



UNIVERSITÀ DEGLI STUDI DI NAPOLI
FEDERICO II

iteePhD
information technology
electrical engineering



Leonardo Sito

Metamaterials for beam-coupling Impedance mitigation at CERN

Tutor: Prof. Giovanni Breglio

co-Tutor: Prof. Francesco Fienga (DIETI)
Dr. Carlo Zannini (CERN)
Dr. Benoit Salvant (CERN)

Cycle: XXXVIII

Year: Second

My background

- **MSc degree:** Electronics Engineering @ UNINA
- **Research group/laboratory:**
 - DIETI, OptoPowerLab
 - CERN Beam, Accelerator and Beam Physics, Coherent Effects and Impedance (**BE-ABP-CEI**) section
 - CERN Experimental Physics, CMS TOTEM (**EP-CMT**)
- **PhD start date:** 01/01/2023
- **Scholarship type:** CERN Doctoral Student Program
- **Partner company/Period abroad:** European Organization for Nuclear Research (CERN)

Summary of study activities

- **Ad hoc PhD courses:**

- “**Numerical Methods for Thermal Analysis, Modeling, And Simulation: Application to Electronic Devices And systems**”
 - Lecturer: Dr. Antonio Pio Catalano, DIETI

- **PhD schools:**

- “**Metalenses for Antenna Applications**”, European School of Antennas and Propagation (ESoA), Sevilla, Spain.
 - Lecturers: Prof. Oscar Quevedo-Teruel (KTH), Prof. Francisco Mesa (Universidad de Sevilla), Dr. Astrid Algaba-Brazalez (Ericsson).
- “**Advanced Accelerator Physics**”, CERN Accelerator School (CAS), Spa, Belgium.
 - Lecturers: Dr. Frank Tecker (CERN)

- **Conferences / events attended:**

- Beam-Beam Wire Compensation Review Meeting 2024 (BBWC24 Review), CERN, Geneva, Switzerland.

Summary of study activities

- **Seminars:**

- Teledyne LeCroy - “TDR for Instant Highly Accurate Impedance Measurements”
- CERN ABP Seminar - “Studies on the interplay between beam- beam and impedance at the FCC-ee”
- CERN ABP Seminar - “Collective effects for muons during ionisation cooling”
- CERN ABP Seminar - “LHC DA studies with e-cloud in the triplets”
- CERN ABP Seminar - “wakis: 3D Electromagnetic Time- Domain Wake and Impedance Solver”
- CERN ABP Seminar - “Characterization of low-beta impedances”
- RF Seminars - “Large signal characterization of High-Power Amplifier”
- CERN CEI Meeting Seminar - “Xwakes in Xsuite”
- RF Seminars – “Examples and procedures for High Power Amplifiers measurements”
- CERN ABP CEI Meeting - “Non-relativistic wakes and resonator”
- CERN ABP CEI Meeting - “Impedance model for FCC-ee”
- UNINA - “From ACE Technologies to Sustainable, Accessible and Equitable Urban Mobility: An Optimization Journey”
- WC Review - “The beam dynamics case of the Beam-Beam Wire Compensators in HL era”
- Tektronix – “Fundamentals of Oscilloscopes and Probes”
- Tektronix – “Fundamentals of Jitter Analysis ”
- Tektronix – “Multichannel Radio Frequency Signal Analysis ”

