UNIVERSITÀ DEGLI STUDI DI NAPOLI FEDERICO II

DOTTORATO DI RICERCA / PHD PROGRAM IN
INFORMATION TECHNOLOGY AND ELECTRICAL ENGINEERING

Activities and Publications Report

PhD Student: Leonardo Sito

Student DR number: DR996982

PhD Cycle: XXXVIII
PhD Chairman: Prof. Stefano Russo

PhD program student's start date: 01/01/2023
PhD program student's end date: 31/12/2025

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PhD scholarship funding entity:

Student funded by the European Organization for Nuclear Research (CERN) under the CERN Doctoral Student Program.

General information

Leonardo Sito received in year 2022 the Master Science degree in Electronic Engineering from the University of Napoli Federico II. Within the PhD program in Information Technology and Electrical Engineering, he attended a curriculum in Electromagnetic Fields. He received a grant from the European Organization for Nuclear Research (CERN) under the CERN Doctoral Student Program.

Study activities

Attended Courses

Year	Course Title	Type	Credits	Lecturer	Organization
1st	Statistical data analysis for science and engineering research	Ad hoc course	4	Prof. Roberto Pietrantuono	ITEE PhD Program
1st	Academic Entrepreneurship	Ad hoc course	4	Prof. Pierluigi Rippa, DIE, UNINA	ITEE PhD Program
1st	Artificial Intelligence and Natural Language Processing	Ad hoc course	3	Prof. Francesco Cutugno, Dr. Maria Di Maro, Prof. Antonio Orilia, Prof. Vincenzo Norman Vitale	ITEE PhD Program
2nd	Numerical Methods for Thermal Analysis, Modelling, And Simulation: Application to Electronic Devices And systems	Ad hoc course	4	Prof. Antonio Pio Catalano	ITEE PhD Program
3rd	Fiber optic sensing and optoelectronic circuits: design and application	Ad hoc course	4	Prof. Vincenzo Romano Marrazzo	ITEE PhD Program

Attended PhD Schools

Year	School title	Location	Credits	Dates	Organization
1st	Wakefields and Collective Beam Instabilities	Houston, Texas, USA	5	23/01 - 03/02/2023	USPAS and Northern Illinois University
1st	Spring School on Transferable Skills	Online	2	24 - 25/05/2023	University of Napoli Federico II, Department of Pharmacy
1st	Surface Electromagnetics for Wireless Communications and Sensing	Trento, Italy	4	15 to 19/05/2023	University of Trento and ELEDIA Research Centre
2nd	Metalenses for Antenna Applications	Sevilla, Spain	4	26/02 to 01/03/2024	European School of Antennas and Propagation (ESoA)

2nd	Advanced Accelerator Physics	Spa, Belgium	12	10/11 to 22/11/2024	CERN Accelerator Schools (CAS)

Attended Seminars

Year	Seminar Title	Credits	Lecturer	Lecturer affiliation	Organization
1st	5G Academy – Open Digital Framework	0.6	Alberto Curcio, Valeria Crimaldi	TMT Portfolio, Capgemini Invent, Italy	5G Academy
1st	Multi-Robot Control of Heterogeneous Herds	0.2	Prof. Eduardo Montijano	Universidad de Zaragoza, Spain	Scuola Superiore Meridionale
1st	5G Academy – Il cloud e gli Hyperscalers / High Performance Computing	0.6	Giovanni Vendramel, Klodiana Goga	Capgemini Invent	5G Academy
1st	5G Academy – Sustainable Strategy	0.6	Anna Bartnik, Andrea Spitaleri	Capgemini Invent	5G Academy
1st	The Laser-hybrid Accelerator for Radiobiological Applications	0.2	Prof. Kenneth Richard Long	Imperial College (GB)	CERN ATS
1st	High Power targetry R&D Programme with the RaDIATE Collaboration and target perspectives in framework of Snowmass	0.2	Dr. Frederique Pellemoine	Fermi National Accelerator Laboratory, Batavia, USA	CERN ABP Forum
1st	Beam-Beam Bremsstrahlung Beam- Size Effects and FCC-ee Beam Lifetime	0.4	Krzysztof Piotrzkowski	AGH UST Krakow, Poland	CERN ABP Forum
1st	Learning gene association networks using single-cell RNA-seq data: a graphical model approach.	0.2	Prof. Davide Risso	University of Padua, Padua, Italy	DIETI
1st	Accurate and Efficient Numerical Modeling Methods for Superconducting Circuit Quantum Information Processing Devices	0.2	Prof. Thomas E. Roth	Purdue University, Elmore Family School of Electrical and Computer Engineering, USA	DIETI

