5th Hellenic Institute of Nuclear Physics Workshop

12-13 April 2019

Physics Department, Aristotle University of Thessaloniki

HINPw5 *Book of Abstracts*

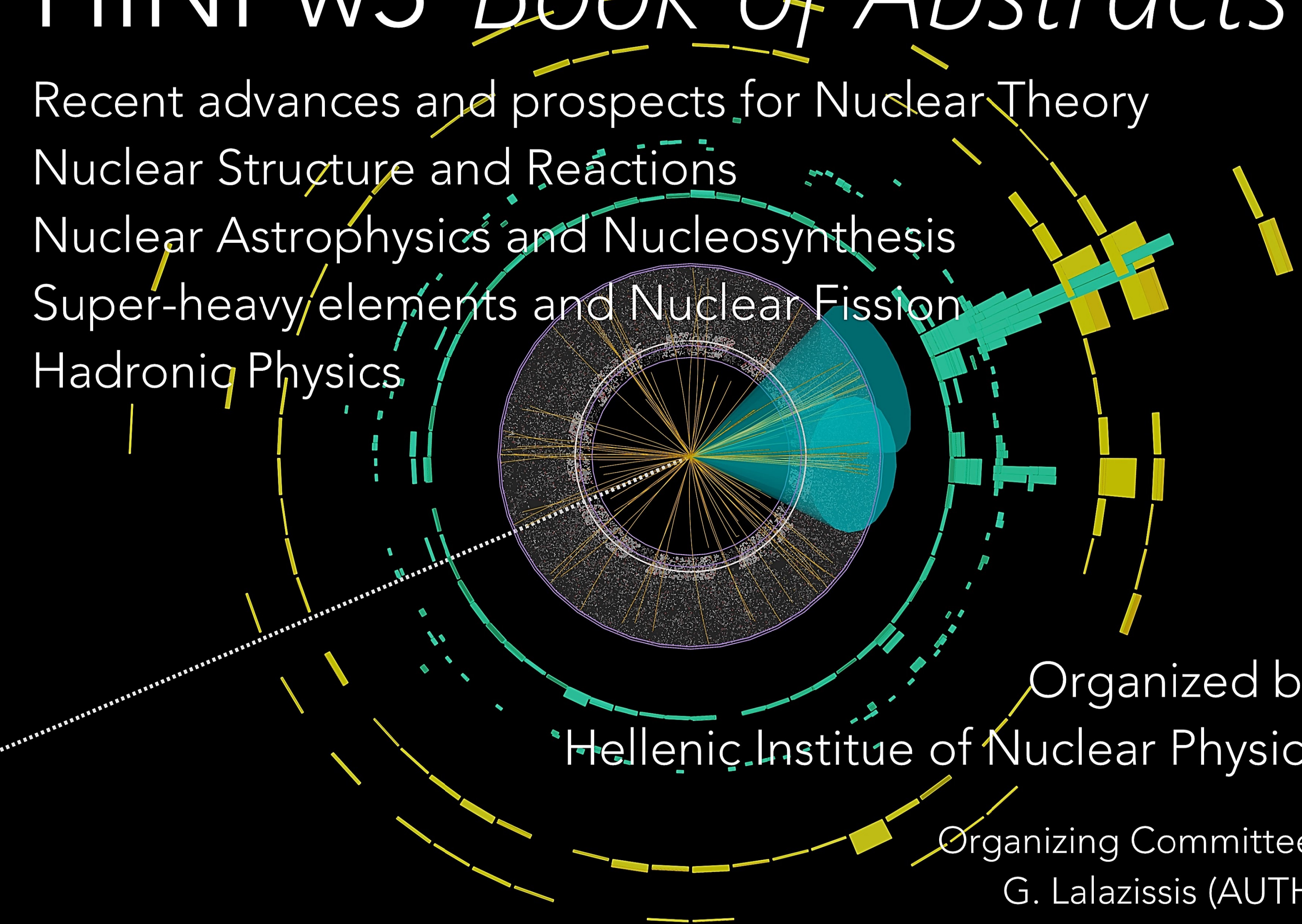
Recent advances and prospects for Nuclear Theory

Nuclear Structure and Reactions

Nuclear Astrophysics and Nucleosynthesis

Super-heavy elements and Nuclear Fission

Hadronic Physics



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	Friday 12 April 2019
08:00-8:40	Registration
08:40-09:00	HINP5 Welcome Speeches

Session 1-Chair	A. Lalazissis	
9:00-9:45	N. Alamanos	Nuclear Physics today - installations in perspective or under construction
9:45-10:15	P. Ring	On the ab-initio derivation of covariant density functionals.
10:15-10:45	F. Cappuzzello	The nuclear matrix elements of $0\nu\beta\beta$ decay and the NUMEN project at INFN-LNS
10:45-11:15	**COFFEE BREAK**	

Session 2-Chair	F.Cappuzzello	
11:15-11:45	H. Lenske	Theory of Heavy Ion Exchange Reactions as Probes for Nuclear Beta Decay
11:45-12:15	M. Gaidarov	Nuclear symmetry energy and its components at zero and finite temperatures
12:15-12:35	S. Nikas	Exploring the astrophysical conditions for the creation of the first
		r-process peak, and the impact of nuclear physics uncertainties
12:35-14:30	**LUNCH BREAK (For the invited and the speakers of the conference) / POSTER SESSION**	

Session 3-Chair	N. Alamanos	
14:30-15:00	L. Acosta	The new facilities and devices at Mexico for low energy nuclear reactions studies
15:00-15:30	S. Zhang	Strongly Resonating Bosons in Hot Nuclei
15:30-15:55	A. Pakou	The breakup of 9Be on a proton target at 5.6MeV/nucleon
15:55-16:15	G. Souliotis	Accessing the most neutron-rich nuclei: toward elucidating the nucleosynthesis of the elements beyond iron
16:15-16:35	O. Fasoula	Angular Distribution Studies of Neutron-Rich Projectile-like Fragments
		from 86Kr -induced peripheral collisions at 15 MeV/nucleon
16:35-17:00	**COFFEE BREAK**	

Session 4-Chair	A. Ioannidou	
17:00-17:20	F. Groppi	Non-conventional radionuclides produced by particle accelerators for theranostic applications
17:20-17:40	M.E. Tomazinaki	A Sparse and Ergonomic Tomographic Image Reconstruction Technique based on Artificial Neural Networks
17:40-18:00	D. Zarketan	Resolution Study of a γ-Camera System for SPECT at Preclinical Level
18:00-18:15	C. Betsou	The use of mosses as biomonitors of trace elements in Greece
20:30	**Dinner (OUZERI-TAVERNA KAMARES)**	

