ERASMUS MUNDUS MASTER IN NUCLEAR PHYSICS
Academic Year 2023/2024

University of Caen - MASTER THESIS PROPOSAL

Experimental nuclear physics

1. Enhancing Data Quality for the KM3NET-ORCA experiment (B.Guillon)
2. Simulation and analysis of nucleon removal experiments on very-exotic nuclei (F.Flavigny, A.Matta)
3. Dynamics and thermodynamics in heavy ion collisions (E.Vient)
4. Phase space analysis of central nuclear collisions matching two approaches (D.Durand)
5. Probing the 12C Hoyle state radius using double-excitation inelastic scattering (D.Gruyer)
6. Artificial Intelligence for Mass Measurement of Exotic Isotopes (P.Delahaye)
7. Exploring magicity and nuclear forces in ^{68}Ni (O.Sorlin)
8. Measurement of beta decay properties of nuclei of interest for nuclear structure and astrophysics, and applications (M.Fallot)
9. Drell-Yan production measurement in proton-proton collisions and preequilibrium dilepton production in heavy-ion collisions with the LHCb experiment at the LHC (M.Winn)

Theoretical nuclear and atomic physics

1. Searching for exotic physics with forbidden beta decays (L.Hayen)
2. Gamow shell model for non-Hermitian interactions (M.Ploszajczak)
3. Neutron-star crusts at finite temperature (A.Fantina)
4. Transport of quantum vortices in tilted pinning landscapes (M.Antonelli)
5. Theoretical study of isolated and solvated molecular systems (J.Douady)

Instrumentation and applications

1. First tests for the development of a micro-dosimeter for targeted Alpha therapy (M.Rousseau)
2. Two-dimensional dose measurement device feasibility for quality control of superficial tumors treated by protontherapy (D.Lebhertz)
3. A new approach to surface functionalization using focused ion beams: applications for energy storage and conversión (S.Guillous)
4. Signal Processing and AI approaches to analyze radiation effects (J.Thariat)
5. Automated quality assurance on DICOM radiotherapy data (J.Thariat)
6. Synthesis and radioresistence of complex organic molecules in space (H.Rothard)
7. Development of proton-rich Fe-Co-Ni radioactive beams (P.Chaveau)
8. Laser spectroscopy developments at the GISELE laboratory for S3-LEB experiments (S.Geldhof)
9. Simulation and design of the mirror charge monitoring system for Advanced VIRGO+ (S.Salvador)

ERASMUS MUNDUS MASTER IN NUCLEAR PHYSICS
Academic Year 2023/2024

MASTER THESIS PROPOSAL

TITLE: Enhancing Data Quality for the KM3NET-ORCA experiment

SUPERVISOR(S): Chiara Lastoria, Benoit Guillon

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UNIVERSITY/RESEARCH CENTER: **LPC CAEN**

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

KM3NeT-ORCA, a cutting-edge water Cherenkov neutrino telescope under construction in the Mediterranean Sea (40 km offshore of Toulon), plays a pivotal role in the early neutrino mass ordering determination and for a precise measurement of atmospheric neutrino oscillation parameters. With 115 detection units planned, the experiment has already collected data in different geometries, currently covering up to 15% of its final volume.

To accomplish its physics goals and to ensure precise event reconstruction and robust background rejection, high quality of the data is essential. In this internship, we offer the possibility to perform statistical tests via data-Monte Carlo and data-data comparisons aimed at optimizing data quality across the various geometries. Join us in progressing neutrino physics and unveiling the mysteries of the universe with the KM3NeT-ORCA team!

ERASMUS MUNDUS MASTER IN NUCLEAR PHYSICS

Academic Year 2023/2024

MASTER THESIS PROPOSAL

TITLE: Simulation and analysis of nucleon removal experiments on very-exotic nuclei.

SUPERVISOR(S): Freddy Flavigny / Adrien Matta

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UNIVERSITY/RESEARCH CENTER: LPC Caen

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

One of the major challenges of modern nuclear physics is to understand how the structure of the atomic nucleus evolves for « exotic » systems with a large difference between the number of neutrons and protons |N-Z| and leads to quantum phenomena unique to this many-body system.
In the nuclear physics group, we study the most neutron-rich systems produced at radioactive ion beam factories such as RIBF-RIKEN (Japan). For that purpose, we use very peculiar reactions, called "direct", during which only one or two nucleons are removed or added without perturbation of their core. To identify these reactions among many others and perform spectroscopic studies, we develop and use state-of-the-art silicon tracking detectors and gamma-ray spectrometers.

In this context, the aim of this master thesis proposal is to pursue specific developments of our existing GEANT4-based simulation package (https://nptool.in2p3.fr, in C++) and confront the output to experimental data or other packages. More specifically the work could be centered on:

- Study of the 3D positioning of a silicon vertex tracker on the final energy resolution achievable by quasi-free scattering reactions
- Development/Benchmark of different gamma-ray detection setups and event generators for in-flight spectroscopy (state of the art Ge arrays, or scintillators).

