Master thesis proposals in Padova for 2019-2020

1. The $^{22}Ne(p,\gamma)^{23}Na$ reaction in Novae and Supernovae explosions

Supervisors: Rosanna Depalo, Carlo Broggini (broggini@pd.infn.it)

Abstract:

The $^{22}Ne(p,\gamma)^{23}Na$ reaction takes part in the neon-sodium cycle of hydrogen burning and it has a strong influence on the synthesis of neon and sodium isotopes in several astrophysical scenario. In particular, at the typical energies of classical nova and supernova explosions the $^{22}Ne+p$ cross section is dominated by a large number of poorly-known resonances. In order to reduce the uncertainty on such reaction, an experiment has been performed at the Helmholtz – Zentrum Dresden – Rossendorf (HZDR), Germany. The goal of the experiment is to determine the strengths of most intense resonances of the 22Ne+p reaction with unprecedented high precision, exploiting gamma spectroscopy techniques. The student will perform a complete analysis of the data acquired at HZDR and evaluate the impact of the new results on the astrophysical reaction rate.

2. Investigation of the molecular structures in ^{21}Ne by measuring the spectroscopic factor in K=1/2,3/2 bands

Supervisor: Daniele Mengoni (daniele.mengoni@lnl.infn.it)

Abstract:

The thesis work is dedicated to the analysis of commissioning experiments of the MUGAST set-up at ALTO. MUGAST is a Silicon array covering backward and 90 deg. angles designed for stripping reactions measurements in combination with the AGATA gamma array and the VAMOS spectrometer at GANIL. The campaign is foreseen in 2019 at GANIL. The Silicon detectors will be commissioned at ALTO through two different experiments detailed below.

In particular the experiment aims at studying molecular states in 21Ne, where alpha clusters are bond together by sharing a "covalent" neutron. Clustering is a universal phenomenon that goes also beyond nuclear physics, and its comprehension is therefore of the utmost importance and large impact.

The proposal aims at the quantitative determination of the clusterization by measuring the alpha spectroscopic factor of the molecular states in 21Ne. The nucleus will be populated by a transfer reaction of a 17O beam on a LiF target. The evaporated deuteron detected in MUGAST will carry information on the populated states and their nature.

3. Isospin Symmetry Breaking in Mirror Nuclei 71Kr – 71Br.

Supervisors: S.M. Lenzi, F. Recchia (francesco.recchia@pd.infn.it)

Abstract:

Mirror Energy Differences (MED) give the possibility to highlight several nuclear structure properties. Systematic studies have been performed with remarkable success in the sd and f7/2 shells, while the experimental information in the upper fp shell is still scarce. Shape coexistence in the region may give rise to different shapes even in mirror nuclei, strongly influencing the MED.
The student will take part in the analysis of an experiment performed at the GANIL laboratory, France, using the AGATA tracking germanium array coupled to the NEDA neutron detector. The student is

expected to take charge of one of the reaction channels performing the analysis and comparing the result to the most recent theoretical calculations.

4. **Mirror energy differences in A = 43: a tool to pin down the nature of cross-shell excitations**

Supervisors: S.M. Lenzi (lenzi@pd.infn.it), F. Recchia (francesco.recchia@pd.infn.it)

Abstract:

In the low part of the f7/2 shell, nuclei present intruder rotational bands of non-natural parity. Its structure can be interpreted as cross-shell particle-hole excitations from the sd shell. The shell model description is, however, not straightforward as several problems arise when dealing with two main shells. Such study has been applied to the positive-parity yrast band in 43Sc and suggest a very interesting structure. There is a competition between proton and neutron excitations from the d3/2 orbital. The comparison with data up to high spin is quite satisfactory.

To test the wavefunction composition and, therefore, the effective interaction that includes both the sd and pf shells, an experiment aimed to measure excited states in the 43Ti mirror nucleus will be performed in Jyvaskyla (Finland) using a gamma-ray array and the recoil mass spectrometer MARA.

From the study of the Mirror Energy Differences (MED) between 43Ti and 43Sc, the nature of the cross-shell excitations will be deduced.

The student will join the group in the analysis of the data and the interpretation of the results with the shell model.

