ERASMUS MUNDUS MASTER IN NUCLEAR PHYSICS
Academic Year 2021/2022

MASTER THESIS PROPOSAL

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

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

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

ABSTRACT

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

The MARS system is composed of 3 (detectors, electronics and adquisition) sub-systems:
1) 16 silicon detectors system;
2) CAEN electronics system;
3) COMPASS data adquisition system.

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

ERASMUS MUNDUS MASTER IN NUCLEAR PHYSICS
Academic Year 2021/2022

MASTER THESIS PROPOSAL

TITLE: Artificial intelligence for the modeling of neutrino-nucleus interactions

SUPERVISOR(S): Joaquín López Herraiz y Raúl González Jiménez

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UNIVERSITY/RESEARCH CENTER: Universidad Complutense de Madrid

ABSTRACT

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

Since neutrino detectors are made of complex nuclei (e.g. oxygen, carbon, or argon), unravelling the neutrino properties requieres to understand with high precision the possible neutrino-nucleus reaction channels in a broad energy range. A defining challenge is to make predictions of the neutrino-nucleus interaction with state-of-the-art nuclear models, this is due to the fact that highly computationally demanding simulations are required.

Artificial Intelligence (AI) tools have shown their capacity to create very accurate models of very complex systems. These models can be trained using the set of available measurements or known values, and after that they can be used to generate new data in a very short time. The model can be evaluated with a set of testing values which can be compared against the predictions obtained by the AI model. The subject of this work will be to apply AI tools to the modeling of the neutrino-nucleus interaction.

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

TITLE: “Theoretical study of nuclear beta decays for recent experimental proposals”

SUPERVISOR(S): Óscar Moreno Díaz, Dpto. Estructura de la Materia, Física Térmica y Electrónica, Facultad de Ciencias Físicas, Universidad Complutense de Madrid.

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We pursue the theoretical study of the nuclear structure of neutron-deficient isotopes in the region of mercury, with a focus on the details related to their beta decays. The microscopic description of the nuclei starts with a self-consistent deformed Hartree-Fock (HF) mean-field calculation for quasiparticles, on top of which residual interactions are introduced within quasiparticle random-phase approximation (QRPA) to obtain the intensities of Gamow-Teller transitions and beta-decay meanlives. The analysis and presentation of results will be specifically designed to support recent experimental proposals at ISOLDE-CERN on the beta decay of isotopes around mercury 186 using the total absorption spectroscopy technique.

TITLE: “Heart-brain link in metabolic imaging of a rat model of Takutsubo syndrome”

SUPERVISOR(S): Mailyn Pérez-Liva, José Manuel Udías, Dpto. Estructura de la Materia, Física Térmica y Electrónica, Facultad de Ciencias Físicas, Universidad Complutense de Madrid.
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Takotsubo syndrome (TS), also known as transient apical ballooning of the left ventricle or broken heart syndrome, was first described as an emotional stress-induced cardiomyopathy in Japan in 1990 [1]. Subsequent studies showed that the incidence of TS accounts for 1-3% of all patients and 5-6% of women hospitalized for suspected myocardial infarction. Although 90% of patients are postmenopausal women, ST can occur in young women, men and children and the triggering causes can originate from various situations such as acute negative or positive emotional cues, physical stress, acute neurological disorders, physical activity, medical procedures and, in some cases, without obvious triggering event [2].
In this work we will explore a rat animal model of TS by using images obtained by FDG Positron Emission Tomography(PET) and Computed Tomography (TAC). The student involved will perform the processing of images and data already acquired, so no animal manipulation is required. Images corresponding to different time intervals after disease induction will be analyzed and the metabolic changes produced in both heart and brain and their evolution over time will be analyzed. We will work with brain atlases for brain segmentation and with registration algorithms for the joint analysis of all the inspected individuals. Heart segmentations will also be performed from PET images and spatial and temporal correlations of all the originated data will be explored. The use of artificial intelligence algorithms for predictive analysis of certain biomarkers relevant to the evolution of the disease will be explored. The final result of the work will be a data analysis package for the interpretation of metabolic neuro-cardiac TS images.
The work will be developed in close collaboration with the Cardiovascular Research Center in Paris, France.

Comments: Programming skills in Matlab and/or Python are required.
Referencias :
[1] Satoh, H. (1990). Takotsubo-type cardiomyopathy due to multivessel spasm. Clinical aspect of myocardial injury: from ischemia to heart failure.
[2] Ghadri, J. R., Kato, K., Cammann, V. L., Gili, S., Jurisic, S., Di Vece, D., ... & Bacchi, B. (2018). Long-term prognosis of patients with Takotsubo syndrome. Journal of the American College of Cardiology, 72(8), 874-882

TITLE: “Proton Range verification in prototherapy from patient activation and deep learning”

SUPERVISOR(S): Joaquín López Herraiz, Paula Ibáñez, José Manuel Udías, Dpto. Estructura de la Materia, Física Térmica y Electrónica, Facultad de Ciencias Físicas, Universidad Complutense de Madrid.
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Two clinical protontherapy beamlines began beam delivery early 2020 in Madrid and another 10 centers are planned in Spain for the following years. Real-time in-beam monitoring of dose delivered by hadrons, and proton range verification, either by means of prompt gammas as well as prompt PET emission is one of the forefronts of research in the field. Recent developments in deep machine learning based on neural networks (NN) have opened new ways to compute the dose in patients undergoing radiotherapy treatments. Neural networks should be trained with hundreds or thousands of 'good' solutions of the problem at hand, in this case of the computed dose for a given treatment plan in a particular location. Monte Carlo dose calculations are the reference for in-patient dosimetry, but it involves a large computational burden, which makes it difficult to use it to compute the training sets for NN approaches. In our group we have developed a very fast Monte Carlo proton dose-calculation engine, running in modern GPUs, which is several thousand faster than the existing CPU codes. We also have extremely fast codes which simulate the radiation emitted from the patients during proton irradiation. With the help of neural networks in this project we will produce pairs of proton irradiations / signal (images) in the radiation detectors, which we will use to train a NN to compute dose distribution from the radiation detected. The student will work with simulations as well as actual data from dose delivered and experiments with phantoms at the CMAM proton accelerator in Madrid and/or protontherapy centers also in Madrid.
http://nuclear.fis.ucm.es
The work will be developed at the Physics School of Complutense University in Madrid.

TITLE: "Deep Learning approaches to improve the time resolution of nuclear detectors employed in fast-timing experiments and ToF-PET"

SUPERVISOR(S): Luis Mario Fraile, Joaquín López Herraiz, José Manuel Udías, Dpto. Estructura de la Materia, Física Térmica y Electrónica, Facultad de Ciencias Físicas, Universidad Complutense de Madrid.

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UNIVERSITY/RESEARCH CENTER: Universidad Complutense de Madrid

The Nuclear Physics Group at Complutense University has been working in improving the time resolution of nuclear detectors since more than two decades, having established a laboratory for testing and building of scintillator-based detectors with better than 70 ps time resolution, in use at several nuclear facilities worldwide, such as ISOLDE@CERN and FAIR@GSI. The group has also been collaborating in the development of PET detectors with companies from the medical sector for more than a decade. Further, during the last years the group has acquired a strong expertise in deep learning (DL) techniques, which recently have been shown to hold promise in improving the time resolution of nuclear detectors. In this work DL will be applied to process fully digitized electronics signals acquired with our ultra fast radiation detectors to assess their potential to improve on the timing accuracy of the detectors.

ERASMUS MUNDUS MASTER IN NUCLEAR PHYSICS
Academic Year 2021/2022

MASTER THESIS PROPOSAL

TITLE: HYPERONIC STARS WITHIN ALTERNATIVE THEORIES OF GRAVITY

SUPERVISOR(S): Stefano Romano (Università di Catania, Italy)
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UNIVERSITY/RESEARCH CENTER:

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

A well-known open problem on neutron star physics is the so-called "hyperon puzzle": the difficulty in reconciling the presence of hyperons inside neutron stars with the recent measurements of 2 solar mass millisecond pulsars. In this project we want to study whether the use of an alternative theory of gravity to describe the neutron stars structure can provide a solution to this problem. Several alternative theories of gravity have been developed and applied to study the properties and the structure of neutron stars. Here we will explore some of them, such as the non-Newtonian theories, using purposely few equation of states of hyperonic matter that in standard General Relativity lead to maximum masses incompatible with current observational constraints.

ERASMUS MUNDUS MASTER IN NUCLEAR PHYSICS
Academic Year 2021/2022

MASTER THESIS PROPOSAL

TITLE: STRUCTURE OF SINGLE-Λ HYPERNUCLEI

SUPERVISOR(S): Luis Robledo (Universidad Autónoma de Madrid, Spain)
Isaac Vidaña (INFN, Sezione di Catania, Italy)
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UNIVERSITY/RESEARCH CENTER: Universidad Autónoma de Madrid & Università di Catania

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

Hypernuclei are bound systems made of neutrons, protons and one or more hyperons (baryons with strangeness content). Their study gives us the opportunity to study baryon-baryon interactions from an enlarged perspective and to extend, in this way, our present knowledge of conventional nuclear physics to the SU(3)-flavor sector. One of the goals of hypernuclear physics is precisely to relate hypernuclear observables with the underlying bare hyperon-nucleon (YN) and hyperon-hyperon (YY) interactions. In this project we want to study the structure of single-Λ hypernuclei in the framework of a finite range interaction among nucleus (the Gogny force). To such end we will incorporate a set of finite range YN and YY interactions into an existing mean field code capable to handle the Gogny force for the nucleons. To start with we will implement the interactions in an axial-symmetry preserving code. In spite of the limitation, the new code can address quadrupole deformation phenomena ranging from ground state deformation to fission. Once the new code is ready, a variety of nuclear structure studies involving hyper-nuclei will be carried out.

ERASMUS MUNDUS MASTER IN NUCLEAR PHYSICS
Academic Year 2021/2022

MASTER THESIS PROPOSAL

TITLE: Study of Low Gain Avalanche Detectors using particle accelerators.

SUPERVISOR(S): Javier García López
Mª Carmen Jiménez Ramos

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

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

This work is part of the international CERN RD 50 collaboration "*Radiation hard semiconductor devices for very high luminosity colliders*". The candidate will participate in the characterization of silicon low gain avalanche detectors (LGAD) using ion beams at the 3 MV Tandem accelerator of the CNA. Moreover, the student will collaborate in the setup of a new sample holder for low temperature measurements in the nuclear microbeam. Therefore, candidates should be motivated to work in experimental nuclear physics and have good knowledge of semiconductor detectors, as well as MATLAB programming language.

ERASMUS MUNDUS MASTER IN NUCLEAR PHYSICS
Academic Year 2021/2022

MASTER THESIS PROPOSAL

TITLE: Magnetic Diagnostic for the SMall Aspect Ratio Tokamak of the University of Seville

SUPERVISOR(S):

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UNIVERSITY/RESEARCH CENTER:

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

The main parameters of the plasma experiments consist of the magnitude of currents and magnetic and electric fields inside and outside the plasma volume. Reliable measurement of these parameters is basic to performing and understanding the experiments. In addition, the measurements of these global quantities can give considerable information about the microscopic properties of the plasma such as temperature, density, and composition. Magnetic diagnostics are the basic devices that a tokamak needs to measure those parameters but also to assess the control of the machine through techniques such as equilibrium reconstructions. The student will design the basic magnetic diagnostic such as magnetic coils, Rogowski coils and flux loops for the SMall Aspect Ratio Tokamak of the University of Seville. The student will develop his/her studies between the Centro Nacional de Aceleradores and the Faculty of Physics of Seville.

ERASMUS MUNDUS MASTER IN NUCLEAR PHYSICS
Academic Year 2021/2022

MASTER THESIS PROPOSAL

TITLE: **Analysis of pedestal structure and confinement in mixed isotope plasmas at JET**

SUPERVISOR(S): Eleonora Viezzer

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UNIVERSITY/RESEARCH CENTER: University of Seville

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

Nuclear fusion on Earth relies on the DT reaction. To study the properties of the plasma in nowadays machines usually pure D plasmas are used in the experiments. In JET (to date the largest tokamak experiment) a series of experiments were carried out with mixed isotopes, using H, D and T. In this master thesis we will study the electron temperature, density and ion temperature profiles with different isotopes (H, D and T). The DT experiments are scheduled for Nov./Dec. 2021 and thus, will complement the existing set of data (HD and HT plasmas). Remote participation for this experiments is available. The student will get familiar with experimental data from the JET tokamak and use fitting routines to determine the pedestal top parameters and compare mixed isotope plasmas with full H, D and T plasmas.

ERASMUS MUNDUS JOINT MASTER DEGREE IN NUCLEAR PHYSICS

UNIVERSIDAD DE SEVILLA

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

ERASMUS MUNDUS MASTER IN NUCLEAR PHYSICS

Academic Year 2021/2022

MASTER THESIS PROPOSAL

TITLE: **Feasibility study of an imaging charge exchange recombination spectroscopy diagnostic**

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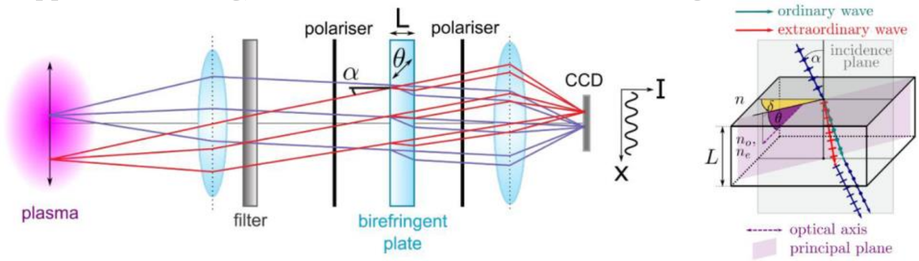
UNIVERSITY/RESEARCH CENTER: University of Seville

ABSTRACT

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

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



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

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

ERASMUS MUNDUS MASTER IN NUCLEAR PHYSICS
Academic Year 2021/2022

MASTER THESIS PROPOSAL

TITLE: Experimental measurement and theoretical analysis of N+N elastic scattering at low energies

SUPERVISOR(S):
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UNIVERSITY/RESEARCH CENTER: University of Seville

ABSTRACT

During this master thesis the student will analyze the data of the 14N+14N experiment performed at CNA, in Seville (Spain) using the program Genie2K. After obtain the elastic scattering angular distribution of the N-N collision at different energies, a theoretical analysis of the experimental data using a optical model approach will be carried out.

ERASMUS MUNDUS MASTER IN NUCLEAR PHYSICS
Academic Year 2021/2022

MASTER THESIS PROPOSAL

TITLE: Development of a two color interferometer and polarimeter for density measurements at the SMall Aspect Ratio Tokamak of the University of Seville

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UNIVERSITY/RESEARCH CENTER:

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

The goal of this project is to develop a diagnostic for electron density measurements at the SMall Aspect Ratio Tokamak (SMART) based on interferometry and polarimetry. Interferometers and polarimeters are the main and essential diagnostics for the operation of a tokamak and we aim here at developing a synthetic diagnostic for SMART. The candidate will use realistic SMART data (magnetic equilibrium, density and temperature profiles, etc.) for her/his feasibility study. The feasibility study and synthetic diagnostic shall be constructed in MATLAB or Python and will form the basis for the final diagnostic.

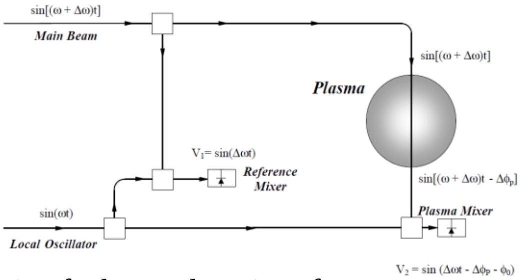

Figure. Schematic of a heterodyne interferometer system for a tokamak.

M. A. Van Zeeland *et al.*, Plasma Phys. Control. Fusion 59 (2017) 125005

ERASMUS MUNDUS MASTER IN NUCLEAR PHYSICS
Academic Year 2021/2022

MASTER THESIS PROPOSAL

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

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

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

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

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

ERASMUS MUNDUS MASTER IN NUCLEAR PHYSICS
Academic Year 2021/2022

MASTER THESIS PROPOSAL

TITLE: Characterization of a strip silicon detection array for the measure of exotic nuclei reactions in the vicinity of the Coulomb barrier.