In all cases, the student will start from an existing simulation example and add new functionalities. Strong interest for data analysis and programming are recommended. Some prior knowledge of either C++, ROOT, GEANT4 would be a real asset.

Depending on the student motivation and skills, data analysis of an experiment performed in 2020 at the RIBF to study nuclei around the N=50 shell closure could be also part of this master thesis.

ERASMUS MUNDUS MASTER IN NUCLEAR PHYSICS
Academic Year 2023/2024

MASTER THESIS PROPOSAL

TITLE: DYNAMICS AND THERMODYNAMICS IN HEAVY ION COLLISIONS

SUPERVISOR(S): Emmanuel Vient

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UNIVERSITY/RESEARCH CENTER: Laboratoire de Physique Corpusculaire de Caen - ENSICAEN-CNRS/IN2P3 6 Boulevard du Maréchal Juin 14050 CAEN CEDEX 4

ABSTRACT

TWO POSSIBLE SUBJECTS ARE PROPOSED

Study of isospin transport in nuclear collisions at Fermi energies using the HIPSE and ELIE models (with D.Durand, durand@lpccaen.in2p3.fr)

The aim of this internship is to study the isospin evolution of the three largest fragments produced in front of the center of mass in ^{58,6}4Ni +^{58,64}Ni collisions at 32 and 52 MeV/nucleon. All these collisions will be simulated with the HIPSE and ELIE event generators, and then filtered by the experimental filter simulating the operation of the INDRA-FAZIA detection set under the conditions of the E789 experiment at GANIL. A comparison can then be made with the experimental data from this experiment.

Study of a method for measuring the temperature and multiplicity of neutrons evaporated from fluctuations in the linear momenta or velocities of evaporation residues, using the GEMINI event generator.

The idea of this internship is to study the influence of the evaporation of a hot nucleus on the width of the momentum and velocity distributions of the evaporation residues formed in this way, and to see how the temperature of the hot nucleus can be derived from the information provided by these distributions. At the same time, we would also like to see how the multiplicity of neutrons evaporated modifies these quantities for a given initial temperature, if we vary the isotopic richness of the hot nucleus formed. To achieve this, we'll be using the GEMINI event generator, which specializes in simulating the evaporation of hot nuclei.

ERASMUS MUNDUS MASTER IN NUCLEAR PHYSICS
Academic Year 2023/2024

MASTER THESIS PROPOSAL

TITLE: Phase space analysis of central nuclear collisions with two approaches: a microscopic transport model and a phenomenological model

SUPERVISOR(S): Dominique DURAND, LPC Caen

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UNIVERSITY/RESEARCH CENTER:

LPC Caen, ENSICAEN, Universite de CAEN

ABSTRACT

Nuclear central collisions can be described either with help of microscopic transport models or with more 'simple' phenomenological descriptions. In this work, we propose to make a comparison between these two approaches and identify their (if any) possible common inputs. Briefly speaking, this will be achieved by comparing the phase space distributions of the two models. Technically, the analysis could be performed within the panda framework using Python language. However, other analysis tools and computer languages can be used. A comparison with experimental data can also be envisaged. **The internship will take place at LPC Caen**

ERASMUS MUNDUS MASTER IN NUCLEAR PHYSICS
Academic Year 2023/2024

MASTER THESIS PROPOSAL

TITLE: Probing the ^{12}C Hoyle state radius using double-excitation inelastic scattering

SUPERVISOR(S): Diego Gruyer

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UNIVERSITY/RESEARCH CENTER: Laboratoire de Physique Corpusculaire (LPC Caen)

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

Few nuclear excited states have attracted the interest of the scientific community as much as the ^{12}C Hoyle state (second 0^+ state at 7.654 MeV excitation energy), which is remarkable in many respects: aside from its key role in the synthesis of ^{12}C, its description still remains a challenge for nuclear structure theory. Theoretical calculations show different hypotheses regarding its spatial configuration but most of them predict a strongly developed 3α structure and a matter radius significantly larger than the ground state. However, only a few attempts to access experimentally the Hoyle state matter radius have been made.

We recently proposed a new method to measure this radius by comparing the differential cross section for single- and double-excitation of ^{12}C to the Hoyle state in $^{12}C + ^{12}C$ inelastic scattering.

During the internship, the candidate will analyse preliminary data that have been measured with FAZIA in 2022, and run the simulations to prepare an experiment that have been proposed to the GANIL Programm Advisory Committee. The candidate will also participate in the in-beam test of a new beam monitoring device. It will be a good occasion to deal with multi-parametric analysis using C++ libraries such as ROOT and KaliVeda.