5. **Characterisation of the detectors and data acquisition system of the Galileo phase II germanium array.**

Supervisors: F. Recchia

Abstract:

the Galileo project consists in the construction of the high efficiency gamma spectrometer that will be the main apparatus for the radioactive beams of the SPES facility at the Legnaro National Laboratories. The first SPES beams will be extracted in 2019 and the Galileo detectors will be used for the study of the beta decay of these beams.

The upgrade of Galileo, namely the phase II of the project, will make use of both single tapered germanium detectors as well as new triple cluster germanium detectors. The construction of the phase II will be ultimate by the end of 2018.

The student will test the new detectors and characterize them both in terms of resolution and efficiency.

The student will study the response of the daq at high count rate. In addition, the student will develop an algorithm for compensating charge collection in radiation damaged detectors.

6. **Measurement of Λ_c^+-meson production in proton-proton, proton-Pb and Pb-Pb collisions at the LHC with ALICE**

Supervisor: Marcello Lunardon (marcello.lunardon@pd.infn.it)

Abstract:

The student will analyse recent data samples collected with ALICE (A Large Ion Collider Experiment) at the LHC, with the goal of measuring and characterise the production of the Λ_c^+ meson, a particle containing a charm quark, in proton-proton, proton-Pb, and Pb-Pb collisions. Heavy quarks are among the most useful probes to investigate the properties of the Quark-Gluon Plasma formed in ultra-relativistic heavy-ion collisions. They are produced in hard-scattering processes with high-momentum transfer in the early stages of the collisions, before the formation of the QGP. Therefore, by interacting with the medium quarks and gluons, they witness the whole evolution of the expanding and cooling systems. Therefore, the study of the kinematic properties of the final-state hadrons that contain charm quarks, allows to retrieve information on the microscopic interactions occurring in the QGP and thus on the properties of the medium itself. In particular, the comparison of the production yields of different hadron species (e.g. D0, Ds+, Lc, Λ_c^+) can clarify how hadrons are formed in the medium and help understanding the coupling of charm quarks to the system and their degree of thermalisation.

The Λ_c^+ is a baryon composed of a charm quark, a strange quark and an up quark. Though its production is rare in comparison to lighter charm hadrons, many models predict that the large abundance of strange quarks in the QGP should yield a significant enhancement of its production, in case hadron formation occurs with a different mechanism ("coalescence") than in pp collisions. Moreover, recent measurements of Ξ_c and Ξ_c^0 production, suggested that charm-baryon formation is not well understood also in "small" collision systems, like pp and p-Pb, where the QGP is not formed. The goal of the thesis is to detect the Λ_c^+ signal and measure its production and kinematic properties (transverse-momentum spectrum) via the reconstruction of its decay into a proton, a charged pion and a kaon. To this purpose the decay topology should be studied in order to best exploit the excellent spatial resolution and particle-identification capabilities of the ALICE detector.

With the foreseen work of thesis, the student will have the opportunity to learn and practice with some of the fundamental techniques used to reconstruct unstable particles in particle physics. She/he will get familiar with invariant mass analyses, particle-track reconstruction and particle-identification techniques in modern detectors at accelerators, event selection, analysis on grid network, and other concepts which are fundamental ingredients for researchers in high-energy particle and nuclear physics. The usage of multi-variate analysis techniques and neural network can also be considered.

7. Study of the tunneling effect in Nuclear Physics through measurement of heavy ion fusion: the case of ^{28}Si+^{100}Mo

Supervisors: G. Montagnoli, A.M. Stefanini

Abstract:

The probability of compound nucleus formation in collisions between heavy ions at energies near the Coulomb barrier has shown many interesting features such as the large influence of nuclear structure on the probability of quantum tunnelling.

The object of this thesis work will be the analysis of the fusion cross section of the ^{28}Si+^{100}Mo system around and below the Coulomb barrier. The measurement was recently performed in Laboratori Nazionali di Legnaro by detecting the fusion evaporation residues. The results have to be compared with the theoretical predictions within the Coupled Channel Model using the code CCFULL with the

Woods-Saxon nuclear potential and taking into accounts the couplings to inelastic excitations and transfer channels.