SUPERVISOR(S): Luis Acosta (IF-UNAM). Juan Pablo Fernández. (US)

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Departamento de Física Atómica Molecular y Nuclear, Universidad de Sevilla, Seville, Spain.
Centro Nacional de Aceleradores, Seville, Spain.

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

To define in the better way the dynamics of a nuclear reaction, particularly when it involves exotic nuclei interactions, a good resolution detection array is extremely important. The high resolution strip detectors of the SIMAS array, in combination with GRAAL array (from Mexico and Seville respectively), may guarantee a powerful tool for the detection of charge particles covering a large solid angle. In order to approach measurements related to the ^{4}He production in the nuclear interaction between the halo nuclei ^{6}He and heavy targets around the barrier, the combination of this two sophisticate systems will bring a new and versatile detection array. The present project is addressed to put together but systems creating the most profit detection geometry, establishing the covered solid angle (assisted by simulations) and characterizing the capabilities of the hybrid array by using radioactive sources and different particle beams. Eventually, the person involved in this characterization will be involve in the measurements planned for it, at different laboratories in America (NotreDame University, Indiana, USA) and Europe (Laboratory Nazionali di Legnaro, Italy).

ERASMUS MUNDUS MASTER IN NUCLEAR PHYSICS
Academic Year 2021/2022

MASTER THESIS PROPOSAL

TITLE: Construction of a tracking array for the future radioactive beams facility at INFN-LNS inside of the FraISe project.

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Laboratori Nazionali del Sud, Istituto Nazionali di Fisica Nucleare, Catania, Italy.

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

The upgrading of the LNS-INfN cyclotron, started at the middle of 2020 is searching increase the intensity and energies of the beams delivered in order to assist new and important measurements for the present nuclear studies. These changes will allow the production of new interesting exotic beams, by using the In-Flight technique. The Project FraISe is addressed to the characterization of these beams, by using a series of high segmentation detectors along the beam line for the exotic beam production. The construction of the tracking array for the FraISe project will be a big challenge for the detection technology, considering the detectors to be used have to be resistant to high levels of radiation as well as to high beam intensities. The aim of this project is to construct the complete experimental setup of the tracking array for FraISe project, participating in the development of digital electronics for the readout, making simulations for the signal tracking experimentally expected and participate in the construction of new kind of detectors with the necessary capabilities for the new facility. Eventually, the person involved in this project will be invited to future measurements, once the facility will be ready for new science.

ERASMUS MUNDUS JOINT MASTER DEGREE IN NUCLEAR PHYSICS

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

ERASMUS MUNDUS MASTER IN NUCLEAR PHYSICS
Academic Year 2021/2022

MASTER THESIS PROPOSAL

TITLE: Optimizing FLASH-proton radiation therapy

SUPERVISOR(S): Miguel Antonio CORTÉS GIRALDO; Alejandro BERTOLET REINA

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UNIVERSITY/RESEARCH CENTER: Universidad de Sevilla / Massachusetts General Hospital-Harvard Medical School

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

FLASH poses as an exciting breakthrough in radiation therapy, which consists of ultra-high dose rate delivery of dose. Recent pre-clinical experiments have shown a significant reduction in the toxicity caused to healthy tissue by radiation while keeping similar damage to tumors. This project will focus on the development of software tools to produce FLASH-based plans with clinical proton beams, investigating both feasibility and suitability of different planning techniques. Python knowledge and skills is highly recommended. The candidate will develop the project in Seville (Spain), and will collaborate with the Proton Therapy Center at the Massachusetts General Hospital and Harvard Medical School (Boston, MA, USA).

ERASMUS MUNDUS MASTER IN NUCLEAR PHYSICS
Academic Year 2021/2022

MASTER THESIS PROPOSAL

TITLE: Study of b- and c-jets identification with quantum machine learning algorithms and application to the H reconstruction at LHCb.

SUPERVISOR(S):
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UNIVERSITY/RESEARCH CENTER:
Department of Physics and Astronomy "G. Galilei" University of Padova

ABSTRACT
(just few lines 5-10 explaining briefly the idea of the proposed work and the place where it will be developed).
The activity will start by applying quantum machine learning algorithms already developed to distinguish b from b-ar quark jets to the b- and c-jets identification. It will require to train the methods for b-to-c quark jets separation. The performance will be determined against classical Deep Neural Network algorithms. The optimized code will be use to determine the H->bb-bar and the H->cc-bar sensitivity. The work will be done at the department of physics and astronomy of the university of Padova in cooperation with the LHCb experiment. The student will present the results to the relevant LHCb sub-groups.

ERASMUS MUNDUS MASTER IN NUCLEAR PHYSICS
Academic Year 2021/2022

MASTER THESIS PROPOSAL

TITLE: Sensitivity analysis of proton microdosimetry in water to changes on interaction models and scoring method

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UNIVERSITY/RESEARCH CENTER: Universidad de Sevilla / Massachusetts General Hospital-Harvard Medical School

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

Microdosimetry provides a theoretical framework to determine the properties of the spatial distribution of energy deposition within a heavy charged particle track at microscopic scale, with which radiobiological effects of ionizing radiation can be estimated. We have recently developed a Monte Carlo code with Geant4-DNA to carry out track-structure calculations of proton track segments to calculate dose-averaged liner energy transfer (LETd) values from microdosimetry quantities. The aim of this project is to assess the impact on these quantities due to the selection of Geant4-DNA physics list and scoring method. The candidate will develop the project in Seville (Spain) using our HPC resources located at CICA (Seville, Spain), and will collaborate with the Proton Therapy Center at the Massachusetts General Hospital and Harvard Medical School (Boston, MA, USA). Knowledge on the Geant4 toolkit and C++ is highly recommended.

Study of the Hoyle state band in 12C via inelastic excitations

Supervisors:
Elena Geraci (Università degli Studi di Catania)
Jesús Casal Berbel (Universidad de Sevilla)
José Antonio Lay Valera (Universidad de Sevilla)

The 12C nucleus takes a prominent position in Nuclear Physics research, since its formation via the so-called triple-alpha reaction and the Hoyle state play a key role in Astrophysics. It is a crucial N = Z system which, even after decades of experimental and theoretical efforts, continues to defy our nuclear structure knowledge. In particular, alpha clustering in 12C is still a topic that attracts substantial interest, with influence not only on the energy spectrum but also for reaction dynamics. In this context, inelastic alpha scattering processes provide an invaluable tool to study this nucleus, as evidenced by numerous scientific works in the literature.

In this thesis, after a bibliographical survey, elastic and inelastic excitations of the 12C nucleus will be studied within the algebraic cluster model for three alpha particles, characterized by rotations and vibrations that give rise to different bands based on discrete symmetries. This model provides densities and transition densities for the low-lying states of 12C, which can be used to generate the corresponding folding form factors for inelastic alpha scattering calculations. The project will build upon existing first-order distorted-wave Born approximation (DWBA) results to analyze full coupled channels (CC) effects in the population of the different states, with emphasis on the Hoyle state and the Hoyle-state band.

Master and PhD position in experimental nuclear physics

Matter's Origin from RadioActivity: first experiments analysis

The MORA project gathers experts of ion manipulation in traps and laser orientation methods for searches of New Physics (NP) in nuclear beta decay, looking for possible hints to explain the matter-antimatter asymmetry observed in the Universe. The precise measurement of the so-called triple *D* correlation is sensitive to Time reversal violation, and via the CPT theorem, to CP violation. As such, the measurement of *D* in nuclear beta decay is a complementary probe to the electric dipole moment of the neutron. It is particularly sensitive to the existence of Leptoquarks, which are hypothetical gauge bosons appearing in the first theories of baryogenesis, and numerous theories beyond the Standard Model.

The symmetries of the MORA detection system and the well-controlled parameters of the trapped and polarized ion cloud permit to aim at a final sensitivity of a few 10^{-5} on *D*. Such a sensitivity is about one order of magnitude better than present limits on *D*, from measurements in neutron and ^{19}Ne decay. It should permit, in addition, to look for signs of CP violation, to probe for the first time the so-called Final State Interaction (FSI) effects. The FSI effects, caused by the electromagnetic interaction of the recoiling nucleus with the particle, are expected to mimic a tiny non-zero *D* at a level that varies from 10^{-5} to 10^{-4}, depending on the decaying nucleus. Their estimates rely on rather old calculations (1970's), which are presently being revised by theoreticians within the MORA project.

The first experiment for the polarization degree (proof of principle) and *D* correlation will be performed by February 2022 at JYFL, Finland. The measurement will be focused on the decay of ^{23}Mg^{+} ions with a half-life of 11.3s, a simple polarization scheme, and will eventually be available in copious intensities at the future DESIR facility at GANIL [2] for measurements with the highest sensitivity to new physics.

The final sensitivity on *D* depends on the level of systematics effects kept under control. The individual simulations of detectors of MORA are already performed with GEANT4 and PENELOPE Monte Carlo code. Dedicated studies for the systematic effects and the analysis tools are under development. The goal of this doctoral thesis will be to analyze the data taken from the experiment, continue the studies to reduce the systematic effects as much as possible, and disseminate the experimental data at national and international conferences.

[1] *The MORA project*, P. Delahaye, E. Liénard, I. Moore et al., Hyp. Int. (2019) 240:63; arXiv:1812.02970

[2] https://anr.fr/ProjetIA-11-EQPX-0012

Expected skills:

- Skills in numerical methods and data analysis, statistics
- Experimental physics
- Good communication skills
- Programming C++/python

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Master and PhD position at the Laboratory : Laboratoire de Physique Corpusculaire in Caen

Title: *Characterization of the simultaneous spin analyser built for the neutron electric dipole moment (nEDM) experiment.*

Subject:

The search for electric dipole moment (EDM) of elementary particles or composite system (electron, neutron, Hg and so on …) probes the origins of the baryogenesis. In particular, it has a high discovery potential of new mechanisms of CP violation, which is one of the elements required to account for the appearance of matter in our Universe.

The LPC Caen is involved in an experiment at Paul Scherrer Institute (PSI) in Switzerland aiming at measuring the neutron EDM. The experiment is carried out with the ultra-cold neutrons (UCN) source from PSI. The project has two phases. The first phase is over. It lead to the publication of the best worldwide limit on the neutron EDM in 2020. The phase II has started and a new highly sensitive spectrometer is under construction (n2EDM). An improvement of one order of magnitude is expected on the statistical and the systematic errors. The experiment commissioning is planned for 2022-23. The LPC laboratory is involved in the collaboration since 2003. It is in charge of the neutron detection, the measurement of the neutron polarisation, the manufacturing of the non-magnetic vacuum tank and the design and the manufacturing of the coils system.

The internship is focused on the neutron detection and the analysis of their polarisation. A simultaneous spin analyser is under construction at LPC (see Fig. 1 for the description). The device will be soon operational and a test is planned at PSI with ultra-cold neutrons in December 2021. The candidate will have to analysis the collected data. The goal is to fully characterize the device and ensure that the neutron polarisation is correctly measured.

Fig 1: scheme of the simultaneous spin analyser (left) and picture of the UCN detectors.

For further information, please call Thomas Lefort at 00.33.2.31.45.24.12 or write an email to lefort@lpccaen.in2p3.fr.

Master and PhD position in experimental nuclear physics

FIssion Studies at VAMOS in Inverse Kinematics (FISVIK)

During the fission process, a heavy nucleus splits into lighter fragments due to the competition between the attractive strong nuclear force and the electrostatic repulsion. This results in a very large distribution of produced nuclei. The nuclear fission process is driven by a complex interplay between the dynamical evolution of a quantum system composed of a large number of nucleons and the intrinsic nuclear structure of the system at extreme deformations as well as heat flows. The balance between these various aspects decide the characteristics of the emerging fragments. Nevertheless, despite almost 80 years of intense research, fission is still far from being fully understood, and the theoretical and experimental knowledge remains incomplete [1].

Innovative experiments are conducted to widen our knowledge of fission, aiming notably at a complete identification and characterization of the fission fragments and the study of unstable fissioning systems. In particular, pre- and post-neutron evaporation isotopic fission yields are good candidates to investigate the mechanism responsible for the fission fragments production. The experimental access to this production probability (fission yields) requires the measurement of the full distribution of the fission fragments, which is experimentally very challenging.

At GANIL, the inverse kinematics technique is used to produced in-flight fission. Accelerated heavy fissionning system is excited through nuclear reactions, in particular multi-nucleon transfer reactions and the produced fission fragments are emitted at forward angles. The VAMOS large-acceptance magnetic spectrometer [2] is used to identify, in mass and nuclear charge, the full distribution of fragments while a silicon telescope is used to characterize the fissionning system by detecting the residual recoil emitted in the transfer reaction [3,4,5,6].

The fission@VAMOS project is undergoing a detection upgrade of the silicon detection system used to tag the fissionning systems produced by transfer reactions. The existing setup will be replaced by a state-of-art device based on highly-segmented silicon detectors (PISTA). This will result in an improved selectivity and precision of the formation condition of the fissionning system (Mass, Atomic charge, and Excitation energy). The detection setup of VAMOS spectrometer has also been improved with new high-performance gaseous detectors. The first experimental campaign using this upgraded setup is expected in 2022.

The proposed thesis project deals with a detailed multi-parameter study of fission using the VAMOS spectrometer and the PISTA charged particle array to study the fission process in the regions of light actinides. The successful candidate will be in charge of the characterisation of the PISTA detectors, and be strongly involved the setup of the VAMOS spectrometer and PISTA array. She/He will be in charge of the analysis and dissemination of experimental data.

[1] K.-H. Schmidt and B. Jurado, Rep. Prog. Phys. 81 (2018) 106301
[2] M. Rejmund et al., Nucl. Instrum. Methods A **646**, 184 (2011).
[3] Y. Kim, A. Lemasson et al., Eur. Phys. J. A **53**, 162 (2017).
[4] M. Caamano et al. Phys. Rev. C 88 (2013) 024605,
[5] D. Ramos et al. Phys. Rev. Lett. 123 (2019) 092503
[6] D. Ramos, M. Caamaño, A. Lemasson, Phys. Rev. Lett. **123**, 092503 (2019)
[7] D. Ramos, M. Caamaño, A. Lemasson, et al. Phys. Rev. C **101**, 034609. (2020)

Expected skills:

The Phd Candidate :

- Is expected to be a strongly motivated person, with good English communication skills and with a basic background in nuclear reactions and physics of fission;
- Experimental profile and skill in the use of scientific software packages for the data analysis (C++/ ROOT) and simulation.
- Is expected to present the results of his work at scientific conferences at both national and international levels, as well as publish them in scientific journals;
- Will join the international researcher team and take an active part in the ongoing experimental program conducted by the group.

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Contribution to the LISA data analysis applying true data taking condition for a realistic analysis.

MASTER AND PHD POSITION

Since 2015, the first gravitational waves (GW) detection has opened a new window on the Universe. LISA, spatial interferometer project, (Laser Interferometer Space Antenna) will be able to measure GW in a new frequency range (from 0.02 mHz to 1 Hz). Many signals from different sources will be reachable : Black Holes (Super Massive, Stellar Mass, Extrem Mass ratio), Galactic binaries and stochastic background from primordial Universe.

Laser beams is exchanged from a spacecraft to another one in the triangular LISA constellation. Inter-spacecraft distance are measured by interferometry technics to reach a relative variation about 10^{-21}. In the LISA data, waveform signatures are specific to the gravitational sources. The waveform data analysis will allow to determine source parameters (coalescence time, position, masses, spins, ...). The objective will be to provide a gravitational sky catalog.

In the analysis timescale, one of the first contribution will be to detect a Super-Massive Black Holes merger by a low latency pipeline in order to let the electro-magnetic detectors to join to the observation.

The proposed work for this internship will be to develop an algorithm in order to localize and estimate the intrinsic parameters of a binary system.

The candidate will have to :

- use the LISA software tools in order to simulate the gravitationnal signal from binaries,
- provide some algortihm to recover the binaries parameters and its location,
- estimate the accuracy and the precision on the binaries location in fonction of the fit resolution duration.

The expected skills of the student are: solid background in physics and programmation (Python, C/C++) for simulation and data analysis. Knowledge in astrophysics and signal waveform data analysis will be appreciated.

