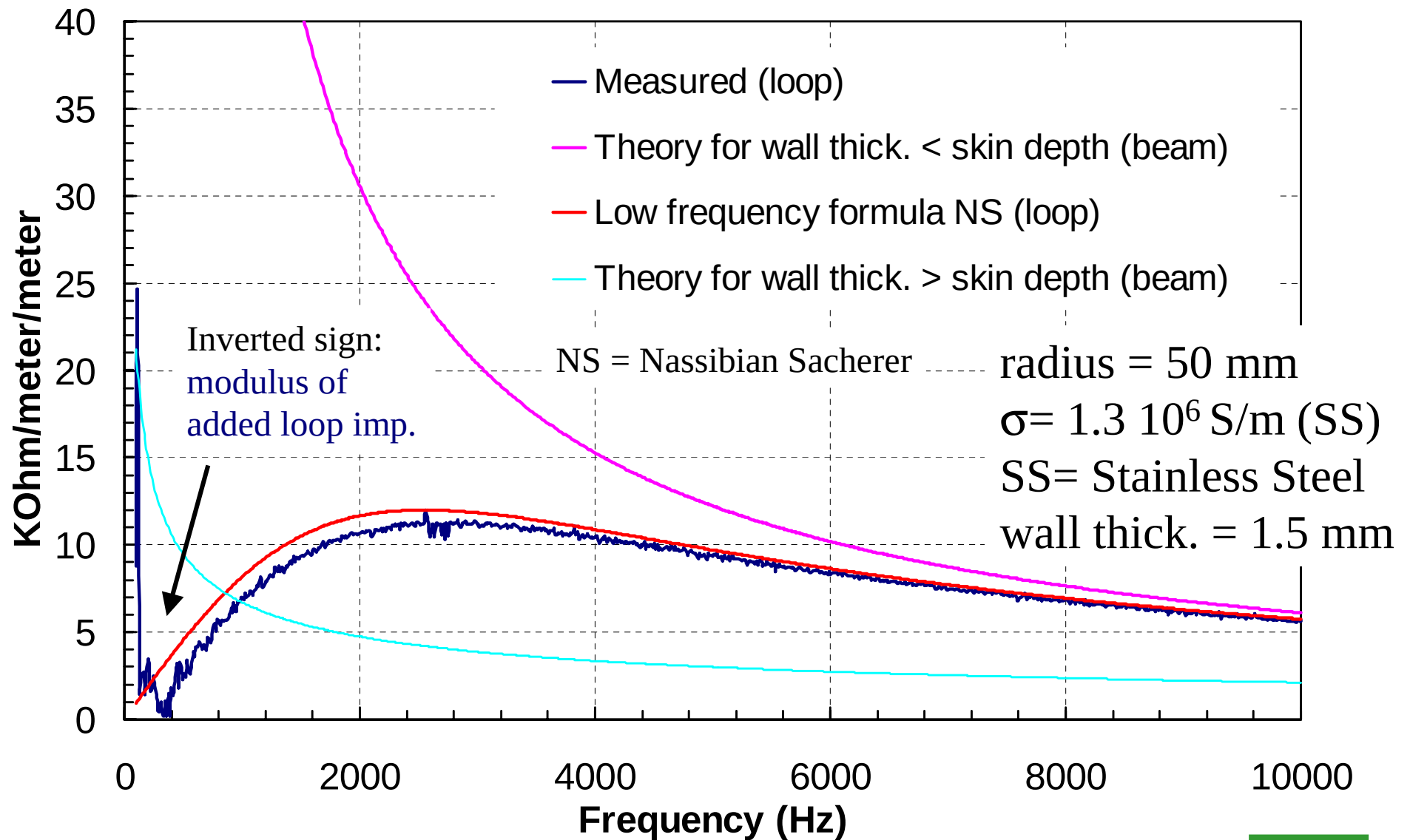
To measure the added loop impedance, two different S-parameters test sets are used, according to the frequency range. The DUT has an impedance much smaller than 50 Ohm.



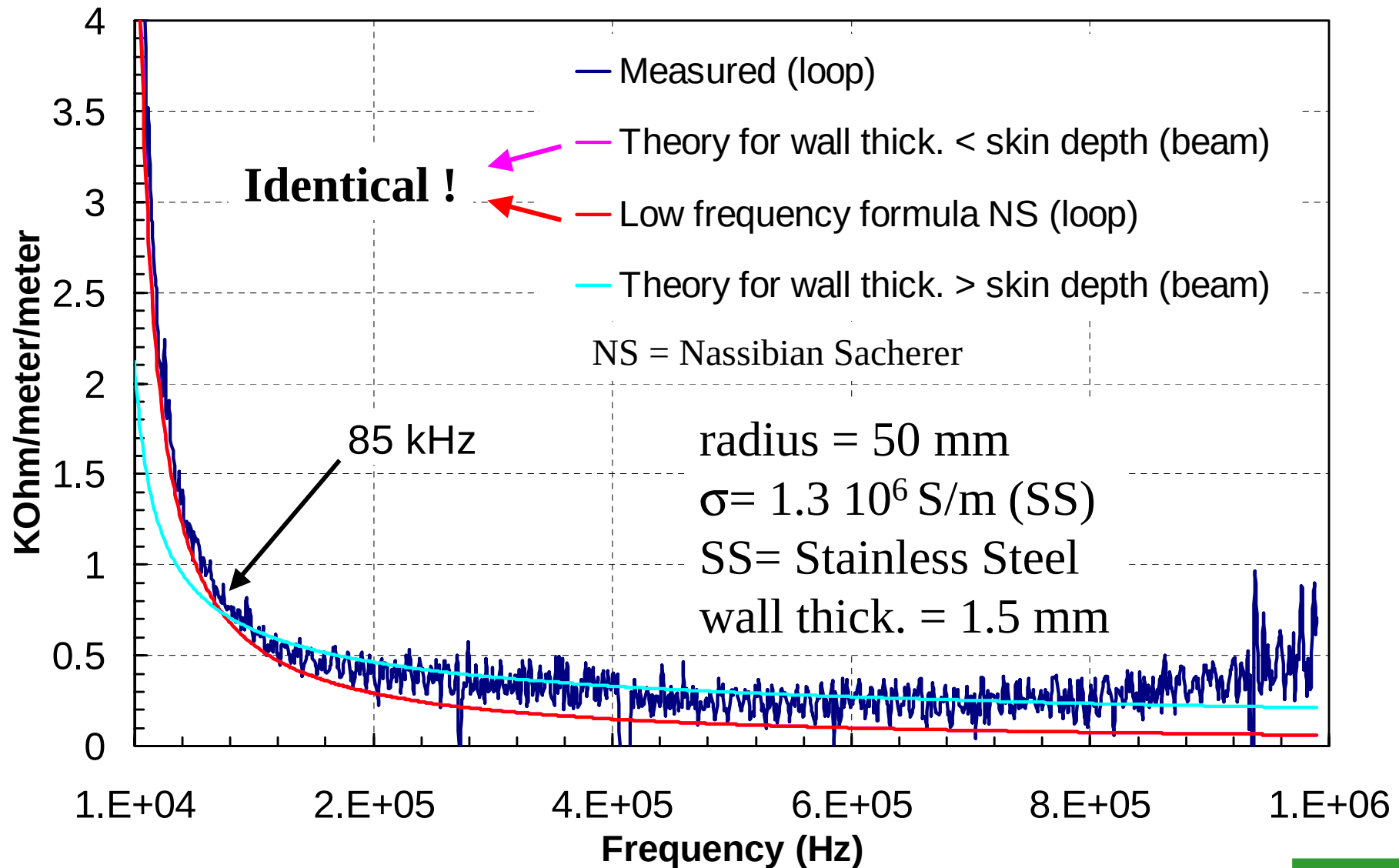
1. Resistive coupling network
100 Hz – 10 kHz (IF-BW=30 Hz)

2. Transformer type dir. coupler
10 kHz – 1 MHz (IF-BW=100 Hz)

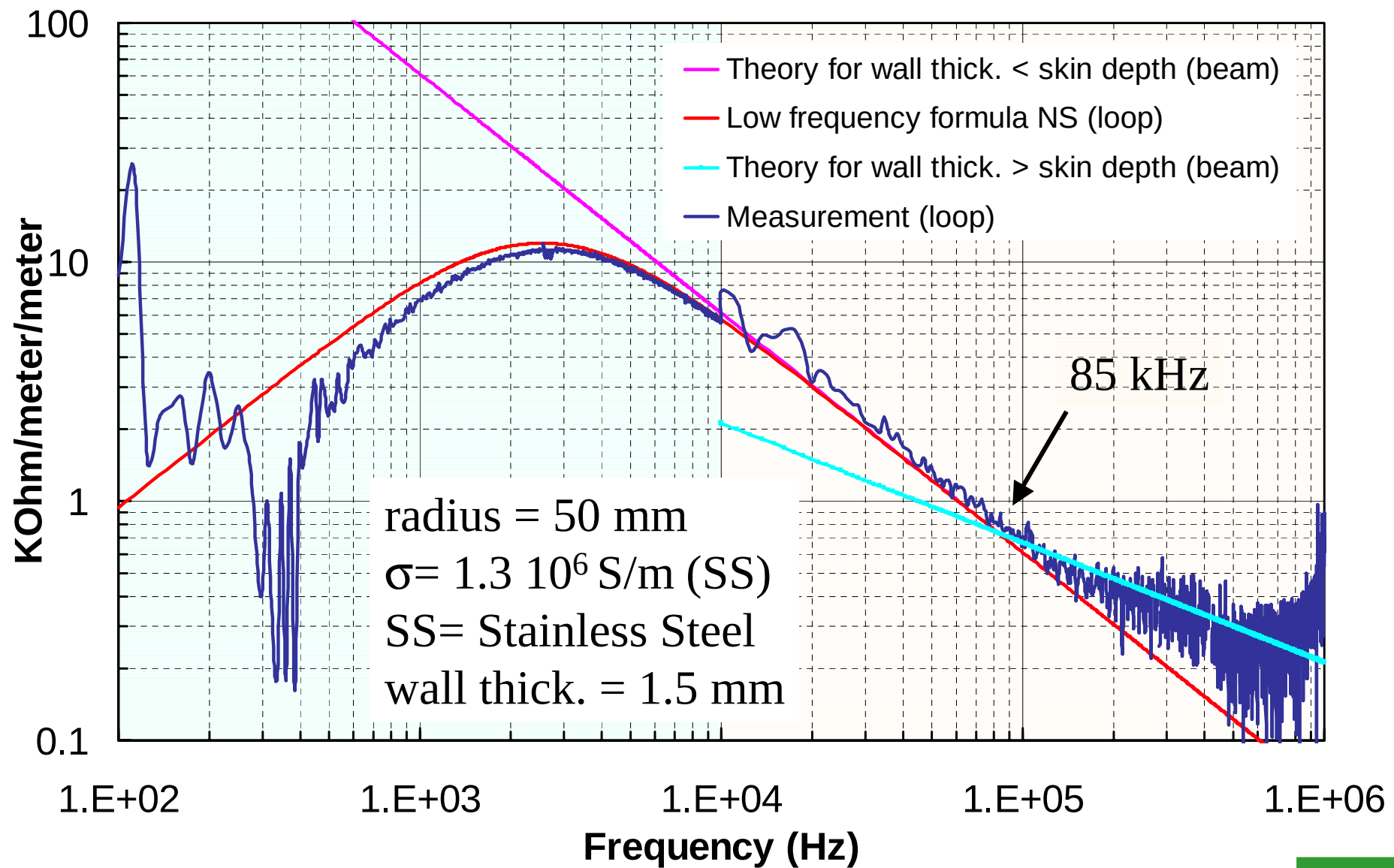
Re {trans. imp. per unit length}: circular pipe



