



ERASMUS MUNDUS JOINT MASTER IN NUCLEAR PHYSICS

Academic Year 2026/2027

MASTER THESIS PROPOSAL

TITLE: Development and characterization of a cryogenic molecular-cluster target

SUPERVISOR(S): Lamia L, D. Lattuada

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UNIVERSITY/RESEARCH CENTER: UNICT, LNS-INFN

ABSTRACT

(just few lines 5-10 explaining briefly the idea of the proposed work and the place where it will be developed).

The thesis will focus on the development and characterization of a cryogenic gas-jet target producing molecular clusters for high-power laser and ion beam experiments. The experimental work will include the optimization of the cryogenic source and the measurement of the gas and cluster properties using optical interferometry and Rayleigh scattering techniques. The student will study the spatial distribution, density and size of the clusters and their dependence on the target operating conditions. The resulting characterization will provide key input parameters for the interpretation and modelling of laser-cluster interaction experiments in nuclear astrophysics. The project will be carried out within the Nuclear Astrophysics experiment (AsFiN) of the National Institute of Nuclear Physics (INFN) in Catania at the Southern National Laboratories (LNS).



ERASMUS MUNDUS JOINT MASTER IN NUCLEAR PHYSICS

Academic Year 2026/2027

MASTER THESIS PROPOSAL

TITLE: PIC and Geant4 simulations for high-power laser-driven nuclear astrophysics

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UNIVERSITY/RESEARCH CENTER: UNICT, LNS-INFN

ABSTRACT

(just few lines 5-10 explaining briefly the idea of the proposed work and the place where it will be developed).

The thesis will focus on the numerical modelling of nuclear reactions induced by high-power laser interaction with clustered cryogenic gas targets. Particle-in-cell (PIC) simulations will be used to study laser energy deposition, plasma formation and ion acceleration, while Geant4 simulations will model particle transport, detector response and relevant nuclear-reaction signatures. The work will aim at connecting plasma dynamics with experimentally measurable observables, with particular emphasis on reactions of interest for nuclear astrophysics. The student will contribute to the development, validation and analysis of simulation workflows and to their comparison with experimental data. The project will be carried out within the Nuclear Astrophysics experiment (AsFiN) of the National Institute of Nuclear Physics (INFN) in Catania at the Southern National Laboratories (LNS).



ERASMUS MUNDUS JOINT MASTER IN NUCLEAR PHYSICS

Academic Year 2026/2027

MASTER THESIS PROPOSAL

TITLE: Characterization of a Timepix4-based Thomson spectrometer for laser-driven nuclear astrophysics

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UNIVERSITY/RESEARCH CENTER: UNICT, LNS-INFN

ABSTRACT

(just few lines 5-10 explaining briefly the idea of the proposed work and the place where it will be developed).

The thesis will concern the characterization and commissioning of a Thomson parabola spectrometer equipped with a Timepix4 pixel detector for the measurement of ions produced in high-power laser-matter interactions. The work will include detector calibration, particle identification, energy reconstruction and the study of the spectrometer response using both experimental data and numerical simulations. Particular attention will be devoted to the detection of proton and deuteron spectra relevant to laser-driven nuclear astrophysics experiments. The student will contribute to the development of the acquisition and analysis chain and to the validation of the detector performance. The project will be carried out within the Nuclear Astrophysics experiment (AsFiN) of the National Institute of Nuclear Physics (INFN) in Catania at the Southern National Laboratories (LNS).



ERASMUS MUNDUS JOINT MASTER IN NUCLEAR PHYSICS

Academic Year 2026/2027

MASTER THESIS PROPOSAL

TITLE: Investigating the $^{22}\text{Ne}(\alpha, n)^{25}\text{Mg}$ Reaction: A Key to Understanding Stellar Nucleosynthesis

SUPERVISOR(S): L.Lamia (UniCT&LNS), R. Spartà (UKE&LNS)

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UNIVERSITY/RESEARCH CENTER: Laboratori Nazionali del Sud (LNS) – INFN, Catania

ABSTRACT

(just few lines 5-10 explaining briefly the idea of the proposed work and the place where it will be developed).

The $^{22}\text{Ne}(\alpha, n)^{25}\text{Mg}$ reaction plays a key role in neutron production in massive stars. This thesis will focus on the calibration of position- and energy-sensitive silicon detectors used at INFN Laboratori Nazionali del Sud (LNS) in Catania to investigate the inverse $^{25}\text{Mg}(n, \alpha)^{22}\text{Ne}$ reaction through the Trojan Horse Method. The student will then analyse the experimental data to extract the astrophysical factors of both $^{25}\text{Mg}(n, \alpha)^{22}\text{Ne}$ and $^{22}\text{Ne}(\alpha, n)^{25}\text{Mg}$. The work will provide practical training in experimental nuclear astrophysics, including ROOT-based data analysis and kinematic simulations with dedicated software such as LISE++. By combining computational modelling and quantitative data analysis, the project offers a good opportunity to students interested in gaining experience in the study of nuclear reactions of significant interest to astrophysics.



ERASMUS MUNDUS JOINT MASTER IN NUCLEAR PHYSICS

Academic Year 2026/2027

MASTER THESIS PROPOSAL

TITLE:

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UNIVERSITY/RESEARCH CENTER:

ABSTRACT

(just few lines 5-10 explaining briefly the idea of the proposed work and the place where it will be developed).

The proposed thesis will consist in performing and analysing Monte Carlo simulations that are necessary to reconstruct variables that are required to reconstruct the excitation function for the reaction $^{10}\text{Be} + ^4\text{He} \rightarrow ^8\text{Be} + ^6\text{He}$. The Monte Carlo code full simulates the experiments and allows to reconstruct, as a function of the center of mass energy, angles (lab and c.m.), solidangles, target thickness and reaction Jacobian. The reaction was measured at INFN-LNS using a gaseous target of “infinite” thickness (i.e. the beam is stopped inside the target) and aims at investigating the sigma-bond linear chain cluster configuration in the neutron-rich ^{14}C nucleus. The work will be carried-out at INFN-LNS



ERASMUS MUNDUS JOINT MASTER IN NUCLEAR PHYSICS

Academic Year 2026/2027

MASTER THESIS PROPOSAL

TITLE: Indirect measurement of the cross section of the thermonuclear reaction $^{11}\text{C}(\alpha, p)^{14}\text{N}$ in the context of supernova nucleosynthesis.

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UNIVERSITY/RESEARCH CENTER: DFA-UniCT & INFN-LNS

ABSTRACT

(just few lines 5-10 explaining briefly the idea of the proposed work and the place where it will be developed).

Neutrino-induced nucleosynthesis in supernovae contributes to the production of several nuclides, including ^7Li , ^{11}B , ^{19}F , ^{92}Nb , ^{98}Tc , ^{138}La , and ^{180}Ta . Recently, the impact of nucleosynthesis involving nuclei in the $A=11$ mass region has been extensively studied, with particular reference to the role of the $^{11}\text{C}(\alpha, p)^{14}\text{N}$ nuclear reaction, for which currently no experimental data are available in the 0.25-1 MeV energy range of astrophysical interest.

The student is required to work on the data analysis of the measurement already carried out for the reaction $^{11}\text{C}(\alpha, p)^{14}\text{N}$ by applying the principle of detailed balance to the $^{14}\text{N}(p, \alpha)^{11}\text{C}$ cross section obtained through the already assessed indirect Trojan Horse Method (THM). In particular, he/she will have to deal with the calibration in angle and energy of the detectors, the selection of the reaction channel and the quasi-free mechanism and the study of the resonances present in the region of astrophysical interest due to excited states of ^{15}O in the energy range below 4 MeV.



ERASMUS MUNDUS JOINT MASTER IN NUCLEAR PHYSICS

Academic Year 2026/2027

MASTER THESIS PROPOSAL

TITLE: Cross section measurement of the $^{24}\text{Mg}(\gamma, \alpha)^{20}\text{Ne}$ reaction at astrophysical energies

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UNIVERSITY/RESEARCH CENTER: Unict & LNS

ABSTRACT

(just few lines 5-10 explaining briefly the idea of the proposed work and the place where it will be developed).

Silicon burning sets a star's final chemical composition before core collapse, but proceeds via photodisintegration of less-bound nuclei (fusion being suppressed by the Coulomb barrier) followed by radiative capture of light particles (p, n, α).

Sensitivity studies show that $^{24}\text{Mg}(\gamma, \alpha)^{20}\text{Ne}$ governs the downward flow from ^{24}Mg to ^4He , thereby controlling the effective ^{28}Si destruction rate. Currently this rate is only inferred indirectly from the inverse reaction $^{20}\text{Ne}(\alpha, \gamma)^{24}\text{Mg}$, carrying systematic uncertainties up to a factor of 2 in the relevant temperature range ($T = 2.8\text{--}4.1$ GK).