Master thesis proposals in LNL for 2019-2020

1. Study of the N=50 shell closure using radioactive ion beam

Supervisors: Andrea Gottardo, Jose Javier Valiente-Dobon

Abstract:

the Master thesis project of the involved students will be based on two experiments likely to be performed at ISOLDE (CERN) this autumn. It concerns the physics around the N=50 neutron shell closure. These two experiments will exploit radioactive beams of 70Ni and 79Zn to study shell structure and shape coexistence on this region of the nuclide chart, respectively. The 70Ni beam will be used to perform one neutron transfer reactions on a deuterated target at the centre of the arrays MINIBALL (for gamma spectroscopy) and T-REX (for particle spectroscopy). The angular distribution of the emitted particles, in coincidence with gamma rays, will enable one to deduce the shell structure at the shell gap. The 79Zn beam will be delivered to a gold target at the centre on the Miniball array for Coulomb excitations. The intensity of the detected gamma rays will help to assess the coexistence of different nuclear shapes in the same nucleus. The student will be involved in the analysis of the measurements, learning the basis of gamma and particle spectroscopy to extract energies and angular distributions of excited states. He will also become acquainted with the instruments at the forefront of modern nuclear research.

2. ATS: an Active Target at SPES

Supervisor: Tommaso Marchi, Fabiana Gramegna

Abstract:

An Active Target is a Time Projection Chamber (TPC) tracker where the detection medium is also used as the Target for a Nuclear Reaction. This allows to use a thick target and an efficient detector, compensating for the small number of incoming particles, like in the case of Radioactive ion Beams of the most exotic species, where the beam intensity can be as low as 10^2-10^3 pps. The NUCLEX collaboration is developing an Active Target to be used in combination with the Radioactive Ion Beams produced by the SPES facility at Legnaro National Laboratories.

The proposed Activity concerns the characterization of the detector using the data collected in the 2018-2019 experimental campaigns. Tracking algorithms are under development and need to be tuned for different physics cases, in order to determine the detector's performances and capabilities. It will be also possible to participate in the experiment's preparation and data taking for the campaign planned for November-December 2019 at Laboratori Nazionali del Sud.

3. Pre-equilibrium emissions in reactions involving medium mass nuclei

Supervisor: Magda Cicerchia, Fabiana Gramegna

Abstract:

Nuclear reactions involving medium mass nuclei are a useful tool to examine the competition between different reaction mechanisms; in particular, the behavior of the different kind of fast emissions, coupled

with incomplete fusion, can be study as a function of energy and of the entrance channel characteristics. Moreover, the study of the emitted particles, comparing pre-equilibrium and thermal components, can highlight possible clustering effects, which may change the expected decay chain probability.

During the last decade, the NUCL-EX collaboration (INFN, Italy) has carried out an extensive research campaign on pre-equilibrium emission of light charged particles from hot nuclei. The GARFIELD+RCo array has been used to detect light charged particles, light fragments and evaporation residues. This setup has the capability to measure charge, mass (up to Z=8-12), energy and emission angles of almost all the charged reaction products. The performances of the apparatus permit the full event reconstruction and the study of many-body correlations.

The proposed activity concerns the active participation in the analysis of the previous experimental campaigns (ACLUST and ACLUST2) and in the preparation of a new experiment planned for 2019.

4. R&D on Doping Processes of Hyperpure Germanium for Gamma Radiation Detectors

Supervisor: Gianluigi Maggioni

Abstract:

the activity is focused on the study of the surface doping of hyperpure germanium crystals, achieved by using a suitable doping element deposited on the Ge surface with a vacuum deposition technique and on the characterization of the surface and electrical properties of the doped crystals. This is an activity of Experimental Physics, in particular Solid State Physics and Semiconductor Physics applied to the R&D of gamma radiation detectors

5. Neutron spectra measurements for nuclear astrophysics

Supervisor: Pierfrancesco Mastinu

Abstract:

the Lenos project, actually running at CN accelerator of the LNL, has the goal to produce maxwellian neutron spectra at kT ranging from 8 to 90 keV thermal temperature. This spectra is the same of stellar interior, where elements heavier than iron are synthetized in the so called s-process. We developed a new method for the production of maxwellian neutron energy distribution (see ref. Appl Radiat Isot. 2012 Aug;70(8):1583-9.) but the stellar spectra at different kT must be measured and well characterized. The thesis will deal with the preparation of the experiment, the run and the subsequent data analysis.

Other possible argument

Abstract:

the above described neutron spectra can be used for neutron activation measurements. In particular, the total cross section obtained with such maxwellian spectra is called MACS (Maxwellian Averaged Cross Section). The MACS ids the unique ingredient of nuclear astrophysics model which try to reproduce the observed abundance of the elements in the Universe. A set of measurements on sample of particular relevance for the s-process will be carried out at the CN accelerator using continuous beam and will be the subject of the thesis.

