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Corso di dottorato in Fisica / Doctoral Programme in Physics

Ciclo 40 / Cycle 40

A.Y. 2024 - 2025

Borse a tematica vincolata / Reserved scholarships:

A - *Development of innovative techniques for anti-matter identification in Cosmic Rays* PHeSCAMI – Pressurized Helium Scintillating Calorimeter for AntiMatter Identification Codice Progetto: PRIN 2022LLCPMH CUP: E53D23002100006
B - *Ultra Fast Outflows from AGN accretion discs in the X-ray calorimeter era*
C - *Dissipative quantum chaos at the interface of cold atoms and gravity theory* Codice Progetto: SERI No. UeMO19-5.1 CUP: E63C23001140007
D – E *Particle, astroparticle, nuclear, theoretical physics, related technologies and applications, including medical Physics*
F - *Particle Acceleration on A Chip*
G - *Development and applications of TERS and TEPL techniques to study semiconductor materials for quantum technologies*
H - *Dopant Characterization in Silicon Carbide (SiC) Semiconductors: Towards Enhanced Electronic Devices*
I - *Photonic quantum-gate based planar lightwave circuits*
J - *Integrative AI for event selection at LHC*

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Scholarship A:

Finanziato dall'Unione europea NextGenerationEU | Ministero dell'Università e della Ricerca | Italiadomani PIANO NAZIONALE DI RIPRESA E RESILIENZA | UNIVERSITÀ DI TRENTO

Reference persons*:* Paolo Zuccon

Funded by: Codice progetto: PRIN 2022LLCPMH

CUP: E53D23002100006

PhD Scholarship Title	**Development of innovative techniques for anti-matter identification in Cosmic Rays**
Research group link	https://www.tifpa.infn.it/projects/adhd/
Contacts	Prof. P. Zuccon
Synthetic description of the activity and expected research outcome	Low energy anti-deuterons in cosmic rays are considered a golden channel for the identification of Dark Matter annihilations in space. The candidate will join the PHeSCAMI (Pressurized Helium Scintillating Calorimeter for AntiMatter Identification) project that will exploit the delayed annihilations of the exotic-He atoms for the identification of anti-deuterons in space. The candidate will contribute to the design and construction of the detector prototype and to the calibration with particle beam.
Ideal candidate (skills and competencies):	The ideal candidate should possess problem solving skills. Knowledge of C++ or Python programming languages.

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Scholarship B:

PhD Scholarship Title	**Ultra Fast Outflows from AGN accretion discs in the X-ray calorimeter era**
Research group link	
Contacts	Dr. Valentina Braito valentina.braito@inaf.it Prof. Albino Perego albino.perego@unitn.it
Synthetic description of the activity and expected research outcome	It is commonly accepted that the co-evolution of supermassive black holes (SMBH) and of their host galaxies is regulated by powerful outflows driven by the central SMBH. The successful candidate will investigate the X-ray emission from SMBH, focusing on some of the most powerful and extreme ultra-fast winds, launched from the accretion disk of SMBH. The main goals of the project are: a. derive an estimate of the physical parameters of these winds; b. investigate the presence or lack of correlations between the wind parameters and the accretion rate of the SMBH; c. deduce the main driving mechanism for the disk winds. The candidate will join a group deeply involved in the observational side as well as in the development of physically motivated models. The group has access to deep, proprietary X-ray observations that will be at the core of the project and will have access to the latest X-ray calorimeter data (i.e. for the XRISM and ATHENA calorimeter). The successful candidate will have the opportunity to participate in the other research activities of the group: from the X-ray observations of heavily obscured SMBH, to the search of and characterization of dual and binary SMBH and the simulations for future mission in the X-ray band and the gravitational wave detectors.
Ideal candidate (skills and competencies):	Knowledge of the physic of compact objects and of Active Galactic Nuclei, in particular of the AGN X-ray emission. Experience with the basic X-ray spectral fitting. Good computational skills.

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Scholarship C:

PhD Scholarship Title	**Dissipative quantum chaos at the interface of cold atoms and gravity theory** Codice Progetto: SERI No. UeMO19-5.1 CUP: E63C23001140007
Research group link	https://hauke-group.physics.unitn.it/
Contacts	philipp.hauke@unitn.it
Synthetic description of the activity and expected research outcome	The holographic principle establishes a deep connection between a bulk gravity theory and a strongly-coupled boundary field theory, with drastic consequences such as the saturation of bounds on quantum chaos, the fast loss of quantum information, or the absence of quasiparticles. Though these properties render such *holographic quantum matter* highly relevant across many fields of physics, its laboratory realization remains elusive. Recently, we have presented a promising implementation, based on cold fermionic atoms in an optical cavity [1]. While first steps have been achieved by an experimental partner group [2], many obstacles remain, in terms of implementation and fundamental theory. In this PhD project, we will understand the impact of—experimentally inspired—deformations, in particular dissipation, on the phenomenology of the model. Can one still reach the holographic limit? And if so, what do the deformations mean on the gravity side? Further, we will apply the cold-atom and quantum-optics toolbox to design improved implementations. From this work, we will achieve significant advances in two routes. First, we will achieve a deeper understanding of quantum chaos, its limits, and how it persists under dissipation. Second, we will make significant strides towards a first laboratory realization of holographic quantum matter. To achieve these goals, the PhD candidate will apply a combination of analytical and numerical techniques, and they will closely collaborate with leading theoretical and experimental groups. The work will be performed within the project Holograph. [1] *A cavity quantum electrodynamics implementation of the Sachdev--Ye--Kitaev model,* Uhrich et al., arXiv:2303.11343 (2023). [2] *Engineering random spin models with atoms in a high-finesse cavity,* Sauerwein et al., *Nature Physics* 19, 1128–1134 (2023).
Ideal candidate (skills and competencies):	The ideal candidate has a strong background in theoretical physics, in particular in field theory, gravity theory, quantum optics, atomic physics, and quantum many-body theory. They should be interested in connecting fundamental theory questions to experimental realizations, they should be

