LNF – FRASCATI NATIONAL LABORATORY

2 Positions: Testing Quantum Foundations Underground within VIP

Title: Is Quantum Mechanics Exact? Testing the Foundations of Quantum Mechanics Underground: The VIP Experiment

Description: Are you fascinated by quantum mechanics and curious about its possible limits? Join the VIP experiment, hosted at the Gran Sasso National Laboratory (LNGS–INFN), one of the world's most advanced underground research facilities, and closely connected to detector development and data-analysis activities at INFN–Laboratori Nazionali di Frascati (INFN-LNF). VIP provides a unique environment to probe the foundations of quantum physics with ultra-low background conditions and cutting-edge technologies.
The VIP experiment is dedicated to testing some of the most fundamental principles of quantum mechanics. Its core mission is the search for possible violations of the Pauli Exclusion Principle (PEP), investigated through the detection of atomic transitions strictly forbidden by standard quantum theory. In parallel, VIP searches for spontaneous radiation predicted by quantum collapse models, theoretical frameworks introduced to address one of the deepest open problems in physics: the quantum measurement problem, exemplified by the Schrödinger's cat paradox.
The VIP collaboration, with main contributions from INFN-LNF, has developed state-of-the-art radiation detectors and Machine-Learning-based data analysis techniques, achieving world-leading constraints on PEP violation probabilities and on predictions of collapse models. As the experiment continues to optimize its apparatus and analyze new data, the goal is to further tighten these limits, or potentially uncover the first experimental evidence of new physics. The impact of these studies extends beyond fundamental science, with important connections to quantum technologies and precision measurement.

Activities: As part of this project, the student will be involved in all major aspects of the VIP experiment, in particular detector development and analysis activities at INFN-LNF. This includes preparing, characterizing, and testing advanced radiation detector systems, as well as analyzing experimental data using modern statistical methods and Machine Learning techniques. The student will also contribute to the theoretical interpretation of the results, within extensions of the Standard Model and beyond-Standard-Model frameworks, including gravity-related collapse models and scenarios inspired by quantum gravity. This is a unique opportunity to participate directly in one of the most ambitious and intellectually exciting experimental programs in quantum foundations.
References: Underground test of gravity-related wave function collapse, A. Donadi et al., Nature Physics volume 17, pages 74–78 (2021) and Experimental test of noncommutative quantum gravity by VIP-2 Lead, K. Piscicchia et al., Phys. Rev. D 107, 026002 – Published 4 January 2023

Tutor: Catalina Curceanu, catalina.curceanu@lnf.infn.it

Activity period: June-July or September-October 2026

Local Secretariat: Alessandra Tamborrino Orsini, alessandra.tamborrinoorsini@lnf.infn.it

Other information:
Accommodation: students may be accommodated, free of charge, in the LNF guesthouse (for information: https://personale.lnf.infn.it/ufficio-concorsi/guesthouse/).
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2 Positions: Kaonic Atoms and Advanced Radiation Detectors within SIDDHARTA-2

Title: Kaonic Atoms and Advanced Radiation Detectors: Probing Fundamental Interactions with Exotic Atoms

Description: Are you ready to explore the fundamental laws of Nature using exotic atoms and state-of-the-art radiation detectors? Join the SIDDHARTA-2 experiment, a world-leading research program at the DAΦNE collider (INFN–LNF, Frascati), the only facility worldwide capable of performing precision spectroscopy of kaonic atoms. In these unique systems, one electron is replaced by a kaon, a particle containing a strange quark, providing a powerful laboratory to study the strong interaction at low energies. Using the very low-energy kaon beam, SIDDHARTA-2 measured X-ray transitions in various kaonic atoms, enabling unprecedented investigations of the strong interaction in the strangeness sector. The experiment employs cutting-edge Silicon Drift Detectors (SDDs) for high-precision X-ray spectroscopy, complemented by advanced detector technologies such as CdZnTe (CZT) and High-Purity Germanium (HPGe) detectors.
SIDDHARTA-2 is the first experiment to measure kaonic deuterium as well as in heavier kaonic atoms, including neon, fluorine, and lead. These measurements provide unique constraints on strong and bound-state quantum electrodynamics, with far-reaching implications, from particle and nuclear physics to the physics of neutron stars and even search of physics beyond the Standard Model.
With data analysis and theoretical interpretation intensifying in 2026, including the application of Machine Learning techniques, together with the development and testing of novel radiation detectors for future kaonic-atom experiments in Italy and Japan and for societal applications (in medicine), this is an ideal moment for a motivated student to enter this exciting field and make a meaningful contribution.