A phd thesis is possible with the LISA team at LPCCaen.

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Master 2/Erasmus Mundus internship

Proposed by Olivier LOPEZ (LPC Caen, France), CNRS researcher
Location : GANIL / LPC Caen
Duration: 5 months (February – July 2021)

Title: ***Participation of the new INDRA-FAZIA experimental campaign E818 at GANIL***

Subject

The *INDRA-FAZIA* collaboration will perform a new experiment at *GANIL* called *E818* during spring 2022 (March-June). The aim of this experiment is to investigate the equation of state of hot nuclear matter at low densities, and more specifically the in-medium properties for clusters. These latter are defined as light nuclei with atomic number $Z=1\text{-}8$. Indeed, the properties of such clusters are fundamental to investigate the structure of the inner crust of compact stars and also the dynamical evolution of core collapse supernovae for massive stars, as well as the recently observed phenomenon of neutron stars mergers. To do so, we will use the state-of-the-art experimental setup *INDRA-FAZIA*, one of the most powerful apparatus worldwide for the detection of charged products coming from heavy-ion induced reactions around the Fermi energy. *INDRA-FAZIA* is composed of 240 (INDRA) + 192 (FAZIA) Si-CsI(Tl) telescopes read out with a cutting-edge digital electronics. The objective of the internship is to participate to the preparation, the commissioning and the data taking of the *E818* experiment.

Figure 1: 3D sketch of the INDRA-FAZIA experimental setup at GANIL (2021).

PHD follow-up: yes, conditioned by getting a grant (CNRS/Region or University). See hereafter for the PHD subject.

Contact

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PHD for October 2022 at LPC Caen

Towards a better experimental characterization of the isovector part of the equation of state of nuclear matter

Context of the thesis

This work is part of the program initiated by the *INDRA* collaboration since many years and more recently by the *INDRA-FAZIA* collaboration concerning the study of the properties of nuclear matter through nuclear collisions around the energy range available at the *GANIL* facility. This range corresponds to the so-called Fermi energy range between 10-100 *AMeV* for stable beams (*GANIL/CSS2*), and limited to 10-20 *AMeV* for radioactive beams (*GANIL/CIME-SPIRAL1/SPIRAL2*). The aim of the thesis is to provide better experimental constraints on the study of the isovector part (symmetry term) of the Equation of State (*EoS*) of nuclear matter. Indeed, the *EoS* allows to predict the behavior of nuclear matter subjected to conditions that can be encountered not only in collisions between nuclei but also in massive stars at the end of their life during the collapse phase of supernovae and the creation of neutron stars as well as the fusion of binary systems of neutron stars (*Kilonova*). Moreover, the comparison of experimental data with transport models allows to provide constraints on the description of nuclear reactions in general, and more specifically on the dynamics of multifragmentation (*spinodal instabilities*) and the connection with the liquid-gas phase transition of nuclear matter. Table 1 gives the current evaluations concerning some of the empirical parameters of the nuclear equation of state extracted from [1].

	~1%	~10%		~30%		???				
P_α	E_{sat} MeV	E_{sym} MeV	ρ_0 fm^{-3}	L_{sym} MeV	K_{sat} MeV	K_{sym} MeV	Q_{sat} MeV	Q_{sym} MeV	Z_{sat} MeV	Z_{sym} MeV
$\langle P_\alpha \rangle$	-15.8	32	0.155	60	230	-100	300	0	-500	-500
σ_{P_α}	±0.3	±2	±0.005	±15	±20	±100	±400	±400	±1000	±1000

Table 1: Mean values and standard deviations of the empirical parameters of the EoS extracted from [1].

They represent our actual knowledge about the EoS and can be divided in 3 groups: the first one is associated to relative standard deviations at *1-2%* level (saturation energy E_{sat} and density ρ_{sat}), the second one to larger standard deviations between *10-30%* constituting the low order empirical parameters, here the symmetry energy E_{sym} and the slope parameter L_{sym}, and the last one to almost unconstrained empirical parameters like K_{sym}, Q_{sat}, Q_{sym}, Z_{sat} and Z_{sym} which represent the high order parameters in density/isospin.

Subject

The *INDRA* experimental database accumulated over the last 25 years, supplemented by the latest *INDRA-FAZIA* experiment performed in 2019 (*E789*) and the next experiment scheduled in 2022 (*E818*), is the ideal tool to make comparisons with transport models on a large scale in terms of mass, incident energy and isospin since *INDRA* and *FAZIA* are among the most powerful multi-detector for charged products in the Fermi energy domain. Figure 1 shows the experimental *INDRA-FAZIA* setup (*INDRA* at the left and *FAZIA* at the right) located in the experimental room *D5* in *GANIL*.

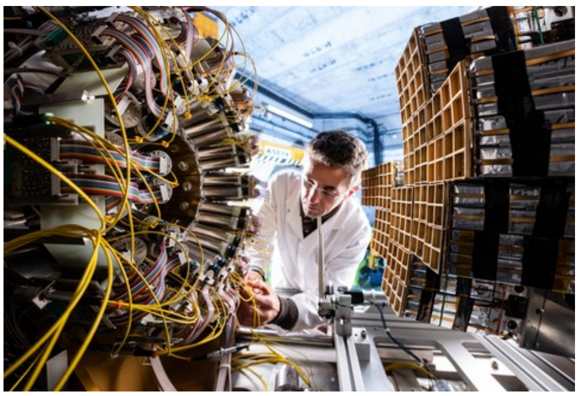


Fig. 2: INDRA-FAZIA au GANIL in room D5 at GANIL.

The thesis work will be based on the development of comparisons with different state-of-the-art phenomenological or semi-classical transport models such as *HIPSE* (*Heavy Ion Phase Space Exploration*), *AMD* (*Antisymmetrized Molecular Dynamics*) and *SMF/BLOB* (*Stochastic Mean Field/Boltzmann-Langevin One-Body*) using a specific Bayesian inference [2]. In conjunction with the high quality data from the *INDRA* and *FAZIA* detectors, the Bayesian approach will provide more precise constraints on the characterization of the equation of state, including the quantitative estimation of uncertainties associated with the parameterizations of the models. Also, the use of an innovative identification/calibration technique developed conjointly with M. Parlog called *AME* (*Advanced Mass Estimate*) for *INDRA* as well as *AMI* (*Advanced Mass Identification*) for *FAZIA* [3] will bring significant improvements concerning the comparisons between experimental data and model predictions, especially regarding the isotopic identification of light nuclei (IMF) $Z<10\text{-}12$ for *INDRA* and $Z<22$ for *FAZIA*, and will certainly bring new constraints when looking at isospin observables. The candidate will be required to deploy this new identification/calibration technique on *INDRA* and *INDRA-FAZIA* data, and to build the framework of the Bayesian approach to implement the use of the different models. In this context, she/he will be part in the international *INDRA-FAZIA* collaboration comprising about 50 members and 10 laboratories. The aim of the thesis is to provide the most possible accurate constraints from the study of dissipative collisions on the determination of the *EoS*, with a particular interest for the part related to the symmetry energy and its dependence on the density. To this end, she/he will also exploit multi-particle correlations in order to estimate experimentally the densities and temperatures reached in dissipative collisions. These results will then be confronted with the predictions of the models in order to determine as precisely as possible the empirical parameters of the equation of state of nuclear matter such as the binding energy at saturation, the compressibility, the symmetry energy, the slope and the curvature of the latter as a function of the density. This determination is indeed crucial to determine the structure of neutron stars (mass, radius, deformability) but also concerning the cooling of the proto-neutron stars during the collapse of the core of massive stars at the end of their life, which is partly constituted of hot nuclear matter at low density such as it can be encountered in dissipative collisions between heavy ions at Fermi energy.

References

[1] J. Margueron, R.H. Casali, and F. Gulminelli, Phys. Rev. C **97** (2018) 025805

[2] O. Lopez, Habilitation à diriger des recherches, Université de Caen (2014), *https://tel.archives-ouvertes.fr/tel-01091352/document*

[3] O. Lopez, M. Parlog, *et al.*, Nucl. Instr. and Meth. in Physics Research A **884** (2018) 140

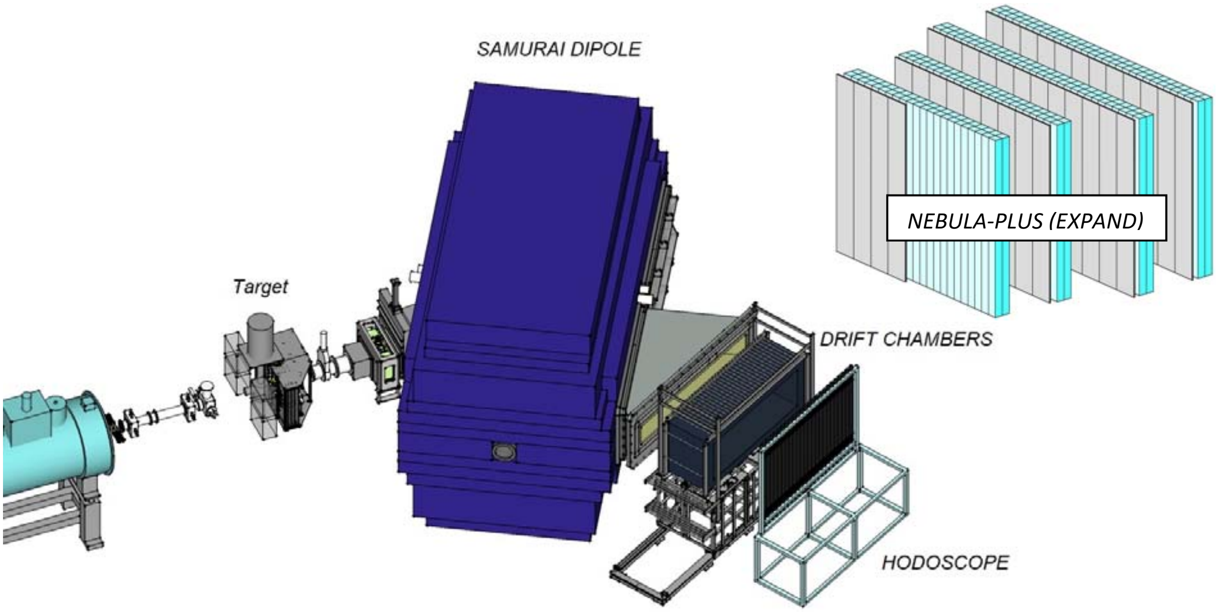
Location/funding

Start - End of the PHD : October 2022 - October 2025
Location: LPC Caen, France
Funding (if granted): CNRS/Region or University

Master 2 Internship in Nuclear Structure

Multi-neutron detection for the investigation of exotic nuclei

The Nuclear Structure Group at LPC-Caen studies the properties of light neutron-rich nuclei. In this context, several experiments have been undertaken at the RIKEN accelerator in Tokyo (Japan), probing isotopes at the neutron dripline (^{19}B, ^{22}C…) and beyond ($^{20-21}$B, ^{16}Be, ^{7}H, ^{4}n…). Recently, an ANR project (EXPAND) has been funded in order to extend the multi-neutron capabilities of the NEBULA modular array with two extra walls, into the future NEBULA-PLUS array (see picture below).



The aim of the internship is the development and validation of a Monte-Carlo simulation of the new NEBULA-PLUS array. The simulation will be developed within the nptool framework, based on Root and Geant4, and will be part of a wider program to build a full and consistent simulation of the future SAMURAI experiments carried out by the group at RIKEN.

The candidate will implement the geometry of the detector array, and then compare the predicted 1n efficiency to the experimental one measured with the existing NEBULA array. Finally, the simulation will be used to characterize and optimize the cross-talk rejection algorithms used in the case of 3 and 4 neutron detection.

Depending on the RIKEN schedule in the spring of 2022, the candidate may eventually participate in the installation of the NEBULA-PLUS array on site and its commissioning. A PhD focusing on an experiment using the SAMURAI+NEBULA-PLUS setup, with a start date of October 2022, will be proposed by the group.

Group members: A. Matta (matta@lpccaen.in2p3.fr), M. Marqués (marques@lpccaen.in2p3.fr), L. Achouri, F. Delaunay, F. Flavigny, J. Gibelin, N. Orr.

Master and PhD position in experimental nuclear physics

Development of an X-ray detection system for particle ID of superheavy nuclei

The synthesis and study of the heaviest nuclei in the region of superheavy elements (SHE) is still one of the major challenges of modern nuclear physics. Despite world-wide efforts and achievements throughout more than half a century, resulting in atomic number $Z = 118$ and isotopes of element oganesson as heaviest nuclear species synthesized so far, the envisaged "island of stability" of superheavy nuclei (SHN) has not yet been reached. The major ingredients for the stability and existence of those heavy systems are nuclear structure features, the so-called shell effects. Predictions of the various models on the market for closed proton and neutron shells point to numbers like 174 and 182 for the closed neutron shell and 114, 120 and 126 for the respective number of protons.

Experimental studies of the nuclear structure of the already known nuclei as well as the synthesis of new isotopes are essential for the progress of the field. Complex instrumentation at heavy ion accelerator facilities like the new linear accelerator facility SPIRAL2 at GANIL are the key ingredients to allow these investigations. So far, those SHN are produced in heavy ion fusion reactions, where the reaction products are separated from the primary beam by an effective ion-optical separator and then studied by a comprehensive detection system for particles and photons, including alpha-, gamma-, fission fragment and conversion electron spectroscopy.

The identification of the studied nuclei in atomic charge Z and nuclear mass A, typically based on decay features of known nuclei, e.g. by alpha spectroscopy of subsequent decay chain members, face severe limitations for hitherto unknown nuclei. The separator-spectrometer set-up S^3 at GANIL-Spiral2 is equipped with mass spectroscopic capabilities sufficient to resolve the mass A of SHN. At its focal plane the comprehensive detection system SIRIUS consists of an efficient silicon detection array for particle (reaction products, alphas, fission fragments, e^- and light charged particles). It will be accompanied by an array of large volume (typical dimensions: $(10\times10\times9)$ cm^3) germanium detectors for gamma spectroscopy. To establish the atomic charge of the species of interest, characteristic X-rays can be used, whose energies are, however, at and below the energy detection threshold of those large volume germanium detectors. To provide the means for an efficient X-ray spectroscopy, the development and implementation of a photon detection system with lower energy threshold and enhanced efficiency for X-ray energies in the range from $\approx$15 keV to $\approx$100 keV is the major task of the Ph.D. thesis work.

On the instrumental side, our group has recently achieved experience in the use of so-called Low-Energy Photon Spectrometers (LEPS) which provide the specifications required for X-ray spectroscopy, consisting of small volume (thickness $\approx$ 1cm) Ge crystals with a thin (0.5 mm carbon) entrance window. An array with similar features will be needed at the S^3 focal plane. The development of such a system, its integration in the SIRIUS set-up as well as its in-beam test and use for SHN decay spectroscopy will be the main tasks of the Ph.D. thesis.

On the physics side our group pursues and is involved in the spectroscopic studies of very heavy and superheavy nuclei on site at GANIL-SPIRAL2 as well as in activities at international accelerator laboratories like Argonne National Laboratory (ANL), Argonne, U.S.A., Flerov Laboratory of Nuclear Reactions of the Joint Institute for Nuclear Research (FLNR-JINR), Dubna, Russia, Helmholtzzentrum for Heavy Ion Research GSI, Darmstadt, Germany, Japanese Atomic Energy Agency (JAEA), Tokai, Japan and others. The subjects of our research comprise spectroscopic studies of heavy and superheavy nuclei produced in fusion reactions as well as the investigation of alternative reaction schemes to produce exotic heavy nuclear systems like the exchange of nucleons between projectile and target in heavy-ion collisions, so-called multi-nucleon transfer (MNT) reactions. A Ph.D. thesis work is presently being performed on a recent experiment, studying MNT in the reaction $^{238}U+^{238}U$ at GANIL-SPIRAL2. A possible continuation at GANIL-SPIRAL2 or elsewhere depends on the outcome of this present thesis work. Concerning gamma and decay spectroscopy, we have an accepted experiment at ANL to study the doubly magic nucleus ^{252}Fm by in-beam gamma spectroscopy at the separator-gamma-detection array combination FMA+GRETINA, scheduled to run in October 2021. The decay of ^{254}Lr and its decay products to study the region around ^{252}Fm, employing the competing alpha and electron capture (beta) decay modes is envisaged to be studied also at ANL or elsewhere. These activities in which the Ph.D. student will be involved, are efficient preparatory studies for the experiment campaigns planned at S^3 which is scheduled to come online in 2024. This Ph.D. thesis work is a major ingredient for the preparation of the detection instrumentation needed for the S^3 operation.

