HELMHOLTZ
Helmholtz-Institut Jena

RESEARCH FOR
GRAND CHALLENGES

Summary BMBF Project 2021-24

Cryogenic Current Comparator (CCC)

Volker Tympel, HI-Jena

June 19th, 2024
CCC Meeting @CERN
Helmholtz Institute Jena

Content of the working points

Beam line Ø

WP1 Stabilization CCC with FAIR dimensions (-xD version) in the particle beam — 150 mm

- GSI Darmstadt talks: Thomas and Lorenzo
- Later: Sensor development in Jena

WP2 Small and powerful CCC (-Sm Version: small & smart) — 63 mm

- Why?
  - Faster and more flexible in sensor construction and sensor testing
  - Then knowledge transfer to larger dimensions (-xD or 100 mm)
  - Tests in a GRP beam cryostat (non-conductive glass fiber reinforced plastic)

Working point 2

Main goals for the Smart & Small (Sm) series

Current resolution

Limits?

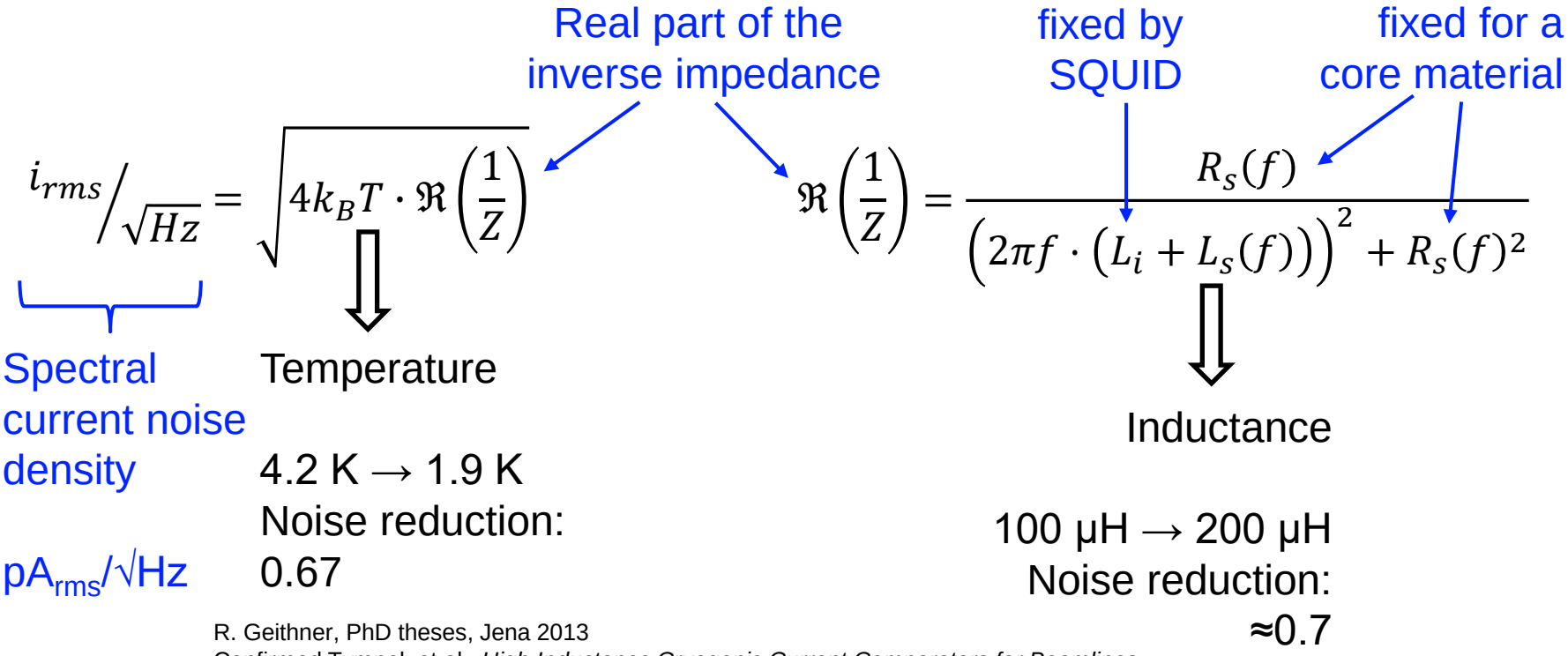
Frequency bandwidth

Limits?

System susceptibility

Current resolution

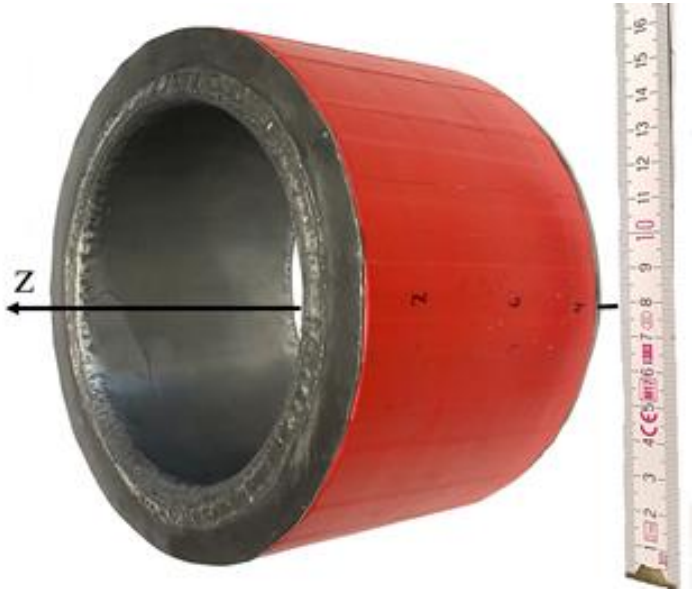
CCCs with core => core is main noise source

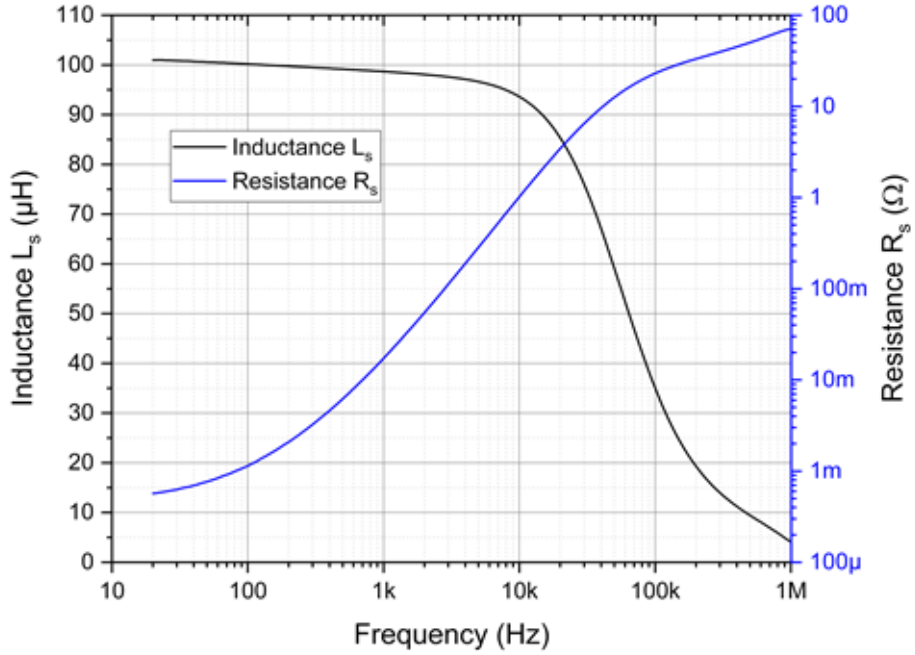


R. Geithner, PhD theses, Jena 2013
Confirmed Tympel, et al., *High Inductance Cryogenic Current Comparators for Beamlines*
IEEE Trans. Appl. Supercon. Vol. 34, Is.: 3, May 2024

Current resolution

Pickup coil #1 of Pb-DCCC-Sm-200 (Lead DualCore-CCC)

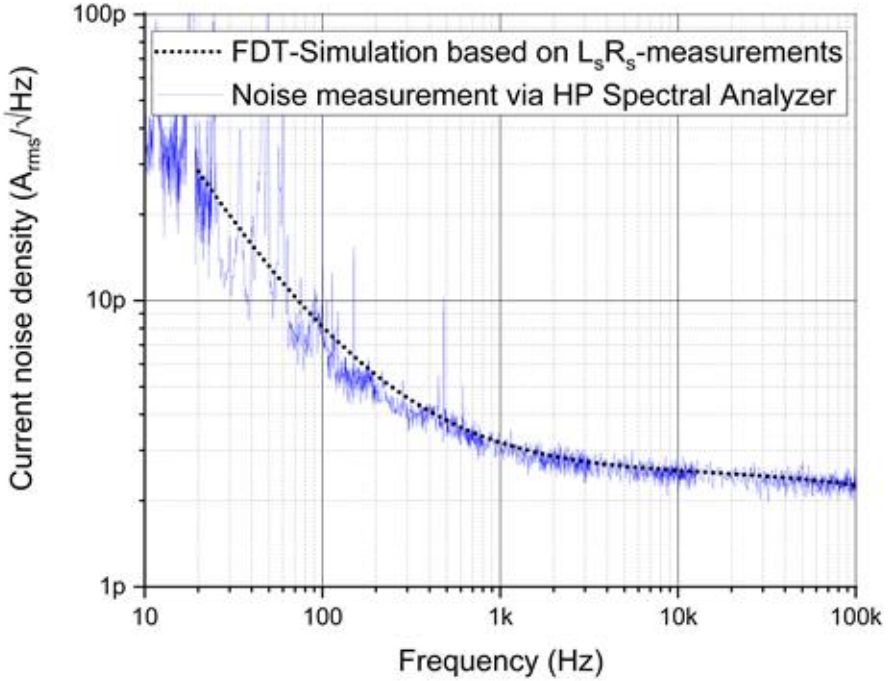


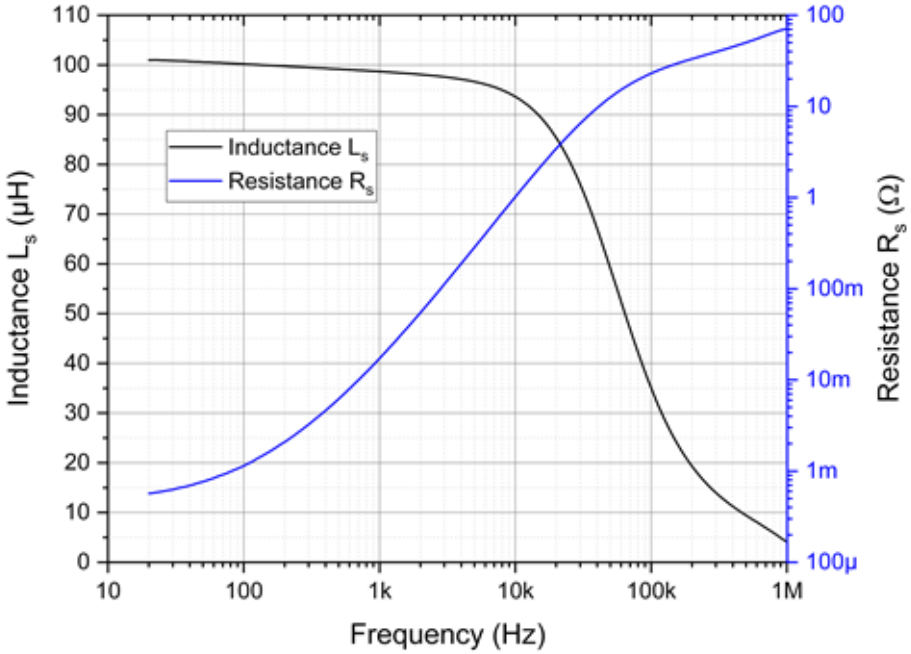


Measured at 4.2 K

Current resolution

Pickup coil #1 of Pb-DCCC-Sm-200 (Lead DualCore-CCC)