ERASMUS MUNDUS MASTER IN NUCLEAR PHYSICS
Academic Year 2023/2024

MASTER THESIS PROPOSAL

TITLE: Artificial Intelligence for Mass Measurement of Exotic Isotopes

SUPERVISORS: Pierre Delahaye and David Etasse

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UNIVERSITY/RESEARCH CENTER: GANIL and LPC, Caen, France

ABSTRACT

Artificial intelligence opens new perspectives for basic science. It is no exception for nuclear structure studied at the extreme of the nuclear chart by the Super Separator Spectrometer (S^3) under construction at GANIL-SPIRAL2. The Piège à Ions Linéaire du Ganil pour la Résolution des Isotopes en Masse (PILGRIM) is a Multi-Reflection time-of-flight Mass Spectrometer (MR-ToF-MS), with state-of-the-art performances that can only be exploited fully thanks to a joint development with the FASTER (http://faster.in2p3.fr/) data acquisition at LPC Caen.
The full project (internship + PhD thesis), will consist in carrying out this development with the FASTER developers and the physicist in charge of PILGRIM. Machine learning techniques will have to be employed to recognize patterns in the time-of-flight of ions extracted as bunches from the S^3 Low Energy Branch (S^3 LEB). For each individual ion, the time of flight will have to be determined with sub-nanosecond precision, correcting for effects due to pile-up, gain and baseline fluctuations. This development should lead to the determination of masses of exotic nuclei with exquisite precision, enabling tests of nuclear physics models in previously uncharted territories.

The internship will have the following objectives, **as a pre-requisite for the PhD thesis**:

- Analysis of traces of events recorded with a 5GHz scope, using the PILGRIM spectrometer
- Defining a training model for the neural network technique, to recognize different event patterns
- Participation to all PILGRIM performance upgrades
    - resolving power improvement thanks to PILGRIM voltage stabilization
    - study of systematic effects due to RF in the RFQ coolers in charge of forming the bunches in the S^3 LEB, prior to their injection into PILGRIM
    - Data acquisition improvements - FASTER to python visualization / monitoring interface

ERASMUS MUNDUS MASTER IN NUCLEAR PHYSICS

Academic Year 2023/2024

MASTER THESIS PROPOSAL

TITLE: Exploring magicity and nuclear forces in ^{68}Ni

SUPERVISOR: Olivier Sorlin

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UNIVERSITY/RESEARCH CENTER: GANIL, Caen, France

ABSTRACT

We propose to study the magicity of ^{68}Ni by means of neutron adding and neutron removal transfer reactions (d,p) and (p,d), respectively. This way, we get unique access to the occupancy of the normally occupied orbits and the vacancy of the valence ones. If a sharp transition in occupancy is found, the nucleus is considered as magic, otherwise rather superfluid. Furthermore, this study also allows to study the spin-orbit and tensor forces, essential to the modeling of atomic nuclei, in a unique manner.

^{68}Ni was produced by means of the LISE spectrometer at GANIL, protons and deuterons produced arising from transfer reactions are detected in the highly-segmented Si array MUST2, gamma-rays with EXOGAM2 and incoming/outgoing nuclei tracks, energy losses and time-of-flights with sets of gas-filled detectors. The experiment was a true success.

The student will analyse data on this experimental work (which is the subject of a PhD) and participate to other experiments from March-July 2024 using the same experimental setup. It is therefore planned for the student to learn about the methods for producing radioactive ion beams with the LISE spectrometer, calibrating detectors, handling digital electronics, and to be educated to data analysis of a transfer reaction. On the physics point of view, one experiment planned next year during the internship on ^{34}Si has very strong similarities as the one ^{68}Ni with a characterization of its magicity and study of the role of spin-orbit forces. The other experiment of this campaign will deal on a topic related on nuclear clustering, thus ensuring a good physics background and experimental skill for the student.

ERASMUS MUNDUS JOINT MASTER DEGREE IN NUCLEAR PHYSICS

UNIVERSIDAD DE SEVILLA

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

ERASMUS MUNDUS MASTER IN NUCLEAR PHYSICS
Academic Year 2023/2024

MASTER THESIS PROPOSAL

TITLE: Measurement of beta decay properties of nuclei of interest for nuclear structure and astrophysics, and applications

SUPERVISOR(S): Fallot Muriel, Estienne Magali

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UNIVERSITY/RESEARCH CENTER: Subatech laboratory, Nantes, France

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

The Nuclear Structure and Energy (SEN) team of Subatech laboratory performs measurements of beta decay properties of neutron-rich nuclei of interest for nuclear structure, nuclear astrophysics and neutrino and reactor physics. Recently it has co-developed a new detector with the IFIC of Valencia and the University of Surrey, named e-Shape, to measure the shape of the energy spectra of electrons from non-unique forbidden beta decays. The next e-Shape experiment will take place in December 2023 at the JYFL accelerator Laboratory of Jyväskylä in Finland. The master student will be able to contribute to the characterization of the detector and its calibration. He/she will also start the analysis of the data from one nucleus measured during the 2023 experimental campaign depending on the time remaining. This master thesis could be followed up by a PhD thesis.