To obtain a direct, more accurate measurement, an experiment was performed at HIGS (Duke University) using a collimated photon beam (10.5–13 MeV) and the SIDAR array. The research activity involves analyzing the data (ROOT format), starting from detector calibration, with GEANT4 simulations to cross-check the results.



ERASMUS MUNDUS JOINT MASTER IN NUCLEAR PHYSICS

Academic Year 2026/2027

MASTER THESIS PROPOSAL

TITLE: Activation Technique and Gamma-Ray Spectrometry for Laser-Induced $p-^{11}\text{B}$ Fusion Diagnostics

SUPERVISOR(S): G.G. Rapisarda, G.L. Guardo, G.A.P. Cirrone

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UNIVERSITY/RESEARCH CENTER: Università di Catania / LNS-INFN

ABSTRACT

(just few lines 5-10 explaining briefly the idea of the proposed work and the place where it will be developed).

The thesis will focus on the gamma-spectrometric analysis of samples activated during an experimental campaign at the PALS (Prague Asterix Laser System) facility, as part of a study on the laser-induced proton-boron ($p-^{11}\text{B}$) fusion reaction.

The activation technique serves as a powerful experimental approach for obtaining quantitative information on the particle flux generated during laser-matter interaction.

The thesis work will involve detector calibration, analysis of the acquired spectra, identification of the radioactive elements produced, and assessment of the number of induced reactions.

The results obtained will be compared with data from other diagnostic systems.

The project will be carried out within the framework of the Nuclear Astrophysics (AsFiN) experiment of the National Institute for Nuclear Physics (INFN) at the Southern National Laboratories (LNS) in Catania.



ERASMUS MUNDUS JOINT MASTER IN NUCLEAR PHYSICS

Academic Year 2026/2027

MASTER THESIS PROPOSAL

TITLE: Experimental Investigation of the $^3\text{H}(\text{d},\text{n})^4\text{He}$ Reaction: Implications for Nuclear Astrophysics, Nuclear Structure and Fusion Research

SUPERVISOR(S): R.G. Pizzone (UniCT), Roberta Sparta (UKE&LNS).

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UNIVERSITY/RESEARCH CENTER: Laboratori Nazionali del Sud (LNS) – INFN, Catania

ABSTRACT

(just few lines 5-10 explaining briefly the idea of the proposed work and the place where it will be developed).

The $^3\text{H}(\text{d},\text{n})^4\text{He}$ reaction is of major interest in nuclear astrophysics, owing to its role in Big Bang nucleosynthesis, in nuclear structure for the opportunity it provides to investigate cluster configurations in light nuclei. and in applied nuclear physics, for its importance as the reference reaction for fusion-energy applications. This thesis will study the reaction indirectly using the Trojan Horse Method. The project may lead to multiple results, including the extraction of the $^3\text{H}(\text{d},\text{n})^4\text{He}$ astrophysical S-factor and reaction rate, as well as new information on the $^3\text{He}-\text{t}$ cluster structure of ^6Li , its momentum distribution and related spectroscopic properties. The student will participate in the complete experimental workflow, including kinematic simulations, detector setup and calibration, data acquisition in a foreign laboratory, particle identification and data analysis. For this reason, the thesis offers comprehensive training for students interested in experimental nuclear astrophysics, nuclear structure and the applied aspects of nuclear-reaction studies.



ERASMUS MUNDUS JOINT MASTER IN NUCLEAR PHYSICS

Academic Year 2026/2027

MASTER THESIS PROPOSAL

TITLE: Study of double charge exchange reactions and impact on neutrinoless double beta decay physics

SUPERVISOR(S): Francesco Cappuzzello, Manuela Cavallaro

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UNIVERSITY/RESEARCH CENTER: University of Catania

ABSTRACT

(just few lines 5-10 explaining briefly the idea of the proposed work and the place where it will be developed).

The student will analyze the data collected during the experimental campaigns of the NUMEN (NUclear Matrix Elements for Neutrinoless double beta decay) project, in synergy with the activities of the research group. A priority will be to study in detail quasi-elastic nuclear reaction channels, with particular emphasis on nucleon-transfer, charge-exchange, and double charge-exchange reactions, in order to extract from the measured cross sections, the nuclear structure information relevant to neutrinoless double beta decay. The student will employ advanced nuclear structure and nuclear reaction models and will develop appropriate analysis strategies and codes to enable comparisons with theoretical predictions.

Most of the work will be developed at University of Catania, however collaborations with different Italian University departments and with the University of Sevilla are planned, as part of the NUMEN research program.



ERASMUS MUNDUS MASTER IN NUCLEAR PHYSICS
Academic Year 2026/2027

MASTER THESIS PROPOSAL

TITLE: Nuclear Matrix Elements for neutrinoless double beta decay

SUPERVISOR(S): D.Gambacurta (INFN-LNS), M.Colonna (INFN-LNS and UniCT)

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UNIVERSITY/RESEARCH CENTER: Laboratori Nazionali del Sud (INFN) – Catania (Italy)

ABSTRACT

The experimental observations of neutrino's oscillations indicate that they have non- zero mass but do not provide any information on the absolute scale of their masses. The neutrinoless double beta decay, if observed, would shed light on many fundamental aspects such as: the absolute neutrino mass scale; whether the neutrino is a Dirac or a Majorana particle; the type of neutrino mass ordering (normal or inverted). The neutrinoless double beta decay rate can be factorized in terms of a phase-space factor, the Nuclear Matrix Element (NME) containing the nuclear structure information and a term depending on the combination of the neutrino's masses, the mixing coefficients and the Majorana phases. A reliable extraction of the neutrino masses is possible only if the NMEs are known with sufficient precision. One of the most employed and promising approaches for the evaluation of NMEs is the Skyrme-Quasiparticle Random Phase Approximation (QRPA). The goal of this thesis is to employ and extend a Skyrme-QRPA code for the calculations of the NMEs. Moreover, the role of the proton-neutron pairing and deformation on the NMEs will be studied.



ERASMUS MUNDUS MASTER IN NUCLEAR PHYSICS

Academic Year 2026/2027

MASTER THESIS PROPOSAL

TITLE: Development of Fast Emulators for Nuclear-Matter Calculations and Astrophysical Applications

SUPERVISOR(S): S.Burrello (INFN-LNS), M.Colonna (INFN-LNS and UniCT), D.Gambacurta (INFN-LNS)

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UNIVERSITY/RESEARCH CENTER: Laboratori Nazionali del Sud (INFN) – Catania (Italy)

ABSTRACT

The nuclear matter Equation of State (EoS) is a key ingredient for understanding nuclear systems and compact stars. Its study requires combining different theoretical approaches, ranging from microscopic calculations of structure and nuclear response to dynamical simulations of heavy-ion collisions (HIC). However, the computational cost of these calculations can limit systematic explorations of model parameters and their connection to EoS and astrophysical observables.

This thesis proposes the development of fast emulators for computationally demanding nuclear calculations, including Random Phase Approximation (RPA) and/or transport simulations of HIC. The emulators will be trained and validated against high-fidelity calculations, with the aim of reproducing relevant observables at a significantly reduced computational cost. They will then be used to efficiently explore the dependence of nuclear observables on the underlying EoS and to facilitate their connection with astrophysical applications of compact stars and neutron-star mergers.



ERASMUS MUNDUS MASTER IN NUCLEAR PHYSICS

Academic Year 2026/2027

MASTER THESIS PROPOSAL

TITLE: Microscopic Benchmarks of Quasi-Deuteron Correlations in Asymmetric Nuclear Matter

SUPERVISOR(S): S. Burrello (INFN-LNS), M. Colonna (INFN-LNS and UniCT), A. Rios (University of Barcelona)

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UNIVERSITY/RESEARCH CENTER: Laboratori Nazionali del Sud (INFN) – Catania (Italy)

ABSTRACT

Nuclear matter at densities around and below saturation exhibits strong many-body correlations, which affect both its equation of state and the momentum distributions of its constituent nucleons. In particular, short-range correlations associated with the tensor component of the nucleon-nucleon interaction generate high-momentum components in the nucleon momentum distributions, with a pronounced dependence on the isospin asymmetry. A phenomenological description of these correlations can be introduced through effective quasi-deuteron degrees of freedom, providing a connection between microscopic nuclear dynamics and density functional approaches.

The aim of this thesis is to investigate the microscopic foundations of such an effective quasi-deuteron description by using momentum distributions obtained within self-consistent Green's function calculations of asymmetric nuclear matter. The calculated neutron and proton momentum distributions will be compared with an effective description based on correlated neutron-proton pairs, with particular attention to the high-momentum components associated with short-range correlations. The dependence of the effective quasi-deuteron fraction on density and isospin asymmetry will be investigated and compared with existing phenomenological approaches. The results will provide microscopic constraints on the in-medium properties of effective deuteron-like correlations and, in particular, on the corresponding in-medium mass shift. A possible extension to finite temperature will also be explored, with the aim of investigating the temperature dependence of the effective quasi-deuteron correlations and their connection with the in-medium modification and dissolution of light clusters.



