MASTER THESIS proposals 2018-2019

PATH 3: APPLICATIONS

1. MODELLING PARAMETERS OF INTEREST IN RADIOBIOLOGY (LET, RBE) USING A MONTE CARLO APPROACH AT BOTH MACRO AND MICRO-DOSIMETRIC SCALE

LNS (Catania, Italy)

Supervisor: Giacomo Cuttone: cuttone@lns.infn.it

Abstract:

Montecarlo approach is mandatory if we want to improve the capability to predict the radiobiological effects of different radiation qualities.The study has to be done at micro and macro dosimetric level simulating these effects at cell level. The work will be carried out with a research group having great experience and responsibilities in the Geant4 collaboration in this field.

2. INVESTIGATION OF NEW IRRADIATION AND IMAGING APPROACHES TO ENHANCE THE RADIOBIOLOGICAL EFFECTIVENESS OF PROTON BEAM USING NUCLEAR REACTIONS. EXPERIMENTAL AND SIMULATION ACTIVITIES

LNS (Catania, Italy)

Supervisor: Giacomo Cuttone: cuttone@lns.infn.it

Abstract:

Nowadays proton therapy is a clinical tool well established while carbon therapy in still considered at the level of clinica research. There is even now a great research interest in studying alternative scheme od irradiation for protons in conjunction with new molecules to enhance the radiobiological effectiveness. In particular proton boron nuclear reactions or proton fluorine nuclear reactions will be studied either at the level of simulations and experimentally. The work will be carried out in a research group already well involved and active in this field

3. STUDY OF SEMICONDUCTOR DETECTORS USING LOW ENERGY PARTICLE ACCELERATORS

(CNA-Sevilla, Spain)

Supervisor: Dr. Javier García López (fjgl@us.es).
Dra. Mª Carmen Jiménez Ramos (mcyjr@us.es).

Abstract:

There are many fields of research and technology which require the use of semiconductor detectors working in harsh radiation environments, for example, in high energy physics facilities, remote control systems in nuclear reactors, radiation therapy systems, nuclear fusion devices and the aerospace sector.

In this work we will carry out different experiments with the 3 MV Tandem accelerator of the CNA, combined with theoretical modelling and simulation, for improved understanding of how radiation induced defects influence the electronic properties of Si, SiC and diamond detectors. Our main tool will be the use of a nuclear microprobe, together with the Ion Beam Induced Current (IBIC) technique, for controlled irradiation and characterization of the devices at the micrometric scale.

Candidates should have interest in experimental nuclear physics and a good background in radiation detectors, nuclear electronics and Matlab.

4. FEASIBILITY STUDY OF IMPURITY IMAGING SPECTROSCOPY

University of Seville

Supervisor: Manuel García Muñoz: mgm@us.es
Eleonora Viezzer: eviezzer@us.es

Abstract:

Doppler spectroscopy provides a wealth of information on the physics of plasma confinement in tokamaks. The standard approach makes use of a grating spectrometer that disperses the spectrum in one spatial dimension and reserves the other to obtain a 1D spatial section of the region of interest. In many cases, however, such as scrape-off-layer (SOL) and divertor spectroscopy, a 2D imaging capability is required in order to correctly interpret the spectral information. "Coherence-imaging" systems (CIS) have the unique capability to obtain time-resolved 2D projections of key spectral quantities in passive Doppler spectroscopy. This project aims to develop a synthetic diagnostic for ASDEX Upgrade and to perform a feasibility study on the possibility of measuring the impurity distribution in the SOL.

5. EDGE MOMENTUM TRANSPORT STUDIES USING TRANSP AND ASTRA

University of Seville

Supervisor: Manuel García Muñoz: mgm@us.es
Eleonora Viezzer: eviezzer@us.es

Abstract:

The connection between the plasma rotation profile and the stability and confinement of the plasma has made momentum transport an active area of tokamak research. It is commonly accepted that velocity shear can lead to improved confinement through the suppression of turbulence. This project aims to get a better under standing of momentum transport at the plasma edge of the plasma. The student will get familiar with the transport code TRANSP to calculate the torque density profiles. First, simulations for a steady phase during H-mode will be performed. Afterwards, the study will be extended to the entire ELM cycle. The ultimate goal is to study the edge momentum transport. The edge toroidal rotation profile will be modelled with ASTRA using the toroidal torque balance equation. The modelled result will be compared to the measured profile.

