ERASMUS MUNDUS JOINT MASTER IN NUCLEAR PHYSICS

Academic Year 2026/2027

MASTER THESIS PROPOSAL

TITLE: Study of the optical properties of a Cherenkov telescope in seawater using muons.

SUPERVISOR(S): Valentin PESTEL, Gregory Lehaut

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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 is an international collaboration currently deploying and operating two large neutrino telescopes at the bottom of the Mediterranean Sea. Both rely on the same detection principle: charged particles produced in neutrino interactions emit Cherenkov light as they travel through water. The deep sea provides an ideal environment for this detection, offering a vast volume of water in complete darkness, with several kilometers of water above acting as a shield against background particles. The trajectories of these particles are accurately reconstructed using a network of photo-sensors that time-sample the light emission in 3D.

Water optical properties, such as the absorption and scattering lengths, introduce systematic uncertainties in the energy estimation, which is one of the dominant sources of systematic error in the neutrino mass ordering measurement.

Muons are a free source of events for our telescope: they emit light as they travel through it via different processes, thanks to their broad energy spectrum. While high-energy muons lose energy through stochastic interactions, low-energy muons are mainly in the minimum-ionizing regime, where the energy loss is approximately constant.

During this internship, we propose to validate a detector-agnostic selection of stopping muons (i.e., a selection of low-energy muons that can be used for different detector sizes). After the selection, a statistical comparison of the light yield between data and simulation will place constraints on the absorption and scattering lengths.

The required skills for this internship are knowledge of particle interactions with matter, statistical analysis, and programming in Python.

ERASMUS MUNDUS JOINT MASTER IN NUCLEAR PHYSICS

Academic Year 2026/2027

MASTER THESIS PROPOSAL

TITLE: CLUSTERS IN THE MEDIUM

SUPERVISOR(S): Francesca Gulminelli, Maria Colonna, Stefano Burrello

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UNIVERSITY/RESEARCH CENTER: Universita' di Catania, LNS and LPC Caen, France

ABSTRACT

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

The ultra-dense matter in the central regions of core-collapse supernovae can be represented as a strongly interacting plasma composed of neutrons and protons and their bound states (deuterons and heavier nuclei), neutralized by a homogeneous electron background and assumed to be in local thermodynamic equilibrium. To evaluate the relative abundance of monomers and composite particles, the standard astrophysical treatment (Clayton, 1968) consists in considering the nucleon fluid as a statistical ensemble consisting of an ideal gas of nucleons and clusters treated as independent quasi-particles. However, this description does not account for the dissolution of clusters in a dense medium, a phenomenon known as the Mott effect (Schmidt et al., 1990). To understand this feature, a microscopic evaluation of the quasiparticle energy of composites can be obtained within the thermal Green-function formalism. After a quasiparticle reduction of the Bethe-Salpeter equation in ladder approximation (Fetter & Walecka, 1971), it is possible to obtain an in-medium eigenvalue equation for the quasi-particle composites, that is solved in perturbation (Schmidt et al., 1990; Ropke, 2009). In this project, we will develop an improved non-perturbative method based on channel decomposition to study the asymptotic regime associated to the continuum threshold. An implementation in a quasi-particle statistical model will allow us to evaluate cluster abundancies and compare with the results of the perturbative method, as well as with other simplified approaches introduced in the literature.

The project is a collaboration between LPC France and University of Catania. The student will spend part of the time in both sites.

ERASMUS MUNDUS JOINT MASTER IN NUCLEAR PHYSICS

Academic Year 2026/2027

MASTER THESIS PROPOSAL

TITLE: **Transformer-Based Event Reconstruction for Neutrino Physics with KM3NeT/ORCA**

SUPERVISOR(S): Antonin VACHERET, Benoît GUILLON

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UNIVERSITY/RESEARCH CENTER: Université de Caen Normandie.
Laboratoire de Physique Corpusculaire de 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 is the low-energy neutrino telescope of the KM3NeT research infrastructure. Its main goal is to study neutrino oscillations and determine the Neutrino Mass Ordering (NMO), one of the remaining open questions in neutrino physics. The detector is expanding rapidly, with 34 of its 115 detection lines currently operational.

The LPC KM3NeT group is developing advanced analysis methods in preparation for the NMO measurement. This internship will focus on improving nuT, a transformer-based algorithm for neutrino event reconstruction, with the aim of increasing the sensitivity of KM3NeT/ORCA to neutrino-oscillation measurements. The project may lead to a PhD on this topic.

The student will work at the interface of neutrino physics, detector response, and machine learning. They will contribute to the development and evaluation of next-generation transformer models for event reconstruction.

The internship will take place within the LPC KM3NeT group, which has expertise in detector instrumentation, calibration, data analysis, and machine learning for scientific applications.

A strong interest in neutrino and particle physics is expected. Good programming skills in Python are required, and experience with machine-learning libraries such as PyTorch would be an advantage.

MSc 2 Internship 2027

Research field: Experimental nuclear physics
Subject: Space-Charge Effects On the Transmission of Bunched Ion Beams

"Master day" on Saturday the 21st of November to present the laboratory, the facility and PhD proposals. Programme and registration at https://www.ganil-spiral2.eu/en/jobs/master-students-day/

Description:
The *Matter's Origin from RadioActivity* (MORA [1, 2]) experiment searches for signatures of CP violation in the nuclear beta decay that could help explain the matter-antimatter asymmetry observed in the Universe. The most sensitive and complementary isotopes for this search for physics beyond the Standard Model are ^{23}Mg and ^{39}Ca.
MORA is currently taking data at the University of Jyväskylä, where both isotopes are produced with beam intensities of approximately 10^5 particles per second (pps). At GANIL, where the experiment is expected to reach its highest sensitivity, beam intensities exceeding 10^7 pps are anticipated.

To effectively transport and inject these radioactive ions into the MORA setup, the beams are converted from a continuous ion stream into temporally narrow, dense ion bursts, also known as bunches, by using a device called a Radiofrequency Quadrupole Cooler Buncher (RFQ-CB). At the University of Jyväskylä, MORA uses the so-called "minibuncher" [3] to perform such a conversion. However, it was observed that the transmission efficiency of the bunches decreases as a function of the number of ions in the bunch, for numbers as low as a few 10^5. One hypothesis for the source of these losses is that the Coulomb repulsion drives the ions apart, losing some of them inside the beamline.

The objective of this M2 project is to study and report these transmission losses by simulating the transport of ion bunches in SIMION, utilizing its in-built Poisson equation solver to account for space-charge effects. This work will be conducted within the MORA project at GANIL.

For more information, see https://mora.ganil-spiral2.eu/.

[1] P. Delahaye, E. Liénard, I. Moore, M. Benali, M. L. Bissel, L. Canete, T. Eronen, A. Falkowski, X. Fléchard, M. Gonzalez-Alonso, W. Gins, R. P. D. Groote, A. Jokinen, A. Kankainen, M. Kowalska, N. Lecesne, R. Leroy, Y. Merrer, G. Neyens, et al., "The MORA project," *Hyperfine Interact.,* no. 240, pp. 63 - 75, 2019.

[2] N. Goyal, A. Singh, S. Daumas-Tschopp, L. M. Motilla Martinez, G. Ban, V. Bosquet, J. F. Cam, P. Chauveau, S. K. Chinthakayala, G. Fremont, R. P. De Groote, F. de Oliveira Santos, T. Eronen, A. Falkowski, X. Flechard, et al., "Performance of the MORA Apparatus for Testing Time-Reversal Invariance," *Eur. Phys. J. A (2025) 61: 221,* 2025.

[3] V.A. Virtanen, T. Eronen, A. Kankainen, O. Beliuskina, P. Campbell, R. Delaplanche, Z. Ge, R.P. de Groote, M. Hukkanen, A. Jaries, R. Kronholm, I.D. Moore, A. Raggio, A. de Roubin, J. Ruotsalainen, M. Schuh, "Miniaturised cooler-buncher for reduction of longitudinal emittance at IGISOL" *NIM-A 1072: 170186, 2025*

"Master day" on Saturday the 21st of November to present the laboratory, the facility and PhD proposals. Programme and registration at https://www.ganil-spiral2.eu/en/jobs/master-students-day/

Expected skills: The M2 student is expected to be interested in experimental physics, to have a firm grip on the basics of electromagnetism, and to have prior experience in programming, for example, in python, lua, C++, or in other comparable language.