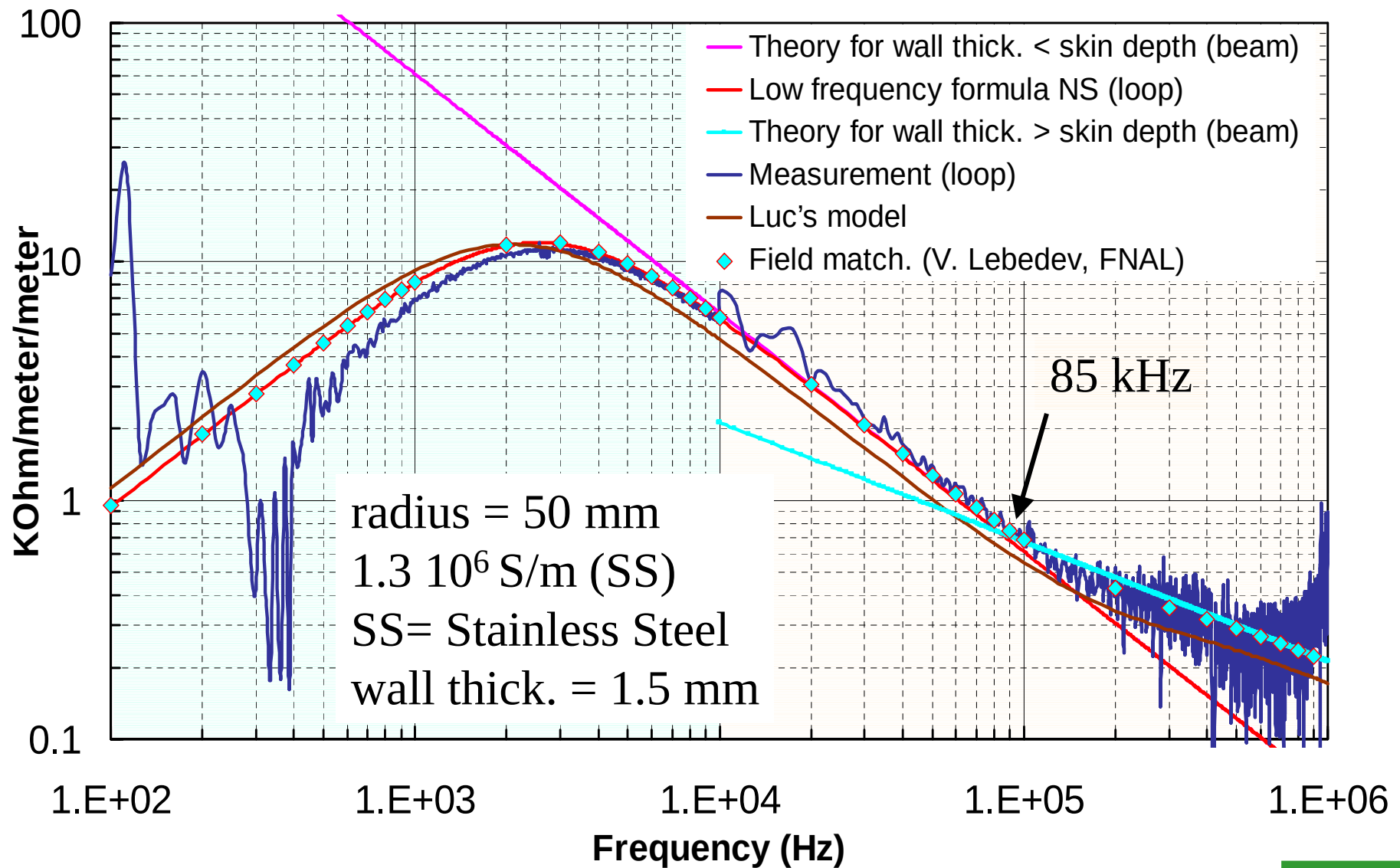
Re {trans. imp. per unit length}: circular pipe



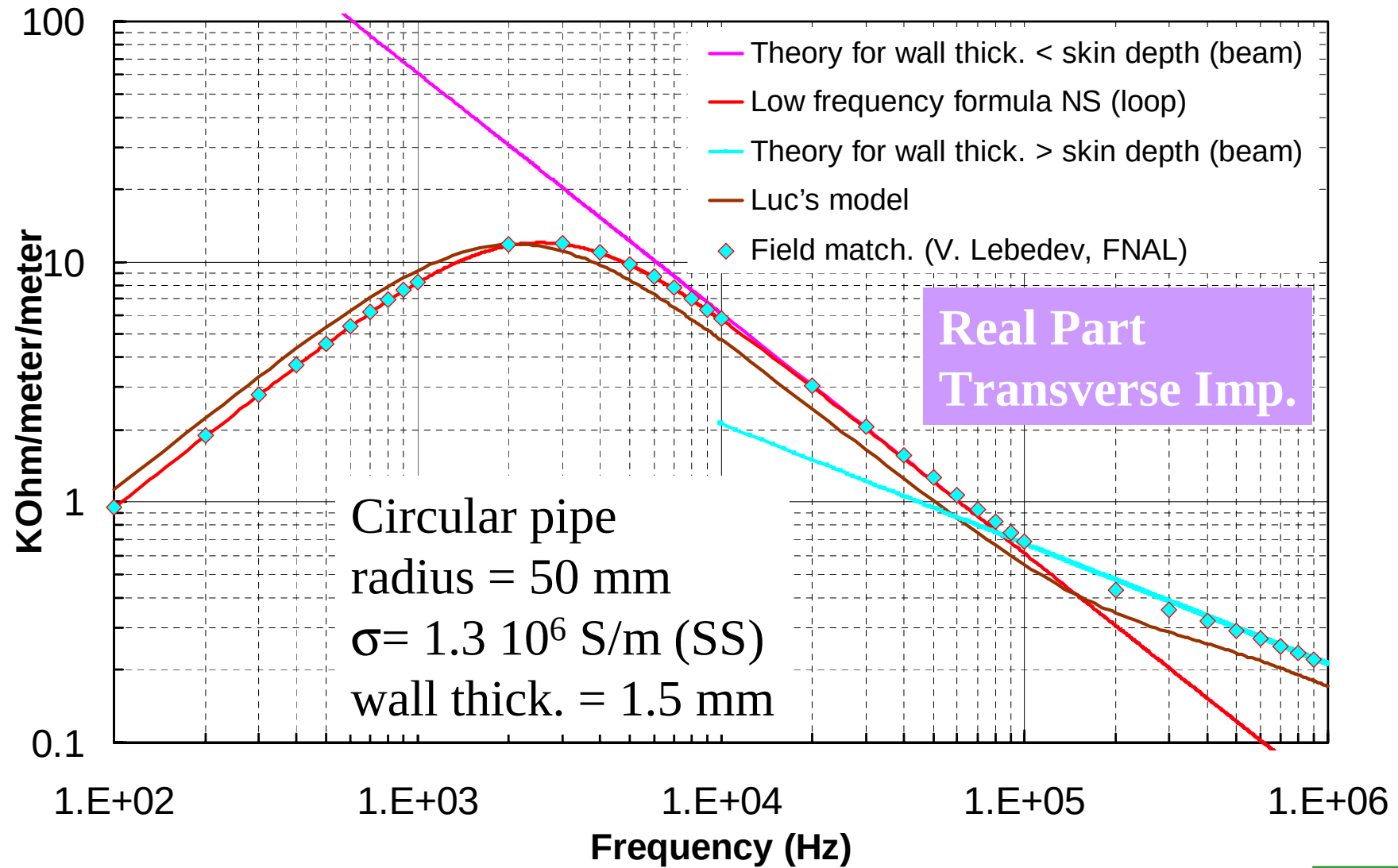
Re {trans. imp. per unit length}: circular pipe



Re {trans. imp. per unit length}: circular pipe



From theory ...



