JOINT EUROPEAN MASTER IN NUCLEAR PHYSICS
Academic Year 2025/2026

MASTER THESIS PROPOSAL

TITLE: Measurement of heavy-flavour hadron production in proton and nuclear collisions at the LHC with ALICE

SUPERVISOR(S): Dr . Andrea Rossi (INFN), Prof. Serena Mattiazzo, Dr. Mattia Faggin (INFN, co-supervisor)

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UNIVERSITY/RESEARCH CENTER: Physics and Astronomy Department of Padua University

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

When nuclei are collided at very high energies at the CERN LHC, matter passes for a very short time through a quark-gluon plasma (QGP) phase, in which, as in the Early Universe, quarks and gluons are not confined into hadrons. Charm and beauty quarks are excellent probes of the QGP because they can be used as tracers of the partonic interactions ongoing in this expanding medium. Measurements of the momentum and angular distributions of mesons and baryons containing these quarks in nuclear and proton-proton collisions constrain the QGP transport properties, the mass dependence of quark energy loss, and the quark-to-hadron transition.
The student will analyse data collected by the ALICE experiment and learn how these short-lived particles are identified by reconstructing their decays. State-of-the art particle-identification techniques and vertexing techniques exploiting the high-resolution silicon-pixel tracker will be used together with machine-learning algorithms to reject the huge combinatorial background.

JOINT EUROPEAN MASTER IN NUCLEAR PHYSICS
Academic Year 2025/2026

MASTER THESIS PROPOSAL

TITLE: Characterization of MAPS prototypes for the ALICE ITS3

SUPERVISOR(S): Prof. Serena Mattiazzo

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UNIVERSITY/RESEARCH CENTER: University of Padova (Italy)

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

During Long Shutdown 3 (LS3) (2026-28), the ALICE experiment at CERN is replacing its innermost three tracking layers with a new detector, the Inner Tracking System 3 (ITS3). It will be based on newly developed wafer-scale monolithic active pixel sensors, which are bent into truly cylindrical layers and held in place by light mechanics made from carbon foam. After a successful R&D phase 2019-2023, which demonstrated the feasibility of this innovative detector, the final sensor and mechanics are being developed right now. The student will contribute to the test of the MOSAIX, the prototype for the final full-functionality sensor of the upgraded ALICE ITS3, which uses 1D-stitching of sensor tiles on a wafer-scale chip to create a very thin (50µm), large-area (≈26×2 cm^2) sensor.

JOINT EUROPEAN MASTER IN NUCLEAR PHYSICS
Academic Year 2025/2026

MASTER THESIS PROPOSAL

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

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

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UNIVERSITY/RESEARCH CENTER:

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INFN - Laboratori Nazionali di Legnaro, viale dell'Università 2, I-35020 Legnaro (Padova, Italy)

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 $^{12}C + ^{16}O$ 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 $^{12}C + ^{16}O$, 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 taken care of the first phase of the data analysis.

JOINT EUROPEAN MASTER IN NUCLEAR PHYSICS
Academic Year 2025/2026

MASTER THESIS PROPOSAL

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

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).

The excitation function for elastic and quasi-elastic scattering at backward angles will be measured, for the system ^{64}Ni + ^{238}U at several energies from ≃10% below to ≃10% above the Coulomb barrier. This will be done by detecting the Ni-like ions in the angular range $\theta_{lab} \simeq 132^{\circ}$–$156^{\circ}$, 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}Ni + ^{238}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 MASTER IN NUCLEAR PHYSICS
Academic Year 2024/2025

MASTER THESIS PROPOSAL

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

SUPERVISOR(S): Daniele Mengoni

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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).

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 the simulation using Montecarlo code to explore suitable beta emitters and the interaction of beta rays with materials, by determining the energy deposition and penetration depth. Moreover, the candidate will be finding the best geometrical configuration for the battery, using the complementary COMSOL suite, able to model the key components of the semiconductor device and its power yield by using finite element numerical calculations. Finally, the student will be measuring experimental values of power to compare with the simulated values at the SEM setup at LNL-INFN

JOINT EUROPEAN MASTER IN NUCLEAR PHYSICS
Academic Year 2025/2026

MASTER THESIS PROPOSAL

TITLE: Quantum Entanglement in Open Nuclear Systems

SUPERVISOR(S): Daniele Mengoni (University of Padova), Lorenzo Fortunato (University of Padova), Tomohiro Oishi (RIKEN, Japan)

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UNIVERSITY/RESEARCH CENTER: University of Padova and INFN Padova, and INFN Legnaro National Laboratory

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

For the Master Thesis, the student will explore experimental and theoretical aspects of studying spin entanglement in nuclei undergoing two-proton (2p) radioactive decay.