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"Master day" on Saturday the 21st of November to present the laboratory, the facility and PhD proposals. Programme and registration at https://www.ganil-spiral2.eu/en/jobs/master-students-day/

Internship in medical nuclear physics

Study of dosimetry based on MRI and autoradiography in Targeted Radiotherapy

Targeted alpha therapy (TAT) is a treatment modality in which a labelled α-emitting radioisotope is injected to the patient. The labelled molecules specifically target tumour cell biomarkers. As a result, particles emitted during the decay of the radioisotope deliver the dose locally, close to tumour cells, especially in the case of α-emitters. The favourable properties of α-particles (short range, high linear energy transfer, potent cytotoxicity) explain the increasing development and use of TAT [1]. This project is therefore part of the willingness to evaluate and implement new radiopharmaceuticals based on alpha-emitting radioisotopes: ^{223}Ra, ^{211}At, ^{212}Pb, ^{225}Ac.

Like any new treatment, TAT requires research to evaluate the efficiency of new molecules and to compare results with other existing modalities. These studies include in vivo experiments to assess the efficiency of the treatment on tumours and the toxicity to healthy tissues. The accuracy of this evaluation and the understanding of the biological effects depend in particular on the knowledge of the dose absorbed by the different organs.

Three-dimensional dosimetry for internal radiotherapy in general and TAT in particular is more complex than for external beam radiotherapy and is described in **Figure 1**. It involves the acquisition of the biodistribution of the radiopharmaceutical, usually by positron emission tomography (PET) or Single Photon Emission Tomography (SPECT) imaging and the calculation of the absorbed dose by Monte Carlo or kernel convolution.

M. Bardiès, J.I. Gear / Clinical Oncology 33 (2021) 117–124

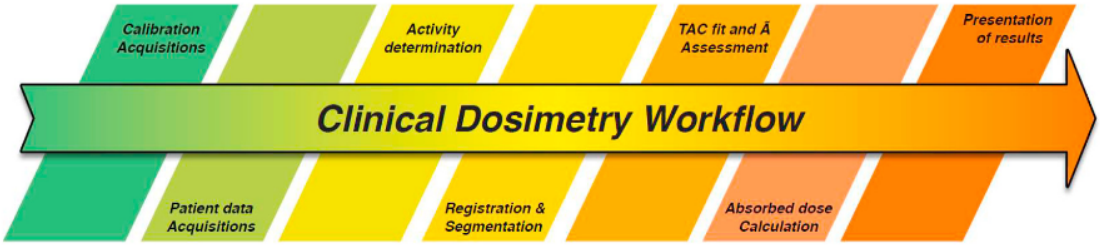

Fig 1. The basic steps to performing and recording an absorbed dose from radiopharmaceuticles.

The objective of this internship is part of the preclinical study of a new TAT treatment for brain metastases being carried out by ISTCT, CLCC Baclesse, INTHERES and GANIL. At this stage, the efficiency of the treatment with a vector labelled with an alpha-emitting isotope on metastases and its toxicity on normal tissues must be evaluated and quantified in relation to the absorbed dose in small animals.

To address this aim, a dosimetry process has been implemented and tested with preclinical and clinical SPECT and PET acquisitions. Nevertheless, these modalities lack of spatial resolution in the case of brain metastases in small animals.

To address this issue, complementary *ex vivo* autoradiography measurements were performed using an antibody labelled with ^{125}I. These measurements provide 2D distributions of the antibody in several layers of the brain.

The objective of the internship is thus to integrate autoradiography measurements in the dosimetry process developed prior to this internship, to determine the dose

delivered to the metastases and the heathy tissues in the brain. The internship will rely on several steps:

1. Bibliography on the integration of autoradiography in dosimetry
2. Characterization and calibration of autoradiography acquisitions
    - Characterization of the background
    - Calibration of autoradiography films in terms of activity
    - Analysis of the activity distribution in the metastases and the healthy tissues
    - Analyse du nombre et des tailles de métastases -> rapprochement avec CPOP (cross-fire) + à partir de quelle taille/nb de cellules on détecte l'activité

Autoradiography measurements, including known activity drops and ex vivo samples, have been performed prior to the internship.

3. Modelling of the activity distribution in 3D and registration with anatomic data acquired in MRI (homogeneous vs. heterogeneous distribution, distribution geometry, spatial resolution…)
4. Implementation of the anatomy and modelled activity distribution in Monte Carlo simulation (OpenGate v10) and simulation of different beta and alpha-emitting isotopes
5. Analysis of the dose distributions corresponding to the different activity distribution models and isotopes.

The internship will be -supervised by the GANIL but will include close collaboration with ISTCT, LITO, LPCC, CLCC François Baclesse, INTHERES.

References:

[1] F. Guerard, J. Barbet, J.-F. Chatal, F. Kraeber-Bodere, M. Cherel and F. Haddad, "Which radionuclide, carrier molecule and clinical indication for alpha-immunotherapy," *Q J Nucl Med Mol Imaging,* vol. 59, pp. 161-167, 2015.

Expected skills

The student should have a formation in medical physics with a good knowledge of radiation-matter interactions, radiotherapy and dosimetry. Knowledge in Monte Carlo simulation (OpenGATE), 3DSlicer and Python would be a plus.

This work does not lead to a PhD-thesis.

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ERASMUS MUNDUS JOINT MASTER IN NUCLEAR PHYSICS

Academic Year 2026/2027

MASTER THESIS PROPOSAL

TITLE: Development of an Hamiltonian optics propagation code

SUPERVISOR(S): Gilles Quéméner (CNRS / IN2P3)

SUPERVISOR(S) contact- email: quemener@lpccaen.in2p3.fr Telephone: 0231452540

UNIVERSITY/RESEARCH CENTER: LPC Caen – UMR 6534

ABSTRACT

Context: Ray propagation in optical systems in the Hamiltonian formulation (H=-sqrt(n^2-p_x^2-p_y^2)): each optic element is a Lie map computed as a Truncated Power Series Algebra (TPSA). The Generalized TPSA (GTPSA) developed for MAD-NG at CERN allows maps to arbitrary order with parameters which is ideal for aberration analysis.

Objective: Develop a Python code based on Hamiltonian optics / Lie algebra / GTPSA to simulate devices with multiple optic elements and compute associated aberrations.

Work program:
1. Bibliography on Hamiltonian optics and Lie methods (Dragt, Forest, Berz).
2. Implementation of Hamiltonian and maps for drift, refraction, mirror, and compound systems.
3. Composition of maps via GTPSA to obtain system map to higher order and extraction of Seidel aberrations (spherical, coma, astigmatism).
4. Validation against either analytical formulas or ray-tracing (Zemax/COMSOL).

Profile: Solid Python required. Notions of C++, Mathematica and Hamiltonian mechanics appreciated but not mandatory. Curiosity for computational physics and optics.

Environment: LPC Caen (Virgo group). The candidate must contact the supervisor before choosing this internship.

Internship in experimental nuclear physics

Space-Charge Effects On the Transmission of Bunched Ion Beams

The *Matter's Origin from RadioActivity* (MORA [1, 2]) experiment searches for signatures of CP violation in the nuclear beta decay that could help explain the matter-antimatter asymmetry observed in the Universe. The most sensitive and complementary isotopes for this search for physics beyond the Standard Model are ^{23}Mg and ^{39}Ca.

MORA is currently taking data at the University of Jyväskylä, where both isotopes are produced with beam intensities of approximately 10^5 particles per second (pps). At GANIL, where the experiment is expected to reach its highest sensitivity, beam intensities exceeding 10^7 pps are anticipated.

To effectively transport and inject these radioactive ions into the MORA setup, the beams are converted from a continuous ion stream into temporally narrow, dense ion bursts, also known as bunches, by using a device called a Radiofrequency Quadrupole Cooler Buncher (RFQ-CB). At the University of Jyväskylä, MORA uses the so-called "minibuncher" [3] to perform such a conversion. However, it was observed that the transmission efficiency of the bunches decreases as a function of the number of ions in the bunch, for numbers as low as a few 10^5. One hypothesis for the source of these losses is that the Coulomb repulsion drives the ions apart, losing some of them inside the beamline.

