Master 2 Internship 2026

Research field: Data science and nuclear physics
Subject: **Explainable state observers and interpretable classification of faults in RF superconducting cavities.**
Description: SPIRAL2 is a state-of-the-art superconducting LINAC, housing 26 cavities cooled at 4.2 K. These cavities are subject to faults such as quenches, microphonics, and thermoacoustic oscillations, which compromise beam availability and reliability. The current monitoring chain is based on FPGA-triggered LLRF post-mortem buffers, generating high-dimensional time series of RF, cryogenic, and control signals. While operators can diagnose obvious failures, many events remain ambiguous [4,5]. In control theory, state observers (Kalman filters, Luenberger observers, Unknown Input Observers) have long been used for fault detection: they reconstruct hidden states and generate residuals—differences between predicted and measured outputs—that act as natural indicators of anomalies [1-3]. In anomaly detection, residuals are analyzed through statistical tests, clustering, or machine learning. Modern extensions combine observer-based prediction with data-driven self-supervised classifiers, producing both timely alarms and interpretable diagnostics [6]. This internship will explore this classical but under-used connection in accelerator physics: building simple observers for SPIRAL2 cavities, generating residuals, and testing how they can feed anomaly detection and classification pipelines, paving the way for larger-scale developments in a PhD [4,5]. Explainability focus: Depending on progress and in addition to implementing observers and classifiers, this internship will explore post-hoc explainability methods (e.g. SHAP, LIME) on observer residuals and classification outputs. The aim is to identify which RF and cryogenic signals contribute most to a failure class. This aligns with insights from recent accelerator AI research that feature attribution, and causal graphs make anomaly detection usable and trustworthy for operators [6]. **Objectives** - Implement a simple virtual state observer (Luenberger/Kalman) for cavity RF signals [1-3]. - Extract residuals and test anomaly detection methods (thresholds, clustering, first self-supervised models) [4-6]. - Focus case: discriminate between true quenches and false alarms. - Produce a demonstration dashboard for visualizing observer states, residuals, and classifications. **Expected outcome** - Feasibility study of observer-based anomaly detection. - First dataset benchmarks and candidate methods. - Deliverables that pave the way for the PhD (advanced observers, explainability, generalisation).
Required skills: Python, signal processing, ML basics, control/observer theory

"Master day" on Saturday the 15th 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/

Does the internship lead to a PhD? Yes

Contact

Name: Adnan Ghribi / Marco Di Giacomo

Address: GANIL
B.P. 55027
14076 CAEN CEDEX 5

Phone: 02 31 45 46 80
e-mail: adnan.ghribi@ganil.fr / marco.digiacomo@ganil.fr

References

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2. Chen, J., & Patton, R. (1999). Robust Model-Based Fault Diagnosis for Dynamic Systems. Springer.
3. Ding, S.X. (2008). Model-based Fault Diagnosis Techniques. Springer.
4. Tennant, C., Carpenter, A., Powers, T., et al. (2020). Superconducting RF cavity fault classification using machine learning at Jefferson Laboratory. Phys. Rev. Accel. Beams, 23, 114601.
5. Boukela, L., Eichler, A., Branlard, J., & Jomhari, N.Z. (2024). A two-stage machine learning-aided approach for quench identification at the European XFEL. arXiv:2407.08408.
6. Edelen, A.L., Biedron, S.G., Chase, B.E., et al. (2016). Neural networks for modeling and control of particle accelerators. IEEE Trans. Nucl. Sci., 63(2), 878–897.
7. Ribeiro, M.T., Singh, S., & Guestrin, C. (2016). "Why Should I Trust You?" Explaining the Predictions of Any Classifier. KDD 2016.
8. Lundberg, S.M., & Lee, S.I. (2017). A unified approach to interpreting model predictions (SHAP). NeurIPS 2017.

