



JOINT EUROPEAN MASTER IN NUCLEAR PHYSICS

Academic Year 2026/2027

MASTER THESIS PROPOSAL

TITLE: : Data analysis of the sub-barrier fusion experiment for $^{12}\text{C}+^{16}\text{O}$ performed by gamma-particle coincidences with AGATA + Silicon detectors

SUPERVISOR(S): Giovanna Montagnoli, A.M. Stefanini

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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).

Heavy-ion fusion reactions are essential to investigate the fundamental problem of quantum tunnelling of many-body systems in the presence of intrinsic degrees of freedom, and the fusion of light systems is very important from the astrophysical point of view. At far sub-barrier energies the fusion dynamics is complicated by the hindrance phenomenon. Fusion hindrance in the system $^{12}\text{C} + ^{16}\text{O}$ was possibly observed in recent experiments where, however, the large uncertainties prevent clear-cut conclusions.

The work of this thesis will focus on the analysis of a new experiment on $^{12}\text{C} + ^{16}\text{O}$, recently performed with the combined setup of AGATA and a dedicated array of silicon detectors. The fusion events have been identified by coincidences between the prompt gamma-rays and the light-charged particles (p, α) evaporated from the compound nucleus. The student will have take care of the first phase of the data analysis.



JOINT EUROPEAN MASTER IN NUCLEAR PHYSICS

Academic Year 2026/2027

MASTER THESIS PROPOSAL

TITLE: Capture barrier distribution of $^{64}\text{Ni} + ^{238}\text{U}$ from large-angle scattering

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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 excitation function for elastic and quasi-elastic scattering at backward angles will be measured, for the system $^{64}\text{Ni} + ^{238}\text{U}$ at several energies from $\approx 10\%$ below to $\approx 10\%$ above the Coulomb barrier. This will be done by detecting the Ni-like ions in the angular range $\theta_{\text{lab}} \approx 132^\circ - 156^\circ$, by using a double-sided silicon detector DSSD installed in the scattering chamber at LNL. By differentiating the excitation function with respect to the energy, the barrier distribution for capture will be extracted. The hot fusion of $^{64}\text{Ni} + ^{238}\text{U}$ might lead to the production of the still unknown $Z=120$ superheavy nuclei. The capture barrier distribution is likely to be strongly influenced by the low-lying collective structure of ^{238}U as well as by its strong octupole vibration. In such a heavy system the usual methods (fusion-evaporation excitation function and its second energy derivative) to extract the barrier distribution cannot be applied. The capture barrier distribution will indicate the optimum energy for the possible synthesis of $Z=120$. The student will participate in the experiment, and will perform the first part of the data analysis.



ERASMUS MUNDUS JOINT MASTER IN NUCLEAR PHYSICS

Academic Year 2026/2027

MASTER THESIS PROPOSAL

TITLE: Isospin mixing from electric dipole transitions in mirror nuclei: lifetime of the $1/2^-$ state in ^{19}Ne with the AGATA γ -ray tracking array

SUPERVISOR(S): Prof. Francesco Recchia

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UNIVERSITY/RESEARCH CENTER: University of Padova, Department of Physics and Astronomy “Galileo Galilei” and INFN Padova, in collaboration with INFN Legnaro National Laboratories (LNL)

ABSTRACT

In the isospin formalism, E1 transitions in mirror nuclei have a purely isovector character and must have identical strengths; any difference measures the isospin mixing induced by the Coulomb interaction. The same mixing enters the isospin-breaking corrections applied to superallowed beta decays to extract V_{ud} and test the unitarity of the CKM matrix. Pure E1 transitions between $J = 1/2$ states offer a particularly clean probe, and the $A = 19$ mirror pair is the only one in which both states are bound and have a lifetime accessible to the recoil-distance Doppler-shift (RDDS) method.