ERASMUS MUNDUS JOINT MASTER IN NUCLEAR PHYSICS

Academic Year 2026/2027

MASTER THESIS PROPOSAL

TITLE: Characterization of the response of a liquid argon double-phase TPC within the ReD+ project

SUPERVISOR(S): Luciano Pandola (LNS), Marisa Gulino (LNS), Marzio De Napoli (University of Catania)

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UNIVERSITY/RESEARCH CENTER: INFN, Laboratori Nazionali del Sud and University of Catania, Department of Physics and Astronomy

ABSTRACT

(just few lines 5-10 explaining briefly the idea of the proposed work and the place where it will be developed).

Uncovering the nature of dark matter is one of the most compelling challenges in modern physics. The DarkSide-20k experiment will search for dark matter in the form of Weakly Interacting Massive Particles (WIMPs) using a dual-phase argon Time Projection Chamber (TPC). A precise understanding of the detector response is essential for identifying the extremely rare events expected from dark matter interactions and an extensive experimental program is currently underway, involving dedicated argon TPC prototypes such as ReD+ at INFN-LNS.

The ReD+ experiment investigates the response of an argon TPC to low-energy nuclear recoils (below 10 keV), which are expected from interactions of low-mass WIMPs. A first measurement campaign achieved sensitivity down to approximately 2 keV, while the ReD+ aims to extend this sensitivity down to 0.5 keV.

The thesis project will provide the opportunity to contribute directly to this research program at INFN-LNS. Activities will include both an experimental component, involving the integration, commissioning, and participation in data-taking campaigns, and a computational component focused on data analysis and Monte Carlo simulations.

The project will offer hands-on experience in particle detection, detector operation, experimental techniques, simulations, and data analysis. The expected results will contribute to the characterization of liquid argon detector response, also supporting the development and validation of the technologies employed in next-generation dark matter experiments.



ERASMUS MUNDUS JOINT MASTER IN NUCLEAR PHYSICS

Academic Year 2026/2027

MASTER THESIS PROPOSAL

TITLE: Time Calibration of the KM3NeT neutrino Telescope.

SUPERVISOR(S): Giorgio Maria Riccobene (LNS), Salvatore Viola (LNS), Alessia Tricomi (University of Catania)

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UNIVERSITY/RESEARCH CENTER: INFN, Laboratori Nazionali del Sud, Catania

ABSTRACT

(just few lines 5-10 explaining briefly the idea of the proposed work and the place where it will be developed).

The KM3NeT Neutrino telescope deployed offshore Sicily has detected the most energetic cosmic neutrino, opening a new era in astroparticle physics.

One of the paramount aspects for the detector operation is its time calibration, which is necessary to ensure precise reconstruction of direction of neutrino events and, thus locate neutrino sources in the skymap.

For this purpose, the KM3NeT ARCA detector has upgraded his architecture in its time synchronization system, adopting a full White Rabbit system, to improve timing distribution across the detector.

The thesis will deal with experimental work finalised at the analysis and implementation of the time calibration and to study its effects on the anular resolution of the telescope.



ERASMUS MUNDUS JOINT MASTER IN NUCLEAR PHYSICS

Academic Year 2026/2027

MASTER THESIS PROPOSAL

TITLE: Acoustic Monitoring of the Mediterranean Sea.

SUPERVISOR(S): Giorgio Maria Riccobene (LNS), Salvatore Viola (LNS), Alessia Tricomi (University of Catania)

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UNIVERSITY/RESEARCH CENTER: CSFNSM, Univ. Catania, INFN, Laboratori Nazionali del Sud, Catania

ABSTRACT

Title: *Underwater Acoustic Monitoring and Soundscape: Installation of new sensors and data analysis Using Advanced Acoustic Sensors and Artificial Intelligence Techniques*

The thesis will be carried out at CSFNSM **and Laboratori Nazionali del Sud (INFN-LNS)** and it will focus on the analysis of underwater acoustic data collected within the **VONGOLA-PNRR, CLIMED**, (Italy-Tunisia) and **TOGETHER** (Italy Malta) projects. The student will acquire both experimental hardware and software skills. The work will consist in following the construction, test and integration of acoustic observatories and in developing and applying advanced signal processing techniques to characterize the underwater acoustic environment using data acquired by digital hydrophones and Distributed Acoustic Sensing (DAS) systems. Attention will be devoted to the identification and classification of natural and anthropogenic sound sources, including vessel traffic, marine mammal vocalizations, and geophysical phenomena. Machine Learning and Artificial Intelligence algorithms will be employed for automated sound recognition and soundscape characterization. The activity will contribute to the development of innovative tools for marine environmental monitoring, biodiversity assessment, and the study of human impacts on marine ecosystems. The student will have the opportunity to work with real-time data from permanent deep-sea observatories and participate in a multidisciplinary research environment involving underwater acoustics, oceanography, environmental sciences, and astroparticle physics. The results are expected to support both environmental monitoring applications and the development of future underwater acoustic detection technologies.



ERASMUS MUNDUS JOINT MASTER IN NUCLEAR PHYSICS

Academic Year 2026/2027

MASTER THESIS PROPOSAL

TITLE: Heavy-Quark Dynamics in Light-Ion Collisions within a Relativistic Transport Approach

SUPERVISOR(S): Prof. Salvatore Plumari, Prof. Vincenzo Greco

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UNIVERSITY/RESEARCH CENTER:
University of Catania, Department of Physics and Astronomy “E. Majorana”

ABSTRACT

(just few lines 5-10 explaining briefly the idea of the proposed work and the place where it will be developed).

Heavy quarks are powerful tool to probe the strongly interacting matter produced in ultra-relativistic nuclear collisions. Owing to their large masses, charm and bottom quarks are predominantly created in early stages of the collisions and subsequently experience the entire evolution of the medium. Their momentum distributions and collective flow therefore provide valuable information on the strength of the interaction with the quark–gluon plasma and on the degree of thermalization reached by the system. This project aims to investigate heavy-quark dynamics in light-ion collisions, including oxygen–oxygen, neon–neon and other collision systems, within a relativistic transport approach. Particular attention will be devoted to the dependence of the main heavy-flavour observables on the system size, collision geometry, medium lifetime. Light-ion collisions are emerging as a major focus of the current and future heavy-ion programme at the LHC, where recent O–O and Ne–Ne collisions already providing the first experimental results for light hadrons thereby offering strong motivation for a systematic investigation of heavy-flavour dynamics in these systems.



ERASMUS MUNDUS JOINT MASTER IN NUCLEAR PHYSICS

Academic Year 2026/2027

MASTER THESIS PROPOSAL

TITLE: Electrical Conductivities of the Quark–Gluon Plasma in a Relativistic Transport Approach

SUPERVISOR(S): Prof. Salvatore Plumari, Prof. Vincenzo Greco

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UNIVERSITY/RESEARCH CENTER:

University of Catania, Department of Physics and Astronomy “E. Majorana”

ABSTRACT

(just few lines 5-10 explaining briefly the idea of the proposed work and the place where it will be developed).

The characterization of the transport properties of the quark–gluon plasma (QGP) produced in ultra-relativistic heavy-ion collisions is essential for understanding its collective dynamics. While shear and bulk viscosities have been extensively investigated, the electrical conductivities remain less constrained. In particular, the electrical conductivity governs the response of the QGP to the intense electromagnetic fields generated during the early stages of non-central collisions and influences their space-time evolution. Its determination is therefore especially relevant in light of the recent interest in the charge-dependent directed flow, $\langle v_1 \rangle$, of D mesons as a possible probe of electromagnetic-field effects on heavy quarks. This project aims to perform a systematic calculation of the electrical conductivities of a relativistic system within a kinetic transport approach. The relativistic Boltzmann equation will be used to extract the electric conductivity from equilibrium current-current correlation functions through the Green–Kubo formalism. The numerical results will be benchmarked against calculations based on the relaxation-time approximation.



ERASMUS MUNDUS JOINT MASTER IN NUCLEAR PHYSICS

Academic Year 2026/2027

MASTER THESIS PROPOSAL

TITLE: Open Quantum Systems Approach to study quarkonium dissociation and decoherence in strongly interacting matter

SUPERVISOR(S): Prof. Salvatore Plumari, Prof. Gabriele Coci, Prof. Giuseppe Falci

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UNIVERSITY/RESEARCH CENTER:
University of Catania, Department of Physics and Astronomy “E. Majorana”

ABSTRACT

(just few lines 5-10 explaining briefly the idea of the proposed work and the place where it will be developed).