The objective of this M2 project is to study and report these transmission losses by simulating the transport of ion bunches in SIMION, utilizing its in-built Poisson equation solver to account for space-charge effects. This work will be conducted within the MORA project at GANIL.

For more information, see https://mora.ganil-spiral2.eu/.

[1] P. Delahaye, E. Liénard, I. Moore, M. Benali, M. L. Bissel, L. Canete, T. Eronen, A. Falkowski, X. Fléchard, M. Gonzalez-Alonso, W. Gins, R. P. D. Groote, A. Jokinen, A. Kankainen, M. Kowalska, N. Lecesne, R. Leroy, Y. Merrer, G. Neyens, et al., "The MORA project," *Hyperfine Interact.,* no. 240, pp. 63 - 75, 2019.

[2] N. Goyal, A. Singh, S. Daumas-Tschopp, L. M. Motilla Martinez, G. Ban, V. Bosquet, J. F. Cam, P. Chauveau, S. K. Chinthakayala, G. Fremont, R. P. De Groote, F. de Oliveira Santos, T. Eronen, A. Falkowski, X. Flechard, et al., "Performance of the MORA Apparatus for Testing Time-Reversal Invariance," *Eur. Phys. J. A (2025) 61: 221,* 2025.

[3] V.A. Virtanen, T. Eronen, A. Kankainen, O. Beliuskina, P. Campbell, R. Delaplanche, Z. Ge, R.P. de Groote, M. Hukkanen, A. Jaries, R. Kronholm, I.D. Moore, A. Raggio, A. de Roubin, J. Ruotsalainen, M. Schuh, "Miniaturised cooler-buncher for reduction of longitudinal emittance at IGISOL" *NIM-A 1072: 170186, 2025*

Expected skills

The M2 student is expected to be interested in experimental physics, to have a firm grip on the basics of electromagnetism, and to have prior experience in programming, for example, in python, lua, C++, or in other comparable language.

This work does not lead to a PhD-thesis.

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Internship in medical nuclear physics

Characterization and correction of optical artifacts in 3D scintillation dosimetry for proton beam scanning

Context

Radiotherapy is a major modality for cancer treatment where proton therapy offers a significant ballistic advantage over photon therapy, thanks to the dose deposition profile of protons. Among current proton delivery techniques, Pencil Beam Scanning (PBS) is one of the most advanced approaches, providing high flexibility and better dose conformation.

However, the increasing use of small and highly modulated pencil beams requires dedicated and accurate dosimetry tools for quality assurance (QA). In this context, a scintillator-based dosimetry system has been developed. It consists of a $10 \times 10 \times 10$ cm³ scintillating block, a mirror, and an ultra-fast camera. The scintillation light emitted by the irradiated volume is recorded from two orthogonal points of view, enabling the reconstruction of three-dimensional dose distributions [1].

While this system offers promising capabilities for volumetric dosimetry, the measured signal is affected by several physical and optical effects. A previous study identified multiple sources of artifacts, including lens vignetting, reflections at the scintillator boundaries, light diffusion within the scintillating material, and refraction at the scintillator–air interface [2]. In addition, the camera images can contain hot pixels, resulting from scattered radiation directly hitting the camera sensor. Another important effect is scintillation quenching, which leads to a non-linear relationship between the scintillation yield and the Linear Energy Transfer (LET) of the charged particles [3]. These effects are complex and depend strongly on both the beam energy and its position within the scintillator. Their accurate characterization and correction are therefore essential to obtain reliable and robust 3D dose reconstructions.

Objectives

The objective of this internship is to characterize the different artifacts affecting the optical measurement of proton pencil beams and to develop correction strategies to improve the accuracy of 3D dose reconstruction.

The study will rely on the comparison of previously acquired experimental images with images generated from simulated dose and scintillation distributions. The work will involve several complementary steps:

1. *Simulation of proton pencil beams*

Individual pencil beams will be simulated using the treatment planning system (TPS), for a range of beam energies and positions within the scintillator. The simulations will provide 3D dose distributions with a spatial resolution of approximately 1 mm in the three dimensions.

2. *Calculation of LET and scintillation quenching*

LET distributions will be computed using analytical methods or the TPS. Based on these LET maps, scintillation quenching effects will be modelled to convert the simulated 3D dose distribution into a physically realistic 3D scintillation distribution.

3. *Modelling of the imaging system*

A projection matrix of the experimental optical setup will be developed to calculate the projection of the 3D scintillation distribution corresponding to the camera images. The resulting synthetic images will reproduce, as closely as possible, the geometry and acquisition conditions of the experimental system, providing a direct basis for comparison with measured images.

4. *Characterization and separation of optical artifacts*

Experimental and simulated images will then be compared for different beam energies and positions. The analysis of differential projection images will be used to characterize the spatial dependence of the observed artifacts and to investigate their respective contributions, including:

- camera hot pixels;
- lens vignetting and spatial variations in detection efficiency;
- reflections at the scintillator boundaries;
- light diffusion and refraction effects;
- geometrical effects related to the imaging setup;

The objective will be to distinguish the different sources of discrepancies between the experimental and simulated measurements and to establish a quantitative model of the main systematic effects.

5. *Development and evaluation of correction strategies*

Finally, several strategies for correcting the identified artifacts will be investigated. Both conventional analytical corrections and machine-learning-based approaches will be considered. Their implementation will be investigated at different stages of the reconstruction pipeline, notably:

- directly at the image level, by correcting the camera projections;
- at the 3D scintillation level, before dose reconstruction;
- potentially within the 3D reconstruction process itself.

The different approaches will be evaluated in terms of their ability to improve the agreement between measured and reconstructed dose distributions, as well as their robustness with respect to beam energy and position.

Expected outcomes

The internship will lead to:

- a modelling framework linking proton dose, LET, scintillation and camera images;
- a quantitative characterization of the main optical and instrumental artifacts;
- an improved understanding of their dependence on beam energy and position;
- one or several correction strategies for improving the accuracy of the 3D dosimetry system;
- a quantitative assessment of the impact of these corrections on 3D dose reconstruction.

The project will involve medical physics, proton therapy, analytical modelling, image processing, inverse problems and potentially machine learning, providing a

multidisciplinary research experience at the interface between physics and computational methods.

Expected skills

The student should have an education background in medical physics with a good knowledge of radiation-matter interactions, radiotherapy and dosimetry. The candidate must thus have strong interest for data analysis and simulation, and will have to develop skill in image manipulation, programming and Monte Carlo simulations.

This work leads to a PhD-thesis.

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Internship in experimental nuclear physics

Ion trajectory simulations for laser spectroscopy behind S^3

Spectroscopy of superheavy elements (SHEs) provides fertile ground for advancing our understanding of the properties of matter at the limits of existence. Our experiments focus on elucidating the atomic and nuclear properties of these elements using laser spectroscopy. Since conventional spectroscopic approaches practically reach their limits at the element nobelium (Z=102), a novel type of laser spectroscopy, called laser resonance chromatography (LRC) [1], was conceived to extend the frontier of optical spectroscopy to even heavier elements such as lawrencium (Z=103) and the superheavy element rutherfordium (Z=104). The technique has been proven to work in offline experiments [2] and is currently being prepared for first online experiments at the S^3 facility of GANIL/SPIRAL2. In order to efficiently stop and extract sample ions online, a gas catcher is necessary. To this end, a cryogenic helium gas cell will be developed to connect the LRC instrument to S^3.
During the internship, the successful candidate will perform ion trajectory simulations using the SRIM and the SIMION packages to extract optimal working parameters for ion stopping and extraction. The internship can be followed by a PhD thesis on the development of this stopping cell, which will be installed at the S^3 focal plane.

[1] M. Laatiaoui *et al.*, Phys. Rev. Lett. 125 (2020) 023002.
[2] E. Kim *et al.*, Nucl. Instrum. Methods Phys. Res. B 555 (2024) 165461.

Expected skills
Good level in atomic and nuclear physics academic knowledge. Affinity for experimental work. Good communication skills in English (both verbal and written). Knowledge of scientific programming such as C++ and Python will be considered an added qualification.

This work leads to a PhD-thesis.