1st	Enhancing qubit readout with Bayesian Learning	0.2	Dr. Nicola Lo Gullo	University of Calabria, Italy	QST Seminars, Department of Physics, University of Napoli Federico II
1st	Nanoneuro: the power of nanoscience to explore the frontiers of neuroscience	0.2	Dr. Aitzol Garcia-Etxarri	Donostia International Physics Centre, Spain	DIETI
1st	Nonlinear surface impedance of superconductors in high magnetic fields	0.4	Prof. Ruggero Vaglio	University of Naples Federico II and CNR-SPIN, Genova, Italy	CERN
1st	Symbiotic Control of Wearable Soft Suits for human motion assistance and augmentation	0.4	Prof. Lorenzo Masia	Institut für Technische Informatik (ZITI) Heidelberg University, Germany	DIETI
1st	Optimization of the High-Brightness Beam Performance of the CERN PSB with H- Injection	0.2	Dr. Tirsi Prebibaj	CERN	CERN
1st	The design of the ENUBET beamline	0.2	Dr. Elisabetta Giulia Parozzi	CERN	CERN
1st	Collective Effects in Lepton Circular Colliders and Synchrotron Light Sources	0.2	Prof. Mikhail Zobov	National Institute of Nuclear Physics, LNF-INFN Rome, Italy	High Brightness Hadron Beams Workshop
1st	Predominantly electric “E&m” storage ring with nuclear spin control capability	0.2	Prof. Richard Talman	Cornell University, New York, USA	High Brightness Hadron Beams Workshop
1st	Diffusive models and chaos indicators for non-linear betatron motion	0.2	Dr. Carlo Emilio Montanari	University of Manchester, Manchester (GB)	CERN ABP Seminar
1st	Ensuring Electronic Reliability Against CERN's Radiation Environment	0.4	Dr. Salvatore Danzeca	CERN	DIETI
2nd	TDR for Instant Highly Accurate Impedance Measurements	0.2	Giuseppe Leccia	Teledyne LeCroy	Teledyne LeCroy
2nd	Studies on the interplay between beam-beam and impedance at the FCC-ee	0.2	Dr. Roxana Soos	Université Paris-Saclay (FR)	CERN ABP