The thesis concerns a proposed measurement, with the Advanced GAMMA Tracking Array (AGATA), of the ≈ 60 ps lifetime of the $1/2^-$ state in ^{19}Ne , aiming at a precision of about 5%. The only existing value comes from a single experiment with one 15 cc Ge(Li) detector, a volume corresponding to 1/20 of a single AGATA crystal. The state will be populated in the $^{20}\text{Ne}(d,t)^{19}\text{Ne}$ reaction at 8 MeV/u on a deuterated titanium target mounted on a plunger, with tritons identified in the SAURON particle detector. AGATA is the key to the measurement: its highly segmented HPGe crystals, pulse shape analysis and γ -ray tracking provide the interaction position of each γ ray, and hence an event-by-event Doppler correction, together with a gain of about a factor 400 in efficiency. This makes it possible to separate cleanly the shifted and unshifted components of the 275 keV line at every target–stopper distance and to control the feeding through γ –triton coincidences.

The student will work directly with AGATA: simulations of the array response in the plunger geometry, energy calibration, pulse shape analysis and tracking of the data, Doppler reconstruction, and extraction of the lifetime with the RDDS analysis, together with the reaction kinematics and triton identification. The resulting $B(E1)$ will be compared with that of the mirror ^{19}F to constrain isospin mixing. The work will be carried out at the University of Padova and at INFN-LNL, where AGATA is currently installed, within the AGATA collaboration.



ERASMUS MUNDUS JOINT MASTER IN NUCLEAR PHYSICS

Academic Year 2026/2027

MASTER THESIS PROPOSAL

TITLE: Pulse shape analysis for sub-millimetre position sensitivity in a double-sided strip HPGe detector for soft gamma-ray space astronomy

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ABSTRACT

High-purity germanium (HPGe) detectors provide the best energy resolution available for gamma-ray spectroscopy and are now candidates for the focal plane of future Laue-lens telescopes for soft gamma-ray astronomy (50–700 keV). Such an application requires a 3D position resolution of about 200–300 μm , well below the 2 mm strip pitch currently achievable with segmented electrodes.

The thesis aims to reach this goal through pulse shape analysis (PSA), transferring the techniques developed for the AGATA gamma-ray tracking array to a $40 \times 40 \times 13 \text{ mm}^3$ double-sided strip planar HPGe detector (20+20 orthogonal strips, 2 mm pitch). The student will calculate the detector response (electric and weighting fields, charge transport, Shockley–Ramo induced signals) for different strip widths and gaps, build a database of basis signals, and implement a grid-search algorithm for the lateral coordinates, together with an electron–hole timing method for the depth. The calculations will be validated with data acquired with fast digitizers (500 MS/s, 14 bit) in scans with collimated radioactive sources, including a quantification of cross-talk between strips, to establish the achievable position and energy resolution.

The work will be carried out at the Department of Physics and Astronomy of the University of Padova and at INFN-LNL, within the HRIS project (INAF PRORIS programme) in collaboration with INAF-OAS Bologna.



ERASMUS MUNDUS JOINT MASTER IN NUCLEAR PHYSICS

Academic Year 2026/2027

MASTER THESIS PROPOSAL

TITLE: Protons and neutrons in the mirror: first γ -ray spectroscopy of ^{46}Fe and ^{44}Cr with the GRETA tracking array

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UNIVERSITY/RESEARCH CENTER: University of Padova, Department of Physics and Astronomy “Galileo Galilei” and INFN Padova, in collaboration with the Facility for Rare Isotope Beams (FRIB), Michigan State University (USA)

ABSTRACT

If protons and neutrons were interchangeable, apart from the electric charge, two mirror nuclei (in which the numbers of protons and neutrons are swapped) would have the same excited states at the same energies. Small differences in these energies, called mirror energy differences, reveal how the nuclear force itself treats protons and neutrons differently. So far they have been measured mostly for nuclei close to $N = Z$.

