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

Academic year 2022-2023

CT-01

Title: Study of Reaction Mechanisms and isospin equilibration dynamics at Fermi energies

Abstract: The project aims at investigating topics related to reaction mechanisms, peculiar of heavy ion collisions at Fermi energies. The analysis of data collected in experiments performed with Chimera and Farcos multi-detectors, operating at Laboratori Nazionali del Sud, in Catania, will allow to study data analysis techniques employed in this energy domain. In particular, the influence of the isospin degree of freedom on reaction mechanisms will be investigated and variables useful to improve the knowledge of the behavior of nuclear matter will be analyzed. In particular, the competition between reaction mechanisms and the Intermediate Mass Fragment production phenomenon will be analyzed for the reactions produced accelerating ^{124}Sn, ^{124}Xe and ^{112}Sn beams at 20 AMeV on targets of ^{64}Ni, ^{64}Zn and ^{58}Ni. Comparisons of the experimental data with semiclassical transport models and/or molecular dynamics models will be encouraged.

Supervisors: E. Geraci (UniCT), P. Russotto (INFN-LNS), E. Pagano(INFN-LNS)

CT-02

Title: Isospin dependence of Fragment Production in central collisions for 58,62Ni+40,48Ca systems at 35 AMeV

Abstract: The project aims at investigating the influence of the isospin degree of freedom on fragment production for sources formed in central collisions of 58,62Ni+40,48Ca systems at 35 AMeV. The experimental data, collected in an experiment performed with Chimera multi-detector at Laboratori Nazionali del Sud, in Catania, allow to investigate the multifragmentation process and to extract variables useful to study the decay path of sources of one hundred nucleons and excitation energies around 2-4 AMeV. The isotopic composition of fragments emitted in the two systems will allow to study and to explore the isospin dependence of the nuclear equation of state (EOS) of nuclear matter under laboratory-controlled conditions. In addition, information about the space–time evolution of the reaction zone could be obtained via fragment-fragment correlation functions. Comparisons of the experimental data with semiclassical transport models will allow to characterize the entering of the system in the spinodal region and to obtain valuable information on fragment formation at sub saturation densities.

Supervisors: E. Geraci (UniCT), E. De Filippo (INFN-sez Ct)

CT-03

Title: Constraint Molecular Dynamics and Equilibration Phenomena

Abstract: Nuclear Iso-vectorial forces determining the not-well known EOS for asymmetric matter lead in finite systems the “so called” Isospin equilibration phenomena. The project aims at investigating this equilibration process and the connection with the excitation and decay of the pre-equilibrium Dipolar ɣ-ray emission as a precursor messenger of the process. The goal is to get information on the Iso-Vectorial forces at density far from the saturation one. Calculations obtained with the recently improved Costraint Molecular Dynamics Model [Papa M, Phys. Rev. C 87 014001, M.Papa et al PRC 91 041601] will be performed for systems $^{48}Ca+^{27}Al$ and/or Ni+Ca isotopes at 20-40 AMeV. The study will be focused on reaction mechanisms mainly produced in central/semi-central collisions. For such systems some experimental data were collected with Chimera apparatus at Laboratori Nazionali del Sud, in Catania. Therefore, comparisons of the calculations with experimental data could be performed. The thesis project could thus include:

-calculation with the model of the dipolar signal from the charge and mass distribution of the produced clusters for different reaction mechanisms.

-calculation of the same quantity microscopically in the overlap region.

-calculation of the pre-equilibrium ɣ-ray yield

-improvement of the clusterization stage.

Supervisors: E. Geraci (UniCT), M. Papa (INFN-sez Ct)

CT-04

Title: STUDY OF THE $^{17}O(p,)^{14}N$ REACTION AT ASTROPHYSICAL ENERGIES VIA THE INDIRECT TROJAN HORSE METHOD

Nuclear astrophysics aims at studying nuclear reactions responsible for both energy generation and the nucleosynthesis of chemical elements. Among them, the CNO species are the most abundant in the Universe beyond hydrogen and helium and play a key role in several astrophysical scenario. In details, the $^{17}O(p,)^{14}N$ reaction enters at least in three different scenarios, ranging from the energy production in stars via the CNO-cycle or consuming oxygen during AGB evolutionary stages or producing the radioactive ^{18}F isotope during NOVAE explosion.

