Master thesis proposals in University of Catania for 2020-2021

1) Study of the 17O(p,alpha)14N at ultra-low energies via Trojan Horse Method

Contact: M.L. Sergi sergi@lns.infn.it

Abstract: The aim of this project is the study of the astrophysically relevant 17O(p,alpha)14N reaction by using the indirect technique called "Trojan Horse Method, THM". The reaction is of importance in several astrophysical scenarios, from AGB star nucleosynthesis up to Nova explosion.

The student will take part on the data analysis, data reduction and evaluation of the reaction rate. For the analysis will be required the use of tools such as energy loss calculations in addition to the standard data analysis tools such as Root.

2) Indirect investigation of p-induced 19F destruction in evolved stars to constrain s-process nucleosynthesis

Contact: M. La Cognata lacognata@lns.infn.it

Abstract: The s-process is responsible for the production of part of the heavy element beyond the iron peak. In order to constrain it, a detailed evaluation of the involved nuclear processes is mandatory. For such reason, we propose the study of the 19F(p,alpha)16O reaction at ultra-low energies via the indirect Trojan Horse Method. The student will take part to data analysis and reduction by also using devoted codes developed for resonant reaction studies. For the analysis the use of tools such as energy loss calculations will be required, in addition to standard data analysis tools such as Root.

3) The cosmological lithium problem in view of the recent 7Be(n,alpha)4He studies

Contact: L. Lamia llamia@lns.infn.it

Abstract: The cosmological lithium problem represents of the most interesting open problem in cosmology. Indeed, primordial "observed" abundances largely exeed the predicted ones thus requiring detailed studies. Among the nuclear reactions of interest, those involving the unstable 7Be isotope are of importance. The student will be involved in data analysis and reduction, by also using devoted codes for Big Bang Nucleosynthesis. For the analysis will be required the use of tools such as energy loss calculations in addition to the standard data analysis tools such as Root.

4) Exploring cluster structure in n-rich Carbon isotopes

Contact: A. Di Pietro dipietro@lns.infn.it

Abstract: In nature, objects in all physical scales tend to clusterise; the reason for that is the realization a greater stability. As an example on the largest scale, the universe, clusters of galaxies are formed bound together by gravity. Atoms form molecules and, at the smallest possible scale quarks are clusterised to form hadrons. Hence, it is not surprising that cluster phenomena appears in nuclei. This thesis deals with the investigation of molecular like structure in nuclei which have an excess of neutrons (n-rich nuclei). The exceeding neutrons may act as electrons in covalent binding, stabilising the nuclear structure that can assume extreme configurations as the one of a linear chain of alphas bound toghether by neutrons. The thesis will involve the analysis of the experiment using the most intense 10Be radioactive beam worldwide on 4He measured at INFN-LNS. For the analysis will be required the use of tools such as energy loss calculations and Monte Carlo simulations in addition to the standard data analysis tools such as Root.

5) MEASUREMENT OF NUCLEAR DENSITY IN HEAVY ION REACTION AT FERMI ENERGIES

A. Pagano (UNICT), E. De Filippo (INFN-CT)

The research work aims at studying the nuclear reaction mechanisms in Heavy Ions collisions at Fermi energies. An important role in these studies is played by the gradient of the nuclear density affecting the isospin asymmetry of the reaction products. Experimental determination of the value of the nuclear density in the early phase of the collision between two heavy nuclei is a crucial step towards the understanding of the underlying mechanism responsible for the production of nuclear clusters of intermediate atomic number ($Z< 10$), that is still an unsolved problem. The experimental method consists in constructing kinetic energy correlations of couple of clusters and its comparisons with the most advanced nuclear transport theories.