Expected skills:
Team work capabilities
English
Computer coding (C++, ...)

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Master and PhD position in experimental nuclear physics

FISSION STUDIES WITH VAMOS++ AND FALSTAFF SPECTROMETERS

The fission mechanism is a violent complex reaction in which a heavy nucleus is split in two fission fragments. This process is strongly determined by the nuclear structure along with the nuclear dynamics that drives the system from an initial state to the final break-up through different states of extreme deformation.
Despite more than 80 years of intense research on fission, the complex interplay between intrinsic and collective degrees of freedom still prevents from a full microscopic description and hence, the theoretical knowledge of the process is still limited.
From the experimental point of view, the relative production of the different fission fragments, pre- and post-neutron evaporation isotopic fission yields, together with the their kinetic energies are good candidates to reveal the mechanism behind the fission process. However, the access to the complete identification of fission fragments is still very challenging due to the large number of produced species ---more than 300 different isotopes are produced from one fissioning system--- and their low kinetic energy.
A new setup based on low pressure gaseous detectors, the FALSTAFF spectrometer, offers a new opportunity to identify fission fragments in terms of mass, nuclear charge and velocity vector. In combination with the VAMOS++ magnetic spectrometer and the associated setup, both fission fragments will be identified at the same time and their energy will be measured.
This experiment, to be run at GANIL in 2022, will benefit from the inverse-kinematics technique using a beam of ^{238}U and light targets in order to produce fissioning systems from different incoming channels, either fusion or transfer reactions.
The objectives of this PhD are two-fold: the full characterization of the FALSTAFF spectrometer, and the determination of isotopic fission-fragment yields and the scission configuration of exotic minor actinides. For this, the selected candidate will be in charge of the data analysis of both spectrometers, the production and interpretation of results, and dissemination of the experimental data in national and international conferences. The scientific results of this work are expected to be published on international journals of high impact.

Expected skills:
The PhD candidate is expected:
- To have a good background in nuclear structure and reactions and in the physics of fission as well as in the radiation-matter interaction.
- To have skills on computing languages such as C++ and knowledge on software packages of data analysis and simulation such as ROOT and GEANT4.
- To be a motivated person with strong communication skills and good English level.

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MASTER AND PHD PROPOSAL

Topic: **Microscopic reaction model for nucleon scattering on light nuclei**

Context:

Nuclear reactions are an essential link for the understanding of the world around us. Their diversity (decays, particle scattering, fission…) and their complexity reflect different dynamical aspects of the many-body problem. The modeling of the mechanisms underlying these physical processes is a major challenge for both the understanding the formation of the universe and some applications. For example, the nuclear scattering reactions on light nuclei such as Li, Be and B, are of interest in astrophysics: a better knowledge of the cross section of the reaction ^{7}Be(n, p)^{7}Li, which is responsible for the disappearance of a large part of ^{7}Be, could help to elucidate the problem of the abundance of Li occuring in cosmological models [1].

Light nuclei are interesting and very special systems. Within them, complex correlations occurs giving rise to very unusual structures, such as halos with one or more nucleons and aggregates of alpha particle type. The existence of such substructures plays an important role during the interaction between the projectile and the target and must have an impact on reaction mechanisms and cross sections.

Objective of the PhD thesis:

The resolution of a (A + 1)-body scattering problem, where A is the mass of the target nucleus, remains too complex to be solved exactly. The reaction models often consider that this problem can be simplified in a two-body problem in which the incident nucleus interacts with the A nucleons of the target via a potential which is complex, the imaginary part allowing the treatment of the absorption. These models are known as the optical model. The effective cross sections are then calculated by solving a radial equation derived from the Schrödinger equation, making use of this complex potential whose parameters are adjusted in order to reproduce some experimental data. Some extensions of this optical model, notably the Continuum Discretized Coupled Channels (CDCC) used in this thesis [2-4], allow to take into account the internal structure of the target, but this structure is introduced phenomenologically by assuming, for example, a structure in two aggregates: the target is described using a relative wave function between the aggregates which is obtained using a potential adjusted to obtain the right binding energy and the right mean square radius.

The objective of this thesis is to extend the CDCC model by introducing ingredients from a microscopic description of the target and of the target-projectile interaction potential. For this purpose, we will use a many-body method developed in the laboratory, the multi-particle-multi-hole configuration mixing method (MPMH)[5-7], which solves exactly or almost exactly the structure of the target, aggregates and from which one can built microscopic optical and transition potentials. Thus, starting from a chiral interaction, we will be able to determine the spectra and the A-body wave functions of the light nuclei.

Outline of the PhD thesis:

During the PhD thesis, the student will therefore have to:

1. calculate the MPMH wave functions of the low-energy states of light nuclei and those of the aggregates that may constitute them;
2. calculate the overlaps between these different wave functions;
3. extract the optical and nucleon-aggregate transition potentials;
4. integrate these overlaps and potentials into the CDCC approach;
5. and finally obtain the cross sections which will be compared to the existing experimental data.

During the thesis, the PhD student will gain expertise in the field of nuclear many-body problem, both on aspects of nuclear structure and reactions. He will collaborate with G. Blanchon and M. Dupuis who are expert of the domain. In addition, the PhD student will benefit from exceptional computing resources from CEA / DAM / DIF. A pre-thesis internship will be possible.

References:

[1] L. Damone et al, Phys. Rev. Lett., vol. 121, p. 042701, 2018.
[2] N. C. Summers, F. M. Nunes, and I. J. Thompson, Physical Review C, vol. 74, p. 014606, 2006.
[3] R. de Diego, J. M. Arias, J. A. Lay, and A. M. Moro, Physical Review C, vol. 89, p. 064609, 2014.
[4] P. Chau Huu-Tai, Nuclear Physics A 773 (2006) 56–77.
[5] C. Robin, PhD thesis, Université Paris-Sud 11, 2014.
[6] C. Robin, N. Pillet, D. Pena-Arteaga, and J.-F. Berger, Phys. Rev. C, vol. 93, p. 024302, 2016.
[7] C. Robin, N. Pillet, M. Dupuis, J. Le Bloas, D. Pena-Arteaga, and J.-F. Berger, 2017.

Place of the PhD thesis: CEA, DAM, DIF, Bruyères-leChâtel, F-91297 Arpajon Cedex, France

Directeur de thèse et école doctorale :	Nathalie Pillet / Ecole doctorale PHENIICS (ED 576)
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Master and Phd position in nuclear theory

Unified theory of nuclear structure and reactions in the open quantum system framework

Light weakly bound or resonant nuclei play an important role in various stellar processes of nucleosynthesis. The comprehensive understanding of these nuclei requires a correct treatment of the multi-particle continuum. It is proposed to study various structural and reaction effects of the coupling between discrete and continuum states using the Gamow Shell Model. This model provides the first unitary formulation of a standard nuclear shell model in the open quantum system framework for the description of well bound, weakly bound and unbound nuclear states. Gamow Shell Model in the representation of coupled reaction channels provides also the unified description of nuclear structure and low-energy reactions. In this thesis, the emphasis will be put on the studies of spectra and low-energy reactions of astrophysical interest, as well as the formation of near-threshold narrow resonances which play crucial role in the nucleosynthesis of heavier elements.

Expected skills:
Good knowledge of quantum mechanics, nuclear physics and computational aspects of the nuclear many-body problem. Excellent skills in computing and numerical analysis.

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Master and PhD position in instrumental nuclear physics

3-dimensional scintillation dosimetry for small irradiation fields control in protontherapy

Radiotherapy is an important modality in treatment cancer. In this domain, proton beams have ballistic superiority against photon beams. Nevertheless, the use of protontherapy to treat small volume tumors (typically less than 27 cm^3) is limited because of the lack of well adapted dosimetry tools for small irradiation fields quality assurance. To answer this issue, an innovative dosimetry system has been developed. It is based on a scintillating block of 10 × 10 × 10 cm^3, a mirror and an ultra-fast camera recording the scintillation from different points of view. The system can be used to perform beam assurance quality (verification of the beam characteristics: position, energy, intensity), or treatment assurance quality (verification of the delivered dose distribution).
The system has already shown very good performance for beam assurance quality and is very promising for 3-dimensional dosimetry
The objective of this PhD thesis will be to develop numerical methods to convert the scintillation maps into dose maps. This includes the study of the energy dependence of the scintillation yield with proton beams, methods of image treatment and the development of calibration methods.
After the development of appropriate reconstruction methods, the detector will be evaluated and compared to reference dosimeter and treatment plans.
This project will be done at GANIL in collaboration with the LPC Caen from experimental acquisitions performed at the Cyclhad proton therapy center in 2021 and the first semester of 2022. It will involve the analysis and treatment of the scintillation acquisitions as well as Monte Carlo simulation.

Expected skills:
The student must have a formation in nuclear physics with a good knowledge of the detection of radiations and their interactions with matter. Knowledge in radiotherapy and dosimetry would be a plus.
The student will participate to the analysis and the treatment of the scintillation images to achieve 3-dimensional 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.
The candidate will need to be able to work in an interdisciplinary domain with people from other research fields such as biology, medical physics or medicine.

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Master and PhD position in accelerator physics

AI for cryogenics and RF of superconducting accelerators

SPIRAL2 is one of its kind heavy ions accelerator located in Caen-France. Its heart, a superconducting linear accelerator, relies on 26 superconducting resonating cavities, cooled down to 4.2 Kelvin and operated at 88 MHz. SPIRAL2 faces specific challenges ranging from high dynamics of thermal loads, drastic level and pressure control of the superconducting cavities Helium bath, long distribution lines, vacuum pressure degradation, field emissions, cavities quenches and detuning among other ponderomotive effects. All these effects are completely different and might seem uncorrelated at first sight but they could all be linked either to the process-control or to one or several related sub-systems by some elaborated relations. Moreover, these correlations may depend on the beam parameters. When optimizing the beam from the Machine Learning and Artificial Intelligence perspective, the usual approach uses a model of the accelerator that relies on particle tracking codes. The twin model is then upgraded with hyper parameter tuning based on different diagnostics (beam, vacuum, RF, …). While this is a promising approach, it suffers from a high complexity and requires important computing resources. In this project, we propose a different yet complementary approach. It relies on utilities and sub-system level modelling, control and diagnostics. Two main sub-systems are considered: Cryogenics and Radio-Frequency. Cryogenics for superconducting accelerators has been, for some time now, mistakenly considered as a simple process utility. Yet this sub-system proved to be more complex than imagined with control parameters that heavily depend on the RF system control and, to a lower extent, on the beam configuration. In 2009, a joint R&D program between GANIL and CEA has led to the development of a thermodynamic model of the SPIRAL2 LINAC. The resulting model-based control allowed to optimize the cryogenic operation of SPIRAL2 while opening a new gateway into Machine Learning approaches for dynamic operation and intelligent fault detection through virtual sensors. However, RF and cryogenics are heavily interlaced and the models need to be completed with their RF counterpart.

The present PhD program is a continuity of the previous developments. It has two complementary phases. The first bridges previous thermodynamic models with RF modeling of the superconducting cavities. The second is the development of a fault detection framework matched to the use of classification learner algorithms such as decision trees, support vector machine (SVM), logistic regression and nearest neighbors. Offline physics-informed supervised learning is also considered for hyper parameter tuning with the use of GPU facilities at the CNRS calculation platform CCIN2P3 Lyon.

The benefits of the proposed developments are many. They span from increasing beam availability and accelerator reliability to cost saving thanks to predictive maintenance and monitoring slow performances deviations such as degradation of cavity quality factors.

Expected skills:
Applied physics, scientific computing, machine learning, radio-frequency, thermodynamics

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Master and PhD position in nuclear instrumentation

SHELA (Super Heavy Element LAser spectroscopy at GSI and GANIL)

GSI Helmholtz Centre for Heavy Ion Research in Germany, Darmstadt, and GANIL Grand Accélérateur National d'Ions Lourds in France, Caen, have a common interest in developing laser spectroscopic instrumentation to measure nuclear hyperfine interactions of actinide and trans-actinide isotopes.
Laser spectroscopy is a powerful and precise tool to measure atomic levels and their hyperfine structure, revealing atomic and chemical properties, in addition to information on the shape and the size of the atomic nuclei.
Elements above the actinide element fermium (100 protons), known as super-heavy elements, lack such information and therefore their atomic structure information relies on atomic theory calculations. Here, experimental investigations are needed to validate modern atomic theory calculations of such heavy and highly correlated atomic systems. In particular, for the element Lr (with 103 protons), the last member of the actinide series, the atomic ground state configuration has not yet been confirmed unambiguously by any experiment, calling for experimental investigation at the highest sensitivity.

The super heavy elements physics research section at GSI has a leading role in experiments of laser spectroscopy experiments of the heaviest elements. Here, the RADRIS (Radiation Detected Resonance Ionization Spectroscopy) technique [1], based on in gas cell laser spectroscopy, has been employed for several years in pioneering experiments on Fm-No isotopes. At GANIL, the S3 (Super Separator Spectrometer) Low Energy Branch, S3LEB, is currently under construction as part of the SPIRAL2 facility. In the near future, it will become a new-generation source of new and pure radioactive ion beams at low energy, in particular of super-heavy elements.
In these two complementary facilities, techniques for laser spectroscopy in a gas-jet, aiming at an improved spectral resolution [2], are under construction and show a large overlap in the required technical developments.

To strengthen the synergy of the two institutes in this topic, a PhD position - shared between GSI and GANIL - is proposed. The PhD candidate will contribute to the common developments, in particular on the production and characterization of a supersonic gas jet and on the optimization of the gas cell behavior at the super-heavy element spectrometer of GSI. He or she will also participate in experiments for the investigation of actinides and transactinide spectroscopy by resonance- ionization laser spectroscopy. Finally, he or she will participate to the commissioning of the S3LEB set-up at GANIL with emphasis for the heavier elements.
The position will be shared between Darmstadt and Caen.

[1] Nature 538, 19345 (2016)
[2] Nature Communications 8, 14520 (2017)

Expected skills:

Good knowledge in nuclear and atomic physics, photonics, ion optics, instrumentation, and computing is desirable

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Master Thesis Project " QARaML" : Machine-learning for radiotherapy quality assurance of clinical trials (cRTQA)

Background

Machine learning is identified as a major field where medical physicists should be involved and identify skills for their daily routine and research.
Many publications on ML based prediction of gamma passing rates to predict the deliverability of increasingly complex RT plans (see Wall and Fontenot 's 2020 publication) == > future aim of Dose-painting IMRT (increasing photon modulation complexity, Wall Fontenot 2020)
No yet investigated (at least not published) in RTQA for clinical trials == > valuable by 1 publication (rank B or A journal)

Aims

To develop machine learning approaches for automated clinical trial RTQA instead of manual error-prone and more subjective physician or physicist based cRTQA
Might be for Benchmark cases or clinical trial patient-cRTQA
Gradual risk (time, technical issues with data, knowledge programming) based approach to account limited time availability (February - June 2022)

Requirements

Python knowledge (note that your supervisor has experience in radiotherapy and some in medical physics but is a py learner (basic knowledge))
Basic knowledge in radiotherapy planning

Material and methods

- Database available: 700 head and neck cancer patients underwent postoperative RT + 700 undergoing definitive chemoRT
- Supervised modelling with annotated major deviations
- Format: DICOM RT format including images.dcm, RTSTRUCT.dcm, RTDose.dcm +/- RT plans for beam ballistics BUT **Dose volumes histograms** showing incremental percentage of volume receiving a given dose in Gy can be extracted == > to be used as the basis for ML RTQA

Contact

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Centre de Cancerologie François Baclesse. Caen, France
Laboratoire de physique Corpusculaire IN2P3/ENSICAEN/CNRS UMR 6534, Normandie Université, Caen France

Master Thesis Topics – University of Catania – INFN-Ct – INFN-LNS

Title; Gamma ray detection with CHIMERA 4π array

Abstract: The CHIRONE research group (CNS3-INFN) proposes to study the response function of the 4π array CHIMERA with its CsI(Tl) detectors, of the high energy gamma rays, including calibration methods using ion beams and cosmic rays. The work will be completed with the search of such gamma rays coming from neutral pion decay produced in central collisions, in various reactions performed during last years, using light and heavy ions as Al, Ca, Ni, Kr, Sn, Au at energies from 15 AMeV to 45 AMeV. The search will try to investigate the dependence from the N/Z, impact parameter and center of mass energy of the colliding system on the production of neutral pions.