	Saturday 13 April 2019

Session 5-Chair P. Ring

9:15-9:45	N. Minkov	Theoretical predictions for the decay rates and magnetic moment in 229mTh
9:45-10:05	D. Bonatsos	Approximate SU(3) symmetries in heavy deformed nuclei
10:05-10:25	A. Martinou	A mechanism for shape coexistence
10:25-10:45	A. Assimakis	Breaking SU(3) spectral degeneracies in heavy deformed nuclei
10:45-11:05	P. Georgoudis	Non-relativistic conformal symmetry in nuclear structure
11:05-11:25	V. Prassa	Microscopic studies of fission dynamics based on energy density functionals

11:25-11:55	**COFFEE BREAK**	

Session 6-Chair D. Bonatsos

11:55-12:10	K. Karakatsanis	Two quasiparticle k-isomers within the covariant density functional theory
12:10-12:25	A. Chorozidou	Relativistic Equations of State for hot matter and neutron star dynamics
12:25-12:40	P. Koliogiannis	Equation of state of cold rapidly rotating neutron stars and the effects of the Keplerian sequence
12:40-12:55	Ch. Margaritis	Speed of sound bounds in dense matter and its effects on the bulk properties of rapidly rotating neutron stars
12:55-13:10	A. Kanakis	Constraints on neutron stars equation of state, from the observation of the tidal deformability of the GW170817 system
13:10		CLOSING OF THE WORKSHOP

Poster Session

	S. Koulouris	Study of the Momentum Distributions of Projectile-like Fragments from 86Kr -induced peripheral collisions at 15 MeV/nucleon
	I. Dimitropoulos	Study of the Momentum Distributions of Projectile-like Fragments from 40Ar -induced peripheral collisions at 15 MeV/nucleon
	G. Smaragdi	COMPARATIVE DOSIMETRIC RADIOTHERAPY ANALYSIS IN RECTAL CANCER
	P. Koliogiannis	Constraints on the equation of state from the stability condition of neutron stars
	L. Tsaloukidis	EQUATION OF STATE EFFECTS ON THE CRUST-CORE INTERFACE OF SLOW ROTATING NEUTRON STARS

Nicolas Alamanos

Research Director at the CEA

Deputy Director of IRFU (Institute of Research into the Fundamental Laws of the Universe)

Title: "Nuclear Physics today - installations in perspective or under construction".

Abstract: Taking the cosmological model as a time line, nuclear physics is an integral part of this model that describes the evolution of our universe from the Big Bang to nowadays, I would present nuclear physics facilities in perspective or under construction around the world.

The fundamental questions that animate hadronic physics at high temperature and temperature T=0 will be discussed and the installations in perspective will be presented. Special attention will be given to installations under construction or in perspective, which addresses the synthesis of super-heavy elements and the physics of exotic nuclei.

On the ab-initio derivation of covariant density functionals.

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The successes of covariant density functional theory, that start from effective Lagrangians, to describe nuclear ground and excited-state properties all over the nuclear chart are confronted with the fact, that the parameters of such density functionals are determined in a completely phenomenological way. The challenges and ambiguities of predictions for unstable nuclei without data or for high-density nuclear matter, arising from covariant density functionals are discussed. The basic ideas in building an ab initio covariant density functional for nuclear structure from ab initio calculations with realistic bare nucleon-nucleon interactions for both nuclear matter and finite nuclei are presented. The current status of fully self-consistent relativistic Brueckner-Hartree-Fock (RBHF) calculations for both finite nuclei and neutron drops is presented. The guidances and perspectives towards an ab initio covariant density functional for nuclear structure derived from RBHF results are discussed

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The nuclear matrix elements of 0νββ decay and the NUMEN project at INFN-LNS

The presentation aims at describing the main achievements of the NUMEN project [1], together with an updated and detailed overview of the related R&D activities and theoretical developments. NUMEN proposes an innovative technique to access the nuclear matrix elements entering the expression of the lifetime of the double beta decay by cross section measurements of heavy-ion induced Double Charge Exchange (DCE) reactions [2]. The main experimental tools for this project are the K800 Superconducting Cyclotron and MAGNEX spectrometer [3]. The former is used for the acceleration of the required high resolution and low emittance heavy-ion beams and the latter is the large acceptance magnetic spectrometer for the detection of the ejectiles. The use of the high-order trajectory reconstruction technique, implemented in MAGNEX, allows to reach the experimental resolution and sensitivity required for the accurate measurement of the DCE cross sections at forward angles. However, the tiny values of such cross sections and the resolution requirements demand beam intensities much larger than those manageable with the present facility. The on-going upgrade of the INFN-LNS facilities in this perspective is part of the NUMEN project and will be discussed at the Workshop.

[1] F.Cappuzzello et al., Eur. Phys. J. A (2018) 54: X (in press).
[2] F.Cappuzzello et al., Eur. Phys. J. A (2015) 51: 145
[3] F.Cappuzzello et al., Eur. Phys J. A (2016) 52: 167

Theory of Heavy Ion Exchange Reactions as Probes for Nuclear Beta Decay

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Heavy ion charge exchange reactions are of many-fold interest for nuclear re-action and structure physics. In a recent paper [1] a fully microscopic theory of heavy ion single charge exchange (SCE) reactions was formulated. Here, a new theoretical approach is presented, emphasizing the role of single and double charge exchange reactions for probing nuclear response functions of the same type as encountered in single and double beta decay [2]. A special class of nuclear double charge exchange (DCE) reactions proceeding as a one-step reaction through a two-body process are shown to involve nuclear matrix elements of the same diagrammatic structure as in $0\nu2\beta$ decay. These correlated Majorana-DCE (MDCE) reactions are distinct from second order DCE reactions which are characterized the best as sequential double single charge exchange (DSCE), thus carrying a close resemblance to $2\nu2\beta$ decay. The results suggest that ion-ion DCE reactions are the ideal testing grounds for investigations of double-beta decay nuclear matrix elements as proposed by the NUMEN project [3]. Nuclear response functions for charge-changing excitations and applications to recent single and double charge exchange data measured by the NUMEN collaboration at LNS Catania are discussed.