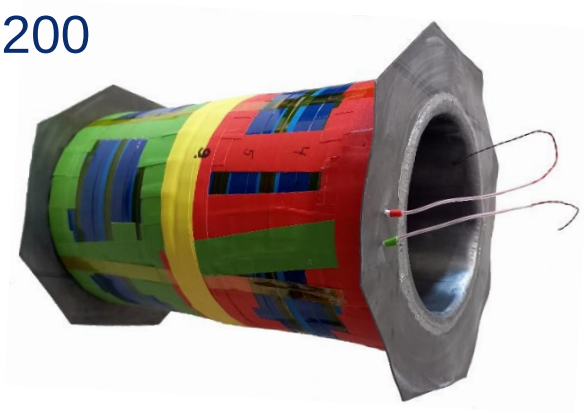


Measured at 4.2 K

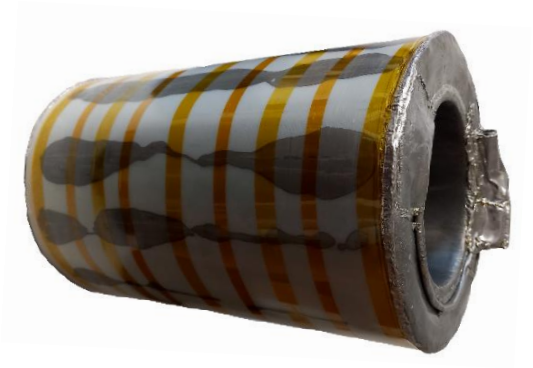
Current resolution

Pb-DCCC-Sm-200

Pickup coils
#1 and #2
with inner loop
of the shielding.



DCCC completed
by the
outer meander
shielding.



2 coils with each 3 commercial cores M-616

Pb-DCCC-Sm-300

2 coils with each 4 special deep-temp. cores

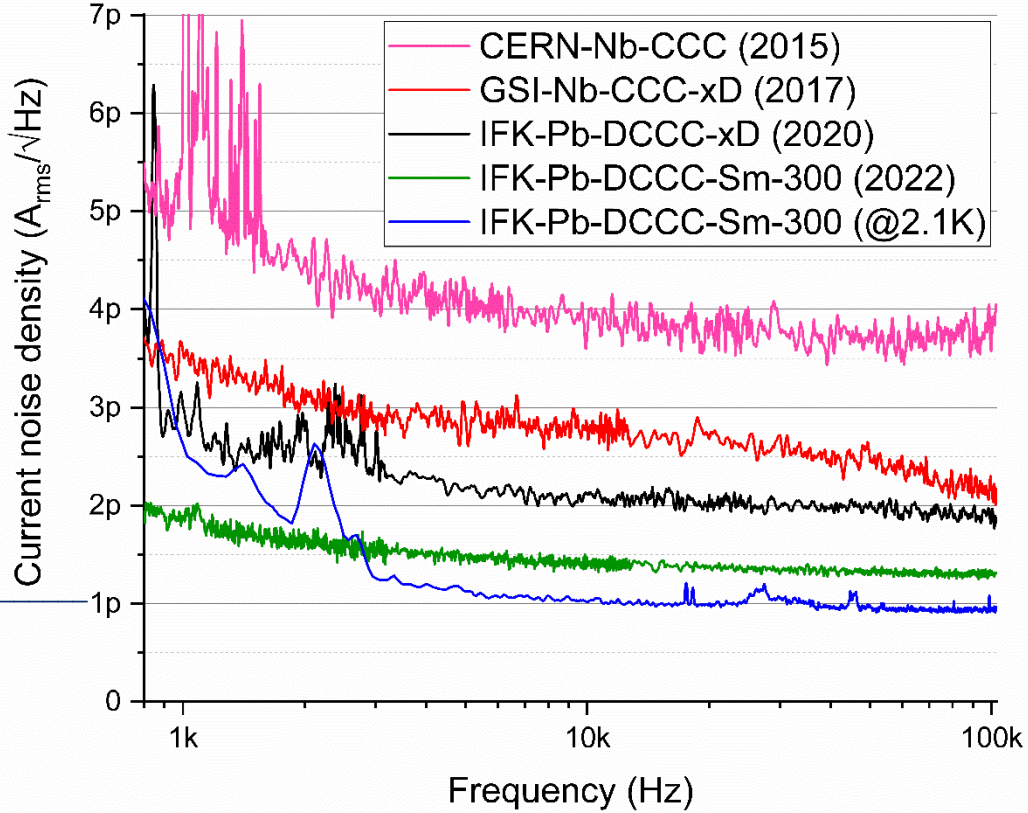
Current resolution

White noise

Special core material
+ 300 µH
+ 2.1 K

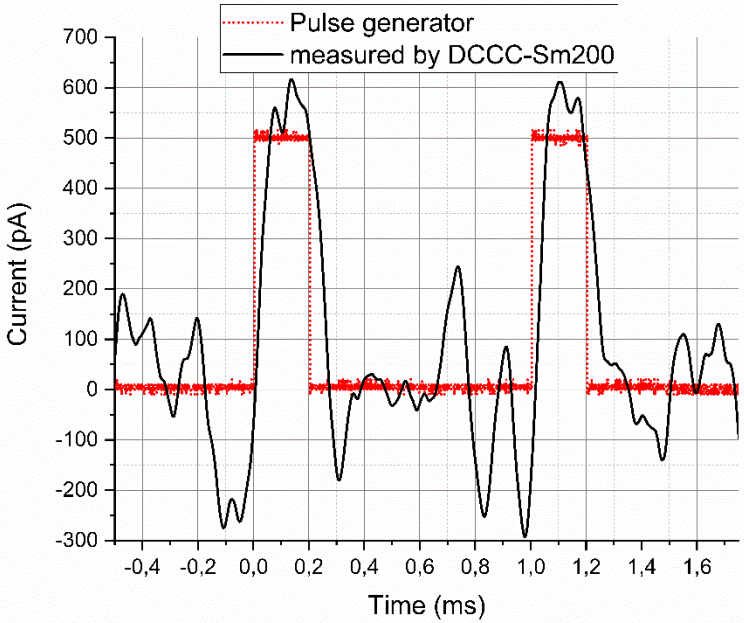
---

1 $pA_{rms}/\sqrt{Hz}$

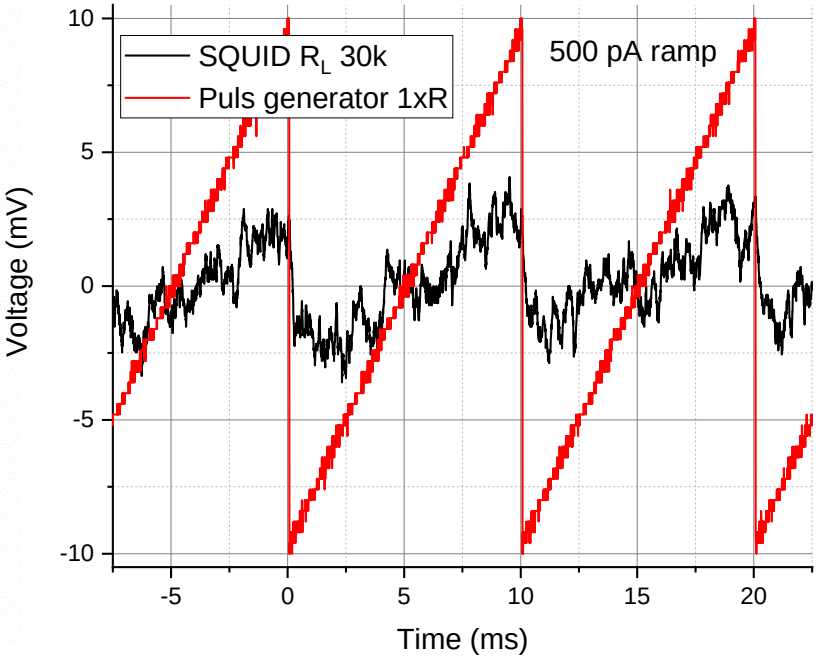


Current resolution

Pulse: 500 pA 200 µs
(Sm-200 un-damped)



Ramp: 500 pA 10 ms
(Sm-300 un-damped)



Working point 1

Main goals for the Smart & Small (Sm) series

Current resolution

$1nA_{pp}$

Frequency bandwidth

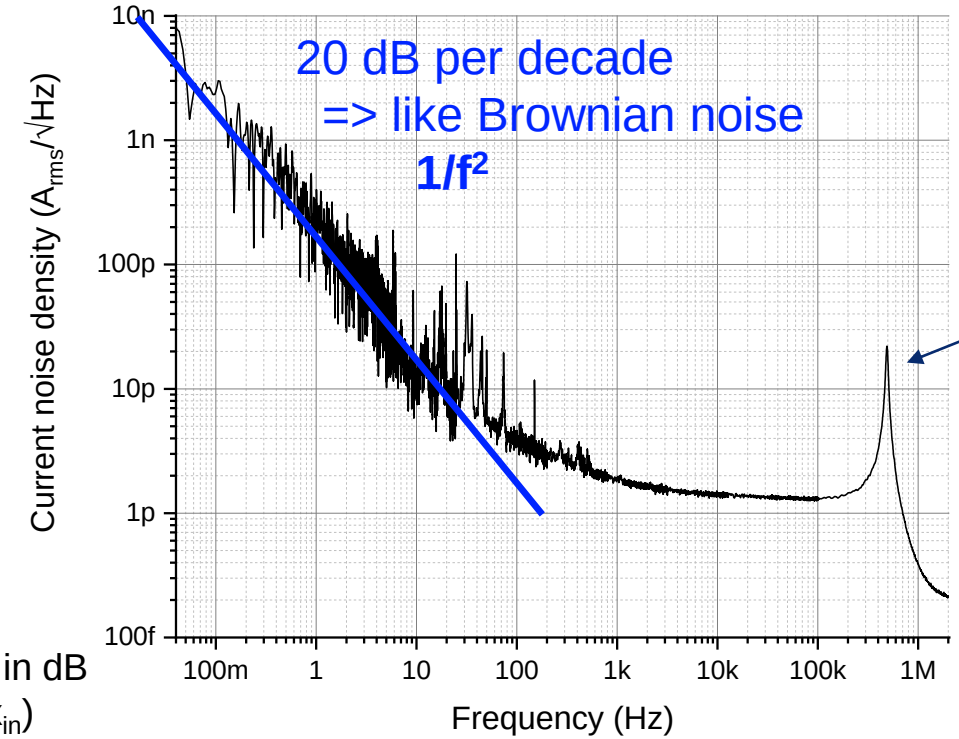
Limits?