The application of Open Quantum Systems (OQS) theory to high-energy physics is emerging as an important research field. This thesis work proposes the development of an OQS framework to study quarkonium suppression in strongly interacting matter under extreme temperature and density conditions. This phenomenon has been experimentally observed in relativistic heavy-ion collisions and provides important insights into the properties of the quark–gluon plasma (QGP) and the state of strongly interacting matter produced in the early Universe. The quantum master equation in the Born-Markov regime will be formulated to describe the interaction between quarkonia and the surrounding thermal QGP, incorporating spectral functions and heavy-quark transport coefficients obtained from perturbative QCD calculations or effective field theories available in the literature. Furthermore, the study will investigate the role of memory effects in the non-Markovian dynamics arising from the interaction between quarkonia and the non-equilibrium, expanding QGP medium, and their impact on quantum decoherence and quarkonium observables.



ERASMUS MUNDUS JOINT MASTER IN NUCLEAR PHYSICS
Academic Year 2026/2027

MASTER THESIS PROPOSAL

TITLE: Study of Tau Neutrinos in the KM3NeT/ARCA Neutrino Telescope

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UNIVERSITY/RESEARCH CENTER: University of Catania; INFN - Laboratori Nazionali del Sud

ABSTRACT

(just few lines 5-10 explaining briefly the idea of the proposed work and the place where it will be developed).

Tau neutrinos represent a particularly interesting component of the astrophysical neutrino flux observed by high-energy neutrino telescopes. Their simulation involves several distinctive aspects related to tau-lepton production, propagation and decay, including polarization effects and tau neutrino regeneration during propagation through matter. This thesis will focus on the study of tau-neutrino events in the KM3NeT/ARCA neutrino telescope through Monte Carlo simulations, with the aim of investigating their characteristics and the physical processes relevant to their detection. The work will be carried out at INFN-LNS in Catania within the KM3NeT Collaboration.



ERASMUS MUNDUS JOINT MASTER IN NUCLEAR PHYSICS
Academic Year 2026/2027

MASTER THESIS PROPOSAL

TITLE: Impact of the Seabed and Bathymetry on High-Energy Neutrino Simulations

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ABSTRACT

(just few lines 5-10 explaining briefly the idea of the proposed work and the place where it will be developed).

The morphology of the seabed can affect high- and ultra-high-energy neutrino interactions and the propagation of secondary particles. This is particularly relevant for the KM3NeT/ARCA neutrino telescope, located close to the Malta Escarpment. This thesis will investigate the impact of a realistic description of the seabed and bathymetry on neutrino Monte Carlo simulations, including interactions in the surrounding rock and Earth-skimming neutrino events. The work will be carried out at INFN-LNS in Catania within the KM3NeT Collaboration.



ERASMUS MUNDUS JOINT MASTER IN NUCLEAR PHYSICS
Academic Year 2026/2027

MASTER THESIS PROPOSAL

TITLE: Automated Validation of KM3NeT Monte Carlo Productions

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UNIVERSITY/RESEARCH CENTER: University of Catania; INFN - Laboratori Nazionali del Sud

ABSTRACT

(just few lines 5-10 explaining briefly the idea of the proposed work and the place where it will be developed).

Monte Carlo simulations are a fundamental component of the KM3NeT analysis chain, providing the reference needed to understand the detector response, characterize backgrounds, and interpret experimental data. Their validation against experimental data is therefore essential to ensure the reliability of physics analyses. This thesis will focus on the development of automated validation procedures, including the definition of relevant plots, Data–Monte Carlo and Monte Carlo–Monte Carlo comparisons, and automatic reporting of the results. The developed procedures will be applied to ongoing KM3NeT Monte Carlo productions. The work will be carried out at INFN-LNS in Catania within the KM3NeT Collaboration.



ERASMUS MUNDUS JOINT MASTER IN NUCLEAR PHYSICS

Academic Year 2026/2027

MASTER THESIS PROPOSAL

TITLE: Analysis of events detected in the dual-phase argon Time Projection Chamber of the ReD+ experiment

SUPERVISOR(S): Gioacchino Alex Anastasi, Marzio De Napoli, Sebastiana Puglia

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UNIVERSITY/RESEARCH CENTER: Istituto Nazionale di Fisica Nucleare INFN - Sezione di Catania, and Dipartimento di Fisica e Astronomia, Università di Catania.

ABSTRACT

The search for Weakly Interacting Massive Particles (WIMPs) as Dark Matter candidates is increasingly focusing on low-mass (below $10 \text{ GeV}/c^2$) scenarios. Dual-phase argon Time Projection Chambers (TPCs), such as those developed within the DarkSide experiment, are among the leading technologies in this field.

A thorough understanding of the detector response is crucial for identifying the extremely rare events expected from Dark Matter interactions, especially at the lowest recoil energies. The ReD+ experiment, operating a compact argon TPC, aims to study the detector response down to the sub-keV scale, improving on the result achieved in the previous campaigns with the ReD apparatus.

The thesis project will focus on the analysis of ReD+ data, encompassing detector stability, signal calibration, and event reconstruction. The student will contribute to developing and refining algorithms to process the signals recorded by the experimental setup, with the goal of extracting and characterizing fundamental physical quantities.

The project will eventually offer the opportunity to explore advanced Machine Learning (ML) techniques applied to the TPC Silicon Photomultiplier waveforms. These include unsupervised representations for event selection and anomaly detection, as well as deep neural networks for spatial reconstruction, complementing and extending standard reconstruction methods.

The research activities will be primarily based at the Catania Department of Physics and Astronomy, and at INFN Sezione di Catania, in close synergy with the experimental operations at the INFN Laboratori Nazionali del Sud (LNS). This thesis work will offer a mixture of data science and experimental physics: the student will be involved in data analysis and advanced ML development, alongside hands-on participation in the commissioning and data-taking campaigns of the ReD+ detector.



ERASMUS MUNDUS JOINT MASTER IN NUCLEAR PHYSICS

Academic Year 2026/2027

MASTER THESIS PROPOSAL

TITLE: Development of a new Neutron detector **A**rray for **C**orrelation and **S**pectroscopy (NArCoS)

SUPERVISOR(S):

Prof.ssa Brunilde Gnoffo, Dr. Emanuele Vincenzo Pagano

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Università degli Studi di Catania

INFN - Sezione di Catania

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ABSTRACT

The main aim of this research is to study the design, development, and assembly of a new detector array for, both, neutron and charged particle, to be used in heavy-ion nuclear reactions studies at Fermi ($E/A \approx 10\text{-}50$ MeV/nucleon). The basic unit of the new detector is a cubic cell (3 cm side) of EJ276G scintillating material read out by SIPM matrices. This choice has shown very good neutron-gamma separation capabilities and time resolution. The student will take part in experimental tests, by using beams and radioactive sources, and simulation of detector response/performance, aiming to validate and drive the development of a 64 cells prototype.



ERASMUS MUNDUS JOINT MASTER IN NUCLEAR PHYSICS

Academic Year 2026/2027

MASTER THESIS PROPOSAL

TITLE: Development of a new Radioactive Ion Beams (RIBs) tagging detector based on novel Sic technology

SUPERVISOR(S):

Prof. Giuseppe Politi, Dr.ssa Nunzia Simona Martorana

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UNIVERSITY/RESEARCH CENTER:

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ABSTRACT

Main aim of the research is the development and characterization of a novel detector for the tagging of Radioactive Ion Beams (RIBs), produced by means of the ‘in-flight’ technique. Intense RIBs will be available in the near future at the INFN-LNS laboratory, following the upgrade of the superconducting cyclotron and the building of a new fragment separator (FraSe). The new detector will be constituted by an array of several (≈ 120) Silicon Carbide independent pads, covering an active area of $\approx 6 \times 3 \text{ cm}^2$, read out by newly developed fast integrated electronics. The use of this innovative material (SiC) will allow to obtain excellent detector performances in terms of sustainable rate and time resolution. The student will take part in experimental tests, by using beams and radioactive sources, and simulation of detector response/performance, aiming to validate and drive the development of the prototype.