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Nuclear symmetry energy and its components at zero and finite temperatures

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We derive the volume and surface components of the nuclear symmetry energy (NSE) and their ratio [1] within the coherent density fluctuation model [2,3]. The estimations use the results of the model for the NSE in finite nuclei based on the Brueckner and Skyrme energy-density functionals for nuclear matter. The obtained values of these quantities for the Ni, Sn, and Pb isotopic chains are compared with estimations of other approaches which have used available experimental data on binding energies, neutron-skin thicknesses, and excitation energies to isobaric analog states. Apart from the density dependence investigated in our previous works [4,5,6], we study also the temperature dependence of the symmetry energy in finite nuclei [7] in the framework of the local density approximation combining it with the self-consistent Skyrme-HFB method using the cylindrical transformed deformed harmonic oscillator basis. The results for the thermal evolution of the NSE in the interval *T*=0-4 MeV show that its values decrease with temperature. The same formalism is applied to obtain the values of the volume and surface contributions to the NSE and their ratio at finite temperatures [8]. We confirm the existence of “kinks” of these quantities as functions of the mass number at *T*=0 MeV for the double closed-shell nuclei ^{78}Ni and ^{132}Sn and the lack of ”kinks” for the Pb isotopes, as well as the disappearance of these kinks as the temperature increases.

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Exploring the astrophysical conditions for the creation of the first r-process peak, and the impact of nuclear physics uncertainties.

Stylianos Nikas[1,2], Andre Sieverding[1,2], Gabriel Martinez - Pinedo[1,2], and Meng Ru Wu[3,4] ,

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The r-process is responsible for the production of about half of the heavy elements observed in the solar abundances. The site of the r- process was unknown until recent observations. The gravitational wave event GW170817, which was identified as a binary Neutron Star Merger (NSM), was followed by the detection of fast fading optical counterpart consistent with the predictions for a kilonova, associated with r-process nucleosynthesis. The observation of bright, fast fading UV component, established the production of heavy elements in the aftermath of NSM. The complicated atomic structure of lanthanides implies high opacity ejecta which would shift the wavelength of the observed light to the red, the blue color of the emission spectra at early time indicates that part of the ejecta only contains relatively high Ye and consequently low lanthanide production. We present a study of nucleosynthesis for conditions of high Ye outflows from NSMs and investigate the effect of uncertainties in nuclear masses as well as in beta decay rates and the astrophysical conditions under which this could be the site for the production of the elements of the r-process abundance pattern for A < 100.

This work was supported by DFG through Grant No. SFB1245 and HGS-HIRe.

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The new facilities and devices at Mexico for low energy nuclear reactions studies.

L. Acosta[1], E. Chávez-Lomelí[1], L. Barrón-Palos[1], M.E. Ortiz[1], E. Andrade[1], J. Miranda[1], D. Marín-Lambarri[1], F. Favela[2], K. de los Ríos[1], S. Murillo[1], J. García[1], L.E. Charón[1], J. Mas[1], L.R. Ríos[1], F. Morales[1], G. Reza[1], C. Flores-Vázquez[1] and A.M. Sánchez-Benítez[3].

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Since 2013 a new investment in facilities and devices occurred at Instituto de Física, UNAM (IFUNAM), promoted by a Program to implement National Laboratories placed at different research Institutions around the country. One of this National facilities is the Mass Spectrometer Accelerator Laboratory (LEMA), inaugurated 6 years ago [1]. The main equipment at LEMA is a high precision 1 MV accelerator performed by HVE, where different radioisotopes can be produced an analyzed by using AMS technique. Presently, ^{14}C, ^{10}Be and ^{26}Al concentrations can be well establish with the LEMA isotope separator. In such direction, we have developed experiments related with the measure of reaction cross sections using AMS, taking some interesting reactions related with the radioisotopes mentioned. First of all, to produce the radionuclei, we used other Mexican older facilities, such as a Van de Graaff accelerators from IFUNAM and Instituto de Ciencias Nucleares (ININ), where as well slow neutrons can be produced at a TRIGA-III reactor. Many other reactions are presently under study.

Recently a beam line was included at LEMA accelerator, where high current beams with a good precision low energy of many isotopes can be produced. The new line is equipped with a multipurpose reaction chamber where besides nuclear studies, IBA measurements (as RBS and PIXE) can be carry out.

From the Nuclear Physics point of view, a special detection system is under construction: the so called SIMAS array, which will be composed of DSSSD-PAD telescopes (20 + 130 micron thickness) and small PIPS-Surface barrier telescopes (10 + 300 micron thickness) in order to measure low energy channels by using ΔE-E technique. The readout will be make with commercial Mesytec preamplifiers and the very recent FEBEX3 digitizer data acquisition system. SIMAS is thought to be used as well for experiments abroad.

Other interesting devices at Mexico for low energy physics, are the Super Sonic Jet Gas Target, SUGAR and the Neutron wall, MONDE which could be coupled to different beamlines and thus to be used along with detection array as the mentioned before [2].

This Projects are been partially funded by CONACyT-LN294537, PAPIIT-DGAPA IA103218, IG101616, IA101016 and PIIF-2018 Projects.

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Strongly Resonating Bosons in Hot Nuclei

S. Zhang[1], A. Bonasera[2, 3], M. Huang[1], H. Zheng[4], G. Zhang[5], Z. Kohley[2, 6], J.C. Wang[1], L. Lu[1], Y.G. Ma[5, 7], S.J. Yennello[2, 6]

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When two heavy ions near the Fermi energy collide, a warm and low-density region can form in which fragments appear. This region is mainly dominated by proton (p) and alpha (α) particles. In such an environment, the αs interact with each other, and especially through strong resonances, form complex systems such as ^{8}Be and ^{12}C. Our experimental data analysis results show that in the reactions $^{70(64)}Zn(^{64}Ni)+^{70(64)}Zn(^{64}Ni)$ at E/A=35 MeV/nucleon levels of ^{8}Be appear around relative energies E_{ij}=0.092 MeV, 3.03 MeV as well as above 10 MeV and 100 MeV. We propose a different method to derive the correlation function based on the relative transverse energy distribution to minimize the experimental uncertainties. For the 3α systems, multi resonance processes give rise to excited levels of ^{12}C. The interaction between any two of the 3 particles provides events with one, two or three ^{8}Be. Their interfering levels are clearly seen in the minimum relative energy distributions. Events of three couple α relative energies consistent with the ground state of ^{8}Be are observed with the decrease of the instrumental error at the reconstructed 7.458 MeV excitation energy of ^{12}C, which was suggested as the Efimov (Thomas) state [1]. Also, the Hoyle state at 7.654 MeV excitation energy shows a decay component through the ground state of ^{8}Be and also components where two different α couples are at relative energies consistent with the ground state of ^{8}Be at the same time [2].