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ERASMUS MUNDUS JOINT MASTER IN NUCLEAR PHYSICS

Academic Year 2026/2027

MASTER THESIS PROPOSAL

TITLE: *Development of the STRASSE and HYPATIA detector systems for the study of exotic nuclei.*

SUPERVISOR(S): Juan Lois Fuentes, Freddy Flavigny, Adrien Matta
Nuclear Structure Research Group, LPC-Caen

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UNIVERSITY/RESEARCH CENTER: LPC Caen (UMR6534), ENSICAEN

ABSTRACT

Our group is involved in the development of two state-of-the-art detector systems – the STRASSE silicon tracker and the HYPATIA hybrid photon detector – for experiments in nuclear structure research at the RIKEN, Radioactive Isotope Beam Factory in Japan. The combination of these devices aims to enable simultaneous high-resolution gamma-ray spectroscopy and charged-particle (essentially proton) tracking to study nuclei with very asymmetric neutron-to-proton ratios – the so-called "exotic" nuclei. To produce and characterize the exotic nuclei of interest, quasi-free scattering (QFS) reactions are employed, whereby a single-neutron or proton is "knocked out" from the projectile.

The Master's Thesis project will contribute to one or more aspects of the development of these devices and the associated experiments:

- **STRASSE data analysis**: contribute to the processing of data from in-beam commissioning and/or prototype detector measurements (timestamp reconstruction, tracking, etc.).
- **HYPATIA design simulations**: study the impact of various detector configurations on the gamma-ray response of the array (efficiency, resolution and Doppler reconstruction).
- **Quasi-free scattering event generator benchmarking**: compare basic QFS event generators with theoretical calculations, including effects such as the internal momentum distribution of the kocked out nucleon.

The different studies will require the student to employ nptool, a Root and Geant4 framework, for the simulations and data analysis developed in our group. They will improve and validate existing simulations and benchmark reconstruction algorithms using "Monte Carlo truth". Ideally, basic skills in c++ and familiarity with ROOT would be beneficial.

By the end of the thesis project, the student will have gained hands-on experience with cutting edge detector simulation tools and data analysis for nuclear physics experiments. This will form an ideal basis for a PhD in nuclear structure physics and related fields.

Internship in experimental nuclear astrophysics

New Judicious Experiments for Dark sectors Investigations
ANDROMEDE Experiment Analysis

Understanding the composition and functioning of our Universe are among the most fundamental and challenging questions in Physics. To date, the intrinsic nature of dark matter remains a mystery. The New JEDI project aims to study through several nuclear physics experiments a fascinating alternative scenario, such as the existence of an indirect interaction between ordinary matter, well described by the Standard Model, and the Darks Sectors of the Universe via portals (so called bosons). In other words, does a new fifth force of nature exist?

The construction of a new detection system (named New JEDI as well) has been completed in 2021. As opposed to all other experiments, New JEDI is designed to be versatile in order to make a proposal for a large-scale broadband experimental program. The project relies on pathfinder experiments conducted at the ARAMIS facility (France). The commissioning of New JEDI has been completed successfully on June 2021 at a tandetron facility (Czech Republic).

The first experiment took place Orsay from June to July 2022, at the ANDROMEDE facility. A complementary experiment (FASERED project) was also realized in October 2023, at the iThemba LABS laboratory (South Africa). We plan to develop a long-term research program in the MeV terra incognita energy range at the new SPIRAL2 facility (Fr), that will deliver unique high-intensity beams of light, heavy-ions and neutrons in Europe. This project outlines as well an ambitious experimental program to advance to new levels the precision on Big Bang Nucleosynthesis (BBN) modelling. The New JEDI project gathers world-wild experts on nuclear physics and astrophysics, dark sectors theory and BBN.

During the internship the student will get familiar with the scientific topic and will contribute to the data analysis of the new JEDI first experiment at the ANDROMEDE facility (calibration, comparison with simulation…). The student will participate actively on the New JEDI experimental program as well.

The supervision will be done by Beyhan BASTIN (GANIL) and New JEDI project co-spokespersons.

Expected skills

Experimental profile. Very good levels on programming, English, Nuclear Physics and/or Particle Physics academic knowledge. Affinity for experimental work and work in an international environment.

This work does not lead to a PhD-thesis.

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Internship in experimental nuclear astrophysics

New Judicious Experiments for Dark sectors Investigations
iThemba LABS Experiment Analysis

Understanding the composition and functioning of our Universe are among the most fundamental and challenging questions in Physics. To date, the intrinsic nature of dark matter remains a mystery. The New JEDI project aims to study through several nuclear physics experiments a fascinating alternative scenario, such as the existence of an indirect interaction between ordinary matter, well described by the Standard Model, and the Darks Sectors of the Universe via portals (so called bosons). In other words, does a new fifth force of nature exist? The construction of a new detection system (named New JEDI as well) has been completed in 2021. As opposed to all other experiments, New JEDI is designed to be versatile in order to make a proposal for a large-scale broadband experimental program. The project relies on pathfinder experiments conducted at the ARAMIS facility (France). The commissioning of New JEDI has been completed successfully on June 2021 at a tandetron facility (Czech Republic).

The first experiment took place Orsay from June to July 2022, at the ANDROMEDE facility. A complementary experiment (FASERED project) was also realized in October 2023, at the iThemba LABS laboratory (South Africa). We plan to develop a long-term research program in the MeV terra incognita energy range at the new SPIRAL2 facility (Fr), that will deliver unique high-intensity beams of light, heavy-ions and neutrons in Europe. This project outlines as well an ambitious experimental program to advance to new levels the precision on Big Bang Nucleosynthesis (BBN) modelling. The New JEDI project gathers world-wild experts on nuclear physics and astrophysics, dark sectors theory and BBN.

During the internship the student will get familiar with the scientific topic and will contribute to the data analysis of the new JEDI experiment at the iThemba LABS facility (calibration, comparison with simulation…). The student will participate actively on the New JEDI experimental program as well.

The main supervising team will be composed of: Beyhan BASTIN (GANIL), François Didierjean (IPHC), Philip Adsley (Texas A&M), Lindsay Donaldson (iThemba LABS), Kgashane Malatji (iThemba LABS) and Alain Coc (IJCLab).

Expected skills

Experimental profile. Very good levels on programming, English, Nuclear Physics and/or Particle Physics academic knowledge. Affinity for experimental work and work in an international environment.

This work does not lead to a PhD-thesis.

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Stage de 6 mois :

« Simulations numériques de sondes gamma pour la prospection minière et établissement par Machine Learning de modèles de prédiction de la teneur en uranium »

Le **CEA/DES/IRESNE/SMTA (Cadarache)**, propose un **stage de 6 mois** au sein du projet **Laboratoire des Mesures Nucléaires (LMN)**.

Contexte et objectifs

Dans le cadre d'une collaboration avec Orano, le CEA étudie la performance de sondes gamma utilisées pour la détermination de la concentration en uranium du minerai dans des puits de forage. Plusieurs types de sondes, dont le principe repose sur la détection des rayonnements gamma émis par l'uranium et ses descendants, peuvent être mises en œuvre, ainsi que différentes méthodes d'analyses. Associé à cet aspect expérimental, des codes de calcul sont utilisés pour modéliser et prendre en compte des effets physiques – tels que le déséquilibre radioactif de la chaine de décroissance ou l'atténuation des rayonnements dans le minerai – pour obtenir une teneur en uranium la plus précise et la plus juste.

L'objectif du stage est de réaliser des études comparatives calculs/calculs et calculs/expérience pour évaluer les performances (justesse, précision, temps de calcul) de différents codes Monte Carlo (TRIPOLI4, MCNP, PHITS) pour la simulation de la réponse de sondes de spectrométrie gamma utilisées en prospection minière de l'uranium. Cette étude permettra d'identifier les limites et les pistes d'améliorations possibles des voies de modélisation proposées.

Une autre étude se focalisera sur la réponse de détecteurs de type Geiger-Müller, qui repose sur des mécanismes d'interaction différents des sondes à cristaux solides comme les détecteurs germanium, NaI ou CeBr.

Enfin, un troisième volet portera sur des méthodes d'analyse avancées (Machine Learning, méta-modèles) afin de simuler la réponse de sondes gamma spectrales dans différents environnements de forage en vue d'établir des modèles de prédiction de la teneur en uranium par apprentissage automatique. La validité de ces simulations sera ensuite testée sur des diagraphies de puits réels.