Used formulae: circular pipe

$$\frac{Z_T}{L} = \frac{1+j}{2\pi} \mu_r \frac{Z_0 \delta}{b^3} \quad \delta \ll d \quad (\text{thick wall})$$

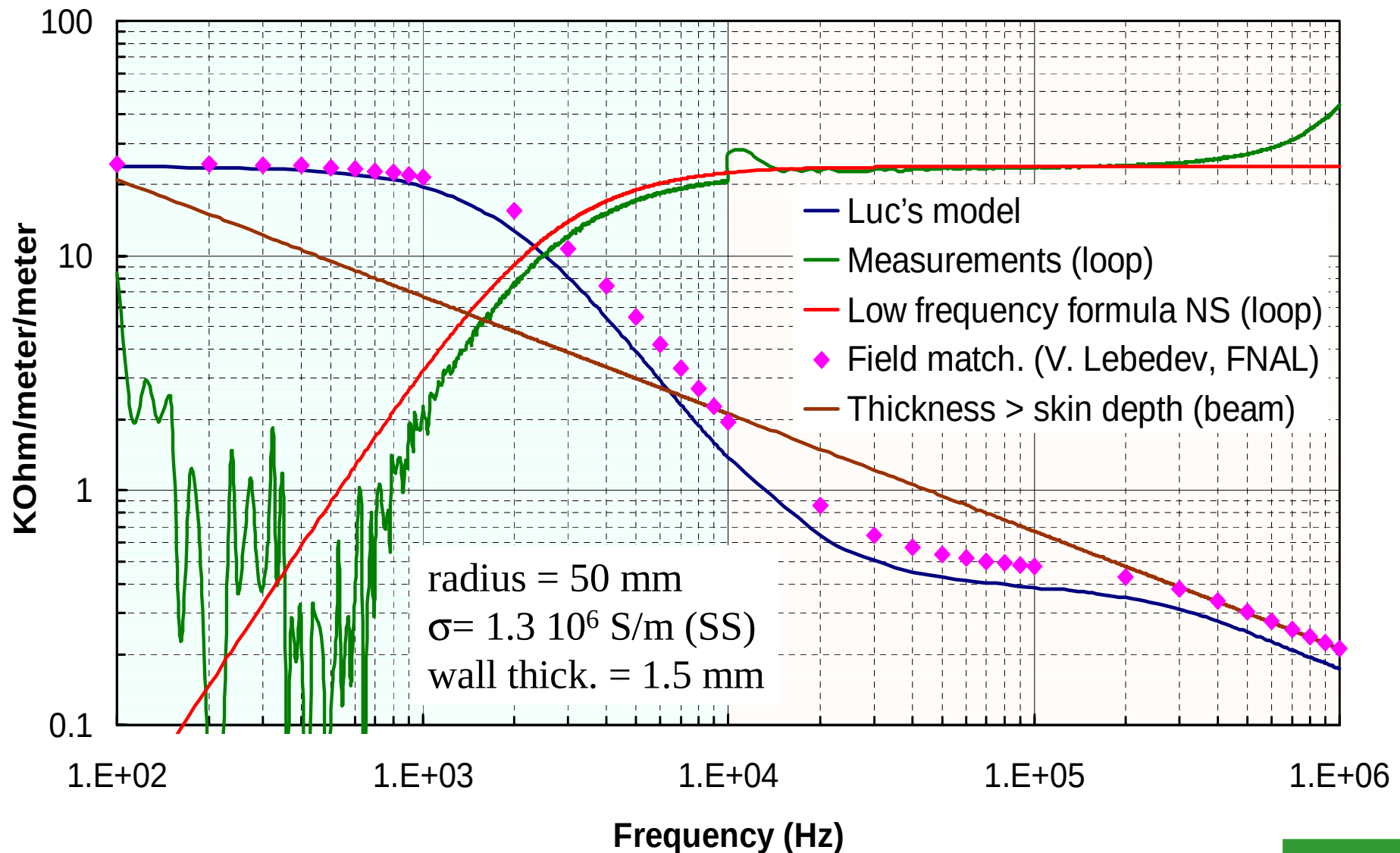
b radius
 d wall thickness
 σ wall conductivity
 L device length
 δ skin depth

$$\frac{Z_T^{\text{Re}}}{L} = \frac{c}{\pi b^3 \sigma \omega d} \quad \delta \gg d \quad (\text{thin wall})$$

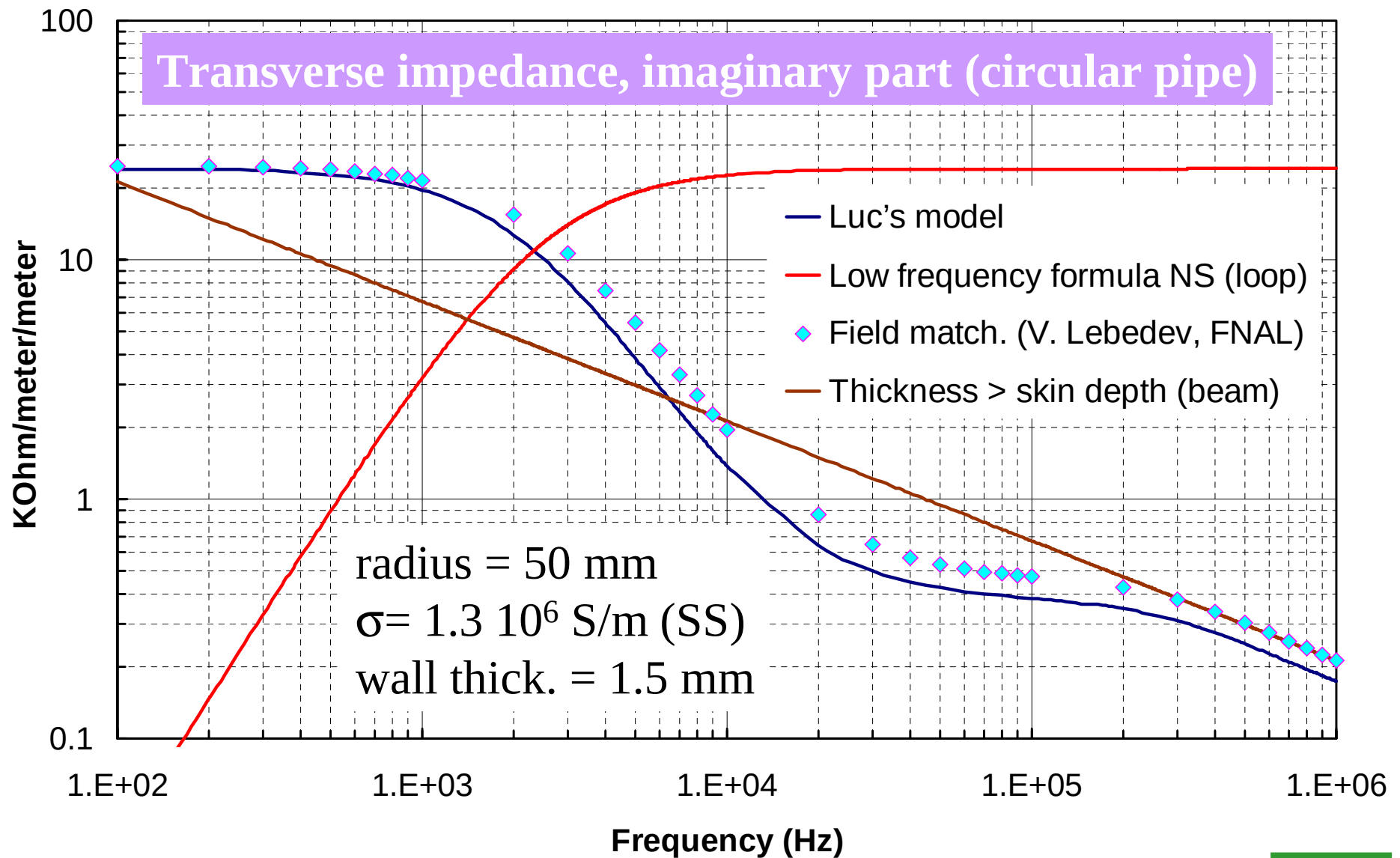
Nassibian Sacherer

$$Z_T = \frac{c}{4\omega b^2} \frac{R_W - j\omega L_W}{1 + (\omega_c/\omega)^2} \quad \omega_c = \frac{R_W}{L_W} \quad R_W = 8 \frac{L}{2\pi b d \sigma} \quad L_W = \frac{2\mu_0 \mu_r}{\pi} L$$