6) STUDY OF PYGMY RESONANCE IN RADIOACTIVE BEAMS EXCITED WITH BOTH ISOSCALAR AND ISOVECTOR PROBES

F. Rizzo (UNICT), G. Cardella (INFN-CT)

The NEWCHIM group of LNS is involved in the construction and use of the FARCOS correlator (Femtoscopy ARray For Correlation measurements and Spectroscopy). This array will consist in its final configuration of 20 triple telescopes of silicon strip and CsI, 12 of which will be already available in the second semester of 2019. This array will be used with fragmentation beams at LNS performing measurements on the excitation of Pygmy Dipole Resonance (PDR) on ^{68}Ni by isoscalar and isovector probes (Carbon and Gold targets). Gamma rays from PDR will be detected in the CsI(tl) detectors of the CHIMERA array, while ^{68}Ni scattered will be detected and identified around zero degree with some FARCOS telescopes. The student will participate at LNS to this experiment and eventually to other experiments performed in the same experimental campaign. He will then perform part of the data analysis of the experiment in order to complete its master thesis. It will be involved also in the mounting and test of FARCOS telescopes. He can learn how to use the full digital electronics of the array and the use of ASIC preamplifiers developed for FARCOS. The student will also learn modern methods of production of radioactive beams, with the setting of the tagging systems for event by event identification of the fragmentation beam. Techniques for the synchronization of acquisition systems will be also used. If the student is also interested to theoretical aspect of the population and decay of Pygmy Resonances he will be able to collaborate with the theory group of the Catania, Padova and Valencia Universities, also involved in the project.

7) RESEARCH AND DEVELOPMENT OF A NEW MODULAR DEVICE FOR CHARGED PARTICLE AND NEUTRON DETECTION WITH HIGH ANGULAR RESOLUTION

G. Politi (UNICT), A. Pagano (INFN-CT)

The NEWCHIM group of LNS has been working from some years to the development of a new modular device for the simultaneous detection of light charged particles and neutron with high energy and angular resolution. Several test on a new scintillating plastic material have been done in order to study its characteristics in term of pulse shape identification of neutron gamma and charged particles, using a digitalization of the light signal. Several simulations and experimental tests are still to be done in order to define the good light sensor between photodiode and SiPM, and to choose the precise geometry in term of dimensions, number and assembly of the single detection cell of the final array. The student will thus be involved in simulation concerning neutron detection with single and multiple cells in a particular surrounding environment. Moreover, he will carry on several tests for the choice of the ideal light sensor to be coupled to the plastic scintillator, and to test its performance in term of light yield, timing response and pulse shape identification capabilities. The use of a dedicated front end electronics coupled to a fully digital electronics for signal acquisition is foreseen, and the student will be engaged in the development and test of all these systems. The work will be carried on between the LNS and the Dipartimento di Fisica e Astronomia, profiting of all the experience of the NEWCHIM in the field of detector and associated electronics development.

8) EFFECTIVE INTERACTION AND DYNAMICS OF EQUILIBRATION PHENOMENA IN THE SYSTEM ^{48}CA+^{27}AL AT 40 MEV/NUCLEON

E. Geraci (UNICT), M. Papa (INFN-CT)

The proposed thesis work starts with the analysis of the data collected for the 48Ca+27 Al at 40 MeV/nucleon collision recently performed in Catania at the LNS by using the 4π multi-detector CHIMERA.The aim of this study is to investigate on isospin equilibration processes in different reaction mechanisms. The charge, mass, velocity and multiplicity measurements of the produced fragments and the comparison with molecular dynamics approaches will allows to get information about the effective interaction describing the iso-vectorial force and at what extent it affects the spontaneous clustering process. By working on the collected data the student will have the opportunity to work on the most important and modern identification techniques associated to the charged particle detection (E-DE technique, time of flight, pulse-shaping analysis and related software) together with the fundamental criteria for the analysis of complex-multi-particles events.

Finally, the theoretical interpretation of the experimental results will allow the knowledge of one of the most sophisticated semi-classical approaches to the nuclear many-body problem.

9) STUDIES OF NUCLEAR REACTIONS IN LASER-PRODUCED PLASMAS BY INNOVATIVE SILICON CARBIDE DETECTORS

S. Tudisco (INFN-LNS); C. Altana (INFN-LNS)

The study of nuclear reactions in plasmas is one of the most important iusees in the modern sciences, with interdisciplinary implications in nuclear physics, astrophysics, cosmology, etc. In fact, laser beams can generate plasma from interaction with solid targets, and, in proper conditions, they can also trigger nuclear reactions. Moreover, performing accurate measurements of nuclear reaction rates of proton and alpha burning processes is essential for the correct understanding of many astrophysical processes, such as stellar evolutions, supernova explosions, Big Bang nucleosynthesis, etc. However, electron screening prevents a direct measurement of the bare nucleus cross section at the energies of astrophysical interest. Therefore, it is of relevant importance the measurements of cross-sections at extremely low energetic domains including plasmas effect, i.e. in an environment that under some circumstances and assumptions can be considered as “stellar-like”.
Silicon Carbide appears to be especially well-suited for the realization of ionizing radiation detectors due to its electrical and physical properties. In fact, the main advantages of SiC are, for example, its wide band-gap, high thermal conductivity, high field breakdown strength and high carrier saturation velocity. A further important aspect, in connection with the large bandgap, is SiC’s insensitivity to photons in the visible range, making SiC devices very promising for neutrons and charged particles detection in a plasma environment.
In order to study nuclear reactions in laser-produced-plasmas, we are developing and testing an innovative system based on Silicon Carbide detectors.

