ERASMUS MUNDUS MASTER IN NUCLEAR PHYSICS
Academic Year 2022/2023

MASTER THESIS PROPOSALS MADRID

UCM-01
Tutors: Daniel Sánchez Parcerisa (dsparcerisa@ucm.es)
Title: Viability study for a vertical 10-MeV proton beamline at CMAM

Abstract: The tandem accelerator at the Centro de Microanálisis de Materiales (CMAM), at the Universidad Autónoma de Madrid, can accelerate protons up to 10 MeV, corresponding to a range in water of slightly more than 1 mm. This beam can be used to perform numerous experiments in radiobiology, including irradiations of cell cultures and other more complex models, such as chicken embryos. However, its only horizontal arrangement makes it difficult to position samples and perform some experiments. The work will consist of a conceptual analysis of the CMAM facility, supported by Monte Carlo codes such as TOPAS and particle beam optics calculation codes, to study the feasibility of a future installation of a vertical irradiation line in CMAM, studying its dosimetric characteristics and technical requirements for its installation.

UCM-02
Tutors: Daniel Sánchez Parcerisa (dsparcerisa@ucm.es)
Title: Modeling of post-irradiation radiochemistry in high-rate radiotherapy (FLASH)

Abstract: High-rate radiotherapy or FLASH has been a revolution in radiotherapy, as it has been shown that it could allow a significant decrease in the side effects of radiation, while maintaining its tumor control capacity. The radiobiological mechanisms underlying the FLASH effect are still unknown. The work proposes to use Monte Carlo modeling tools such as TOPAS-nBIO and others developed internally within the Nuclear Physics Group to study the chemical kinetics of free radicals created in water radiolysis, which are determinants in the biological effects of radiation. With this data we intend to make experimentally testable predictions (such as the concentration of molecular oxygen or post-irradiation hydrogen peroxide) to design future experiments by controlling the irradiation conditions.

UCM-03
Tutors: Raúl González Jiménez (raugon06@ucm.es)
José Manuel Udías Moinelo (jose@nuc2.fis.ucm.es)
Óscar Moreno Díaz (osmoreno@ucm.es)
Title: Realistic theoretical models for neutrino-nucleus interactions

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. In these experiments is essential to have theoretical models able to make precise predictions of the neutrino-nucleus interaction. In this work we will study different theoretical models for several reactions channels. From the comparison with experimental data we aim to improve our knowledge on the nuclear response to leptons.

UCM-04
Tutors: Raúl González Jiménez (raugon06@ucm.es)
Joaquín López Herraiz (jlopezhe@ucm.es)
Title: Artificial intelligence for the modeling of neutrino-nucleus interactions

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.

UCM-CIEMAT-05
Tutors: José Luis Velasco, joseluis.velasco@ciemat.es
Title: Energetic ion confinement in optimized stellarators

Abstract: Very good confinement of fusion-generated alpha particles is a sine qua non for a fusion reactor. These very energetic ions are expected to contribute to heat the fusion reactants, which implies that their confinement time must be sufficiently longer than the time that it takes them to thermalize by giving their energy to the plasma. An even more restrictive criterion is set by the heat loads on the walls: alpha particles that are promptly lost, and that therefore retain most of their original energy, could damage the plasma-facing components of the reactor wall. In magnetic fusion devices of the stellarator type, neoclassical processes are the main concern with respect to energetic ion confinement. Particles trapped in the magnetic field of axisymmetric tokamaks, while moving back and forth along the field lines, experience radial excursions that produce banana-shaped orbits, but, on average, no net radial displacement takes place in the absence of collisions. Things are

different in a generic stellarator, where collisionless trapped orbits are not confined (this also applies to tokamaks in which axisymmetry is not perfect). For this reason, the magnetic configuration of a stellarator has to be carefully designed in order to minimize energetic ion losses. The student will characterize the confinement of energetic ions in stellarators by numerically solving kinetic plasma equations. This will be done for a variety of optimized stellarator configurations, including Wendelstein 7-X (Greifswald, Germany) and the Large Helical Device (Toki, Japan). With his/her calculations, the student will be contributing to the participation of the Laboratorio Nacional de Fusión in the experimental campaigns of these two devices. Additionally, he/she will be taking part in a longer term project that has the goal of designing new optimized stellarator configurations that can be candidates for future fusion reactors. Webpages: http://fusionsites.ciemat.es/jlvelasco/ http://fusionsites.ciemat.es/multitranstell/

