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DI TRENTO

**Corso di dottorato in Fisica / PhD in Physics**
**Ciclo 36 / Cycle 36**
*A.Y. 2020-2021*

## Borse a tematica vincolata / *Reserved scholarships*

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| A - Interplay of slow dynamics and X-ray induced dynamics in glass-forming liquids |
| B - Space data science and technology |
| C - Data science for High Energy and Space Physics |
| D - Development of a read-out system for particle sensors with applications in radiotherapy and space radioprotection |
| E - Physics of biological macromolecules investigated via advanced computational methods |
| F - Entangled photon sources for an integrated photonics quantum simulator |
| G - Twin photons and single photon entanglement for QRNG and QCD |
| H - Quantum many-body systems and ultracold gases |
| I - SOCCEr (SupercOnducting Circuits for the Casimir Effect) |
| L - Quantum sensing with laser-synthesized NAno-DIAmond NV color centers (NaDia) |
| M-N - Particle, astroparticle, nuclear, theoretical physics, related technologies and applications, including medical Physics |
| O - Nanopillar cavity enhanced emission from diamond |
| P - Statistical physics and nonlinear dynamics of highly and interdependent systems |
| Q - Statistical physics of social dynamics and urban systems |

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## Scholarship A

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| **Topic**: Interplay of slow atomic dynamics and X-ray induced dynamics in glass-forming liquids |
| **University of Trento e Department of Physics** |
| **Contacts**.: Giulio Monaco giulio.monaco@unitn.it |
| The nature of the liquid to glass transition remains one of the big unsolved problems in Physics at the focus of the scientific community. New experimental techniques and numerical approaches have recently contributed to shine a new light on this fascinating problem.<br>One such experimental techniques is X-ray photon correlation spectroscopy which will be employed in this project to probe density fluctuations at the atomic scale in glass-forming liquids close to the glass-transition. Both spontaneous and X-ray induced density fluctuations will be studied, which give different and complementary information on the atomic dynamics. These experiments are now becoming more and more feasible thanks to the worldwide development of coherent X-ray sources that behave like laser sources in the visible range. In particular, these experiments will be carried out using synchrotron radiation at storage rings and X-ray free electron lasers. |
| **Ideal candidate** (skills and competencies)**:**<br>The ideal candidate should have a solid background in Condensed Matter Physics. She/he should be confident with both experimental work (samples preparation and characterization in the laboratory; experiments at large scale facilities) and with basic numerical work (programming with matlab or equivalent; dealing with datasets of large size). She/he should also be ready to work in autonomy, and able to collaborate with international research groups. |

## Scholarship B

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| **Topic**: Space Data Science and Technology |
| **University of Trento e Department of Physics** |
| **Contacts**: Roberto Iuppa, Roberto Battiston, Paolo Zuccon, Rita Dolesi, William J. Weber e Stefano Vitale |
| **Synthetic description of the activity and expected research outcome**<br>The student will dedicate her/his research work to the study of critical aspects of scientific space missions in the field of gravitational wave astronomy and astroparticle physics at large. Missions in the framework of which the research work may be carried out include LISA Pathfinder, LISA, AMS, Limadou, and the development of future missions in Astroparticle Physics. The specific subject of the thesis can be negotiated and may be on: the development of data analysis methods and algorithms; the analysis of data and the performance of scientific observations with those missions that are or have been in operation; the development of instrumentation including laboratory studies in support of such developments. |
| **Ideal candidate** (skills and competencies)**:**<br>A graduate in physics or engineering, with a genuine passion for scientific space missions |

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## Scholarship C

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| **Topic**: - Data science for High Energy and Space Physics |
| **University of Trento and FBK** |
| **Contacts**: **Roberto Iuppa** roberto.iuppa@unitn.it |
| **Synthetic description of the activity and expected research outcome**<br>This project will focus on data science and deep learning to quantify and model observations made within experiments of particle physics (ATLAS at the LHC, future colliders) and in space (HEPD-01/02, Aladino). The project will develop novel analytics tools for event building software, including feature tagging, consequent event selection and particle identification. |
| **Ideal candidate** (skills and competencies)**:**<br>tbd……. |