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The breakup of ^{9}Be on a proton target at 5.6MeV/nucleon

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Our on-going systematic study of the interactions of protons with light weakly-bound nuclei in inverse kinematics, completed for ^{6,7}Li with measurements of elastic scattering [1,2,3] and reactions [3,4,5,6], is extended in this work with the elastic scattering and breakup of the borromean nucleus ^{9}Be. The goal of this work is the determination of decay rates at the three configurations: α+α+n, ^{8}Be(2^{+})+n, ^{5}He+^{4}He. These rates are prerequisite to both nuclear structure in clustering theories and to astrophysical problems (r-process-building of heavy elements). While the breakup of ^{9}Be via the ^{8}Be$_{g.s}$ has been measured for many of the low-lying excited states of ^{9}Be, and is well established, the breakup branching via the first-excited 2^{+} state of ^{8}Be and via ^{5}He + ^{4}He remains uncertain while no attention has been given to the direct process α + α + n). Into this context an experiment was performed at the MAGNEX facility [7] in Catania, measuring the two alpha fragments and the recoil proton in a triple coincidence mode. One alpha fragment was acquired by MAGNEX spectrometer [7] and the other as well as the proton recoil at one module of the EXPADES array [8]. With the appropriate experimental setup, a clear signature of the three modes was observed in the recoil proton energy spectra, reconstructed in a full kinematical approach together with energy spectra for all fragments, included the unobserved neutron, as well as with relative energies and Q-value spectra. Our results will be discussed in detail.

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Accessing the most neutron-rich nuclei: toward elucidating the nucleosynthesis of the elements beyond iron

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The origin and distribution of the chemical elements are among the central topics of nuclear physics and chemistry today [1]. The light elements H, He and Li were formed at the late stages of the Big Bang, whereas heavier elements up to iron are products of thermonuclear fusion in the stars. Furthermore, elements beyond iron cannot be produced in fusion reactions. Instead, they are made by neutron capture reactions via the (slow) s-process and the (rapid) r-process, each contributing equally to their production. Whereas the details of the s-process are well understood [2], the precise site and conditions of the r-process remain elusive [3]. Supernova explosions and the merging of neutron stars are now believed to be the proper r-process sites [4]. The r-process takes place in astrophysical environments of extremely high neutron density (10^{20} neutrons/cm^3) and involves nuclei that are extremely neutron rich, reaching the limits of nuclear binding (the so-called neutron drip line). The production and study of such nuclei is key in understanding and modeling the r-process and, thus, unveiling the origin of the chemical elements from iron all the way to uranium [5]. The main traditional avenues to produce and study neutron rich nuclei are spallation reactions, fission and high-energy projectile fragmentation. Surpassing the limits of these approaches and reaching out to the neutron drip line is nowadays highly desirable. Thus, the study of new synthesis routes constitutes a vigorous endeavor of the nuclear physics community.

Motivated by these developments, we have devoted a substantial part of our efforts to study the production of neutron rich nuclei in peripheral multinucleon transfer reactions in the beam energy range 15-25 MeV/nucleon. We have systematically studied the production of neutron rich projectile-like fragments from the reactions of a ^{86}Kr beam (15 and 25 MeV/nucleon) on ^{64}Ni and ^{124}Sn targets using the MARS recoil separator at the Cyclotron Institute of Texas A&M University [6], and have provided a detailed theoretical description of the measured distributions based on microscopic modeling of the involved reactions [7,8,9]. In parallel, we have experimentally and theoretically investigated the fission of an ^{238}U (20 MeV/nucleon) beam interacting with a ^{208}Pb target [10]. After an overview of these works, I will discuss recent work and plans to continue our efforts at LNS/Catania, at Texas A&M University, and, in the near future, at RISP/IBS, Korea.

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Angular Distribution Studies of Neutron-Rich Projectile-like Fragments from ^{86}Kr -induced peripheral collisions at 15 MeV/nucleon

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In this talk, we will present our recent efforts to study the angular distributions of neutron-rich isotopes from the interaction of a ^{86}Kr beam at 15 MeV/nucleon with targets of ^{64}Ni and ^{124}Sn. Experimental data on the differential cross sections at two angles (4 and 7 degrees) were obtained from the previous work [1] of our group with the MARS spectrometer at the Cyclotron Institute of Texas A&M University. The experimental data will be compared with model calculations based on a two-step approach in which the dynamical stage of the collision is described with either the phenomenological Deep-Inelastic Transfer model (DIT) [2], or with the microscopic Constrained Molecular Dynamics model (CoMD) [2,3,4]. The de-excitation of the hot heavy projectile-like fragments is performed with the Statistical Multifragmentation Model (SMM) [5]. The calculations provide an overall fair description of the experimental data and indicate further improvements and extensions in the models.
We will continue with the calculation of the production cross sections of neutron-rich nuclides from collisions of the stable ^{86}Kr beam and the radioactive ^{92}Kr beam (15 MeV/nucleon) with a ^{238}U target and we will demonstrate that the multinucleon transfer mechanism leads to extremely neutron-rich nuclides in the mass region of A∼90-120, toward and beyond the astrophysical r-process path. In the near future, we wish to experimentally investigate such reactions with the MAGNEX spectrometer at LNS/INFN, Catania, and with the KOBRA spectrometer at RISP/IBS, Korea. In conjunction with our recent work [4,6], our continued progress in the study of multinucleon transfer reactions using heavy-ion beams at 15 MeV/nucleon, combined with the enhanced capabilities of present and upcoming low-energy accelerator facilities worldwide, enable new opportunities in the neutron-rich rare isotope research and may effectively contribute to the study of the r-process.