Because of its key importance in astrophysics, the $^{17}O(p,)^{14}N$ reaction rate needs to be measured at the astrophysically relevant energies, often inaccessible via direct measurements because of Coulomb barrier penetration effects. Indeed, the low-energy $^{17}O(p,\alpha)^{14}N$ reaction cross section is dominated by two resonances: one at about 65 keV above the ^{18}F proton threshold, corresponding to the E_x =5.673MeV level in ^{18}F, and one at 183 keV (E_x =5.786 MeV). Thus the indirect Trojan Horse Method could be applied to the quasi-free ^{2}H(^{17}O, ^{14}N)n reaction thus allowing one to by-pass the typical difficulties of a direct investigations. A devoted experiment has been already performed at INFN-LNS of Catania by using a 43.5 MeV ^{17}O beam provided by the TANDEM accelerator. The experimental data are already “in-house” and the good candidate will be called to perform detector calibrations (angular and energy ones), energy loss evaluations, reaction channel selection, reaction mechanism selection and extraction of the ^{17}O(p,α) ^{14}N cross section of interest here. A nuclear physics background, basic skills in C++ and ROOT represent a further advantage.

Supervisors: Romano S. (romano@lns.infn.it), Lamia L. (llamia@lns.infn.it), M.L. Sergi (sergi@lns.infn.it)

CT-05-06-07

Titles:

1) Modeling of direct inelastic reactions as a tool to learn about nuclear structure properties;
2) Modeling of charge-exchange nuclear reactions and study of the analogies with electroweak (beta and double beta decay) processes;
3) Theoretical description of dissipative Heavy Ion Collisions and impact on the nuclear Equation of State and 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 and their connection with (double) beta-decay processes, to more dissipative heavy ion collisions, allowing to explore the nuclear matter Equation of State.

Supervisor: M. Colonna (colonna@lns.infn.it)

CT-08-09

Titles:

1) Radiation tolerance tests for SiPM candidates as sensors for a dRICH detector at EIC
2) Study the forward dRICH (dual-radiator Ring Imaging Cherenkov)detector at Electron Ion Collider (EIC)for particle identification

Abstract: The Electron Ion Collider **(EIC)** project at Brookhaven National Laboratories (BNL) by the US Department of Energy (DoE) has triggered intense R&D programs, towards the choice of detectors.A new experimental Collaboration is born **(ePIC)** on July 2022.
The experimental activity in which the Catania group is involved is to build and to test an dRICH (dual-radiator Ring Imaging Cherenkov) detector.

The forward RICH (dRICH) at ePIC experiment is expected to cover the intermediate and high momenta hadron particle identification exploiting a dual radiators (gas and aerogel) design and with mirrors providing focusing off acceptance.
The photosensors currently considered as baseline option are Silicon PhotoMultipliers (SiPM). INFN is currently leading a structured R&D program, supported also by aDoE, to investigate the radiation effects on these devices, while maintaining the possibility to act as single photon detectors. The radiation environment will be moderately hostile, with a radiation load that should reach at maximum a fluence of 1011 1-MeV neq cm−2. An irradiation campaign on SiPM has been carried out at theTIFPA (Trento Institute for Fundamental Physics and Applications) and others will take place in the coming months.

Supervisor: Prof. Cristina Natalina Tuvè (UniCt)

CT-10-11-12-13

Titles:

1) Physics at The Electron Ion Collider (EIC)
2) Heavy flavor production and hadronization at Electron Ion Collider (EIC) project at Brookhaven National Laboratories (BNL)
3) Deep Inelastic Scattering at Electron Ion Collider (EIC) project at Brookhaven National Laboratories (BNL)
4) Artificial Intelligence (AI) at Electron Ion Collider (EIC) project at Brookhaven National Laboratories (BNL, USA)

Abstract: The Electron Ion Collider (EIC) project at Brookhaven National Laboratories by the US Department of Energy has triggered intense simulation on Physics topics.
The Electron Ion Collider facility will allow the study of collisions between electrons and ions ranging from proton to Uranium, with 70% polarized beams for electrons and light ions (proton, 3He, 3H, 7Li), at variable center-of-mass energy between 20 and 140 GeV and a foreseen peak luminosity of 1034 cm−2 s−1. Given its unique features, the EIC is expected to play a major role in investigating important aspects of the structure of nucleons and nuclei, such as the origin of nucleon mass and spin, and our understanding of how nuclear forces and binding emerge from QCD, the theory of strong interactions.