10) Transport solutions for the INFN-LNS laser-driven acceleration facility

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

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

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

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

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

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

11) Dosimetric approaches and detector developments for "Flash radiotherapy"

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

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

ABSTRACT

In the last decades, ion acceleration from laser-plasma interaction has become a popular topic for multidisciplinary applications and opened new scenarios in the protontherapy framework, representing a possible future alternative to classic acceleration schema. The high-intensity dose rate regime that can be obtained with this approach is also strongly attracting the radiation oncologist community thanks to the evident reduction of the normal tissue complication probability, this new radiotherapy technique was called "flash radiotherapy". One of the many challenges to bring laser acceleration to a clinical setting consists in the development techniques and technologies that allow for accurate dosimetry of a short and intense ion bunch length.

In comparison with conventional accelerators, dosimetry of laser-accelerated beams is an ambitious task. Conventional accelerators typically operate at quasi-continuous milliampere currents rather than proton bunches with a temporal structure of the order of nanoseconds. Several international collaborations and experiments have been launched in the last years aiming at exploring the feasibility of using laser-driven sources for potential medical applications. A collaboration between the LNS-INFN, ELI-Beamlines (Czech Republic) and Queen's University (Ireland) was recently established to develop and investigate new devices for diagnostic and dosimetric purposes for laser-driven ion beams.

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

Supervisors:
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Giacomo Cuttone, INFN-LNS, UNICT), cuttone@lns.infn.it
Giada Petringa (INFN-LNS), giada.petringa@lns.infn.it

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.

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

Supervisors:
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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.

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

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

15) Detectors development for 2D dosimetry of conventional and laser-accelerated ion beams

Supervisors:
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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

16) New transport solution for eye-protontherapy beamlines

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

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

References

[1] J.S. Loeffler , M. Durante, Nature Rev. Clinical Oncology, 10, 411 (2013)

[2] Particle Therapy Co-Operative Group (PTCOG), http://www.ptcog.ch/index.php/ptcog-patient-statistics

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

17) INVESTIGATION OF THE ANEUTRONIC PROTON-BORON FUSION REACTION IN PLASMA FOR ENERGETIC STUDIES

Supervisors

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

11B + p → 3α + 8.7 MeV

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

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

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

References

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[2] H. Hora et al., Energy Environ. Sci. 3, 479 (2010).
[3] G. A. P. Cirrone, et al., Sci. Rep. 8, 1141 (2018).

[4] A. Macchi, M. Borghesi, M. Passoni, Rev. Mod. Phys. 85, 751 (2013)

[5] A. Picciotto et al., Phys. Rev. X 4, 031030 (2014).

[6] L. Giuffrida al., Phys. Rev. E 101, 013204 (2020).

18) Dosimetric characterization of an x-ray system for in-vivo irradiations

Supervisors:
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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.

19) PET RADIOMICS IN ONCOLOGICAL PATIENTS

IBFM-CNR Cefalù and LNS-INFN Catania

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

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 collect radiomic features through a standardized procedure and analyze them in order to improve treatment response prediction and prognostication, and potentially allowing personalization of cancer treatment.
The IBFM-CNR has massive experience in the development of quantification tool in Nuclear Medicine environment. The group exhibits a long-standing collaboration with the LNS-INFN, Cannizzaro Hospital in Catania and Fondazione G. Giglio in Cefalù (PA). The student will take care of the analysis of PET images in order to extract new functional parameters both in oncological patient and pre-clinical PET studies. The obtained results will be relevant from the point of view of the demands of everyday clinical activity in order to support healthcare operators in cancer treatment decision making.