The research will focus on investigating the potential violation of Bell's inequalities and the role of spin correlations in these decay processes. The student will explore the concept of spin entanglement and its implications in nuclear physics. They will study theoretical models that describe 2p decay and the associated spin correlations, with a particular emphasis on the 6Be = alpha + 2p system.

The experimental component of the thesis will involve designing and simulating an experiment to study spin entanglement in the 7Be(p,d)6Be → alpha+p+p reaction. The student will assess the feasibility of conducting such an experiment, considering the required beam characteristics, such as a 7Be beam with an intensity of approximately 10^5 particles and an energy of 10 MeV/A, by performing realistic Montecarlo simulations, to evaluate the level of statistics and the opening angle plus energies of the two emitted protons.

To this aim the student will perform coupled-channels calculations, employing codes like FRESCO, to estimate the cross-sections for the (p,d) reaction on 7Be. These calculations will aid in evaluating the feasibility of the proposed experiment. The data analysis will involve studying angular distributions for different angular momentum values (L) and extracting correlations between the spin projections (s1_z, s2_z) for each L value. The student will verify the adherence to momentum conservation rules and assess the potential violation of Bell's inequalities, which would

indicate the presence of spin entanglement.

Motivation, independence and proficiency in programming are essential qualities for successfully carrying out this research.

JOINT EUROPEAN MASTER IN NUCLEAR PHYSICS
Academic Year 2025/2026

MASTER THESIS PROPOSAL

TITLE: Nuclear Astrophysics: Cross section measurements at LUNA in Underground

SUPERVISOR(S): A. Caciolli, D. Piatti

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UNIVERSITY/RESEARCH CENTER: University of Padua (Host) – Laboratory of Gran Sasso (to participate the experimental shifts for about two weeks during the thesis)

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

This thesis focuses on cross section measurements in Nuclear Astrophysics conducted at the LUNA underground facility. The research aims to enhance our understanding of stellar nucleosynthesis and evolution. Students actively participate in all aspects of the experimental setup construction and data analysis, gaining hands-on experience in detector assembly, data acquisition, and target preparation. This comprehensive approach contributes to the field while developing crucial skills in experimental nuclear physics and data interpretation.

JOINT EUROPEAN MASTER IN NUCLEAR PHYSICS
Academic Year 2025/2026

MASTER THESIS PROPOSAL

TITLE: Experimental study of semi-magic exotic mirror nuclei

SUPERVISOR(S): Francesco Recchia, Kseniia Rezynkina

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UNIVERSITY/RESEARCH CENTER: Laboratory of Jyvaskyla (Finland) and University of Padova (Italy)

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 travel for 15 days to Jyvaskyla, Finland, in order to participate to the experiment in JYFL laboratory, aiming to study the excited structure of 37Ca. The aim of this study is to probe the fundamental symmetry of nuclear structure, the isospin symmetry, by comparing the structure of 37Ca to its T=3/2 mirror partner, 37Cl. The impact of this isospin symmetry is maximal near the N = Z line, where protons and neutrons occupy the same orbitals. This symmetry is violated by the electromagnetic interaction, which is in turn charge-dependent.
The mirror energy differences for the analogue states characterized by the same isospin can be strongly enhanced by the Coulomb effects, acting as a magnifying glass for any proton-neutron asymmetry. In order to extend the level scheme of 37Ca, a fusion-evaporation reaction between 28Si beam and the 12C target will be used; the reaction products will be studied with the JUROGAM III - MARA spectrometer. The thesis work will consist in the preliminary analysis of the data, and the extraction of the reaction cross-section.

ERASMUS MUNDUS JOINT MASTER DEGREE IN NUCLEAR PHYSICS

Co-funded by the Erasmus+ Programme of the European Union

ERASMUS MUNDUS MASTER IN NUCLEAR PHYSICS
Academic Year 2024/2025

MASTER THESIS PROPOSAL

TITLE: Exploitation of unsupervised artificial neural networks for particle identification with silicon detectors in nuclear physics and astrophysics.

SUPERVISOR(S): Daniele Brugnara
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UNIVERSITY/RESEARCH CENTER: Laboratori Nazionali di Legnaro, INFN-LNL, and University of Padova.

ABSTRACT

The identification of light charged particles emitted from a nuclear reaction is a crucial aspect for most experiments in nuclear physics. In the case of silicon detectors, the identification is usually performed with several techniques such as correlating the maximum current (the derivative of the collected charge) with the total energy.
We propose to study the performance of artificial neural networks for the discrimination of different charged particles in silicon detectors. The student will have access to several datasets and a code developed for supervised network. The student will be able to evaluate the outcomes of different approaches such as:

- Unsupervised learning: exploiting the autoencoder topology to extract features from the charge signal that could lead to the separation of different particles. This approach can be particularly useful for detectors that do not measure the partial deposited energy.