ERASMUS MUNDUS MASTER IN NUCLEAR PHYSICS

Academic Year 2020/2021

MASTER THESIS PROPOSAL

TITLE: **Feasibility study of an imaging charge exchange recombination spectroscopy diagnostic for the Wendelstein 7-X stellarator**

SUPERVISOR(S): Eleonora Viezzer

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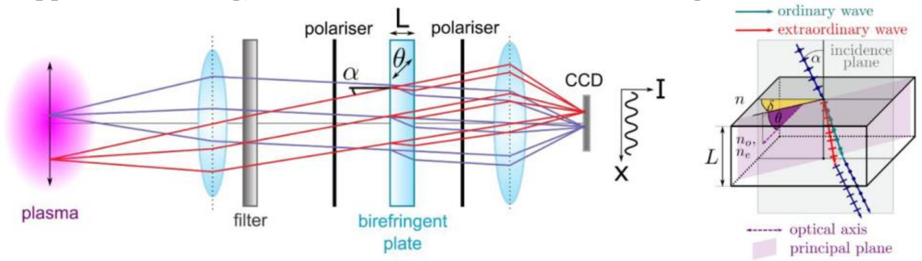
UNIVERSITY/RESEARCH CENTER: University of Seville

ABSTRACT

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

Doppler Coherence Imaging Spectroscopy (CIS) is a camera-based passive diagnostic technique. It measures a two-dimensional plasma image modulated with an interference fringe pattern, which encodes the spectral function of the observed plasma light. The spectral function of an atomic emission line determines its coherence, therefore basic spectral properties can be derived from the interference pattern, such as the line emission, the central position of a (Doppler-shifted) emission wavelength and the broadening of that wavelength along the line-of-sight of the camera. Since the emission lines are emitted by the atomic shells of moving ions in a plasma, these three quantities could be used to derive the line density, averaged speed of the ions along the line-of-sight and the ion temperature (from Doppler broadening) [1]. An overview is shown in the figure below:



In this master thesis we will perform a feasibility study of a charge exchange recombination spectroscopy (CXRS) CIS diagnostic for the W7-X stellarator in Greifswald, Germany. In collaboration with the Max Planck Institute for Plasma Physics in Greifswald and the W7-X Team we will simulate and optimize the optical setup to be able to study impurity intensities and flows along the flux surfaces. The feasibility study will be the base for the design of a new CXRS-CIS diagnostic for the W7-X stellarator.

[1] D.Gradic, "Doppler Coherence Imaging of Ion Dynamics in the plasma experiments VINETA.II and ASDEX Upgrade," PhD thesis, Technische Universität Berlin, Berlin, 2018.

ERASMUS MUNDUS MASTER IN NUCLEAR PHYSICS
Academic Year 2020/2021

MASTER THESIS PROPOSAL

TITLE: **Modelling and control of vertical displacement events in the SMART tokamak employing highly shaped equilibria**

SUPERVISOR(S): S. J. Doyle, M. Garcia-Munoz

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UNIVERSITY/RESEARCH CENTER: Dept. of Atomic, Molecular and Nuclear Physics, University of Seville, Seville, Spain

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

The modeling of plasma equilibria is a fundamental aspect of tokamak physics, enabling predictions of plasma shaping and MHD-stability in magnetic confinement devices. Magnetically confined plasmas are subject to a wide range of instabilities leading to energy losses. One such instability, the Vertical Displacement Event (VDE), consists of a rapid uncontrolled vertical movement of the plasma column, leading to quenching of the plasma current and complete loss of confinement. This project will assess the growth and evolution of VDEs within the *SMall Aspect Ratio Tokamak* (SMART) device; a novel compact (R_{geo} = 0.42 m, a = 0.22 m, A > 1.71) spherical tokamak, currently in development at the University of Seville. A thorough study of simulated VDE growth rates γ, current quench timescales τ_{cq}, and resulting vessel eddy currents I_{eddy}, will be undertaken for a wide range of equilibrium configurations (elongation $\kappa < 2.0$ and triangularity $-0.50 < \delta < +0.47$). Simulations will be performed employing a 2D axisymmetric Grad-Shafranov force balance solver (Fiesta), in combination with a circuit equation rigid current displacement model (RZIp) to obtain time-resolved vessel and plasma currents. Analysis of VDEs in the SMART device will enable vessel optimisation to enhance passive mitigation, and the development of an active vertical control system capable of VDE suppression.

ERASMUS MUNDUS MASTER IN NUCLEAR PHYSICS

Academic Year 2020/2021

MASTER THESIS PROPOSAL

TITLE: **Renormalization group for relativistic Bose gases**

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UNIVERSITY/RESEARCH CENTER: Universitat de Barcelona

ABSTRACT

At sufficiently low temperatures, systems of interacting bosons can form a novel state of matter known as a Bose-Einstein condensate. In relativistic contexts, one of the simplest systems to study condensation is the interacting Bose gas [1]. Even though relativistic Bose gases have not been produced experimentally, they can be used as an approximate model for a meson condensate [2].

In this project, the student will study a relativistic Bose gas within quantum field theory using the functional renormalization group [3]. The student is expected to learn general aspects of effective field theory, spontaneous symmetry breaking, and many-body systems. The project builds upon a previous work [4], and during its course, the student will be required to program in a symbolic language.

The project will take place at the Institute of Cosmos Sciences of the University of Barcelona, where the student will join the Hadronic, Nuclear and Atomic Physics group. Some knowledge of field theory and statistical mechanics is required.