ERASMUS MUNDUS MASTER IN NUCLEAR PHYSICS

Academic Year 2023/2024

MASTER THESIS PROPOSAL

TITLE: Drell-Yan production measurement in proton-proton collisions and preequilibrium dilepton production in heavy-ion collisions with the LHCb experiment at the LHC

SUPERVISOR(S): Michael Winn

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UNIVERSITY/RESEARCH CENTER:

CEA Paris-Saclay, Irfu, Université Paris-Saclay

ABSTRACT

At the Large Hadron Collider (LHC) at Geneva, collisions of lead nuclei are used to create a thermodynamic system under extreme conditions. The temperature of the short-lived system is sufficiently large in order to release the building blocks of matter, quarks and gluons: the quark-gluon-plasma (QGP) is formed. However, key features of the early stages of these collisions, the thermalisation phase, are largely unknown. The dilepton production in the intermediate mass scale between 1.5 and 5 GeV/c² is highly sensitive to this transition from the initial condition towards the equilibrium QGP. In addition, dileptons allow to access the structure of the projectiles. So far, no measurement down to masses of 3 GeV/c² at a hadron collider has been published. In fact, semileptonic decays from heavy-flavour hadron decays dominate the dilepton production there. The first goal is the measurement of dimuons at low invariant masses at the LHC in proton-proton collisions in LHCb. In a second part, the feasibility in heavy-ion collisions will be investigated. The student will be part of a team consisting of Michael Winn as thesis director and two postdocs working on the subject. In addition, the team will profit from the expertise of Benjamin Audurier at Irfu, heavy-ion reconstruction expert of LHCb, and Patrick Robbe from IJCLab expert on dimuon measurements and LHCb simulation expert. In parallel, the group is working on theoretical aspects of dimuon production in collaboration with IPhT Saclay, the Bielefeld university and the theory colleagues at Irfu, and on the conception of the LHCb upgrade 2 tracker to make the preequilibrium dilepton measurement feasible in the harshest heavy-ion environment. Depending on progress and interest, after the initial phase focused on the Drell-Yan measurement in proton-proton collisions, a side project in the directions of reconstruction optimization, phenomenology or upgrade preparation works in terms of hardware or software can be envisaged. The thesis is fully funded by a grant.

ERASMUS MUNDUS MASTER IN NUCLEAR PHYSICS
Academic Year 2023/2024

MASTER THESIS PROPOSAL

TITLE: Searching for exotic physics with forbidden beta decays

SUPERVISOR(S): Leendert HAYEN

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UNIVERSITY/RESEARCH CENTER: LPC Caen

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

Nuclear beta decay lies at the basis of our current understanding of modern particle physics, and keeps being an interesting channel for discovery with a vast array of observables and experimental techniques. The interplay between nuclear structure and particle physics have resulted in many cases where the former can provide an enhanced sensitivity towards the latter, and is one of the unique strengths within the field of fundamental symmetries with radioactive decays. Recently, so-called forbidden beta decays (where the lepton fields carry off some angular momentum leading to strongly reduced transitions rates) have been proposed as an interesting candidate for exotic physics searches in the weak interaction.

The project consists of identifying the dominant corrections to angular correlations in forbidden beta decays and comparing their estimated effect to potential exotic physics signals. Aided by shell model calculations, interesting candidate decays will be summarized and connections made to experimental efforts. In particular, we will investigate their potential for precision recoil spectroscopy using novel superconducting detectors.

ERASMUS MUNDUS MASTER IN NUCLEAR PHYSICS
Academic Year 2023/2024

MASTER THESIS PROPOSAL

TITLE: Gamow shell model for non-Hermitian interactions

SUPERVISOR: Marek Płoszajczak

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UNIVERSITY/RESEARCH CENTER: GANIL, Caen, France

ABSTRACT

Loosely bound nuclei are currently at the centre of interest in low-energy nuclear physics. The deeper understanding of their properties provided by the shell model for open quantum systems changes the comprehension of many phenomena and offers new horizons for spectroscopic studies from the driplines to the well-bounded nuclei for states in the vicinity and above the first particle emission threshold [1].
The configuration-interaction approach based on Gamow states, the so-called Gamow shell model (GSM) [1,2], is a complex-energy generalization of the standard shell model in which the harmonic oscillator basis is replaced by the Berggren basis that includes bound states, resonant states, and complex-energy scattering states. The shell model in this formulation respects unitarity in all regimes of the binding energy and provides a comprehensive description of both the configuration interaction and the shell structure, while removing inconsistencies and limitations present in the standard shell model. To describe nuclear reactions, one has to express GSM in the coupled-channel representation [1]. In this representation, the GSM unifies nuclear structure and nuclear reactions because the same Hamiltonian and the same many-body approach describes both the discrete part of the energy spectrum and the reaction cross-sections at low excitation energies.
The application of GSM for nuclear reactions faces a problem of an insufficient completeness of the reaction channel basis in realistic applications which might be circumvented by introducing complex correction factors in the channel-channel coupling potentials.
In this internship, it is proposed to investigate Berggren completeness relation and properties of the GSM spectra with the non-Hermitian interaction.

[1] N. Michel, M. Płoszajczak, "*Gamow Shell Model - The Unified Theory of Nuclear Structure and Reactions*", Lecture Notes in Physics 983 (Springer, Cham, 2021).
[2] N. Michel, W. Nazarewicz, M. Płoszajczak, and T. Vertse, J. Phys. G. Nucl. Part. Phys. 36, 013101 (2009).