The thesis is based on an experiment proposed at FRIB to observe for the first time the excited states of ^{46}Fe and ^{44}Cr , very proton-rich nuclei whose mirrors are ^{46}Ca and ^{44}Ca . ^{46}Fe is the most extreme mirror pair that can ever be studied with γ -ray spectroscopy. The measurement relies on GRETA, the new-generation γ -ray tracking array at FRIB. The nuclei are produced at about 40% of the speed of light, so their γ rays are strongly Doppler shifted. GRETA reconstructs the position of each γ -ray interaction inside its segmented germanium crystals, which allows a precise Doppler correction and gives sharp peaks with high efficiency. This is essential for ^{46}Fe , where only a few tens of counts are expected. The S800 spectrometer identifies the reaction products.

The student will work on the GRETA data: simulations, calibrations, Doppler reconstruction, γ - γ coincidences and construction of the level schemes, followed by a comparison with shell-model calculations. The work will be carried out at the University of Padova and INFN Padova, with the possibility of taking part in the experiment at FRIB.



ERASMUS MUNDUS JOINT MASTER IN NUCLEAR PHYSICS

Academic Year 2026/2027

MASTER THESIS PROPOSAL

TITLE: Experimental studies of nuclear reactions of astrophysical interest at LUNA

SUPERVISOR(S): Antonio Caciolli

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UNIVERSITY/RESEARCH CENTER: Department of Physics and Astronomy “Galileo Galilei”, University of Padova / INFN Padova; experimental activity at LNGS

ABSTRACT

The thesis will be carried out within the LUNA (Laboratory for Underground Nuclear Astrophysics) collaboration at the INFN Laboratori Nazionali del Gran Sasso. The student will participate in the preparation and characterization of the experimental setup, data taking and data analysis using one of the two underground accelerators. Depending on the experimental schedule, the activity may focus on one of the following reactions: $^{12}\text{C}+^{12}\text{C}$ fusion studied through gamma-ray detection, a key process for carbon burning in massive stars; $^{22}\text{Ne}(\alpha,\gamma)^{26}\text{Mg}$, which competes with the neutron-producing $^{22}\text{Ne}(\alpha,n)^{25}\text{Mg}$ reaction and therefore affects the neutron budget of the weak s-process; or $^{19}\text{F}(\text{p},\alpha)^{16}\text{O}$, with particular emphasis on the $\alpha\pi$ transition, investigated through coincidence measurements of the 511 keV gamma rays produced by positron annihilation using a new segmented detector. The student will contribute to detector characterization, experimental optimization and the analysis of the acquired data.



ERASMUS MUNDUS JOINT MASTER IN NUCLEAR PHYSICS

Academic Year 2026/2027

MASTER THESIS PROPOSAL

TITLE: Nuclear structure studies around the doubly-magic ^{34}Si nucleus via direct transfer reactions

SUPERVISOR(S): Raquel Nicolás del Álamo, Franco Galtarossa

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UNIVERSITY/RESEARCH CENTER: INFN Sezione di Padova

ABSTRACT

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

A recent experiment performed at GANIL with a radioactive ^{34}Si beam at 50 MeV/u investigated the one-neutron removal reaction $^{34}\text{Si}(p,d)^{33}\text{Si}$, providing valuable information on the role of the spin-orbit interaction and the evolution of the spin-orbit splitting at $N = 19$. The study can now be extended through the analysis of the two-neutron transfer reaction $^{34}\text{Si}(p,t)^{32}\text{Si}$, which offers a unique probe of the low-lying 0^+ states and other low-spin excitations in ^{32}Si .

The student will have the opportunity to analyse data from a successful experiment performed at GANIL in 2025, using a radioactive ion beam (RIB) and a state-of-the-art detection system combining beam tracking detectors, Si+CsI telescopes, a zero-degree detection system and a γ -ray array.

The project will provide hands-on experience in particle spectroscopy, reaction analysis and nuclear structure, working with data from a cutting-edge RIB experiment and with modern programming languages (C++, Python) and analysis frameworks (ROOT).



