

MITIGATION OF STRAY MAGNETIC FIELD EFFECTS IN CLIC WITH PASSIVE SHIELDING

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INTRODUCTION

- Stray magnetic fields (SMFs) are **external dynamic magnetic fields**.
- The Compact Linear Collider (CLIC) [1] is sensitive to SMFs **O(nT)** [2].
- Measurements performed on the CERN site exceed this tolerance [3].
- Shielding the beam pipe with mu-metal is envisaged as a mitigation strategy.

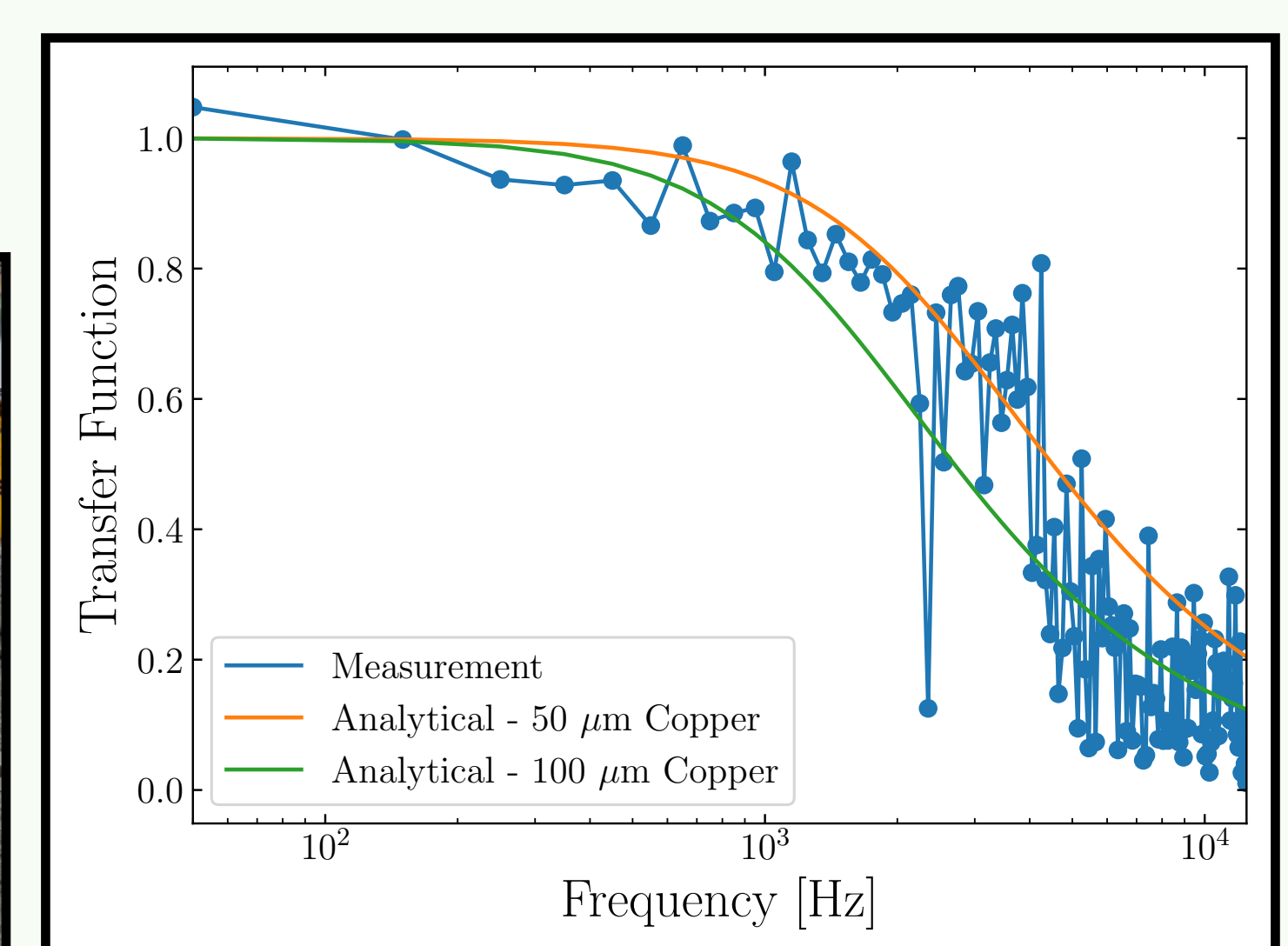
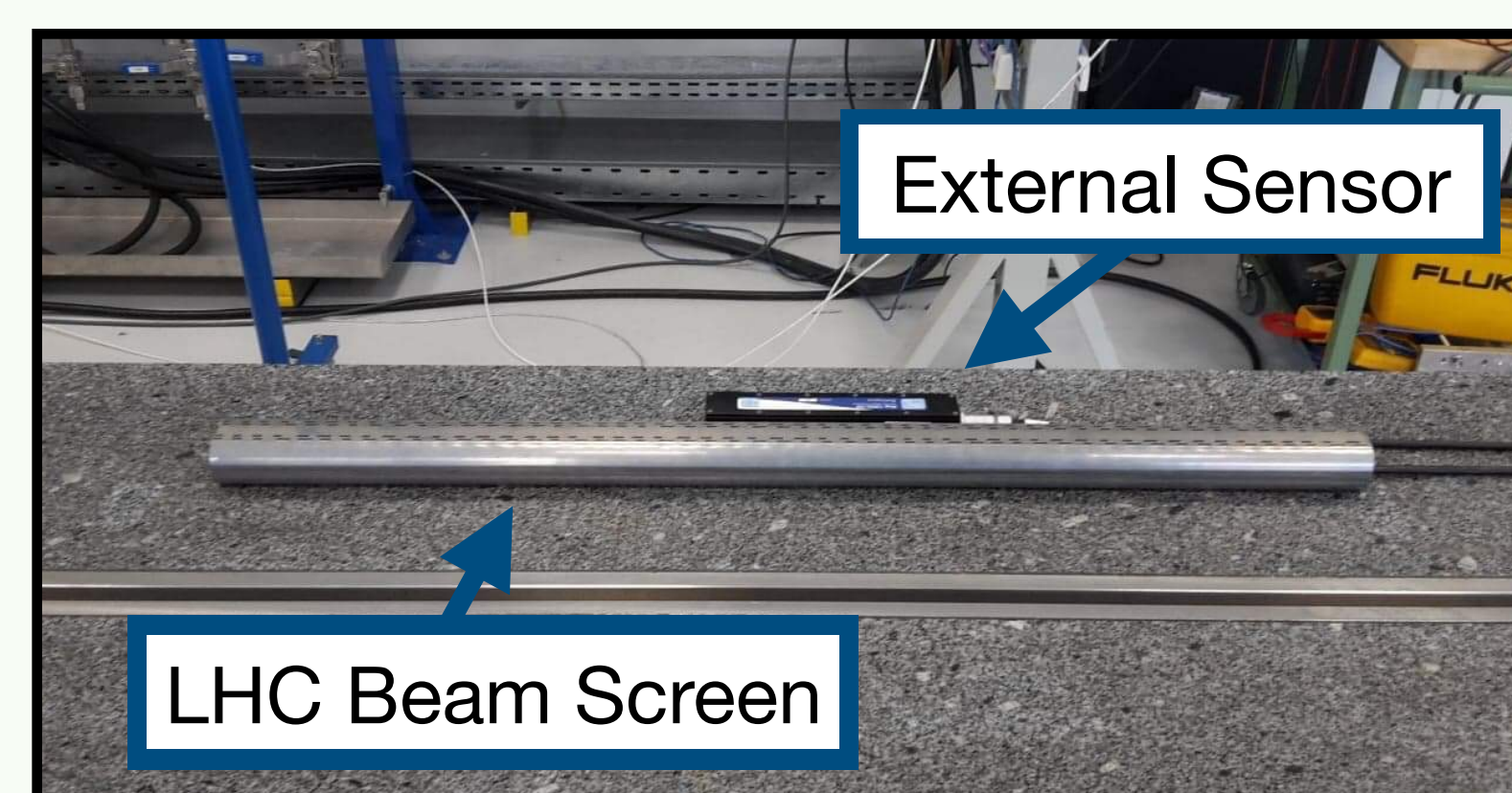
PASSIVE SHIELDING