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Non-conventional radionuclides produced by particle accelerators for theranostic applications

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The use of High Specific Activity Radionuclides HSARNs, obtained by either proton, deuteron or alpha cyclotron irradiation, followed by selective radiochemical separation from the irradiated target in No Carrier Added (NCA) form, is a powerful analytical tool for plenty applications in pure and applied sciences and technologies. The main applications of these RNs are in medical radiodiagnostics and metabolic radiotherapy in addition to toxicological, environmental and industrial studies. Nowadays the new challenge in Nuclear Medicine is the so called theranostic medicine, a relatively novel paradigm that involves specific individual 'dual-purpose' radionuclides or radionuclide pairs with emissions that are suitable for both imaging, therapy and monitor the response to therapy. The theranostic radionuclides would potentially bring us closer to the age-long dream of personalized medicine [1]. A subchapter is the multifunctional nanoplatform that is an emerging highlight in nanomedicine, in which a suitable radionuclide is encapsulated in nanocarriers. Many of the "neutron-rich" radionuclides suitable for metabolic radiotherapy are produced by nuclear reactor with a very low specific activity (A_S). In selected cases, they can be produced by bombardment of targets by charged particle beams in NCA with very high A_S. If the irradiations are made with deuteron beams some more advantages are obtained as reported, as an example, in ref [2] for ^{186g}Re production.

At the Radiochemistry Laboratory of LASA, a wide range of high specific activity accelerator-produced radionuclides have been produced since the 70-ties in NCA form. Presently, nuclear activations are carried out at the cyclotron IBA K=70 of ARRONAX Center in Nantes France. The experimental measurements for the excitation functions determination are carried out at the Physics Measurements Laboratory in LASA, Italy. The experimental cross-sections were determined with the well-known staked foil technique and compared with the data present in literature and the curves of theoretical calculations obtained with suitable computer codes like EMPIRE-II, EMPIRE-3.2.2 and TENDL.

We will present some examples [2,3] of the more recent results in order to study and to obtain the optimal conditions for the production in NCA form of radionuclides with high A_s, highlighting the irradiation, measurements and data analysis techniques used by our research group.

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A Sparse and Ergonomic Tomographic Image Reconstruction Technique based on Artificial Neural Networks

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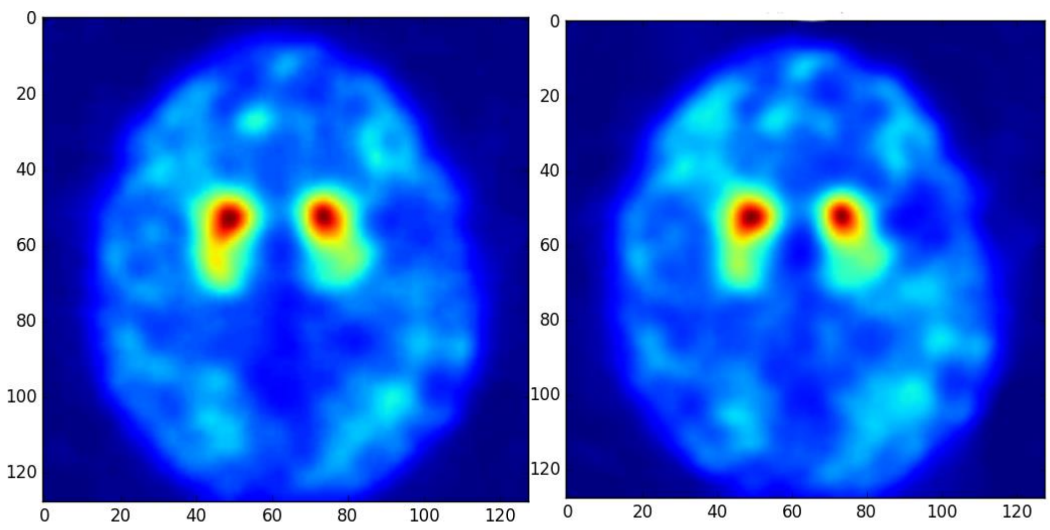
The recent advances in Artificial Intelligence (AI) and Machine Learning (ML) have affected Medical Physics and tend to set new frontiers in Image Reconstruction in Medicine. Nowadays modalities of tomography, such as SPECT, make use of software novelties since the current hardware have reach an upper limit. The aim of this study focuses on new approaches in Tomographic Image Reconstruction exploiting Radon Transform symmetries and novel training structures based on Artificial Neural Networks (ANNs). Having in mind that the mathematical transform of the tomographic process must be preserved, by keeping the simplicity and the strictly labeled service that each layer could provide in the network, the following conditions should be fulfilled [2]: The input data always has to be characterized by the sinogram of the image while the output has to reflect information about the image's representation. Instead of using the conventional sinogram technique, a new approach has to be introduced. A simple remapping [3] of the well-known sinogram free of dependencies of the images' features could lead to reconstructed images of diagnostic power and low time cost. The efficiency of this altered sinogram is tested as input of various ANN architectures in the current work in order to predict pixel values which guide the full image reconstruction. The proposed prototype is implemented in combined techniques with well-established algorithms, such as Algebraic Reconstruction Technique (ART) [4], leading to accurate results characterized by low chi-square values, even with limited available data. The results of this work as a prototype study could serve further research with ANN involvement for accurate Image Reconstructions of high clinical value.



Clinical SPECT data for Parkinson's disease. (Left) In-hospital reconstructed image, (Right) Reconstructed data with Newton-Raphson ART and ANN implementation.

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Resolution Study of a γ-Camera System for SPECT at Preclinical Level

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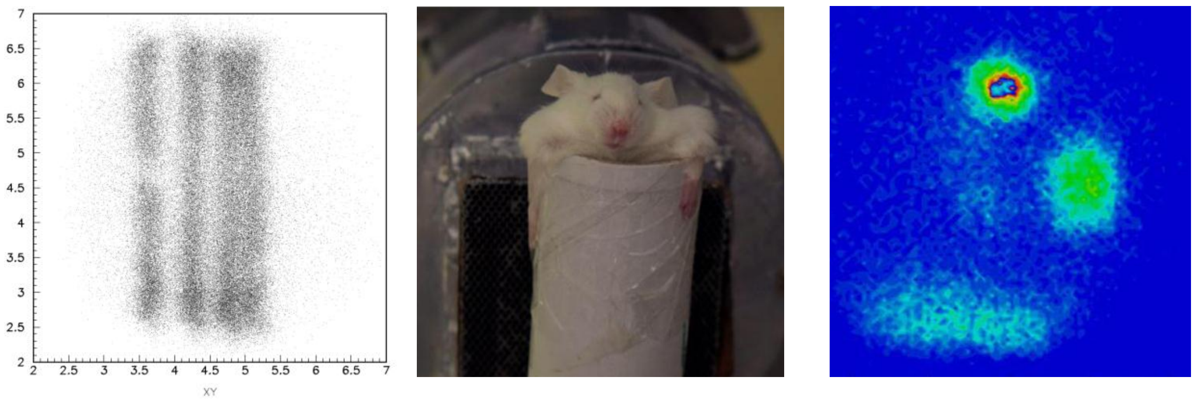
One of the most important imaging systems in Medical Physics is the γ-Camera, mainly used for Single Photon Emission Computed Tomographic (SPECT) scans. The present study focuses on the characterization at preclinical level of a small field, high resolution γ-Camera system developed in our laboratory with respect to its energy and spatial resolution. The system consists of a Position Sensitive PhotoMultiplier Tube (PSPMT) and is optimized for the ^{99m}Tc radiotracer. The intrinsic resolution of this tube is primarily checked with a series of measurements using LED pulses of variable duration, which are guided to the surface of the PSPMT. Accumulated charge from the wires of the anodic grid is then analyzed for various high voltage working values. The performance of the integrated system is further studied at planar and tomographic level by acquiring projective images of simple geometrical phantoms. For this purpose, a set of capillaries filled with ^{99m}Tc water solution was measured at different orientations and the obtained planar images were offline improved by implementing correction algorithms to eliminate spatial distortions. Further characterization of the system includes the tomographic reconstruction of more complicated geometrical phantoms. Finally, the performance of the γ-Camera system at preclinical level was tested by imaging specific organs of a small mouse targeted with ^{99m}Tc labelled pharmaceutical substances.