Profil recherché

Étudiant en Master 2 ou dernière année école d'ingénieur, physique nucléaire ou interaction rayonnement-matière, présentant un attrait pour la simulation et le machine learning appliqués aux mesures nucléaires.

Méthodes/logiciels

Codes de transport Monte Carlo : PHITS, MCNP6, GEANT4, TRIPOLI4
Logiciels de programmation : C, C++, Python...

Début du contrat : 1er trimestre 2027

Durée : 6 mois

Unité : CEA Cadarache – Laboratoire de Mesures Nucléaires
CEA DES IRESNE DTN/SMTA/LMN

Contacts : GRUEL Adrien adrien.gruel@cea.fr
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MARCHAIS Thomas thomas.marchais@cea.fr

Références : IRESNE - Laboratoire de mesures nucléaires

Lien pour postuler : Fiche du poste

ERASMUS MUNDUS JOINT MASTER IN NUCLEAR PHYSICS

Academic Year 2026/2027

MASTER THESIS PROPOSAL

We're looking for M2 student to join our team in Caen on Monte Carlo calculations for dosimetry research. (La thèse peut également être effectué en français).

🔬 **Topic:** "Monte Carlo calculations of Linear Energy Transfer in proton treatment plans"

📍 **Location:** Corpuscular Physics Laboratory, Caen, France

📅 **Duration:** February – June 2027 (negotiable)

🤝 **Supervisors:** Mateusz SITARZ (University of Caen), Nicolas ARBOR (University of Strasbourg)

📖 **Context:**

Linear Energy Transfer (LET) describes the average ionization density caused by particle beams. It is a widely used parameter in dosimetry, radiobiology, and radiotherapy. However, it remains challenging to measure and calculate precisely.

The goal of this project is to employ Monte Carlo method to calculate proton LET (and other relevant quantities) in various reference treatment plans. The internship will focus on the simulations in GATE10 environment and manipulation of medical files (DICOM format).

The results of this and similar works will be compared in a study coordinated by The European Radiation Dosimetry Group and Danish Centre for Particle Therapy.

🎯 **Objectives:**

- Implement virtual set-up in GATE10
- Design a chain to upload treatment plans and score dose, LET and fluence distributions
- Compare results with available data

👤 **Candidate Profile:**

- Master 2 student in physics
- Proficiency in Python
- Desired: basic knowledge on radiation interaction with matter, experience with Monte Carlo codes

📩 **Application:** send CV + short cover letter to sitarz@lpccaen.in2p3.fr

Stage de 6 mois – Ingénieur.e en mesures nucléaires : Intégration et validation de la diffusion dans les simulations d'imagerie X haute-énergie

Contexte scientifique et industriel

Dans le cadre de la R&D que le CEA mène sur les réacteurs de 4ème génération, le Laboratoire de Mesures Nucléaires (LMN) participe aux études sur les accidents graves dans le cadre de la sûreté nucléaire (fonte du cœur d'un réacteur). Des dispositifs de radioscopie X haut-énergie, utilisant un accélérateur de particules comme source de rayonnement, permettent d'étudier la phénoménologie de l'interaction du corium (combustible nucléaire fondu) avec le caloporteur (eau ou sodium selon la génération du réacteur).

Dans ce contexte, la radioscopie est une technique essentielle pour :

- Visualiser en temps réel les phénomènes dynamiques (ex. : fragmentation, dispersion et vitesse du corium).
- Mesurer des paramètres critiques (ex. : taille des fragments, densité, répartition spatiale, volume de vapeur produite).

Problématique clé

Les niveaux de gris des images radiographiques obtenues avec les dispositifs existants contiennent des informations quantitatives sur les matériaux traversés (ex. : épaisseur, densité, composition). Cependant, aujourd'hui, ces informations ne sont pas pleinement exploitées à cause de la diffusion Compton qui augmente la quantité de photons atteignant le détecteur ce qui perturbe l'analyse des niveaux de gris de l'image. Il est ainsi indispensable de prendre en compte ces phénomènes de diffusion.

Enjeux du stage

Le code de simulation déterministe MODHERATO, développé au sein du laboratoire, ne permet pas la simulation de ces phénomènes de diffusion mais seulement la transmission du rayonnement direct.

Dans le cadre de l'amélioration de ses capacités de simulation, le LMN souhaite donc :

- Valider l'introduction de la simulation X Haute Energie dans le logiciel CIVA (code CEA)
- Comparer les résultats de simulation Haute Energie avec rayonnement diffusé produits par les logiciels CIVA et aRTist (code du BAM en Allemagne) aux résultats de simulation avec un code Monte Carlo de référence (MCNP)
- Comparer les résultats obtenus avec des mesures expérimentales sur maquette à des énergies de 9 ou 15 MeV.

Missions Principales

- Prise en main des outils de simulation
- Exécution des simulations et analyse comparative des résultats
- Validation avec des données expérimentales obtenues sur maquette

Profil Recherché

- Formation : Étudiant(e) en Bac+5 (Master 2, école d'ingénieur) en physique nucléaire.
- Compétences techniques :
  - Maîtrise des principes de physique des rayonnements (interactions photon-matière, atténuation, diffusion).
  - Expérience en simulation Monte Carlo (ex. : Geant4, MCNP, ou équivalent) – un plus.
  - Connaissances en traitement d'images et reconstruction tomographique (algorithmes de rétroprojection, FBP, etc.) – un plus.
  - Maîtrise d'un langage de programmation (Python, C++) pour l'analyse des données.
  - Expérience avec des outils de visualisation scientifique (ex. : Matplotlib, ROOT).
- Qualités personnelles :
  - Rigueur scientifique et capacité d'analyse.
  - Autonomie et esprit d'initiative.
  - Bonnes capacités rédactionnelles et de synthèse.
  - Aisance en anglais (documentation technique).
- Environnement de Travail
  - Encadrement : Vous serez encadré(e) par une équipe d'experts en physique nucléaire et imagerie haute énergie.
  - Outils mis à disposition :
    - Accès aux licences des logiciels MODHERATO, CIVA et aRTist.
    - Cluster de calcul pour les simulations lourdes.
    - Logiciels d'analyse (Python, ROOT, etc.).

Unité d'accueil :	CEA, DES, IRESNE, Cadarache, Laboratoire de Mesures Nucléaires	
	Bâtiment 224, 13108 Saint-Paul-lez-Durance	
Contact	Alix Sardet	alix.sardet@cea.fr

Radiative corrections in forbidden β decays for Standard Model tests

Contact: Leendert Hayen (hayen@lpccaen.in2p3.fr)

INTRODUCTION

Forbidden β decays are increasingly recognized as a promising avenue for Beyond Standard Model tests. However, approximate calculations of radiative corrections have recently been shown to be exceptionally sensitive to the type of nuclear β decay [1], and can provide similar signatures as some Beyond Standard Model physics operators. As part of an ongoing collaborative effort, we are reformulating β decays in an explicitly covariant decomposition to tackle the calculation systematically.

DESCRIPTION OF THE WORK

The student will be involved in the construction of the covariant amplitude for forbidden beta decays and comparison with other, traditionally used formalisms. Additionally, nuclear structure calculations will be performed for specific cases of physical interest for Standard Model tests. A solid background in nuclear and particle physics is recommended. A natural possibility exists for extending the work into a PhD.

[1]: C.Y. Seng, A. Glick-Magid and V. Cirigliano, Physical Review Letters 134 (2025) 081805

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

MASTER THESIS PROPOSAL

TITLE: Radiation-induced processes within fibronectin peptides studied at the molecular scale

SUPERVISOR(S): Jean-Christophe POULLY

SUPERVISOR(S) contact- email: poully@ganil.fr Telephone: 0231454442
email: Telephone:

UNIVERSITY/RESEARCH CENTER: University of Caen, CIMAP institute

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

It is crucial to describe, understand and quantify the effects of radiation on matter, especially biological systems, since the consequences can be highly deleterious, in particular regarding ionizing radiation. However, little is known about the processes of radiation action at the molecular scale, and almost no information is available for the extracellular matrix, which is mainly composed of proteins. Among them, fibronectin plays a key role in the adhesion of cells notably thanks to a higher-order geometrical structure that is stabilized by numerous disulfide bonds.