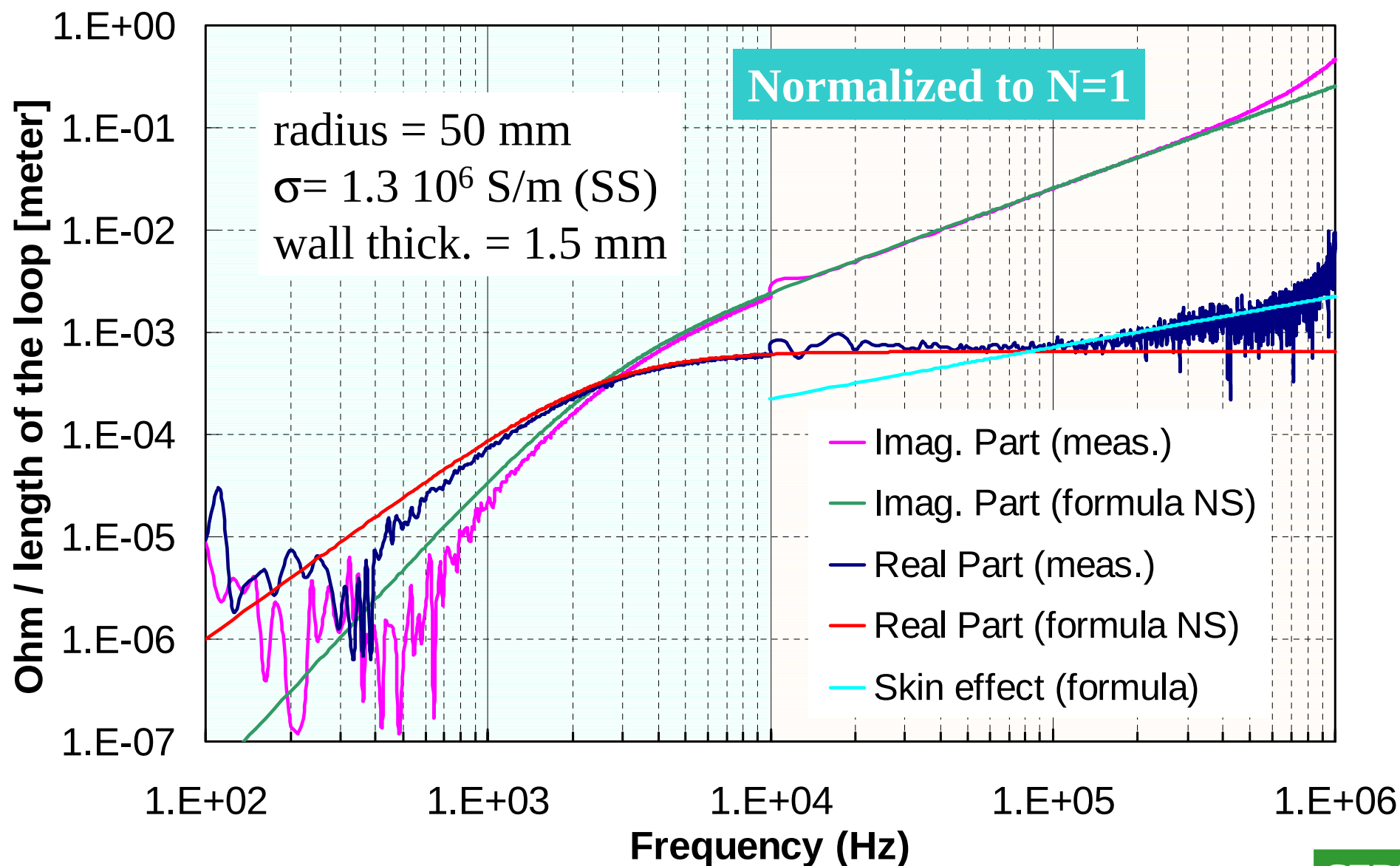
Im {trans. imp. per unit length}: circular pipe



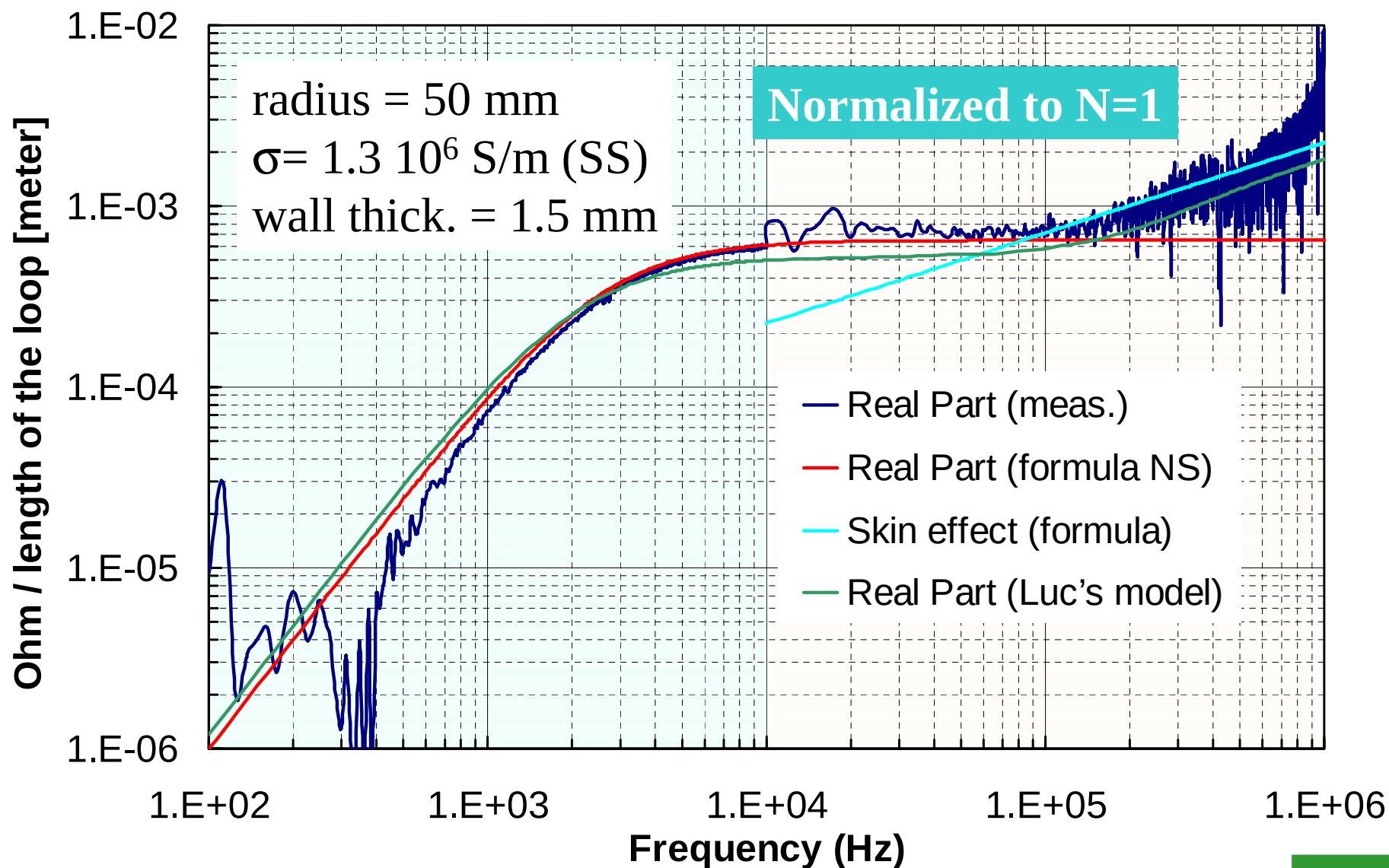
From theory ...