1. **PET RADIOMICS FOR TREATMENT EVALUATION 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.
Primarily, lesion volume delineation in PET studies is challenging because of the low spatial resolution and high noise level of PET images. Nowadays, the biological target volume (BTV) is manually contoured on PET studies. This procedure is time expensive and operator-dependent. For this reason, an automatic and user independent algorithm for the BTV delineation must be used to extract structures containing targets and, consequently, to extract radiomic features, i.e. using the open-source "Chang-Gung Image Texture Analysis" (CGITA) toolbox.

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 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

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

   LNS-INFN Catania

Supervisor: Giorgio Russo: giorgio-russo@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

3. ANALYSIS OF THE BREAKUP CHANNEL OF THE 7LI+119SN SYSTEM AT ENERGIES AROUND THE COULOMB BARRIER.

LNS - CATANIA

Supervisor: A. Di Pietro (dipietro@lns.infn.it)

ABSTRACT:

The aim of this work is to investigate the excitation function for the elastic scattering process 10Be+4He. This study, performed at INFN-LNS, may shed some light upon the existence of linear-chain cluster states in the n-rich 14C nucleus. These states are expected to have a con figuration in which 10Be and are spatially separated, and thus they can be observed by the 10Be+alpha resonant elastic scattering. In order to identify the 14C states comparison between experimental data and theoretical calculations will be persformed.

4. STUDY OF PYGMY RESONANCE IN RADIOACTIVE BEAMS EXCITED WITH BOTH ISOSCALAR AND ISOVECTOR PROBES

LNS – CATANIA

Supervisor: Prof. F. Rizzo (rizzo@lns.infn.it), Dipartimento di Fisica e Astronomia di Catania, and dott. P. Russotto (russotto@lns.infn.it), INFN-LNS

ABSTRACT:

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.

5. **RESEARCH AND DEVELOPMENT OF A NEW MODULAR DEVICE FOR CHARGED PARTICLE AND NEUTRON DETECTIOIN WITH HIGH ANGULAR RESOLUTION**
   LNS – CATANIA

Supervisor: Prof. G. Politi (giuseppe.politi@ct.infn.it), Dipartimento di Fisica e Astronomia di Catania, and dott. A. Pagano (angelo.pagano@ct.infn.it), Sezione INFN-CT

ABSTRACT:

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.

6. **STUDY OF CLUSTER STRUCTURE OF EXOTIC 13B NUCLEI PRODUCED AT FRIBS FACILITY OF LNS – CATANIA**

Supervisor: Prof. G. Politi (giuseppe.politi@ct.infn.it), Dipartimento di Fisica e Astronomia di Catania, and dott. S. Pirrone (sara.pirrone@ct.infn.it), Sezione INFN-CT

ABSTRACT:

The study of the nuclear clustering is one of the oldest and important subject in the field of the nuclear physics, since it reveals much about the nature of the force through which the nucleons interact and the resulting symmetries. The α-particle is one of the most highly bound cluster nuclei, but also heavier nuclei tend to optimize their own binding energy by generating internal clusters. This can lead to clustering in alpha shape as well in other possible exotic configurations, particularly favoured in light neutron rich systems, producing strongly deformed and easy to break up nuclei.

In this framework we are going to study the break-up of the Boron isotope ^{13}B, measuring the ccompetition between the different decay channels, related to different cluster states. Experiment will be realized at LNS with a beam of ^{13}B produced by the on line fragmentation system FRIBS and impinging on the hydrogen of a plastic (CH_2) target. Decay products of the ^{13}B will be measured with CHIMERA and FARCOS multi detector devices. Activity will concern experiment preparation and realization at LNS as well as following data analysis carried out also at the Dipartimento di Fisica e Astronomia.

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

LNS-CATANIA

Supervisor: Prof. F. Rizzo rizzo@lns.infn.it, Dipartimento di Fisica e Astronomia di Catania and dott. E.V.Pagano epagano@lns.infn.it, INFN-LNS

ABSTRACT:

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

8. ELIMED project - First dosimetric and radiobiological measured with laser-accelerated ion beams

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

ABSTRACT:

INFN-LNS realized the first Users'-open beamline (called ELIMED) completed 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 cells 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.