Contact:

Prof. Francesca Rizzo rizzo@lns.infn.it, Dipartimento di Fisica e Astronomia di Catania

Dr. Giuseppe Cardella, cardella@ct.infn.it, INFN-Sez. di Catania

Dr.Nunzia Simona Martorana, martorana@lns.infn.it, INFN-LNS

Title: Dynamical processes in projectile break-up and Intermediate Mass Fragments production at 20 A.MeV beam incident energy studied with the CHIMERA and FARCOS devices at LNS-CATANIA

Abstract: The CHIRONE research group (CNS3-INFN) performed at LNS an experiment on Dynamical processes in projectile break-up and Intermediate Mass Fragments production at 20 A.MeV beam incident energy studied with the CHIMERA and FARCOS devices (CHIFAR). The group in the past measured the Intermediate Mass Fragments (IMF) production in the collisions of 124/112Sn + 64/58Ni and 124Xe + 64Zn at the bombarding energy of 35 A. MeV. Following a carefully method to study the IMFs emission mechanism, it has been observed a competition between dynamic and statistical emission with the former one being favored in neutron rich system. This studies are of fundament importance in order to explore the influence of the isospin in the reaction mechanism. The CHIFAR experiment aims is to extend such measurements toward lower energies where fragmentation scenario is partially overlapping with deep inelastic collisions. A new generation Correlation FARCOS array (Femtoscopy ARray for Correlation measurements and Spectroscopy) was used for the first time in its full configuration in CHIFAR experiment. This array consists in a configuration of 10 triple telescopes of silicon strip (300 and 1500 um) and CsI(Tl) crystals. Thanks to its high angular and energy resolution, it will be possible to study different correlations among light particles (femtoscopy) and light fragments.

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Title: Study of the ^{23}Na(p,γ)^{24}Mg reaction for astrophysical purposes

Abstract: The reaction ^{23}Na(p,γ)^{24}Mg reaction represents the turning point between the so-called NeNa and MgAl cycles. Its cross-section is affected by wide uncertainties (circa two orders of magnitude), and a complete understanding of its direct, non-resonant contribution could be of great help to better understand the ratio between the quantity of material that escapes the NeNa-cycle and the one that stays within it via the ^{23}Na(p,α)^{20}Ne one.

The student will carry out the calibration of the silicon detectors (both position sensitive and not) that are used to extract angular distributions of the ^{23}Na(^{3}He,^{3}He)^{24}Mg and ^{23}Na(^{3}He,d)^{24}Mg reactions, necessary to study the ^{23}Na(p,γ)^{24}Mg via the Asymptotic Normalization Coefficients (ANC) method. The project will allow learning the basics of a typical nuclear physics experiment and the methodologies used in a standard ANC one, along with the ones regarding data analysis. This will require data analysis programs (like ROOT) and simulations (like LISE++) to identify the reaction channel of interest and the excited states involved.

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Title: The ^{19}F(p,α_π)^{16}O direct measurement at energies of astrophysical relevance using the ELISSA+LHASA detection arrays

Abstract: Fluorine abundance is used as probe for Asymptotic Giant Branch (AGB) models and nucleosynthesis and it is one of the most important input parameters for the analysis of s-process in AGB star conditions because its nucleosynthesis takes place in the hydrogen-helium intershell region of AGB stars, together with s-elements production. At present, theoretical models overproduce fluorine abundances in AGB stars with respect to the observed values, thus calling for further investigation of the nuclear reaction rates involved in the production and destruction of fluorine.

Despite its importance, the S-factors and the branching ratio between the α_0, α_π and α_γ outgoing channels in the ^{19}F(p,α)^{16}O reaction are still largely uncertain at astrophysical energies, emphasizing the need for better measurements. In order to reduce those uncertainties, a direct experiment devoted to the measurement of the α0 channel was performed at INFN - LNS using a silicon strip detector array (LHASA - Large High-resolution Array of Silicon for Astrophysics) showing promising preliminary results. Moreover, a new direct measurement to collect α_0 and α_π data for a more accurate determination of the resonance parameters is already approved by the PAC of the IFIN-HH laboratory (Bucharest, Romania). In this case, the experimental setup will consist of LHASA together with the Extreme Light Infrastructure Silicon Strip Array (ELISSA), that is a charged particle detection array that was developed by Extreme Light Infrastructure - Nuclear Physics (ELI-NP) in INFN-LNS.

The student will be involved in the final part of the analysis of the previous experiment and in the preparation of the new one starting from the detector test and simulation analysis. The IFIN-HH experiment will be scheduled in spring-summer 2022 giving to the student the possibility to participate and carry out the calibration of the silicon arrays.

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Title: MSc Theses available at the interface between particle and nuclear astrophysics.

Abstract: The aim of these Theses will be on the experimental determination of cross sections of key nuclear processes involved in Supernova nucleosynthesis with a particular emphasis on neutron induced reactions on short lived radioactive isotopes. Also, the role of neutrinos in these astrophysical environments could be investigated.

Contact: S Cherubini (UniCT & INFN-LNS) cherubini@lns.infn.it

Titles:

- **Modeling direct reactions between heavy ions**
- **Description of fluid dynamics with transport theories**
- **Theoretical description of dissipative Heavy Ion Collisions and impact on the modeling of neutron stars**

Abstract: Heavy ion reactions at low/Fermi energies are modeled with quantum scattering theory or semi-classical approaches. We propose to investigate reaction mechanisms of current experimental interest, ranging from direct charge-exchange to more dissipative collisions, allowing to explore the nuclear matter Equation of State.
Within such a common framework, we propose the above three subjects.

Contact: Maria Colonna (INFN-LNS) colonna@lns.infn.it

Title: Machine learning aided identification of rare resonances in pp and Pb-Pb collisions at the LHC energies with the ALICE detector

Abstract: The high luminosity reached at the Large Hadron Collider and the unique characteristics of ALICE detector for tracking and Particle Identification allow to investigate about rare and new resonances. Identification of these particles is a challenge due to the large particle multiplicity. Machine learning algorithms will be deployed to aid in the identification of new excited states, in particular of the Ω baryon. The student will use different machine learning algorithms on simulated and on real ALICE data. The student will conduct the data analysis activity as part of the ALICE experiment.

Contact: Angela Badalà (INFN-CT) angela.badala@ct.infn.i; Marco Fargetta (INFN-CT) marco.fargetta@ct.infn.it; Paola La Rocca (UniCT & INFN-CT) paola.larocca@dfa.unict.it

Title: Characterization of the response of a liquid argon double-phase TPC within the ReD project

Abstract: Time projection chambers (TPC) based on liquified noble gases, as Argon and Xenon, are being employed in a number of world-leading projects searching for Dark Matter in the form of WIMPs. In particular, the DarkSide-20k project will use a double-phase TPC filled with liquid argon (LAr). The WIMP interactions with the TPC are expected to generate Ar40 nuclear recoils, having kinetic energy below a few tens of keV. The ReD project aims to characterize the response of the LAr TPC to nuclear recoils, that can be produced by neutrons. After the measurement taken at INFN, Laboratori Nazionali del Sud in February 2020, the main scientific goal is to explore the response of the TPC to nuclear recoils of very low energy (below a few keV of kinetic energy).

ReD consists in the irradiation of a miniaturized LAr TPC with neutrons at the INFN, Sezione di Catania. Neutrons of suitable energy (a few MeV) are produced by a Cf252 fission source, which is hosted in a dedicated shielding with a collimator. Fission events can be identified by means of BaF2 detectors deployed close to the source, thus providing an event-by-event neutron tagging. Neutrons scattered from the TPC are detected by using an array of 18 1-inch plastic scintillators. Since the experiment is targeted to the reponse to very low-energy nuclear recoils, it is expected that the primary scintillation signal from the TPC cannot be detected and that the study will be focused to the delayed ionisation signal. Furthermore, the ReD TPC uses all the innovative features of the DarkSide-20k design (in particular the optoelectronic readout based on Silicon PhotoMultipliers and cryogenic electronics), so it can provide an early and crucial benchmark in real-life experimental conditions.The integration of detectors will be performed before the end of 2021. The program of physics measurement, which includes the irradiation with Cf252 and a number of ancillary calibrations and studies, will start in early 2022.

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MSc Thesis available in the framework of the SBN and DUNE collaborations.

Abstract: The international Short-Baseline Neutrino Program at Fermilab will measure properties of neutrinos, specifically how the flavor of a neutrino changes as it moves through space and matter. The program emerged from a joint proposal, submitted by three scientific collaborations, to use particle detectors to perform sensitive searches for νe appearance and νμ disappearance in the Booster Neutrino Beam. All of the detectors are types of liquid-argon time projection chambers, and each contributes to the development of this particle detection technology for the long-baseline Deep Underground Neutrino Experiment (DUNE). DUNE will pursue three major science goals: find out whether neutrinos could be the reason the universe is made of matter; look for subatomic phenomena that could help realize Einstein’s dream of the unification of forces; and watch for neutrinos emerging from an exploding star, perhaps witnessing the birth of a neutron star or a black hole.

Various MSc Thesis are available with focus on

- Track reconstruction and data analysis in the SBN Far Detector ICARUS
- Characterization of the SAND detector in the DUNE Near Detector Complex

Contact: Piera Sapienza (INFN-LNS) sapienza@lns.infn.it; Giacomo Cuttone (INFN-LNS) cuttone@lns.infn.it

MSc Thesis available in the framework of the KM3Net collaboration.

Abstract: KM3NeT is a research infrastructure housing the next generation neutrino telescopes. Once completed, the telescopes will have detector volumes between megaton and several cubic kilometers of clear sea water. Located in the deepest seas of the Mediterranean, KM3NeT will open a new window on our Universe, but also contribute to the research of the properties of the elusive neutrino particles. With the ARCA telescope, KM3NeT scientists will search for neutrinos from distant astrophysical sources such as supernovae, gamma ray busters or colliding stars. The ORCA telescope is the instrument for KM3NeT scientists studying neutrino properties exploiting neutrinos generated in the Earth's atmosphere. Arrays of

thousands of optical sensors will detect the faint light in the deep sea from charged particles originating from collisions of the neutrinos and the Earth. The facility will also house instrumentation for Earth and Sea sciences for long-term and on-line monitoring of the deep-sea environment and the sea bottom at depth of several kilometers.

Various MSc Thesis are available with focus on

- Estimate of systematic uncertainties in the ARCA data
- Study of the data quality and stability of ARCA data.
- Effect of environmental parameters on the ARCA neutrino telescope performances
- ARCA data analysis
- Calibration of the detection Units of ARCA
- Acoustic positioning in ARCA
- Parameterizations and measurements of atmospheric neutrino fluxes in KM3NeT
- Study of characteristics of PMTs and their implications on the response of KM3NeT detectors

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Title: PET RADIOMICS STUDIES (IBFM-CNR Cefalù)

Abstract:
Positron Emission Tomography (PET) imaging is increasingly utilized for treatment evaluation purpose in oncological patients. Radiomic analysis of uptake distribution inside the tumor in PET images may be helpful for a more personalized patient care of cancer. Nevertheless, many technical and clinical challenges still need to be addressed in radiomic studies.
The extracted radiomic features are grouped into first-order, second-order, and higher-order features. First-order features derive from the histogram of PET voxel intensities. Second-order textural features provide information about the regional spatial arrangement of the voxels such as their homogeneity, and contrast simulating the human perception of tumors in PET images. Higher-order features provide information on local collinear voxels with the same grey level. A total of 106 imaging features can be calculated for each tumor, considering additional 49 standardized uptake value (SUV) statistic indices.
The aim of this thesis is to collect radiomic features through a standardized procedure and analyze them in order to improve treatment response prediction and prognostication, and potentially allowing personalization of cancer treatment.
The IBFM-CNR has massive experience in the development of quantification tool in Nuclear Medicine environment. The group exhibits a long-standing collaboration with the LNS-INFN, Cannizzaro Hospital in Catania and Fondazione G. Giglio in Cefalù (PA). The student will take care of the analysis of PET images in order to extract new functional parameters both in oncological patient and pre-clinical PET studies. The obtained results will be relevant from the point of view of the demands of everyday clinical activity in order to support healthcare operators in cancer treatment decision making.

<u>Possibility of joint project with other clinical PET institutes</u>

Contact: Giorgio Russo (giorgio-russo@cnr.it) ; Alessandro Stefano, CNR Researcher (alessandro.stefano@ibfm.cnr.it)

Title: RADIOPROTECTION STUDIES AT LNS-INFN USING A MONTE CARLO APPROACH (LNS-INFN Catania)

Abstract:
The characterization of environmental radiation fields around the particle accelerators, in terms of dosimetric and spectrometric quantity, is essential for the protection of workers and population.
At LNS the K800 Superconducting Cyclotron (SC) is a three sector compact machine with a wide operating range, being able to accelerate heavy ions with values of q/A ranging from 0.1 to 0.5 to an energy from 2 to 100 MeV/u. The SC was designed as an accelerator to perform nuclear physics experiments, which requires low intensity beams.
In the last years, new experimental demand require an upgrade of SC, in order to make extraction by stripping possible in the SC to achieve high intensity for a set of beams of interest. The new requests of high power light beams propose to accelerate ions to energies between 15 and 70 MeV/u, producing an high flow of neutrons when the beams interact with beam-line. In order to ensure compliance with the dose limits and the general principles of radiation protection (ALARA), it is necessary an evaluation of the neutron ambient dose equivalent H*(10), as well as the flow of neutrons and their energy spectra, resulting from high intensity ion beams extraction by stripping. Moreover, a shielding upgrade will be realized in order to reduce the doses. This study will be performed with the use of FLUKA simulation code[1]. The simulations will also allow to estimate the materials and air activation.

Reference

[1] http://www.fluka.org/fluka.php

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Title: Challenges and solutions for beam monitoring and dosimetry of ultra-high dose rates beams.

Abstract: The main goal of radiation therapy is to kill cancerous cells while minimizing radiation damage to the adjacent healthy tissues. Preclinical studies have shown that the use of ultra-high dose rate (UHDR) beams may substantially improve normal tissue sparing (so-called FLASH effect) while maintaining high tumour control probability (TCP) compared to conventional dose-rate radiotherapy. The FLASH effect is not fully understood and a series of hypotheses based on fundamentals of radiophysics and radiochemistry has been proposed in the literature. Various platforms for FLASH radiotherapy have been demonstrated using electrons generated by linear accelerators, x-rays generated in a synchrotron facility, and protons using isochronous cyclotrons and a synchrocyclotrons. FLASH radiotherapy is characterized by average dose rates of dozens/hundreds of Gy/s instead of only a few Gy/min of conventional radiotherapy. To support a reliable clinical translation of FLASH RT, the challenges related to accurate dosimetry and real-time beam monitoring of UHDR beams must be properly addressed. The thesis will focus on the development and characterization of novel approaches for monitoring and dosimetry of UHDR particle beams for FLASH radiotherapy. The student will closely work with Researchers of the INFN - Catania Division and will receive training in detector modelling and radiation dosimetry. The student will be actively involved in the development and characterization of novel technologies, participating in experimental campaigns at national and international laboratories and having the opportunity to join a stimulating international research environment.

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Luca Lanzanò (UNICT) (luca.lanzano@dfa.unict.it)

Title: Microdosimetry for clinical hadron beams.