6. INSTRUMENTATION AND MC SIMULATION TO IN-BEAM REAL TIME MONITORING OF DOSE DEPOSITION IN HADRONTHERAPY

Universidad Complutense de Madrid

Supervisor: José M. Udías: jose@nuc2.fis.ucm.es

Summary:

At least two clinical protontherapy beamlines will begin beam delivery early 2020 in Madrid. Within this MSc project instrumentation for real-time in-beam monitoring of dose delivered by hadrons would be developed, either by means of prompt gammas as well as prompt PET emission. The Nuclear Physics Group of Complutense University in Madrid has massive experience in the development of gamma detectors with state of the art spatial, energy and time resolution, and being based on SiPM, they are compatible with magnetic fields.

The group exhibits a long standing collaboration with the company SEDECAL in Madrid that develops and sells nuclear imaging equipment all over the world and it is also involved in this project. The MSc project would be involved in MC simulations of the detectors, in the actual detector development in our lab, as well as in image reconstruction of dose delivery'

http://nuclear.fis.ucm.es

Possibility of funding for PhD: yes.

Possibility of joint project with Catania: yes

7. NUMERICAL TOOLS FOR THE DESIGN OF OPTIMIZED STELLARATORS.

CIEMAT, Madrid, Spain

Supervisor: Jose Luis Velasco. Theory Group, Laboratorio Nacional de Fusión, CIEMAT. Madrid (Spain), joseluis.velasco@ciemat.es
http://fusionsites.ciemat.es/jlvelasco

Abstract:

Neoclassical transport is a fundamental part of stellarator plasma physics, since it is expected to account for most of the energy losses in a stellarator reactor [1]. Therefore, its minimization is in the core or any process of stellarator design. In the course of this master thesis, the student will become involved in the use of a recently developed numerical code [2,3] that it is able to characterize accurately and fast the neoclassical transport of a magnetic configuration.

Bibliography: Papers available at http://fusionsites.ciemat.es/jlvelasco/

[1] A Dinklage, et al. Validation Study of Neoclassical Transport Modeling in Medium- to High-Density Stellarator-Heliotron Plasmas. Nuclear Fusion, 53(6):063022, 2013.
[2] I Calvo et al. The effect of tangential drifts on neoclassical transport in stellarators close to omnigeneity. Plasma Physics and Controlled Fusion, 59(5):055014, 2017.
[3] J. L. Velasco, et al. Large tangential electric fields in plasmas close to temperature screening. Plasma Physics and Controlled Fusion, accepted https://arxiv.org/abs/1712.03872.

Web of one of our ongoing projects:
http://fusionsites.ciemat.es/stellaratortransport/

Required skills: Scientific computer programming, good physics background.
Preferred skills: Good mathematics background.

8. FAST PARTICLE DYNAMICS IN THERMO-NUCLEAR FUSION PLASMAS.

CIEMAT, Madrid, Spain

Supervisors: Álvaro Cappa (EC Heating group), José M. García-Regaña (Theory Group): alvaro.cappa@ciemat.es / jose.regana@ciemat.es

Abstract:

Highly energetic α particles will be the main fusion product in future reactors. The good performance of the reactors strongly depends on the fact that these particles transfer their energy through collisions back the reactants (Deuterium and Tritium) before they abandon the confining magnetic field (which can be of tokamak or stellarator type). In the present project we propose the study of the transport properties of fast particles in thermo-nuclear fusion plasmas, the causes for their bad confinement, and in particular the effect of inducing externally currents into the plasma.

Bibliography: Basic physics of Alfvén instabilities driven by energetic particles in toroidally confined plasmas. W. W. Heidbrink et al. Phys. Plasmas 15 055501 (2008)

Required skills: Good physics background.
Preferred skills: Scientific computer programming.

9. IMPURITY TRANSPORT IN STELLARATORS

CIEMAT, Madrid, Spain

Supervisor: José Manuel García-Regaña, José Luis Velasco. Theory Group. Laboratorio Nacional de Fusión, CIEMAT. Madrid (Spain): jose.regana@ciemat.es / joseluis.velasco@ciemat.es
http://fusionsites.ciemat.es/stellaratortransport/

Abstract:

The viability of nuclear fusion as source of energy depends to a great extent on the low presence of impurities (highly charged ions) present on its fuel (a plasma of Deuterium and Tritium). In the present project we aim at studying the collisional transport of impurities embedded in such plasmas and addressed by means of massive parallel computing simulations. In particular we aim at finding plasma operation windows where its accumulation is mitigated or absent.