ERASMUS MUNDUS MASTER IN NUCLEAR PHYSICS
Academic Year 2023/2024

MASTER THESIS PROPOSAL

TITLE: Neutron-star crusts at finite temperature

SUPERVISOR: Anthea F. Fantina

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UNIVERSITY/RESEARCH CENTER: GANIL, Caen, France

ABSTRACT

Neutron stars are among the densest objects in the Universe. Being born from core-collapse supernova explosions, they are initially very hot. Therefore, their outer layers (the so-called crust) are expected to be made of a dense liquid composed of various nuclear species immersed in a background of electron (and eventually neutron/proton) gas. At the bottom of the crust, more "exotic" non-spherical nuclear configurations, collectively known as "pasta" phases, may also exist. As the neutron star cools down, it is generally assumed that this plasma crystallizes and remains in full thermodynamic equilibrium until eventually reaches a cold solid crystalline phase.

In the latter hypothesis, the final structure of the crust would be that made of layers, each of which consists of only one nuclear species. However, it is likely that the star does not maintain full equilibrium after crystallization. Therefore, the picture of the crust made of one-species layers is challenged, and a co-existence of various nuclear species, and eventually various geometries, could still persist. This, in turn, can have important consequences on the neutron-star properties and dynamics, such as its cooling.

Although the crust accounts for only around 1% of the neutron-star mass and about 10% of its radius, it is crucial for different astrophysical phenomena. Currently, several questions remain open concerning the physics of the neutron-star crust. These include, among others, a proper treatment of the clusters immersed in a dense medium of nucleons and electrons, and its surface properties. In this respect, two aspects can be considered in order to improve in the cluster modelling: (i) the existence of a neutron "skin", and (ii) a better determination of the maximum temperature at which the nuclear clusters can coexist with the nucleon "gas". Both points require benchmarks of current estimations with more microscopic calculations and, possibly, accounting for beyond mean-field effects.

During the Master internship, a theoretical study of the neutron-star crust at finite temperature will be performed. In particular, the internship will focus on an improved description of the cluster surface (point (i)), while the second and more involved part (point (ii)) of the project could be further developed within a PhD.

ERASMUS MUNDUS MASTER IN NUCLEAR PHYSICS
Academic Year 2023/2024

MASTER THESIS PROPOSAL

TITLE: *Transport of quantum vortices in tilted pinning landscapes*

SUPERVISOR: *Marco Antonelli*

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UNIVERSITY/RESEARCH CENTER: **LPC-Caen**

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

Cold neutron stars contain extended layers where the neutrons are in a superfluid phase. This naturally allows for the presence of quantum vortices (stable microscopic vortices of definite circulation). There are strong fundamental reasons to believe that observations of pulsar glitches and pulsar timing noise (two different kinds of rotational pulsar instabilities) are best explained in terms of the collective dynamics of these quantum vortices.

During the internship, the student will study and simulate how vortices move in the complex environment of the inner crust of a neutron star: while the presence of ions provides a "pinning landscape" that tends to block vortices in optimal positions (where the free energy of the configuration is minimized), the presence of a neutron current has the effect of tilting this potential, up to a point where pinning is no longer possible.

We will revise a simple but widely used prescription for vortex motion called "vortex creep" and go beyond it by implementing stochastic simulations of an ensemble of vortices. In this way, the candidate will also learn how to simulate simple stochastic processes (that have a broad spectrum of possible applications) and how to theoretically extract statistical observables (in our case, the average velocity of vortices). The project is especially suited for students with a strong interest for theory and computational techniques.

ERASMUS MUNDUS MASTER IN NUCLEAR PHYSICS
Academic Year 2023/2024

MASTER THESIS PROPOSAL

TITLE: Theoretical study of isolated and solvated molecular systems.

SUPERVISOR : Julie DOUADY

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UNIVERSITY/RESEARCH CENTER: CIMAP

ABSTRACT

Context :
In the last 20 years, there has been a growing interest for mass spectrometry as a powerful tool to unravel the structure of isolated molecular systems. This way, one may further perform experiment on molecular systems by storing and irradiating them in an ion trap by means of synchrotron radiation in the VUV and soft X-ray ranges. VUV and soft X-ray action spectroscopy techniques are powerful methods to investigate the electronic and some aspects of the geometric structure of biomolecules.

In the thesis of Juliette LEROUX, they combine both action spectroscopy and structural approaches to investigate radiation-induced processes in biomolecular systems (peptides and proteins (accepted article). Later, they will study the influence of a controlled number of water molecules on the radiation-induced processes in peptides and proteins.

Project:
The master student will study theoretically small model peptides like pentaglycine in the (de)protonated form.
First, the student will have to generate different isomers for the isolated and hydrated system (1 to 10 water molecules). This exploration of potential energy surface (PES) will be done using a program based on the Molecular Dynamics.
In a second step, the student will have to reoptimize these geometries with DFT calculations. For the lowest-isomers the student will calculate infrared and X-ray spectra to analyze the role of the water environment. These calculations will be done with the ORCA program.