UCM-CIEMAT-06
Tutors: Edilberto Sánchez González, edi.sanchez@ciemat.es
Title: Global gyrokinetic simulations in stellarators

Abstract: Turbulence is considered one of the key issues limiting energy and particle confinement in present magnetic confinement fusion devices. Nowadays, the study of turbulence in magnetized plasmas largely relies on gyrokinetic theory [1]. This formalism, based on first principles, makes plasma turbulence more tractable and permits the development of simulation codes. Nevertheless, the numerical simulation of plasma instabilities and the turbulence they produce using gyrokinetic codes requires huge computational resources and is only possible using large supercomputers. This master's thesis proposal deals with the numerical simulation of plasma instabilities and turbulence in stellarator devices employing the global gyrokinetic code EUTERPE [2], which allows the simulation of the full radial domain. It continues previous work carried out at the Laboratorio Nacional de Fusión, CIEMAT [3]. The project will include simulations in the Mare Nostrum [4] and Marconi [5] supercomputers. The outcome of numerical simulations will eventually be compared with experimental measurements from the stellarators TJ-II [6], operated at the Laboratorio Nacional de Fusión, in Madrid, and W7-X [7], the most advanced stellarator in the world, in operation at the Max Planck Institute für Plasmaphysik, in Greifswald, Germany. [1] P. Catto. Plasma Phys. 20 719-722 (1978). [2] G. Jost, et al. Physics of Plasmas, 8(7) 3321 (2001). [3] http://fusionsites.ciemat.es/picgklnf/ [4] https://www.bsc.es/es/marenostrum/marenostrum [5] https://www.hpc.cineca.it/hardware/marconi [6] http://www.fusion.ciemat.es/tj-ii-2/ [7] https://www.youtube.com/watch?v=u-fbBRAxJNk Webpages: http://fusionsites.ciemat.es/picgklnf/ http://fusionsites.ciemat.es/multitranstell/

UCM-CIEMAT-07
Tutors: José Manuel García Regaña, jose.regana@ciemat.es;
Iván Calvo, ivan.calvo@ciemat.es
Title: Theory and simulation of stellarator plasma turbulence

Abstract: Thermonuclear fusion and its success as a future energy source rely on achieving tolerable levels of heat transport losses out of the confined plasma. In present day experiments, these losses are attributed, to a large extent, to the turbulent processes associated with fluctuations of the plasma electromagnetic fields with characteristic spatial scale of the order of the Larmor radius of the plasma species. The theoretical framework for the study of these fluctuations is gyrokinetic theory [1]. The quantitative evaluation of the transport driven by gyrokinetic turbulence is in most situations carried out by numerical simulations performed in massive parallel computing platforms. For tokamaks, gyrokinetic codes are mature and have been extensively validated against experiments. Whereas tokamaks are axisymmetric (which reduces the dimensionality of the equations to be simulated), stellarators are intrinsically three-dimensional, and this has led to specific difficulties and, until recently, a comparatively slower progress of the field (see e.g. [2]). The aim of the present master's thesis project is to investigate turbulence in stellarator plasmas by means of the modern, advanced gyrokinetic code stella [3]. The project includes applications to present-day stellarators such as W7-X (Greifswald, Germany) [4], LHD (Toki, Japan) [5] and TJ-II (Madrid, Spain) [6]. Interest of the candidate on theory and numerical simulations is highly recommended. [1] P. Catto, Plasma Phys. 20, 719 (1978) [2] P. Helander et al., Plasma Phys. Control. Fusion 54, 124009 (2012) [3] M. Barnes et al., J. Comput. Phys. 391, 365 (2019) [4] https://www.youtube.com/watch?v=u-fbBRAxJNk [5] http://www.lhd.nifs.ac.jp/en/home/lhd.html [6] http://fusionsites.ciemat.es/tj-ii * Webpage: http://fusionsites.ciemat.es/icalvo/

UCM-CIEMAT-08
Tutors: Arturo Alonso, arturo.alonso@ciemat.es
Iván Calvo, ivan.calvo@ciemat.es
Title: Neutral particle transport in nuclear fusion reactors