[1] J. Bernstein and S. Dodelson, Phys. Rev. Lett. **66**, 683 (1991).
[2] M. Mannarelli, Particles **2**, 411 (2019).
[3] C. Wetterich, Phys. Lett. B **301**, 90 (1993).
[4] B. Krippa, J. Phys. G **44**, 075002 (2017).

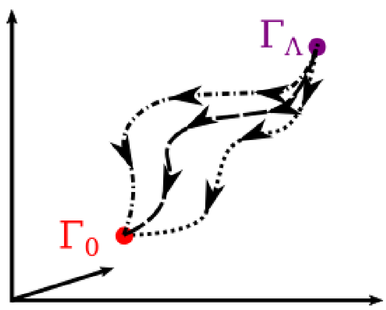

Fig: Illustration of the renormalization group flow of the effective action Γ.

ERASMUS MUNDUS MASTER IN NUCLEAR PHYSICS
Academic Year 2020/2021

MASTER THESIS PROPOSAL

TITLE: **Study of Low Gain Avalanche Detectors using ion beams**

SUPERVISOR(S): Javier Garcia Lopez
Mª Carmen Jimenez Ramos

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UNIVERSITY/RESEARCH CENTER: University of Sevilla / National Accelerator Center

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

This work is part of the international CERN RD 50 collaboration "*Radiation hard semiconductor devices for very high luminosity colliders*". The candidate will participate in the characterization of silicon low gain avalanche detectors (LGAD) using ion beams at the 3 MV Tandem accelerator of the CNA. The LGAD detectors present intrinsic gain due to the multiplication layer implanted below the cathode in which the electric field is enhanced significantly. The goal will be to measure the gain vs. applied voltage curve for ions with different stopping powers, to study possible plasma effects. The work will include both experimental measurements and simulations of the current pulses emitted by the detector. Therefore, candidates should have good knowledge of semiconductor detectors, as well as MATLAB programming language

ERASMUS MUNDUS MASTER IN NUCLEAR PHYSICS
Academic Year 2020/2021

MASTER THESIS PROPOSAL

TITLE: **Statistical analysis of hadron spectra produced in hot dense and vortical matter**

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UNIVERSITY/RESEARCH CENTER:
University of Barcelona, Department of Quantum Physics and Astrophysics

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

We will investigate the hadron production from the vortical quark-gluon plasma created in relativistic heavy-ion
collisions based on statistical hadronization model.

Recently measured at RHIC polarization of Λ and anti-Λ baryons [L. Adamczyk et al. [STAR Coll.], Nature 548, 62 (2017)] most researchers associate with vorticity of the matter created in the collision (QGP is the most vortex fluid observed to date!). However a recent study [H. Taya et al. [ExHIC-P Coll.] Phys. Rev. C102 (2020) 2, 021901] shows (qualitatively) that vorticity does not only generate polarization, but also affects the total number of produced hadrons and their spectra. We will test this result in a more quantitative way in a semi-analytical "toy model".

The student will have to study the statistical hadronization model and its modification in the presence of local vorticity; prepare the program for the production of hadrons of different types depending on temperature, baryon potential and flow vorticity; fit these parameters to reproduce "particle ratios" observed experimentally; analyze the vorticity effects in the model.

ERASMUS MUNDUS MASTER IN NUCLEAR PHYSICS
Academic Year 2020/2021

MASTER THESIS PROPOSAL

TITLE: **Monte Carlo simulations of AIDA implantation detector.**

SUPERVISOR(S): Alejandro Algora
Jose A. Victoria

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UNIVERSITY/RESEARCH CENTER:
IFIC (CSIC-Univ. Valencia)

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 exotic nuclei at fragmentation facilities requires implanting radioactive nuclei in silicon strip detectors. One example of such advanced detector is AIDA, a detector developed by the University of Edinburgh group for the DESPEC experiment at FAIR (Germany) that has been already used in many large facilities around the world. In this work we propose the realisation of Monte Carlo simulations (using GEANT4) of this detector and the study of the best conditions for selecting beta events from implantation experiments. Depending of the time available we can consider also the implementation of machine learning techniques for selecting valid decay events.
The work will be developed at IFIC (CSIC-Univ. of Valencia), Valencia, Spain.

ERASMUS MUNDUS MASTER IN NUCLEAR PHYSICS
Academic Year 2020/2021

MASTER THESIS PROPOSAL

TITLE: **INSTRUMENTATION AND MC SIMULATION TO IN-BEAM REAL TIME MONITORING OF DOSE DEPOSITION IN HADRONTHERAPY**

SUPERVISOR(S): Luis Mario Fraile, José Manuel Udías

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UNIVERSITY/RESEARCH CENTER:
Universidad Complutense de Madrid, Facultad de Ciencias Físicas and IPARCOS

ABSTRACT

Two clinical protontherapy beamlines began beam delivery early 2020 in Madrid. Within this MSc project instrumentation for real-time in-beam monitoring of dose delivered by hadrons would be developed, either by means of prompt gammas as well as prompt PET emission. The Nuclear Physics Group of Complutense University in Madrid has massive experience in the development of gamma detectors with state of the art spatial, energy and time resolution, and being based on SiPM, they are compatible with magnetic fields. The group exhibits a long standing collaboration with the company SEDECAL in Madrid that develops and sells nuclear imaging equipment all over the world and it is also involved in this project. The MSc project would be involved in MC simulations of the detectors, in the actual detector development in our lab, as well as in image reconstruction of dose delivered and experiments with phantoms at the CMAM proton accelerator in Madrid and/or Quiroon protontherapy center also in Madrid.

http://nuclear.fis.ucm.es
The work will be developed at the Physics School of Complutense University in Madrid.