ERASMUS MUNDUS MASTER IN NUCLEAR PHYSICS
Academic Year 2023/2024

MASTER THESIS PROPOSAL

TITLE: First tests for the development of a micro-dosimeter for targeted Alpha therapy

SUPERVISOR(S): Marc Rousseau

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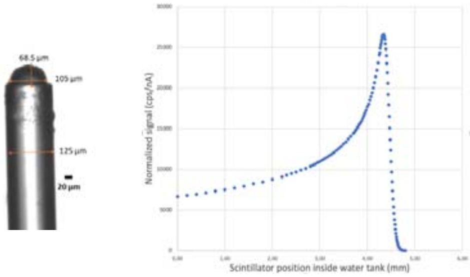
UNIVERSITY/RESEARCH CENTER: LPC Caen

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

Our team is currently working, in partnership with two laboratories in Strasbourg and Marseille, on the development of a new micro-dosimeter consisting of an optical fiber (100 µm diameter), one end of which is terminated by a scintillating powder embedded in PMMA. The extremely small dimensions (60-100 µm) of these detectors make them the system of choice for preclinical micro-dosimetry associated with ion-beam radiotherapy. Indeed, these micrometric detectors have low interceptivity, enabling measurement of linear energy transfer with a spatial resolution rarely achieved. These dosimeters have been successfully tested on hard X-ray beams (4 to 15 MeV) and on proton beams at 4 and 25 MeV where it was possible to measure the bragg peak (Figure below).



On this basis, we intend to develop an endoscope for measuring the internal dose deposited in the patient during alpha vectorized internal radiotherapy sessions. This new development is preliminary, as the detector still needs to be miniaturized and its response to alpha irradiation measured. The aim of this internship is to take part in the first measurement campaigns (under beam or using sealed or unsealed sources) and to analyze the results. The results will be compared with Monte Carlo simulations, which will also be carried out.
The internship will take place at LPC Caen, with the possibility of carrying out experiments in France.

ERASMUS MUNDUS MASTER IN NUCLEAR PHYSICS

Academic Year 2023/2024

MASTER THESIS PROPOSAL

TITLE:
Two-dimensional dose measurement device feasibility for quality control of superficial tumors treated by protontherapy

SUPERVISOR(S): Lebhertz Dorothée and Jean-Marc Fontbonne

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UNIVERSITY/RESEARCH CENTER:
Laboratoire de physique corpusculaire de Caen, France
Centre François Baclesse de Caen, France

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

At Normandy protontherapy center (CYCLHAD), prior to each patient treatment, two-dimensional (2D) dose distributions are performed with an IBA MatriXX ONE at several depths to ensure the quality of each proton beams. This dose distribution can't be measured at depths shallower than 7.3 mm because no commercial device allows 2D superficial dose measurement.

In the framework of developing treatment for superficial tumors like non-melanoma skin cancers, the François Baclesse Center (CFB) and the Corpuscular Physics Laboratory (LPC) from Caen will mutualized their expertise in order to develop a measuring device to assess dose for depth shallower than 3 mm. No preferred technical solution has yet been chosen. The student will work at CYCLHAD and LPC, on the device specifications and on the first proof of concept.

ERASMUS MUNDUS MASTER IN NUCLEAR PHYSICS
Academic Year 2023/2024

MASTER THESIS PROPOSAL

TITLE: A new approach to surface functionalization using focused ion beams: applications for energy storage and conversion.

SUPERVISOR(S): Stéphane GUILLOUS

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UNIVERSITY/RESEARCH CENTER: UNICAEN/CIMAP

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

Very recently, the CIMAP laboratory developed a tool unique in the world (PELIICAEN apparatus) which, under certain conditions, enables the controlled production of hollow structures. These hollow structures are of definite and innovative interest for applications linked to energy storage and conversion. The proposed project concerns the development and characterization of these structures using complementary methods available in the PELIICAEN apparatus, such as scanning electron microscopy, scanning ion microscopy, and near-field microscopy for local measurements of electrical, mechanical and magnetic properties. Other ex-situ characterization methods available in the CIMAP laboratory, such as Secondary Ion Mass Spectrosopy or Raman microscopy, can be used to complete the characterization.

ERASMUS MUNDUS MASTER IN NUCLEAR PHYSICS
Academic Year 2023/2024

MASTER THESIS PROPOSAL

TITLE: Signal Processing and AI approaches to analyze radiation effects in human, application to vision prediction in patients

SUPERVISOR(S): Juliette Thariat

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UNIVERSITY/RESEARCH CENTER: LPC Caen

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

This project is part of the PIOTox project (Proton Induced Optical Toxicities) carried out for 3 years to better understand and predict radiation effects on the vision of patients undergoing radiotherapy for brain or head and neck tumors.
We have collected radiotherapy dose maps (dicom format), and doses to the organs of the visión. We also have clean raw data before and after radiotherapy. These data inform us on how the patients see (“visual field”), how their organs of the vision, the optic nerves, transmit the electric signal (light stimulus) to the brain often detected as the “p100” wave (“visual evoked potentials” (vep)) and if their optic nerves are damaged (“retinal nerve fiber length”) and get atrophic on high resolution optical coherence tomography.
The vep data is intended to be analyzed using standard signal approaches (detection of the “p100” wave by Fourier transform approaches. In comparison, machine learning and deep learning models can also be used to analyze vep signals. These approaches will be compared for their performances in classifying visión outcomes. Regression models integrating visual field as output and other input data could be developed too. Initiation to handling of 3D DICOM data could also be done if time allows.