System susceptibility

Frequency bandwidth

Pb-DCCC-Sm-300
un-damped

Low Frequency Noise



LC meander resonance

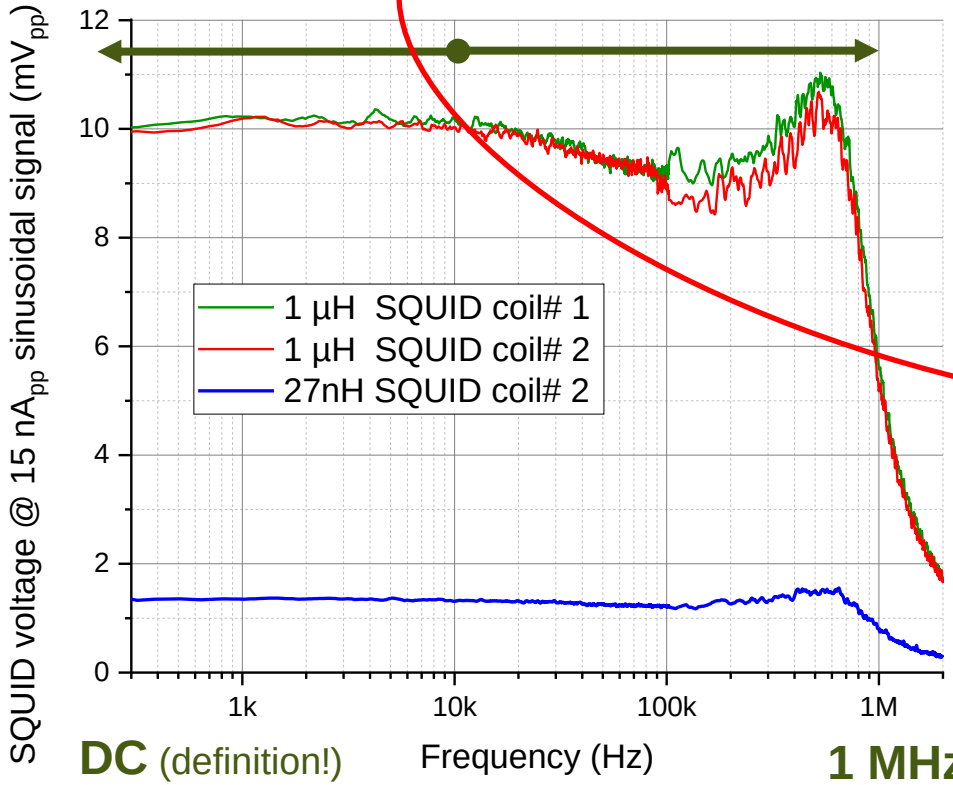
Measured @ 4.2 K

Current or voltage in dB
=> $20 \cdot \lg_{10}(x_{out} / x_{in})$

Frequency bandwidth

Calibration U=>I via factor via deconvolution

Pb-DCCC-Sm-300
final damped version



Part of a
new BMBF-CCC project
by University of Applied
Sciences Jena (2024-27)

DC (definition!)

1 MHz

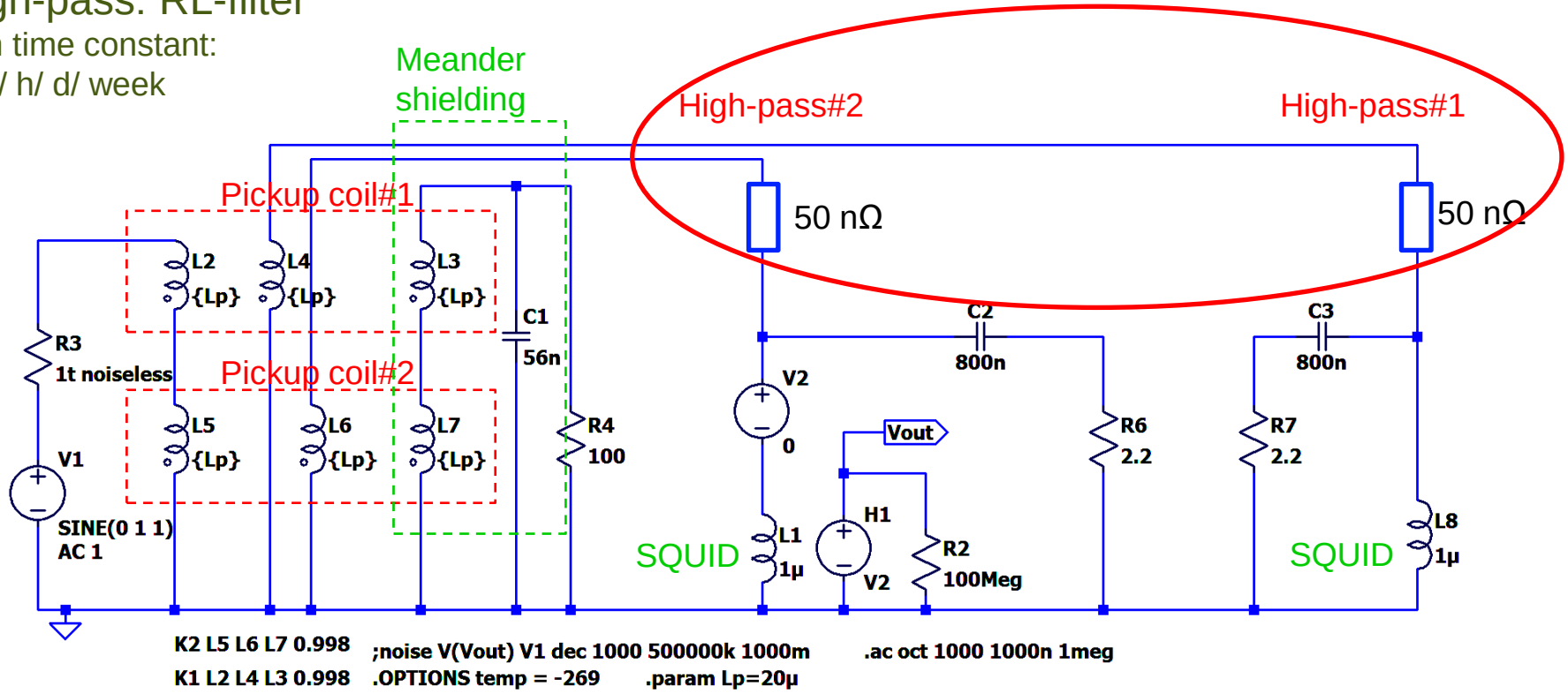
Low signal response

Frequency bandwidth

High-pass: RL-filter

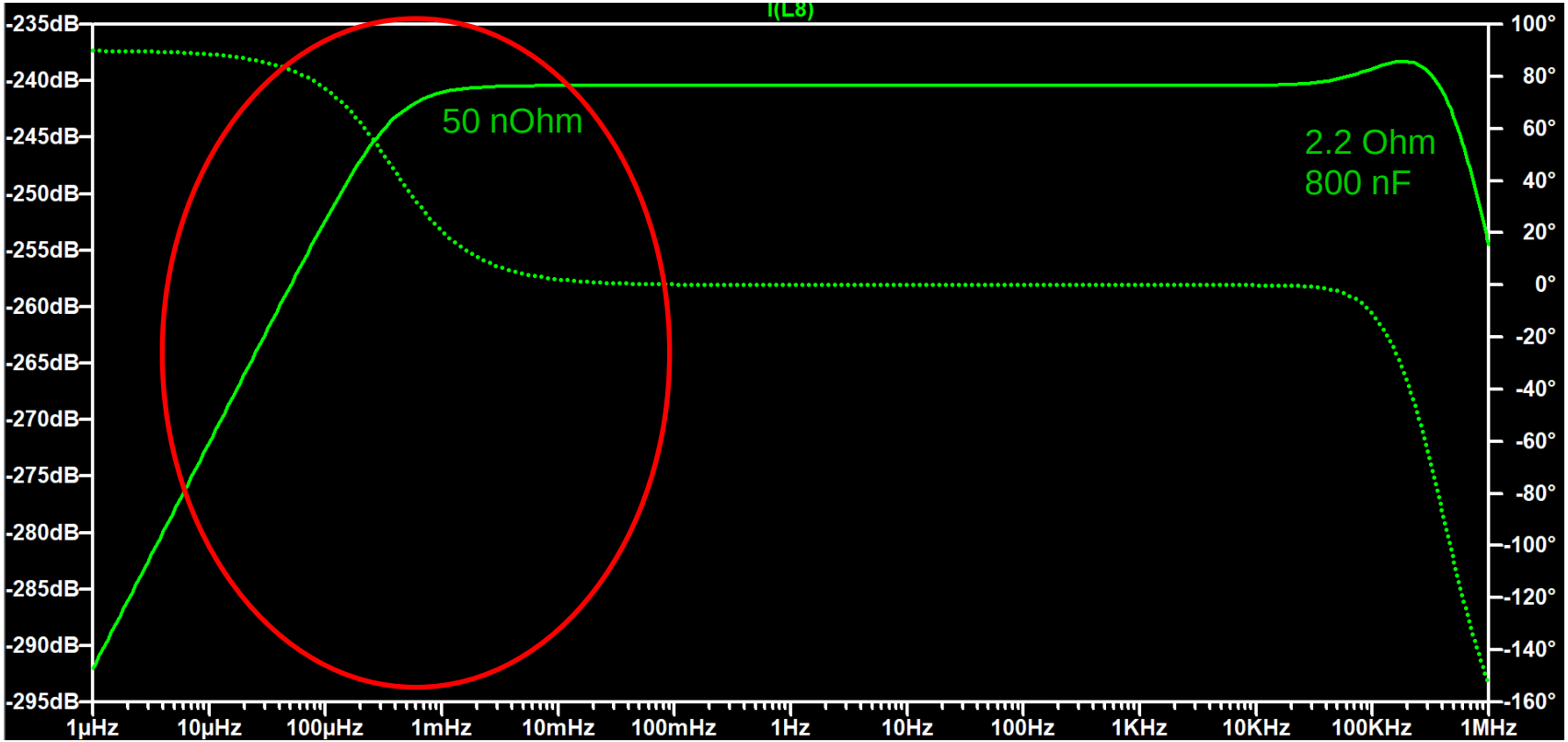
with time constant:
min/ h/ d/ week

DC (definition!)