## Scholarship D

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| **Topic**: Development of a read-out system for particle sensors with applications in radiotherapy and space radioprotection |
| **University of Trento and TIFPA** |
| **Contacts:** Chiara La Tessa chiaralatessa@unitn.it |
| **Synthetic description of the activity and expected research outcome**<br>The candidate will develop a read-out system for different types of particle detectors, including dosimeters and microdosimeters, to be used in applied nuclear physics experiments as well as in<br>measurements of interest for radiotherapy, medical physics, biophysics and space radiation research. |
| **Ideal candidate** (skills and competencies)**:**<br>The ideal candidate should have some knowledge in particle detectors, electronics (including FPGA<br>technology) and computer programming. |

## Scholarship E

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| **Topic**: E - Physics of biological macromolecules investigated via advanced computational methods |
| **Department of Physics (H2020-ERC StG VARIAMOLS)** |
| **Contacts**: Raffaello Potestio, raffaello.potestio@unitn.it |
| **Synthetic description of the activity and expected research outcome**<br>The objective of the research activity is to investigate the properties of large macromolecules by means of coarse-grained models. The methods employed have been developed in the research group, however the candidate is expected to contribute to their extension and application. The focus of the research activity will be on large biomolecules, in particular |

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| proteins. The candidate will acquire competence in the foundations of the most common molecular modelling and coarse-grained simulation methods employed in the context of soft matter, and perform and analyze molecular dynamics simulations at the all-atom and coarse-grained level. |
| **Ideal candidate** (skills and competencies):<br>The ideal candidate holds a M.Sc. in physics, chemistry, biology, engineering, or interdisciplinary courses involving at least one of the aforementioned ones. The competent use of programming languages (C, C++, python, bash, and similar), as well as a good knowledge of the English language, are required. |

## Scholarship F

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| **Topic**: F - Entangled photon sources for an integrated photonics quantum simulator |
| **Department of Physics** |
| **Contacts**: Lorenzo Pavesi lorenzo.pavesi@unitn.it |
| **Synthetic description of the activity and expected research outcome**<br>An European project will start 1 october 2020 to develop chip-scale quantum photonic-electronic integrated platform, fully interfaced to a classical computer (project EPIQUS: Electronic-photonic integrated quantum simulator platform). At the core of the EPIQUS project, a quantum photonic chip based on a low-loss (≤ 1dB/cm) SiN platform and operating at NIR wavelengths (800-850nm) will be developed. The use of SiN will enable a monolithic integration of the quantum photonic circuits (pump distribution, generation and manipulation of entangled photons) with silicon SPADs on the same chip – a far-reaching goal that will represent a leap forward in<br>the field of photonic quantum technologies. The PhD will contribute to this project by designing, testing and characterizing multiple (up to 16) scalable entangled photon sources (pumped by a NIR pulsed diode laser to produce on-chip photon pairs via nonlinear four wave mixing), for the quantum simulator. Here the idea is to build up on recent results of the NL lab (https://www.nature.com/articles/s41467-020-16187-8) and develop a suitable integrated source. After a first phase of design of the source, the source will be fabricated and tested to prove the generation of multi entangled photon pairs. These will be ten feed into the quantum circuitry for quantum simulation experiments. The work will be carried out in the NL laboratory with strong interactions with the European partners in Austria, Germany, Spain and Korea.<br>For information and preliminary interview contact prof. Pavesi (email lorenzo.pavesi@unitn.it) |
| **Ideal candidate** (skills and competencies):<br>Background in quantum optics and photonics |

## Scholarship G

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| Topic: G - Twin photons and single photon entanglement for QRNG and QCD |
| **Department of Physics** |
| **Contacts**: Lorenzo Pavesi lorenzo.pavesi@unitn.it |
| **Synthetic description of the activity and expected research outcome** |