Supervisor: Prof. Cristina Natalina Tuvè (UniCt)

CT-14

Title: Study of rare resonances and light nuclei in high energy nuclear collisions at the LHC with the ALICE detector

Abstract: The high luminosity reached at the Large Hadron Collider and the unique characteristics of the ALICE detector for tracking and identification of particles allow to investigate rare probes, such as short-lived resonances and light nuclei. The identification of these particles in high energy nuclear collisions is a challenge due to

the large particle multiplicity. The thesis will be focused on the study of one of these rare signals, using traditional techniques as well as machine learning algorithms. The student will conduct the data analysis activity as part of the ALICE experiment.

Supervisors: Angela Badalà (INFN-CT), Giuseppe Mandaglio (UniME & INFN-CT), Paola La Rocca (UniCT & INFN-CT)

CT-15

Title: Characterization of silicon pixel structures for the new Inner Tracking System of the ALICE experiment at LHC.

Abstract: ALICE is an experiment based at the CERN LHC that has been designed and optimised for heavy-ion physics. It performs particle tracking and identification through several techniques and multiple detector technologies. ALICE is developing the ITS3 (Inner Tracker System) as upgrade of the inner layers of the presently installed ITS, with the aim to improve its tracking performance and reduce the material budget. The ITS3 will be based on truly cylindrical silicon sensor and readout electronics implemented in the same device. In order to develop the proper technology, an intense Research and Development activity is currently ongoing on a large number of sensors protypes. The thesis work will be focused on the characterization of small and large pixel matrixes, which will be tested in the lab and under beam.

Supervisors: Paola La Rocca (UniCT & INFN-CT), Antonio Trifirò (INFN-CT & UniME), Angela Badalà (INFN-CT)

CT-16

Title: PET RADIOMICS STUDIES

Summary:
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 analyze radiomic features using Artificial Intelligence (AI) methods, like Machine Learning and Deep Learning, 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.

Possibility of joint project with other clinical PET institutes

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

CT-17

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

Summary:
The Laboratori Nazionali del Sud are one of the four national laboratories of Istituto Nazionale di Fisica Nucleare (INFN). At LNS, two accelerators are operating, a Tandem Van de Graaf with a maximum terminal voltage of 15 MV, and a Superconducting Cyclotron. The two machines allow to produce and accelerate heavy ion beams in a very wide range of mass. The beams are used to several research application from nuclear studies to healthcare and heritage fields.
The implementation of research activities needs to a radioprotection study of gamma and neutron field inside and outside experimental rooms, and a characterization of radionuclides produced. 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. In the next years, a new machine will be implemented using laser plasma interaction to accelerate proton and electron beams. To perform radioprotection studies, several montecarlo simulations need to be developed using FLUKA code. The aim of thesis will be to understand radioprotection issues inside a complex environment, to use FLUKA tool and to perform gamma spectrometry measurements and analysis.

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

Supervisors: Giorgio Russo (giorgio-russo@cnr.it);
Renata Leanza, Technologist LNS INFN (renata.leanza@lns.infn.it);
Salvo Russo, Chief of Radiation Protection Unit at LNS, (russos@lns.infn.it)

CT-18

PANDORA PROJECT

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

Polarimetric setup - able to measure the magnetoplasma-induced Faraday rotation in a compact size plasma trap - has been proven to provide reliable measurement of the plasma line-integrated electron density [1]. This thesis work will develop an analysis method for polarimetric measurements on a mm-wave testbench [2] – based on the detection of Lissajous figure from a two channels scope (80 gigasample) in an x-y representation of a direct probing RF signals crossing the magnetiplasma. The system was on purpose designed and developed for the PANDORA chamber case study [3], which represents an “intermediate” case between the ultra-compact plasma ion sources and the large-size thermonuclear fusion devices).

*[1] E. Naselli et al. (2018) JINST **13** C12020.*

*[2] G. Torrisi et al. (2022) Front. Astron. Space Sci. **9** 949920.*

*[3] D. Mascali et al. (2022) Universe **8**, 80.*

UniCT Supervisor: David Mascali

Co-Tutors: Giuseppe Torrisi (INFN-LNS), Eugenia Naselli (INFN-LNS)

CT-19

Title: Photonics crystals for ultracompact dielectric accelerators

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).

UniCT Supervisor: David Mascali

Co-Tutors: Giuseppe Torrisi (INFN-LNS), Giorgio Mauro (INFN-LNS), Gino Sorbello (UniCT)

CT-20

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

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

UniCT Supervisor: D. Mascali

Co-Tutors: G. Sorbello/ L. Di Donato (UniCT-DIIEI), G. Torrisi (INFN-LNS)

CT-21

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

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, 2]. 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 [3].