ERASMUS MUNDUS MASTER IN NUCLEAR PHYSICS
Academic Year 2020/2021

MASTER THESIS PROPOSAL

TITLE: **Deep Learning approaches to treatment planning and dosimetry of radiotherapy of protons, photons and electrons**

SUPERVISOR(S): Paula Ibáñez, Joaquín López Herraiz, José Manuel Udías Moinelo

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UNIVERSITY/RESEARCH CENTER:
Universidad Complutense de Madrid, Facultad de Ciencias Físicas and IPARCOS

ABSTRACT

Recent developments in deep machine learning based on neural networks (NN) have opened new ways to compute the dose in patients undergoing radiotherapy treatments. Neural networks should be trained with hundreds or thousands of 'good' solutions of the problem at hand, in this case of the computed dose for a given treatment plan in a particular location. Monte Carlo dose calculations are the reference for in-patient dosimetry, but it involves a large computational burden, which makes it difficult to use it to compute the training sets for NN approaches. In our group we have developed a very fast Monte Carlo dose-calculation engine, running in modern GPUs, which is several thousand faster than the existing CPU codes. With the help of this tool, this project will evaluate the possibility to train and use NN to compute dose in several frequently encountered locations.

The work will be developed at the Physics School of Complutense University in Madrid.

ERASMUS MUNDUS MASTER IN NUCLEAR PHYSICS
Academic Year 2020/2021

MASTER THESIS PROPOSAL

TITLE: **Radiative capture reaction rates of astrophysical interest in a three-body model**

SUPERVISOR(S): Manuela Rodríguez Gallardo
José Antonio Lay Valera
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UNIVERSITY/RESEARCH CENTER: Universidad de Sevilla

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

We will estimate reaction rates for radiative capture processes that can have interest to explain the nucleosynthesis in different astrophysical scenarios. We will consider the formation of nuclei that can be studied in a three-cluster model. We will obtain the bound and continuum states of the nucleus in the three-body model and compute the electric and magnetic transition probabilities from the ground state to the excited states. Using these probabilities we will estimate the radiative capture reaction rate via the cross section of the inverse process, the photodissociation.

ERASMUS MUNDUS MASTER IN NUCLEAR PHYSICS
Academic Year 2020/2021

MASTER THESIS PROPOSAL

TITLE: **Analytic stability criteria for edge harmonic oscillations and comparison to ASDEX Upgrade data**

SUPERVISOR(S): Eleonora Viezzer, Lidia Piron

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UNIVERSITY/RESEARCH CENTER: 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).

Edge localized modes (ELMs) have a detrimental effect on the plasma facing components and pose one of the most serious obstacles for steady-state operation in a future fusion device. For future fusion machines, the control or even full suppression of ELMs is mandatory. Natural no-ELM are potential candidates as they feature many aspects required for the operation of ITER and future fusion devices. The Quiescent H-mode (QH-mode) is such a natural ELM-free high confinement regime characterized by an edge harmonic oscillation. In this work we will analyze the stability criteria for edge harmonic oscillations and compared to experimental data at the ASDEX Upgrade tokamak.

ERASMUS MUNDUS MASTER IN NUCLEAR PHYSICS
Academic Year 2020/2021

MASTER THESIS PROPOSAL

TITLE: **Machine learning for the interpretation of the edge main ion charge exchange spectra at the ASDEX Upgrade tokamak**

SUPERVISOR(S): Eleonora Viezzer, Pilar Cano Megías, L. Piron

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UNIVERSITY/RESEARCH CENTER: 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).

Charge exchange recombination spectroscopy (CXRS) is a widely extended technique to evaluate ion temperature and rotation in tokamaks [1]. The technique is based on the observation of spectral lines, typically fully-ionized impurities which emit light after a charge exchange reaction with diagnostic neutrals. The Doppler shift, width and intensity of the line allow for the evaluation of rotation, temperature and density, respectively [2]. The main ion spectra is rarely analyzed because its interpretation is substantially more complex than for impurities due to the halo effect. The halo is a thermal neutral population which is born in multiple generations after the first direct charge exchange (DCX) reaction between the thermal plasma and the diagnostic neutral.
The interpretation of the main ion D_α spectra strongly relies on forward modelling of the halo neutrals and their contribution to the spectra. The FIDASIM code [3,4] is an excellent tool for our purpose. FIDASIM is a Monte Carlo code that calculates the neutral density of several deuterium populations and its associated photoemission, so it can model all contributions to the main ion spectra.
The interpretation of the core main ion spectra has been speeded up by using look up tables based on FIDASIM simulations [5]. At the plasma edge, due to the steep gradients, a more time iterative approach is adopted. In this work, we want to explore the possibility of applying neural networks (NN) for the reconstruction of the edge main ion spectra measured at the ASDEX Upgrade tokamak. The goals of the work are to construct a database with FIDASIM and use it to train a neural network. This NN should be able to, given an experimental spectrum, resolve the underlying deuterium properties which are responsible for the spectra.