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Master 2 Internship 2026

Research field: Data science and nuclear physics
Subject: Smart isotope identification with causal state observers at the SPIRAL1 GANIL facility
Description: SPIRAL1 produces exotic radioactive ion beams via the ISOL method. Identifying isotopes relies on β–γ decay spectroscopy, which is challenged by complex decay schemes, overlapping peaks, detector background, and beam-induced fluctuations. Traditionally, isotope assignment is based on expert analysis and calibration, but the increasing diversity of isotopes and noise conditions calls for AI assistance [1]. In system and control theory, state observers are used to model hidden dynamics such as release kinetics and decay profiles. Their prediction residuals capture mismatches between expected and measured spectra. These residuals can then serve as features for anomaly detection and isotope classification [2,3]. Linking causal observers with machine learning classifiers creates an interpretable framework: predictions explain why a spectrum is assigned to a specific isotope, while residual analysis highlights discrepancies due to noise or background [4,5]. Recent AI research emphasizes combining physics-informed models with semi-supervised or self-supervised classifiers to tackle scarce or noisy labels [1-3]. This internship will test such hybrid methods on SPIRAL1 spectra, setting up a proof-of-concept that a full PhD project can generalize and industrialize. Explainability focus: Depending on progress, this internship will also explore causal explainability, linking observed β–γ spectra to latent isotope states estimated by the observer. Simple causal graphs [6] and uncertainty bands will be used to show why an isotope ID decision was made, distinguishing genuine isotope signatures from noise or background. This reflects state-of-the-art approaches where causal inference is key for interpreting anomalies in multivariate time series under uncertainty [7]. **Objectives** - Develop a basic state observer for isotope release and decay curves. - Use observer residuals as inputs to classifiers (semi/self-supervised learning). - Explore causal graphs and uncertainty as interpretability tools. - Focus case: robust isotope ID under background noise. **Expected outcome** - Proof-of-concept observer-assisted classifier for isotope identification. - Clear roadmap for deeper PhD-level work (advanced causal observers, generalisation, large-scale benchmarking).
Required skills: Python, ML, control/observer basics, spectrum analysis, nuclear physics interest. Optional: C++, Root
Does the internship lead to a PhD? Yes

"Master day" on Saturday the 15th 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/

Contact

Name: Adnan Ghribi / Jean-Charles Thomas / Pierre Chauveau

Address: GANIL
B.P. 55027
14076 CAEN CEDEX 5

Phone: 02 31 45 46 80
e-mail: adnan.ghribi@ganil.fr / jean-charles.thomas@ganil.fr / pierre.chauveau@ganil.fr

References

1. Kamuda, M., Zhao, J., & Huff, K. (2020). Semi-supervised classification to improve isotope identification. NIM-A, 954, 161508.
2. Qiu, C., Pfrommer, T., Kloft, M., Mandt, S., & Rudolph, M. (2021). Neural transformation learning for deep anomaly detection beyond images. ICML 2021, 8703–8714.
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5. Lundberg, S.M., & Lee, S.I. (2017). A unified approach to interpreting model predictions (SHAP). NeurIPS 2017.
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"Master day" on Saturday the 15th 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/

Master 2 Internship 2026

Research field: Nuclear Astrophysics and Cosmology
Subject: **New Judicious Experiments for Dark sectors Investigations ANDROMEDE Experiment Analysis**

Description:

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 main supervising team will be composed of: Beyhan BASTIN (GANIL), Isabelle Deloncle (IJCLab), Jurgen Kiener (IJCLab), and Alain Coc (IJCLab).