ERASMUS MUNDUS JOINT MASTER IN NUCLEAR PHYSICS

Academic Year 2026/2027

MASTER THESIS PROPOSAL

TITLE: Study of the of the symmetry energy at supra-saturation densities with neutron/proton elliptic flows

SUPERVISOR(S):

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ABSTRACT

The study of the equation of state (EoS) of nuclear matter is a crucial topic in modern nuclear physics. In particular, determining the symmetry energy—which describes the behavior of asymmetric nuclear matter with different neutron-to-proton ratios—at densities above saturation density remains a major challenge. The symmetry energy in this high-density regime can be investigated using multi-messenger signals, such as gravitational waves from binary neutron star mergers and observations of neutron star properties, as well as terrestrial laboratory experiments involving heavy-ion collisions at beam energies around hundreds of MeV/nucleon. To this end, Au+Au collisions were measured at the GSI Helmholtzzentrum für Schwerionenforschung in Darmstadt, Germany, in 2025. The analysis of the neutron-to-proton elliptic flow ratio from these measurements is expected to provide new constraints on the symmetry energy at supra-saturation densities. The aim of this thesis will be the analysis of the collected experimental data and their comparison with state-of-the-art results from theoretical transport models.



ERASMUS MUNDUS JOINT MASTER IN NUCLEAR PHYSICS
Academic Year 2026/2027

MASTER THESIS PROPOSAL

TITLE: Study of light (anti-)nuclei in high energy nuclear collisions at the LHC with the ALICE detector.

SUPERVISOR(S): Paola La Rocca

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UNIVERSITY/RESEARCH CENTER: Dept. of Physics and Astronomy of the University of Catania / INFN Section of Catania

ABSTRACT

(just few lines 5-10 explaining briefly the idea of the proposed work and the place where it will be developed).

The high luminosity and energies reached at the Large Hadron Collider (LHC), together with the unique particle tracking and identification capabilities of the ALICE detector, allow the investigation of rare probes, such as light (anti-)nuclei. The identification of these nuclei in high-energy nuclear collisions is challenging due to the large particle multiplicity and their low production cross-section. The thesis will focus on the study of one of these rare signals in central and ultra-peripheral collisions. The student will carry out the data analysis as part of the ALICE experiment.



ERASMUS MUNDUS JOINT MASTER IN NUCLEAR PHYSICS

Academic Year 2026/2027

MASTER THESIS PROPOSAL

TITLE: Development, Characterization and Validation of MAPS Sensors for the upgrades of the ALICE experiment at CERN.

SUPERVISOR(S): Paola La Rocca

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UNIVERSITY/RESEARCH CENTER: Dept. of Physics and Astronomy of the University of Catania / INFN Section of Catania

ABSTRACT

(just few lines 5-10 explaining briefly the idea of the proposed work and the place where it will be developed).

The activity will be carried out in the context of the ALICE experiment at CERN and in particular of the development of its Inner Tracking System (ITS3) and of the future ALICE 3 experiment.

The activity involves the characterization and development of monolithic pixel sensor (MAPS) sensors in 65 nm CMOS technology, for the construction of the ALICE ITS3 detector and for the future ALICE 3 inner tracker.

The ITS3 will consist of only 3 layers of MAPS sensors thinned to approximately 50 μm with purely cylindrical geometry, supported only by minimal carbon foam supports and air-cooled. The performance of the prototypes, particularly the large-area sensors fabricated with the stitching technique, are under test in laboratory and in particle beam. The activities will be carried out in Catania and at different beam test facilities, depending on the project schedule.

In parallel, the activity will investigate MAPS developments for ALICE 3, addressing the requirements of a future-generation inner tracker and providing continuity between the short-term ITS3 development and the longer-term ALICE 3 R&D.

The results will provide feedback to sensor designers and contribute to the optimization of the MAPS technology for both detectors.



ERASMUS MUNDUS JOINT MASTER IN NUCLEAR PHYSICS

Academic Year 2026/2027

MASTER THESIS PROPOSAL

TITLE: Machine learning-based extrapolation of the astrophysical S-factor in nuclear astrophysics

SUPERVISOR(S): Jorge Segovia, Isaac Vidaña and Edoardo G. Lanza

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UNIVERSITY/RESEARCH CENTER:

Universidad Pablo de Olavide di Sevilla, INFN di Catania, and Università di Catania

ABSTRACT

(just few lines 5-10 explaining briefly the idea of the proposed work and the place where it will be developed).

The astrophysical S-factor is a crucial quantity in nuclear astrophysics, representing a reparameterization of the nuclear reaction cross-section that removes the dominant Coulomb barrier effects. It plays a central role in calculating reaction rates in nucleosynthesis processes, including those occurring in stellar interiors, supernovae, and during the Big Bang. Accurate knowledge of the S-factor is essential for modeling the production of chemical elements and predicting neutrino fluxes from stars.

Despite its importance, the S-factor is challenging to determine theoretically and experimentally. At the low energies relevant for astrophysical environments (often in the keV range), direct measurement of reaction cross-sections becomes infeasible due to the exponential suppression by the Coulomb barrier. Theoretical models often involve large uncertainties, especially for complex or weak interactions. As a result, experimental data are typically obtained at higher energies and then extrapolated down to astrophysical energies—a process highly sensitive to the chosen fitting method and underlying physical assumptions.

This project aims to explore the application of machine learning (ML) techniques to improve the extrapolation of the S-factor from experimental data. ML models—such as Gaussian processes, neural networks, or physics-informed regression—will be trained on existing high-energy cross-section data and constrained by known physical laws (e.g., threshold behavior, resonance structures). The objective is to develop a ML-based framework that provides robust uncertainty quantification and enhances predictive power at low energies.

The project will involve:



- Gathering and preprocessing experimental cross-section and S-factor data for selected reactions (e.g, $p+p$, ${}^3\text{He}+{}^3\text{He}$, ${}^{12}\text{C}+\alpha$).
- Implementing and comparing ML models for function extrapolation.
- Incorporating physical constraints into the models.
- Evaluating the extrapolated S-factors against theoretical predictions and low-energy benchmarks.

The outcome is expected to contribute both to the methodological field of scientific ML and to nuclear astrophysics by offering improved tools for reaction rate modeling under stellar conditions.



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ERASMUS MUNDUS MASTER IN NUCLEAR PHYSICS

Academic Year 2024/2025

MASTER THESIS PROPOSAL

TITLE: Improving gamma detection by isolating signal from background – a machine learning approach

SUPERVISOR(S): David Mascali (UniCT and INFN-LNS)

Eugenia Naselli (INFN-LNS), Angelo Pidotella (INFN-LNS)

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ABSTRACT

(just few lines 5-10 explaining briefly the idea of the proposed work and the place where it will be developed).

In-plasma measurement of beta-decay rate is based on tagging the secondary gamma released by the excited daughter nucleus. The gamma photon emitted from radioisotopes considered lies in the keV range which overlaps with high energy bremsstrahlung from the plasma. In order to separate the gamma peak from the self-emission background with n-sigma level certainty, the plasma needs to be kept stable for days or weeks [1, 2]. This thesis will be a feasibility study to assess whether the measurement time can be reduced by using machine learning and deep neural networks as peak finding algorithms [3].

[1] D. Mascali et al, *The PANDORA project: an experimental setup for measuring in-plasma beta-decays of astrophysical interest*, EPJ Web of Conferences 227, 01013 (2020).

[2] E. Naselli et al., *Design study of a HPGe detector array for β -decay investigation in laboratory ECR plasmas*, Front. Phys. 10, 935728 (2022).

[3] S. Wu et al, *Peak-searching method for low-count rate gamma spectrum under short-time measurement based on a generative adversarial network*, Nuclear Inst. And Methods in Physics Research A 1002, 165252 (2021).



Co-funded by
the European Union

ERASMUS MUNDUS MASTER IN NUCLEAR PHYSICS

Academic Year 2024/2025

MASTER THESIS PROPOSAL

TITLE: Investigation of kinetic instabilities in laboratory plasmas emulating astrophysical emission of radio and X-ray bursts

SUPERVISOR(S): David Mascali (UniCT and INFN-LNS)
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UNIVERSITY/RESEARCH CENTER: University of Catania, INFN-LNS

ABSTRACT

(just few lines 5-10 explaining briefly the idea of the proposed work and the place where it will be developed).

Several experiments demonstrated that plasma kinetic instabilities limit the flux of highly charged ions extracted from Electron Cyclotron Resonance Ion Sources (ECRIS). Onset of the instability is typically characterized by fast RF and X-ray bursts and causes beam ripple and unstable ion source conditions. These instabilities are really relevant for astrophysical scenarios. Even if many studies have been carried out, the exact mechanism of turbulent regimes of plasmas is still under investigation. The thesis will be focused on the experimental setup that are able to reproduce and study these interesting phenomena of interest for astrophysics, such as the so-called Cyclotron Maser Instability, which is a typical kinetic turbulence occurring in astrophysical objects. The thesis activity will aim to investigate turbulent plasma regimes in Radio and X-ray domains in laboratory, performing space- and time-resolved spectroscopy simultaneously. The activities will be carried out at the INFN-LNS on the axis-symmetric Flexible Plasma Trap based on a Simple Mirror configuration. A multi-pins RF probe connected with a diode and an 80 Gs/s scope allows to obtain high-resolution time-resolved but fully integrated power emitted by the plasma to detect RF bursts (signature of the plasma instability regime), so this value will be used as trigger signal for an X-ray CCD camera to perform X-ray imaging and spectroscopy [1]

[1] E. Naselli et al., JINST, 17 C01009 (2022)



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ERASMUS MUNDUS MASTER IN NUCLEAR PHYSICS

Academic Year 2024/2025

MASTER THESIS PROPOSAL

TITLE: Development of a movable Langmuir probe system for measuring local electron density and temperature in a magnetized plasma

SUPERVISOR(S): David Mascali (UniCT and INFN-LNS)
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UNIVERSITY/RESEARCH CENTER: University of Catania, INFN-LNS

ABSTRACT

(just few lines 5-10 explaining briefly the idea of the proposed work and the place where it will be developed).