[1] J. Fonck *et al.* Phys. Rev. A, 29(6) (1984)
[2] E.Viezzer *et al.* Rev. Sci. Instrum. **83** 103501 (2012)
[3] W.W. Heidbrink *et al.* Commun. Comput. Phys. 10 716 (2011)
[4] B. Geiger, PhD thesis, LMU München (2013)
[5] B. Grierson *et al.*, Rev. Sci. Instrum 83, 10D529 (2012)

ERASMUS MUNDUS MASTER IN NUCLEAR PHYSICS
Academic Year 2020/2021

MASTER THESIS PROPOSAL

TITLE: **Geant4 simulation of an Elekta Versa HD treatment head equipped with Agility multi-leaf collimator**

SUPERVISOR(S): Miguel A. Cortés-Giraldo

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UNIVERSITY/RESEARCH CENTER: Universidad de Sevilla

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

In this work the student will develop a Geant4 application to simulate the treatment head of an Elekta Versa HD equipped with Agility multi-leaf collimator (MLC) installed recently at the Virgen Macarena University Hospital (HUVM, Seville, Spain). The student will create the geometry model using the technical information and blueprints provided by Elekta. The simulation outcomes will be benchmarked against reference dosimetric measurements carried out routinely at HUVM.

The student is expected to have some knowledge on the Geant4 Monte Carlo toolkit and C++ programming language. Further, knowledge on version control systems, especially Git, will be desirable, especially if remote supervision is recommended due to Covid-19 pandemic. Simulations will be carried out at our CentOS computing cluster installed at CICA (Seville, Spain).

ERASMUS MUNDUS MASTER IN NUCLEAR PHYSICS
Academic Year 2020/2021

MASTER THESIS PROPOSAL

TITLE: **"Interpretation of deuteron breakup data using the Ichimura, Austern, Vincent model and its implication in the deuteron polarizability"**

SUPERVISOR(S): Antonio M. Moro (US) /Jin Lei (Tongji Univ, Shanghai)

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UNIVERSITY/RESEARCH CENTER: University of Sevilla

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

The breakup of a nucleus into two or more fragments is an important mechanism occurring in nuclear collisions, particularly when one of the colliding nuclei is weakly bound. The analysis of this kind of processes has provided useful information on the structure of these nuclei, such as binding energies, spectroscopic factors and angular momentum, and has contributed to the understanding of the dynamics of the reactions among composite systems.

When all fragments arising from the projectile dissociation are measured the reaction is said to be exclusive. The observables measured in these reactions, such as the angular or energy distribution of the fragments, can be accurately described with available models, such as the continuum-discretized coupled-channel (CDCC) method, the most sophisticated Faddeev formalism, and a variety of semiclassical approximations.

A different scenario occurs when one or more fragments are not measured, in which case the reaction is said to be inclusive (with respect to the undetected fragments). The evaluation of the angular and energy distribution of the measured fragments becomes much more challenging because of the large number of possible contributing channels. In fact, the models developed to deal with these reactions are scarce and their accuracy not fully tested. One of these models, proposed in the 1980s by Ichimura, Austern and Vincent (IAV) [1] has been recently revisited and implemented by our group [2,3,4,5]. First calculations with this model have shown a very encouraging agreement with exiting data, but further systematic calculations are needed to better establish its accuracy and predictibility.

In this project, we propose to make use of this recent implementation of the IAV model to analyze existing inclusive breakup data, such as (d,px). In particular, we will study the ^{208}Pb(d,px) reaction, employing modern neutron-^{208}Pb dispersive potentials which account for both positive (unbound) and negative (bound) ^{209}Pb states. Calculations will be compared with recent data for this reaction. These results will be later used to study the sub-Coulomb deuteron elastic data in connection with the extraction of the deuteron polarizability.

Bibliography:

[1] Ichimura, Austern and Vincent , Phys. Rev. C 32, 431 (1985).
[2] J. Lei and A.M. Moro, Phys. Rev. C 92, 044616 (2015); ibid Phys.Rev. C 97, 011601 (2018); ibid Phys. Rev. C 95, 044605 (2017).
[3] G. Potel et al, Eur.Phys.J. A 53, 178 (2017).
[4] A.M. Moro et al,Acta Phys.Pol. B47, 821 (2016).
[5] A.M. Moro and J. Lei, Few-Body Systems 57, 319 (2016).

ERASMUS MUNDUS MASTER IN NUCLEAR PHYSICS
Academic Year 2020/2021

MASTER THESIS PROPOSAL

TITLE: **Gamma-ray detection system for breast cancer biopsy**

SUPERVISOR(S): Luis Caballero Ontanaya, phD

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email: Telephone:

UNIVERSITY/RESEARCH CENTER**: Instituto de Física Corpuscular (CSIC-Universidad de Valencia)**

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

The Master Thesis applicant will be enrolled in the nuclear medicine applications field in the GAMUS project developing a novel device for guiding the breast cancer biopsy procedure on real-time. This development will take place at the Instituto de Física Corpuscular in Valencia. The GAMUS hybrid system consists on the combination of an array of gamma-ray Compton detectors and an ultrasound probe. The applicant will work hands on this novel nuclear instrumentation participating in the gamma-ray detectors mounting, their individual and full system performance characterization as well as in the system configuration optimization through Monte Carlo simulations. Applicant will participate as well in the development of gamma-ray imaging tomographic algorithms (iterative, Machine Learning) for improving the gamma images obtained of the radionuclides distribution which, combined with the ultrasound images, will allow clinicians to guide the biopsy needle.