"Master day" on Saturday the 15 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/

Required skills: Experimental profile. Very good levels on C/C++ programming, English, Nuclear Physics and/or Particle Physics academic knowledge. Affinity for experimental work and work in an international environment.
Does the internship lead to a PhD? This work will not lead to a PhD-thesis

Contact

Name: Beyhan BASTIN

Address: GANIL
B.P. 55027
14076 CAEN CEDEX 5

Phone: 02 31 45 49 92
e-mail: bastin@ganil.fr

"Master day" on Saturday the 15 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/

Master 2 Internship 2026

Research field: Nuclear Astrophysics and Cosmology
Subject: **New Judicious Experiments for Dark sectors Investigations iThemba LABS Experiment Analysis**

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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), Isabelle Deloncle (IJCLab), Jurgen Kiener (IJCLab), Philip Adsley (Texas A&M), Lindsay Donaldson (iThemba LABS), Kgashane Malatji (iThemba LABS) and Alain Coc (IJCLab).

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Required skills: Experimental profile. Very good levels on C/C++ programming, English, Nuclear Physics and/or Particle Physics academic knowledge. Affinity for experimental work and work in an international environment.
Does the internship lead to a PhD? This work will not lead to a PhD-thesis

Contact

Name: Beyhan BASTIN

Address: GANIL
B.P. 55027
14076 CAEN CEDEX 5

Phone: 02 31 45 49 92
e-mail: bastin@ganil.fr

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JOINT EUROPEAN MASTER IN NUCLEAR PHYSICS
Academic Year 2025/2026

MASTER THESIS PROPOSAL

TITLE: Characterization of YAP:Ce detectors for precise beta shape measurements.

SUPERVISOR(S): Dr. Xavier Fléchard, Prof. Oscar Naviliat-Cuncic

SUPERVISOR(S) contact- email: flechard@lpccaen.in2P3.fr Telephone: 0231452542
email: naviliat@lpccaen.in2p3.fr Telephone:

UNIVERSITY/RESEARCH CENTER: LPCCaen

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

Context
The search for new physics beyond the Standard Model is one of the most exciting frontiers in fundamental physics. Precision measurements of beta decay spectra shapes offer a highly sensitive and complementary approach to high-energy collider experiments. The bSTILED project focuses on the beta decay of 6He, aiming to set stringent constraints on exotic tensor contributions to the weak interaction with a precision goal competitive with results from the LHC.
This level of precision requires a perfect understanding of the detection system's response function, only achievable through offline calibration using dedicated sources, including conversion electron emitters (207Bi, 137Cs, 133Ba, 57Co) and beta emitters (114In, 106Ru/106Rh, 90Sr/90Y). These sources are currently under development by collaborators at the LNHB laboratory.

Objectives
If the schedule permits, contribute to detector preparation at LPCCaen and, participate in calibration measurements at LNHB.
Analyze offline data acquired at LNHB, comparing experimental results with Geant4 simulations to validate and refine the detector response model.
Preparation for future analysis of 6He data, with the possibility of continuing the work in a PhD thesis starting in fall 2026.

JOINT EUROPEAN MASTER IN NUCLEAR PHYSICS
Academic Year 2025/2026

MASTER THESIS PROPOSAL

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

SUPERVISOR(S): Dr Emmanuel Vient (Associate Professor-HDR)

SUPERVISOR(S) contact- email:vient@lpccaen.in2p3.fr Telephone: +33231452974
email:emmanuel.vient@unicaen Telephone:

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

ABSTRACT

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 and charged particles which have been evaporated. The aim is to find out how the temperature of the hot nucleus can be deduced from the information provided by these distributions as a whole. At the same time, we also want to see how the multiplicity of neutrons evaporated modifies these quantities for a given initial temperature, if we vary the isotopic richness of the initial hot nucleus. To do this, we'll be using the GEMINI event generator, which specializes in simulating the evaporation of hot nuclei. We may use multidimensional analysis and artificial intelligence tools for this study. For further information about this internship, please contact Emmanuel Vient at the above e-mail address.

The internship will take place at LPC Caen. The work will be done using Python language.