2nd	Collective effects for muons during ionisation cooling	0.2	Josephine Potdevin	École Polytechnique Fédérale de Lausanne (EPFL), Lausanne (CH)	CERN ABP
2nd	LHC DA studies with e-cloud in the triplets	0.2	Dr. Konstantinos Paraschou	CERN	CERN ABP
2nd	wakis:3D Electromagnetic Time- Domain Wake and Impedance Solver	0.2	Dr. Elena de la Fuente Garcia	Universidad Politécnica de Madrid, Spain	CERN ABP
2nd	Characterization of low-beta impedances	0.2	Ing. Elena Macchia	Sapienza Università di Roma and INFN, Rome, Italy	CERN CEI
2nd	Large signal characterization of High-Power Amplifiers	0.4	Ing. Simone Chicarella	CERN	CERN RF Seminar Series
2nd	Xwakes in Xsuite	0.2	Dr. Lorenzo Giacomel	CERN	CERN ABP
2nd	Examples and procedures for High Power Amplifiers Measurements	0.4	Ing. Simone Chicarella	CERN	CERN RF Seminar Series
2nd	Non-relativistic wakes and resonators	0.2	Ing. Elena Macchia	Sapienza Università di Roma and INFN, Rome, Italy	CERN ABP-CEI Meetings
2nd	Impedance model for FCC-ee	0.2	Dora Gibellieri	University of Caen Normandy, France	CERN ABP-CEI Meetings
2nd	From ACE Technologies to Sustainable, Accessible and Equitable Urban Mobility: An Optimization Journey	0.4	Prof. Mauro Salazar	Eindhoven University of Technology, Eindhoven, Netherlands	University of Napoli Federico II
2nd	The beam dynamics case of the Beam-Beam Wire Compensators in HL era.	0.2	Philippe Belanger	TRIUMF, Vancouver, Canada	Wire Compensator Review Workshop
2nd	On Fundamentals of Oscilloscopes and Probes	0.6	Ing. Pietro Bianco	Tektronix	Tektronix, CERN Learning Hub
2nd	On Fundamentals of Jitter Analysis	0.6	Ing. Pietro Bianco	Tektronix	Tektronix, CERN Learning Hub
2nd	On Multichannel Radio Frequency Signal Analysis	0.6	Ing. Pietro Bianco	Tektronix	Tektronix, CERN Learning Hub
3rd	Superconducting Radio Frequency Cavities for Quantum Computing and Communication	0.2	Dr. Silvia Zorzetti	Fermilab, Batavia, IL, USA	University of Napoli Federico II

Research activities

Leonardo Sito participated in the research activities of the Accelerator and Beam Physics group at CERN, focusing on the modelling of beam-structure electromagnetic interactions in high-intensity particle accelerators through beam-coupling impedance analysis. His work initially covered a broad range of studies on impedance and beam-induced heating, carried out through electromagnetic simulations and bench-measurement techniques. This led to contributions to the design, refinement, and experimental validation of impedance models for several accelerator components, including both R&D structures and operational devices requiring impedance mitigation.
In parallel, he contributed to the development of an innovative bench-measurement methodology and a numerical Python package for beam-induced heating analyses, which he validated through dedicated and innovative measurements. The resulting tools and procedures are now commonly employed within the group for operational studies. His contributions supported component design reviews, mitigation strategies, and the definition of improved measurement workflows.
This research activity laid the foundations for his thesis work based on exploring promising impedance mitigation strategies with metamaterial absorbers. This enabled him to demonstrate, both numerically and experimentally, that metamaterials can provide frequency-selective damping of longitudinal and transverse impedance resonances. He also explored alternative designs and assessed their heat-management capabilities, further strengthening the applicability of the proposed approach.

Tutoring and supplementary teaching activities

Credits summary

PhD Year	Courses	Seminars	Research	Tutoring / Supplementary Teaching
1st	22	5.8	34.2	0
2nd	20	5	39	0
3rd	4	0.2	55.8	0

Research periods in institutions abroad and/or in companies

PhD Year	Institution / Company	Hosting tutor	Period	Activities
1st	CERN, Geneva, Switzerland	Dr. Benoit Salvant, Dr. Carlo Zannini, Staff Scientists		Research on beam-coupling impedance and wake fields for high energy accelerator. Beam-induced heating analysis and code development.
2nd	CERN, Geneva, Switzerland	Dr. Benoit Salvant, Dr.		Research on metamaterial design and characterization with on field experimental activity

		Carlo Zannini, Staff Scientists		
3rd	CERN, Geneva, Switzerland	Dr. Benoit Salvant, Dr. Carlo Zannini, Staff Scientists		Experimental activity on accelerator device bench-measurements with metamaterial insertions.