The proposed work is to study the response of fibronectin peptides upon collision with ionizing particles (X-rays or carbon ions), by means of experiments at large-scale facilities such as synchrotrons or ion beam accelerators. Mass spectrometry will be used to analyze the ionic products of radiation, in order to study processes such as ejection of multiple valence electrons due to the decay of core atomic vacancies, cleavage of disulfide and backbone bonds of this peptide, etc.

ERASMUS MUNDUS JOINT MASTER IN NUCLEAR PHYSICS

Academic Year 2026/2027

MASTER THESIS PROPOSAL

TITLE: Laser-Radiofrequency Double Resonance at S3-LEB

SUPERVISOR(S): Antoine de Roubin

SUPERVISOR(S) contact- email: deroubin@lpccaen.in2p3.fr Telephone: 0231452968

UNIVERSITY/RESEARCH CENTER: LPC Caen

ABSTRACT

Atomic nuclei are intricate many-body systems, and their structure remains only partially understood. Among the experimental tools available for probing nuclear properties, **laser spectroscopy** stands out due to its unique ability to determine nuclear electromagnetic moments in a model-independent manner. To date, these techniques have provided access only to the two lowest-order electromagnetic moments: **the magnetic dipole and electric quadrupole moments**. These observables have been studied for years, enabling a deeper understanding of nuclear structure and its evolution in unstable nuclei [1]. To our knowledge, the next-order moment, **the magnetic octupole moment**, has been measured in only 21 stable nuclei and never in radioactive isotopes [2].

This project proposes to develop the **Laser-Radiofrequency Double Resonance** method, which will enable, for the first time, the measurement of the **octupole moment** in radioactive atoms. Successfully achieving this would unlock a new pathway for investigating the properties of short-lived atomic nuclei, advancing our understanding of nuclear structure.

By joining this project, you will participate in commissioning the **Laser-Radiofrequency Double Resonance** method on stable ions. The work will involve:

- Operating and aligning lasers,
- Developing laser/RF schemes,
- Conducting measurements,
- Performing data analysis using Python.

You will be integrated into a large, collaborative research team, working closely with PhD students, postdocs, and permanent research staff members.

[1] X. F. Yang *et al.*, **Laser spectroscopy for the study of exotic nuclei**, Progress in Particle and Nuclear Physics (2023)

[2] S. Bofos, T.J. Mertzimekis, **Revisiting the nuclear magnetic octupole moment**, Atomic Data and Nuclear Data Tables (2024)

ERASMUS MUNDUS JOINT MASTER IN NUCLEAR PHYSICS

Academic Year 2026/2027

MASTER THESIS PROPOSAL

TITLE: Finalization of the characterization of PIPERADE at LP2iB

SUPERVISOR(S): Pauline Ascher, Mathias Gerbaux

SUPERVISOR(S) contact- email: ascher@lp2ib.in2p3.fr Telephone: 0557120905
email: Telephone:

UNIVERSITY/RESEARCH CENTER: LP2iB / Université de Bordeaux

ABSTRACT

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

PIPERADE (PIèges de PEnning pour les RAdionucléides à DESIR) is a double Penning trap being developed in Bordeaux, which will be installed at the DESIR facility at GANIL.

This instrument has two objectives: 1) perform precision mass measurements of exotic nuclei, providing valuable information on nuclear structure, the forces acting within the atomic nucleus (strong and weak interactions), and stellar nucleosynthesis, 2) perform the mass selection of nuclei of interest among a large number of contaminants, with very high resolving power (> 10^6) and a high capacity (> 10^4 ions per bunch). It will therefore provide to all other experimental setups in the DESIR hall an ultra-pure ion beam, greatly improving the precision of measurements of various observables, such as lifetimes, charge radii or electromagnetic moments.

The characterization of PIPERADE using a stable-ion beam has been ongoing at LP2iB since 2019 and will be completed in 2027, before the instrument is transferred to GANIL in summer 2027. This M2 internship will therefore be perfectly synchronized with the final phase of the project at LP2iB. It will focus primarily on finalizing the characterization of the PI-ICR (Phase-Imaging Ion-Cyclotron-Resonance) mass-measurement technique.

Finally, funding is available for a PhD position to contribute to the installation of PIPERADE at GANIL in Caen and to carry out the first mass measurements of radioactive nuclei. The M2 student will therefore have the opportunity to continue working on the project as a PhD student at the University of Bordeaux while being based in Caen, contributing to the on-site characterization of the instrument and to the first online mass measurements of light exotic nuclei.

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

MASTER THESIS PROPOSAL

TITLE: Si-cube characterisation for detection of rare decay modes

SUPERVISOR(S): Silvia Bara

SUPERVISOR(S) contact- email: bara@lpccaen.in2p3.fr Telephone:
email: Telephone:

UNIVERSITY/RESEARCH CENTER: LPC Caen (UNICAEN)

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

Nuclei along the drip lines are characterised by rare composite decay modes, such as β-delayed particle emission and β-delayed fission (βDF), that serve as essential probes of nuclear structure yet remain experimentally elusive. No validated multi-purpose detection platform currently exists to characterise these processes using low-energy radioactive ion beams (RIBs). Therefore, we want to test whether a single detection architecture, a segmented silicon array (Si-cube) coupled with high-purity germanium detectors, can serve as a universal platform for exotic decay spectroscopy, detecting both heavy fission fragments and light charged particles.

In this context, the student will be involved in the recommissioning of the Si-cube setup. This will include simulations with Geant4 combined with practical work in the laboratory. First, the student will perform simulations (eventually, varying the configuration of the system) to estimate the basic properties of the setup (energy calibration, detection efficiency, resolution). Then, the student will get the chance to perform off-line measurements with calibration sources to compare the simulation results with the experimental ones.

6 MONTHS INTERNSHIP

Understanding the Role of Phase Modifiers in Uranium Extraction

General information:

- Location: ICSM (Elise Guerinoni, Sandrine Dourdain in collaboration with Marie Plazanet from Université Grenoble Alpes)
- Duration: 6 months
- Field: Physical Chemistry, Soft Matter, Neutron Scattering

Context and missions:

Uranium extraction using solvent-extraction processes is central to the nuclear fuel cycle. To ensure efficiency and safety, specific additives called phase modifiers (e.g., n-octanol) are introduced into organic extraction mixtures. Their primary role has long been associated with preventing third-phase formation, but recent observations show that phase modifiers play a much deeper role: they influence aggregation, interfacial structure, dynamics, and ultimately extraction selectivity.

Despite their widespread use, the microscopic mechanisms by which phase modifiers reshape the organic phase—and how these changes affect uranium uptake—remain poorly understood.

This intership aims to elucidate the molecular interactions and mobility of octanol and water in trioctylamine (TOA)/dodecane extraction systems, providing insights essential for optimizing industrial extraction formulations. Water plays a central role in metal extraction, yet its degree of incorporation, confinement, and interaction with TOA or octanol remains poorly understood. By combining structural techniques (SANS) with dynamic measurements (QENS, PFG-NMR, 2D-IR), we will determine to what extent water and octanol are free in the solvent or adsorbed at specific sites within the aggregate (polar cores, interfaces or bulk) and ultimately selectivity in the AMEX (AMine EXtraction) process.

Candidate Profile:

We are looking for an autonomous and motivated M2 student with a background in physical chemistry, soft matter, or physics. Experience with Python/Matlab data analysis, soft-matter models, or theoretical scattering. Curiosity for complex fluids, interfaces, and energy-related applications. Ability to analyse experimental data and work in a collaborative research environment.

This position offers a unique opportunity to work directly on neutron beamlines and contribute to world-leading studies of extraction phases, using advanced structural and dynamical methods to push our understanding of phase modifiers and confined water further than ever before.

If you are interested, please send a resume and a short motivation letter to Elise Guerinoni (elise.guerinoni@cea.fr).