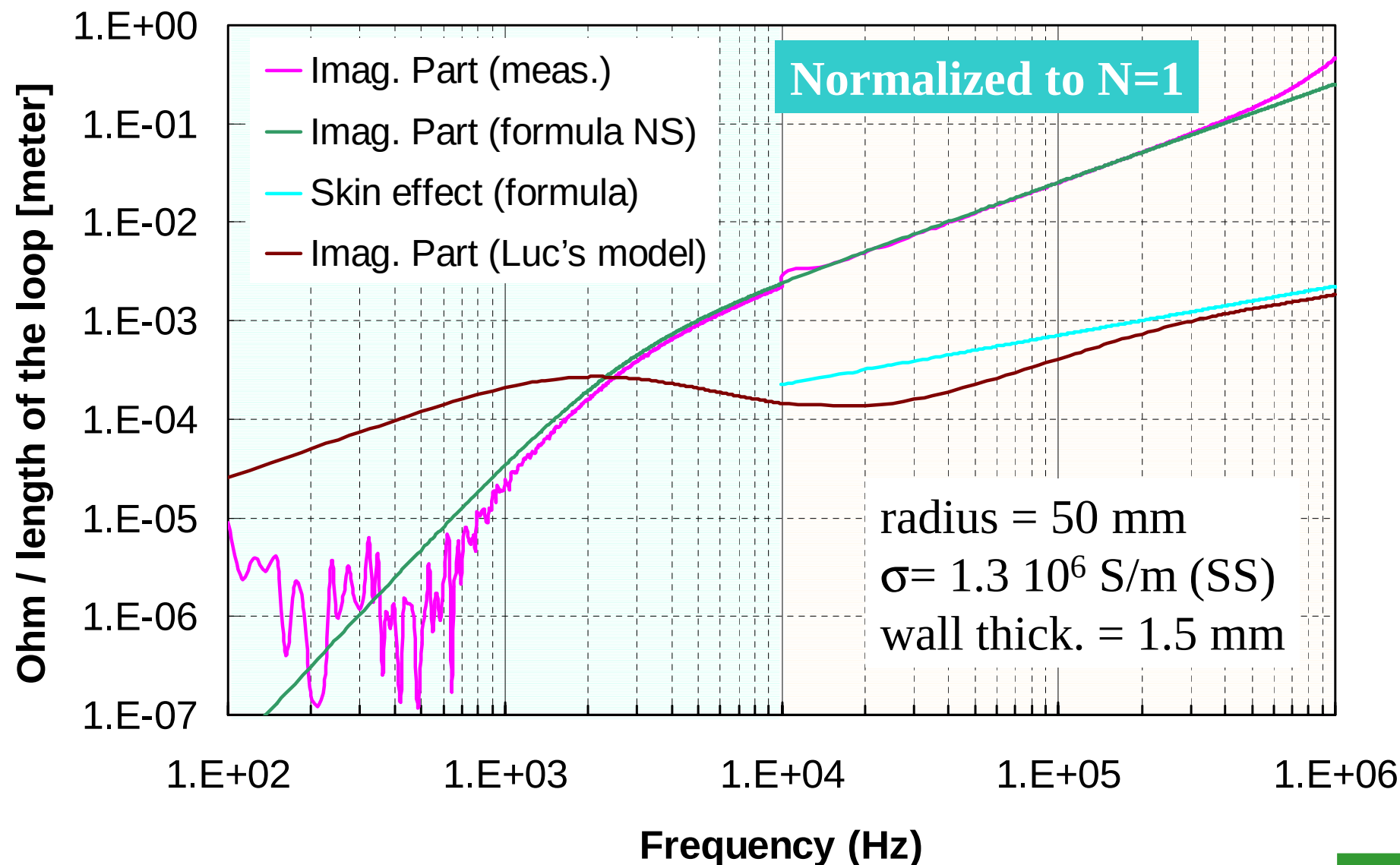
Added loop impedance: circular pipe



Added loop impedance: circular pipe



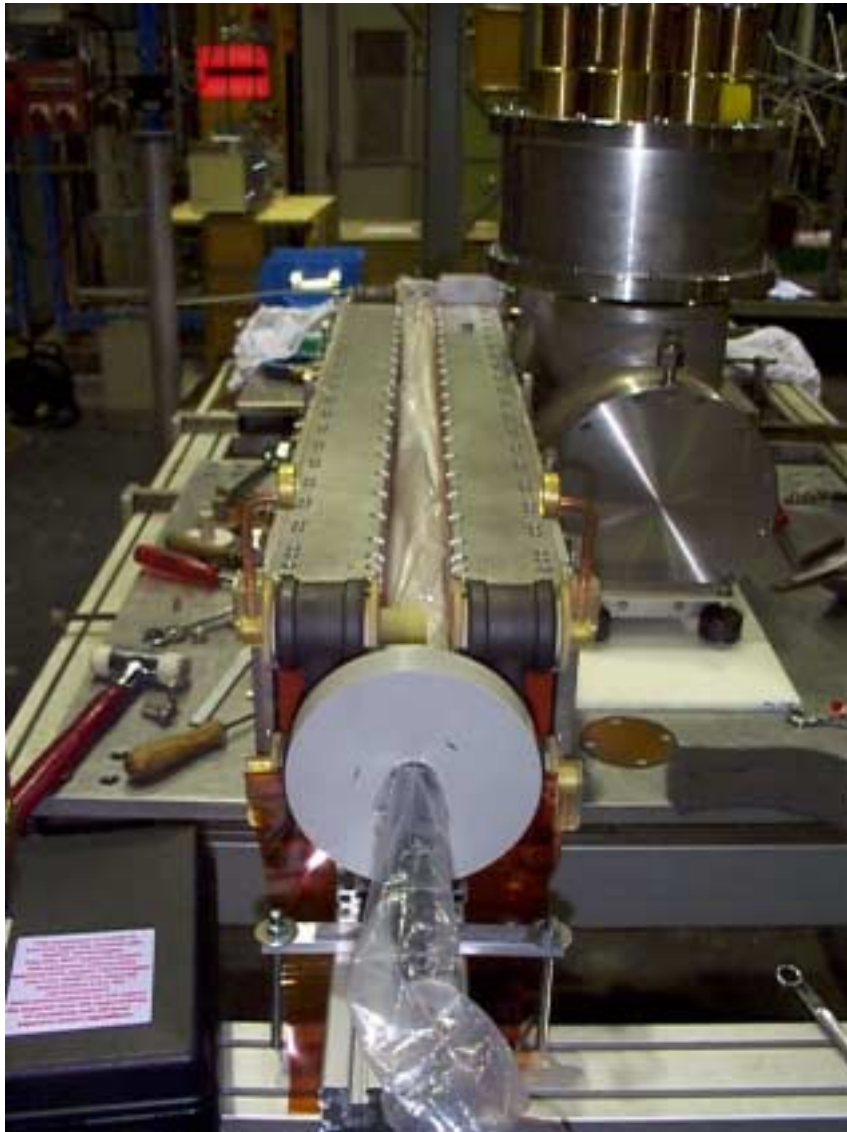
Added loop impedance: circular pipe



The reference measurement surprise

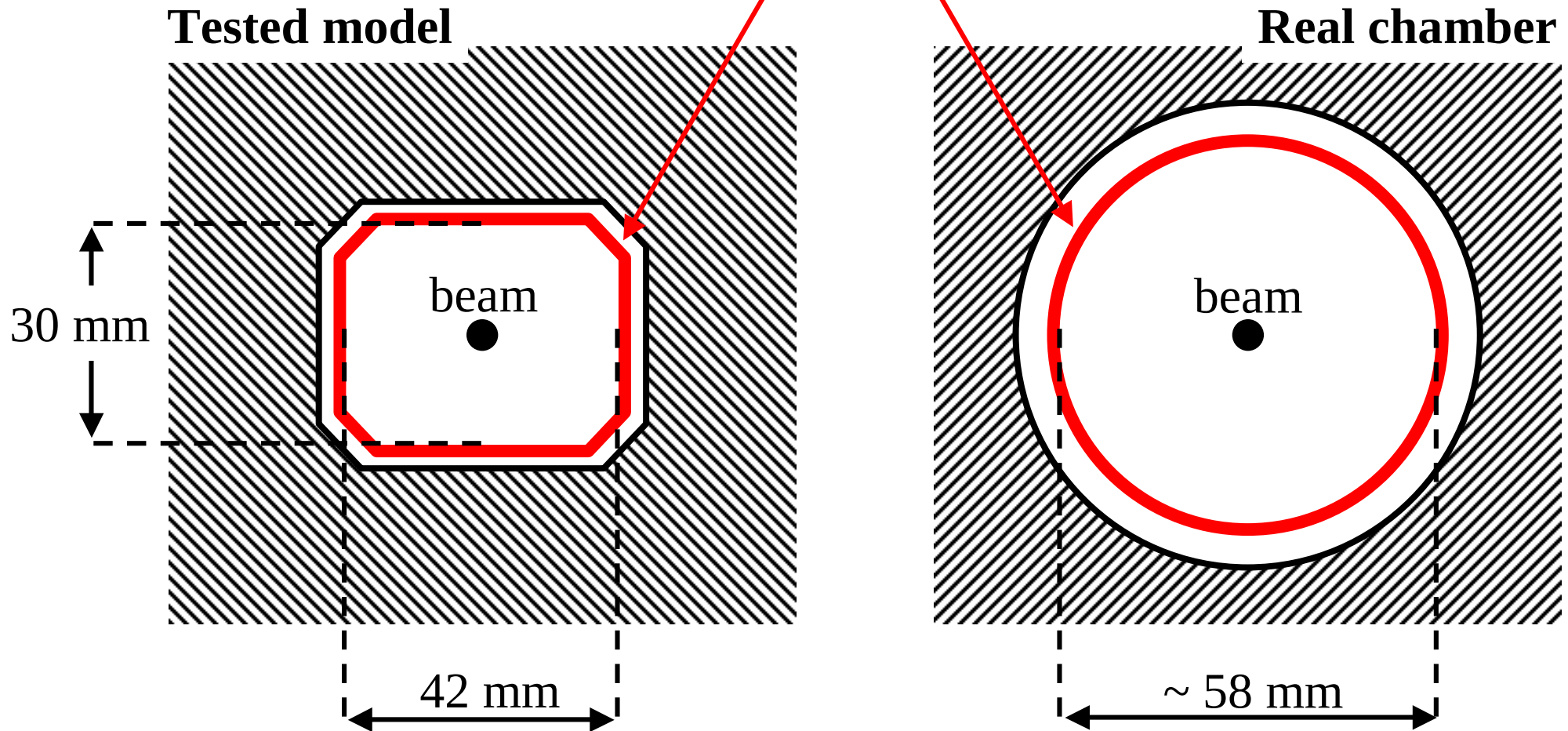
- At low frequencies the imaginary part **CAN NOT** be deduced from loop measurements. (hints of possible explanation from international discussion group).
- Good agreement measurement/theory of the real part (Nassibian Sacherer algorithm, both for added loop impedance and its conversion to transverse coupling impedance).
- The resonance frequency of the loop in the free space is about 1.5 MHz.

Kicker model under test



Kicker model under test: ceramic chamber

Titanium film ($R_{\text{square}} \sim 0.1 \text{ Ohm}$)



Longitudinal impedance from meas. data (I)

The length of the DUT is much smaller than the wavelength.

Transmission measurements

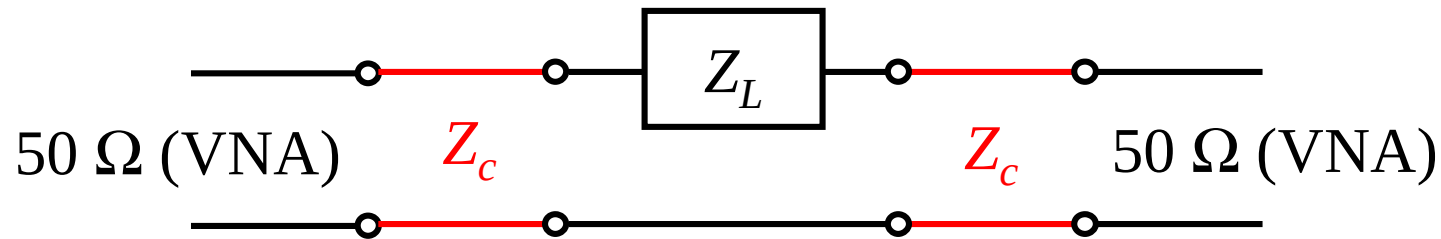
$$Z_L = 2Z_c \frac{1 - S_{12}}{S_{12}}$$

Reflection measurements

$$Z_L = Z_c \frac{1 + S_{11}}{1 - S_{11}}$$

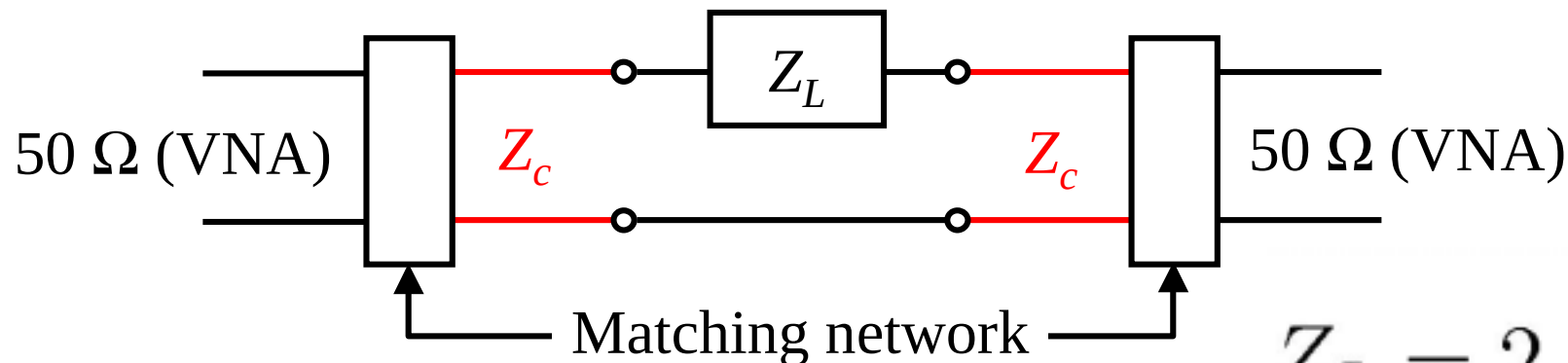


Longitudinal impedance from meas. data (II)