- There are two mechanisms for magnetic shielding:
 - **Flux-shunting** - attenuates static fields - requires high μ .
 - **Eddy current cancellation** - attenuates dynamic fields - requires high σ .
- Amplitude transfer function of a magnetic shield:

$$TF(f) = \frac{B_i(f)}{B_o(f)} = \frac{P_{xy}(f)}{P_{xx}(f)}$$

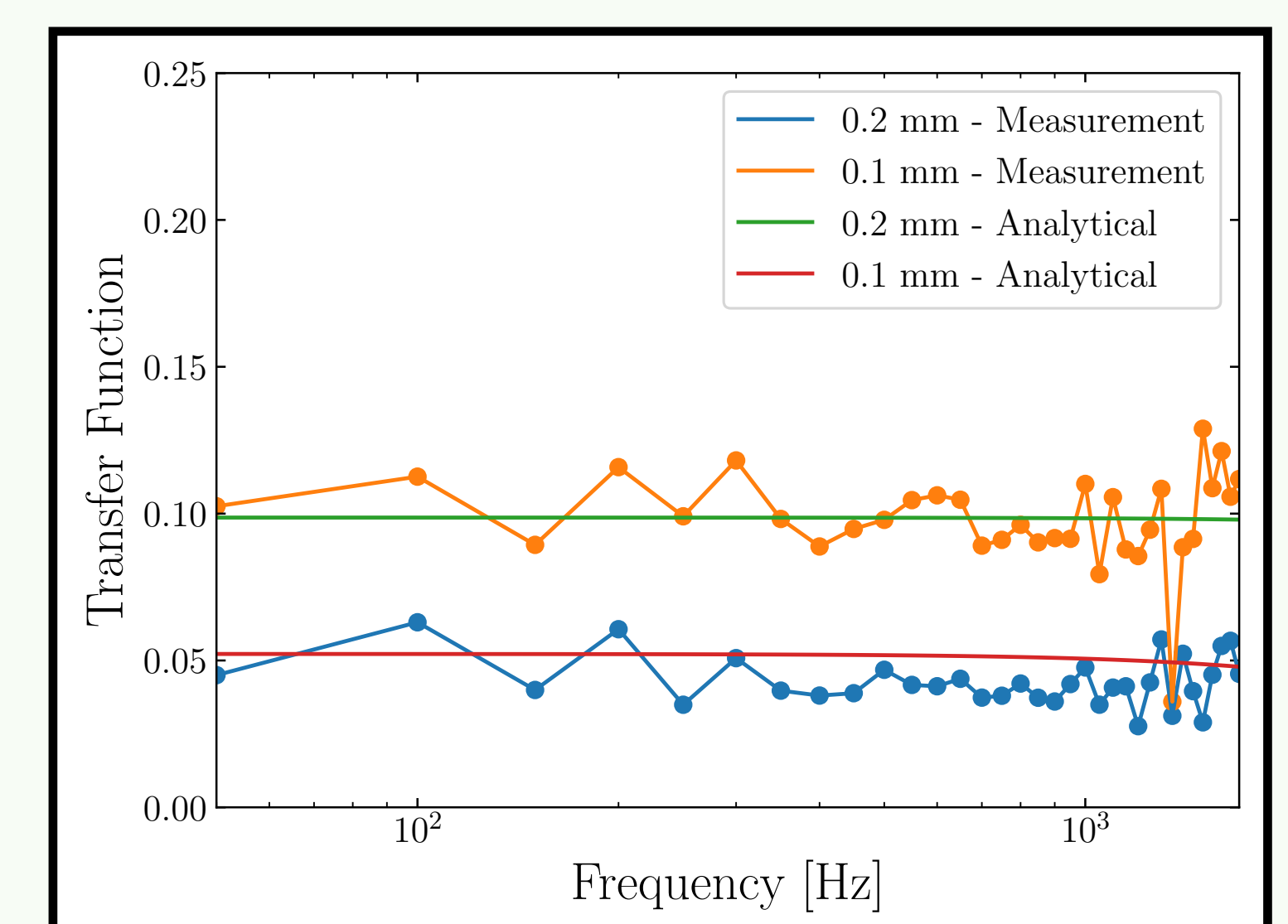
LHC BEAM SCREEN

- Represents a typical beam pipe in a collider.
- Consists of: 1 mm steel and 50-100 μm copper, inner radius 2.2 cm.
- The shielding originates solely from the copper layer.
- Above 10 kHz, the magnetic field is almost completely attenuated.