Langmuir probes are valuable diagnostics methods capable of measuring local plasma parameters such as electron density and temperature by reconstructing the current-potential (I-V) curve in both electrons and ions regions. Thermodynamical parameters are the reconstructed by appropriate models of electrostatic particle collection in the magnetized plasma. The thesis will consist in the theoretical investigation of an optimized tool to be used for the analysis of ECR plasmas, and then the realization of the probe to be tested in a real experimental setup.



Co-funded by
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ERASMUS MUNDUS MASTER IN NUCLEAR PHYSICS

Academic Year 2024/2025

MASTER THESIS PROPOSAL

TITLE: Photonic crystals for ultracompact dielectric accelerators

SUPERVISOR(S): David Mascali (UniCT and INFN-LNS)
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UNIVERSITY/RESEARCH CENTER: University of Catania, INFN-LNS

ABSTRACT

(just few lines 5-10 explaining briefly the idea of the proposed work and the place where it will be developed).

Laser acceleration of electrons with silicon dielectric structures was demonstrated in with accelerating gradients of more than 200 MeV/m. Many of the proposed configurations have an intrinsically limited interaction length, because they require a plane wave that impinges laterally throughout the whole structure's length. In order to have both high laser-induced accelerating gradients and adequate interaction length, this thesis work will focus on the EM design and beam dynamics study of hollow-core waveguides, based on photonic crystals, employed as accelerating structures (with possibly co-linear propagation of the accelerating electromagnetic field and the particle bunch to be accelerated).



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ERASMUS MUNDUS MASTER IN NUCLEAR PHYSICS

Academic Year 2024/2025

MASTER THESIS PROPOSAL

TITLE: Studying spatial distribution of ion properties in ECR plasmas with self-consistent numerical codes for the PANDORA project

SUPERVISOR(S): David Mascali (UniCT and INFN-LNS)
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UNIVERSITY/RESEARCH CENTER: University of Catania, INFN-LNS

ABSTRACT

(just few lines 5-10 explaining briefly the idea of the proposed work and the place where it will be developed).

Calculating the charge state distribution (CSD) and level population of ions as a function of their position in an ECR plasma is integral for understanding the nature of the extracted beam, as well as for estimating beta-decay rates of radioisotopes diffused into such systems [1,2]. To this effect, the thesis will be concerned with evaluating the 3D distribution of ion properties in ECR plasmas using self-consistent numerical codes connecting warm electron 3D space-resolved evolution in time with ion dynamics through collisional ionisation, charge exchange and particle transport models.

[1] D. Mascali et al., *A novel approach to β -decay: PANDORA, a new experimental setup for the future in-plasma measurements*, 2022 *Universe* 8, 80.

[2] K. Takahashi and K. Yokoi, *Nuclear B-Decays of Highly Ionised Heavy Atoms in Stellar Interiors*, *Nucl. Phys. A* 404, 3 (1983)



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ERASMUS MUNDUS MASTER IN NUCLEAR PHYSICS

Academic Year 2024/2025

MASTER THESIS PROPOSAL

TITLE: Development of an experimental setup and measurement of magneto-plasma opacity in laboratory

SUPERVISOR(S): David Mascali (UniCT and INFN-LNS)
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ABSTRACT

(just few lines 5-10 explaining briefly the idea of the proposed work and the place where it will be developed).

Opacity is a key ingredient in many relevant astrophysical scenarios, which impact on the energy transport and spectroscopic observations is still debated. Electromagnetic transient signal emitted from neutron-star mergers (kilonova - KN) is of interest in the multi-messenger astronomy frame because of delivered information on the expelled plasma ejecta's composition (r-process nucleosynthesis), however its interpretation strongly depends on the system opacity, which is an almost unfolded observable. The activity proposed in this thesis is in the context of experimental investigations of in-laboratory magneto-plasma opacities, for metallic species abundant in a specific time-stage of KN diffusion, at plasma electron density and temperatures resembling the ejecta plasma conditions [1, 2]. In this framework, the on-construction facility PANDORA, and the working Flexible Plasma Trap (FPT), both at the INFN – LNS (Catania, Italy) suite for the purpose. The thesis will concern the development of an experimental multi-diagnostic setup, based on optical spectroscopy and microwave interferometry, thus employing complementary techniques and methods, for studying opacity of gaseous plasmas magnetically confined in compact plasma traps. The setup assembling (design, calibration) and measurements will be carried out on the FPT, as ground experiments projected to be then extended in the PANDORA facility. The investigation will help in shedding light on atomic uncertainties on the KN problem, as well as to further extend knowledge on the stellar opacity problem for the Astrophysics and Nuclear Astrophysics interests.

[1] Pidatella, A., *et al.*, IL NUOVO CIMENTO 44 C (2021) 65.

[2] Pidatella, A., *et al.*, Frontiers in Astronomy and Space Sciences 9, 225 (2022).



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ERASMUS MUNDUS MASTER IN NUCLEAR PHYSICS

Academic Year 2024/2025

MASTER THESIS PROPOSAL

TITLE: Microwave/mm-wave polarimetry for magneto-plasmas of ECR ion source

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UNIVERSITY/RESEARCH CENTER: University of Catania, INFN-LNS

ABSTRACT

(just few lines 5-10 explaining briefly the idea of the proposed work and the place where it will be developed).

Polarimetric setup - able to measure the magnetoplasma-induced Faraday rotation in a compact size plasma trap - has been proven to provide reliable measurement of the plasma line-integrated electron density [1]. This thesis work will develop an analysis method for polarimetric measurements on a mm-wave testbench [2] – based on the detection of Lissajous figure from a two channels scope (80 gigasample) in an x-y representation of a direct probing RF signals crossing the magnetoplasma. The system was on purpose designed and developed for the PANDORA chamber case study [3], which represents an “intermediate” case between the ultra-compact plasma ion sources and the large-size thermonuclear fusion devices.

[1] E. Naselli et al. (2018) *JINST* **13** C12020.

[2] G. Torrasi et al. (2022) *Front. Astron. Space Sci.* **9** 949920.

[3] D. Mascali et al. (2022) *Universe* **8**, 80.



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ERASMUS MUNDUS MASTER IN NUCLEAR PHYSICS

Academic Year 2024/2025

MASTER THESIS PROPOSAL

TITLE: Numerical design of high Q resonant cavities for dark matter research

SUPERVISOR(S): David Mascali (UniCT and INFN-LNS)
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ABSTRACT

(just few lines 5-10 explaining briefly the idea of the proposed work and the place where it will be developed).

It is hypothesized that dark matter is composed of extremely light particles called axions, which form a halo around our galaxy. A haloscope is a specialized detector used to search for dark matter, specifically targeting hypothetical low-mass particles called axions. The basic working principle states that when an axion passes through a strong, static magnetic field, it can convert into a detectable photon. Because axions are expected to have a very low mass, these converted photons fall into the microwave frequency range. This thesis work will focus on the design of radio-frequency, high quality factor cavities that are the core of the haloscope: if the frequency of the converted photon matches the resonant frequency of the cavity, the signal is significantly amplified. The work will be carried out by employing commercial electromagnetic simulators and the case studies will include both standard, metallic cavities and novel dielectric cavities based on photonic crystals.



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ERASMUS MUNDUS MASTER IN NUCLEAR PHYSICS

Academic Year 2024/2025

MASTER THESIS PROPOSAL

TITLE: Space-resolved X-ray spectroscopy and imaging of ECR plasmas using quasi-optical methods

SUPERVISOR(S): David Mascali (UniCT and INFN-LNS)
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UNIVERSITY/RESEARCH CENTER: University of Catania, INFN-LNS

ABSTRACT

(just few lines 5-10 explaining briefly the idea of the proposed work and the place where it will be developed).