ERASMUS MUNDUS MASTER IN NUCLEAR PHYSICS
Academic Year 2020/2021

MASTER THESIS PROPOSAL

TITLE: **Monte Carlo event generators and the simulation of neutrino-nucleus interaction**

SUPERVISOR(S): José Manuel Udías Moinelo and Raúl González Jiménez

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UNIVERSITY/RESEARCH CENTER:
Universidad Complutense de Madrid, Facultad de Ciencias Físicas

ABSTRACT

Why the Universe is made of matter instead of matter and antimatter in equal proportions? What is the nature and origin of dark matter? The answers to these and other fundamental questions could be in the neutrino oscillation. This phenomenom, which shows that netrinos have mass, has opened the door to Physics beyond the Standard Model of Particle Physics and placed the study of these particles in one of the frontiers of the knowledge. DUNE (https://www.dunescience.org/) and Hyperkamiokande (http://www.hyperk.org/) are the two main projects that represent the community medium and long term plans.

Monte Carlo (MC) neutrino event generators are a fundamental tool in these neutrino oscillation experiments. They are the necessary bridge between what is experimentally measured in the detectors and what one wants to determine (the neutrino properties). One of the roles of the MC generators is to simulate the interaction between the neutrino (projectile) and the target nucleus (detector), typically: oxygen (from water), carbon (from mineral oils) and argon (liquid argon detectors).

The goals of this work will be:
1) Familiarization with different theoretical models for neutrino-nucleus interaction.
2) Familiarization with one of the MCs used by the community for the propagation of hadrons in the nuclear medium: NuWro, GENIE, ...
3) Implementation of theoretical models in the MC event generator.

The work will be developed at the Physics Faculty of Complutense University in Madrid.

ERASMUS MUNDUS MASTER IN NUCLEAR PHYSICS

Academic Year 2020/2021

MASTER THESIS PROPOSAL

TITLE: **Parity violating electron scattering: a door to physics beyond the Standard Model**

SUPERVISOR(S): Raúl González Jiménez and Óscar Moreno Díaz

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UNIVERSITY/RESEARCH CENTER:
Universidad Complutense de Madrid, Facultad de Ciencias Físicas

ABSTRACT

Electron-proton scattering occurs via the electromagnetic (EM) and weak neutral current (WNC) interactions. Since the EM interaction is around 5 orders of magnitude stronger than the WNC one, it is a real challenge to find effects related to the weak interaction in this process. The "parity violating asymmetry" is one of the quantities that allows for that. It is defined as the difference between the cross sections for electrons polarized with opposite helicities and it is only different from zero due to the role played by the WNC interaction. Recently, the Qweak experiment published in Nature (https://doi.org/10.1038/s41586-018-0096-0) the highest precision measurement of this quantity to date. The results show that this kind of measurements enables searches of physics beyond the Standard Model.

This project has strong connections with different fields in Physics:
+ Hadron physics: structure of the nucleons and nucleon resonances (form factors).
+ Particle physics: neutrino oscillations, and electroweak interactions within Standard Model.
+ Nuclear physics: using nuclear targets instead of hydrogen.

The work will be developed at the Physics Faculty of Complutense University in Madrid.

ERASMUS MUNDUS MASTER IN NUCLEAR PHYSICS
Academic Year 2020/2021

MASTER THESIS PROPOSAL

TITLE: **High-resolution gamma-ray spectroscopy at relativistic energies**

SUPERVISOR(S): Andrea Jungclaus

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email: Telephone:

UNIVERSITY/RESEARCH CENTER: IEM (Madrid)

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

In this project, the candidate will learn how to analyse data taken in a state-of-the-art experiment in experimental nuclear physics. Taking advantage of the high energy resolution offered by the array of segmented Ge detectors HiCARI, an experiment has been conducted at the Radioactive Isotope Beam Factory (RIBF) at RIKEN (Tokyo, Japan) in November 2020 to study nuclei in the region around doubly-magic 132Sn. The radioactive beams of interest were produced in the projectile fission of a 238U beam at relativistic energies, separated and identified by the BigRIPS spectrometer and finally induced secondary reactions (nucleon removal and inelastic scattering) on light and heavy targets.

ERASMUS MUNDUS MASTER IN NUCLEAR PHYSICS
Academic Year 2020/2021

MASTER THESIS PROPOSAL

TITLE: **Study of isomeric states with microscopic theories**

SUPERVISOR(S): Luis M. Robledo, Tomás R. Rodríguez

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UNIVERSITY/RESEARCH CENTER: Universidad Autónoma de Madrid / Departamento de Física Teórica.

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

The atomic nucleus is a system made of protons and neutrons that interact through complex nuclear forces. Due to its quantum nature, the bound states of the nucleus are discrete energy levels. Then, the excited states decay with very short half-lives to lower levels emitting gamma radiation. However, there are certain states whose decay probability is very small due to their structural characteristics. These are the so-called isomeric states and they are very relevant in Experimental Nuclear Physics and Astrophysics.
In this Master's Thesis work, we propose the study of isomeric states with state-of-the-art techniques to solve the nuclear many-body problem from a microscopic approach.

ERASMUS MUNDUS MASTER IN NUCLEAR PHYSICS
Academic Year 2020/2021

MASTER THESIS PROPOSAL

TITLE: **Modelling the activation at CMAM**

SUPERVISOR(S): Sílvia Viñals and Gastón García

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UNIVERSITY/RESEARCH CENTER: Centro de Micro-Análisis d eMateriales (CMAM) - Universidad Autónoma de Madrid

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

At CMAM there is a Coaxial Tandetron Accelerator of 5MV with two ion sources that allows to produce different ions, from H to Au. Nowadays, the External Microbeam line (EuB) is involved in experiments that require high-energy protons (10 MeV) and other beams that can produce activation in the line and the samples.
The master project will be focused on doing a spectroscopic study of the elements that are already activated in the line and deduce how the activations were produced, modelling this phenomenon with the conditions of the center. The contribution of this study will be a decalogue of the “forbidden elements” in the relevant beam optics elements to avoid or minimize activation.