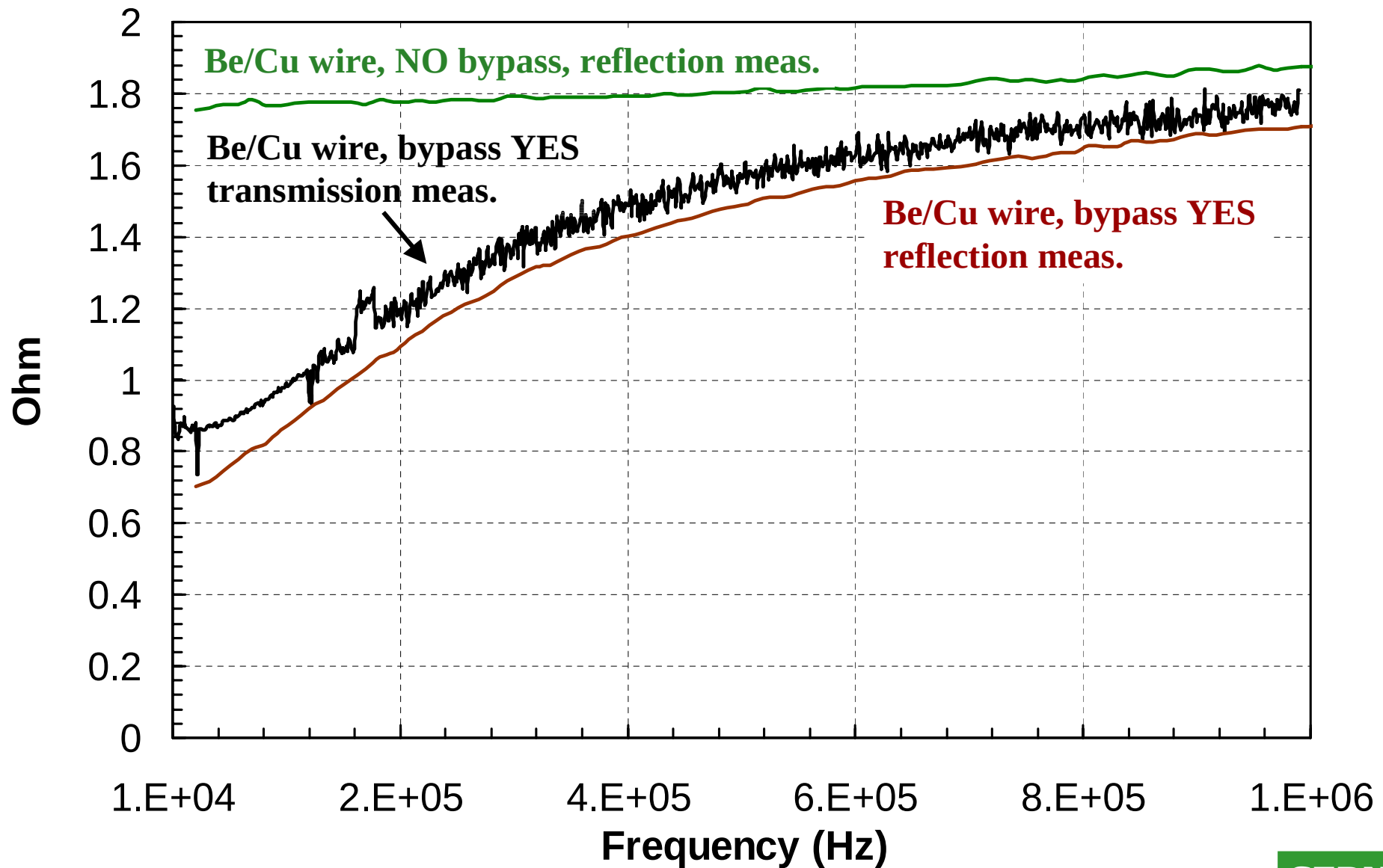
If Z_L is a lumped element and neglecting the two **very short** lines with Z_c (no matching network)