Abstract: Microdosimetry is the only experimental method to assess the biological effectiveness of different type radiations. Despite being formalized in the 1950, there is still not a coherent and standardized approach for microdosimetric measurements and the clinical use of its parameters (although it is used for radiation protection). New technology (mini-Tissue Equivalent Proportional Chambers, silicon and diamond detectors) can now offer methods for microdosimetric characterization of clinically relevant beams. Biological effectiveness of radiotherapy is related to the spatial distribution of the ionisations at the scale of the particle tracks and sub-cellular structures. Microdosimetry aims at establishing measurable characteristics of the particle track structure at the and micro-meter scale that can be translated into radiation quality factors. A correlation between measured microdosimetric quantities and radiobiological data has been suggested, but further work is needed. The thesis will focus on the characterization and cross-comparison among different experimental microdosimetric approaches. The student will be actively involved in the experimental activity carried out at national and international laboratories. Monte Carlo simulation codes will be also used for a detailed study of the radiation´s spatial pattern of energy deposition for the simulation of the detectors, as well as for the development of radiobiological models.

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Luca Lanzanò (UNICT) (luca.lanzano@dfa.unict.it)

Title: Microwave/mm-wave interferopolarimetry for magneto-plasmas of ECR Ion Source

Abstract: Interfero-polarimetric setup - able to measure the phase shift and the magnetoplasma-induced Faraday rotation in compact size plasma trap - has been proven to provide reliable measurements of the plasma density [G. Torrisi *et al* 2017 *JINST* **12** C10003].

This thesis work will develop an analysis method for polarimetric measurements on a mm-wave testbench on purpose developed for the PANDORA chamber case study [Mascali *et al.* PANDORA, a new facility for interdisciplinary in-plasma physics. *Eur. Phys. J. A* **53,** 145 (2017). https://doi.org/10.1140/epja/i2017-12335-1]

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Title: Photonics crystals for ultracompact dielectric accelerators

Abstract: Laser acceleration of electrons with silicon dielectric structures was demonstrated in with accelerating gradients of more than 200 MeV/m. Many of the proposed configurations have an intrinsically limited interaction length, because they require a plane wave that impinges laterally throughout the whole structure's length. In order to have both high laser-induced accelerating gradients and adequate interaction length, this thesis work will focus on the EM design and beam dynamics study of hollow-core waveguides, based on photonic crystals, employed as accelerating structures (with possibly co-linear propagation of the accelerating electromagnetic field and the particle bunch to be accelerated).

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Title: Microwave Inverse profilometry for magneto-plasmas of ECR ion source and/or fusion reactors devices

Abstract: In this thesis a new profilometry diagnostic method is investigated to measure the plasma electron density profile in front of the Ion Cyclotron Range of Frequencies (ICRF) antennas. Specifically, the profilometry needs to solve an inverse scattering problem, which is non-linear and ill-posed. Recently papers plasma imaging profilometry has been applied in compact plasma reactors, such as the electron cyclotron ion sources (ECRIS), by means of electromagnetic inverse scattering techniques requiring only measurements of the reflection coefficient. In this thesis, we would like to extend this method also to large-size (scale-length) fusion reactors by addressing the profilometry of a fusion plasma

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Title: ***Study of magneto-plasma opacity in laboratory***

Abstract: Opacity is a key ingredient in many relevant astrophysical scenarios, which impact on the energy transport and spectroscopic observations is still debated. Stellar plasma opacity contributes to the energy transport in stars, by radiative diffusion and regulating the convective transport. Moreover, molecular opacity is a hot topic in the study of both exoplanets' composition and accretion disk dynamics. Furthermore, electromagnetic transient signal emitted from neutron-star mergers (kilonova - KN) is of interest in the multi-messenger astronomy frame because of delivered information on the expelled plasma ejecta's composition (r-process nucleosynthesis), however its interpretation strongly depends on the system opacity. The activity proposed in this thesis concerns the experimental investigation of in-laboratory magneto-plasma opacities, for metallic species abundant in a specific time-stage of KN diffusion, at plasma electron density and temperatures resembling the ejecta plasma conditions [1]. In this context, the on-construction facility PANDORA, and the working Flexible Plasma Trap (FPT), both at the INFN – LNS (Catania, Italy) suite for the purpose. Complementary experimental techniques and methods will be employed in studying plasmas magnetically confined in compact plasma traps, to address atomic uncertainties on the KN problem, as well as to further extend knowledge on the stellar opacity problem for the Astrophysics and Nuclear Astrophysics interests.

[1] Pidatella, A., *et al.*, IL NUOVO CIMENTO 44 C (2021) 65.

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Title: Studying spatial distribution of ion properties in ECR plasmas with self- consistent numerical codes for the PANDORA project

Abstract: Calculating the charge state distribution (CSD) and level population of ions as a function of their position in an ECR plasma is integral for understanding the nature of the extracted beam, as well as for estimating beta-decay rates of radioisotopes diffused into such systems [1,2]. To this effect, the thesis will be concerned with evaluating the 3D distribution of ion properties in ECR plasmas using self-consistent numerical codes connecting warm electron 3D space-resolved evolution in time with ion dynamics through collisional ionisation, charge exchange and particle transport models.

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[2] K. Takahashi and K. Yokoi, Nuclear Β-Decays of Highly Ionised Heavy Atoms in Stellar Interiors, Nucl. Phys. A 404, 3 (1983)

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Title: Space-resolved X-ray spectroscopy and imaging of ECR plasmas using quasi-optical methods

Abstract: Soft X-ray spectroscopy is a powerful passive diagnostic technique to characterize warm electrons in ECR plasmas whose properties govern the sequential ionisation processes. Using special optical setups like pinholes coupled with CCD cameras, the technique can be extended to investigate spatial structure of the plasma and confinement dynamics, performing X-ray imaging and space-resolved spectroscopy. The thesis will be focused on an elaborate post-processing of data acquired during experiments at ATOMKI in 2018 for various plasma configurations. The work will involve sequential application of a set of algorithms developed indigenously at INFN-LNS, and in collaboration with the ATOMKI laboratories (Debrecen, Hungary) to generate 2D space-resolved maps of X-ray fluorescence, followed by interpretation of the results [1]. Tool and analysis techniques will be very useful for the future experimental measurements at INFN-LNS and at ATOMKI, in the framework of the PANDORA Gr3 project, for plasma volume on-line evaluation and for plasma parameters monitoring.

[1] E. Naselli et al, High-resolution X-ray imaging as a powerful diagnostics tool to investigate in-plasma nuclear beta-decays, Il Nuovo Cimento 44 C, 64 (2021).

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Title: Improving gamma detection by isolating signal from background - a machine learning approach

Abstract: In-plasma measurement of beta-decay rate is based on tagging the secondary gamma released by the excited daughter nucleus. The gamma photon emitted from radioisotopes considered lies in the keV range which overlaps with high energy bremsstrahlung from the plasma. In order to separate the gamma peak from the self-emission background with n-sigma level certainty, the plasma needs to be kept stable for days or weeks [1]. This thesis will be a feasibility study to assess whether the measurement time can be reduced by using machine learning and deep neural networks as peak finding algorithms [2].

[1] D. Mascali et al, The PANDORA project: an experimental setup for measuring in-plasma beta-decays of astrophysical interest, EPJ Web of Conferences 227, 01013 (2020).

[2] S. Wu et al, Peak-searching method for low-count rate gamma spectrum under short-time measurement based on a generative adversarial network, Nuclear Inst. And Methods in Physics Research A 1002, 165252 (2021).

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Title: Radioactive Disequilibria in Volcanic Plumes

Abstract: Study of ^{210}Pb-^{210}Bi-^{210}Po radioactive disequilibria in gaseous emanations from Mount Etna volcano (Sicily, Italy) and correlation with a new degassing model, which accounts for ^{222}Rn enrichment in volcanic gases and its subsequent decay into ^{210}Pb within gas bubbles emitted towards the surface.
The student will be involved in gamma spectrometry measurements of Etna ashes, in the analysis and interpretation of the results. The activity will be performed in collaboration with the Italian Institute of Geophysics and Volcanology (INGV) and with the Laboratoire de Physique de Clermont (France).

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Title: Transport solutions for the INFN-LNS laser-driven acceleration facility

** This is a thesis work envisaging experimental measurements campaigns at International laboratories

Abstract: Plasma-based accelerators use the strong electromagnetic fields that can be supported by plasmas to accelerate charged particles to high energies. Accelerating field structures in plasma can be generated by powerful laser pulses or charged particle beams.

At INFN-LNS a new high-power short-pulse laser system will be installed in the next years. It will be part of a new facility (I-LUCE: INFN Laser induced particle acceleration) where the laser will be dedicated to particles (electrons and ions) acceleration.

Accelerated particle must be then transported in vacuum and air up to the irradiation point where irradiations will be performed.

The work here proposed is related to the study and implementation of new transport solutions of laser accelerated particles. The developed solutions will be then implemented in the new facility that is in construction at INFN-LNS.

Contact: GA Pablo Cirrone (INFN-LNS, UNICT), pablo.cirrone@lns.infn.it

Title: Dosimetric approaches and detector developments for "Flash radiotherapy"

** This is a thesis work envisaging experimental measurements campaigns at International laboratories

Abstract: In the last decades, ion acceleration from laser-plasma interaction has become a popular topic for multidisciplinary applications and opened new scenarios in the protontherapy framework, representing a possible future alternative to classic acceleration schema. The high-intensity dose rate regime that can be obtained with this approach is also strongly attracting the radiation oncologist community thanks to the evident reduction of the normal tissue complication probability, this new radiotherapy technique was called “flash radiotherapy”. One of the many challenges to bring laser acceleration to a clinical setting consists in the development techniques and technologies that allow for accurate dosimetry of a short and intense ion bunch length.
In comparison with conventional accelerators, dosimetry of laser-accelerated beams is an ambitious task. Conventional accelerators typically operate at quasi-continuous milliampere currents rather than proton bunches with a temporal structure of the order of nanoseconds. Several international collaborations and

experiments have been launched in the last years aiming at exploring the feasibility of using laser-driven sources for potential medical applications. A collaboration between the LNS-INFN, ELI-Beamlines (Czech Republic) and Queen's University (Ireland) was recently established to develop and investigate new devices for diagnostic and dosimetric purposes for laser-driven ion beams.

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Title: ELIMED project
First dosimetric and radiobiological measured with laser-accelerated ion beams at ELI-beamlines (Prague, CZ)

Abstract: INFN-LNS realized the first Users'-open beamline (called ELIMED) completely dedicated to the transport of proton/ion beams generated in the laser-matter interaction. The ELIMED beamline is now installed at the ELI-Beamlines facility (Prague, CZ) and first experiments with this new accelerated beams will start within the end of 2019.
INFN-LNS also developed and realized the dosimetric system of the beamline and will be responsible for the first cell irradiations that will be carried out within 2020.
The thesis work will be focused on the characterization of the developed dosimetric devices (ionization chambers, Faraday cup, Gafchromic films, ...) and on the preparation of the first experimental runs at the ELI-Beamline facility.
Travels to ELI-Beamlines will be expected.

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Title: Modelling parameters of interest in radiobiology (LET, RBE) using a Monte Carlo approach at both macro and micro-dosimetric scale.

Abstract: A reliable prediction of the spatial Linear Energy Transfer (LET) distribution in biological tissue is a crucial point for the estimation of the radiobiological parameters on which are based the current treatment planning. Nowadays, the accuracy and approach for the LET calculation can significantly affect the reliability of the calculated Relative Biological Effectiveness (RBE).
Monte Carlo (MC) technique is considered the most accurate method to account for complex radiation transport effects and energy losses in a medium. However, as a computation method, the accuracy and precision of the MC calculation result strongly depend on the physics interaction cross sections applied as well as the simulation algorithms used and the transport parameters are chosen. In this framework, the goal of the project consists of the development, study and validation of a completely new open-source tool based on Geant4 code for the calculation of the LET-track, LET-dose and RBE distributions of therapeutic proton and ion beam completely independent of transport parameters.

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Title: Investigation of new irradiation and imaging approaches to enhance the radiobiological effectiveness of proton beams using nuclear reactions. Experimental and simulation activities

Abstract: A charged particle inverted dose-depth profile represents the physical pillar of protontherapy. Reduced integral dose to healthy tissues entails lessened risk of adverse effects. On the other hand, there is no obvious radiobiological advantage in the use of protons since their LET in the clinical energy range (a few keV/micron) is too low to achieve a cell-killing effect significantly greater than in conventional radiotherapy. Thus, enhancing proton RBE is desirable. To this end, the INFN-funded NEPTUNE (Nuclear process-driven Enhancement of Proton Therapy UNravEled) project will exploit the possibility to use the p + 11B → 3α reaction to generate high-LET alpha particles with a clinical proton beam. The p-11B reaction will be studied in all their relevant aspects: from modeling (using analytical and Monte Carlo approaches) to microdosimetry and radiobiology.

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Title: Detectors development for 2D dosimetry of conventional and laser-accelerated ion beams

Abstract: Hadrontherapy currently represents the most advanced form of external radiation modality in tumor treatments, thanks to the increased selectivity of charged particles in terms of dose released and biological effectiveness compared to photons. It makes use of high energetic proton/ion beams accelerated by cyclotrons or synchrotrons, while, in the last years, many efforts have been addressed to validate the clinical feasibility of laser-driven beams.

We propose the development of a device for 2D relative dosimetry of both conventional and laser-accelerated ion beams based on innovative optical and geometrical solutions. The system will allow the on-lime determination of all clinical-relevant beam quality parameters and will be characterized by extremely high efficiency and spatial resolution. The validation of the system will be carried out with both conventional and laser-accelerated proton beams at the TIFPA-INFN (Trento, Italy) and ELIMED (Prague, Czech Republic) beamlines, through an inter-comparison with other routinely-used devices for QA tests.

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Title: New transport solution for eye-protontherapy beamlines

Abstract: Nowadays, the use of particle beams in clinical radiotherapy is applied in an increasing number of particle therapy centers worldwide [1]. In particular, hadrontherapy, based on the use of protons and ions for cancer treatment, shows many physical and biological advantages with respect to the conventional radiotherapy with X- and gamma rays, such as the higher ballistic precision in the radiation release which allows maximizing the damage to the cancer volume while sparing the surrounding healthy tissues [2]. Recently, a collaboration between the INFN-LNS and the BEST Cyclotron company has been established for the development and the commercialization of a new protontherapy beamline for the eye treatment with the 70 MeV protons accelerated from a BEST Cyclotron. The beamline component will be designed by the LNS-INFN also providing a complete Monte Carlo Geant4 simulation of the beam transport. The Monte Carlo simulation will serve to choose the beam line element characteristics in terms of material, thickness and shape in order to respect the clinical tolerances of the beam parameters for protontherapy. New solutions are currently under investigation for making the beamline as compact and automatic as possible as for instance for what concern the modulation and the degradation section of the beam line. Moreover, in order

to open to the possibility to use the beam line with high-dose rate proton beams (>40 Gy/s in the so-called flash regime [3]) the implementation of an innovative ionization monitor chamber for the relative dosimetry along the beam line which would allow correcting for the ion recombination effect due to the high-dose rate, is currently under discussion.

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[3] Vozenin M-C, Hendry JH, Limoli CL. Biological Benefits of Ultra-high Dose Rate FLASH Radiotherapy: Sleeping Beauty Awoken. Clin. Oncol. (Royal Coll. Radiol. (Great Britain)) 2019;31:407–415. doi: 10.1016/j.clon.2019.04.001.

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Title: INVESTIGATION OF THE ANEUTRONIC PROTON-BORON FUSION REACTION IN PLASMA FOR ENERGETIC STUDIES

Abstract: The interaction of protons with 11B atoms triggers the following aneutronic fusion reaction:

11B + p → 3α + 8.7 MeV

In such reaction, the final product is the generation of three energetic α-particles having a large energy spectrum strongly peaked around 4 MeV. In particular a main resonance occurs at 675 keV proton energy in the lab frame, with a maximum cross section of 1.2 barn [1].

The absence of produced neutrons makes the pB fusion reaction particularly appealing involving the possibility to build an ultraclean nuclear-fusion reactor where no activation of the material and no radioactive wastes are expected [2]. Recently, the pB fusion reaction has become an interesting topic also for applications in the space domain as well as for the medical physics with the possibility to use the alpha particles generated by the reaction to improve the biological efficiency of protontherapy [3].