Research area

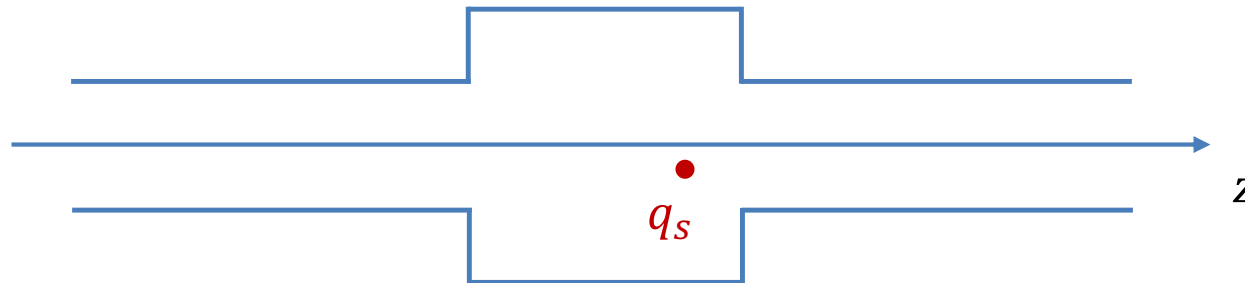


Electromagnetism applied to High-Energy Particle Accelerator Physics:

In an accelerator machine:

Bunches of charged particles → accelerated and contained in **vacuum chambers**.

Section of a vacuum chamber



Research area

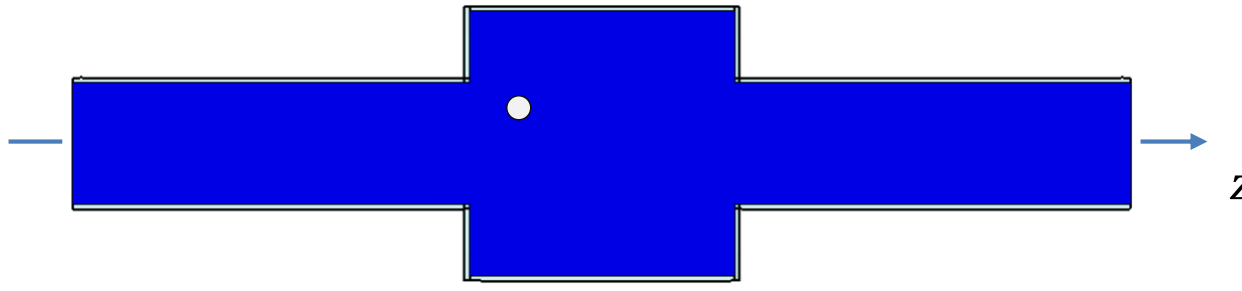


Electromagnetism applied to High-Energy Particle Accelerator Physics:

In an accelerator machine:

Bunches of charged particles → accelerated and contained in **vacuum chambers**.

Section of a vacuum chamber



Due to field interactions:

- Instabilities in the particle motion
- Dissipated power on the device

This interaction is studied in the frequency domain with a formalism called **Beam-Coupling Impedance**, a complex frequency dependent vector function

Research Problems

1. Evaluation of Beam-coupling Impedance:

A. Electromagnetic Simulations (CST)

B. VNA measurements **[P1]**

2. Evaluation of power dissipated on the vacuum chamber:

BIHC Python code:

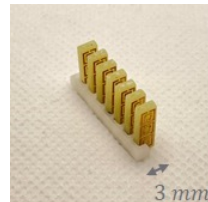
<https://github.com/ImpedanCEI/BIHC>

3. Techniques for mitigating the beam-coupling impedance:

A. Ferrites, Couplers **[P2, P4]**

B. Metamaterials **[P3]**

“Artificially structured materials that allow to engineer the interaction of fields with matter with properties (ϵ and μ) that depend on constituent materials and geometry”