STAGE 6 MOIS

Compréhension du rôle des modificateurs de phase dans l'extraction de l'uranium

Informations générales :

- Lieu : ICSM (Elise Guerinoni, Sandrine Dourdain, en collaboration avec Marie Plazanet, Université Grenoble Alpes)
- Durée : 6 mois
- Domaine : Chimie physique, matière molle, diffusion des neutrons

Contexte et missions :

L'extraction de l'uranium par des procédés de solvant est un élément central du cycle du combustible nucléaire. Pour garantir efficacité et sécurité, des modificateurs de phase (n-octanol) sont introduits dans la phase d'extraction. Leur rôle principal a longtemps été associé à la prévention de la formation de la « troisième phase », mais des observations récentes montrent que les modificateurs de phase jouent un rôle beaucoup plus large : ils influencent l'agrégation, la structure interfaciale, la dynamique et, en fin de compte, la sélectivité de l'extraction.

Malgré leur utilisation répandue, les mécanismes microscopiques par lesquels les modificateurs de phase modifient la phase organique — et comment ces changements affectent la récupération de l'uranium — restent mal compris.

Ce projet vise à élucider les interactions moléculaires et la mobilité de l'octanol et de l'eau dans les systèmes d'extraction trioctylamine (TOA)/dodécane, apportant des informations essentielles à l'optimisation des formulations industrielles. L'eau joue un rôle central dans l'extraction des métaux, mais son degré d'incorporation, de confinement et son interaction avec la TOA ou l'octanol restent peu connus. En combinant des techniques structurales (SANS) et des mesures dynamiques (QENS, PFG-NMR, 2D-IR), nous déterminerons dans quelle mesure l'eau et l'octanol sont libres dans le solvant ou adsorbés sur des sites spécifiques au sein des agrégats (cœurs polaires, interfaces ou phase organique), et comment cela influence la sélectivité du procédé AMEX.

Profil du candidat :

Nous recherchons un·e étudiant·e de niveau M2, autonome et motivé·e, possédant une formation en chimie physique, en matière molle ou en physique. Une expérience en analyse de données Python/Matlab, en modélisation de la matière molle ou en théorie de la diffusion constitue un atout. Une curiosité pour les fluides complexes, les interfaces et les applications liées à l'énergie est également souhaitée. La capacité à analyser des données expérimentales et à travailler au sein d'un environnement de recherche collaboratif est indispensable.

Ce poste offre une opportunité unique de travailler directement sur des lignes de faisceaux neutroniques et de contribuer à des études de pointe sur les phases d'extraction, en utilisant des méthodes structurales et dynamiques avancées pour approfondir notre compréhension des modificateurs de phase et de l'eau confinée.

Merci d'envoyer un CV et une courte lettre de motivation à Elise Guerinoni : (elise.guerinoni@cea.fr)

CHALLENGING AOT-BASED IONIC LIQUIDS AS NEW ECO-FRIENDLY LUBRICANT *(CHANEL)*

Laboratoire de Theorie et Methodologie multiechelles (LTeM) & Laboratoire des Interfaces et systèmes pour la Séparation Avancée (LISA)

Niveau, Durée 6 mois à partir de fevrier 2026

Contacts :

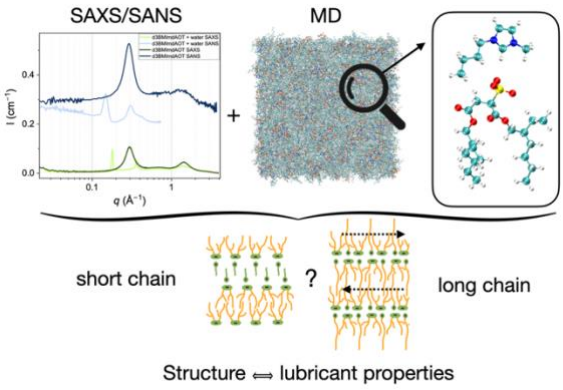
- Kateryna GOLOVIZNINA – kateryna.goloviznina@cnrs.fr
- Elise GUERINONI – elise.guerinoni@cea.fr

Contexte

La friction a un impact majeur sur la consommation énergétique mondiale et les coûts industriels [1]. Les **SAILs** (*Surface-Active Ionic Liquids*) apparaissent comme une alternative durable aux lubrifiants fluorés, offrant une excellente lubrification sans les risques environnementaux et sanitaires des PFAS. [2] Cependant, les mécanismes moléculaires sous-jacents restent mal compris. Ce projet vise à élucider comment la structure ionique influence la nanostructure, l'auto-assemblage et la dynamique collective dans les liquides ioniques, via des **simulations de dynamique moléculaire (MD)**. L'approche combine innovations méthodologiques et analyses multi-échelles pour interpréter les données expérimentales et proposer des solutions écoénergétiques.

Sujet

Ce stage vise à étudier l'anion **AOT** (bis(2-éthylhexyle) sulfosuccinate) combiné à des cations imidazolium/ammonium, dont les performances lubrifiantes exceptionnelles près de la phase lamellaire pourraient provenir d'une organisation en bicouches, d'une réduction des frottements inter-couches et de relaxations collectives optimisées [3]. Pour explorer ces relations structure-propriété, des expériences (**SAXS, SANS, NSE**) ont révélé un comportement complexe, nécessitant des simulations MD pour une interprétation atomique. Le/la stagiaire développera un **champ de force polarisable** [4] pour l'AOT et des cations à chaînes latérales variables, puis validera le modèle par comparaison avec des données expérimentales. Des simulations à grande échelle généreront des trajectoires atomiques pour analyser la nanostructure et la dynamique collective.



Profil du candidat

- Etudiant(e) de Master 2, école d'ingénieurs ou équivalent specialisé(e) en chimie, physique et/ou chimie physique
- Intérêt pour pour la chimie physique, la modélisation, les calculs numériques

Apport pour le candidat

- Première expérience de recherche en en modélisation moléculaire et développement de modèles.
- Expérience de recherche sur des centres de calcul haute performance, renforçant ainsi vos compétences en modélisation numérique.
- Possibilité de financement de thèse sur un sujet connexe.

Références

K. Holmberg *et al.*, **Friction**, *5*, 263 (2017) ; Y. Zhang *et al.*, **J. Colloid Interface Sci.** *630*, 931 (2023) ; E. Guerinoni *et al.*, **J. Colloid Interface Sci.** *723*, 140970 (2026) ; K. Goloviznina *et al.*, **J. Chem. Theory Comput.** *15*, 5858 (2019).

MASTER SUMMER TRAINING PROPOSAL

Academic Year 2026/2027

TITLE: Integrate AI-control with a laser platform for quantum sensing experiment.

FRIB ADVISOR: Xing Wu
FRIB ADVISOR CONTACT: email: wux@frib.msu.edu Phone: 517 908 7161.

UNIVERSITY/RESEARCH CENTER of the TRAINING:
Michigan State University, Facility for Rare Isotope Beams (FRIB), East Lansing Michigan, USA;
International Research Laboratory NPA, East Lansing Michigan, USA;

LEVEL: Master 1 or 2.

DURATION: 3 months at FRIB, 1 month remote.

TOPIC: instrumental developments, nuclear experimental analysis.

ABSTRACT

Quantum metrology has become increasingly precise in probing fundamental laws of physics, especially with the recent experimental breakthroughs that transform atoms and molecules into quantum sensors. However, for decades it has remained a formidable challenge to protect such quantum sensors against environmental noise, system drift, and imperfections in the experimental control. In this project, we aim to integrate physics-informed learning and reinforcement learning into a closed-loop and autonomous control of a laser platform, which will be used in our quantum metrology experiment.

Please note that this summer training does not imply a continuation for a PhD, but a CNRS grant and support for local expenses are included.

More information is available on the website https://npa.in2p3.fr/summer-training-program/ and registration is mandatory on the following website: https://indico.frib.msu.edu/event/87/

MASTER SUMMER TRAINING PROPOSAL

Academic Year 2026/2027

TITLE: Precision laser spectroscopy of ThO molecules for testing fundamental symmetries.

FRIB ADVISOR: Xing Wu

FRIB ADVISOR CONTACT: email: wux@frib.msu.edu Phone: 517 908 7161.

UNIVERSITY/RESEARCH CENTER of the TRAINING:

Michigan State University, Facility for Rare Isotope Beams (FRIB), East Lansing Michigan, USA;
International Research Laboratory NPA, East Lansing Michigan, USA;

LEVEL: Master 1 or 2.

DURATION: 3 months at FRIB, 1 month remote.

TOPIC: instrumental developments, nuclear experimental analysis.

