PHD IN TECHNOLOGIES FOR FUNDAMENTAL RESEARCH IN PHYSICS AND ASTROPHYSICS

CYCLE 41 – A.Y. 2025/26

Description of the proposed PhD projects

SCHOLARSHIP N.1

TOPIC: ***"Research and development of a methodological framework for the prospective assessment of the sustainability of research activities in nuclear physics experiments"***

CURRICULUM: Computing

CONTACTS: Alessandro Manzardo

HOSTING UNIVERSITY/RESEARCH CENTRE: Università degli Studi di Padova

The research project focuses on the development and characterization of an innovative methodological framework for the prospective sustainability assessment of research activities in nuclear physics experiments. The research will delve into the environmental, economic, and social aspects of sustainability in this field, with particular attention to experimental practices and research infrastructures. Areas of application include particle accelerators, research reactors, high-energy physics experiments, and radioactive waste management, also considering the potential contribution to sustainability of the research outcomes in these areas. The project encompasses the identification of key sustainability indicators, the elaboration of specific metrics, and the implementation of case studies to validate the methodological framework. The research aims to improve the understanding and optimization of sustainability in nuclear physics research activities, promoting more efficient and responsible practices. It is anticipated that the results of this project will lead to significant advancements in sustainability assessment in the scientific domain, driving innovation in research methodologies and contributing to a more sustainable future for nuclear physics and related sectors.

SCHOLARSHIP N.2

TOPIC: ***"Design and Development of Adaptive Optics Systems and Components"***

CURRICULUM: Detectors, Lasers and Optics

CONTACTS: Davide Greggio

HOSTING UNIVERSITY/RESEARCH CENTRE: Università degli Studi di Padova

This PhD activity will take place within the national ADONI (Adaptive Optics National Laboratory) framework of INAF and is part of the EKARUS project, which aims to relocate the PAPYRUS adaptive optics test bench from the T152 telescope at OHP to the Copernico telescope in Asiago. Originally developed at LAM, PAPYRUS has served as a key training and experimental platform for early-career researchers, enabling on-sky testing of advanced AO technologies. Its relocation to Copernico, with direct and structured involvement of INAF, will strengthen the national AO network and foster collaboration among European PhD students.

The doctoral research will focus on the development and integration of advanced AO system components—optical, mechanical, electronic, or control-related—addressing some of the urgent technological challenges for the next generation of Extremely Large Telescope (ELT) instruments. Potential topics include: handling of fragmented pupils, implementation of high-contrast dual-stage AO systems, development of high-sensitivity wavefront sensors, and efficient fiber coupling of AO-corrected beams. The activity will be carried out at one of the INAF sites associated with ADONI, with strong ties to the international AO community.

SCHOLARSHIP N.3

Funded by INAF (National Institute for Astrophysics) – see file "INAF RESEARCH TOPICS – 2025/26" to read about the proposed projects

SCHOLARSHIP N.4

Funded by INAF (National Institute for Astrophysics) – see file "INAF RESEARCH TOPICS – 2025/26" to read about the proposed projects

SCHOLARSHIP N.5

Funded by INAF (National Institute for Astrophysics) – see file "INAF RESEARCH TOPICS – 2025/26" to read about the proposed projects

SCHOLARSHIP N.6

TOPIC: ***"Development of HTS Dipole Magnets for the FCC-hh Collider"***

CURRICULUM: Electrotechnics and electrotechnics for accelerators

CONTACTS: Lucio Rossi

HOSTING UNIVERSITY/RESEARCH CENTRE: INFN – Milano Lasa

The FCC-hh collider is the hadronic component of the "Future Circular Collider" (FCC) project, the current reference design for the future of CERN and high-energy physics. This next-generation accelerator will be hosted in a 90 km tunnel and aims to reach a center-of-mass energy of 85 TeV. Achieving this requires dipole magnets capable of generating a 14 T magnetic field—nearly twice the field strength of the current LHC magnets (~8 T).

This doctoral research project, carried out within a close INFN–CERN collaboration, aims to investigate the feasibility of achieving such magnetic fields using High-Temperature

Superconductors (HTS), and specifically REBCO tapes (rare-earth-based superconductors, such as yttrium or gadolinium compounds). Compared to traditional Nb_3Sn superconductors, HTS offers the advantage of reaching higher magnetic fields (16–20 T may be achievable) and operating at higher temperatures (~20 K), thus avoiding the need for liquid helium and greatly reducing cryogenic costs.

The core of the PhD project will be the design, construction, and experimental testing of a 10 T HTS dipole demonstrator, operated under realistic conditions. Based on the results obtained, the candidate will contribute to the conceptual design of a full-scale HTS dipole for FCC-hh, targeting 14 T or beyond.

The research will address key challenges in accelerator magnet technology, including:

- Optimization of coil geometry and minimization of HTS tape usage (due to its high cost);
- Design of the magnetic field profile to meet beam optics constraints;
- Development of quench protection strategies and early diagnostics for thermal runaway events.