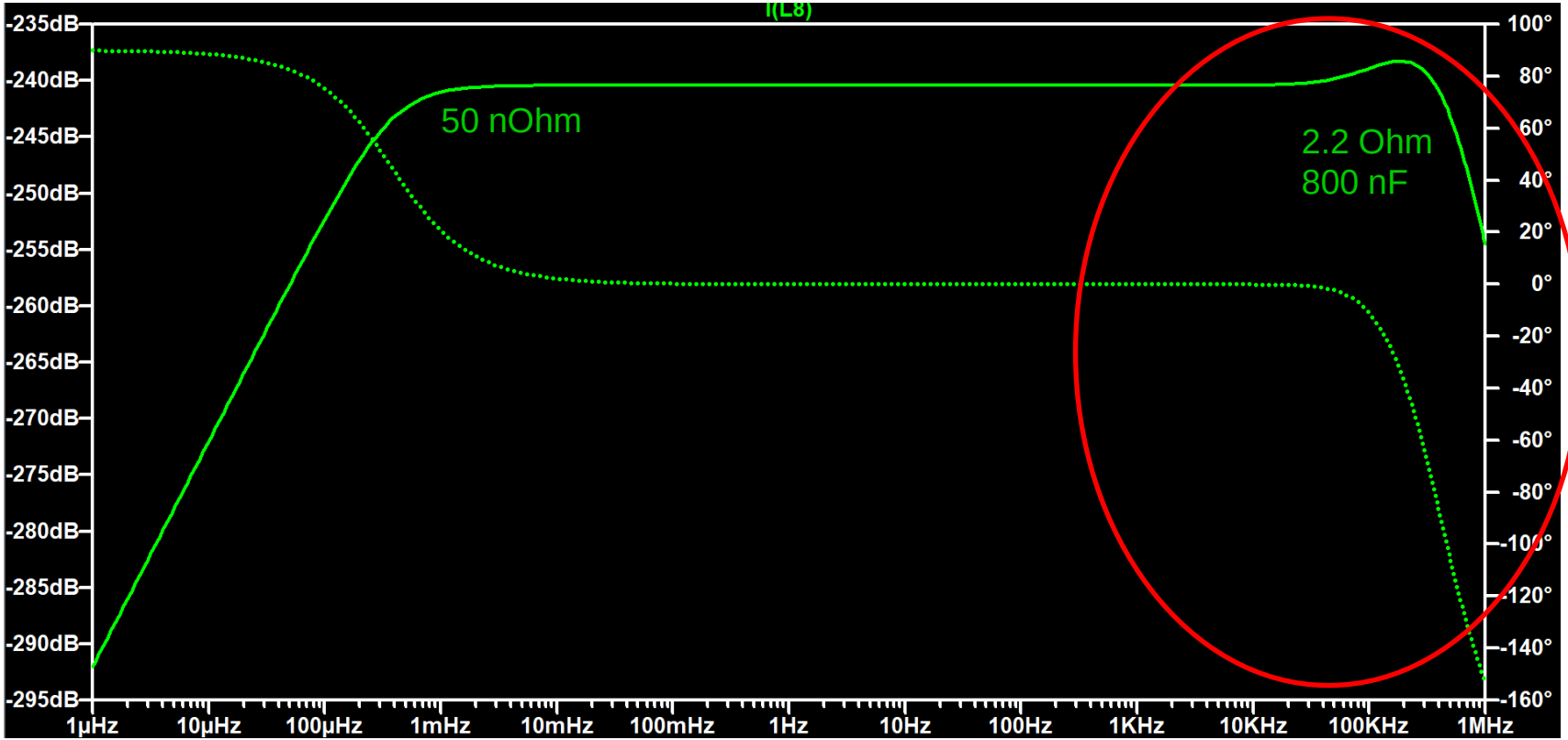
Frequency bandwidth

High-pass: RL-filter with time constant: 15 min



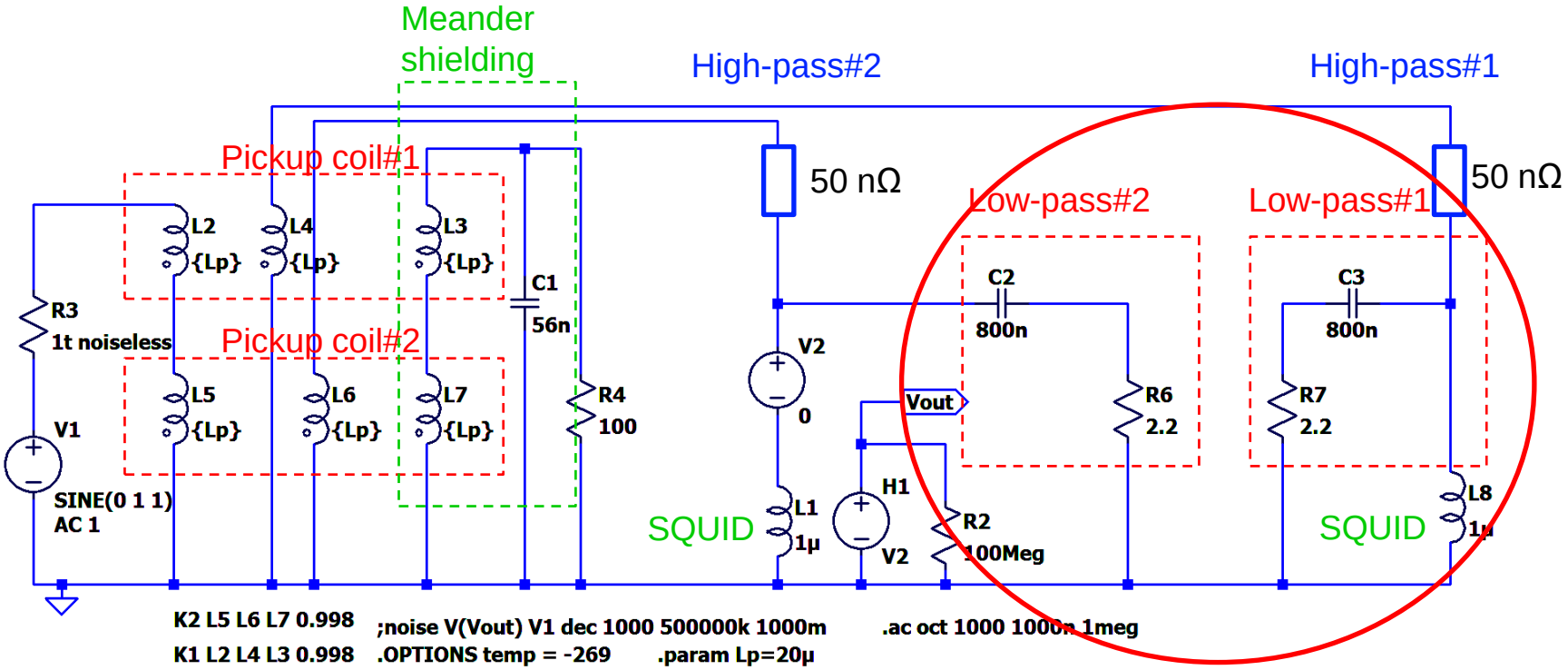
Frequency bandwidth

Low-pass & damping



Frequency bandwidth

Low-pass & damping



Working point 2

Main goals for the Smart & Small (Sm) series

Current resolution

$1nA_{pp}$

Frequency bandwidth

1 MHz

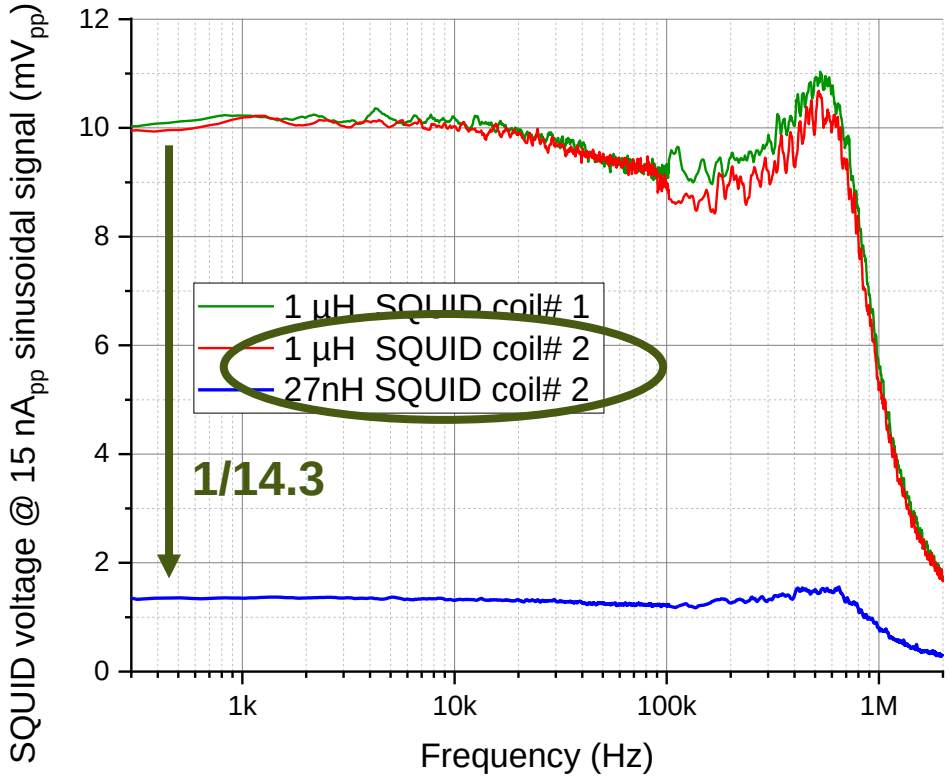
System susceptibility

System susceptibility

Slew rate increase

Pb-DCCC-Sm-300
final damped version

2x10 mV_{pp}



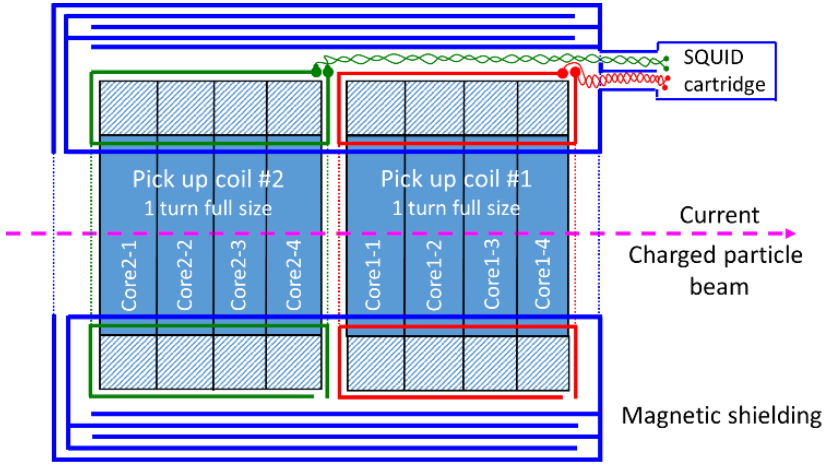
1.4 mV_{pp}

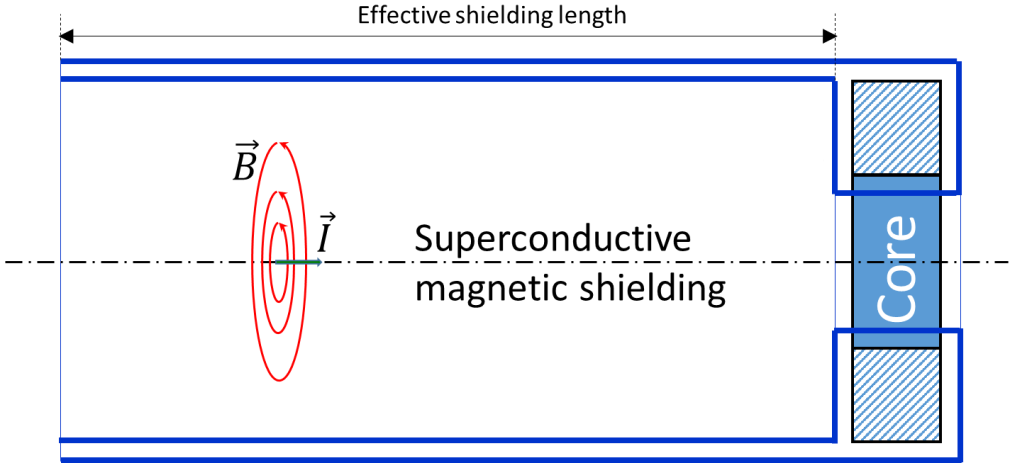
Low signal response

System susceptibility

Magnetic shielding increase

Pb-DCCC-Sm-300





Not real, tubes is shortened by meanders!