Activities: As part of the team, the student will play a key role in analyzing data to identify kaonic atoms signals, and interpret the data in the framework of theories within and beyond the Standard Model. In particular, his/her contributions will deepen our understanding of the strong interaction in the strangeness sector and open windows into its implications for the physics of neutron stars.
The student will gain hands-on experience with advanced data analysis tools, including Machine Learning, and advanced Monte Carlo simulations. As if that weren't enough, he/she will help test pioneering radiation detector systems designed for future kaonic atom measurements and for societal applications (such as imaging in medicine).
Reference: The modern era of light kaonic atom experiments, C. Curceanu et al., Rev. Mod. Phys. 91, 025006 (2019); Kaonic atoms at the DAϕNE collider: a strangeness adventure, C. Curceanu et al., Front.in Phys. 11 (2023) 1240250

Tutor: Catalina Curceanu, catalina.curceanu@lnf.infn.it

Activity period: June-July or September-October 2026

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FLASH/GravNet

Title: Development of Advanced Signal Processing and Machine Learning Techniques for High-Frequency Gravitational Wave Detection with the FLASH Experiment

Description: The Laboratori Nazionali di Frascati (LNF) plan to host a new detector for the search for High-Frequency Gravitational Waves (HFGWs), named FLASH. The detector exploits the haloscope technology originally developed for axion searches and is based on a large radio-frequency cavity, cooled to cryogenic temperatures and immersed in a strong magnetic field of 1.1 T.
Although the expected sensitivity may not be sufficient for guaranteed detection, the main potential sources include the stochastic gravitational-wave background and primordial black holes, which would manifest in the detector as spurious signals at the cavity resonance frequency.
The signal data acquisition and processing pipeline is currently under development and testing at LNF using a smaller haloscope experiment, QUAX. In 2026, additional tests are foreseen using a room-temperature cavity, which will allow the production of real experimental data to validate and optimize both the pre-analysis and post-analysis data processing chains.
The project aims to exploit online signal filtering techniques and machine learning methods to enhance the sensitivity to possible candidate signals. The selected candidate will be actively involved in the design, implementation, and testing of the data filtering and analysis chain, contributing to the development of advanced techniques for signal extraction in high-noise environments.

Activities: Although the activity will be mainly focused on software development and the implementation of online filters, it cannot be carried out without a solid understanding of the detector. Therefore, the work will require direct involvement in laboratory activities, including data acquisition and subsequent data analysis.

Tutor: Giovanni Mazzitelli, giovanni.mazzitelli@lnf.infn.it / Giorgio Dho, giorgio.dho@lnf.infn.it

Activity period: preferably September-October 2026

Local Secretariat: Maddalena Legramante, maddalena.legramante@lnf.infn.it

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Belle II

Title: Optimization of the Belle II detector glass Resistive Plate Chambers in avalanche operation mode.

Description: The Belle II experiment runs at the e^+e^- SuperKEKB collider in Japan. SuperKEKB, currently holding the world record of instantaneous luminosity, aims to reach in 2026 the unprecedented luminosity $10^{35}cm^{-2}s^{-1}$, which will allow Belle II to collect a huge-statistics dataset of B, D and τ decays (among others).
An ambitious upgrade program of SuperKEKB and Belle II to further increase the luminosity is foreseen in the coming years. One of the possible upgrade options for the K_L and muon detector (KLM) is to operate its glass RPC (Resistive Plate Chambers) in avalanche rather than in streamer mode, as done in the current detector to reduce the dead time and the sensitivity to high neutron fluxes. The Frascati group, which together with the Roma3 INFN group has built and commissioned the RPC readout electronics, is now engaged in an R&D program to determine the optimal working point for the glass RPCs operating in avalanche regime.

Activities: The student will work in the test experimental apparatus set up in our group laboratory in Frascati, with the aim of studying different gas mixtures, High Voltage settings, and Front-End Electronics characteristics for the glass RPCs operated in avalanche mode. He/she will operate the system, collect and analyse data from cosmic rays and possibly from radioactive sources.
Finally, simulation of the detector properties with Monte Carlo (MC) programs and comparison of simulation with real data will also be a qualifying part of the program.

Basic laboratory skills are requested, as well as good knowledge of the C++ and python programming languages and ROOT analysis package, to analyse the data and use the MC simulation programs.