Soft X-ray spectroscopy is a powerful passive diagnostic technique to characterize warm electrons in ECR plasmas whose properties govern the sequential ionisation processes. Using special optical setups like pinholes coupled with CCD cameras, the technique can be extended to investigate spatial structure of the plasma and confinement dynamics, performing X-ray imaging and space-resolved spectroscopy. The thesis will be focused on performing a new set of measurements to characterize magnetoplasmas confined in the Flexible Plasma Trap, the compact trap installed at INFN-LNS specifically designed as test bench of PANDORA [1]. The work will involve sequential application of a set of algorithms developed indigenously at INFN-LNS, and in collaboration with the ATOMKI laboratories (Debrecen, Hungary) to generate 2D space-resolved maps of X-ray fluorescence, followed by interpretation of the results [2]. The diagnostic system will be also upgraded by installing a new mechanical X-ray shutter able to suppress the CCD camera readout effects and to allow acquisition at low exposure times as never done before ($\sim$ ms), in order to perform simultaneous time and space-resolved investigations of the X-ray fluxes emitted by the plasmas.

[1] D. Mascali et al. (2022) *Universe* **8**, 80.

[2] E. Naselli et al. (2022) *Condens. Matter* **7**, 5.



ERASMUS MUNDUS JOINT MASTER IN NUCLEAR PHYSICS

Academic Year 2026/2027

MASTER THESIS PROPOSAL

TITLE: Characterization of Radiation Detectors for Ultra-High Dose Rate Electron Beams in FLASH Radiotherapy

SUPERVISOR(S): Giacomo Cuttone, Giada Petringa, Roberto Catalano

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UNIVERSITY/RESEARCH CENTER: INFN Laboratori Nazionali del Sud (INFN-LNS) /
University of Catania (CAPIR), Catania, Italy

ABSTRACT

(just few lines 5-10 explaining briefly the idea of the proposed work and the place where it will be developed).

The thesis will focus on the experimental characterization of radiation detectors under ultra-high dose rate (UHDR) conditions relevant to FLASH radiotherapy. FLASH electron beams deliver high doses in very short pulses and at dose rates several orders of magnitude higher than those used in conventional radiotherapy, creating demanding conditions for dosimetry and beam monitoring. The experimental activity will be performed mainly using the SIT ElectronFLASH linear accelerator installed at the Center for Advanced Preclinical in vivo Research (CAPIR) of the University of Catania, a system dedicated to preclinical FLASH studies and able to provide pulsed electron beams at 7 and 9 MeV in conventional and UHDR regimes. Different detector technologies, including solid-state and fast radiation detectors, may be investigated and compared as a function of dose per pulse, average and instantaneous dose rate, pulse repetition frequency and accumulated dose. Particular attention will be devoted to linearity, sensitivity, temporal response, reproducibility, saturation effects and radiation hardness, with comparison against reference dosimetry and beam diagnostics. The work aims at identifying and characterizing detector solutions suitable for real-time dosimetry and beam monitoring under the extreme irradiation conditions required by FLASH radiotherapy. Part of the thesis may also include experimental activities carried out outside Catania at collaborating international research facilities and laboratories.



ERASMUS MUNDUS JOINT MASTER IN NUCLEAR PHYSICS
Academic Year 2026/2027

MASTER THESIS PROPOSAL

TITLE: Laser-Driven Electron Acceleration in Gas-Jet and Capillary-Discharge Plasmas

SUPERVISOR(S): G.A. Pablo Cirrone, José Suarez

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UNIVERSITY/RESEARCH CENTER: Istituto Nazionale di Fisica Nucleare - Laboratori Nazionali del Sud (INFN-LNS), Catania, Italy

ABSTRACT

(just few lines 5-10 explaining briefly the idea of the proposed work and the place where it will be developed).

The thesis will focus on the experimental study of laser-driven electron acceleration in gaseous and plasma targets. The student will contribute to the characterization of a high-intensity femtosecond laser system, reaching intensities up to 10^{18} W/cm², and to the optimization of the parameters relevant for laser-plasma interaction. Two target configurations will be investigated: gas jets and plasmas generated in gas-filled capillary discharges. The interaction conditions and the accelerated electron beams will be characterized using suitable plasma and particle diagnostics, with attention to beam stability, reproducibility and possible applications in medical application as the VHEE radiotherapy. The thesis is expected to include experimental activities to be carried out, at least in part, at foreign research institutes and international laboratories within existing collaborations.



ERASMUS MUNDUS JOINT MASTER IN NUCLEAR PHYSICS

Academic Year 2026/2027

MASTER THESIS PROPOSAL

TITLE: Interferometric and Spectroscopic Diagnostics of Plasmas for Laser-Driven Particle Acceleration

SUPERVISOR(S): G.A. Pablo Cirrone, José Suarez

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UNIVERSITY/RESEARCH CENTER: Istituto Nazionale di Fisica Nucleare - Laboratori Nazionali del Sud (INFN-LNS), Catania, Italy

ABSTRACT

(just few lines 5-10 explaining briefly the idea of the proposed work and the place where it will be developed).

The thesis will focus on the development and application of diagnostic techniques for plasmas and electron beams relevant to novel laser-driven acceleration schemes. Two plasma configurations will be considered: capillary-discharge plasmas and plasmas produced by the interaction of high-intensity femtosecond laser pulses with gas-jet targets. Interferometric techniques will be used to determine electron-density profiles and their temporal evolution, while optical emission spectroscopy will provide information on plasma temperature, ionization state and dynamics through the analysis of emitted spectral lines. In laser wakefield acceleration experiments, plasma diagnostics will be complemented by magnetic spectrometry of the accelerated electrons to determine their energy distribution. The activity is framed within the development of I-LUCE at INFN-LNS, a new high-intensity laser facility devoted to laser-plasma physics and laser-driven particle acceleration. The thesis may include the development and calibration of diagnostic setups, data acquisition and analysis. Part of the experimental activity may also be carried out at collaborating international laboratories and high-power laser facilities.



ERASMUS MUNDUS JOINT MASTER IN NUCLEAR PHYSICS

Academic Year 2026/2027

MASTER THESIS PROPOSAL

TITLE: Proton Stopping Power in Warm Dense Matter and Discharge Plasmas: Physics, Experiments and Modelling for Inertial Fusion

SUPERVISOR(S): G.A. Pablo Cirrone

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UNIVERSITY/RESEARCH CENTER: Istituto Nazionale di Fisica Nucleare - Laboratori Nazionali del Sud (INFN-LNS), Catania, Italy

ABSTRACT

(just few lines 5-10 explaining briefly the idea of the proposed work and the place where it will be developed).

The thesis will investigate the physics of proton energy loss in ionized matter within the INFN PSP (Proton Stopping Power) and European Hiper+RF projects, with particular emphasis on warm dense matter (WDM) and capillary-discharge plasmas. In these regimes, stopping power depends on plasma temperature and density, ionization state, free- and bound-electron contributions, screening and collective effects, and may differ significantly from conventional cold-matter descriptions. The work may combine experimental and theoretical/computational activities. Experiments are foreseen at ELI-ALPS in Szeged, Hungary, and within the I-LUCE activities at INFN-LNS in Catania, where the highest-intensity laser system in Italy and one of the most intense in Europe is being installed. The computational activity may include the development, implementation and validation of stopping-power models for partially and fully ionized plasmas, including their integration in Geant4 and comparison with experimental data. These studies are relevant to high-energy-density physics and inertial confinement fusion, where accurate modelling of charged-particle transport and energy deposition is essential for target heating, ignition and fusion-energy applications.



ERASMUS MUNDUS JOINT MASTER IN NUCLEAR PHYSICS

Academic Year 2026/2027

MASTER THESIS PROPOSAL

TITLE: Dosimetric planning with a Treatment Planning System and PET/CT radiomic assessment of treatment response in a preclinical FLASH radiotherapy study

SUPERVISOR(S): Giorgio Russo

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UNIVERSITY/RESEARCH CENTER:

Institute of Bioimaging & Complex Biological Systems (IBSBC) - National Research Council (CNR)
University of Catania

ABSTRACT

(just few lines 5-10 explaining briefly the idea of the proposed work and the place where it will be developed).

The project GIOCONDA (Understanding the radiobiological effects of FLASH radiotherapy), part of the ANTHEM initiative (Spoke 4, CUP B53C22006590001), investigates the biological mechanisms underlying the FLASH effect by comparing FLASH and conventional (CONV) electron radiotherapy in a preclinical Wistar rat lung model, at doses of 20-30 Gy, evaluating treatment response through ¹⁸F-FDG and FAPI PET/CT imaging performed 2 and 8 weeks after irradiation, and extracting predictive features of tissue toxicity through radiomic analysis with the in-house matRadiomics software.

Within this project, the thesis work will contribute to the dose distribution study of the FLASH and CONV irradiation plans by supporting their calculation and verification with a Treatment Planning System (TPS), so as to ensure an accurate and reproducible delivery of the prescribed dose to the target and to the surrounding healthy tissue in the animal model.