<u>Proposal IPHT:</u>

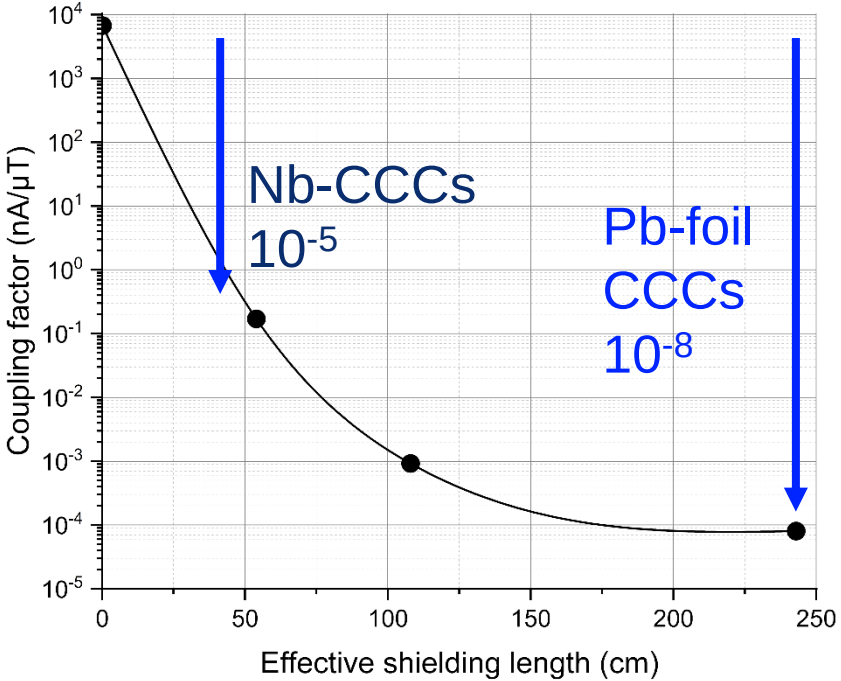
Lead foil and wrapping inside or outside

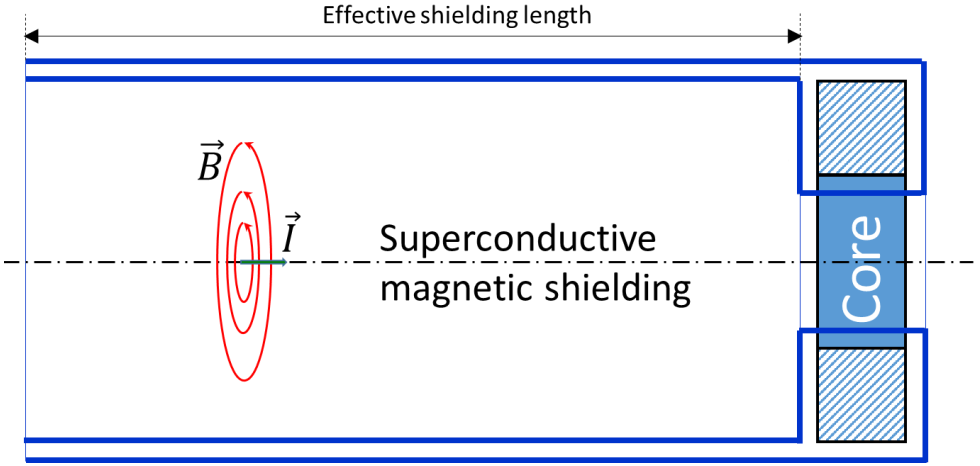
$\Rightarrow$ longer effective tube lengths

System susceptibility

Magnetic shielding increase

Pb-DCCC-Sm-300

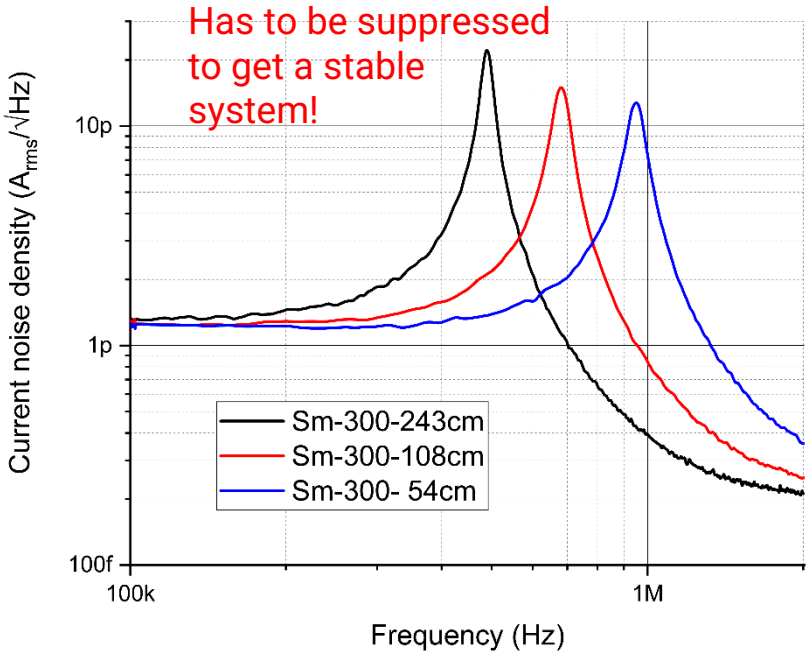




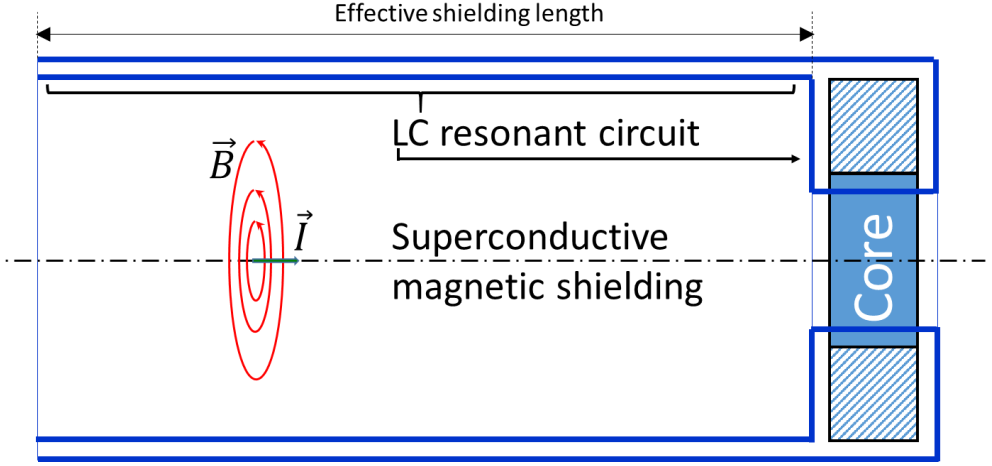
Not real, tubes is shortened by meanders!

System susceptibility

Pb-DCCC-Sm-300

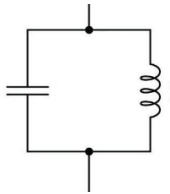


Magnetic shielding increase



Q factor
(Güte)

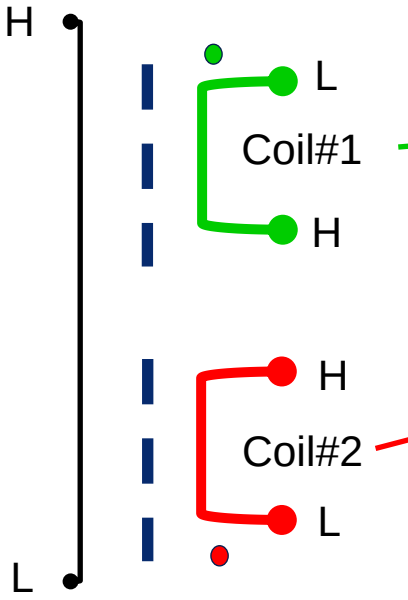
$$Q = R \cdot \sqrt{\frac{C}{L}}$$



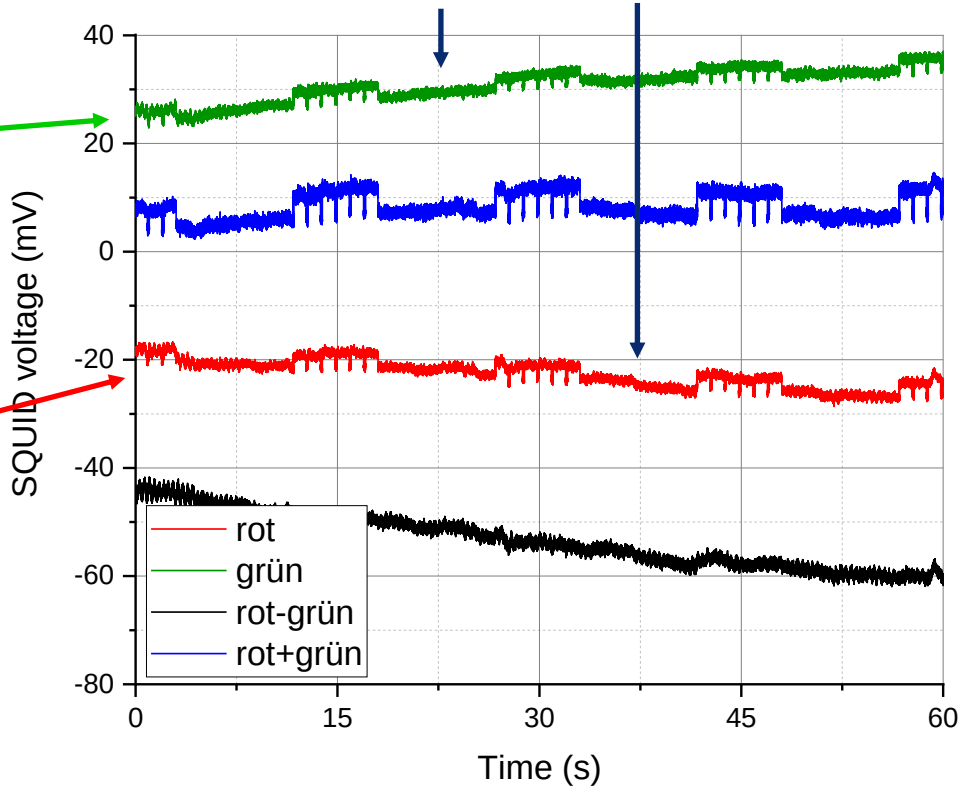
System susceptibility

Common mode rejection

DualCore-CCC



100 mW RF @ 434 MHz 6x 1-sec all 15 sec.



false wiring (+)

- Measuring signals compensated
- Disturbance of the double

correct wiring (-)

- Measuring signals of the double
- Disturbance compensated

unpublished

System susceptibility

Tests with GFK beam cryostat

First results:

1. Grounded electrical shielding is necessary !

2. Be careful with high frequency on the metallic beam tube !

In progress.