Master 2 thesis 2026

Research field: **nuclear physics**	
Title: **Tuning and calibration of the full FALSTAFF spectrometer**	

Description: Basic research in nuclear physics remains necessary within the framework of the French program of renewal of nuclear energy. The development of nuclear deexcitation & fission models, phenomenological as well as microscopic has had a renewal of interest in the past decades. However, the capacity of these models to explain or predict fission observables such as mass yields, charge or kinetic-energy spectra of the fission fragments (FF), neutron or gamma multiplicities remains somewhat limited. The phenomenological models used for data evaluation or for the production of nuclear data bases necessary for nuclear reactor simulations use even more microscopic modelling in order, on the one hand, mass and charge yields of FF at scission or the sharing of the excitation energy between both FF or, on the other hand, level densities of FF de excitation through particle emission (neutrons, gammas). Parameters used in these modelling are not sufficiently known and need to be determined from measurements of experimental observables. Hence, more complete data are necessary combining fission-yield measurements with FF kinematics reconstruction on a large range of excitation energy.

Within this context, we have developed the FALSTAFF spectrometer, to study the fission of actinides, induced by neutrons in an energy ranging from ~0.5 to 40 MeV, available at the NFS facility (Neutron For Science), one of the experimental area of the GANIL/SPIRAL2 accelerator. FALSTAFF is based on the time-of-flight and residual-kinetic energy measurement technique. FALSTAFF is made of two identical detection arms (for coincidence measurement of FF on an event-by-event basis), which allows the determination of the velocity vectors and kinetic energies of both FF. We used the first arm in two experiments at SPIRAL2-NFS in 2022 & 2024. The results were promising and hence the basis of the motivation to build the second detection arm, which will be finished by end of 2025. We achieve a high time resolution with two secondary-electron detectors (SED) for the time-of-flight. An axial ionisation chamber permits the measurement of the FF residual kinetic energies. The combination of both observables gives access to the FF masses after neutron evaporation, through the EV method (energy-velocity). The FF coincidence detection provide information on the FF masses prior to their de excitation, through the 2V method. We will therefore be able to determine the neutron multiplicity on an event-by-event basis and correlate it to the FF masses. This is an experimental observable of great importance in order to study the sharing of the excitation energy between both FF.

The student will take part in the tuning up and final calibration of the FALSTAFF spectrometer in its full two-arm detection geometry, including final tests with a 252Cf two-fragment radioactive source. She/he will have thus the opportunity to get familiar with the detector and more generally with the different aspects of a nuclear physics experiment, such as detection, front-end electronics, data acquisition and on-line analysis. The student will have the opportunity to prepare a thesis on the subject afterwards.

"Master day" on Saturday the 15th 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/

Required skills: **Nuclear physics, particle detection, C++ programming &/or CERN/ROOT analysis**
Does the internship lead to a PhD? **YES**

Contact

Name: Jean-Eric Ducret

Address: GANIL
B.P. 55027
14076 CAEN CEDEX 5

Phone: 02 31 45 44 51
e-mail: ducret@ganil.fr

"Master day" on Saturday the 15th 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/

Thermal simulations of cryogenic quantum sensors for new physics searches

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

INTRODUCTION

ASGARD is a novel proposed experiment using superconducting quantum sensors coupled to the new DESIR facility at GANIL for searches for Beyond Standard Model physics. Its detectors will be operated in a windowless dilution refrigerator (around 100mK) coupled directly to a room temperature isotope beam line, which presents significant thermal engineering challenges for this pioneering effort. Together with ion beam transport studies, the optimal geometry and mode of operation are not yet well-defined.

DESCRIPTION OF THE WORK

The student will contribute to the thermal simulation study of the proposed ASGARD experiment and interface directly with ion beam transport simulations. The combination will be used to inform the final design of the dilution refrigerator and its coupling to DESIR's radioactive beam line. This information will be studied hand in hand with the manufacturer and the involved engineers.