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	confident with addressing difficult theoretical questions through analytical and numerical tools, and they should have excellent team-working capacities.

Scholarship D – E:

PhD Scholarship Title	**Particle, astroparticle, nuclear, theoretical physics, related technologies and applications, including medical Physics** (2 positions)
Contacts.:	For further information on the possible research topics see www.infn.it or contact Rita Dolesi for experimental Physics (Rita.Dolesi@unitn.it); Francesco Pederiva for theoretical Physics (Francesco.Pederiva@unitn.it) Chiara La Tessa for applied and medical physics (chiara.latessa@unitn.it)
Synthetic description of the activity and expected research outcome	The thesis topics will be selected within the many areas of forefront research pursued at Trento Institute for Fundamental Physics and Applications (TIFPA) of INFN. Current main activities include: 1) experimental particle and astroparticle Physics, 2) experimental gravitation both earth and space based, 3) gravitational wave astronomy, 4) antimatter related experiments, 5) R&D on particle and radiation detectors and other solid state quantum micro devices, 6) computational Physics and AstroPhysics, 7) theory of fundamental interactions, 8) theoretical cosmology, 9) medical physics applied to therapy with high energy charged particles

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Scholarship F:

PhD Scholarship Title	**Particle Accelerator on A Chip**
Research group link	https://sd.fbk.eu/en/
Contacts	Antonino Picciotto picciotto@fbk.eu & Richard Hall-Wilton rhallwilton@fbk.eu
Synthetic description of the activity and expected research outcome	Accessing advanced acceleration structures with microfabrication techniques: Particle accelerators are becoming huge - the proposed Future Circular Collider with 100km circumference. Here, acceleration is addressed from the opposite end, using microfabrication to obtain extremely compact structures, to produce particle beams for a variety of possible applications. In other words: particle acceleration on a chip. The topic will study and design possible devices. It will then utilise the micro- and nano- fabrication facilities at the Sensors&Devices to realise them and to test these prototype structures. Consideration of potential applications of such devices will be considered from the beginning of the design.
Ideal candidate (skills and competencies):	An interest and aptitude for design and microfabrication of silicon devices is expected. A hands on and practical mentality is desired. Experience of data handling and analysis is similarly helpful. An interest in the particle acceleration and applications of particle beams is useful.

Scholarship G:

PhD Scholarship Title	**Development and applications of TERS and TEPL techniques to study semiconductor materials for quantum technologies**
Research group link	Materials & Topologies for Sensors & Devices group (MTSD), Center for Sensors and Devices (SD - https://sd.fbk.eu/), Fondazione Bruno Kessler (FBK).
Contacts	Dr Rossana Dell'Anna – dellanna@fbk.eu Dr Massimo Bersani – bersani@fbk.eu
Synthetic description of the activity and expected research outcome	Tip-enhanced Raman Spectroscopy (TERS) combines the chemical analysis of the Raman technique with the increased sensitivity of the SERS (Surface Enhanced Raman Spectroscopy) approach and the nanometric spatial resolution of the Scanning Probe Spectroscopy (SPM). Since the technique uses a Raman spectrometer, Tip-Enhanced Photoluminescence (TEPL) is also possible for probing chemical, electrical and optical properties at the nanoscale. The spectroscopy information is provided along with all the measurements enabled by SPM, such as topography and electrical and mechanical properties. The advantages of these spectroscopies, namely the lateral resolution beyond the diffraction limit and the non-destructive, label-free and in-air interaction, open new possibilities for nanotechnology and quantum applications. A new TERS/TEPL equipment was recently installed in the FBK-SD laboratories. This PhD project aims to set up the TERS/TEPL techniques and apply them to the study of optical and morphological properties of semiconductor materials, also nanostructured, used for quantum technologies, down to the single quantum object scale. This research activity will be carried out in the framework of some ongoing projects on quantum sensors and devices at FBK-SD.
Ideal candidate (skills and competencies):	Master degree in physics or chemistry; background in Raman and photoluminescence spectroscopy or quantum optics; background in data and image analysis and processing; teamwork approach, good communication and relational skills; aptitude for problem-solving.