(End of project Dec. 2024)

Working point 2

Main goals for the Smart & Small (Sm) series

Current resolution	*Frequency bandwidth*	*System susceptibility*
$1nA_{pp}$	*1 MHz*	in progress

Working point 1

Stabilization CCC-xD versions in beam

Pb-Coreless CCC-xD	*Pb-DualCore CCC-xD*	*Kryo-system*
Possible?	*Reasonable?*	*=> GSI*

Working point 1

Stabilization CCC-xD versions in beam

Pb-Coreless CCC-xD

- *Excellent magnetic shielding*
- *High frequency problems*

Pb-DualCore CCC-xD

Reasonable?

Kryo-system

=> GSI

Working point 1

Stabilization CCC-xD versions in beam

Pb-Coreless CCC-xD

- *Excellent magnetic shielding*
- *High frequency problems*

Pb-DualCore CCC-xD

- *Excellent magnetic shielding*
- *Better lab parameter*

Kryo-system

=> GSI

Working point 1

Stabilization CCC-xD versions in beam

Pb-Coreless CCC-xD

- *Excellent magnetic shielding*
- *High frequency problems*

Pb-DualCore CCC-xD

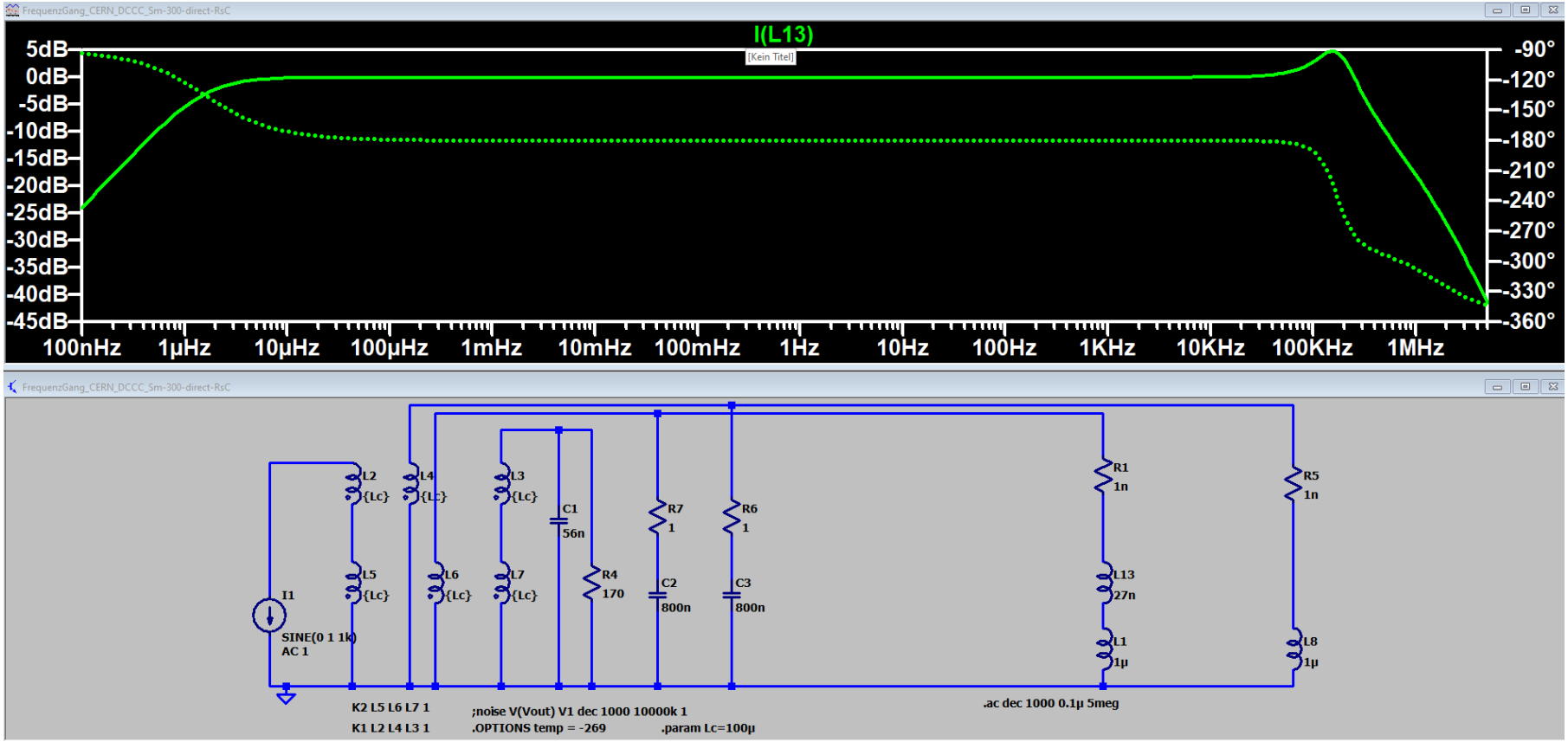
- *Excellent magnetic shielding*
- *Better lab parameter*