JOINT EUROPEAN MASTER IN NUCLEAR PHYSICS
Academic Year 2025/2026

MASTER THESIS PROPOSAL

TITLE: **Neutrino detection with KM3NeT/ORCA: exploring a novel event-containment method**

SUPERVISOR(S): Valentin PESTEL, Benoît GUILLON

SUPERVISOR(S) contact- email: vpestel@lpccaen.in2p3.fr Telephone: +33 2 31 45 29 83
email: guillon@lpccaen.in2p3.fr Telephone: +33 2 31 45 25 47

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

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

The KM3NeT research infrastructure comprises two neutrino telescopes at the bottom of the Mediterranean Sea. The KM3NeT/ORCA telescope is located off-shore Toulon in France at about 2.5 km depth and has been optimized to perform neutrino oscillation measurement. Since the deployment and operation of the 6 lines configuration, the collaboration is providing regular measurement of neutrinos, already contributing to neutrino oscillation and atmospheric neutrinos flux landscapes. In October of this year, the detector is expected to reach 34 detection lines, out of the 115 it will have when fully completed.

While many aspect of a neutrino oscillation measurement have been explored with the early configuration, the detector is now reaching a size that allow for selecting a new type of topology: events that are totally contained in the detector. This so-called contained events are of paramount importance for precise neutrino oscillation measurement, as for these we expect to reach the best energy resolution. However, defining what is contained is not as evident as it may seems for a border-less detector, which deform under the influence of sea-currents.

The internship aimed at exploring a novel method to defined a containment volume, based on a convex-hull describing the external surface formed by the detector, which adapt dynamically to follow the detector movement. The project aimed at introducing the derived quantities into a neutrino selection and evaluate its performances. This study will take place in the LPC Caen KM3NeT group, and will mainly involve data-analysis and visualization skills, while discovering the complex reconstruction and simulation landscape of an experiment like KM3NeT.

JOINT EUROPEAN MASTER IN NUCLEAR PHYSICS
Academic Year 2025/2026

MASTER THESIS PROPOSAL

TITLE: Anomaly detection and data quality studies for KM3NeT/ORCA neutrino telescope

SUPERVISOR(S): Iván MOZÚN MATEO, Chiara F. LASTORIA

SUPERVISOR(S) contact- email: mozun@lpccaen.in2p3.fr Telephone: +34 633 562 708
email: lastoria@lpccaen.in2p3.fr Telephone: +33 2 31 45 25 18

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

ABSTRACT

The KM3NeT/ORCA detector is a neutrino telescope installed in the Mediterranean Sea optimized for the study of atmospheric neutrino oscillations through the detection of Cherenkov light emitted by charged particles produced by the interaction of neutrinos with matter [1-2].

The proposed research topic will consist of the analysis of the experimental data, focusing on an incomplete section of the detector with between 6 and 18 lines deployed. It will involve studies on data quality and anomaly identification. First, the student should study the main sources of background contamination of the detector, composed of atmospheric muons, the decay of the 40K contained in seawater as well as bioluminescence, to be properly identified and rejected. Then, the student should focus on identifying sparks events and improve the methodology to remove these events for physics analysis. It will consist on developing efficient techniques and a Snakemake pipeline to do so [3].The aim of these studies will be to understand the limitations of selecting sparks, relate them to real physics events and improve the current state-of-the-art sparks selection. The final objectives will be to quantify the effect and impact on the sensitivity studies of neutrino oscillation parameters.

[1] https://www.km3net.org/
[2] Letter of Intent for KM3NeT 2.0, Journal of Physics G: Nuclear and Particle Physics, 43 (8), 084001, 2016 [arXiv:1601.07459].
[3] https://snakemake.readthedocs.io/en/stable/index.html

JOINT EUROPEAN MASTER IN NUCLEAR PHYSICS
Academic Year 2025/2026

MASTER THESIS PROPOSAL

TITLE: Theoretical study of isolated and solvated peptides.

SUPERVISOR : Julie DOUADY

contact- email: julie.douady@ensicaen.fr
Telephone: 02.31.45.25.77.