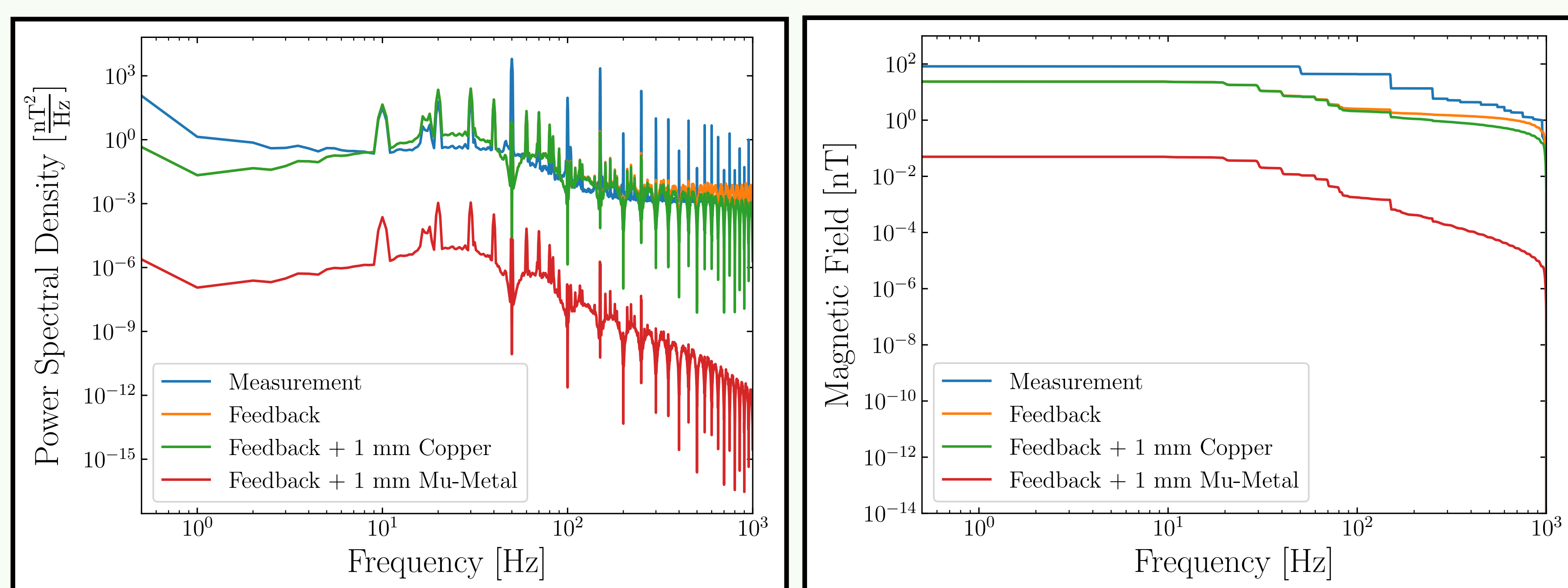
MU-METAL SHIELDS

- Shielding factor of a mu-metal foil was measured.
- The foil was provided by Magnetic Shield Corporation, USA - **MU004-12** [4].
- Measurement is consistent with a material of $\mu_r = 5,000$.
 - An order of magnitude improvement is expected from re-annealing the material.
- The shielding factor is directly proportional to the shield thickness.



CLIC MAGNETIC FIELD POWER SPECTRUM

- Largest measurement taken in CLEAR [3]:



CONCLUSIONS

- 50 Hz harmonics appear static to the beam because the repetition frequency of the beam is 50 Hz.
- ~5 nT remains for the magnetic field measured in CLEAR after suppressing the 50 Hz harmonics.
- Passive shielding will be required.
- Mu-metal shields can be used to mitigate SMFs in CLIC.
- The behaviour of permeability for very small amplitude magnetic fields is:

$$\mu = \mu_i + \nu H \simeq \mu_i$$

- Mu-metal shields with sufficiently high μ_i should be able to attenuate magnetic fields to sub-nT levels.

REFERENCES

- [1] M. Aicheler *et al.*, "The Compact Linear Collider (CLIC) - Project Implementation Plan", CERN, Geneva, Switzerland, Rep. CERN-2018-010-M, Dec. 2018.
- [2] C. Gohil, D. Schulte, and P. N. Burrows, "Stray Magnetic Field Tolerances for the 380 GeV CLIC Design", CERN, Geneva, Switzerland, Rep. CERN-ACC-2018-0052, Nov. 2018.
- [3] C. Gohil *et al.*, "Measurements of Stray Magnetic Fields at CERN for CLIC", presented at the 10th Int. Particle Accelerator Conf. (IPAC'19), Melbourne, Australia, May 2019, paper MOPGW081, this conference.
- [4] Magnetic Shield Corporation, <http://www.magnetic-shield.com/index.html>.