$$Z_L = 2 Z_{50} \frac{1 - S_{12}^{50}}{S_{12}^{50}}$$

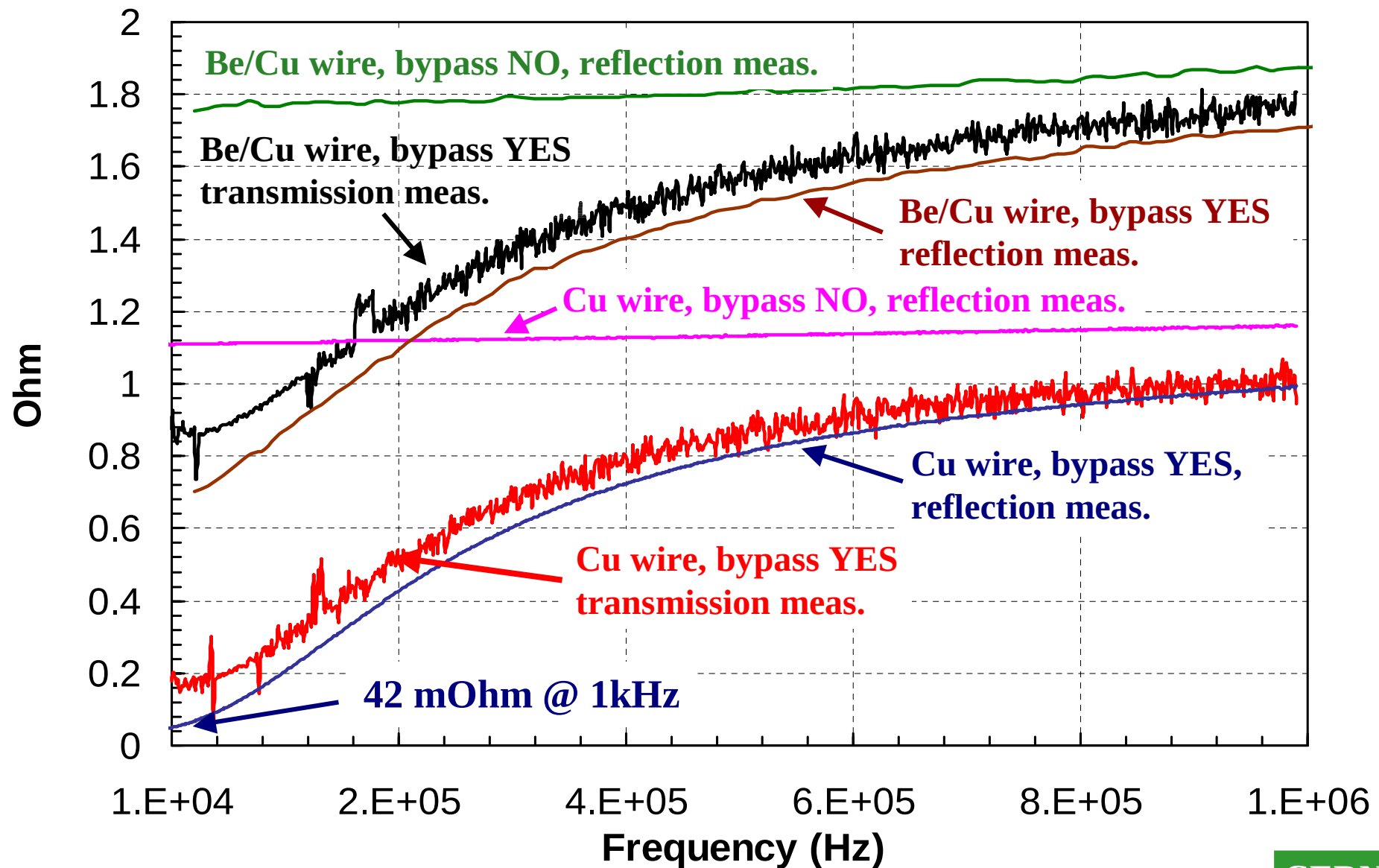


$$Z_L = 2 Z_c \frac{1 - S_{12}^{50}}{S_{12}^{50}}$$

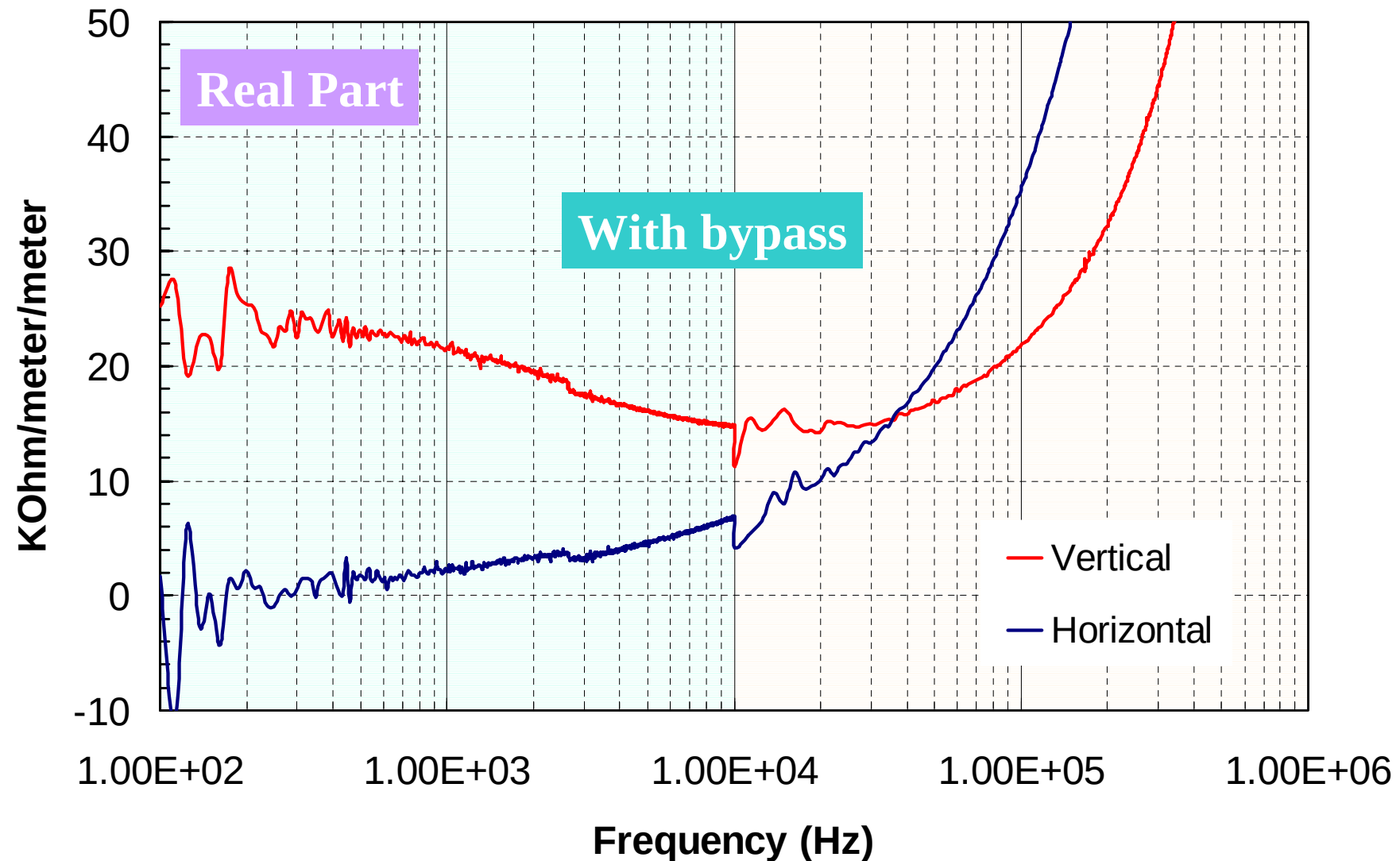
Longitudinal impedance (real part)



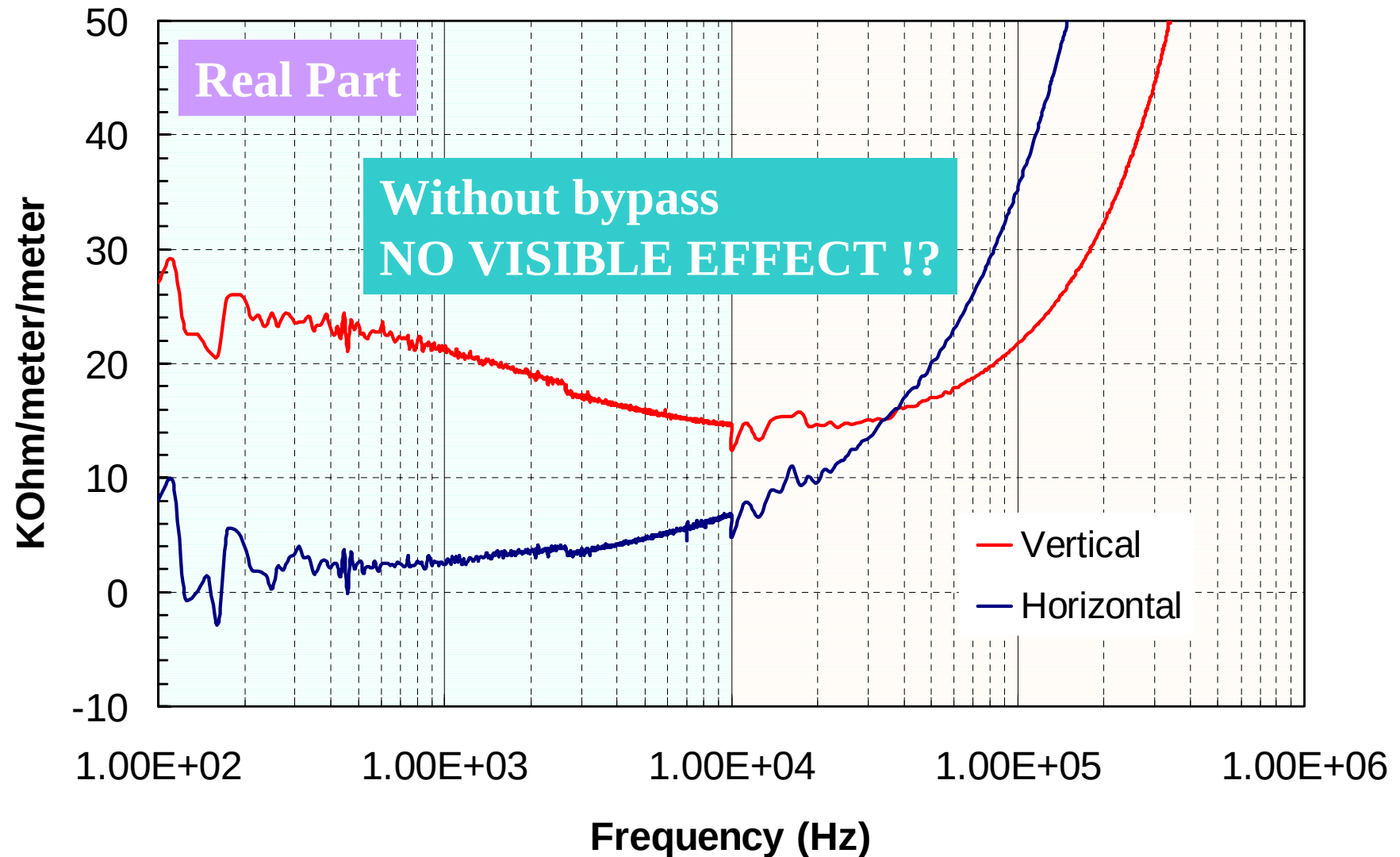
Longitudinal impedance (real part)



Trans. imp. per unit length: coil measurement



Trans. imp. per unit length: coil measurement



Trans. imp. from displaced wire meas.

According to Nassibian Sacherer:

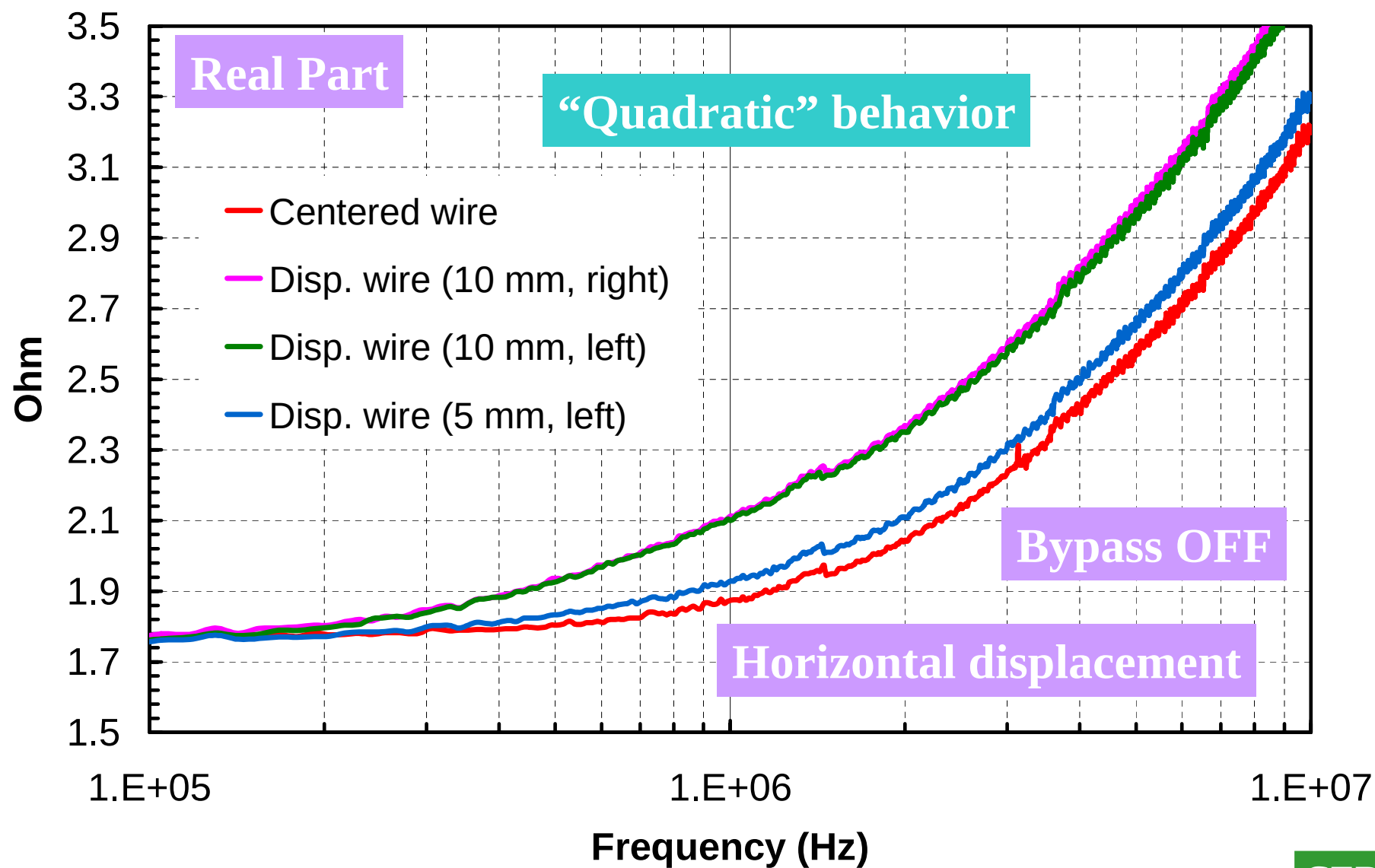
$$\text{IF } Z_L = \text{const} + F^2(x_0) \quad \Rightarrow \quad Z_T = \frac{c}{\omega} \left(\frac{dF}{dx_0} \right)^2$$

$$\text{Since } Z_L(x_0) = Z_L(-x_0) \quad \Rightarrow \quad Z_L(x_0) = Z_L(x_0 = 0) + a^2 x_0^2 + \dots$$