Bibliography: "Electrostatic potential variation on the flux surface and its impact on impurity transport", J. M. García-Regaña et al. Nucl. Fusion 57, 056004 (2017).

Some useful links: www.iter.org, https://www.ipp.mpg.de/w7x

Required skills: Good physics background.
Preferred skills: Scientific computer programming

10. PET QUANTIFICATION FOR TREATMENT EVALUATION PURPOSE IN PATIENT AND PRE-CLINICAL STUDIES

IBFM-CNR Cefalù and LNS-INFN Catania

Supervisor: Giorgio Russo: giorgio.russo@ibfm.cnr.it

Summary:

Positron Emission Tomography (PET) is a non-invasive medical imaging technique which has the advantage over Computerized Tomography (CT) and Magnetic Resonance (MR) of providing direct information about patient's functional processes. Parameters derived from PET imaging might be predictive of patient therapy response to the pharmacological treatment of cancer. They are useful in obtaining an objective evaluation of the changes in the patient condition improving clinical cancer treatment decision making. In addition, metabolic parameters are often faster changing and more indicative of therapy effects than morphological changes (CT or MR). For these reasons, PET imaging is being increasingly considered for the quantitative assessment of individual response to therapy and for clinical testing of novel cancer therapy protocols.
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 and Cannizzaro Hospital in Catania. 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.

Possibility of joint project with other clinical PET institutes

11. RADIOPROTECTION STUDIES FOR SUPERCONDUCTING CYCLOTRON UPGRADE AT LNS-INFN USING A MONTE CARLO APPROACH

LNS-INFN Catania

Supervisor: Giorgio Russo: giorgio.russo@ibfm.cnr.it

Summary:

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, as NUMEN ones [1], 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[2]. The simulations will also allow to estimate the materials and air activation.

Reference

[1] https://web.infn.it/NUMEN/index.php/it/

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

12. INSTRUMENTATION AND MC SIMULATION OF A X-RAY POSITION SENSITIVE DETECTOR FOR X-RAY SCANNING MACHINE IN AIRPORTS.

Università di Catania, Italy

Supervisors: Bogdan Wojtsekhowski (bogdanw@jlab.org) (College of William and Mary, Williamsburg, VA, USA), Catia Petta (catia.petta@ct.infn.it) (University of Catania, Italy)

Summary:

High quality x-ray scanners are very important for safety in the transportation industry.
At the same time, the radiation dose induced during such a scan is always a concern.
One possibility to reduce the dose is provided by a coordinate sensitive detector. The student in this project will do the study of the current state of the x-ray machinery and the MC study of a novel high efficiency coordinate detector. Results of this development could provide a starting point for an industrial application of the proposed instrument.

13. MEASUREMENT OF LONG-LIVED RADIONUCLIDES IN ATMOSPHERIC SAMPLES BY ACCELERATOR MASS SPECTROMETRY (AMS)

University of Seville

Supervisors: Elena Chamizo Calvo: e-mail echamizo@us.es
Jose María Lopez Gutierrez: e-mail lguti@us.es

Summary:

The origin of radionuclides in the atmosphere can be both natural and artificial. In any case, especially if these radionuclides have a long half-life, it can be very interesting to analyse the evolution of their concentrations in the air, as the are excellent tracers of environmental processes. This can give information on their origin, transport and exchange of matter between different environmental compartments.

The use of radiometric techniques to detect long-lived radionuclides is often very inefficient and therefore does not allow evaluating their presence in the air with enough sensitivity. This happens commonly in environmental samples. The use of Accelerator Mass Spectrometry (AMS) is an alternative. This technique is based on the use of accelerators and presents much higher sensitivity.

We propose the use of AMS for the detection of long-lived radionuclides (as ^{129}I and Pu isotopes) in the air at the Centro Nacional de Aceleradores (CNA) in Seville. This work will be carried out under the supervision of the Applied Nuclear Physics group of the University of Sevilla. This group has more than 20 years of experience in this technique and an excellent reputation at an international level.