In this context, a huge effort of the researchers has been addressed on the possibility to induce the pB fusion reaction in plasma using the high power-laser matter interaction. The extremely high flux (up to 1012 p/s) typical of laser-accelerated proton beams [4], is indeed a great advantage allowing to enhance the reaction rate and the alpha particle production yield, which might be interesting also for the applications previously mentioned. Moreover, the theoretical as well as the experimental investigation of the energy and angular distribution of the reaction products, i.e. alpha particles, are particularly interesting for the study of the fusion reaction in plasma induced by high power lasers. Many experiments have been carried out so far demonstrating the increase of the alpha particle production (up to1011) in the laser-induced pB reaction in comparison with the classical scheme [5,6]. The activity here proposed, regards the experimental study of the pB fusion reaction in plasma and of the alpha particles yield, angular and energy spectrum using innovative detectors through the systematic variation of the following fundamental parameters: laser energy and pulse duration, contrast, target thickness, target material and structure. A particular effort will be addressed to develop new solutions for the on-line and simultaneous diagnostics of protons and alpha particles. A part of the experimental as well as theoretical (through Monte Carlo simulations) activity could

also be dedicated to the study the possible modification on the stopping power values of protons and ions when traversing extremely high-density and hot plasma.

References

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Title: Dosimetric characterization of an x-ray system for in-vivo irradiations

Abstract: In-vivo irradiation systems can facilitate scientific testing of biomedical hypotheses in a lar-ge variety of tumor models and normal tissues with the ultimate aim of both promoting research and providing novel protocols for human cancer treatments. At the LNS-INFN an x-ray-based and high-voltage system, able to deliver an homogeneous and shaped photon beam, was developed in or-der to perform both 2D imaging and small animal irradiations.

We propose the complete characterization of the x-ray tube in terms of linearity, output stabili-ty and repeatability, together with the final commissioning of the whole system. Specific procedures both for the absolute and the relative dosimetry will be developed and validate as well, in according to the most recent and worldwide accepted protocols. A customized software will be developed within the NI LabView environment for enabling the computer-controlled image acquisition and dose delivering. The validation of the system will be carried out through several in-vitro and in-vivo studies.

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Master thesis proposals in Padova and LNL for 2022

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1. *Title:* Simulation of neutron inspection techniques based on the laser plasma neutron beam and first experiments with a Cf source.

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Abstract

Elemental characterization tests and simulation by fast neutron transmission spectroscopy in view of material identification (e.g.explosives, illicit drugs, contraband…). The feasibility of these techniques and their applicability to cargo containers will mainly be studied by numerical Monte Carlo simulations with the MCNP computer code and experimental tests in Legnaro facility.

(Part of H2020 EUROPEAN project MULTISCAN3D. Aim of the project: Non-intrusive inspection (NII) techniques for cargo currently heavily rely on high energy planar imaging. For cargo purposes, additional techniques have been considered and tested, some using X-rays (backscatter, transmission, tomography), others using alternative radiation or other methods (vapor detection, neutron interrogation, photofission). MULTISCAN 3D aims at developing the technological components of static (without a rotating gantry) high energy computed tomography system for cargo, capable of providing accurate 3D imaging. this project will investigate the capability of these laser-plasma technologies to produce several other types of radiations)

2. *Title:* Study for a toolbox probes for UGV platform in D&D operations.

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Abstract

Develop a toolbox of probes addressing both the gamma spectroscopy and the gamma/neutron detection and source identification equipping the UGV platform in D&D operations. The systems will be prepared and tested extensively in laboratory, before with point-like laboratory sources and in laboratories
with gamma
(Part of the H2020 EUROPEAN project Cleandem: CLEANDEM plans to significantly improve Decommissioning and Dismantling (D&D) operations by introducing some technological breakthrough and offering the possibility to deploy new methodologies.
The CLEANDEM Key features are: continuous and online dose rate monitoring, measurement of low-level alpha/beta contamination, gamma-ray spectrometry and neutron, measurements using single detectors, remote localization of hot spots using miniaturized gamma-ray imagers, air contamination monitoring.)

3. ***Title:*** Detector and readout studies (experimental tests and simulation) for neutron and gamma detection.

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Abstract
In this work different scintillation detectors with different readout configurations will be tested and compared. The scintillation detector will be new composite materials based on silicon matrixes with different dopants for neutron detection, and commercial ones, like CLLB NaIL. The readout will be low power digitizer and SIPM to be compare to standard readout with PMT and laboratory digitizer. This work is part of a research program aimed to define new detector setup for homeland security, environmental monitor, D&D operation ecc.

4. ***Title:*** Study of the communication system for a UAV system in the environmental radioactive monitoring

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Abstract
The DRAGON project funded by INFN, involves the design and development of a radioactivity monitoring system (gamma and neutrons) on a drone. The thesis proposal concerns the study of communication protocols between the UAV and the detection system.
The thesis work will be devoted to the software analysis (algorithm, graphical interface, results) for the specific tasks the UAV, i.e. environmental monitor. So, gamma spectra analysis, neutron and gamma identification, threshold identification will be part of the work.

5. ***Title:*** Low-energy heavy-ion fusion. Upgrade of the PISOLO setup with coincidences between evaporation residues and charged particles

Thesis type: Experimental, Branch: Nuclear Physics

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Abstract
In the field of nuclear physics, measurements of fusion cross sections far below the barrier are of deep interest to understand fusion dynamics and the structure of interacting nuclei. When medium-mass and light systems are considered, the interest goes beyond nuclear physics, and the astrophysical implications of the process come into play.
The PISOLO electrostatic deflector, installed at Legnaro National Laboratories, presently allows to measure cross sections down to 0.5-1 μb through the detection of fusion-evaporation residues. The sensitivity of the setup could be increased detecting the light charged particles evaporated by the compound nucleus in coincidence with the fusion-evaporation residues. Indeed, the coincidence may allow to significantly suppress the background of beam-like particles that cannot be rejected by the electrostatic deflector.
In order to verify the effectiveness of the coincidence technique, a test experiment will be performed at the Tandem accelerator of Legnaro National Laboratories. For the experiment, light particles will be detected by an array of Silicon detectors installed around the target.
The amplified sensitivity could allow us to reach unexplored energy regions and give decisive information in reaction systems where the low-energy trend of the fusion cross section is still unclear.
The student will take part in the setup preparation, data taking (depending on the Tandem beam time schedule), and data analysis.

6. ***Title:*** MACS measurements with neutron activation method

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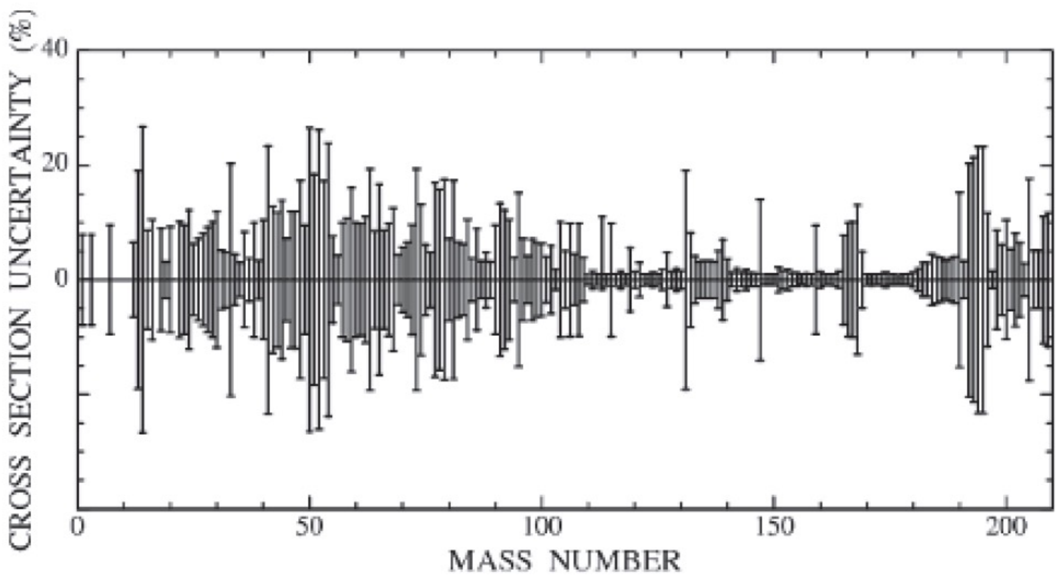
Abstract

All elements of mass greater than iron are produced in stellar nucleosynthesis, both through the s (slow) process and the r (rapid) process. In particular, the elements of the stability valley and those adjacent to it are produced trough s- process by neutron capture and subsequent decay.
In order to try to reproduce the observed abundance of elements in the universe, stellar models have to calculate the nuclear reaction rates that occur in stars and therefore need to have the precise measurement of the neutron capture cross section and beta decay lifetime. At LNL, we have a pulsed neutron beam line for Time of Fligth measurements and devised a method to produce a neutron spectrum very similar to the stellar one. Thanks to the availability of the spectrum, the measurement of the cross section can be made by irradiating the target with the neutron stellar-like spectrum, so measuring directly the cross section integrated over the stellar neutron spectrum (the us the so called MACS, Maxwellian Averaged Cross Section). This is the only ingredient necessary for calculating reaction rates in stars, a fundamental input of the stellar evolution model.
The thesis topic can be either the measurement of the stellar like neutron spectrum at different temperature (kT) experienced by then star during its like (8<kT<100 keV) or the measurement of a MACS of particular relevance, as it is not measured or measured with too high uncertainty.
The figure below shows the elements for which the MACS has been measured and the related uncertainty. Since an accuracy of no more than 3% is required for the elements of s-process , it can be seen that the measurements that need to be made are really a lot.



7. ***Title****:* beta-delayed gamma-ray spectroscopy of 101Cd

Thesis type: Experimental, Branch: Nuclear Physics

Supervisor: Gungxin Zhang (guangxin.zhang@pd.infn.it), Daniele Mengoni (daniele.mengoni@unipd.it)
University of Padova, INFN-Padova and INFN-LNL.

Abstract:
101In is produced via in-flight fission of 124Xe beam on Be target, and indented by FRS spectrometer in GSI. The structure of 101Cd can be studied by collecting the gamma-ray which are in coincidence with the beta-ray emitted from 101In after being stopped by AIDA (double-side silicon-strip detector). By using LaBr3 and beta-plastic scintillators for the detection of gamma-rays and beta-rays, respectively, the life-times of the exited states which are larger than few hundreds ps in 101Cd can be measured by beta-gamma or gamma-gamma time difference method.

8. ***Title:*** In-beam commissioning of the AGATA Tracking array with ancillary instrumentation.
Thesis type: Experimental, Branch: Nuclear Physics
Supervisor: Contacts: Franco Galtarossa (franco.galtarossa@lnl.infn.it), Daniele Mengoni (daniele.mengoni@unipd.it)
INFN-LNL and University of Padova.

Abstract:
The thesis work consists in participating to the proposal, preparation and run of the first in-beam commissioning of the AGATA array at Legnaro National Laboratory. The student will be in charge for preparing the setup, participating in running the experiment and analysing the data, with particular emphasis on the on the coupling of gamma-ray tracking array AGATA with complementary instrumentation, such as silicon detectors and/or the PRISMA magnetic spectrometer, and the resulting resolving power.

9. ***Title*: Study of the 12C(p,gamma)13N and 13C(p,gamma)14N at astrophysical energies**
Supervisor: Antonio Caciolli
Physics and Astronomy Department Padova University
Via Marzolo 8, 35131-PADOVA-ITALY
antonio.caciolli@unipd.it
Abstract:
The 12C(p,gamma)13N and 13C(p,gamma)14N reactions determine the relative abundance of 12C and 13C in the deepest layers of the H-rich envelope of any stars. For both reactions, the Gamow peak is between 20 and 70 keV. These reactions will be studied in a wide energy range with different setups in order to reduce the systematic uncertainties and to cover properly the energy range where these reactions occur in stars.
The candidate will work on the design of the setups and in the following data taking. Then will perform the analysis of the data acquired with both setups in order to obtain the cross. The experiment will be performed at the LUNA experiment,placed at the Gran Sasso National Laboratory of INFN (the biggest underground laboratory worldwide), and also at the HZDR Dresden Rossendorf (Germany) to cover both high and lower energies. Therefore the candidate will do shifts in both research centres in order to work on the setup.

10. ***Title:*** **Study of the 20Ne(p,gamma)21Na reaction at astrophysical energies**
Supervisor: Antonio Caciolli
Physics and Astronomy Department Padova University
Via Marzolo 8, 35131-PADOVA-ITALY
antonio.caciolli@unipd.it
Abstract:

The NeNa-MgAl cycles are involved in the synthesis of Ne, Na, and Mg isotopes. The 20Ne(p,gamma)21Na is the first reaction of the NeNa cycle and having the slowest reaction rate, it controls the speed at which the entire cycle proceeds. Proton capture on 20Ne nuclei may occur in different stellar scenarios such as red giants stars (during H shell-burning), asymptotic giant branch stars, novae, and massive stars. This reaction can proceed in these environments if the temperature reaches T = 0.05 GK. The LUNA collaboration is interested in studying the resonance at E = 366 keV and to measure the 20Ne(p,gamma)21Na reaction cross section at proton energies below 400 keV, in particular the contribution from the sub-threshold state, in order to better constrain the overall astrophysical rate of this important reaction. A setup, characterised by two HPGe detectors fully shielded with copper and lead, will be installed on the LUNA400 accelerator at the beginning of 2020 to measure the cross section and the resonance. The candidate will participate at the design and setup construction and at its characterisation. Then, the candidate will coordinate the study of the E = 366 keV resonance strength and the direct capture component of the cross section at energies below 400 keV. The LUNA experiment is placed at the Gran Sasso National Laboratory of INFN (the biggest underground laboratory worldwide), therefore the candidate will do shifts there in order to work on the setup.

11. ***Title*: Study of the Er = 65 keV resonances in the 17O(p,gamma)18F reaction at the underground experiment LUNA**

Supervisor: Antonio Caciolli
Physics and Astronomy Department Padova University
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Abstract:

A precise determination of proton capture rates on oxygen is mandatory to predict the abundance ratios of the oxygen isotopes in a stellar environment where hydrogen burning is active. The 17O(p,gamma)18F reaction, in particular, plays a crucial role in AGB nucleosynthesis as well as in explosive hydrogen burning occurring in type Ia novae. At temperature of interest for the former scenario (20 MK < T < 80 MK) the main contributions to the astrophysical reaction rate come from the Er = 65 keV resonance. The strength of this resonance is presently determined only through indirect measurements and it has never been measured by direct experiment.
Thanks to the extreme low background environment of Laboratori Nazionali del Gran Sasso, the intense and stable beam provided by the LUNA accelerator and the long experience in Oxygen target production, the LUNA collaboration is planning to measure for the first time the resonance strength of the Er = 65 keV resonance with a direct technique. The candidate should work with different aspects of the experimental setup performing the data taking at the LUNA facility and the data analysis. The impact of the obtained results will be also evaluated in the framework of nucleosynthesis code thanks to the collaboration at UniPD with experts in stellar codes.

12. ***Title:*** Commissiong of the gamma-ray tracking array

Supervisor: Jose Javier Valiente Dobon/Rosa Perez
Laboratori Nazionali di Legnaro LNL
office: +39 049 8068 480
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Abstract:

The Advanced GAmma Tracking Array (AGATA) is a collaborative European project to construct and operate a 4p gamma-ray tracking spectrometer. This spectrometer is the next generation of gamma-ray spectroscopy instruments and involves achieving the goal of a 4p Ge ball through the technique of gamma-ray energy tracking in electrically segmented Ge detectors. AGATA is allowing the pursuit of a very rich science program using both radioactive and stable ion beams. From the second half of 2021, the European AGATA spectrometer will be installed at the National Laboratories of Legnaro (LNL) and we expect the commissioning of AGATA in combination with PRISMA to happen in the first quarter of 2022. The student will be involved in the commission and characterisation of the AGATA spectrometer at LNL. The student will contribute to the analysis and preparation of the sorting stages of AGATA. In the local level processing, that handles the crystals separately for the PSA task, the energy and time calibrations together with the important corrections for an improved energy and position resolutions (such as cross-talk corrections and neutron-damage corrections) will be carried out . In the global level processing, where the tracking is performed, the relevant parameters for the best performance will be optimized.