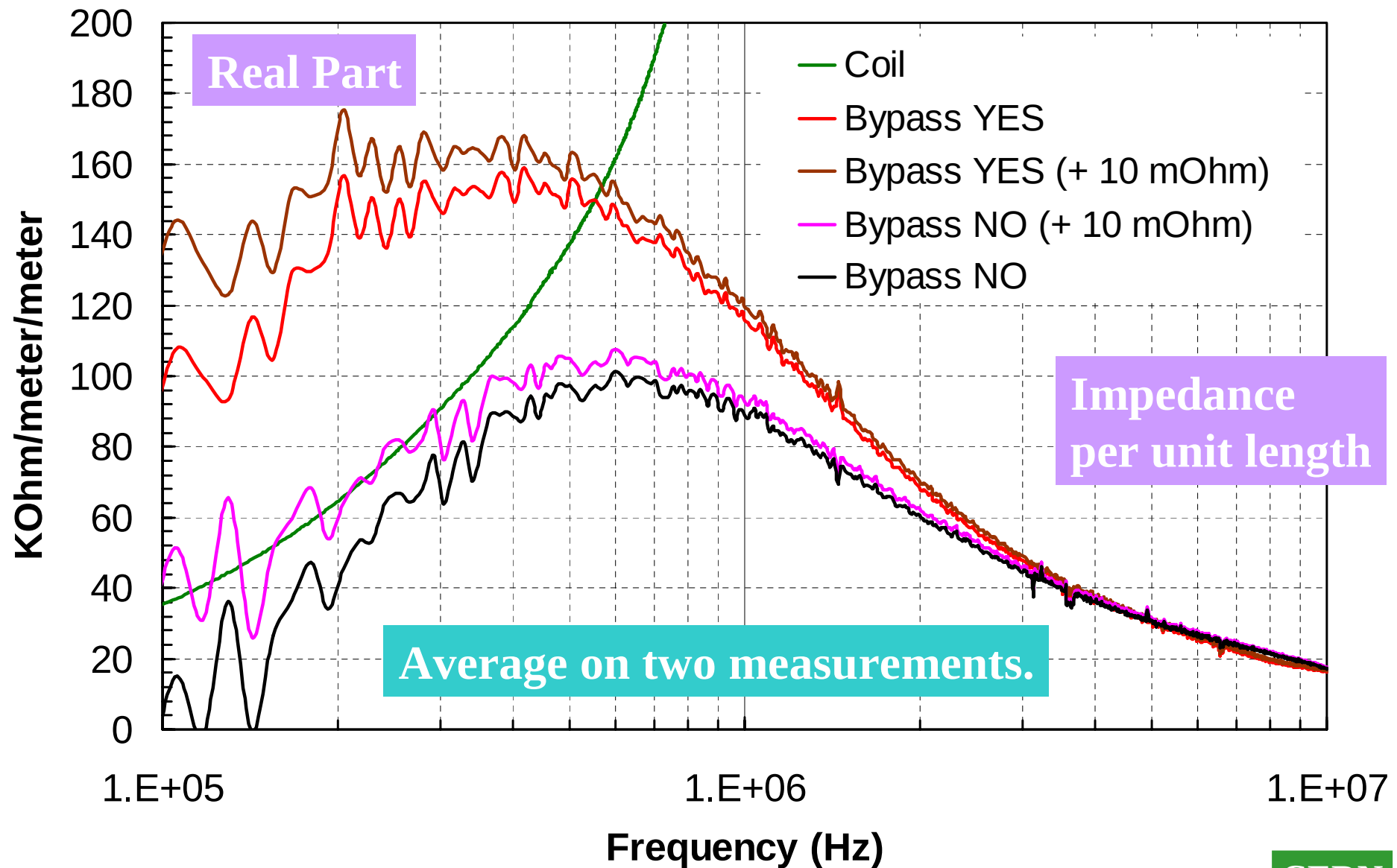
Then, assuming $F(x_0) \approx a x_0$

$$\Rightarrow Z_T = \frac{c}{\omega} \frac{Z_L(x_0) - Z_L(x_0 = 0)}{x_0^2} \quad \leftarrow \text{measured displacing the wire of } x_0.$$

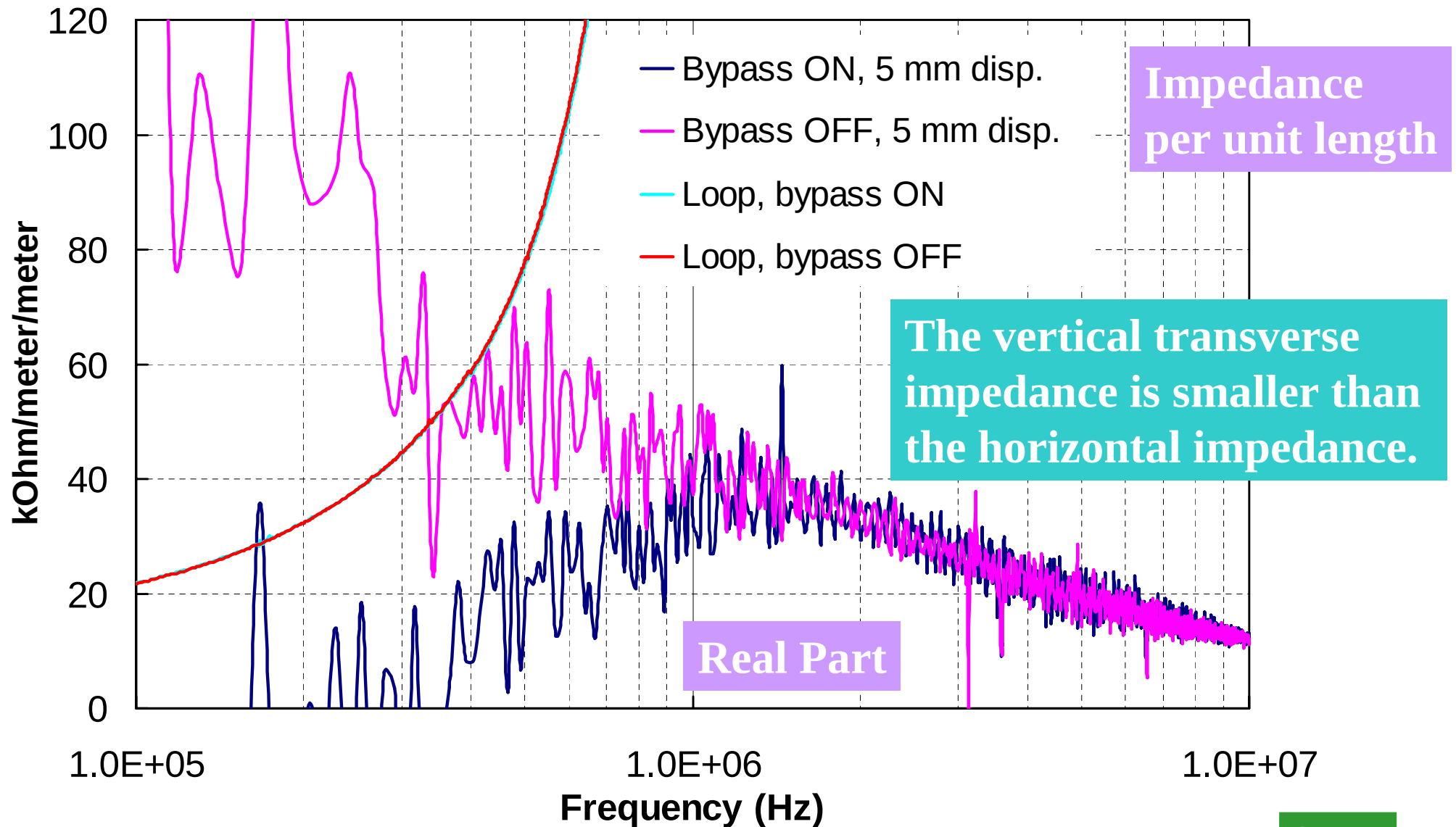
Long. imp. vs wire displacement



Horizontal transverse imp.: displaced wire



Vertical transverse imp. : displaced wire



Conclusion (I)

- Clear effect of the bypass on the longitudinal impedance.
- No effect of the bypass on the coil measurement (transverse impedance).
- Clear effect of the bypass on the offset wire measurement (transverse impedance).

Conclusion (II)

- The presently available model is pessimistic by a factor 3÷5 with respect to the final version (different ceramic chambers). The loop was designed for a model (with diameter 60 mm) and it is too big for the actual model.
- At frequencies > 0.5 MHz, the resistive horizontal impedance $>$ than the vertical one (from displaced wire and loop meas.), contrary to what one would expect.
- From the available data, we estimate (scaling) the maximum of the transverse impedance (final dump kicker) is ~ 1 MOhm/m at 0.5 MHz and considerably less at ~ 10 kHz.

Bibliography

- 1) G. Nassibian and F. Sacherer, “*A method for measuring the transverse coupling impedance*”, CERN-PS-BR-77-40, October 1977.
- 2) S. Kheifets and B. Zotter, “*Impedances and wakes in high energy particle accelerators*”, World Scientific, 1998.
- 3) A. Chao and B. Tigner, “*Handbook of accelerator physics and technology*”, World Scientific, 1999.
- 4) V. Lebedev, “*Control of the transverse multibunch instabilities in the first stage of the VLHC*”, VLHC mini-workshop, SLAC, March 2001, http://cosmo.fnal.gov/organizationalchart/VLHC/VLHC_index.htm

Acknowledgements

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