14. RADIOBIOLOGICAL STUDIES WITH LOW ENERGY PROTONS AT CABIMER AND CNA

University of Seville

Supervisor: Dr. M.I. Gallardo; gallardo@us.es
Dr. Pablo Huertas. pablo.huertas@cabimer.es

Summary:

Proton radiation induces biological effects that are distinct of those caused by irradiation with photons or beta particles. The differences could be mostly due to the way protons (or other heavy particles) delivered their energy in their paths through matter. The Linear Energy Transfer (LET) is a magnitude that characterizes this property beyond the absorbed dose. In order to analyze and better understand those differences, we propose to study the repair of DNA lesions caused by protons at various LET and dose values. To do so, we will use human cells in culture that will be irradiated with protons or beta/gamma particles to perform several simple experimental approaches. First, using fluorescent microscopy we will study the formation of ionizing-radiation induced foci of several DNA repair factors (such as γ-H2AX; 53-BP1; Ku70; Brca1; Rad51, etc...) in cells treated with similar doses of both types of radiation. We will analyze both the formation and the kinetics of disappearance of those foci as a proxy for DNA repair. Additionally, we will check for signs of genomic instability in response of sublethal doses of radiation, such as the persistence of γ-H2AX foci or the formation of micronuclei 24 hours after radiation. This will allow us to estimate the long term effects associated to either class of radiation. Finally, we well measure the sensitivity to radiation using clonogenic assays of cells treated with either type of radiation. If times allow it, we could combine those approaches with the depletion of several bona fide DNA repair factors like CtIP or BRCA1.

Proton irradiations will be done at CNA (National Center of Accelerators) with the external line of the 3 MV tandem accelerator that has already been optimized for monolayer cell culture irradiations. The student will star with the current set-up introducing, if necessary, (minor) modifications to control the uniformity of the proton field over the new cell cultures. She/he will be able to calculate, measure and control absorbed dose and LET in the sample.

Reference irradiations will be performed using the 137-Cs irradiator at CABIMER. Measurements of dose distributions should be done.

15. FEASIBILITY STUDY AND DEVELOPMENT OF NEW TECHNIQUES FOR ENHANCE THE CT IMAGE IN RADIOTHERAPY BY MEANS OF NANOPARTICLES

University of Seville

Supervisor: Antonio Leal Plaza (alplaza@us.es)
Tutor: Maribel Gallardo Fuentes (gallardo@us.es)

Summary:

Functional imaging is a key topic for individualized radiotherapy (RT) of patients with cancer. In spite of there are many image modalities as functional MRI or PET/CT based on multiple radiotracers, the direct implementation of the image in the treatment planning systems is a controversial issue due to inherent spatial and temporal uncertainties linked to technical aspects and also because of the no direct correlation between the intensity value in the image and the specific biological entity.

Nanoparticle based on high Z elements, such as Au (GNP), is an approach raising high interest since would provide the possibility of using the conventional CT image for providing morfo-functional information [1] with an adequate spatial resolution and also with the electronic density, which is always required for dose calculation. Moreover, GNP is also considered as potential theranostic agent, by exploring its possibilities for dose enhancement and radiosensitization under therapeutic beams [2]. Anyway, toxicity linked to these inorganic elements has to be assessed before under preclinical models based on experiments with animals, where pharmacodynamic aspect can be put into play and mass concentration values for theragnostic purpose can be assessed.

Unfortunately, the commitment with toxicity leads to low concentrations what reduce ability of CT contrast by means of NP. To improve CT performance, several approaches are under study. On one hand, X-ray fluorescence is a technique that can identify, quantify, and locate elements within objects by detecting x-ray fluorescence (characteristic x-rays). X-ray fluorescence computed tomography (XFCT) is performed often under synchrotron source but benchtop settings with conventional polychromatic x-ray sources are being evaluated for routine biomedical applications [3]. On the other hand, dual-energy CT is an advanced imaging technique that allows for selective visualization and quantification of multiple high atomic number materials in a single scan [4]. Since the mass concentration plays an essential role for the clinical applicability of NP, beyond the relative information in the CT image, having the possibility of quantifying the presence of the element in the same CT study is of great interest.