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 her thesis,Juliette LEROUX (PhD from CIMAP), has combined both action spectroscopy and structural approaches to study radiation-induced processes in biomolecular systems (peptides and proteins). In particular, she demonstrated that the NEXAMS (near-edge X-ray absorption mass spectrometry) technique is sensitive to backbone protonation by studying protonated triglycine and pentaglycine at the nitrogen and oxygen K-edge [1]. In the futur she will plan to study the influence of a controlled number of water molecules on radiation-induced processes in peptides and proteins.

Project:
The master student will study theoretically small model peptides like triglycine and pentaglycine in the (de)protonated form. First, the student will have to generate different isomers for the hydrated pentapeptide (1 to 5 and 10 water molecules). This exploration of potential energy surface (PES) will be done using a program based on the Molecular Dynamics where the energy will be described with the AMBER force field [2]. In a second step, the student will have to reoptimize these geometries with DFT-B3LYP calculations. For the lowest-energy 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 [3].

[1] J. Leroux et al., Physical Chemistry Chemical Physics, 25, 37, 25 603–25 618, (2023)
[2] J. Wang et al., J Comput Chem 21, 1049 (2000).
[3] F. Neese et al., J Chem.Phys., (2020), 152, 224108.

Towards condensed matter effects in electron capture for new physics

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

INTRODUCTION

Following the advent of novel quantum sensors, direct detection of the recoiling ion following electron capture is experimentally accessible. With it come a host of novel ways to look for physics Beyond the Standard Model, but the added complexity of a radioactive decay in-medium is currently poorly understood.

DESCRIPTION OF THE WORK

The project consist of work towards an extension of the beta decay formalism to include condensed matter effects. This will proceed in incremental steps, starting with atomic physics results by developing numerical routines, and - time permitting - followed by conceptual developments to rewrite the beta decay process using the Kubo-Greens formalism.

REQUIREMENTS

Strong python skills, a good understanding of nuclear and condensed matter state physics and many-body Green's functions.

Proposition de stage 2026 au CEA Cadarache, Laboratoire de Mesures Nucléaires

Surrogate models and Bayesian inference for the characterization of radioactive waste packages by active photonic interrogation

Context

The medium- and long-term management of waste packages from the nuclear industry requires verification of their radiological content using non-destructive characterization methods based on nuclear measurements. This involves detecting, locating, and quantifying nuclear material [1]. Passive techniques use the radiations directly emitted by the material, while active techniques use interrogating radiations (neutrons or photons) and exploit secondary particles produced by reactions induced in the material.

Complementary to other techniques, such as high-energy imaging, active photonic interrogation (API) is a method of choice for characterizing the contents of large concrete-encased packages. The principle is as follows: high-energy photons (>9 MeV) produced by a linear electron accelerator (LINAC) penetrate deep into the package and induce fission in the nuclear material. The radiation emitted by the radioactive fission products is detected, in particular those that emit high-energy gamma rays, which are themselves able to escape from the package. Knowing the characteristics of the interrogating beam (energy, intensity, direction), it is possible to reverse the problem, i.e., obtain a reaction rate from the measurement of radiation from photofission.

At the IRESNE institute (CEA Cadarache), the Nuclear Measurements Laboratory (LMN) is developing API for the needs of the French agency in charge of nuclear waste management (ANDRA) as well as for characterizing the 870 L concrete waste packages produced by CEA. The laboratory operates an irradiation cell (CINPHONIE) recently equipped with a new linear electron accelerator dedicated to high-energy imaging and API. Studies conducted at the LMN since 2019 have focused on high-resolution gamma spectrometry of short-lived fission products [2], with the aim of detecting and discriminating between different types of nuclear material (e.g., enriched or depleted uranium). This technique is promising but does not allow inspections to be carried out within a realistic timeframe as it requires significant irradiation and measurement times.