Tutor: Giuseppe Finocchiaro, giuseppe.finocchiaro@lnf.infn.it

Activity period: September-October 2026

Local Secretariat: Maria Cristina D'Amato (maria.cristina.damato@lnf.infn.it)

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Mu2e

Title: Commissioning and performance of the Mu2e detectors

Description: Starting from spring 2026, the Mu2e detector will be fully installed in the so-called extracted position (i.e. outside of the Detector Solenoids) over its installation rails. The detector consists of a fast and precise CsI+SiPM calorimeter, a 3-meter-long tracker with 20000 straws, and a portion (25 m^2) of the Cosmic Ray Veto system made of long scintillation counters readout by SiPMs. Throughout the summer and until the end of the year, a combined data taking with all three detectors will take place. This will support the preparation for beam data taking, foreseen in 2027, in several ways: calibration of individual detectors will be performed using cosmic rays events and specialized systems (Calorimeter Laser, Calorimeter source, Tracker Pulse, CRV gain runs), enabling final adjustments and fine tuning of the detectors; performance studies (resolutions, linearity, alignment) of the detectors will be conducted, with particular focus on cross-calibration among systems, such as tracker to calorimeter (or CRV) alignment, using track extrapolation. These studies will provide time and position calibration that will inform the future PID algorithms and other specialized studies, like the calibration of the calorimeter response along the crystal axis.

Activities: The activity will be focused on detector calibration and reconstruction, data analysis using ROOT and/or Python, detector monitoring and data-quality checks. The candidate will acquire technical competence on electromagnetic calorimetry and its calibration techniques, and expertise in professional software coding in C++, Python and ROOT.

Tutor: Simona Giovannella, simona.giovannella@lnf.infn.it

Activity period: September-October 2026

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LHCb Semileptonics

Title: Search for New Physics in semileptonic decays of the B_s meson

Description: LHCb is one of the main experiments collecting data at the Large Hadron Collider accelerator. One of its primary goals is to accurately study the properties of b-hadrons copiously produced in the proton-proton collisions at LHC. The semileptonic decays of the B mesons have been studied with great precision at B-Factories. These decays are processes like B—>Dmu nu_mu, where the b-quark inside the B meson transforms in a c-quark (giving the D meson in the final state) with the emission of a virtual W-boson, which subsequently couples to the muon and the anti-neutrino in the final state. At present, there are various puzzles and anomalies observed in studying semileptonic decays of these mesons. Some of these anomalies could be hints of Physics Beyond the Standard Model. It is paramount to study semileptonic decays in other b-hadron species to check these anomalies in alternative environments and to access other observables very sensitive to new physics contributions. The LHCb group in Frascati is deeply involved in the study of semileptonic decays of B_s mesons. The B_s mesons (contain an anti-b quark and a s-quark instead of a u- or d-quark, as in ordinary B meson) are interesting because they offer various advantages compared with the B mesons on both the experimental and theoretical side.
Activities: The student will be deeply involved in key aspects of the data analysis using data collected in 2024 and 2025. Depending on her/his interests and when she/he will be with us, the work can focus on:

- The optimization of signal selection to reduce the most dangerous backgrounds using Neural Networks or other Machine Learning approaches.
- The search of CP violation in these decays from an angular analysis of these decays.
- The measurements of the relative branching fractions of semileptonic B_s decays into various excited D-mesons in the final state.

Some knowledge in computing (e.g. Python, C++) is desirable but not mandatory.

Tutor:
Marcello Rotondo (marcello.rotondo@lnf.infn.it)
Elisa Minucci (elisa.minucci@lnf.infn.it)
Patrizia de Simone (patrizia.desimone@lnf.infn.it)

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PROJECT AVAILABLE ONLY FOR THE LNF SUMMER STUDENT PROGRAM

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NA62

Title: 4D tracking in the NA62 experiment

Description:
The NA62 experiment is designed with the final purpose of studying the rare decay of a positive kaon to a pion and a neutrino-antineutrino pair, to improve our understanding of the Standard Model and probe potential new physics. The momentum and direction of the kaon are measured thanks to four stations of a silicon pixel detector called Gigatracker. The NA62 Gigatracker is the first 4-D tracking pixel detector in operation in an experiment, having a single hit timing resolution of ~150 ps.
The project is focused on the improvement of the reconstruction of the Gigatracker using state-of-the-art deep learning techniques and the understanding of the performance of the reconstruction using real data.

Activities:
The activity of this project focuses on learning the main characteristics of the NA62 Gigatracker silicon pixel detector, understanding the physical quantities involved in its calibration and reconstruction, and developing machine learning–based reconstruction algorithms..
Although not mandatory, general knowledge of particle physics, detectors, and c++/python is desiderable.

Tutor: Gemma Tinti (gmtinti@lnf.infn.it)
Leonardo Plini (leonardo.plini@lnf.infn.it)

Activity period: Preferred September- October 2026

Local Secretariat: Maria Cristina D'Amato (maria.cristina.damato@lnf.infn.it)

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