This work proposes a feasibility study of the equipment available at the National Accelerator Center (CNA) and at the Virgen Macarena Hospital in Seville (HUVM),

to implement these special CT techniques in a research project already started for the implementation of NP as a theragnostic agent in Radiotherapy. PET/CT device installed in the CNA, as well as the dual-energy CT in the HUVM will be available. The work will be carried out in the Medical Physics laboratory in the Faculty of Medicine, where a multinode computation system will allow carrying out Monte Carlo studies to obtain the involved theoretical results.

References:

[1] L. E. Cole, R. D. Ross, J. M. R. Tilley, T. Vargo-Gogola, and R. K. Roeder, "Gold nanoparticles as contrast agents in x-ray imaging and computed tomography," Nanomedicine, vol. 10, no. 2, pp. 321–341, 2015.

[2] Z. Kuncic and S. Lacombe, "Nanoparticle radio-enhancement: Principles, progress and application to cancer treatment," Phys. Med. Biol., vol. 63, no. 2, p. 02TR01, Jan. 2018.

[3] N. Manohar, F. J. Reynoso, P. Diagaradjane, S. Krishnan, and S. H. Cho, "Quantitative imaging of gold nanoparticle distribution in a tumor-bearing mouse using benchtop x-ray fluorescence computed tomography," Sci. Rep., vol. 6, no. 1, p. 22079, Apr. 2016.

[4] J. R. Ashton, K. D. Castle, Y. Qi, D. G. Kirsch, J. L. West, and C. T. Badea, "Dual-Energy CT Imaging of Tumor Liposome Delivery After Gold Nanoparticle-Augmented Radiation Therapy," Theranostics, vol. 8, no. 7, pp. 1782–1797, 2018.

16. ACTINIDES ISOTOPES STUDIES ON HOT PARTICLES BY ACCELERATOR MASS SPECTROMETRY (AMS)

Centro Nacional de Aceleradores (CNA, Seville, Spain)

Supervisors:
Elena Chamizo Calvo, CNA
MªCarmen Jiménez Ramos, CNA
Rafael García-Tenorio, CNA-ETSA

Summary:

Following nuclear events such as nuclear weapons tests and nuclear accidents, particles of different sizes containing actinides in high concentrations are released into the environment. 235U (T1/2=7.04x108 y) and 239Pu (T1/2=24110 y) are the fissible radionuclides that have been used as a source of nuclear energy in nuclear weapons and reactors, therefore U and Pu isotopes and the major constituents of those so-called hot-particles (HP). To date, much information on HP composition has been published on a series of radionuclides that can be determined by conventional radiometric (e.g. alpha or gamma spectrometry) and/or mass spectrometry techniques (e.g. ICPMS). This is the case of 241Am (T1/2=432.2 y) (i.e. decay product of 241Pu (T1/2=14 y)), 239Pu, 240Pu (T1/2=6524 y) (i.e. produced by neutron activation of 239Pu) and 234,235U (ie. naturally occurring but with a different isotopic compositions in nuclear devices). However, there is almost any information on 237Np (T1/2= 2.14x106 y) and 236U (T1/2=2.34x107 y), which are present in HP at ultra-trace levels. 237Np is produced from neutron activation of 238U and 235U, and is the decay product of 241Am. 236U is mostly produced by neutron activation of 235U. Relevant information on the source of the hot particles and on their history of irradiation can be obtained from the study of their isotopic abundance in HP, in combination with Pu and U isotopic ratios. At the CNA, HP samples from different scenarios are available: i) from Trinity nuclear test site in New Mexico, where the first US nuclear detonation was carried out in 1945; ii) from Semipalatinks nuclear test site, the main proving grounds by the former Soviet Union in the period 1949-1989; and iii) from Thule (Greenland) and Palomares (Spain), where the fuel of thermonuclear devices was spread accidentally in 1966 and 1968, respectively. In the frame of this Master Thesis, actinides measurements (236U, 237Np, 239,240Pu and 241Pu(241Am)) will be performed on the 1 MV Accelerator Mass Spectrometry (AMS) system at the Centro Nacional de Aceleradores (CNA, Seville, Spain). This device is the only AMS system in operation in Spain, and is part of a short list of AMS devices worldwide that have demonstrated their potential to measure actinides on a routine basis.