Abstract: In magnetic confinement fusion reactors, a plasma consisting of a mixture of deuterium and tritium is confined by strong magnetic fields. In the reactor core, the deuterium and tritium atoms are completely ionized due to the extremely high temperatures necessary for fusion reactions to happen sufficiently frequently. However, close to the reactor wall, temperatures are lower, the plasma is only partially ionized and the presence of neutral particles cannot be neglected. On the one hand, these neutral particles do not interact with magnetic fields and, consequently, the description of their dynamics is completely different from that of the main plasma. On the other hand, the transport and confinement of the main plasma, and therefore the performance of the reactor, is heavily affected by neutrals. Although, in general, the description of neutral particle processes require kinetic theory, simpler fluid equations can be derived under the often reasonable assumption of high collisionality (or, equivalently, short mean-free-path). In this master's thesis project, the student will: } become familiar with the derivation of a simplified 1D fluid transport model for neutrals including charge-exchange reactions with main plasma ions and electron-impact ionization; } adapt an existing 1D neutral transport code to reactor conditions; } evaluate charge-exchange processes. * Webpages: http://fusionsites.ciemat.es/jaalonso/
http://fusionsites.ciemat.es/icalvo/

UCM-CIEMAT-09
Tutors: Pedro Calvo Portela Pedro.Calvo@ciemat.es
Title: Study of a new H- radiofrequency-based ion source design for accelerators with medical applications.

Abstract: The Particle Accelerator Unit at CIEMAT develops different components for accelerators with applications in nuclear medicine, from radioisotope production to radiotherapy. The project on offer aims to study a new prototype radiofrequency-based ion source that could be installed in compact cyclotrons, providing an improvement in the initial beam conditions. The study will be based initially on a theoretical understanding of the design and the performing of simulations of the plasma and beam extraction with different codes, making a benchmarking comparison of the results. The aim is to optimize the operation of the source and the improvement of the extracted ion beam, both from the point of view of the beam dynamics and the global operation of the accelerator. In parallel, the student will contribute to the assembly of an experimental facility where experimental measurements of the ion source will be carried out in order to verify its correct operation, contrasting all the results obtained in the simulations.

UCM-10
Tutors: Tomás R. Rodríguez tr.rodriguez@ucm.es
Title: Structure of exotic N=Z nuclei with variational approaches

Abstract: Medium-mass N=Z nuclei are suitable systems to test several many-body phenomena, e.g., proton-neutron pairing correlations, multiple shape-coexistence or isospin symmetry breaking. Additionally, some of these neutron deficient nuclei are of astrophysical interest because they could be waiting-points of rp-process and/or νp-process nucleosynthesis. The theoretical description of these systems is still challenging, in particular, the calculation of their properties within a self-consistent mean-field and beyond-mean-field framework. The aim of this Master's Thesis proposal is the study of even-even and odd-odd N=Z nuclei in the 28 < N (= Z) < 50 region using a recently developed computer code (TAURUS) that implements those many-body techniques with realistic nuclear interactions. Requirements: Basic knowledge of: nuclear many-body methods, linux, programming (preferable in FORTRAN).

UCM-11
Tutors: Tomás R. Rodríguez tr.rodriguez@ucm.es
Title: Microscopic description of particle-plus-rotor nuclei

Abstract: The structure of some nuclei with an odd number of particles (odd-even or even-odd number of protons-neutrons) can be understood as the motion of the unpaired particle and a rotating even-even core. One can distinguish some characteristic spectra depending on the strength of the interaction between the particle and the core. Our goal in this Master's Thesis proposal is the description, from microscopic calculations where the individual nucleons are the actual degrees of freedom of the system, of the spectra obtained with the geometrical picture. Requirements: Basic knowledge of: nuclear many-body methods, linux, programming (preferable in FORTRAN).