13. Title: Study of compact high intensity linear accelerators.

Supervisor: Andrea Pisent
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mail andrea.pisent@lnl.infn.it,

Abstract:

In recent years there have been important developments in the low energy components of linear accelerators, for applications such as materials testing for fusion (IFMIF), transmutation of radioactive waste (TRASCO, MYRRHA), materials testing with neutron probes (spallation sources), fundamental nuclear physics (radioactive beam production), medical applications (therapy, BNCT, or radioisotope production). The development of ion sources, RFQ and DTL are the key elements to obtain high intensity beams. The purpose of this study will be the use of the results achieved and the components developed for new compact high-performance accelerators.

14. *Title:* Monte-Carlo based dosimetry using PET/CT imaging in radiopharmaceutical therapy in the context of the ISOLPHARM project.

Supervisor: Alberto Andrighetto
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Abstract:

The ISOLPHARM collaboration has the aim of producing a set of innovative, high specific activity, carrier-free radioisotopes for pharmaceutical therapy exploiting the ISOL technique at SPES. The success of a particular radiopharmaceutical cancer treatment relies on an accurate assessment of the tissue response and toxicity. Since biological effects are mediated by the absorbed dose, which is defined as the energy absorbed per unit mass of tissue, internal dosimetry is of fundamental importance because it allows for the maximization of the therapeutic effect while minimizing the radiation burden to other organs. The proposed thesis work consists in the calculation of internal absorbed dose, following radiopharmaceutical treatments (e.g. with F-18 or Ag-111), by the use of different Monte Carlo based approaches (using the PHITS MC code) coupled with PET/CT images of mice acquired by our group.

Laboratoire de Physique Corpusculaire de Caen
(UMR 6534 CNRS-ENSICAEN)

Proposal for a Master Thesis 2022
(October 2021)

Precision measurement of the Fierz term in ^{6}He decay

Context

Experiments in nuclear beta-decay have been instrumental for the development of our current understanding of weak interactions. Precision measurements in nuclear beta decay provide today sensitive windows to search for new physics beyond the standard electroweak model which describes particles and interactions at the most elementary level. In nuclear beta decay, the "new physics" can be parametrized in terms of "exotic" scalar and tensor interactions. In the past few years, it has been recognized that for interactions involving left-handed neutrinos, measurements from beta decay can be competitive with direct searches performed at particle colliders such as the Large Hadron Collider (LHC) at CERN, provided they address the appropriate observables like for instance the beta-energy spectrum.
After an exploratory work performed at the National Superconducting Cyclotron Laboratory (Michigan State University, USA), in the beta decay of ^{6}He and ^{20}F, we are performing experiments at GANIL with both, fast and slow beams of ^{6}He. In this respect, GANIL offers a unique opportunity for such experiments since it is the only facility worldwide where both beam energies are available. The interest in using both energies resides in the associated systematic effects of experiments, which have to be very carefully studied.
The goal of this project is to perform the most precise measurement of the beta-energy spectrum in ^{6}He decay in order to deduce a parameter which is related to the presence of exotic tensor interactions. More quantitatively, the final goal of the project is to reach a total uncertainty which will result in an order of magnitude improvement in sensitivity compared to current constraints obtained from the LHC.

Internship work

The work within this internship involves both, hands-on activities for the preparation, tests and characterization of detectors to be used for the measurements with the high energy beam as well as Monte-Carlo simulations. The candidate is expected to take part to the analysis of data which will be collected in May-June 2020 with the low energy beam and to be actively involved in tests of scintillator detectors using a digital data acquisition system. This research work is not expected to lead to a PhD thesis this year.

Location

The work will be carried out at the Laboratoire de Physique Corpusculaire in Caen.

Contacts

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Second year Master internship offer

Study of forbidden transitions in weak interaction decays

Keywords
Nuclear Physics, instrumentation, Beta decays

Scientific background

Weak interaction transitions are the most widely spread decay mode among known nuclei. For several decades, beta decays have been studied by researchers around the world in order to measure characteristic parameters such as Q-values, half-lives, branching ratios… If these studies have allowed to characterize correctly some of these parameters, the energy spectra of the emitted beta particles are less known, in particular in the case of forbidden transitions.

The last ten years, numerous research projects have identify a strong need for better constrains on these decays, on both experimental and theoretical side. This is notably the case in dark matter studies to constrain the background of certain experiments or in neutrino physics to investigate the antineutrino flux anomaly observed from nuclear reactors. An accurate description of the energy spectrum of electrons is also mandatory in activity metrology to improve the definition of the Becquerel unit by reducing the uncertainty of measurements made by liquid scintillation. Finally, high-precision measurements of beta particle energy spectra could also be used to test certain predictions of the Standard Model, and to highlight the contribution of new physics.

The Laboratoire National Henri Becquerel (LNHB) has been working for several years to improve the experimental and theoretical knowledge on the shape of beta spectra. On the theoretical side, a computational code (BetaShape) has been developed and allows to treat with increased precision the allowed and forbidden unique transitions. On the experimental side, a 4π device has been developed in the last years in the laboratory. Based on the use of two silicon detectors in coincidence in a compact configuration, it has already been the subject of two theses and has allowed excellent results to be obtained on ^{14}C, or ^{99}Tc.

In this context, the LNHB is involved in the ANR (French national grant) b-STILED (in collaboration with LPC Caen and GANIL), which aims at measuring the energy spectrum of the ^{6}He decay in search for a new Physics beyond the Standard Model. The laboratory is in charge of the fabrication and characterization of calibration sources of interest for the project.

Offer description

The LNHB is offering a 2nd year Master internship of 6 months starting early 2022. The candidate will join the beta spectrometry group and will contribute to the experimental development of the project.

1. Experimental setup characterization

The current setup has proven successful to measure with good level of accuracy the energy spectra of several nuclei: ^{14}C, ^{36}Cl, ^{99}Tc, ^{207}Tl. In order to characterize the calibration sources of the b-STILED project, it is necessary to replace the PIPS silicon detectors used by lithium-doped silicon detectors, which are thicker and allow the measurement of higher energy beta particles. The associated acquisition chain will also be improved with the use of a FASTER module developed by the LPC Caen. The candidate will participate in the installation of the new measurement device and in its characterization in order to compare the performances obtained with those of the old device. Beyond the instrumental work, he will also participate in the development of the analysis codes used to process the data.

2. **Measurement of energy spectra of b-STILED project sources**

Once the new setup has been characterized, a campaign of measurement will be performed on the b-STILED sources (^{32}P, ^{89}Sr, $^{90}Sr/^{90}Y$) in order to assert their emission properties. The candidate will be able to assist to the source preparation and will be responsible for the data analysis. The measured spectra will be compared to the theoretical predictions calculated in the group. The data analysis might lead to the publication of the results in conference ND2022 (15^{th} International Conference on Nuclear Data for Science and Technology) to be held late July 2022.

During internship, the candidate will be working in collaboration with the beta spectroscopy group members but will also interact with the other members of the laboratory, most notably during the source fabrication. He is also expected to take part in the collaboration with the LPC Caen within the scope of b-STILED.

The LNHB would like the candidate to follow the internship by a Ph.D. thesis on the improvement of the knowledge of beta energy spectra. Depending on the candidate interest, the Ph.D. subject can be conducted mostly on theoretical developments (around non-unique forbidden transitions, strongly dependent on the nuclear structure) or on experimental work (around the future development of the setup with addition of gamma detector in coincidences, to investigate decay of nuclei with complex level scheme).

Contract	**Expected starting date**	**Site**
6 months	Between January and March 2022	CEA Saclay

Host laboratory

The LNHB, located in CEA Paris-Saclay, is a laboratory from CEA (French Alternative Energies and French Alternative Energies and Atomic Energy Commission) responsible for the French ionizing radiation metrology. It is one of the national metrology institutes federated by the Laboratoire National de métrologie et d'Essais (LNE) since 2005. The LNHB is composed of around 50 permanents staff members among which about 25 are part of the LMA (Laboratoire de Métrologie de l'Activité – Activity Metrology Laboratory). LMA is in charge of primary metrology for the measurement of activity and the transfer of references to accredited calibration laboratories and users in the fields of application such as: nuclear medicine, nuclear industry, environmental monitoring.

Contacts

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CENTRE DE RECHERCHE SUR LES IONS,
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PLATEFORME D'ACCUEIL AUPRÈS DU GANIL

Ion collision induced fragmentation of water clusters

Water is ubiquitous in the human body thus it plays a fundamental role in the application of radiation damage in radiotherapy. On the one hand, the water environment can act as a buffer able to dissipate part of the excess of energy deposited by the ionising radiation and therefore can play a protective effect on the so-called direct effect of the radiation. However, on the other hand, the ionisation of water can lead to the formation of secondary particles (electrons, radicals, ions) which can further induce damage, being responsible for a part of the so-called indirect effects of radiation. Thus it is usually considered that indirect effects are responsible for about two-third of the radiation damage as water is the major constituent of cells [1].

Water clusters are an intermediate state between vapour water and liquid water with specific physical properties. Thus from a fundamental point of view they form an interesting series of objects to be studied. Moreover by studying them in the gas phase, it is possible to perform precise spectroscopies giving deeper insights into their properties [2]. Nevertheless depending on the size of the cluster, some properties tend to the ones of the liquid phase. Give some handles helping to better understand the indirect effects of radiation damage.

In the present master thesis, we propose to study in the gas phase the dissociation of water clusters following the interaction with ions. These experimental studies will be performed at GANIL at the low-energy ion beam facility ARIBE. They will complement former studies performed with swift heavy ions [3]. The dynamics of the fragmentation will be studied using coincidence time-of-flight mass spectrometry. In the present work, we will focus on the nature of the emitted cationic species and on the determination of their kinetic energy distribution as a function of the cluster size, the charge state of the cluster, or its excitation energy.

References:

[1] B. D. Michael and P. O'Neill, *Science* **287** (2000) 1603.

[2] F. N. Keutsch and R. J. Saykally, *PNAS* **98** (2001) 10533.

[3] L. Adoui et al., *J. Phys. B: At. Mol. Opt. Phys.* **42** (2009) 075101.

Contact:

Patrick Rousseau patrick.rousseau@unicaen.fr 02.31.45.48.06

ERASMUS MUNDUS MASTER IN NUCLEAR PHYSICS
Academic Year 2021/2022

MASTER THESIS PROPOSAL

TITLE: Measurement of charm-baryon production in proton-proton, proton-Pb and Pb-Pb collisions at the LHC with ALICE

SUPERVISOR(S): Marcello Lunardon, Andrea Rossi

SUPERVISOR(S) contact- email: marcello.lunardon@unipd.it Telephone: +393498275643
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UNIVERSITY/RESEARCH CENTER: University of Padova, Department of Physics and Astronomy and INFN

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

The student will analyse recent data samples collected with ALICE (A Large Ion Collider Experiment) at the LHC, with the goal of measuring and characterise the production of baryons with charm quarks, as Λ_c^+ or $\Sigma_c^{0,++}$ in p-p, p-Pb, and Pb-Pb collisions. Heavy quarks are produced in hard-scattering processes with high-momentum transfer in the early stages of the collisions, before the formation of the QGP. Therefore, by interacting with the medium quarks and gluons, they witness the whole evolution of the expanding and cooling systems. In particular, the comparison of the production yields of different hadron species (e.g. D^0, D_s^+, Λ_c^+ or $\Sigma_c^{0,++}$) can clarify how hadrons are formed in the medium and help understanding the coupling of charm quarks to the system and their degree of thermalisation. The student will work at the Dept. of Physics and Astronomy tacking advantage of the interaction with the research group and the distributed computing resources (GRID and CloudVeneto).

Preparation and participation to the first experiment on surrogate reactions at heavy-ion storage rings

The fusion of two neutron stars, for which gravitational and electromagnetic waves have recently been detected, appears to be one of the preferred scenarios in which a large part of the chemical elements beyond ^{56}Fe are synthesized. This scenario is characterized by an enormous neutron flux that allows the production of increasingly heavy elements from multiple neutron capture reactions followed by β decays. Our current understanding of the formation of the heaviest chemical elements relies on models describing this stellar environment in which the cross sections of neutron-induced reactions on short-lived exotic nuclei are essential ingredients.

However, the measurement of these cross sections is very complicated, or even impossible, due to the high radioactivity of the required targets. The use of inverse kinematics in which the heavy nucleus is in motion (in the form of a radioactive ion beam) and the neutron is at rest (in the form of a target) would allow one to overcome the difficulties caused by radioactive targets. However, this is not yet possible because of the unavailability of free-neutron targets. The most promising alternative is the use of surrogate reactions in inverse kinematics. With surrogate reactions it is possible to form the same nuclei as those formed after neutron capture but using proton or deuteron targets which are available. However, the development of the surrogate-reaction method requires overcoming the limitations caused by the large thickness and the impurities of the required targets.

Storage rings, which are precision instruments where high-quality radioactive beams revolve at high frequencies to repeatedly interact with pure and ultra-thin targets, can overcome these limitations. This is why, since January 2021, we develope the NECTAR (Nuclear rEaCTions At storage Rings) project, which aims to combine for the first time surrogate reactions with heavy-ion storage rings. The detection systems placed inside the rings must be ultra-high vacuum compatible (10^{-11} to 10^{-12} mbar), which represents a considerable technological challenge. For comparison, in most nuclear physics experiments the vacuum level is 10^{-6}-10^{-7} mbar. The use of such detection systems implies the development, from design to commissioning, of a completely new experimental device based on cutting-edge technology. The interest and originality of NECTAR have been rewarded by a grant from the European Research Council (ERC). This is one of the most prestigious research grants in Europe and it will allow to finance the whole project.

The experiments to be carried out within the framework of NECTAR will take place at the storage rings of the GSI/FAIR facility, located in Darmstadt, Germany. A first pilot experiment will take place in June 2022 and the final experiment in 2024. In the first experiment we will study surrogate reactions induced by a ^{208}Pb beam on a hydrogen target. In the final experiment, a ^{238}U beam will interact with a deuterium target.

The objective of this internship is to participate in the preparation and realization of the pilot experiment. The candidate will work with the researchers and engineers of the CENBG on the assembly and testing of the detection systems for this experiment. These systems are composed of highly segmented silicon detectors that are connected to the latest generation of electronic boards dedicated to the processing of their signals. She/he will also participate in the assembly and realization of this first experiment at GSI/FAIR in June 2022. This internship will be an ideal way to get acquainted with the subject of the doctoral thesis that will follow and whose goal will be the preparation, the realization and the analysis of the final experiment of 2024. The doctoral thesis will be financed by the ERC grant.

Candidates should have a strong interest in experimental nuclear physics, the ability to work in a team and a good knowledge of English.

The internship should take place from March to June 2022 at least. Deadline for application 8 December 2021.

Contact: Beatriz Jurado, jurado@cenbg.in2p3.fr

ERASMUS MUNDUS MASTER IN NUCLEAR PHYSICS
Academic Year 2021/2022

MASTER THESIS PROPOSAL

TITLE: Clinical feasibility study of an ionizing radiation detector device based in multiple miniature plastic scintillation sensors

SUPERVISOR(S): Antonio Leal Plaza

SUPERVISOR(S) contact- email: alplaza@us.es Telephone: 954559864
email: Telephone:

UNIVERSITY/RESEARCH CENTER:
Universidad de Sevilla, Depto. Fisiología Médica y Biofísica (Física Médica)

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

Modern radiotherapy is based on complex treatment plannings based on multiple incidence beams shaped with narrow leaves of tungsten able to deliver over the patient very small irradiation fields. These treatments are based on intensity modulation radiotherapy (IMRT) technique and they are even delivered under ablative conditions such as stereotactic ablative radiotherapy (SABR) which requires a high quality assurance for clinical implementation. In this scenario, detector devices for physical and clinical dosimetry demand a high resolution and precision for dose measurements pre-treatment and along the sessions.
A new ionizing radiation detector device based in multiple miniature plastic scintillation sensors is an interesting proposal due to a very small measurement effective volume and a more suitable cross section facing to the irradiation beam than conventional ionization chambers based in a cavity closed with metal chassis.
This work try to evaluate the clinical feasibility this detector device based in multiple miniature plastic scintillation sensors by means a comparison study of experimental measurements against several conventional detectors including ion-chamber and radiochromic film under irradiation with actual clinical lineal accelerators (linacs) and Monte Carlo simulations considered as the gold standard of the dose values.
The measurements will be carried out in the Virgen Macarena Hospital of Seville and the detector under study will be supported by Bluephysics based in Tampa, Florida (https://bluephysicsmed.com/).

For more details put in contact with alpalza@us.es