Scholarship H:

PhD Scholarship Title	**Dopant Characterization in Silicon Carbide (SiC) Semiconductors: Towards Enhanced Electronic Devices**
Research group link	Materials & Topologies for Sensors & Devices group (MTSD), Center for Sensors and Devices (SD - https://sd.fbk.eu/), Fondazione Bruno Kessler (FBK).
Contacts	bersani@fbk.eu
Synthetic description of the activity and expected research outcome	Silicon Carbide (SiC) has emerged as a promising semiconductor material for electronic devices due to its exceptional material properties, including high thermal conductivity, wide bandgap, and excellent chemical and mechanical stability. As SiC-based devices become increasingly integral to various applications, understanding and optimizing dopant characteristics is crucial for advancing their performance and reliability. This thesis focuses on the comprehensive characterization of dopants in SiC semiconductors, aiming to bridge the gap between material science and device engineering. The research involves the exploration of various dopant types, concentrations, and their impact on the electrical, structural, and thermal properties of SiC. Both traditional and novel doping techniques are investigated, with an emphasis on their effects on carrier mobility, doping efficiency, and device functionality. The experimental methodology encompasses advanced analytical techniques such as Secondary Ion Mass Spectrometry (SIMS), X-ray Photoelectron Spectroscopy (XPS), and Hall effect measurements to precisely quantify and analyze dopant profiles, dopant activation levels, and their distribution within the SiC lattice. Additionally, the impact of dopants on defect formation and migration in SiC will be investigated to gain insights into the material's long-term stability and reliability. The research also explores the practical implications of dopant characterization on SiC device performance. Through the integration of the acquired knowledge, this study aims to propose optimized doping strategies for enhancing the efficiency and reliability of SiC-based electronic devices. The findings of this research hold significant potential for advancing the field of SiC semiconductors, enabling the development of next-generation electronic components with improved performance, efficiency, and longevity.
Ideal candidate (skills and competencies):	Master degree in physics or engineering; background in Semiconductor materials and analytical characterization; teamwork approach, good communication and relational skills; aptitude for problem-solving; good English level.

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Scholarship I:

PhD Scholarship Title	**Photonic Quantum-gate based planar lightwave circuits**
Research group link	Integrated & Quantum Optics group, Centre for Sensors and Devices, FBK (https://sd.fbk.eu/en/research/research-units/iqo/)
Contacts	Supervisor - Mher Ghulinyan (ghulinyan@fbk.eu) Co-supervisor - Iacopo Carusotto (iacopo.carusotto@unitn.it)
Synthetic description of the activity and expected research outcome	The working principle of a quantum computer is based on two basic concepts: high quality qubits and reliable quantum gates to satisfy the DiVincenzo criteria. In the integrated photonics framework, the low interaction between photons and the environment or other photons guarantees for free the stability of qubits, but makes the realization of multi-photon gates a challenging task. The development of a well characterized, scalable, high-performance two-qubit gate, such as the CNOT gate, would be a breakthrough for the implementation of powerful quantum algorithms in a photonic quantum computer. While some proposals have already been implemented, none of them has achieved sufficient performance and novel ideas and technologies are needed to enable the application of such an overwhelming technology. This PhD activity will be aimed at the investigation and development of new approaches towards the realization of multi-photon integrated quantum gates.
Ideal candidate (skills and competencies):	The Candidate will work within the context of the realization of integrated optical chips for applications in the field of quantum technologies. The PhD activity will be performed within the research unit of Integrated and Quantum Optics (I&QO, FBK), which develops integrated optical circuits starting from design to fabrication and testing. The candidate will closely collaborate with the group of Prof. I. Carusotto on the theoretical aspects of the quantum photonic devices. **The ideal candidate should have:** A Master degree in Physics or Electrical Engineering, ideally with some background in Photonics and quantum optics. Basic knowledge of free-space optics or integrated photonic chips characterisation is highly desirable.

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Scholarship J:

PhD Scholarship Title	**Integrative AI for event selection at LHC**
Research group link	https://www.physics.unitn.it/en/237/astro-particle-physics
Contacts	roberto.iuppa@unitn.it marco.cristoforetti@fbk.eu
Synthetic description of the activity and expected research outcome	The LHC experiments produce about 90 petabytes of data per year. Inferring the nature of particles produced in high-energy collisions is crucial for probing the Standard Model with greater precision and searching for phenomena beyond the Standard Model. In this context, event selection is becoming more difficult than ever before and requires expertise at the border between physics and computer science. During the PhD the student will be guided in exploring and designing algorithms that mix background knowledge with Deep Learning to tackle this problem, learning to apply rigorous Data Science methodologies. The activity will be carried out in collaboration with INFN-TIFPA, Fondazione Bruno Kessler, and within the ATLAS experiment at the LHC. Candidates familiar with High Energy Physics are welcome, and basic knowledge of Machine Learning/Deep Learning is recommended.
Ideal candidate (skills and competencies):	