UCM-CIEMAT-12
Tutors: Dr. Roberto Santorelli (CIEMAT) (Roberto.Santorelli@ciemat.es)
Luciano Romero (CIEMAT) (Luciano.Romero@ciemat.es)

Title: Study, construction and development of a new dual-phase argon detector for direct search of Dark Matter with the DarkSide-20k experiment

Abstract: The direct detection of dark matter is one of the main challenges in modern physics and its discovery would mean an tremendous advance in knowledge both in the fundamental ingredients of the universe and in the role they played in its early evolution. The CIEMAT's Dark Matter group (CIEMAT-DM) has a long time experience in this field, particularly in the design, construction, operation and data analysis of experiments based on liquid argon detectors. We are currently participating in the ArDM (LSC, Canfranc, Spain) and DEAP-3600 (SNOLAB, Canada) experiments. In order to overcome the current experimental limits on the detection of weakly interacting massive particles called (WIMPs), it is required a new generation of very massive detectors. DarkSide-20k will be the largest liquid argon detector for direct detection of dark matter. With 20 tons of active material in the fiducial volume, it will have an unprecedented sensitivity to WIMP signals. This detector will be installed underground at the Gran Sasso National Laboratory (Italy) and will start taking data in 2022. For this investigation, the purity of the materials from the point of view of natural radioactivity and the ability to discriminate signal and background are fundamental aspects. The objectives of the work can be adapted to the interests of the student, focusing on the material radio-purity analysis and/or on Monte Carlo simulations necessary for the calculation of the background of the experiment. All the proposed tasks involve an intense learning of particle physics, nuclear and detectors, providing an excellent experience to face a thesis in particle physics or astrophysics

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UCM-CIEMAT-13

Tutors: Dr. Vicente Pesudo (CIEMAT) (Vicente.Pesudo@ciemat.es)
Dr. Pablo García-Abia (Pablo.Garcia@ciemat.es) (CIEMAT)

Title: Analysis of the data of Dark Matter ArDM/DART and DEAP-3600 Dark Matter experiments

Abstract: The nature of Dark Matter is widely considered as one of the most important open questions of modern physics. Multiple observations suggest that less than 15% of the universe's matter content is made of ordinary matter, while the largest contribution is given by non-luminous and non-baryonic matter that manifests itself only through its gravitational effects. A possible explanation for the Dark Matter problem lies in the existence of weakly interacting massive particles called WIMPs, remnants of the Big Bang. There are several global projects underway, carried out in underground laboratories, looking for tiny signals produced by WIMP interactions. One of them is the DEAP-3600 experiment, with 3600 kg of liquid argon, which is located in the SNOLAB laboratory (Canada). The CIEMAT-DM group participates in data collection and analysis, developing advanced analysis techniques in order to optimize the sensitivity of the WIMPs signal, significantly reducing the background events. On the other hand, our group participates in the ArDM/DART experiment, installed in the Canfranc Underground Laboratory under the Pyrenees, which aims to measure radionuclide contamination in argon radiopure, which is one of the most important parameters to define the sensitivity to WIMPs detection. The purpose of this master's work is to contribute to the analysis of the data currently being taken by the DEAP-3600 and ArDM/DART experiments, to verify the performance of liquid argon detectors and their capability to reject background events. The proposed tasks involve an intense learning of particle physics, nuclear and detectors, providing an excellent experience to face a thesis in particle physics or astrophysics

ERASMUS MUNDUS JOINT MASTER DEGREE IN NUCLEAR PHYSICS

Universidad de Sevilla

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UCM-CIEMAT-14

Tutors: Dr. José I. Crespo-Anadón (CIEMAT) (jcrespo@ciemat.es)

Title: Search for physics processes beyond Standard Model with the SBND experiment at Fermilab

Abstract: Neutrino masses and their huge difference with those from the rest of elementary particles poses a strong suggestion towards existence of beyond Standard Model physics. The SBND experiment, a liquid-Ar time projection chamber located 110 m from the neutrino beam origin, at the Booster Neutrino Beam (BNB) in Fermilab (Illinois, EEUU), aims, among other things, to search for new physics processes. Within the current TFM the sensitivity to several extensions to the Standard Model will be studied.

UCM-CIEMAT-15

Tutors: Dr. Clara Cuesta (CIEMAT) (Clara.Cuesta@ciemat.es)

Title: Sensibility to supernova neutrinos of the Deep Underground Neutrino Experiment

Abstract: The Deep Underground Neutrino Experiment (DUNE) is a powerful tool to perform low energy physics searches. DUNE will be uniquely sensitive to the electron neutrinos coming from the burst of a core-collapse supernova. Detecting neutrinos from a supernova will bring information about the supernova itself, but also about the neutrino nature. Studies of the DUNE potential for different supernova models will be carried out to evaluate the sensitivity of DUNE to provide an insight on the core-collapse supernova explosion or neutrino physics.