[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] E. Naselli et al., Design study of a HPGe detector array for β-decay investigation in laboratory ECR plasmas, Front. Phys. 10, 935728 (2022).

[3] 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).

UniCT Supervisor: David Mascali (INFN-LNS and UNICT-DFA),

Co-Tutors: E. Naselli (INFN-LNS), A. Pidatella (INFN-LNS), D. Santonocito (INFN-LNS), B Mishra (INFN-LNS and UniCT)

CT-22

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

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.

[1] D. Mascali et al., A novel approach to β-decay: PANDORA, a new experimental setup for the future in-plasma measurements, 2022 Universe 8, 80.

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

UniCT Supervisor: David Mascali,

Co-Tutors: A. Pidatella (INFN-LNS), B. Mishra (INFN-LNS)

CT-23

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

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 performing a new set of measurements to characterize magnetoplasmas confined in the Flexible Plasma Trap, the compact trap installed at INFN-LNS specifically designed as test bench of PANDORA [1]. 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 [2]. The diagnostic system will be also upgraded by installing a new mechanical X-ray shutter able to suppress the CCD camera readout effects and to allow acquisition at low exposure times as never done before ($\sim$ ms), in order to perform simultaneous time and space-resolved investigations of the X-ray fluxes emitted by the plasmas.

*[1] D. Mascali et al. (2022) Universe **8**, 80.*

*[2] E. Naselli et al. (2022) Condens. Matter **7**, 5.*

UniCT Supervisor: David Mascali (INFN-LNS and UNICT-DFA),

Co-Tutors: E. Naselli (INFN-LNS), G. Finocchiaro (INFN-LNS e UniCT)

CT-24

Title: Development of an experimental setup and measurement 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. 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, which is an almost unfolded observable. The activity proposed in this thesis is in the context of experimental investigations 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, 2]. In this framework, the on-construction facility PANDORA, and the working Flexible Plasma Trap (FPT), both at the INFN – LNS (Catania, Italy) suite for the purpose. The thesis will concern the development of an experimental multi-diagnostic setup, based on optical spectroscopy and microwave interferometry, thus employing complementary techniques and methods, for studying opacity of gaseous plasmas magnetically confined in compact plasma traps. The setup assembling (design, calibration) and measurements will be carried out on the FPT, as ground experiments projected to be then extended in the PANDORA facility. The investigation will help in shedding light on 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.

[2] Pidatella, A., *et al.*, Frontiers in Astronomy and Space Sciences 9, 225 (2022).

UniCT Supervisor: D. Mascali (UniCT-DFA, INFN-LNS),

Co-Tutors: A. Pidatella (INFN-LNS)

CT-25

Alreadyu assigned to Rajka

TITLE: Microdosimetry of Oxygen beams: experimental and simulations

SUPERVISOR(S): GAP Cirron, (UNICT), Giada Petringa (INFN-LNS), Miguel Cortes (Sevilla University)

SUPERVISOR(S) contact- emailpablo.cirrone@lns.infn.it Telephone:

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UNIVERSITY/RESEARCH CENTER: INFN-LNS

ABSTRACT

The thesis project will deal with the simulation of the LET distributions of 62 AMeV Oxygen beams and with the comparison of these distributions with the correspondent microdosimetric spectra acquired with Silicon and Silicon Carbide microdosimetric detectors.

CT-26

Title: The collective (or not collective) nature of the Pygmy Dipole Resonance

Supervisors: E. Geraci (UniCT), Nancy Martorana, E. Lanza (INFN-CT)- lanza@ct.infn.it

Abstract: In the last years special attention has been devoted to the study of the dipole strength at low excitation energy in neutron-rich nuclei, the so-called Pygmy Dipole Resonance (PDR). This mode carries few percent of the isovector EWSR, it is located at an energy well below the one of the Giant Dipole Resonance, it is present in most stable isotopes with a consistent neutron excess and it is more pronounced in nuclei far from the stability line. The PDR is strongly related with the neutron skin and with the symmetry energy. Furthermore, the PDR might have an influence also on the astrophysical r-process. Therefore, a better knowledge of the PDR properties is of paramount importance. For more details, see the recent review articles [1, 2]. One of the still unresolved question regarding the PDR is whether these dipole states are collective or not. From the theoretical point of view, many approaches arrive at the conclusion that it depends on the kind of probe used for the investigation. In fact, it is well established that the study of the PDR can be fruitful done by using an isoscalar probe in addition to the conventional isovector one due to the fact that their transition densities show a strong mixing of their isoscalar and isovector components [1,2]. There are several theoretical works dealing with the concept of collectivity, namely the fact that many nucleons should be involved in the excitation of the state but in a coherent way. The theory could be able to give an answer to this question, while from the experimental side there have not been many attempt to resolve the question. In order to establish the degree of collectivity of a state, one should determine, from both theory and experimental investigation, whether (or not) they have a predominant single particle level nature. Few experimental works have been recently devoted to this investigation and the study of (p,d) or (d,p) reactions should give an answer to this problem.