ERASMUS MUNDUS MASTER IN NUCLEAR PHYSICS
Academic Year 2020/2021

MASTER THESIS PROPOSAL

TITLE: DECAY OF S=-2 HYPERNUCLEI

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LAURA TOLÓS

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UNIVERSITY/RESEARCH CENTER: UNIVERSITAT DE BARCELONA (A. Parreño)
INSITUTE OF SPACE SCIENCES, CSIC (L. Tolós)

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

Hypernuclei are bound systems of conventional nucleons and strange baryons (hyperons) which are unstable against the weak interaction, decaying through processes which do not conserve parity, isospin nor flavor. The study of such systems broadens our knowledge of the fundamental strong and weak interactions from the flavor SU(2) sector to the SU(3) one. Being Λ-hypernuclei the lighter strange nuclei that can be produced in experiments, the study of their structure and decay have focused most of the experimental and theoretical efforts for more than 60 years. Recently, attention has moved to doubly strange nuclei, with an experimental program devoted to the production of ΛΛ- and Ξ-hypernuclei, including laboratories in Europe, USA and Japan. In this work we propose to extend existent theoretical work for the decay of such strangeness -2 systems, including a complete description of the effects of the strong interaction in the decay mechanism.

ERASMUS MUNDUS MASTER IN NUCLEAR PHYSICS

Academic Year 2020/2021

MASTER THESIS PROPOSAL

TITLE: **Nested Sampling for Nuclear Quantum Effects**

SUPERVISOR(S): Fabio FINOCCHI, Martino TRASSINELLI, Antonio PRADOS MONTAÑO

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UNIVERSITY/RESEARCH CENTER:
Insitut des NanoSciences de Paris, Sorbonne Université and CNRS, France
and
Department of atomic, molecular and nuclear Physics, University of Seville, Spain

ABSTRACT

Here we propose a Master thesis at the crossing point between applied mathematics and theoretical physics for studying complex quantum phenomena in materials containing light nuclei for which nuclear quantum effects (NQE: zero-point energy, tunneling, etc.) cannot be neglected. We aim at developing machine-learning based techniques for cluster recognition in the nested sampling algorithm to probe complex potential energy surfaces with specific focus to their topology.

The reference methods to study NQE rely on the computationally demanding Feynman path-integrals in conjunction with a thorough configurational space sampling. Potential energy surfaces of interest display several local minima and high dimensionality, which makes most sampling algorithms converge with difficulty. The recognition of cluster structures of the sampling points will be crucial to identify the minima and other relevant extrema. The master. thesis working plan starts with the development of nested sampling including unsupervised cluster recognition to effectively explore classical Lennard-Jones systems, where many local minima are present. Once the specific methods are validated, nuclear quantum effects will be included. The identification and classification of the very many isomers, whose stability can be upset by NQE, is a stringent test for machine-learning methods. Making the most of the experience gained in Lennard-Jones systems, we will implement the methods to cases of high interest in chemistry and physics, such as H-containing clusters and hydrogen diffusion in real materials, where NQE play a significant yet still largely unknown role.

Presently, few groups worldwide are working on the calculation of the quantum free energy by advanced sampling methods that are largely inspired from statistical mechanics. Here, we adopt an original viewpoint, taking advantage of nested sampling with machine learning via cluster recognition to evaluate free energy minima including NQE. This project stems from the conjunction of two complementary skills: one of us (MT) uses cluster recognition methods in nested sampling for Bayesian data analysis; the other (FF) is developing and using several approaches to investigate NQE in several materials. We look for a student with a solid mathematical background, who is motivated by machine-learning applications; a good knowledge of statistical mechanics is a plus.

Techniques involved: Machine learning methods, Nested sampling, Cluster recognition, Feynman path integrals
Location: Institut des NanoSciences de Paris, Sorbonne Université, Campus Pierre et Marie Curie, 4 Place Jussieu,

75005 Paris, France

ERASMUS MUNDUS MASTER IN NUCLEAR PHYSICS
Academic Year 2020/2021

MASTER THESIS PROPOSAL

TITLE: Exploring cluster structure in n-rich Carbon isotopes

SUPERVISOR(S): Alessia Di Pietro / Juan Pablo Fernandez García

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UNIVERSITY/RESEARCH CENTER: Laboratori Nazionali del Sud (LNS) – INFN (Catania) / University of Seville

ABSTRACT

In nature, objects in all physical scales tend to clusterise; the reason for that is the realization a greater stability. As an example on the largest scale, the universe, clusters of galaxies are formed bound together by gravity. Atoms form molecules and, at the smallest possible scale quarks are clusterised to form hadrons. Hence, it is not surprising that cluster phenomena appears in nuclei. This thesis deals with the investigation of molecular like structure in nuclei which have an excess of neutrons (n-rich nuclei). The exceeding neutrons may act as electrons in covalent binding, stabilising the nuclear structure that can assume extreme configurations as the one of a linear chain of alphas bound toghether by neutrons. The thesis will involve the analysis of the experiment using the most intense 10Be radioactive beam worldwide on 4He measured at INFN-LNS. For the analysis will be required the use of tools such as energy loss calculations and Monte Carlo simulations in addition to the standard data analysis tools such as ROOT.