ERASMUS MUNDUS JOINT MASTER IN NUCLEAR PHYSICS

Academic Year 2026/2027

MASTER THESIS PROPOSAL

TITLE: In-beam tests of solid ^3He targets for inverse-kinematics transfer experiments with AGATA-NEDA

SUPERVISOR(S): Franco Galtarossa, José Javier Valiente-Dobón, Alain Goasduff

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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 study of the structure of low-spin (0^+ , 2^+) states, in particular through the determination of their excitation energies, decay branching ratios and electromagnetic transition probabilities, can give important information on possibly coexisting nuclear shapes and the interplay between single-particle and collective degrees of freedom in atomic nuclei. Two-proton transfer ($^3\text{He},n$) reactions are particularly selective for the population of such states but are typically challenging to study due to the necessity of employing ^3He targets and neutron detectors.

The experimental campaign starting in 2027 at the INFN Laboratori Nazionali di Legnaro will see the combination of the state-of-the-art γ -ray tracking array AGATA and the neutron detector NEDA. Such a set-up will give the possibility to measure short lifetimes (< 1 ps) of states populated in ($^3\text{He},n$) reactions in inverse kinematics. A study case is for instance the doubly-magic ^{56}Ni nucleus, which can be populated in the $^{54}\text{Fe}(^3\text{He},n)^{56}\text{Ni}$ reaction and for which a lot of spectroscopic information is still missing.

The main goal of the Master Thesis work is to characterize the response of thin ^3He targets, produced using sputtering techniques, under the irradiation of an intense (~ 1 pA) heavy-ion beam of mass $A \sim 60$. The student will have the opportunity to follow the complete experimental process, from target installation, detector calibration and, eventually, in-beam characterization through data taking and analysis. Particular emphasis will be placed on understanding the target response under beam irradiation, the determination of the cross sections of the reaction of interest in the angular range covered by NEDA and the γ -ray spectroscopy of nuclei populated in the reaction.

The data analysis will be performed with modern programming languages (C++) and analysis frameworks (ROOT).





ERASMUS MUNDUS JOINT MASTER IN NUCLEAR PHYSICS

Academic Year 2026/2027

MASTER THESIS PROPOSAL

TITLE: Machine Learning for high-resolution ion tracking with the PRISMA spectrometer

SUPERVISOR(S): Daniele Brugnara, Franco Galtarossa

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UNIVERSITY/RESEARCH CENTER: INFN Laboratori Nazionali di Legnaro

ABSTRACT

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

PRISMA is a large-acceptance magnetic spectrometer designed to identify heavy ions produced in multinucleon-transfer reactions at energies of a few MeV/u. Recent experiments using very heavy ^{208}Pb and ^{238}U beams have demonstrated the promising capability of PRISMA to identify ions with masses $A > 200$, opening the possibility of accessing a largely unexplored region of the nuclear chart.

A key challenge is now to achieve a sufficiently precise and complete determination of the mass and charge distributions of these very heavy reaction products. Reaching this goal would pave the way towards high-resolution spectroscopy of nuclei far from the regions traditionally accessible to detailed experimental studies.

This thesis will address this challenge through the development of **Machine Learning techniques for ion trajectory reconstruction** inside the PRISMA spectrometer. The student will play a leading role in developing and testing new algorithms designed to improve the reconstruction of ion trajectories and, ultimately, push the current resolution limits of the spectrometer.

The project will combine **nuclear physics, ion optics, detector physics and modern Machine Learning methods**. Simulated ion trajectories, propagated through realistic magnetic-field maps, will first be used to investigate the performance of the existing reconstruction procedure and to develop improved ML-based approaches. The most promising methods will then be applied to experimental data collected during the **PRISMA-AGATA campaign in 2026**, providing a direct connection between the developed algorithms and real experimental measurements. The results are expected to provide material for publication in specialist nuclear-physics journals.

The project is particularly suited to students interested in the intersection of **experimental nuclear physics and Machine Learning**. Good programming skills in C++ are highly desirable.