Possibility of joint project with other clinical PET institutes

20) Production of light nuclei and antinuclei with the ALICE detector at LHC

Tutors: Francesco Riggi (UniCT & INFN CT), Paola La Rocca (UniCT & INFN CT)

Abstract: The study of the production of light nuclei and anti-nuclei in heavy ions collisions at ultra-relativistic energies allows to deepen the knowledge on hadronization mechanisms and to verify the validity of the theoretical models currently available. The candidate will conduct a data analysis activity as part of the ALICE experiment. In particular he will deal with the study of the production of light nuclei and anti-nuclei (deuteron, triton, ^{3}He), analyzing a set of data selected among the possible ones acquired by ALICE during LHC RUN1 and RUN2 (proton-proton, proton-Lead, Lead- Lead or Xenon-Xenon).

21) Commissioning of the new Inner Tracking System of the ALICE experiment at CERN

Tutors: Paola La Rocca (UniCT & INFN CT), Francesco Riggi (UniCT & INFN CT), Antonio Trifirò (UniME & INFN CT)

Abstract: The ALICE experiment is currently undergoing a major upgrade of its detectors in order to fully exploit the scientific potential of the LHC upgrade scheduled for the Long Shutdown 2. In particular, a new, high-resolution, low material budget Inner Tracking System (ITS) will be installed in 2021. It is based on Monolithic Active Pixel Sensors (MAPS) and its commissioning is ongoing before the final installation in the cavern. The candidate will analyse the commissioning data in order to extract the performance of the individual sensors, optimize the detector calibration parameters and fine-tune the acquisition procedures. This analysis will lead to original results perfectly in line with what is expected for a master's thesis in physics.

22) Pygmy Dipole Resonance: are they collective or not collective states?

E. Geraci (UNICT) – E. Lanza (INFN-CT)

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 article [1].

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]. Indeed, the combined use of real and virtual phonons and experiments employing ($\alpha, \alpha' \gamma$) as well as (^{17}O, ^{17}O' γ), for the investigation of the PDR states, has unveiled a new feature of these states: the energy splitting of the PDR. Namely, the energy region of these low-lying dipole states can be separated in two parts: the lower part is excited by both the isoscalar and isovector interactions while the high energy part is populated only by the electromagnetic probes.

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. 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.

23) Production of K*(892)$^{\pm}$ in Pb-Pb collisions at LHC energies

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

Abstract: Quark Gluon Plasma formation and characteristic of strongly interacting matter are studied in heavy-ion collisions at ultrarelativistic energies. Due to their short lifetime (some fm/c) comparable with the lifetime of the hadronic phase of the system, hadronic resonances as charged and neutral K*(892) are sensitive probes of the dynamical evolution of the fireball in heavy-ion collisions. The data collected from the ALICE experiment at Large Hadron Collider in Pb-Pb collisions at a $\sqrt{s_{NN}}$ = 5.02 TeV will be used to study the K*(892)$^{\pm}$ mesonic resonance production. The student will conduct the data analysis activity as part of the ALICE experiment.

24) Machine learning aided identification of rare resonances in pp collisions at the LHC energies with the ALICE detector

Supervisors: Angela Badalà (INFN-CT), Marco Fargetta (INFN-CT), Paola La Rocca (UniCT & INFN-CT)

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

25) Radiation tolerance tests for SiPM candidates as sensors for a RICH detector at EIC

Supervisors: Prof. Cristina Tuvè (Università di Catania); Dr. Concetta Sutera (Ricercatore INFN)

Abstract: The Electron Ion Collider (EIC) project at Brookhaven National Laboratories by the US Department of Energy has triggered intense R&D programs, towards the choice of detectors and the formation of experimental Collaborations.

The experimental activity in which the Catania group is involved in the EIC is in the dRICH proposal, a dual radiator (gas/aerogel) RICH detector to be placed in the forward hadron region to supply hadron particle identification at intermediate and high momenta (from 3 GeV/c up to 60 GeV/c).

Silicon Photomultiplier (SiPM) seems nowadays a mature technology as photon sensors for a RICH detector, but their capacity to operate in Single Photon mode in such context still needs to be fully demonstrated. Additionally, in the region where the dRICH is supposed to be installed, a moderately low cumulative level of radiation from a total fluence of about 10^{11} n_{eq}/cm^2 is expected after several years of operations.

The aim of this research is to test several commercial SiPM available on the market as well as samples of devices from FBK R&D programs and to evaluate the degradation of the performance following irradiation