UCM-CIEMAT-16

Tutors: Dr. Carmen Palomares (CIEMAT) (mc.palomares@ciemat.es)

Title: LiquidO: A Novel Neutrino Technology

Abstract: The unknowns in neutrino physics demand huge detectors (>kton), with high energy resolution and accurate particle identification. A simple and not costly detector fulfilling these requirements would be a game-changer in neutrino physics. LiquidO is an R+D project for the development of a new neutrino detection technology which uses opaque liquid scintillator, like milk or paraffin. This new technology represents a breakthrough with respect to the traditional neutrino detection with liquid scintillator, essential for future neutrino physics experiments. The tasks proposed in this End-of-Master project cover the development of simulations and the data analysis of a prototype that is currently taking data. LiquidO is an international collaboration that includes research institutes and universities from France, Italy and Japan.

UCM-CIEMAT-17

Tutors: Dr. Miguel Angel Velasco (CIEMAT) (MiguelAngel.Velasco@ciemat.es)
Dr. Jorge Casaus (CIEMAT) (Jorge.Casaus@ciemat.es)

Title: Search for Dark Photons from the Sun with Spaceborne Experiments

Abstract: Dark matter constituents may only interact with the Standard Model through the kinetic mixing of the so-called dark photons, i.e. the gauge bosons of a broken U(1) symmetry, with Standard Model photons. Within this scenario, dark photons are copiously produced in the annihilation of gravitationally captured dark matter in the Sun. These dark photons leave the Sun and decay into pairs of charged SM particles that can be detected by spaceborne cosmic ray detectors. The discovery potential of current experiments (AMS-02, DAMPE, CALET) and future instruments (HERD, ALADInO, AMS- 100) will be investigated.

UCM-CIEMAT-18

Tutors: Dr. Miguel Angel Velasco (CIEMAT) (MiguelAngel.Velasco@ciemat.es)
Dr. Jorge Casaus (CIEMAT) (Jorge.Casaus@ciemat.es)
Title: Gamma Ray Transients and Multi-messenger Physics with Spaceborne Experiments

Abstract: Continuous monitoring of the high energy gamma ray sky is a powerful tool to identify transient events associated to the most energetic phenomena in the cosmos. As an example of this multi-messenger approach, the detection of the high-energy afterglow of the short gamma ray bursts associated to the electromagnetic counterpart of gravitational wave (GW) events may provide key information about the nature and location of the GW progenitor. The potential of future large field-of-view cosmic ray experiments (HERD, AMS-100) to detect transient gamma ray signals will be investigated.

UCM-CIEMAT-19

Tutors: Dr. Pablo Garcia (CIEMAT) (pablo.garcia@ciemat.es)
Dr. Carlos Delgado (CIEMAT) (carlos.delgado@ciemat.es)
Title: Gravitational waves studies with data from the Virgo experiment

Abstract: The CIEMAT Gravitational Waves group participates in the data analysis of the Virgo experiment. We are especially interested in fundamental physics studies, like dark energy, dark matter and the estimation of cosmological parameters. In this TFM, the student will contribute to stochastic background analyses, and in the search for signals without well-defined templates, like Supernovae explosion. For these studies, we envisage introducing Machine Learning and Deep Learning techniques, focusing on Explainable Artificial Intelligence (XAI). XAI will be carried on to generate robust and unbiased classifiers and predictors, that allow identifying the most relevant variables for the predictions.

UCM-CIEMAT-20

Tutors: Dr Alvaro Navarro Tobar (alvaro.navarro@ciemat.es)
Dra. Cristina Fernández Bedoya (cristina.fernandez@ciemat.es) (CIEMAT)
Title: Studies on the new muon trigger algorithm in CMS using collision data from LHC

Abstract: The LHC (Large Hadron Collider) at CERN is planning an upgrade that will achieve a factor 10 in luminosity (10 times the number of collisions per second), so called HL-LHC. In this way, more precise measurements of elementary particles and unexpected processes below the actual sensitivity will be possible. Selecting the best collisions is performed by the algorithms implemented in the Trigger systems, which need to be improved for this new challenging scenario. CIEMAT has developed a new muon trigger algorithm for the CMS detector capable of operating at the maximum luminosity and moreover, providing ultimate resolutions. In this TFM the student will approach the selection process required for the trigger systems of an experiment and learn how to study and improve the performance of the CMS muon trigger both in Montecarlo and collision samples.