A significant part of the activity will involve the integration and testing of the prototype magnet at cryogenic temperatures (4–80 K), supported by multiphysics modeling and analysis.

The project will conclude with the conceptual design of a next-generation HTS dipole suitable for the FCC-hh collider, contributing to Europe's long-term strategy for future high-energy accelerators.

SCHOLARSHIP N.7

TOPIC: ***"Open BIM and Digital Twin: an integrated digital ecosystem to define a new frontier in Asset Management at the Gran Sasso National Laboratories"***

CURRICULUM: Computing

CONTACTS: Ezio Previtali

HOSTING UNIVERSITY/RESEARCH CENTRE: INFN – Laboratori Nazionali del Gran Sasso

A research project that aims to develop management systems that integrate asset management methodologies and open BIM standards with GIS approaches, to support operational decisions at the Gran Sasso National Laboratories.

SCHOLARSHIP N.8

TOPIC: ***"Applications of integrated photonics for a new generation of astrophysical space measurements"***

CURRICULUM: Detectors, Lasers and Optics

CONTACTS: Francesco Bertazzi

HOSTING UNIVERSITY/RESEARCH CENTRE: Politecnico di Torino

The proposed research concerns the exciting domain of integrated photonics and its application in the development of novel astrophysical space measurements. Integrated photonics, and in particular silicon photonics, offers immense potential for revolutionizing space observations and measurements. By integrating various photonic components (waveguides, modulators, detectors, filters, etc.) onto a single chip, the size, weight, and power consumption of the observation instruments can be significantly reduced, making them more efficient and cost-effective for space missions. The project involves theoretical investigations, numerical simulations, and experimental characterizations to design and optimize integrated photonic devices tailored for applications such as high-resolution spectroscopy, wide-field imaging, polarimetry, frequency metrology.

SCHOLARSHIP N.9

TOPIC: ***"Development of solid-state detectors for future high-energy physics experiments"***

CURRICULUM: Detectors, Lasers and Optics

CONTACTS: Raffaella Radogna

HOSTING UNIVERSITY/RESEARCH CENTRE: Università degli Studi di Bari Aldo Moro

The proposed PhD project focuses on study, simulate, and characterize position sensitive solid-state detectors for current and future High Energy Physics experiments. The project will also investigate the applicability of the developed know-how for medical imaging applications based on photon-counting computed tomography.

SCHOLARSHIP N.10

TOPIC: ***"Development and Characterization of Molybdenum Alloys Produced via Laser Powder Bed Fusion for Nuclear Applications"***

CURRICULUM: Mechanics

CONTACTS: Mattia Manzolaro, Marco Actis Grande, Pietro Rebesan

FUNDING INSTITUTION: Newcleo S.p.A.

This PhD project focuses on the development, processing, and characterization of advanced molybdenum-based alloysproduced through Laser Powder Bed Fusion (LPBF), with applications in next-generation nuclear systems. Molybdenum and its alloys are of high interest for their exceptional high-temperature strength, thermal conductivity, and radiation resistance—key properties for structural components operating in extreme nuclear environments.

The research will explore the complete development chain of LPBF-produced molybdenum alloys, covering alloy design, powder characterization, process parameter optimization, and multi-scale material testing. In collaboration with Newcleo – Futurable Energy, the PhD candidate will be involved in the compositional tuning of the alloy system to enhance processability and performance, supported by computational alloy design strategies.

The experimental activity will be initially conducted at INFN-Padova, where the candidate will define and optimize LPBF process parameters and evaluate the physical, thermal (both at room and high temperature), and mechanical properties of the produced samples. A key aspect of the project will include pre- and post-exposure characterization of components tested in contact with liquid lead, in collaboration with Newcleo's R&D facilities.

The project also could foresees irradiation campaigns at INFN's Laboratori Nazionali di Legnaro (LNL) to assess the post-irradiation behavior of selected specimens, providing insights into their long-term performance under neutron beam. Depending on project evolution, a functional smallscale

mockup component may be produced and assessed for integration in lead-cooled reactor systems.

The outcomes will contribute to advancing the applicability of LPBF for refractory metals in nuclear environments, bridging advanced manufacturing, material science, and nuclear engineering in a high-impact multidisciplinary framework.

SCHOLARSHIP N. 11

TOPIC: ***"Development of next-generation thin film SRF cavities in Nb3Sn on Cu"***

CURRICULUM: Electrotechnics and electrotechnics for accelerators

CONTACTS: Cristian Pira

FUNDING INSTITUTION: Zanon Research and Innovation S.r.l.

Superconducting Radio-Frequency (SRF) accelerating cavities are the heart of modern particle accelerators. They are extremely effective tools for accelerating charged particles, capable of producing accelerations of tens of MV/m while dissipating only a few watts of power at the walls, > 6 orders of magnitude less than normal conducting cavities.