The candidate will also contribute to the acquisition of the ¹⁸F-FDG and FAPI PET/CT images foreseen at the pre-treatment baseline and at the post-treatment follow-up time points, and to the processing and analysis of these images through radiomic techniques, in order to evaluate the tumor control probability (TCP) and normal tissue complication probability (NTCP), and to identify imaging biomarkers predictive of the response to FLASH versus CONV treatment.





ERASMUS MUNDUS JOINT MASTER IN NUCLEAR PHYSICS

Academic Year 2026/2027

MASTER THESIS PROPOSAL

TITLE: Experimental validation of a model for estimating the activity and decay time of urban waste containing radionuclides of medical origin through dose rate measurements at multiple distances

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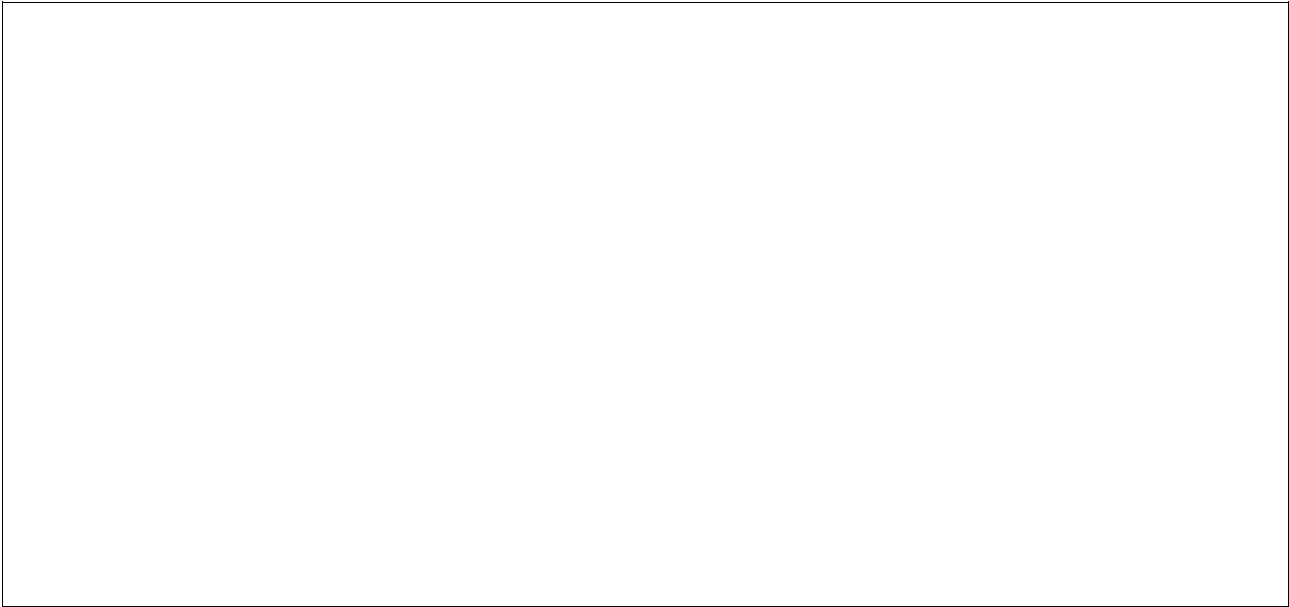
Institute of Bioimaging & Complex Biological Systems (IBSBC) - National Research Council (CNR)
University of Catania

ABSTRACT

Unsealed radioactive sources used in nuclear medicine (radiopharmaceuticals for PET/SPECT diagnostic imaging and for radiometabolic therapy) generate, in hospital departments, solid waste and effluents containing radionuclides of medical origin (e.g. ^{99m}Tc , ^{18}F , ^{131}I , ^{177}Lu), which must be managed and disposed of in compliance with Italian Legislative Decree 101/2020 and must be held until sufficient decay before disposal as conventional waste.

The thesis work, developed in collaboration with the Nuclear Medicine Unit of the Cannizzaro Hospital in Catania, aims to experimentally validate a model for estimating the residual activity and the decay time of urban radioactive waste produced by nuclear medicine diagnostic and therapeutic activities, starting from dose rate measurements performed at multiple distances from the storage container.

The experimental measurements, collected on waste actually produced by the diagnostic and therapeutic treatments carried out at the Cannizzaro Hospital, will be compared with the model estimates, in order to verify their accuracy and applicability as a support tool for the Radiation Protection Expert in the optimized management of storage times and in the controlled release of waste.





ERASMUS MUNDUS JOINT MASTER IN NUCLEAR PHYSICS

Academic Year 2026/2027

MASTER THESIS PROPOSAL

TITLE: Montecarlo studies, using FLUKA toolkit, for a low energy proton beam for nuclear physics and heritage applications

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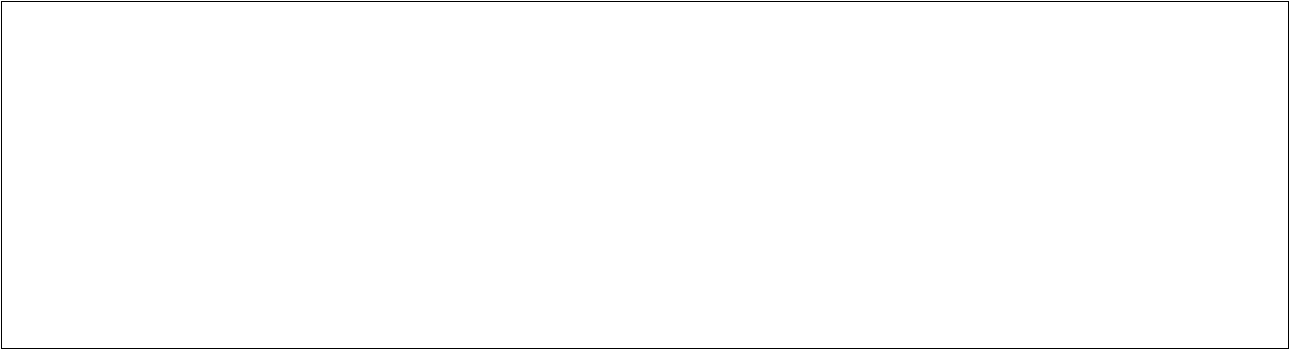
Institute of Bioimaging & Complex Biological Systems (IBSBC) - National Research Council (CNR)

University of Catania

ABSTRACT

At the University of Catania, Department of Physics and Astronomy, there is a proton accelerator capable of reaching energies up to 1.5 MeV, currently used for materials science studies. The aim of the thesis work is to set up a Monte Carlo simulation using the FLUKA toolkit to study the dose distribution—both gamma and neutron—for a generic nuclear physics experiment and the cultural heritage applications.

The nuclear physics activity involves interactions with targets under vacuum conditions. The cultural heritage application consists of irradiating samples, mainly ceramics, in air. In this case, the material radioactivation during a typical experiment has to be assessed using Monte Carlo FLUKA simulations.





ERASMUS MUNDUS JOINT MASTER IN NUCLEAR PHYSICS

Academic Year 2026/2027

MASTER THESIS PROPOSAL

TITLE: Validation of the radiation protection systems installed at the University of Catania for the 9 MeV electron accelerator for FLASH radiotherapy

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UNIVERSITY/RESEARCH CENTER:

Institute of Bioimaging & Complex Biological Systems (IBSBC) - National Research Council (CNR)
University of Catania

ABSTRACT

(just few lines 5-10 explaining briefly the idea of the proposed work and the place where it will be developed).

A recent study (Russo et al., Radiation Protection Dosimetry, 2026) has provided a FLUKA Monte Carlo-based radiation protection assessment for the 9 MeV ultra-high dose rate (UHDR) electron accelerator installed in the animal housing area of the CAPIR Centre for Advanced Preclinical in vivo Research at the University of Catania, simulating the ambient dose equivalent $H^*(10)$ distribution in the accelerator room and in the surrounding areas (corridors, animal housing, monitoring area and offices), both without and with the designed lead shielding, and confirming compliance with the 0.250 mSv/year limit for unrestricted areas.

The thesis work aims to experimentally verify these published simulated data now that the accelerator has been installed, by performing dose-rate measurements at the points of interest already identified in the FLUKA model, in both the unshielded and shielded configurations, and comparing them with the corresponding simulated $H^*(10)$ values in order to assess the accuracy of the Monte Carlo model and the effectiveness of the implemented shielding.

The activity will also include the functional verification of the real-time radiation monitoring systems installed in the facility, checking their response, linearity and reliability during the daytime (conventional and UHDR irradiation) and night-time (unattended dosimetric quality-assurance) work shifts defined in the workload scheme of the published study, so as to confirm their suitability for the routine radiation protection surveillance of the accelerator.

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