Learning objectives:
Understanding of the radiotherapy environment (including scientific literature search) data and data format and manipulation of tabular raw data obtained
Analyses of vep data, including preprocessing and noise (brain signals in the absence of a specific light stimulus) reduction techniques.
Extraction of important features in the vep data, such as latencies, amplitudes, and waveform characteristics, and exploration of data reduction methods, such as dimensionality reduction or feature selection, while ensuring the ability to reconstruct the data.
Development machine learning / deep learning algorithms for classification of visual evoked potential signals.
Requirements: Basic knowledge in medical Physics, signal processing and programming are required.
Contact: Juliette Thariat jthariat@gmail.com (physician and researcher), Jean Marc Fontbonne (Research engineer), Nathan Azemar (3rd year PhD student)

ERASMUS MUNDUS MASTER IN NUCLEAR PHYSICS
Academic Year 2023/2024

MASTER THESIS PROPOSAL

TITLE: AI6ENABLED automated quality assurance on DICOM radiotherapy data

SUPERVISOR(S): Juliette Thariat

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UNIVERSITY/RESEARCH CENTER: LPC Caen

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

60% of patients with cancer undergo radiotherapy (RT); some undergo RT in the setting of a clinical trial when a new "experimental" RT modality is expected to be better than the routine RT modality. In head and neck cancers, RT quality was heterogenous accross patients; it compromised survival and was a confounding factor compromising efforts to assess benefits of the experimental treatment. Consequently, RT quality is systematically assessed with respect to RT guidelines for contours of tumor and organs, dose distribution, in the trial protocol and classified as as correct (pass), in minor (RTQA pass but with corrections) or major deviation (fail). RT quality is assessed by experts but is a very demanding process; adds strong constraints to the busy workload of radiotherapy departments and must not delay patient RT initiation. Interexperts assessment lacks consistency and suggests that the RT quality process may be further standardized and harmonized. To reduce requirements in terms of human resources, technical logistics and time, automated contouring and planning and knowledge-based approaches have been successfully implemented in practice and automation of RT quality assessment is promising. To predict RT quality classification (pass or fail) in in-trial patients using optimal 3D dose map (patients' scanners in DICOM RT data) generated based on knowledge of initial tumor topology (contours and features), tumor relapse location (contours and image features), physics-enabled dose distribution / dose gradients, and dose constraints (as indicated in trials' protocols). For this, 500 scanners ara available and optimal dose maps could be achieved using those without (200) versus those with a relapse (300)
Learning objectives:
Understanding of the radiotherapy environment (including scientific literature search) data and data format and manipulation of tabular raw data obtained
Analyses of DICOM RT data, including preprocessing.
Production of generative adversarial networks and saliency maps (+ other up-to-date tools)
Development machine learning / deep learning algorithms for classification of signals.
Requirements: basic knowledge in medical physics and good knowledge in programming (Python) / datascience are prefferred.
Contact: Juliette Thariat jthariat@gmail.com (physician and researcher), Ozgur Ozer (1st year PhD student, who published his preliminary work on this topic during his master)

ERASMUS MUNDUS MASTER IN NUCLEAR PHYSICS
Academic Year 2023/2024

MASTER THESIS PROPOSAL

TITLE: **Synthesis and Radioresistance of Complex Organic Molecules in Space**

SUPERVISOR(S): ROTHARD Hermann + BODUCH Philippe

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UNIVERSITY/RESEARCH CENTER: CIMAP-CIRIL-Ganil

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

How did life emerge, what is the origin of organic matter in the universe? In space environments, the synthesis of complex organic molecules (COMs) is possible either by implantation of ions trapped in the magnetospheres of giant planets into the icy surfaces of their satellites (e.g. C or S ejected by Io's volcanism and impacting Europe), or following radiolysis of small molecules (H2O, CO, CH4, NH3 etc. on icy grains in dense molecular clouds). We study formation and radio-resistance of COMs like nucleobases and amino acids under swift charged particle irradiation of icy samples in a wide temperature range (10-300K) in the set-up IGLIAS. It allows to simulate space conditions (low temperature, vacuum, irradiation by GANIL beams). The effects of radiation and temperature on the structure and composition of the samples is quantified by infrared absorption spectroscopy and mass spectrometry. Furthermore, a common procedure is to slowly warm-up the irradiated samples to room temperature and to analyze the nonvolatile residues ex-situ by e.g. chromatography or high resolution mass spectrometry to precisely identify the synthesis of large organic molecules.