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| Based on an integrated silicon light source the PhD will elaborate two different devices, which are instrumental for quantum security and quantum communication. These are quantum random number generators and quantum key distribution set-up. The activity will be carried out within the European project Qrange (https://qrange.eu/) and the Italy-India collaboration with prof. U Sinha (https://sites.google.com/site/urbasisinha/home). The generation of random numbers plays a crucial role in many applications in science. It can be used for simulation and cryptography. It is of fundamental importance that the generated numbers are truly random and due to a quantum process, as any deviation may adversely affect modelling or jeopardize security. The aim of this PhD is to develop and test a on-chip quantum photonic scheme of QRNG based on single particle entanglement (https://arxiv.org/abs/2003.09961) and quantum entropy measurements. In addition, to make secure a communication protocol between two parties, quantum mechanics is used to exchange an encryption keys, this scheme is called quantum key distribution (QKD). The second aim of the PhD is to develop and test a scheme of QKD based on single photon entanglement where the developed source will be used on the Indian quantum key distribution on fiber test-bed.<br>The PhD student will join a team of physicist, mathematician and computer scientists. For information and preliminary interview contact prof. Pavesi (email lorenzo.pavesi@unitn.it) |
| **Ideal candidate** (skills and competencies):<br>Background in photonics and in quantum optics |

## Scholarship H

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| Topic: Quantum many-body systems and ultracold gases |
| **Department of Physics** |
| Contacts: Gabriele Ferrari, gabriele.ferrari@unitn.it |
| **Synthetic description of the activity and expected research outcome**<br>Ultracold atomic gases offer a flexible platform to address open problems in fundamental physics such as many-body properties in quantum gases, transport phenomena, quantum simulation of fundamental interactions and gauge fields. The PhD student will work in the experimental group within the interdisciplinary environment of the BEC Center (http://bec.science.unitn.it), where research both on theory and experiments is done covering a wide range of themes. |
| **Ideal candidate** (skills and competencies)**:**<br>the ideal candidate should posses good knowledge of quantum mechanics, statistical physics, atomic physics with applications to data analysis and experimental research. The PhD student will work in the experimental group within the interdisciplinary environment of the BEC Center (http://bec.science.unitn.it), where research both on theory and experiments is done covering a wide range of themes. |

## Scholarship I

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| **Topic**: SOCCEr (SupercOnducting Circuits for the Casimir Effect) |
| **Q@TN** |
| **Contacts**: Gianluigi Casse (FBK), Paolo Falferi (IFN-CNR), Iacopo Carusotto (INO-CNR BEC Center) |

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| **Contacts**: casse@fbk.eu; paolo.falferi@unitn.it; iacopo.carusotto@unitn.it; margesin@fbk.eu |
| **Synthetic description of the activity and expected research outcome**<br>Synthetic description of the activity and expected research outcome The main objectives of the research activity are the fabrication and test of coplanar superconducting waveguides and/or resonators terminated by a SQUID acting as a tunable mirror, and to use them in quantum optics experiments to observe the Dynamical Casimir Effect and related zero-point quantum fluctuation effects in the microwave spectral domain. The project will be carried out in a continuous regular interaction between three teams: theoretical team (INO-CNR BEC Center), fabrication team (FBK with photolithography and, in near future, ebeam lithography), and testing team (IFN-CNR with 20 mK dilution refrigerator). The PhD student will be given the opportunity to participate in all the activity, theoretical and experimental, with the support of the three teams. During the PhD, she/he will be trained on the physics of devices such as SQUIDs, Josephson junctions and microwave resonators that are the building blocks of circuit-QED, one of the most promising approaches to quantum technologies. |
| **Ideal candidate** (skills and competencies)<br>● She/he should have a solid knowledge of electromagnetism and a master-level competence in the general concepts of solid-state physics. She/he should be keen on learning experimental techniques in the following fields: low temperature physics, superconducting microwave technologies, microfabrication technologies and material science. She/he should have a good capacity to work in team with experimentalists combined with a good understanding of theoretical concepts and a manifest ability to work in team with theorists.<br>● She/he should have a proven ability to communicate in scientific english (written and oral) |

## Scholarship L

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| **Topic**: L - Quantum sensing with laser-synthesized NAno-DIAmond NV color centers (NaDia) |
| **Q@TN** |
| **Contacts**.: **Antonio Miotello (DF), Simone Taioli (ECT*), Alberto Quaranta(DII)** |
| **Synthetic description of the activity and expected research outcome**<br>Laser-ablation technique to boost the graphite-to-nanodiamonds transformation rate towards mass scale manufacturing of very sensitive, clean magnetic nanosensors. This task critically relies on a better understanding of nitrogen incorporation under laser ablation conditions of graphite target, as well as in the efficient removal of residual graphite in nanodiamonds. |
| **Ideal candidate** (skills and competencies)**:** Master's degree in Physics, or Chemistry, or Materials Science (or equivalent) and skills in the synthesis of materials and their characterization (compositional, optical, magnetic, etc.). Willingness to interact with computational scientists. |