UCM-21

Supervisor: Luis Mario Fraile (lmfraile@ucm.es)
Department: Grupo de Física Nuclear, EMFTEL department & IPARCOS, Universidad Complutense de Madrid
Title: (alpha,n) nuclear reactions of interest in fusion

Abstract: Alpha particles are important in a magnetically confined fusion plasma as a heating source before escaping the plasma. The rate of alpha release from the plasma is therefore of importance and ITER is exploring methods to measure it, such as a fast-ion loss detector [1]. Other options such as activation foils have also been proposed [2]. Although the latter is challenging owing to the need to discriminate against gamma background arising from neutron activation, several candidate reactions have been put forward, such as ^{10}B(α,n), ^{43}Ca(α,p), ^{76}Ge(α,n) among others [2]. Cross section data for key reactions is nevertheless scarce.

The master thesis will deal with the identification of reactions that occur at energies below 3.5 MeV and produce radionuclides with gamma signals detectable against neutron-induced gamma background. Production yields for specific reactions will be measured in the relevant 1 to 3.5 MeV energy range at the newly commissioned (alpha,n) reaction beamline at the CMAM [2] 5-MV tandetron in Madrid. The reaction thresholds and cross sections will be investigated.

[1] M. Garcia-Munoz et al., Rev. Sci. Instrum. 87 (2016) 11D829
[2] Bonheure et al., Fus. Eng. Des. **86** (2011) 1298
[3] Centro de Micronálisis de Materiales, https://www.cmam.uam.es/

UCM-CIEMAT-22

Supervisor: Daniel Carralero, Teresa Estrada
Laboratorio Nacional de Fusión, CIEMAT. Madrid (Spain).

E-mail: daniel.carralero@ciemat.es
Title: Turbulence in nuclear fusion plasmas: reflectometry in the optimized stellarator Wendelstein 7-X.

Abstract: One of the key obstacles in the path to commercial magnetic nuclear fusion is the lack of predictive capabilities regarding the behavior of turbulence in reactor-relevant plasma conditions. In particular, turbulence has recently proven to be critical for the performance of the optimized stellarator Wendelstein 7-X (W7-X) at the Max Planck Institute for Plasma Physics (Greifswald, Germany), the most recent step of the stellarator line in the path towards the fusion reactor and the world's largest device of its

kind: during the last experimental campaign the ion temperatures achieved at the core of W7-X were severely limited by the onset of electrostatic instabilities of the Ion Temperature Gradient (ITG) kind, which substantially increased turbulent transport, thus significantly degrading the overall confinement of the machine. Because of this, only a handful of high performance scenarios -which were able to stabilize the ITG turbulence through the buildup of strong density gradients- achieved the nominal core ion temperatures of 2-2.5 keV which were expected according to neoclassical optimization.

This process was carefully documented in the LNF using a Doppler reflectometer, a diagnostic developed by CIEMAT as a joint endeavor with the IPP Greifswald, and one of the very few ones installed in W7-X which can be used to characterize turbulence. With this device, the decrease of density fluctuations was measured under high performance scenarios [2], and linked to the suppression of ITG modes by comparison to theoretical models and simulations [3]. This work will be greatly expanded in the upcoming W7-X experimental campaign (November 2022 to April 2023), in which an upgraded reflectometer system will be used in a number of experiments to further investigate the nature of turbulence, and the ways to bring it under external control.

In the course of this master thesis, the student will analyze Doppler reflectometer data from previous and present experimental campaigns in order to characterize turbulence. In particular, the frequency spectra of the density fluctuations will be evaluated over a range of radial positions for the most relevant plasma scenarios. Then, he/she will compare the results to theoretical predictions from state-of the art gyrokinetic simulations already being carried out at the LNF in order to identify the nature of the turbulent instabilities giving rise to the analyzed fluctuations.

Requirements: Basic programing skills in matlab/python. Preferably, some background on plasma physics and data analysis.