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

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

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 on 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 to transport parameters.

10. Investigation of new irradiation and imaging approaches to enhance the radiobiological effectiveness of proton beam using nuclear reactions. Experimental and simulation activities
LNS - CATANIA

Supervisors:
Giacomo Cuttone (INFN-LNS), cuttone@lns.infn.it
GA Pablo Cirrone (INFN-LNS), pablo.cirrone@lns.infn.it

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 $p + {}^{11}B \rightarrow 3\alpha$ 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.

11. Study and development of new Silicon Carbide detectors
LNS-CATANIA

Supervisor: S. Tudisco (INFN-LNS) tudisco@lns.infn.it

ABSTRACT:

Silicon Carbide (SiC) represent the new frontier of high energy and nuclear physics detectors. Silicon carbide is a semiconductor with a wide, indirect band gap. Due to its composition SiC it is the only stable compound in the binary phase diagram of the two groups IV elements, silicon and carbon. It is thermally stable up to about 2000 °C, even in oxidizing and aggressive environments. Of all the wide band gap semiconductors, silicon carbide is presently the most intensively studied one and the one with the highest potential to reach market maturity in a wide field of device applications, such as high-temperature electronics, biomedical sensors, UV photo-sensors, and charged particle and X-ray detectors.

SiC is seriously considered as a valid alternative to silicon for the production of radiation hard ionizing particle detectors, since it gives the opportunity to couple the excellent properties of silicon detectors (efficiency, linearity, resolution) with a much larger radiation hardness, thermal stability and insensitivity to visible light.

12. Study and development of plasma diagnostics for nuclear and astrophysics applications
LNS-CATANIA

Supervisor: S. Tudisco (INFN-LNS) tudisco@lns.infn.it

ABSTRACT:

A direct measure of rates and/or cross-sections (S-factors) in laboratory is important to have a better understanding of many astrophysical processes. It is of paramount relevance the measurement 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” (for example, for the study of the role played by free/bounded electrons on the Coulombian screening in dense and warm plasmas). We propose to study nuclear reactions at low energies inside dense and energetic plasmas generated in the laboratory at unprecedented conditions thanks to the unique characteristics foreseen at the future ELI-NP laser facility. In this framework we are developing at LNS in the LENS Laboratory diagnostics and instrumentations to study and control laser generated plasmas for nuclear and astrophysics applications.

13. Characterization of the response of a liquid argon double-phase TPC within the ReD project at LNS

Supervisor: Luciano Pandola: pandola@lns.infn.it

Abstract:

Time projection chambers (TPC) based on liquified noble gases, as Argon and Xenon, are being employed in a number of world-leading projects searching for Dark Matter in the form of WIMPs. In particular, the DarkSide-20k project will use a double-phase TPC filled with liquid argon (LAr). The

WIMP interactions with the TPC are expected to generate Ar40 nuclear recoils, having kinetic energy below a few tens of keV. The ReD project aims to characterize the response of the LAr TPC to nuclear recoils, that can be produced by neutrons. The two main goals are to explore the response of the TPC at very low energy (below a few keV of kinetic energy) and to look for a possible directional dependence

suggested by earlier experiments. The capability to constrain the direction of the nuclear recoils would be crucial for the next generation of Dark Matter experiments, since WIMPs are expected to come from a specific direction in the Galaxy.

ReD consists in the irradiation of a miniaturized LAr TPC with a neutron beam at the INFN, Laboratori Nazionali del Sud (LNS), Catania. Neutrons are produced via the reaction p(7Li,7Be)n from a primary 7Li beam delivered by the TANDEM accelerator of LNS. A DeltaE/E telescope, made by two Si detectors, identifies the charged particles (7Be) which accompany the neutrons emitted towards the TPC. Neutrons scattered from the TPC are detected by using an array of nine 3-in liquid scintillator (LSci) detectors. Furthermore, the ReD TPC uses all the innovative features of the DarkSide-20k design (in particular the optoelectronic readout based on Silicon PhotoMultipliers and cryogenic lectronics), so it can provide a early and crucial benchmark in real-life experimental conditions.

The integration of the three detector systems was performed within two test beams on 2018, using the TANDEM accelerator of LNS. Neutrons were produced by sending a 28 MeV 7Li beam onto a set of CH2 targets having thickness between 150 and 250 ug/cm2. The program of physics measurements with the TANDEM beam will start in 2019.