ERASMUS MUNDUS JOINT MASTER IN NUCLEAR PHYSICS

Academic Year 2026/2027

MASTER THESIS PROPOSAL

TITLE: *Experimental test of prototypes for innovative batteries for Space, Medicine And Remote sensing applications*

SUPERVISOR(S): Francesco Cottone, Daniele Mengoni

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UNIVERSITY/RESEARCH CENTER: University of Padova, INFN Sezione di Padova and INFN Laboratori Nazionali di Legnaro, University of Perugia, FBK Trento

ABSTRACT

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

The conventional electrochemical batteries have limited longevity and a strong tendency to degrade under extreme environmental conditions. Hence, the need to develop nuclear betavoltaic devices, which are reliable, long-lived, high energy-density power sources for operating electrical systems in hostile and inaccessible environments. For situations where battery replacement is inconvenient or impossible, such as in remote sensing, space or medical applications and where low-power generation can be utilized, betavoltaic batteries are safe, clean and suitable alternative to electrochemical battery technologies. Other possible applications of betavoltaic batteries include implanted medical devices whose long lifespan of more than 30-40 years can improve life quality of patients due to reducing healthcare costs and eliminating periodical invasive surgeries for maintenance. In current state, the simulated maximum efficiency for the Si-based beta cells is 13.7% whereas in real devices it is mostly below 1%. In order to understand how to enhance the efficiency of such devices.

The candidate will be engaged in custom simulation using a python code to calculate the drift diffusion processes in materials irradiated by beta rays. Moreover, the student will be measuring experimental values of power to compare with the simulated values at the SEM microscope at LNL-INFN, producing electrons with and intensity of 20 nA at energies up 20 keV. Finally, the student will participate in prototype detector production at University of Perugia and FBK Trento.

ERASMUS MUNDUS JOINT MASTER IN NUCLEAR PHYSICS

Academic Year 2026/2027

MASTER THESIS PROPOSAL

TITLE: *Quantum Entanglement in Nuclear Systems*

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UNIVERSITY/RESEARCH CENTER: University of Padova, INFN Sezione di Padova and INFN Laboratori Nazionali di Legnaro

ABSTRACT

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

Context and motivation. A recent analysis of AGATA data showed that the 511 keV photon pairs from ^{22}Na have a correlation parameter significantly incompatible with the non-entangled hypothesis, but not fully matching the expected entangled value, so the result is not conclusive. Detector positions and orientations were not recorded in the data and had to be reconstructed a posteriori, introducing an uncertainty that is hard to quantify. For ^{214}Po , the statistics on the cascade transitions are too low to draw a firm conclusion. A dedicated measurement with a known, controlled geometry is therefore needed.

Objective. The student will contribute to the design, construction and characterization of a setup based on gamma-ray tracking detectors used as Compton polarimeters, in order to measure the polarization correlation function and test the Bell-CHSH inequality on two systems. The first is the 511 keV photon pair from para-positronium annihilation in ^{22}Na , measured in a back-to-back configuration extended with additional detectors; the three-photon decay of ortho-positronium may also be explored. The second is a photon pair from a gamma-ray cascade in calibration sources. The work will be carried out at INFN-LNL and the University of Padova.



ERASMUS MUNDUS JOINT MASTER IN NUCLEAR PHYSICS

Academic Year 2026/2027

MASTER THESIS PROPOSAL

TITLE: Impact of the Hoyle state in nuclear structure and reactions

SUPERVISOR(S): L. Fortunato (UNIPD) and J. A. Lay (USE)

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UNIVERSITY/RESEARCH CENTER: University of Padova and University of Seville.

ABSTRACT

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

The Hoyle state in ^{12}C nucleus takes a prominent position in Nuclear Physics research, since its key role in the formation of ^{12}C via the so-called triple-alpha reaction, taking place mainly in stellar environment.

Carbon-12 is a crucial $N = Z$ system which, even after decades of experimental and theoretical efforts, continues to defy our nuclear structure knowledge. In particular, alpha clustering in ^{12}C is a topic that continuously attracts substantial interest, with influence not only on the energy spectrum, but also on reaction dynamics.

In this thesis, we will explore different ways to analyze alpha clustering and the role of the Hoyle state in different structure and reaction cases. We will follow the algebraic cluster model for three alpha particles, characterized by rotations and vibrations that give rise to different bands based on discrete symmetries. From this model, we will calculate transition densities that can be later used to model reactions like $^{12}\text{C} + \alpha/p$ or nuclear structure of nearby nuclei like ^{13}C as a $^{12}\text{C} + n$ system. We will dig in the sensitivity of the obtained observables with respect to the properties of the Hoyle state in this algebraic system.