PhD Thesis

In the PhD Thesis, Leonardo Sito investigates the use of metamaterial structures for mitigating beam-coupling impedance and beam-induced heating in high-intensity circular particle accelerators. In such machines, high-current charged particle beams can excite electromagnetic resonant modes in geometric discontinuities of the vacuum chamber. This beam-structure interaction, described in the frequency domain by the beam-coupling impedance, may compromise beam stability and lead to significant local heating of accelerator components. Traditional mitigation strategies (including higher-order mode couplers, geometric smoothing, and lossy material insertions) offer effective but often limited or non-selective solutions. Metamaterials, with their engineered effective electromagnetic properties, represent a promising alternative for targeted damping of harmful resonant modes.

The thesis develops a comprehensive simulation and experimental framework for the characterization of beam-coupling impedance and beam-induced power deposition. This framework combines established numerical tools with emerging techniques and integrates novel methods developed by the candidate, including an improved impedance measurement procedure based on an extension of bead-pull methodologies, and a dedicated Python-based code for beam-induced heating analysis. These tools are validated through dedicated measurements and benchmarked against analytical and numerical models.

By designing, fabricating, and characterizing tailored metamaterial absorbing slabs, the candidate demonstrates both numerically and experimentally the possibility to selectively suppress longitudinal and transverse impedance resonances in a dedicated test structure. Complementary analyses of power dissipation, spatial energy deposition, and temperature distribution provide insight into the thermal behavior and operational constraints of metamaterial absorbers. Building on these results, alternative metamaterial-based designs with enhanced robustness and improved heat management are proposed and evaluated.

Finally, the thesis assesses the feasibility of integrating metamaterial absorbers into an operational accelerator device, outlining the potential advantages, limitations, and next steps required for their adoption in future accelerator upgrades. The work provides the first comprehensive demonstration of metamaterial-based impedance mitigation in an accelerator-relevant context, opening new perspectives for advanced beam dynamics control and component protection in high-intensity machines.

Research products

Research results appear in *5* papers published in international journals, *0* papers published in national journals, *12* contributions to international conferences, *0* contributions to national conferences, *0* patents.

List of scientific publications

International journal papers

C. Antuono, et al.,
Impact of High-Intensity LHC Beam Operation on Warm Vacuum Modules,
Physical Review Accelerators and Beams,
vol. 28(4), p. 041001, 2025, DOI: 10.1103/PhysRevAccelBeams.28.041001.

C. Antuono, et al.,
A Novel Method for Transverse Beam-Coupling Impedance Measurements in Particle Accelerator Devices Using the Bead-Pull Method,
IEEE Transactions on Instrumentation and Measurement,
vol. 73, pp. 1-9, Art. no. 8005209, 2024, DOI: 10.1109/TIM.2024.3458042.

G. Acampora, et al.,
SND@LHC: The Scattering and Neutrino Detector at the LHC,
Journal of Instrumentation,
vol. 19(05), p. P05067, 2024, DOI: 10.1088/1748-0221/19/05/P05067.

V. R. Marrazzo, et al.,
Experimental Tests of a Full Analog Fiber Optic Monitoring System Suitable for Safety Application at CERN,
IEEE Transactions on Instrumentation and Measurement,
vol. 72, pp. 1–8, Art. no. 7002408, 2023, DOI: 10.1109/TIM.2023.3250283.

F. Fienga, et al.,
Direct Measurement of Beam-Induced Heating on Accelerator Pipes with Fiber Optic Sensors: Numerical Analysis Validation,
IEEE Transactions on Instrumentation and Measurement,
vol. 72, pp. 1-9, Art. no. 9508709, 2023, DOI: 10.1109/TIM.2023.3279420.