Planar images of simple geometrical phantoms and specific organs of a small mouse using 99mTc radiotracer.

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The use of mosses as biomonitors of trace elements in Greece

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Using mosses as biomonitors is a widely accepted method to assess the atmospheric deposition of trace elements. Mosses absorb the nutrients and the water from wet and dry deposition. They have no rooting system, unlike the higher plants, and the elements are absorbed entirely by their surface [1-3]. The simplicity of the sample collection and the ease of the analysis are some of the advantages of this method. Sampling can occur in remote areas easier and with lower costs than the sampling using the traditional methods.

Ninety-five samples of *Hypnum cupressiforme* Hedw. were collected in the region of Northern Greece during the end of summer 2016. Samples were collected from different altitudes (30 to 1450 m above the sea level). During the sampling all the requirements of the Protocol of the European Survey ICP Vegetation were strictly followed. After sampling, mosses were analyzed to the content of heavy metals by means of NAA. The chemical composition database of the moss samples was further used for the application of source apportionment by Positive Matrix Factorization (PMF), and specifically by the EPA PMF 5.0 model. In total 30 species were used for source apportionment (Na, Mg, Al, Si, Cl, K, Ca, Sc, Ti, V, Cr, Mn, Fe, Co, Ni, As, Br, Rb, Sr, Mo, Cd, Sb, Cs, Ba, La, Ce, Tb, Hf, Ta and Th).

Finally, a high sampling density was achieved, providing information for the elemental deposition from the atmosphere to terrestrial systems over the North Greece. The source apportionment results revealed contribution from five sources: Soil Dust, Aged Sea Salt, Vehicular Traffic, Heavy Oil Combustion and Mining Activities, with Soil Dust displaying the highest contribution to the measured metal concentrations among all other sources.

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Theoretical predictions for the decay rates and magnetic moment in ^{229m}Th

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Recently we have predicted the magnetic M1 and electric E2 radiative decay rates for the 7.8 eV isomer ^{229m}Th within a nuclear model with coupled collective quadrupole-octupole and single-particle motions, providing a good description of the low-lying ^{229}Th spectrum and the attendant experimentally observed electromagnetic transition rates [1]. Soon after that the magnetic dipole moment μ in the isomeric state (IS) was determined in a laser spectroscopy experiment providing the value of μ_{IS}= -0.37(6)μ_N [2]. Motivated by this result we extended our theoretical approach and calculated the magnetic moment by keeping the parameter values as obtained in [1] with only taking into account earlier estimates for the collective rotation gyromagnetic ratio g_R. Our calculations yielded a theoretical value of μ_{IS}= -0.35μ_N [3] in surprisingly good agreement with the experimental value, while the ground-state magnetic moment was overestimated by a factor 1.4. The analysis of the overall result suggests that the magnetic dipole moments in ^{229}Th may play a key role as constraints in the determination of the isomer decay rates in favour of the efforts for establishing of a "nuclear clock" frequency standard.

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Approximate SU(3) symmetries in heavy deformed nuclei

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The rapid increase of computational power over the last several years has allowed detailed microscopic investigations of the structure of many nuclei in terms of Relativistic Mean Field theories as well as in the framework of the no-core Shell Model. In heavy deformed nuclei, in which microscopic calculations remain a challenge, algebraic models based on the SU(3) symmetry offer specific predictions directly comparable to experimental data. Two different approximate models for heavy deformed nuclei based on the SU(3) symmetry, the pseudo-SU(3) [1-3] and the proxy-SU(3) [4-6] schemes are discussed and the compatibility between their predictions for the nuclear deformation parameters will be shown.

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A mechanism for shape coexistence

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A mechanism for shape coexistence is proposed. The mechanism is activated by large deformation and involves the coupling of the nuclear shells 14-28, 28-50, 50-82, 82-126 with the harmonic oscillator shells 8-20, 20-40, 40-70, 70-112 respectively. The outcome is, that the phenomenon may occur in certain islands on the nuclear map. The mechanism predicts without any parameters, that nuclei with either proton number (Z), whether neutron number (N) between 8, 18-20, 34-42, 60-72, 96-116 are candidates for shape coexistence. Predictions for the energy and the shape of the 0_2^+ states are made. In the $N\sim 20$ island of inversion the mechanism predicts, that an inversion of $0_{1,2}^+$ states occurs at N=19.

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Breaking SU(3) spectral degeneracies in heavy deformed nuclei

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Symmetries are manifested in nature through degeneracies in the spectra of physical systems. In the case of heavy deformed nuclei, when described in the framework of the Interacting Boson Model, within which correlated proton (neutron) pairs are approximated as bosons, the ground state band has no symmetry partner, while the degeneracy between the first excited beta and gamma bands is broken through the use of three-body and/or four-body terms [1-4]. In the framework of the proxy-SU(3) model [5,6], in which an approximate SU(3) symmetry of fermions is present, the same three-body and/or four-body operators are used for breaking the degeneracy between the ground state band and the first excited gamma band. Experimentally accessible quantities being independent of any free parameters are pointed out in the latter case.