ERASMUS MUNDUS JOINT MASTER IN NUCLEAR PHYSICS

Academic Year 2026/2027

MASTER THESIS PROPOSAL

TITLE: Reaction dynamics studies with weakly-bound Radioactive Ion Beams at near-barrier energies

SUPERVISOR(S): Marco Mazzocco, Anna Togni

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UNIVERSITY/RESEARCH CENTER: University of Padova / Laboratori Nazionali di Legnaro

ABSTRACT

Weakly bound nuclei typically give rise to a wider variety of nuclear processes than well-bound nuclei. Due to their low binding energy, they can more easily undergo breakup or transfer one of their constituent clusters when approaching a target nucleus. Within this framework, we studied the interaction of a ^7Be radioactive ion beam with a ^{208}Pb target at a beam energy of 40 MeV, corresponding approximately to the Coulomb barrier of the reaction. The goal of the experiment was to shed light on the reaction dynamics at near-barrier energies by means of particle–gamma correlations between projectile fragments and gamma rays emitted by target-like fragments. The experiment was performed at the Laboratori Nazionali di Legnaro, where the ^7Be radioactive beam was provided by the EXOTIC facility, while charged particles and gamma rays were detected with the SAURON and AGATA detector arrays, respectively.





ERASMUS MUNDUS JOINT MASTER IN NUCLEAR PHYSICS

Academic Year 2026/2027

MASTER THESIS PROPOSAL

TITLE: Gamma-ray spectroscopy of exotic fission fragments

SUPERVISOR(S): Andrea Gottardo, José Javier Valiente-Dobon

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UNIVERSITY/RESEARCH CENTER: INFN-LNL, University of Padova, IFIC

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 work on the analysis of an experiment to study exotic nuclei above ^{78}Ni , the most doubly-magic neutron-rich nucleus known. The experiment was performed with the AGATA-PRISMA setup at LNL using a ^{238}U impinging on a Be target mounted on a “plunger” device. The fission products of interest were identified event-by-event in PRISMA and the coincidence with the state-of-the-art gamma-ray array AGATA will allow to measure the lifetimes of excited states in exotic nuclei, helping to understand both the $N=50$ gap evolution and the emergence of shape coexistence in the region. The student will become familiar with the RDDS technique to measure ps-scale lifetimes of nuclear levels, applying it to some of the exotic nuclei populated in the fission reaction. During the internship at LNL, he will have the opportunity to participate to the AGATA physics campaign at LNL working hands-on on the AGATA array and ancillary detector preparation.



ERASMUS MUNDUS JOINT MASTER IN NUCLEAR PHYSICS

Academic Year 2026/2027

MASTER THESIS PROPOSAL

TITLE: Study of heavy-flavour production in light- and heavy-ion collisions with the ALICE experiment at the CERN LHC

SUPERVISOR(S): Andrea Rossi, Mattia Faggin

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UNIVERSITY/RESEARCH CENTER:
Padua University

ABSTRACT

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

High-energy collisions of heavy nuclei allow us to create and study in the laboratory a form of matter known as the quark–gluon plasma (QGP), which characterised the Universe during the first few microseconds after the Big Bang. While substantial evidence for the formation of this state of matter has been obtained in heavy-nucleus collisions, many of its properties remain to be determined. In particular, the connection between the global features of the medium’s evolution, described by relativistic hydrodynamics, and the microscopic interactions among its constituent quarks and gluons still relies on theoretical assumptions that are not yet well constrained. The study of heavy-flavour hadron production, i.e. the production of hadrons containing a charm or beauty quark, plays an important role in understanding and modelling this connection. Collisions of lighter nuclei, such as oxygen–oxygen (OO) collisions, allow us to investigate, in smaller systems, the onset of phenomena associated with the formation of an extended QGP.