ABSTRACT

Measurements of electric dipole moment (EDM) of fundamental particles place the most stringent constrains on time-reversal violating new physics beyond Standard Model. Precision spectroscopy on cold ^{232}ThO neutral molecules provides one of the best bounds on electron electric dipole moment. In addition, ^{227,229}ThO neutral molecules provides excellent opportunity to search for nuclear Schiff moment. In this project, the student will be developing the laser and optics system for performing precision spectroscopy measurement on cold ThO molecules. The project will also involve development of the vacuum beamline and cryogenic system necessary to produce the ThO molecules.

Please note that this spring-summer training does not imply a continuation for a PhD, but a CNRS grant and support for local expenses are included.

More information is available on the website https://npa.in2p3.fr/summer-training-program/ and registration is mandatory on the following website: https://indico.frib.msu.edu/event/87/

MASTER SUMMER TRAINING PROPOSAL

Academic Year 2026/2027

TITLE: Centrifuge decelerator of radioactive molecules & atoms for fundamental symmetry tests.

FRIB ADVISOR: Xing Wu
FRIB ADVISOR CONTACT: email: wux@frib.msu.edu Phone: 517 908 7161.

UNIVERSITY/RESEARCH CENTER of the TRAINING:
Michigan State University; Facility for Rare Isotope Beams (FRIB);
International Research Laboratory NPA.

LEVEL: Master 1 or 2.

DURATION: 3 months at FRIB, 1 month remote.

TOPIC: instrumental developments, nuclear experimental analysis.

ABSTRACT

Precision metrology on atoms and molecules benefits tremendously when the particles are prepared in the ultracold regime. This enables control and detection of atoms or molecules at the single-quantum-state level. In this project, we are developing a unique method to decelerate radioactive atoms and molecules to a standstill by centrifugal force. A spinning magnetic guide will be used to guide neutral atomic/molecular species from the periphery to the center of the rotating frame, and an electromagnetic trap will be used to collect the decelerated particles after they exit the centrifuge decelerator. This work will open the avenue to precision spectroscopy of superheavy species like Radium or Thorium containing molecules, as well as light species like Tritium atoms.

Please note that this spring-summer training does not imply a continuation for a PhD, but a CNRS grant and support for local expenses are included.

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MASTER SUMMER TRAINING PROPOSAL

Academic Year 2026/2027

TITLE: Charge Exchange Reactions with the Nuclear Shell Model
FRIB ADVISOR: Filomena Nunes
FRIB ADVISOR CONTACT: nunes@frib.msu.edu
IN2P3 ADVISOR: Chloe Hebborn
IN2P3 ADVISOR CONTACT: hebborn@frib.msu.edu

UNIVERSITY/RESEARCH CENTER of the TRAINING:
Michigan State University, Facility for Rare Isotope Beams (FRIB), East Lansing Michigan, USA;
International Research Laboratory NPA, East Lansing Michigan, USA;
IJCLab, Orsay, France.

LEVEL: Master 1 or 2.

DURATION: 3 months at FRIB, 1 month at IJCLab.

TOPIC: theory of nuclear reactions**.**

ABSTRACT

The equation of state (EoS) of dense matter governs the structure, composition, and stability of neutron stars. Among the least understood terms of the nuclear EoS is the isovector dependence of the symmetry energy. Charge exchange reactions, which occur when a proton collides with a target nucleus, gets absorbed, and emits a neutron, are important for constraining this dependence. Within a recently developed framework, such reactions can be directly computed from microscopic many-body predictions, treating both structure and reactions on equal footing.

In this project, the student will analyze isotopic chains of both Mg and Ca. They will generate, using the microscopic shell models, all relevant spectroscopic amplitudes up to a few MeV above the proton threshold. This includes all compound, compound-minus-neutron, and compound-minus-proton amplitudes. They will extend the formalism, improving the single-particle description of the resonant parameters to proton states. They will combine the single-particle and many-body contributions within the microscopic S-matrix framework to extract cross sections and compare with experiment when available, as well as make predictions where no data exists. The latter can act as a motivation for future experiments.

Please note that this summer training does not imply a continuation for a PhD, but a CNRS grant and support for local expenses are included during the training.

More information is available on the website https://npa.in2p3.fr/summer-training-program/ and registration is mandatory on the following website: https://indico.frib.msu.edu/event/87/

MASTER SUMMER TRAINING PROPOSAL

Academic Year 2026/2027

TITLE: Surrogate models for linear response in finite nuclei.

FRIB ADVISOR: W. Nazarewicz and P. Giuliani.
FRIB ADVISOR CONTACT: nazarewi@msu.edu and giulia27@msu.edu
IN2P3 ADVISOR: Elias Khan.
IN2P3 ADVISOR CONTACT: elias.khan@ijclab.in2p3.fr

UNIVERSITY/RESEARCH CENTER of the TRAINING:
Michigan State University, Facility for Rare Isotope Beams (FRIB), East Lansing Michigan, USA;
International Research Laboratory NPA, East Lansing Michigan, USA;
IJCLab, Orsay, France.

LEVEL: Master 1 or 2.

DURATION: 3 months at FRIB, 1 month at IJCLab.

TOPIC: Many-body nuclear theory.

ABSTRACT

The collective excitation of nuclear systems close to their ground-state is very well described with the linear response theory, which is a well-established method in physics and chemistry. In particular, the quasiparticle random-phase approximation (QRPA) provides a powerful microscopic framework by building excitations on top of the mean-field vacuum; however, its high computational cost limits model calibration and uncertainty quantification studies. We have explored two complementary QRPA surrogate models and applied them to study response functions of finite nuclei. One is a reduced-order model that exploits the underlying QRPA structure, while the other utilizes the recently developed parametric matrix model algorithm to construct a map between the system's Hamiltonian and observables. Both emulators can achieve 0.1\%--1\% accuracy while offering a six to seven orders of magnitude speedup compared to state-of-the-art QRPA solvers. The QRPA emulators are well-positioned to enable Bayesian calibration and large-scale studies of computationally expensive physics models describing the properties of many-body systems.
The internship consists in learning this new technic and in applying it to the understanding of the isoscalar giant monopole resonance.

Please note that this summer training does not imply a continuation for a PhD, but a CNRS grant and support for local expenses are included during the training.

More information is available on the website https://npa.in2p3.fr/summer-training-program/ and registration is mandatory on the following website: https://indico.frib.msu.edu/event/87/

MASTER SUMMER TRAINING PROPOSAL

Academic Year 2026/2027

TITLE: Heavy Ion Collisions from nuclear physics to astrophysics.

FRIB ADVISOR: Oleh Savchuk
FRIB ADVISOR CONTACT: savchuk@frib.msu.edu
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IN2P3 ADVISOR CONTACT: aichelin@subatech.in2p3.fr

UNIVERSITY/RESEARCH CENTER of the TRAINING:
Michigan State University, Facility for Rare Isotope Beams (FRIB), East Lansing Michigan, USA;
International Research Laboratory NPA, East Lansing Michigan, USA;
SUBATECH, Nantes.

LEVEL: Master 1 or 2.

DURATION: 3 months at FRIB, 1 month at SUBATECH Nantes (in person or remote).

TOPIC: Heavy Ion Collisions from nuclear physics to astrophysics.

ABSTRACT

We are a group specializing in the dense nuclear matter theorized to compose neutron stars and created in laboratories by colliding two heavy nuclei. The project aims to understand how pressure builds under these extreme conditions, with densities beyond those found in atomic nuclei, by providing a theoretical description of data from both terrestrial experiments and various astronomical observations.

To that end, light nuclear fragments are important constituents of dense matter that require refined modeling. Potentially formed at the late stages of heavy-ion reactions or found in the crusts of neutron stars, they impact our ability to infer the correct behaviour of the pressure.

By treating clustering in a heavy-ion collision, you will have the opportunity to advance the field by applying expertise in theoretical physics, data-driven modeling, software engineering and scientific computing, while collaborating with the research communities at Subatech, France, and the Facility for Rare Isotope Beams, USA.

Please note that this spring-summer training does not imply a continuation for a PhD, but a CNRS grant and support for local expenses are included.

More information is available on the website https://npa.in2p3.fr/summer-training-program/ and registration is mandatory on the following website: https://indico.frib.msu.edu/event/87/