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## Scholarships M-N

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| **Topic**: Particle, astroparticle, nuclear, theoretical physics, related technologies and applications, including medical Physics (2 positions) |
| **INFN** |
| **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)<br>Chiara La Tessa for applied and medical physics (chiara.latessa@unitn.it) |
| **Synthetic description of the activity and expected research outcome**<br>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:<br>1) experimental particle and astroparticle Physics,<br>2) experimental gravitation both earth and space based,<br>3) gravitational wave astronomy,<br>4) antimatter related experiments,<br>5) R&D on particle and radiation detectors and other solid state quantum micro devices,<br>6) computational Physics and AstroPhysics,<br>7) theory of fundamental interactions,<br>8) theoretical cosmology ,<br>9) medical physics applied to therapy with high energy charged particles |

## Scholarship O

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| **Topic**: O - Nanopillar cavity enhanced emission from diamond |
| **INFN** |
| **Contacts**.: G. Pucker (FBK) |
| **Synthetic description of the activity and expected research outcome**<br>The research focuses on the investigation of Si and Ge based color centers in diamond thin layers grown on silicon. It carries out the realization and study of the properties of these color centers in micro- and nano-cavities. Metal-nanopillars, similar to the ones realized in recent years for semiconductor nanolasers are especially attractive due to their small mode-volume, which favors the coupling of the electronic state to single optical cavity modes, and allows for very dense integration. The activity will include the fabrication and characterisation of all optical components, the measurement of enhanced photoluminescence and decay characteristics from $SiV^-$ and $GeV^-$ centers in metal nanopillar cavities (at RT and cryogenic temperatures) and the reduction of the numbers of colour centres coupled to the optical cavities. The research will give an important contribution to the realization of an integrated scalable platform for realization of single photon emitters and high sensitive magnetometers with optical-read out. |
| **Ideal candidate** (skills and competencies)**:**<br>The ideal candidate has a master degree in experimental or theoretical physics, with a good background in optical spectroscopy, physics and theory of cavities and solid state physics. The candidate should be willing and interested in optical spectroscopy and nanofabrication. |

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| Additional skills: Good skills in teamworking, willing to travel. The selected candidate will have to collaborate on a daily basis with technicians and researchers for both realisation and design of structures and spectroscopic experiments. |

## Scholarship O

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| **Topic**: Statistical physics of social dynamics and urban systems |
| **FBK** |
| **Contacts**: Manlio De Domenico (mdedomenico@fbk.eu); Bruno Lepri (lepri@fbk.eu) |
| **Synthetic description of the activity and expected research outcome**<br>The PhD grant has the goal of developing methodologies, based on statistical physics, for modeling complex systems such as socio-technical, urban, or economic systems. The developed multilayers models will be adopted to investigate and explain the complex characteristics of the observed socio-economic phenomena with the goal of identifying a minimal set of microscopic mechanisms able to reproduce collective phenomena on meso- or macroscopic scales. |
| **Ideal candidate** (skills and competencies)**:**<br>The ideal candidate has a MSc in Physics, or closely related discipline, and past experience on complex systems modeling and network science. Computational skills are required: programming in python or R is needed, the knowledge of existing packages for the analysis of complex networks and publications on the topic of the scholarship will be appreciated. |

## Scholarship P

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| Topic: **Statistical physics and nonlinear dynamics of highly interdependent systems** |
| **FBK** |
| **Contacts**.: Manlio De Domenico (mdedomenico@fbk.eu) |
| **Synthetic description of the activity and expected research outcome**<br>The candidate will perform research on highly correlated and interdependent networks, providing a model for many empirical complex systems, natural and artificial. The underlying framework is based on statistical physics at and out of equilibrium, and nonlinear dynamics. The candidate will develop the theoretical and computational ground for the analysis of collective phenomena emerging in such systems, with application to biological, social and urban networks. |
| **Ideal candidate** (skills and competencies)**:**<br>The ideal candidate has a MSc in Physics, or closely related discipline, and past experience on complex systems modeling and network science. Computational skills are required: programming in python or R is needed, the knowledge of existing packages for the analysis of complex networks and publications on the topic of the scholarship will be appreciated. |