ERASMUS MUNDUS MASTER IN NUCLEAR PHYSICS
Academic Year 2023/2024

MASTER THESIS PROPOSAL

TITLE: Development of proton-rich Fe-Co-Ni radioactive beams

SUPERVISOR: Pierre Chauveau

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UNIVERSITY/RESEARCH CENTER: GANIL, Caen, France

ABSTRACT

Context: The SPIRAL1 facility has been providing post-accelerated radioactive ion beams (RIBs) to GANIL users since 2001. In this facility, radioactive atoms are produced at rest by the interaction of a high energy stable ion beam with a thick target. The atoms are then guided from the target to an ions source, where they are ionized, hence forming a RIB, before being accelerated by a cyclotron. Owing to the wide variety of stable beams available in GANIL and the even wider variety of radioactive isotopes, many feasible RIBs remain to be produced. In particular, proton-rich RIBs of Fe-Co-Ni elements could bring great physics opportunities to GANIL. These beams have been requested multiple times in recent years and SPIRAL1 could produce them at an intensity unmatched by comparable facilities like ISOLDE-CERN and ISAC-TRIUMF. This internship aims at testing and improving the production of those beams.

Master work: An online production test is planned during the summer of 2024. The master student will participate to this test and be responsible for the data analysis to extract the RIB production rates and other information. He/she will then develop a multiphysics model using COMSOL or ANSYS to calculate the temperature distribution inside the irradiation target. Based on experiment and simulation results, the student will deduce ideal operation parameters (primary beam energy and intensity, electrical heating power of the target) to reduce the time delay between the production of an isotope in the target and its ionization in the source. If deemed necessary, he/she can even propose changes in the design of the graphite target and of the target oven to decrease further this time delay. Should the master student be interested, a PhD could follow this internship.

ERASMUS MUNDUS MASTER IN NUCLEAR PHYSICS
Academic Year 2023/2024

MASTER THESIS PROPOSAL

TITLE: Laser spectroscopy developments at the GISELE laboratory for S3-LEB experiments

SUPERVISOR: Sarina Geldhof

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UNIVERSITY/RESEARCH CENTER: GANIL, Caen, France

ABSTRACT

The Super Separator Spectrometer (S3) at GANIL-Spiral2 will start its commissioning and first experimental runs in the coming years, with first data taking on radioactive isotopes for the Low Energy Branch (S3-LEB). S3-LEB relies on the technique of resonant laser ionization, both for direct laser spectroscopy and for production for subsequent experiments, such as atomic mass measurements or nuclear decay spectroscopy. Via laser spectroscopy, several nuclear ground state properties can be extracted, such as the nuclear size, shape and electromagnetic moments.

In order to conduct experiments on radioactive ions, knowledge of laser ionization schemes for each element is required. When doing laser spectroscopy, added information about the sensitivity of the ionization scheme to the underlying nuclear observables is also needed. This requires developing and testing of ionization schemes on the stable isotope(s) of the element of interest, which can be performed at the GISELE laser laboratory in GANIL. GISELE has the same laser system as will be available at S3, and in addition an Atomic Beam Unit (ABU), in which material can be evaporated for subsequent laser ionization tests.

So far ionization schemes for erbium, tin and palladium have been tested at GISELE, but other elements will be studied at S3, such as silver, actinium, cadmium… The main goal of the internship will be to investigate existing laser ionization schemes, or develop new schemes where needed, for elements of interest for the first experimental campaigns at S3-LEB. This will also involve testing of new laser systems which have been recently put in place at GISELE, such as a home-built continuous wave Ti:sapphire laser. The intern will be fully involved in all aspects of the operation of GISELE. This means testing new laser developments, e.g. temperature control for laser frequency doubling; preparing the laser system for the experiments, e.g. tuning the lasers to the required wavelengths; setting up the ABU with its MCP detector; running the experiments with the LabVIEW-based data acquisition system; and analyzing the data using Python-based code.

ERASMUS MUNDUS MASTER IN NUCLEAR PHYSICS
Academic Year 2023/2024

MASTER THESIS PROPOSAL

TITLE: Simulation and design of the mirror charge monitoring system for Advanced VIRGO+

SUPERVISOR(S): Samuel Salvador

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UNIVERSITY/RESEARCH CENTER: LPC Caen

ABSTRACT

Since the discovery of the first gravitational wave in 2015 emitted by the coalescence of a Binary Black Hole (BBH), the well known LIGO (Livingstone and Hanford) and VIRGO terrestrial interferometric detectors underwent several upgrade campaigns in between different Observing runs (O_i). The latest upgrade of VIRGO called Advanced Virgo+ phase I (AdV+ phase I) was active during the run O_3. Previously to this run, a defect on the electronic cards driving the electromagnets controlling the mirror positions showed that electrostatic charges of unknown source(s) were present on the surface of the mirrors and coupled to the defective electronic cards therefore degrading the sensitivity. The defective cards have since been replaced but the continuous reach for improving the detector sensibility requires that for the next upgrade (AdV+ phase II) and the future of interferometric detection, the electrostatic charges must be monitored and neutralized.

As the neutralizing system is being designed, the study of the charge monitoring system has recently started. It should consist of two monitoring pads placed underneath the mirrors on which sine wave potentials can be applied.

Using simulations of different voltage patterns, the characteristics of the electrostatic charges (i.e. location, shape, polarity, amplitude), must be retrieved by developing an algorithm based on a maximum likelihood estimation maximization or a deep learning analysis.