Kryo-system

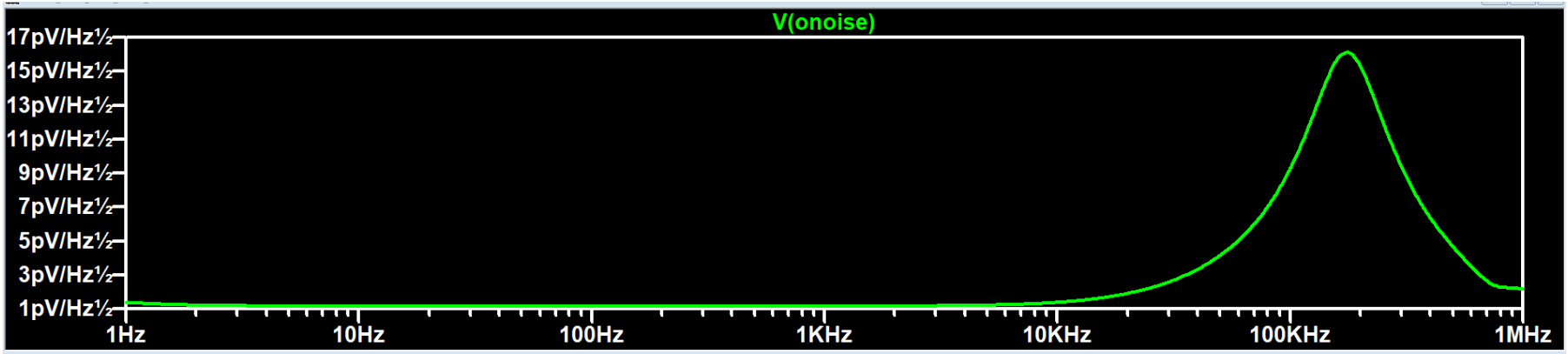
=> GSI

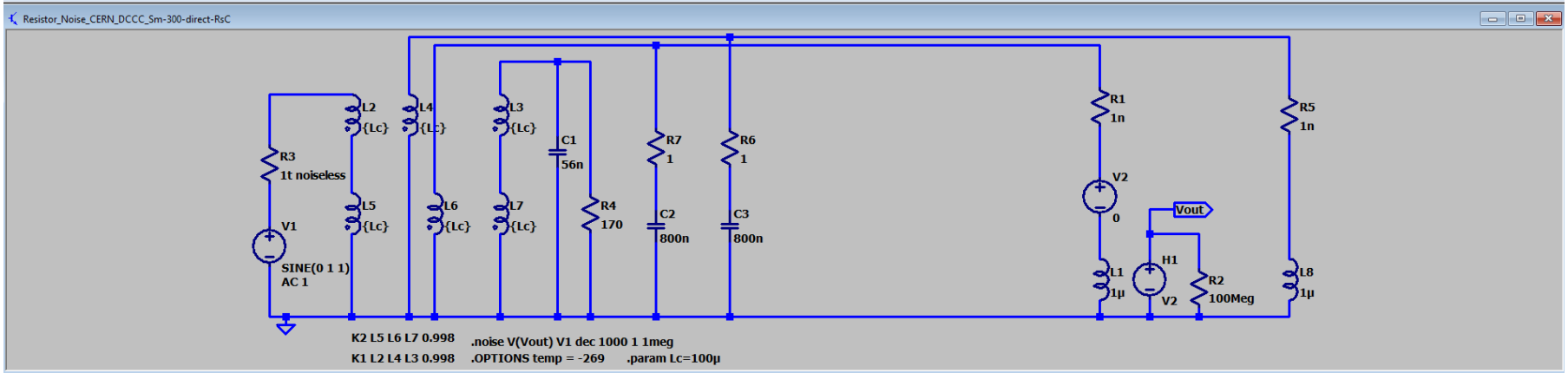
CERN-CCC #2

DualCore Sm version –direct

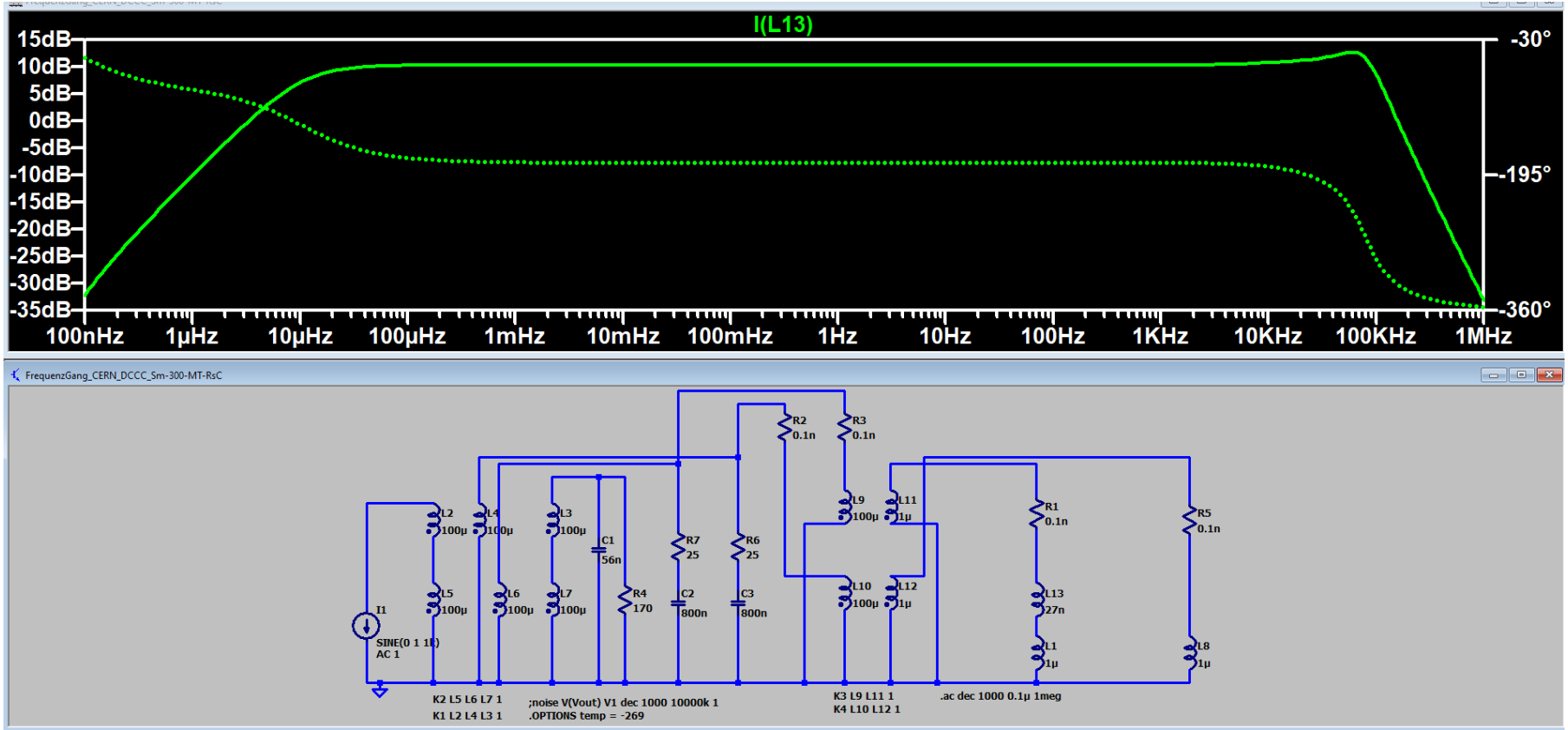


DualCore Sm version –direct

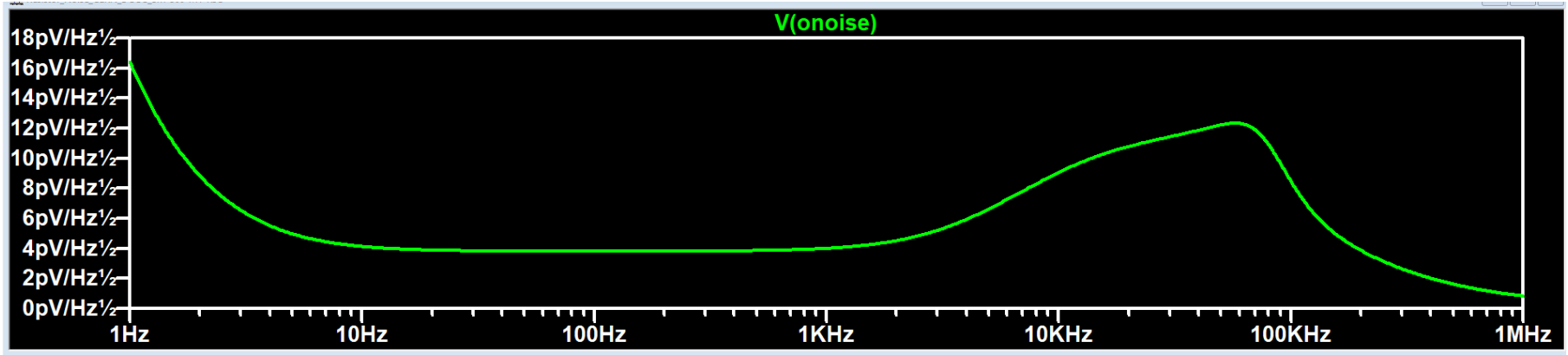


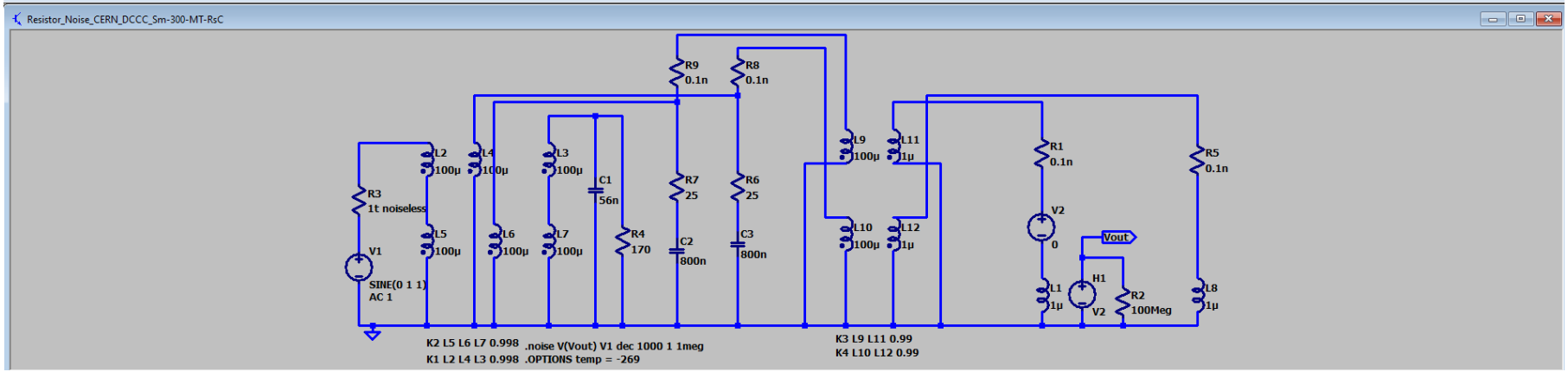


DualCore Sm version – MT



DualCore Sm version – MT





Coreless Sm version (IPHT-CCC)

Ph.D. in 2023

- David Haider, Uni-Frankfurt,

  3. July, Suma cum laude

“Precise intensity monitoring at CRYRING@ESR: On designing a Cryogenic Current Comparator for FAIR”

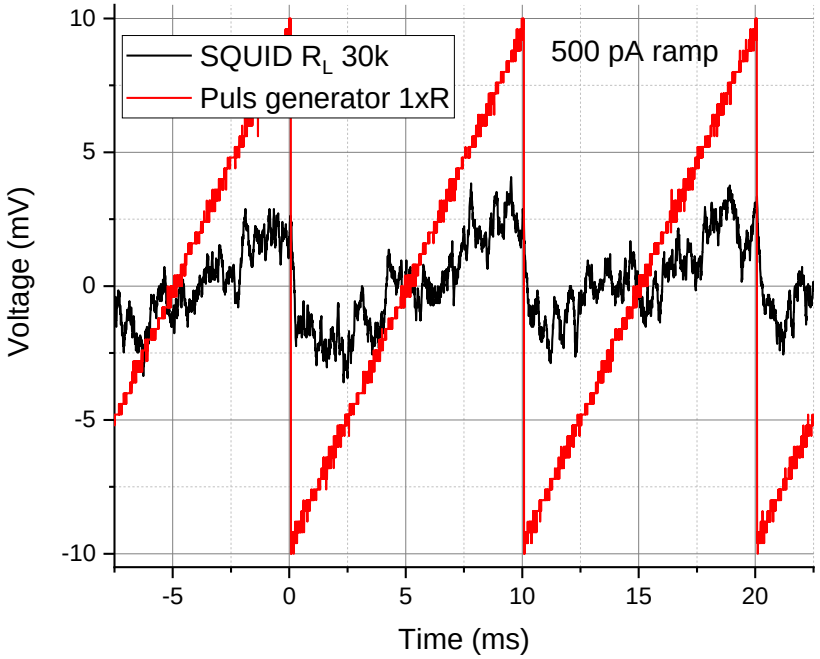
- ➢ Creation of a coreless Pb-CCC-xD
- ➢ Creation of the cryogenic support system
- ➢ Measuring with FAIR-Nb-CCC-xD @ CRYRING@ESR