14. The km3net high energy neutrino telescope at 3500 m depth offshore CapoPassero

Supevisor: Piera Sapienza (sapienza@lns.infn.it), R. Coniglione (coniglione@lns.infn.it)

Abstract:

High energy cosmic neutrinos were discovered in 2013 by the IceCube collaboration by means of a deep under-ice cubic kilometer telescope. This discovery opened the era of high energy neutrino astronomy in the very exciting and expanding field of multimessanger physics for the investigation of the violent Universe. The LNS team is very active in the construction of the underwater cubic kilometer telescope for high energy neutrinos km3net in the Mediterranean sea at 3500 depth off-shore Capo Passero. A very broad range activities is ongoing including simulations, detector construction, data taking and analysis. In particular, investigation on data quality and stability, effects of environmental parameters, sensitivity to galactic and extragalactic sources in the km3net high neutrino detector. Students could therefore participate to various aspects contributing to this gigantic, very challenging project. Indeed, km3net is expected to produced science at the frontier of our knowledge in synergy with photon, Gravitational Waves and cosmic ray observations.

15. Study for a Near Detector for the DUNE experiment at FNAL (USA)

Supevisor: Carla Distefano (distefano_c@lns.infn.it)

Abstract:

After the Big Bang, matter and antimatter were created equally, but now matter dominates. The study of the properties of neutrino and antineutrino oscillations to determine if charge parity (CP) symmetry is violated in the lepton sector is currently the most promising way for understanding this asymmetry. The main objective of the DUNE experiment is the measurement of the CP violation in the leptonic sector with high sensitivity (> 5 sigma). Neutrino and anti-neutrino oscillations will be measured at 1300 m from the production site in the so-called FAR detector. In order to monitor the beam and control the systematics a Near Detector (ND) close to the beam production site is necessary. Moreover the ND can exploit the unique features of (anti)neutrinos to study fundamental interactions with unprecedented precision.The LNS team is working on several topics including simulations finalized to the optimization of the ND performances. The students will have the opportunity to join the activities of the team with special focus on the development of simulations of the ND detector.

16. KM3NeT: Monitoring of Positions of KM3NeT-ARCA detector thorugh the novel acoustic positioning system

Supevisor: G. Riccobene (riccobene@lns.infn.it)

Abstract:

The KM3NeT Experiment is going to be deployed offshore the coast of Sicily. The first line is already operational at 3500m depth. Within INFN a novel acoustic positioning system, fully functional, has been developed with unprecedented accuracy.

The performace of the the KM3Net Experiment strongly depend on the accuracy of positioning. The system can be also used for multidisciplinary and neutrino acoustic detection studies.

The thesis work will consist in data analysis (DSP techniques), simulations and hardware (acoustic emitters and receivers) tests and construction.

17. KM3NeT: Time calibration of KM3NeT-ARCA

Supevisor: G. Riccobene (riccobene@lns.infn.it)

Abstract:

The KM3NeT-ARCA experiment is an underwater neutrino telescope that must reconstruct Cherenkov tracks produced by leptons outgoing neutrino interactions.

The detector is formed by an array of 150.000 optical sensors that must be syncronised with accuracy and precision of 1 ns. A full procedure to time calibrate the fisrt units of the detectors has been developed and applied and must be applied to all detector.

LNS is one of the few integration sites in the collaboration and is committed to time-calibrate tens of DUs and monitor time calibration underwater.

The thesis work wil consist in data analysis, simulations and hardwer setup.

18. Multidisciplinary acoustics: Study of physics and biological sourced of acoustic noise in deep sea for HE neutrino acoustic detection

Supevisor: G. Riccobene (riccobene@lns.infn.it)

Abstract:

The LNS hosts and operates the only deep sea acoustic station active in the mediterranean sea. Acoustic signals are monitored continuosuly in the frequency range from few 10 Hz to 70 kHz, permitting the detection and study of noise backgound and acoustic sources.

Several research items have been tackled (geophysics, bioacoustics, neutrino acoustic detection, environmental monitoring) and reported in hi-level research journals. Nevertheless the enourmous data library acquired and the continous data acquisition leave room to many further analyses on the above mentioned subjects.

The thesis work will consist in data analysis (DSP techniques), simulations and hardware (acoustic emitters and receivers) tests and construction.