A thesis project currently underway is exploring the use of scintillation detectors for the rapid localization of nuclear material in a heterogeneous environment. With this technique, in simple cases involving small uranium samples introduced into a homogeneous concrete matrix, the detection limits are in the order of a few grams. The current challenge is to improve the detection and localization of material in heterogeneous environments that are realistic in terms of their physical and chemical composition and density.

Subject of the internship

The topic of the internship is to contribute to the development of a Bayesian formalism for processing a set of experimental data (typically delayed photon spectra). Bayesian methods offer two advantages for solving inverse problems. First, they provide relevant results when the number of measurements is small compared to the number of variables involved. Second, they rigorously handle uncertainties and provide results with relevant error bars.

Two approaches are under consideration:

1. Develop an analytical model that predicts the useful signal: Bayesian formalism uses the model to produce estimates and sample the problem's variables. The different stages of signal formation has to be modeled with precision. The output is a mass of nuclear material associated with coordinates.
2. Divide the package into small volumes and calculate a response matrix associating to each element. The measurements are used to invert the matrix and produce as an output the distribution of nuclear material in the inspected volume.

The internship aims to contribute to both approaches. The first focus will be on building surrogate models (meta-models) to predict the photofission rate associated with ^{238}U on the one hand, and detection efficiency on the other hand. These models developed in a simple case (homogeneous matrix) will be tested in a realistic case

Proposition de stage 2026 au CEA Cadarache, Laboratoire de Mesures Nucléaires

Surrogate models and Bayesian inference for the characterization of radioactive waste packages by active photonic interrogation

(heterogeneous). The second focus will be on calculating the system response matrix using the models constructed previously. A Bayesian inversion method will be applied in a simple case (homogeneous matrix + known material sample).

To model the configurations of interest, a particle transport code will be used (MCNP6). The output files will be analyzed and the meta-models will be constructed using Python. The Bayesian inversion method will be implemented in Python using the PyMC module.

Depending on the laboratory's schedule and the progress of the internship, participation in additional experiments using the linear accelerator available at the laboratory may be considered.

Skils

Nuclear physics, radiation-matter interactions, data analysis, numerical simulation, and scientific computing. Knowledge of Bayesian inference would be an advantage.

Duration:	9 months		
Profile:	Ingineer school or Master 2 (research)		
Laboratory:	CEA, DES, IRESNE, Cadarache, Laboratoire de Mesures Nucléaires Bâtiment 224, 13108 Saint-Paul-lez-Durance		
Contacts	Benoit Geslot	benoit.geslot@cea.fr	04 42 25 26 67
	Cédric Carasco	cedric.carasco@cea.fr	04 42 25 61 30
	Malo Lebreton	malo.lebreton@cea.fr	

References

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[2] M. Delarue, « Contribution au développement d'une méthode de caractérisation pour des colis de déchets radioactifs bétonnés et volumineux par photofission ». Mémoire de thèse. Université Grenoble-Alpes, 2022

[3] C. Carasco, et al. "Photofission delayed gamma-ray measurements in a large cemented radioactive waste drum during LINAC irradiation". Nuclear Instruments and Methods, A, Vol. 1053, 2023

JOINT EUROPEAN MASTER IN NUCLEAR PHYSICS
Academic Year 2025/2026

MASTER THESIS PROPOSAL

TITLE: Project SMILEI (Stored Molecular Ions in Linear Electrostatic Ion trap)

SUPERVISOR(S): Patrick Rousseau and Sylvain Maclot

SUPERVISOR(S) contact- email: patrick.rousseau@unicaen.fr Telephone: 02.31.45.48.06
email: sylvain.maclot@unicaen.fr Telephone: 06.84.86.44.94

UNIVERSITY/RESEARCH CENTER: University Caen Normandy - CIMAP Laboratory

ABSTRACT

Manipulation of cold molecular ions open the possibility of spectroscopy of well prepared species with application foreseen in molecular physics and in nuclear physics. We propose to use a newly designed linear electrostatic ion beam trap to achieve such experiments. The “open” design of the trap allows for the implementation of laser beam and spectrometer in the field free region between the two ion mirrors.