ERASMUS MUNDUS MASTER IN NUCLEAR PHYSICS
Academic Year 2020/2021

MASTER THESIS PROPOSAL

TITLE: Development of a treatment planning model for the personalized clinical application of ‘trojan-horse’ radiotherapy

SUPERVISOR(S): Antonio Leal Plaza

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UNIVERSITY/RESEARCH CENTER: Universidad de Sevilla; Depto. Fisiología Médica y Biofísica / Instituto de Biomedicina (IBiS)

ABSTRACT

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

New theragnostic strategies propose incorporating "biological shuttles and/or nanoparticles" that allow the more precise diagnosis of the disease through functional imaging, together with an improvement in the delivery of the radiation dose to the tumor by increasing the cross section to the therapeutic beams. This project intends to implement nano Radiotherapy (nanoRT) and Boron Neutron Capture Treatment (BNCT) in a planning system that takes into account the physiological characteristics of the tumor through the Dose Painting technique and a calculation of the distribution of the dose at the cellular level, with the aim of establishing a more personalized radiotherapy adapted to the evolution of the patient throughout the treatment.

ERASMUS MUNDUS MASTER IN NUCLEAR PHYSICS
Academic Year 2020/2021

MASTER THESIS PROPOSAL

TITLE: **M**odular **A**pparatus for nuclear **R**ections **S**pectrometry (**MARS**)

SUPERVISOR(S): Marcos Aurelio Gonzalez Alvarez & Juan Pablo Fernández García

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UNIVERSITY/RESEARCH CENTER: University of Seville/ Faculty of Physics

ABSTRACT

The goal of this work is to set up, test and characterize the **MARS** (**M**odular **A**pparatus for nuclear **R**ections **S**pectrometry) system.
MARS represents an original idea, consisting on the first and unique 100% portable spectrometer for nuclear reactions measurements and analyzes.
MARS is based on a plug and play philosophy, counting on desktop (stand alone) electronic equipment. The desktop character implies no need to use the old bins (crates) and a considerable decrease in size and, therefore, increased portability. The use of last generation digitizers means a considerable gain in terms of resolution, besides saving the need to use conventional amplifiers and, thus, avoiding part of the old fashion analog electronics in the signal processing chain. Along with the digitizers, MARS adds its ability to study both amplitude and pulse shape, a fact that increases its applications and, therefore, versatility.

The MARS system is composed of 3 (detectors, electronic and adquisition) sub-systems:
1) **STAR** (**S**ilicon **T**elescope **A**rray for nuclear **R**eactions) detection system;
2) **DESIRe** (**D**esktop **E**lectronic for **S**pectrometry of heavy **I**on **Re**actions) electronics system;
3) **SAINT** (**S**oftware for **A**dquisiton and **I**nterface for **N**uclear data **Tr**eatment) data adquisition system.

1) STAR will consist of a set of 16 silicon (Si) detectors, each detector constitutes a single independent (detection) channel; 8 Si detectors 16 μm thick and 8 Si detectors 500 μm thick will be coupled and mounted in telescopes configuration.

2) DESIRE will consist of an analog-digital (multi-channel) electronics chain for processing the signals detected by the 16 Si detectors that compose STAR (1).

3) SAINT will consist of a high performance computer (memory and processing) for installation of firmware, permanent program licenses, electronics system control and adquisition software.

The student will test and characterize the system using pulse generators, an emulation kit, radioactive sources and, possibly, real ions beams produced in a particle accelerator.

ERASMUS MUNDUS MASTER IN NUCLEAR PHYSICS
Academic Year 2020/2021

MASTER THESIS PROPOSAL

TITLE: Exploring the halo exotic nucleus 11Li.

SUPERVISOR(S): Juan Pablo Fernández García / Alessia Di Pietro

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UNIVERSITY/RESEARCH CENTER: University of Seville / Laboratori Nazionali del Sud – INFN (Catania)

ABSTRACT

Understanding the structure and reaction mechanisms of the halo nucleus 11Li is essential to shed light on the nucleosynthesis process through rapid neutron capture, known as r-processes.
During the proposed master thesis, the experimental data of the 11Li+64Zn reaction measured at TRIUMF laboratory will be analyzed in collaboration between the University of Seville and the Laboratori Nazionali del Sud. Starting from the characterization of the experimental setup and finishing with the analysis of the elastic scattering angular distribution
The results will be essential to understand the interplay between nuclear and Coulomb interaction in reactions induced by the halo nucleus 11Li.

ERASMUS MUNDUS MASTER IN NUCLEAR PHYSICS
Academic Year 2020/2021

MASTER THESIS PROPOSAL

TITLE: ***Reaction vertex determination with neural networks:***

SUPERVISOR(S): Katrin Wimmer

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UNIVERSITY/RESEARCH CENTER: IEM-CSIC- Madrid

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

In order to be able to perform accurate Doppler correction of gamma-rays emitted in relativistic nuclear reactions, the reaction vertex has to be known for each event.
A new proposal is to use an array of active target detectors to measure the energy loss of the projectile in each layer. The determination of the reaction layer can then be achieved with a trained artificial neural network.
The aim of this work is to develop the neural network analysis using simulated data and benchmark the prediction accuracy.