[1] https://www.youtube.com/watch?v=u-fbBRAxJNk

[2] https://doi.org/10.1088/1741-4326/abddee

[3] https://iopscience.iop.org/article/10.1088/1741-4326/ac112f

CSIC-23
Tutor: Bruno Olaizola - bruno.olaizola@cern.ch
Instituto de estructura de la materia, CSIC.
Title: Study of exotic nuclei with GRIFFIN

Abstract: The GRIFFIN array at TRIUMF, Canada, is currently the state-of-the-art spectrometer, with one of the highest gamma-ray efficiencies and a suit of ancillary detector that allows for in-depth decay experiments. It is routinely used to study the structure of some of the most exotic isotopes with extreme neutron-to-proton ratios.
What are you going to do? The master research project will consist of the data analysis of recent GRIFFIN experiments. You will analyze the beta decay of exotic nuclei and build their level schemes, making use of different nuclear physics techniques, such as angular correlations or conversion electron spectroscopy.
What are you going to learn? During this work, you will familiarize yourself with GRIFFIN and TRIUMF, a world-leading laboratory. You will also learn to use powerful analysis tools like ROOT, the most commonly used software in the nuclear and particle physics field. Finally, you will gain in-depth knowledge about nuclear structure far from stability and a wide range of nuclear physics detectors, able to detect gamma rays or charged particles.

CSIC-24
Tutor: Bruno Olaizola - bruno.olaizola@cern.ch
Instituto de estructura de la materia, CSIC.
Tutor: Andrés Illana – GFN-UCM andres.illana@cern.ch
Title: Beta decay experiments at ISOLDE, CERN

Abstract: The ISOLDE laboratory pioneered the development of radioactive beams, and it is still considered a world-class laboratory in nuclear physics. One of its experimental lines is the ISOLDE Decay Station (IDS), which is the permanent setup to conduct decay experiments of exotic nuclei, with a special focus on beta decay. The CSIC and UCM groups routinely use IDS to unravel the nuclear structure of isotopes far from the Valley of Stability.
What are you going to do? The master research project will consist of the data analysis of recent IDS experiments. You will analyze the beta decay of exotic nuclei, building their level schemes and measuring the lifetime of excited state in the picoseconds (10-12 s) range.
What are you going to learn? During this work, you will familiarize yourself with the fundamental aspects of decays experiments at IDS, and with the ISOLDE facility at CERN. You will also learn how to use powerful analysis tools like ROOT, the most popular software in the nuclear and particle physics field. Finally, you will gain in-depth knowledge about nuclear structure far from stability and a wide range of nuclear experimental techniques.

CSIC-25

Tutor: Teresa Kurtukian Nieto,
Instituto de Estructura de la Materia, CSIC / LP2i Bordeaux CNRS, Francia.
kurtukia@lp2ib.in2p3.fr
Title: Study of A=88-90 Br and Se decay important for the rapid-neutron capture process of stellar nucleosynthesis

Abstract: The study of the properties of neutron-rich nuclei with mass around A=90 is important in order to understand the nucleosynthesis process behind the observed abundances of elements in the solar system and some ultra-metal-poor (UMP) stars. Recent observations of anomalously large abundances of stable Sr, Y, and Zr in some UMP stars, as compared to heavier neutron-capture elements, have brought about new questions regarding the rapid neutron capture process (r-process) mechanism and its possible sites.
The goal of the proposed TFM is to use gamma spectroscopy techniques to identify new states on selenium and bromine isotopes which are the beta decaying precursors of the stable Sr, Y, and Zr.
What are you going to do? The TFM research project will consist of the data analysis of an experiment performed at ILL, Grenoble measuring neutron-induced fission fragments from 235-U. You will analyze the beta decay of exotic nuclei with mass A=88, 89 and 90, measured using an array of two clover Ge detectors and the LOHENIE plastic scintillator array coupled with a BGO detector.
What are you going to learn?
During the TFM work, you will learn about stellar nucleosynthesis processes, in particular about the r-process, as well as the nuclear structure of neutron-rich nuclei studied by beta decay. You will learn about beta and gamma-ray detection techniques, as well as data analysis including coincidences and add-back techniques that will be implemented using CERN/ROOT framework and C++, which are tools extensively used in nuclear and particle physics.

