UNIVERSITÀ DI TRENTO

Corso di dottorato in Fisica / Doctoral Programme in Physics
Ciclo 39 / Cycle 39
A.Y. 2023-2024

Borse a tematica vincolata / Reserved scholarships

A - Quantum Simulation of Gauge Theories and Neutrinos with qudits (QSGTN)
B - Fluctuating Levitated Oscillators Approaching The quantum regime (FLOAT)
C - Thermal Neutron Energy Determination with Multilayer Detection
D - Interazioni a molti corpi in sistemi complessi / Multi-body interactions in complex systems

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Scholarship A

Title	**Quantum Simulation of Gauge Theories and Neutrinos with qudits (QSGTN)**
Research group link	https://webapps.unitn.it/du/it/Persona/PER0016084/Pubblicazioni
Contacts	Alessandro Roggero a.roggero@unitn.it
Synthetic description of the activity and expected research outcome	The main objective of this research project is to begin a systematic exploration of the possibilities offered by the use of qudit-based quantum architectures in the simulation of the real-time dynamics of systems of interest for nuclear and high-energy physics. In particular, we plan to pursue this goal using two distinct but complementary approaches. In the first line of research the student will use the collective neutrino oscillation problem as a simple yet challenging model system to explore in detail the possible benefits of using qutrits to encode naturally the 3 flavors of neutrinos and compare the resulting resource requirements for large scale simulations with qubit-based implementations. The second line of research will focus instead on the extension of a recently proposed qubit-based Quantum Error Correction protocol for Z_2 lattice gauge theories to the case of qudit stabilizer codes starting with a direct application to the case of the Z_3 symmetry group.
Ideal candidate (skills and competencies)	Passion for computational approaches to many-body physics and willingness to learn new methods. Some knowledge of nuclear/subnuclear physics and quantum computing will also be helpful.

Scholarship B

Title	**Fluctuating Levitated Oscillators Approaching The quantum regime (FLOAT)**
Research group link	https://bec.science.unitn.it/BEC/2_People/Rastelli_Author
Contacts	Gianluca Rastelli (CNR-INO), gianluca.rastelli@ino.cnr.it Andrea Vinante (CNR-IFN & FBK), anvinante@fbk.eu
Synthetic description of the activity and expected research outcome	In this project we aim at studying theoretically and experimentally the nonlinear dynamics of levitated magnetic microparticles in the quantum regime. The overarching objective of the research on levitated systems is ambitious and fascinating: the experimental testing of the limits of quantum mechanics, the origin of the quantum collapse [1] and the possible interplay with gravity. The research activity of this project is structured in five parts: (i) Nonlinear dynamics and fluctuations (experiments supported by theory); (ii) Feedback cooling (experiments supported by theory); (iii) Theory of damping due to quasi-particles (theory and testing experiments); (iv) Optomechanical system

	with magnetic coupling (theory); (v) Ground state active cooling and engineered quantum dissipation (theory). The experimental team of Andrea Vinante has performed one of the first and cleanest demonstrations of magnetic levitation at microscale, trapping ferromagnetic microspheres by Meissner effect above a type I superconductor in high vacuum, and using a SQUID as magnetic readout [2]. The long term goal of this research is the realization of quantum superposition of massive levitated microparticles. Experimental confirmations of macroscopic quantum superpositions started using electrons, and have today reached the size of organic molecules containing thousands of atoms. Preparing macroscopic quantum superpositions of objects containing billions of atoms will bring macroscopic quantum physics to an entirely new level, which will give the opportunity to attack some of the biggest open questions of modern physics: is quantum mechanics valid all the way up to the macroscopic world, together with its interpretation issues and paradoxes, or may it break down? [1] A. Vinante et al., "Narrowing the parameter space of collapse models with ultracold layered force sensors", Physical Review Letters 125, 100504 (2020). [2] A. Vinante et al., "Ultralow mechanical damping with Meissner-levitated ferromagnetic microparticles", Physical Review Applied 13, 064027 (2020).
Ideal candidate (skills and competencies)	Basic of quantum mechanics, quantum optics, superconductivity and mesoscopic systems.

Scholarship C

Title	**Thermal Neutron Energy Determination with Multilayer Detection**
Research group link	https://sd.fbk.eu/
Contacts	Richard Hall-Wilton rhallwilton@fbk.eu
Synthetic description of the activity and expected research outcome	Neutrons are a very particular particle, with wide and unique applications for both fundamental studies and as a probe. Thermal neutrons are detected by nuclear interactions, in which their energy information is lost. This project, following on from a proof of concept and a statistical investigation of using the cross section variation of the interaction with energy to extract the neutron energy, will use these in combination with AI/machine learning to produce a practical algorithm to determining the neutron energy and the limits of the technique with multilayer detectors. It will also look at the experimental implement and verification of this. The outcome is a determination of the thermal neutron's energy and an algorithm to do so in a realisable detector, which is very much the holy grail of neutron detection.

The ideal candidate (skills and competencies)	Solid background in particle/nuclear physics and interactions. Knowledge of detection techniques. Experience helpful in Data Analysis, Coding (python or C++), and AI/machine learning and experimental techniques.

Scholarship D

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

- ***Reference persons:*** **Alessandro Roggero, Raffaello Potestio**

D - scholarship on reserved topics

Funded by: Progetto CN1 – HPC – SPOKE 7

Codice progetto CN_00000013

CUP E63C22000970007

Title: Interazioni a molti corpi in sistemi complessi / Multi-body interactions in complex systems

Research group link	https://webapps.unitn.it/du/it/Persona/PER0016084/Pubblicazioni
Contacts	Alessandro Roggero a.roggero@unitn.it Raffaello Potestio raffaello.potestio@unitn.it
Synthetic description of the activity and expected research outcome	The study of properties of physical systems composed of many interacting particles is a very challenging problem for which, in general, no efficient and accurate solution method is known. The aim of the project is to design and test novel numerical methods to simulate interacting many-body systems with controllable approximations. This will be achieved also developing novel approaches inspired by applications in classical statistical mechanics and machine learning.
Ideal candidate (skills and competencies)	Passion for computational approaches to statistical mechanics and many-body physics; some expertise in machine learning and/or molecular dynamics and monte carlo algorithms for many-body simulations; willingness to learn new methods.