ERASMUS MUNDUS MASTER IN NUCLEAR PHYSICS
Academic Year 2020/2021

MASTER THESIS PROPOSAL

TITLE: ***Analysis of the 2^+ doublet at 16.6 and 16.9 MeV of the ^8B***

SUPERVISOR(S): Silvia Viñals

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UNIVERSITY/RESEARCH CENTER: IEM-CSIC- Madrid

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

^{8}B is a unique nucleus that suffers a β^+-decay followed by the break-up of the daughter nucleus into two α. The β/EC-decay of the ^{8}B populates a 2^+ doublet at 16.6 and 16.9 MeV that is interesting by itself as it is strongly mixed in isospin. Due to the strong interference between the states, the doublet only can be studied within the R-Matrix framework.
The master project will analyse the data of the first β-decay experiment of the ^{8}B nucleus that has seen the doublet with enough statistics. This work is in collaboration with IEM-CSIC and topic of a paper to be published in 2021.

ERASMUS MUNDUS MASTER IN NUCLEAR PHYSICS
Academic Year 2020/2021

MASTER THESIS PROPOSAL

TITLE: ***Data adquisition system for Study of reactions of astrophysical interest***

SUPERVISOR(S): Olof Tengblad

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UNIVERSITY/RESEARCH CENTER: IEM-CSIC- Madrid

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

Along this academic year we plan to perform a series of studies of reactions of astrophysical interest, 7Li(3He,p)9Be and 10B(d,alpha)8Be in the tandem accelerator of 5 MV of the UAM.
The master research work will contribute to the preparation of these experiments with emphasis on the Data Acquisition system in relation to fully understand the trigger and timing of the system and to optimize the data storage. Part of this work has though, to be performed in the laboratory.

ERASMUS MUNDUS MASTER IN NUCLEAR PHYSICS
Academic Year 2020/2021

MASTER THESIS PROPOSAL

TITLE: ***Development of a machine learning discriminator for improving the signal-to-background ratio of the 3ΛH hypernuclear signal in HypHI Phase 0 experiment.***

SUPERVISOR(S): Christophe Rappold

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UNIVERSITY/RESEARCH CENTER: IEM-CSIC- Madrid

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

In the previous experiment of the HypHI collaboration , the Phase 0 experiment, the light hypernuclei 3ΛH and 4ΛH were observed in the collision of 6Li+12C at 2AGeV. The goal of the proposed TFM is to use of machine learning techniques for improving the signal-to-background ratio of 3ΛH experimental signal. The experimental data and Monte-Carlo simulations will be used for creating, teaching and evaluating the different ML algorithms.

Requirements : fluent in Python and/or C++ programming, Machine learning, Statistics, High energy nuclear physics.

ERASMUS MUNDUS MASTER IN NUCLEAR PHYSICS
Academic Year 2020/2021

MASTER THESIS PROPOSAL

TITLE: ***Development of a Bayesian filter for track finding in cylindrical detection system.***

SUPERVISOR(S): Christophe Rappold

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UNIVERSITY/RESEARCH CENTER: IEM-CSIC- Madrid

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

In the coming WASA@FRS experiment at GSI-FAIR facility, Germany, a cylindrical detection system inside a solenoid magnet is in use for tracking light hadron produced in the nuclear collision of 6Li and 12C at 2GeV/u. The cylindrical detection system is composed of concentric layers of strawtubes, forming the MDC (Mini Drift Chamber) particle tracking system. Additionally a plastic scintillator barrel at the outer radial layer is in place for the particle identification and final tracking layer.
In the experiment, particles interacts with the different strawtubes and plastic scintillator bars. In each event, the set of detected hits form the MDC and scintillator bar are then used to create a set of track candidates. This procedure is called the track finding process. The goal of the proposed TFM is to develop a new algorithm for finding the tracks in the central detection system. The new idea is to use a Bayesian filter to track backwards from the outer layer to the inner layer and associate sub-set of hits into track candidates using prior probabilistic distributions.
Requirements : fluent in Python and/or C++ programming, Statistics, Monte Carlo simulations, High energy nuclear physics.

ERASMUS MUNDUS MASTER IN NUCLEAR PHYSICS
Academic Year 2020/2021

MASTER THESIS PROPOSAL

TITLE: ***Study of reactions of astrophysical interest***

SUPERVISOR(S): Mª José García Borge

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UNIVERSITY/RESEARCH CENTER: IEM-CSIC- Madrid

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

Along this academic year we plan to perform a series of studies of reactions of astrophysical interest, 7Li(3He,p)9Be and 10B(d,alpha)8Be in the tandem accelerator of 5 MV of the UAM.
The master research work will consist of the preparation of these experiments by means of the study of the optimum energy to realise the experiment, simulations of the best setup configuration and depending of the circumstances some data analysis.

ERASMUS MUNDUS MASTER IN NUCLEAR PHYSICS
Academic Year 2020/2021

MASTER THESIS PROPOSAL

TITLE: ***Experimental tests of IEM-CSIC scanner prototype for medical imaging with protons"***

SUPERVISOR(S):José Antonio Briz

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UNIVERSITY/RESEARCH CENTER: IEM-CSIC- Madrid

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

Our group is building a prototype of scanner for medical imaging using protons at usual beam energies in protontherapy (30-230 MeV). The scanner is built using silicon and scintillation detectors commonly used in Experimental Nuclear Physics.
During 2021, experimental tests of the prototype will be performed in two international facilities: KVI in Groningen (Netherlands) and CCB in Krakow (Poland). The tests will be done acquiring images in radiography mode (single image) and tomography mode (multiple projections at different rotation angles) of simple phantoms.
This TFM student will help in the preparation of both experiments doing tests in our Laboratory in IEM-CSIC and Geant4 simulations and will perform the data analysis and extraction of results.