The internship will focus on commissioning of the apparatus for ion trapping, installation of the laser system and first spectroscopic experiments. The device is located in ARIBE the low-energy ion beam facility of GANIL (Caen). During the internship, the participation to ion-collision beamtimes will be also possible allowing to get familiar with the research activities developed at CIMAP-GANIL.

This project (SMILEI) is part the CaeSAR (Caen Strategy for Advanced Research) program of UNICAEN, including a fully funded PhD fellowship starting in September 2026. The project is reinforced by a strong collaborative network (Bar-Ilan University, Israel - University Autonomous of Madrid, Spain) funded by the international laboratory partnership (UNICAEN).

Master 2 thesis 2026

Research field: **nuclear physics**
Title: **Tuning and calibration of the full FALSTAFF spectrometer**

Description: Basic research in nuclear physics remains necessary within the framework of the French program of renewal of nuclear energy. The development of nuclear deexcitation & fission models, phenomenological as well as microscopic has had a renewal of interest in the past decades. However, the capacity of these models to explain or predict fission observables such as mass yields, charge or kinetic-energy spectra of the fission fragments (FF), neutron or gamma multiplicities remains somewhat limited. The phenomenological models used for data evaluation or for the production of nuclear data bases necessary for nuclear reactor simulations use even more microscopic modelling in order, on the one hand, mass and charge yields of FF at scission or the sharing of the excitation energy between both FF or, on the other hand, level densities of FF de excitation through particle emission (neutrons, gammas). Parameters used in these modelling are not sufficiently known and need to be determined from measurements of experimental observables. Hence, more complete data are necessary combining fission-yield measurements with FF kinematics reconstruction on a large range of excitation energy.
Within this context, we have developed the FALSTAFF spectrometer, to study the fission of actinides, induced by neutrons in an energy ranging from ~0.5 to 40 MeV, available at the NFS facility (Neutron For Science), one of the experimental area of the GANIL/SPIRAL2 accelerator. FALSTAFF is based on the time-of-flight and residual-kinetic energy measurement technique. FALSTAFF is made of two identical detection arms (for coincidence measurement of FF on an event-by-event basis), which allows the determination of the velocity vectors and kinetic energies of both FF. We used the first arm in two experiments at SPIRAL2-NFS in 2022 & 2024. The results were promising and hence the basis of the motivation to build the second detection arm, which will be finished by end of 2025. We achieve a high time resolution with two secondary-electron detectors (SED) for the time-of-flight. An axial ionisation chamber permits the measurement of the FF residual kinetic energies. The combination of both observables gives access to the FF masses after neutron evaporation, through the EV method (energy-velocity). The FF coincidence detection provide information on the FF masses prior to their de excitation, through the 2V method. We will therefore be able to determine the neutron multiplicity on an event-by-event basis and correlate it to the FF masses. This is an experimental observable of great importance in order to study the sharing of the excitation energy between both FF.

The student will take part in the tuning up and final calibration of the FALSTAFF spectrometer in its full two-arm detection geometry, including final tests with a 252Cf two-fragment radioactive source. She/he will have thus the opportunity to get familiar with the detector and more generally with the different aspects of a nuclear physics experiment, such as detection, front-end electronics, data acquisition and on-line analysis. The student will have the opportunity to prepare a thesis on the subject afterwards.

“Master day” on Saturday the 15th 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/

Required skills: **Nuclear physics, particle detection, C++ programming &/or CERN/ROOT analysis**
Does the internship lead to a PhD? **YES**

Contact

Name: Jean-Eric Ducret

Address: GANIL
B.P. 55027
14076 CAEN CEDEX 5

Phone: 02 31 45 44 51
e-mail: ducret@ganil.fr

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