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Non-relativistic conformal symmetry in nuclear structure

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The unitarity limit refers to infinite scattering length in a scattering problem of nucleons and manifests non-relativistic conformal symmetry [1]. A scheme is proposed [2] using group theoretical methods of the Interacting Boson Model [3] and techniques from Bose Einstein Condensates [4] for the introduction of the unitarity limit to nuclear collective states. In this talk I will present the SO(2,1) conformal algebra along with some of its implications in nuclear structure and will discuss the scaling behavior of nuclear collective states at unitarity.

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Microscopic studies of fission dynamics based on energy density functionals

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Static and dynamic aspects of the fission process are analyzed in a self-consistent framework based on energy density functionals. Multidimensionally constrained mean-field calculations in the collective space determine the potential energy surface of the fissioning nucleus, the scission line, the single-nucleon wave functions, energies, and occupation probabilities. For the case of spontaneous fission, the coupling between shape and pairing degrees of freedom is explored. Induced fission dynamics is described using the time-dependent generator coordinate method in the Gaussian overlap approximation. The position of the scission line and the microscopic input for the collective Hamiltonian are analyzed as functions of the strength of the pairing interaction, as well as the effect of static pairing correlations on charge yields and total kinetic energy of fission fragments.

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Two quasiparticle k-isomers within the covariant density functional theory

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Covariant density functionals provide a powerful phenomenological way to study nuclear structure phenomena. They have been mostly used in describing bulk nuclear properties of ground states and have been also very succesful in the description of collective excitations. In this study we concentrate on the single particle excitations of high k isomers. We employ the Equal filling approximation to relativistic hartree bogoliubov calculations to study the high k-isomers in even-even nuclei. We concentrate our interest in medium mass axially deformed nuclei where there have been several experimentally observed k-isomers and we can compare directly our results.

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Relativistic Equations of State for hot matter and neutron star dynamics

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We investigate the properties of compressed and hot hadronic matter within the Non-Linear Derivative (NLD) formalism. The novel feature of the NLD model is an explicit momentum dependence of the mean-fields, which is regulated by cut-off's of natural hadronic scale. It is covariantly and thermodynamical-consistently formulated at the basis of a field-theoretical level. We show that the NLD model describes adequately all the empirical information of cold nuclear matter as function of density (equation of state) and, in particular, as function of particle momenta (optical potential). Finally, we present predictions of the NLD approach for hot and compressed hadronic matter in terms of the Equation of state as function of density and temperature. These studies are relevant for the forthcoming experiments at FAIR@GSI. They are also important for astrophysical purposes, e.g., static neutron stars and dynamic neutron star binary systems.

Equation of state of cold rapidly rotating neutron stars and the effects of the Keplerian sequence

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Rapidly rotating neutron stars are considered to be the perfect laboratory for extreme density and gravity in general relativity. In the present work, we face two extreme configurations: the maximum mass and the maximum rotating frequency at the mass-shedding limit. We study the effects of the Keplerian sequence on the high density part of the equation of state of cold neutron star matter. We mainly focus on the dependence of the maximum rotation frequency from the macroscopic properties of neutron stars. We also study the dimensionless spin parameter (kerr parameter) of rotating neutron stars at the mass-shedding limit. In addition, supramassive time evolutionary rest mass sequences, which have their origin in general relativity, are explored. Supramassive sequences have masses exceeding the maximum mass of a non-rotating neutron star and evolve toward catastrophic collapse to a black hole. Important information can be gained from the astrophysical meaning of the kerr parameter and the supramassive sequences in neutron stars. Finally, the effects of the Keplerian sequence, in connection with the latter, may provide us constraints on the high density part of the equation of state of cold neutron star matter.

Speed of sound bounds in dense matter and its effects on the bulk properties of rapidly rotating neutron stars

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In search of the accurate determination of the maximum mass of neutron stars, the equation of state (EoS) in dense matter plays an important role. However, not only the EoS is directly connected to the neutron star masses, but also the speed of sound in dense matter is a crucial quantity which characterizes the stiffness of the EoS. Generally, the upper bound of the speed of sound imposes strong constraints on the maximum mass of neutron stars. Finally, we explore its effects on rapidly rotating neutron stars in the Keplerian sequence and extend our study to the behavior of their bulk properties (moment of inertia, angular velocity, etc.).

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Constraints on neutron stars equation of state, from the observation of the tidal deformability of the GW170817 system

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The purpose of this work is the study of neutron stars (NS) equation of state (EOS) using constraints on tidal deformability from the multimessenger observation of binary neutron star (BNS) inspiral GW170817. The mathematical formalism of TOV equations is introduced [1], and then for a variety of EOS the system is solved numerically, allowing us to determine the mass, the radius, the tidal love number k_2 and the tidal deformability λ of the NS, each one of them unique for each EOS. Moreover, for a fixed chirp mass of $M_{chirp} = 1.188\ M_{\odot}$ [3] under the assumption that $m_2 < m_1$ (where m_1 is the heavier component mass of BNS system), the effective (mass-weighted) tidal deformability $\widetilde{\Lambda}$ of the binary system is determined for each EOS [2,3,5]. We consider an upper limit of $\widetilde{\Lambda} \leq 800$ (GW170817) [3] and a lower limit of $\widetilde{\Lambda} \geq 400$ (AT2017gfo) [8]. Also, we construct the $\Lambda_1 - \Lambda_2$ space and we compare the behavior of EOS with the most recent LIGO's data [4,6,7]. We found out that the most EOS models give values of $\widetilde{\Lambda}$ less than the upper limit.

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Study of the Momentum Distributions of Projectile-like Fragments from ^{86}Kr -induced peripheral collisions at 15 MeV/nucleon

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In this poster, we present our initial steps in the study of the momentum distributions of projectile-like fragments from peripheral collisions of a ^{86}Kr beam at 15 MeV/nucleon with ^{64}Ni and ^{124}Sn targets. Experimental data on high-resolution momentum distributions were obtained from the previous work of our group [1] with the MARS spectrometer at the Cyclotron Institute of Texas A&M University. The general feature of the momentum distributions, as expected, is the presence of two regions: a) a quasielastic peak that corresponds to direct processes, and b) a broad region that corresponds to deep-inelastic processes. We have characterized the excitation energies in these two regions by employing two-body kinematics. Furthermore, we compare the data with model calculations based on either the phenomenological Deep-Inelastic Transfer model (DIT) [2] or the microscopic Constrained Molecular Dynamics model (CoMD) [2,3,4]. Deexcitation of the hot projectile-like fragments from the dynamical stage is performed with the Statistical Multifragmentation Model (SMM) [5]. Our preliminary comparisons indicate that the calculations provide a partially successful description of the details of the experimental momentum distributions. We are currently investigating possible improvements and extensions in the models.