[1] A. Bracco, E. G. Lanza and A. Tamii, "Isoscalar and isovector dipole excitations: nuclear properties from low-lying states and from the isovector giant dipole resonance", Progress in Particle and Nuclear Physics 106 (2019), pp. 360-433.

[2] E.G. Lanza, L. Pellegri, A. Vitturi and M.V. Andrés, " Theoretical studie of Pygmy Resonances", to be published in Progress in Particle and Nuclear Physics.

CT-27

Title: Machine learning the astrophysical S-factor

Supervisors: Isaac Vidaña Haro (INFN-CT), E. Lanza (INFN-CT) - lanza@ct.infn.it

Abstract: We will employ a feed-forward artificial neural network to determine the astrophysical S-factor extrapolation to low energies for reactions of astrophysical interest such as the very important reaction 14N(p,gamma)15O which being the slowest one of the CNO cycle plays a crucial role for the energy production of the more massive main sequence stars and the detailed understanding of the neutrino spectrum from the sun.

CT-28

Title: Analysis of p-p collisions with the LHCf detector at LHC

Supervisors: A. Tricomi (UniCT) - *alessia.tricomi@dfa.unict.it*

Abstract: The LHCf experiment has recently taken data in p-p collisions at run3 at LHC. LHCf is the smallest of the six LHC experiments and it is aimed at the measurement of the neutral particle spectra produced in the very forward region to calibrate the Monte Carlo models used in high-energy cosmic rays experiments. The thesis will consist in the analysis of the 13.6 p-p collisions to expect the photon, pi0 and eta spectra.

CT-29

Title: SiC UV-photodetectors characterization for astroparticle and environmental physics applications

Supervisors: S. Albergo (UNICT), A. Tricomi (UNICT) - *alessia.tricomi@dfa.unict.it*

Abstract: Large band SiC UV-detectors will be characterized for application in environmental physics, water control and double-readout calorimeter for high-energy and astro particle physics applications. The student will take part to the test set-up preparation as well as detector and electronics calibration. The work will be mainly done in the laboratory and will involve also data analysis experience.

CT-30

Title: Exploring hot QCD matter: heavy quarks dynamics and anisotropic flows in ultra-relativistic heavy-ion collisions.

Abstract: The Quark-Gluon Plasma (QGP) is a state of QCD matter in which quarks and gluons are no longer confined inside hadrons but are the degrees of freedom governing the dynamics of the strongly interacting matter. The QGP can be studied in heavy-ion collisions at ultra-relativistic energy, in which a very hot and dense fireball is formed and expands hydrodynamically. The heavy quarks constitute a unique probe of QCD properties and transport parameters. Realistic phenomenological model calculations allow us to compute heavy quark final observables, such as the flow coefficients, and to compare them to the experimental measurements performed at the RHIC and LHC colliders. The project aims at investigating the impact of the temperature dependence of the heavy quark transport parameters on the heavy quark anisotropic flow coefficients. The goal is an improved understanding of the dynamics of the heavy quarks propagating through the hot QCD medium and of the transport parameters characterizing their interaction.

Supervisor: Prof. V. Greco (UniCT)

CT-31

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

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

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

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CT-32

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

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.

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

Supervisors: GA Pablo Cirrone (INFN-LNS, UNICT), pablo.cirrone@lns.infn.it; Giada Petringa (INFN-LNS), giada.petringa@lns.infn.it

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CT-33

ELIMED project
Title: 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.
Supervisors: GA Pablo Cirrone (INFN-LNS, UNICT), pablo.cirrone@unict.it; Giacomo Cuttone, INFN-LNS, UNICT), cuttone@lns.infn.it; Giada Petringa (INFN-LNS), giada.petringa@lns.infn.it

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CT-34

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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CT-35

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 $p + 11B \rightarrow 3\alpha$ 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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CT-36

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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CT-37

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:

$$11B + p \rightarrow 3\alpha + 8.7\ \mathrm{MeV}$$

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.

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CT-38

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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