The thesis project involves analysing data collected by the ALICE experiment at the CERN LHC in Pb–Pb, OO, or proton–proton collisions to measure the production of hadrons containing charm or beauty quarks. The analysis employs techniques widely used in high-energy particle and nuclear physics to extract rare particle-decay signals, including particle identification, vertex reconstruction, invariant-mass analysis, and machine learning for background rejection. The student will work within the ALICE team at the Physics and Astronomy Department of the University of Padua, collaborating with researchers of the Padua division of the National Institute for Nuclear Physics (INFN). The student may be given the opportunity to visit CERN.



ERASMUS MUNDUS JOINT MASTER IN NUCLEAR PHYSICS

Academic Year 2026/2027

MASTER THESIS PROPOSAL

TITLE: Breaking the mirror: exploring the exotic nucleus ^{57}Zn beyond doubly-magic ^{56}Ni

SUPERVISOR(S): Kseniia Rezyunkina

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UNIVERSITY/RESEARCH CENTER: INFN Sezione di Padova & Dipartimento di Fisica e Astronomia "Galileo Galilei" Università degli Studi di Padova

ABSTRACT

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

Thesis with possible participation in experimental campaigns at the Accelerator Laboratory of the University of Jyväskylä (Finland) and LNL-INFN (Italy).

Are protons and neutrons really twins? To the strong nuclear force, protons and neutrons are almost the same particle: apart from its electric charge, a proton behaves much like a neutron. This symmetry, called isospin, means that a nucleus and its "mirror" twin (with proton and neutron numbers swapped) should manifest the same structure. The small differences that do appear reveal how and why this symmetry is broken, which makes them a stringent test of our understanding of nuclear structure and of the nuclear interaction.

^{57}Zn , with three more protons than neutrons, sits right next to doubly-magic ^{56}Ni , close to the proton drip line. Its mirror partner ^{57}Co is well known, but no excited states of ^{57}Zn have been observed so far, since they are challenging to produce experimentally.

The student will analyse the new data on ^{57}Zn from an experiment performed at the Accelerator Laboratory of the University of Jyväskylä (Finland) with the JUROGAM 3 array of HPGe detectors coupled to the MARA spectrometer. The analysis will provide the first measurement of the production cross-section for this exotic reaction channel and new insight into the structure of ^{57}Zn , to be compared with state-of-the-art theoretical models.

The work will be carried out in the nuclear structure group of the University of Padova and INFN Padova, within an international collaboration, and offers hands-on training in spectroscopy and advanced data analysis.



ERASMUS MUNDUS JOINT MASTER IN NUCLEAR PHYSICS

Academic Year 2026/2027

MASTER THESIS PROPOSAL

TITLE: Development and characterisation of prototype neutron detectors for time-of-flight spectroscopy at LNL

SUPERVISOR(S): Kseniia Rezyunkina, Jaime Benito

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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).

Neutrons emitted in nuclear reactions carry direct information on the structure of the nuclei produced, including exotic systems far from stability. Measuring their energy with high precision, however, requires dedicated detectors combining excellent timing, efficient neutron- γ discrimination and sensitivity down to low neutron energies. A new neutron time-of-flight spectrometer is being designed for future experiments at the Legnaro National Laboratories (LNL-INFN).

Within this project, the student will assemble and characterise prototype detectors based on novel plastic scintillators with pulse-shape discrimination capability, read out by photomultiplier tubes and digital electronics. The measurements will first use radioactive sources to calibrate the detector response, and then neutron beams from an accelerator at LNL. They will determine the key performance parameters: time resolution, neutron- γ separation, energy resolution and detection efficiency. Comparing different scintillator materials and geometries will provide the experimental benchmarks that define the final design of the spectrometer.

The work will be carried out in the nuclear structure group of the University of Padova and INFN Legnaro. It offers the opportunity to take part in all stages of a detector development project, from assembly and testing to data analysis and interpretation. The project suits students interested in experimental nuclear physics who enjoy hands-on laboratory work with detectors, electronics and data acquisition.