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Research products

[P1]	C. Antuono, L. Sito, E. Calzone, D. el Dali, M. Migliorati, A. Mostacci, F. Fienga, V. R. Marrazzo, G. Breglio, G. Rumolo, C. Zannini. <i>A Novel Method for Transverse Beam-Coupling Impedance Measurements in Particle Accelerator Devices Using the Bead-Pull Method,</i> IEEE Transactions on Instrumentation and Measurement, vol. 73, pp. 1-9, 2024
[P2]	L. Sito, et al. <i>Impedance and thermal studies of the CERN SPS wire scanners and mitigation of wire heating,</i> 15 International Particle Accelerator Conference, Nashville, TN, United States, 19 - 24 May 2024, pp.WEPG29
[P3]	C. Zannini and L. Sito <i>Metamaterials for impedance optimization and sustainability,</i> 15 International Particle Accelerator Conference, Nashville, TN, United States, 19 - 24 May 2024, pp.TUXN1
[P4]	R.Veness et al. <i>Overview of beam intensity issues and mitigations in the CERN-SPS fast wire scanners,</i> 15 International Particle Accelerator Conference, Nashville, TN, United States, 19 - 24 May 2024, pp.WEPG26

PhD thesis overview

Main research topic:

Explore the possibility of using EM metamaterials to mitigate the beam coupling impedance.

Objective:

Extend the work: M.R. Masullo et al., “Metamaterial-Based Absorber for the reduction of Accelerator Beam-Coupling Impedance”

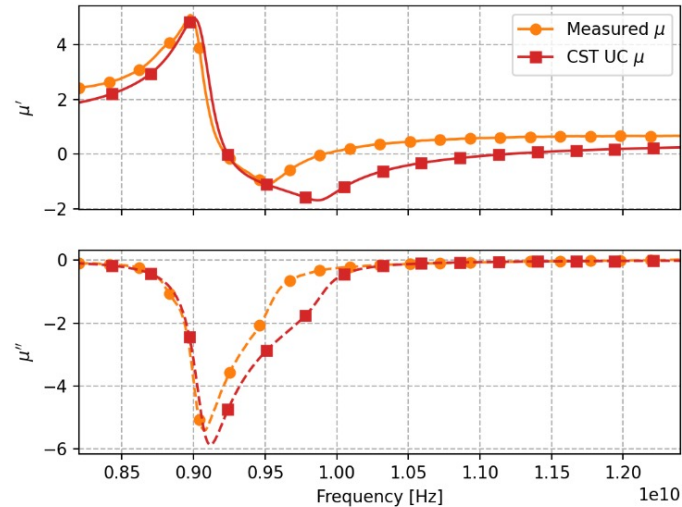
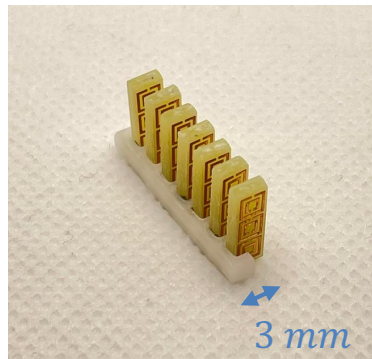
1. Study of the beam-coupling impedance
2. Optimization study
3. Measurements of beam-coupling impedance

PhD thesis overview

Methodology:

1. Controlled engineering of metamaterials

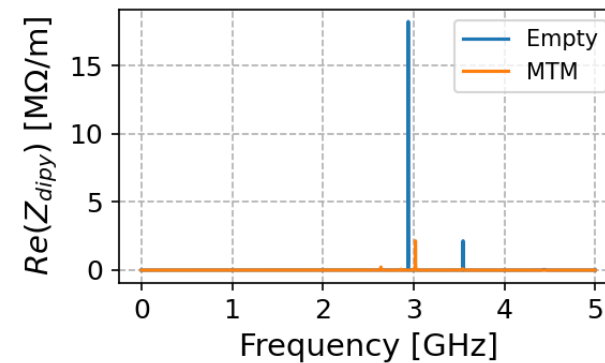
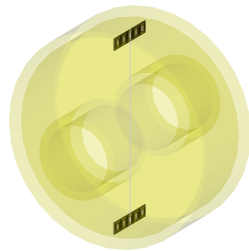
1. Design
2. Production
3. Characterization



PhD thesis overview

Methodology:

2. Testing the use of metamaterials as **mode absorbers** in cavity structures in simulation



3. Optimization

4. Experimental verification



Possible future steps

Thanks