International conference papers

C. Zannini et al.,
Simulations of beam-coupling impedance to guide model-based mitigations in Hadron Rings,
71st ICFA Advanced Beam Dynamics Workshop on High-Intensity and High-Brightness Hadron Beam (HB'25),
Huizhou, China, Oct. 2025, pp. 161-165. DOI:10.18429/JACoW-HB2025-WECDB02

L. Sito et al.,
Metamaterial absorbers for beam-coupling impedance mitigation,
16th International Particle Accelerator Conference (IPAC'25),
Taipei, Taiwan, Jun. 2025, pp. 2172-2175. DOI:10.18429/JACoW-IPAC2025-WEPM085

R. Tomas et al.,
Towards a High Luminosity LHC with even higher performance,

16th International Particle Accelerator Conference (IPAC'25),
Taipei, Taiwan, Jun. 2025, pp. 278-281. doi:10.18429/JACoW-IPAC2025-MOPM008

C. Antuono et al.,
Beam impedance investigation of the elliptical interconnecting vacuum modules of the LHC and prospect for HL-LHC,
16th International Particle Accelerator Conference (IPAC'25),
Taipei, Taiwan, Jun. 2025, pp. 2141-2144. doi:10.18429/JACoW-IPAC2025-WEPM075

L. Sito et al.,
LHC beam-beam wire compensator impedance contribution,
16th International Particle Accelerator Conference (IPAC'25),
Taipei, Taiwan, Jun. 2025, pp. 2176-2179. doi:10.18429/JACoW-IPAC2025-WEPM086

P. Krkotić, et al.,
Understanding of the LHC Warm Vacuum Module Heating,
15th International Particle Accelerator Conference (IPAC'24),
Nashville, TN, USA, May 2024, pp. 947–950, DOI: 10.18429/JACoW-IPAC2024-TUAN3.

C. Zannini, L. Sito
Metamaterials for Impedance Optimisation and Sustainability,
15th International Particle Accelerator Conference (IPAC'24),
Nashville, TN, USA, May 2024, pp. 925–930, DOI: 10.18429/JACoW-IPAC2024-TUXN1.

R. Veness, L. Sito, et al.
Overview of Beam Intensity Issues and Mitigations in the CERN-SPS Fast Wire Scanners,
15th International Particle Accelerator Conference (IPAC'24),
Nashville, TN, USA, May 2024, pp. 2248–2251, DOI: 10.18429/JACoW-IPAC2024-WEPG26.

L. Sito, et al.,
Impedance and Thermal Studies of the CERN SPS Wire Scanners and Mitigation of Wire Heating,
15th International Particle Accelerator Conference (IPAC'24),
Nashville, TN, USA, May 2024, pp. 2260–2263, DOI: 10.18429/JACoW-IPAC2024-WEPG29.

L. Sito, et al.,
A Python Package to Compute Beam-Induced Heating in Particle Accelerators and Applications,
68th ICFA Advanced Beam Dynamics Workshop on High-Intensity and High-Brightness Hadron Beams (HB'23),
Geneva, Switzerland, Oct. 2023, pp. 611–614, DOI: 10.18429/JACoW-HB2023-THBP52.

G. Rumolo, et al.,
Beam Performance with the LHC Injectors Upgrade,
68th ICFA Advanced Beam Dynamics Workshop on High-Intensity and High-Brightness Hadron Beams (HB'23),
Geneva, Switzerland, Oct. 2023, pp. 1–8, DOI: 10.18429/JACoW-HB2023-MOA1I1.

L. Sito, et al.,
Beam-Beam Long Range Compensator Mechanical Demonstrator,
14th International Particle Accelerator Conference (IPAC'23),
Venice, Italy, May 2023, pp. 4916–4918, DOI: 10.18429/JACoW-IPAC2023-THPM015.

Patents and/or spin offs

Awards and Prizes

"Best Student Poster Prize" at the 16th International Particle Accelerator Conference (IPAC'25), for the work titled "Metamaterial absorbers for beam-coupling impedance mitigation".

Date 9/12/2025

PhD student signature Leonardo Sito

Supervisor signature Giovanni Bazzio