CSIC-26

Tutors: Mª José García Borge/Vicente García Távora
Instituto de estructura de la materia, CSIC.
mj.borge@csic.es , vicente.garcia@csic.es
Title: Monte Carlo Simulations for Nuclear Reactions of astrophysical interest.

Abstract: Along this academic year we plan to perform a series of studies of reactions of astrophysical interest, 7Li(3He,p)9Be (scheduled for October 17-19) in the tandem accelerator of 5 MV of the CMAM-UAM (Madrid).
What are you going to do? The master research work will consist of the study of the optimum energy to realise the experiments, performing simulations to obtain the best setup configuration, and analyzing the results of the simulations. A comparison of the simulations with the real data obtained is the final aim.
What are you going to learn? During this Master project, you will learn to use some physical and kinematics calculators like LISE++. You will also perform simulations of the experimental setup using GEANT4, and you will learn advanced data analysis techniques mainly using C++ and python. All those programs and techniques are used nowadays to perform real Nuclear Physics experiments from the top-tier facilities like CERN to the smaller ones like CMAM.

CSIC-27

Tutors: Olof Tengblad / Vicente García Távora
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Title: Experimental study of Nuclear Reactions of astrophysical interest.

Abstract: During this academic year, we plan to perform a series of studies of reactions of astrophysical interest, 10B(d,alpha)8Be in the tandem accelerator of 5 MV of the CMAM-UAM (Madrid).
What are you going to do? The research work of the master will consist of the preparation of the electronics and DAQ (data acquisition system), which represents one of the things that students are most afraid of when they have to face for first time a real experiment. The student will also participate in the experiment and analyze the data obtained.
What are you going to learn? During this work, you will learn about the main detectors, electronics and DAQ used nowadays for frontier experiments also used at Facilities like ISOLDE at CERN and also in the smaller ones like CMAM. You as master student are going to learn also how to use some physical and kinematics calculators like LISE++ and advanced data analysis techniques mainly using C++ and python.

CSIC-28

Tutors: Christophe Rappold / Samuel Escrig López,
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Title: Development of a machine learning discriminator for improving the 3ΛH signal in HypHI Phase 0 experiment

Abstract: In the previous experiment of the HypHI collaboration, the Phase 0 experiment, the light hypernuclei 3ΛH and 4ΛH were observed in the collision of 6Li+12C at 2AGeV. The goal of the proposed TFM is to use of machine learning techniques for improving the signal-to-background ratio of 3ΛH experimental signal.
What are you going to do? The work for the TFM will consist to use the different machine learning framework for tabular dataset to improve the analysis of the experimental data of the HypHI Phase 0 experiment. The experimental data and Monte-Carlo simulations will be used for creating, teaching and evaluating the different ML algorithms.
What are you going to learn? You will learn to use the ROOT and GEANT4 frameworks applied to an already performed experiment of high energy nuclear physics. You will learn advanced data analysis techniques mainly using C++ and python. You will learn about machine learning techniques and how to use them adequately. You learn about the hypernuclear physics and the structure of the observed light hypernuclei.

CSIC-29

Tutors: Christophe Rappold / Samuel Escrig López
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Title: Efficiency study of the particle identification in the HypHI Phase 0 and WASA-FRS experiments.

Abstract: In the experiments of the HypHI collaboration, the phase 0 experiment and the WASA-FRS experiment, light hadron were measured. A new particle identification algorithm is in development based on statistical method. Efficiciency study must be carry out and the experimental yield ratio of identified hadron will be estimated.
What are you going to do? The research work will consist of studying the efficiency of the particle identification algorithm on the GEANT4 simulations of the Phase 0 and of the WASA-FRS experiments. Once the differential efficiency of algorithm as function of the physical observable is defined, the yield ratio of the different identified hadron in the minimum bias dataset of the Phase 0 experiment will be estimated.
What are you going to learn? During this work, you will learn about advanced data analysis techniques of the particle identification mainly using ROOT framework and C++. Those techniques are the base of the analysis in high energy nuclear and particle physics. You will then learn how to applied knowledge from GEANT4 simulations on to the analysis of experimental data to extract physical observable such as yield ratio of measured particle species, and how to relate those observable to the understanding of nuclear collisions.