The aim of this PhD research project is the production of an elliptical cavity prototype in Nb3Sn on Cu to transform conventional SRF technology based on off-shelf bulk niobium operating at 2 K into a technology operating at 4.2 K using a highly functionalized material where all functions are addressed by specific layers.

A high-performance accelerating cavity results, indeed, from the fulfillment of several requirements, and the layered structure allows its properties to be individually optimized: Superconductor in stoichiometric composition, low Surface Resistance (high morphological quality of the SC coating), high thermal conductivity of the substrate, low magnetic flux trapping (reduction of pinning centers, study of cooling protocols), high mechanical strength of the coating (resistance to repeated thermal cycling, squeezing during tuning).

Currently, high-performance superconductive coatings of Nb3Sn have been demonstrated on small and medium-sized planar samples. The goal of this project is to transfer and adapt the technology to elliptical cavities in close collaboration with Zanon, one of the world's leading SRF cavity manufacturers, and within an international collaboration involving CEA, STFC, HZB, and CERN.

The research work will focus on optimizing the set-up and sputtering parameters of Nb3Sn coatings within elliptical copper cavities, guided by the results of morphological and superconducting characterizations and RF performance measurements of the resonant cavities. The project will take place partly at INFN LNL, partly at Zanon Research and for 6 months at one of the project's international partners.

SCHOLARSHIP N. 12

TOPIC: ***"Space Situational Awareness and Characterisation of Resident Space Objects Using Optical Techniques"***

CURRICULUM: Computing

CONTACTS: Carmelo Arcidiacono

FUNDING INSTITUTION: Officina Stellare S.p.A

In the context of increasing congestion in the near-Earth orbital environment, Space Situational Awareness (SSA) has become a strategic priority to ensure the safety and sustainability of space operations. This doctoral research focuses on the advanced characterisation and dynamic modelling of Resident Space Objects (RSOs) including satellites, debris, and potentially hostile objects through the integration of optical tracking systems. The study also considers the application of artificial intelligence-based techniques within the scope of the research.

A multi-layered approach to RSO characterisation is proposed, addressing fundamental physical and dynamical parameters such as size, shape, attitude, rotational velocity, orbital type, material composition, and temporal trajectory. Leveraging Optical Ground Stations (OGSs) and SSA-dedicated satellites, the project develops and validates advanced detection, recognition, and identification techniques based on specialised algorithms capable of interpreting spectral and temporal signatures to infer the status and behaviour of space objects.

A key contribution of this research is the implementation of a dynamic RSO model that accounts for both deterministic influences (e.g., orbital manoeuvres) and stochastic effects (e.g., atmospheric impact on radiation propagation), enabling more accurate orbit prediction and tracking. This is supported by detailed modelling of the radiometric acquisition chain of optical stations, which is essential to optimise the signal-to-noise ratio and resolution in the observation of low magnitude objects.

Furthermore, the research aims to develop algorithms for the detection of anomalous on-orbit behaviour. This includes behaviour-based analysis, detection of proximity to critical assets, unannounced component separation, and anomalous electromagnetic emissions.

Finally, the thesis contributes to the development of an SSA Scenario Simulator capable of forecasting data and generating complex synthetic datasets composed of multiple observational nodes and orbiting assets. The scenario simulator integrates physical models with real-time data assimilation, supporting decision-making processes in both operational and emergency contexts.

This work aims to advance the state of the art in space traffic management and orbital threat detection, providing theoretical foundations and operational tools for next-generation SSA systems.

POSITIONS WITHOUT SCHOLARSHIP

PROPOSED TOPIC: *“Development of test systems for highly segmented silicon detectors for nuclear physics, astrophysics and particle physics”*

CURRICULUM: Electronics

CONTACTS: Daniele Mengoni

The work involves the development of advanced testing systems for highly segmented silicon detectors, which are essential for research in physics, nuclear astrophysics and particle physics. The main objective is to optimise the performance and reliability of these detectors, which are crucial for the detection, discrimination and tracking of interacting particles. The research explores innovative methodologies for the characterisation and calibration of detectors, with a particular focus on spatial and temporal resolution and the ability to discriminate interacting particles. Techniques for improving the signal-to-noise ratio and detection efficiency under different experimental conditions will also be analysed.

PROPOSED TOPIC: *“Advanced Systems for Cryogenic and Superconducting Applications in Fundamental Physics”*

CURRICULUM: Mechanics

CONTACTS: Giuliana Fiorillo

HOSTING INSTITUTION: INFN – Napoli

This PhD project focuses on the development of advanced skills in engineering applied to fundamental physics, with particular emphasis on cryogenic systems, superconducting technologies, and vacuum infrastructures for complex experimental setups. The research activities will include design, automation, cryogenic fluid management, and the integration of measurement systems, with applications ranging from the characterization of innovative high-current superconducting cables to the development of detectors for rare event searches. The project will involve collaboration with industrial and academic partners and will contribute to the technological advancement of superconducting devices and detectors for both fundamental research and applied science.