dio: 10.21248/gups.74487

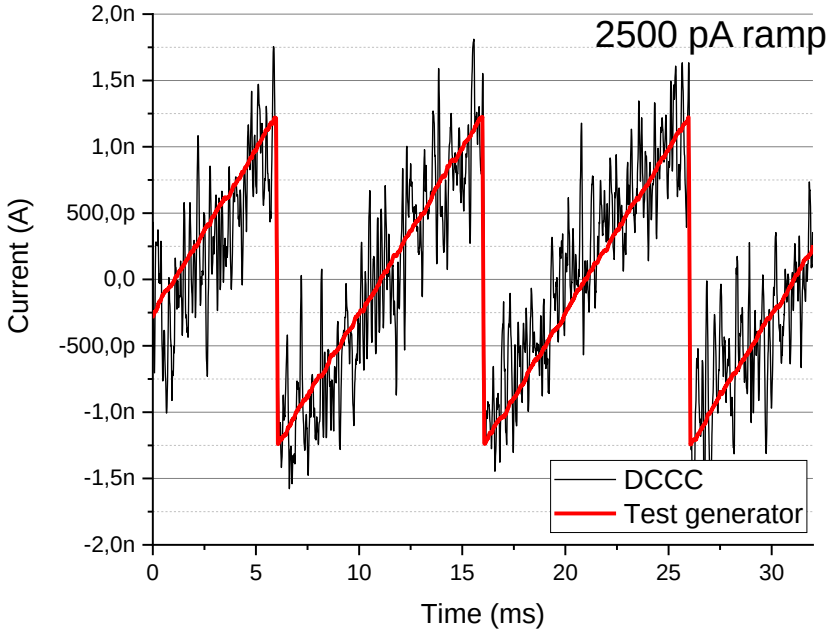
CHALLENGE: LOW TEST CURRENT

Pb-DCC-Sm-300

Undamped



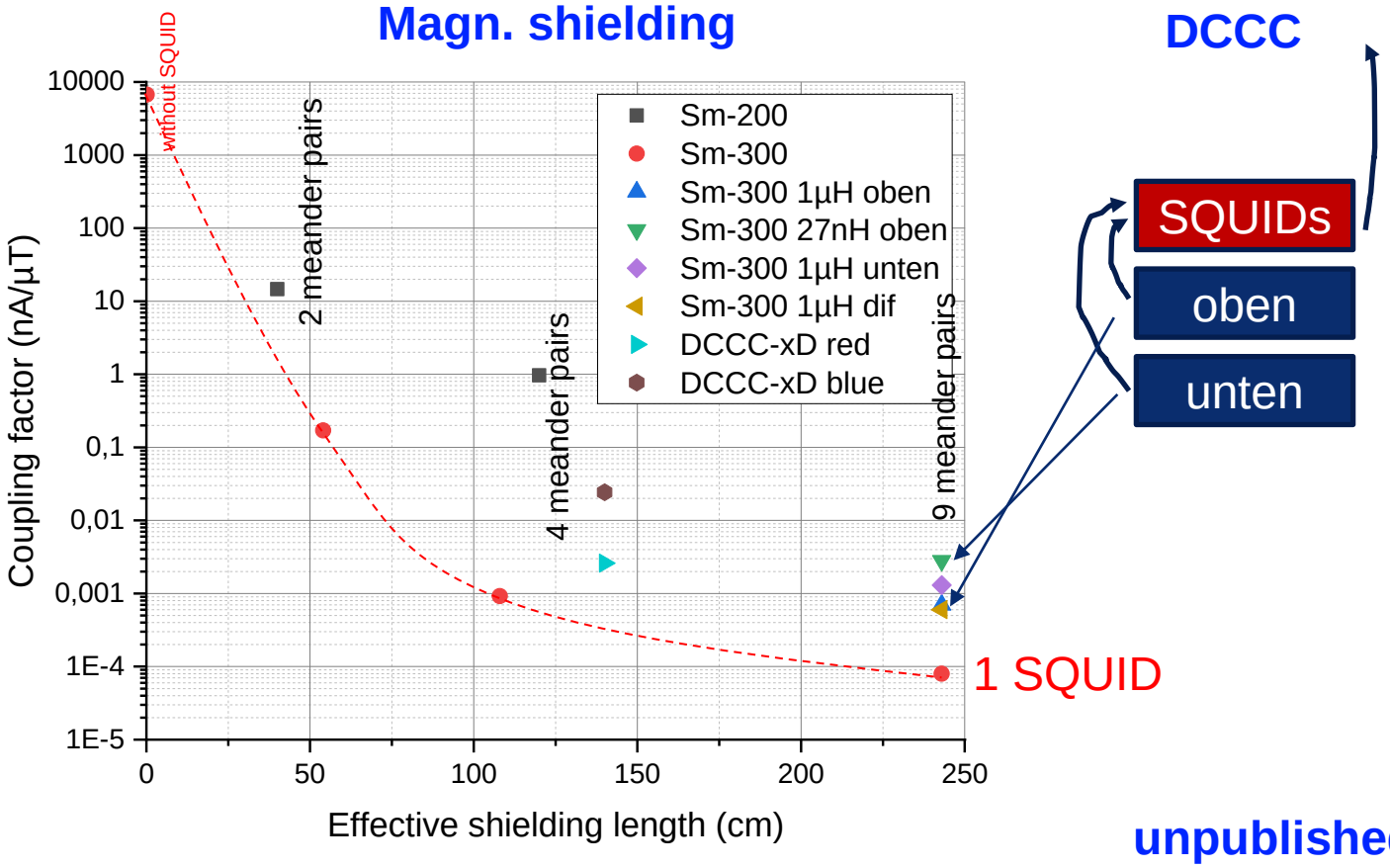
Final damped version (2x 4.7 Ω)



Longer ramp (10 ms)

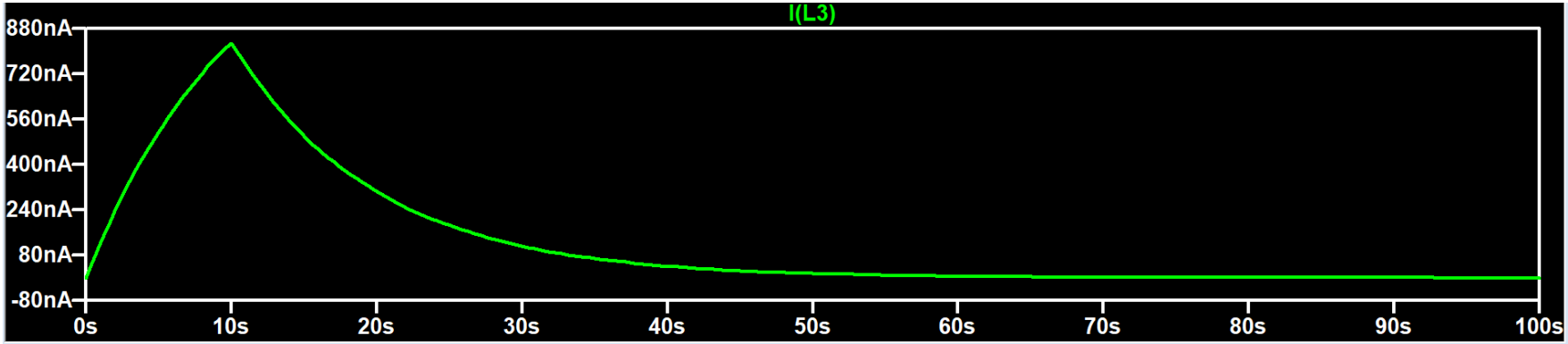
Current BMBF Project

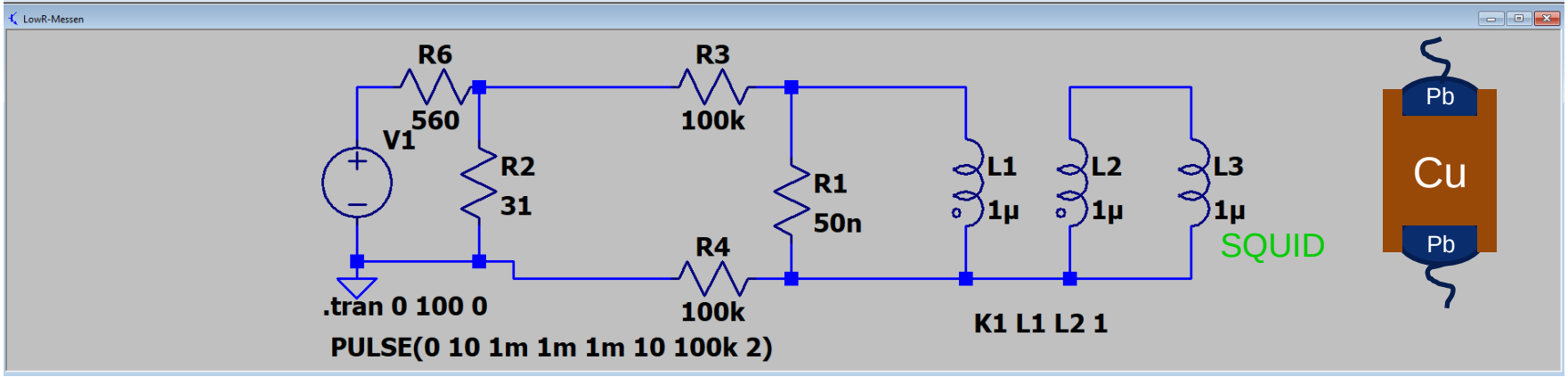
Some physics @ Pb-DCCC-Sm-300



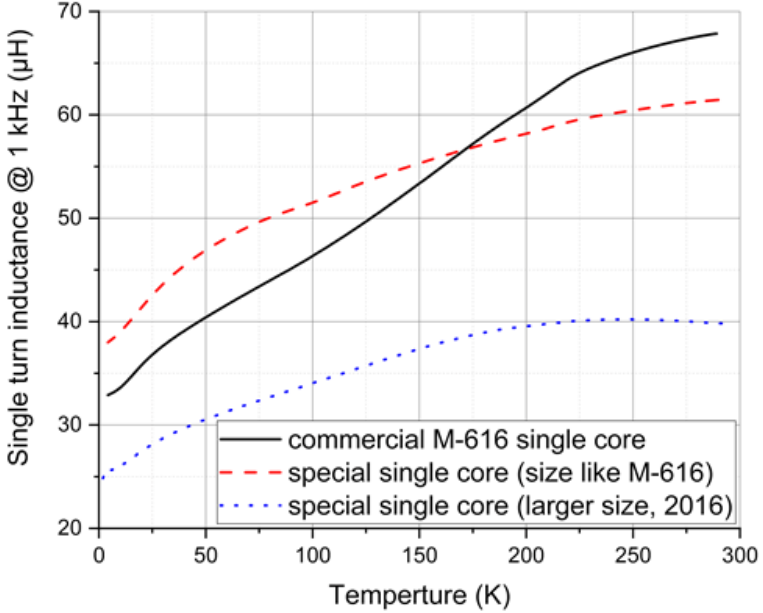
NEXT STEPS

2. High-pass: 50 nΩ

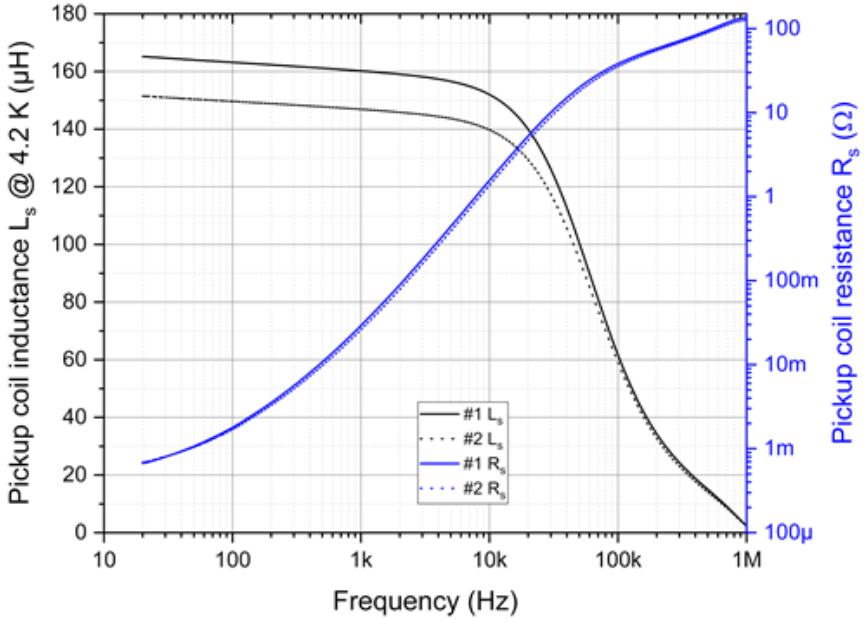




Core material



Temperature-dependent inductance measurements of single cores used for CCC



Frequency-dependent L_sR_s measurements of the two pickup coils of the Sm-300