From an experimental point-of-view, in the near future, we plan to continue the investigation of such reactions with the MAGNEX spectrometer at LNS/INFN, Catania, and with the KOBRA spectrometer at RISP/IBS, Korea. In conjunction with our recent works [4,6,7] on the production cross sections of neutron-rich nuclides, we hope that the study of the momentum distributions will unravel further details of the reaction mechanisms of peripheral collisions of heavy-ions in the energy region below the Fermi energy.

[1] G.A. Souliotis, M. Veselsky et al., Phys. Rev. C 84, 064607 (2011).
[2] L. Tassan-Got and C. Stephan, Nucl. Phys. A 524, 121 (1991).
[3] M. Papa, A. Bonasera et al., Phys. Rev. C 64, 024612 (2001).
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[5] G.A. Souliotis, A.S. Botvina et al., Phys. Rev. C 75, 011601 (2007).
[6] A. Papageorgiou, G.A. Souliotis et al., Journal of Physics G 45, 095105 (2018).
[7] O. Fasoula, G.A. Souliotis et al., contribution in this workshop.

Study of the Momentum Distributions of Projectile-like Fragments from ^{40}Ar -induced peripheral collisions at 15 MeV/nucleon

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In this poster, we present a preliminary study of the momentum distributions of projectile-like fragments from peripheral collisions of a ^{40}Ar beam at 15 MeV/nucleon with a ^{64}Ni target. The experimental data on high-resolution momentum distributions were obtained from previous work of our group [1,2] with the MARS spectrometer at the Cyclotron Institute of Texas A&M University. The momentum distributions are characterized by two regions: a) a quasielastic peak that corresponds to direct processes, and b) a broad region that corresponds to deep-inelastic processes. We have estimated the excitation energies in these two regions by using two-body kinematics. We also compare the data with model calculations based on either the phenomenological Deep-Inelastic Transfer model (DIT) [3], or the microscopic Constrained Molecular Dynamics model (CoMD) [3,4,5]. Deexcitation of the hot projectile-like fragments from the dynamical stage is performed with the Statistical Multifragmentation Model (SMM) [6]. Our comparisons show that the calculations provide a partially successful description of the experimental momentum distributions. We are currently investigating possible improvements and extensions in the DIT model and the CoMD model.

In the near future, we wish to perform high-resolution measurements of the momentum distributions of rare multinucleon-transfer channels with the MAGNEX spectrometer at LNS/INFN, Catania, and with the KOBRA spectrometer at RISP/IBS, Korea. Combined with our recent works [2,5,7] on the production cross sections of neutron-rich nuclides, we expect that the study of the momentum distributions will shead light to further details of the reaction mechanisms of peripheral collisions of heavy-ions in the energy region of 15-25 MeV/nucleon.

[1] G.A. Souliotis, M. Veselsky et al., Phys. Rev. C 84, 064607 (2011).
[2] A. Papageorgiou, G.A. Souliotis et al., Journal of Physics G 45, 095105 (2018).
[3] L. Tassan-Got and C. Stephan, Nucl. Phys. A 524, 121 (1991).
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[7] O. Fasoula, G.A. Souliotis et al., contribution in this workshop.

COMPARATIVE DOSIMETRIC RADIOTHERAPY ANALYSIS IN RECTAL CANCER

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Radiation therapy is an effective and safety method of treating tumors. The use of preoperative radiotherapy in locally advanced rectal cancer may increase total survival and reduce the local recurrence. The aim of this study is the comparative dosimetric analysis in four different radiotherapy techniques, 3DCRT (3D Conformal Radiation Therapy), IMRT (Intensity Modulated Radiotherapy) with three and four fields, and VMAT (Volumetric Modulated Arc Therapy) in rectal cancer.

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Constraints on the equation of state from the stability condition of neutron stars

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The stellar equilibrium and collapse, including mainly white dwarfs, neutron stars and supper massive stars, is an interplay between general relativistic effects and the equation of state of nuclear matter. In the present work, we use the Chandrasekhar criterion of stellar instability by employing a large number of realistic equations of state (EoS) of neutron star matter. We mainly focus on the critical point of transition from stable to unstable configuration. This point corresponds to the maximum neutron star mass configuration. We calculate, in each case, the resulting compactness parameter, $\beta = GM/c^2 R$, and the corresponding effective adiabatic index, γ_{cr}. The role of the trial function $\xi(r)$ is presented and discussed in details. We found that it holds a model-independent relation between γ_{cr} and β. This statement is strongly supported by the large number of EoS and it is also corroborated by using analytical solutions of the Einstein's field equations. Accurate observational measurements of the upper bound of the neutron star mass and the corresponding radius, in connection with the present predictions, may help to impose constraints on the high density part of the neutron star equation of state.

Equation of state effects on the core-crust interface of slowly rotating neutron stars

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We systematically study the symmetry energy effects of the transition density nt and the transition pressure Pt around the crust-core interface of a neutron star in the framework of the dynamical and the thermodynamical methods respectively. We employ both the parabolic approximation and the full expansion, for the definition of the symmetry energy. We use various theoretical nuclear models, which are suitable for reproducing the bulk properties of nuclear matter at low densities, close to saturation density as well as the maximum observational neutron star mass. First we derive and present an approximation for the transition pressure Pt and crustal mass Mcrust . Moreover, we derive a model-independent correlation between Pt and the slope parameter L for a fixed value of the symmetry energy at the saturation density. Second, we explore the effects of the equation of state on a few astrophysical applications which are sensitive to the values of nt and Pt including neutron star oscillation frequencies, thermal relaxation of the crust, crustal fraction of the moment of inertia, and the r-mode instability window of a rotating neutron star. In particular, we employ the Tolman VII solution of the TOV equations to derive analytical expressions for the critical frequencies and the relative time scales, for the r-mode instability, in comparison with the numerical predictions. In the majority of the applications, we found that the above quantities are sensitive mainly to the applied approximation for the symmetry energy (confirming previous results). There is also a dependence on the used method (dynamical or thermodynamical). The above findings lead us to claim that the determination of nt and Pt must be reliable and accurate before they are used to constrain relevant neutron star properties.

[1] L. Tsaloukidis, C. Margaritis, Ch. Moustakidis, Phys. Rev. C 99, 015803 (2019).