WORKSHOP ABSTRACTS

Workshop Program

9:00 – 9:30 Registration

9:30 – 9:35 Welcome address

G. Souliotis (NKUA) on behalf of the Organizing Committee

9:35 – 10:00 Workshop Opening Addresses

G. Lalazissis (Chair of HINP, AUTh)

G. Kokotos (Chair of the Chemistry Department, NKUA)

J. Samios (Director of the Physical Chemistry Laboratory, NKUA)

Session 1 - Chair G. Lalazissis (AUTh)

10:00 - 10:30 D. Bonatsos (NCSRD): The 2015 U.S. Long Range Plan for Nuclear Science (30 min)

10:30 - 10:50 H. Kosmas (UoI) : Black hole microquasars: gamma ray and neutrino emission (20 min)

10:50 - 11:10 Ch.C. Moustakidis (AUTh): Speed of Sound Effects on the Upper Bound of Non-Rotating Neutron Star Mass (20 min)

11:10 - 11:25 A. Martinou (NCSRD) : SU(3) symmetry in deformed nuclei (15 min)

11:25 - 11:40 I. Assimakis (NCSRD) : New coupling scheme in heavy nuclei (15 min)

11:40-12:10 coffee break

Session 2 - Chair H. Kosmas (UoI)

12:10 - 12:30 T. Gaitanos (AUTh): Multi-Strangeness Production in Hadron Induced Reactions (20 min)

12:30 - 12:45 K. Balasi (UoI/NCSRD): Scattering of light in the deep sea (15 min)

12:45 - 13:00 P. Koseoglou (TU-Darmstadt): 148- Ce 4+ lifetime from EXILL&FATIMA experiment (15 min)

13:00 - 13:15 E. Vagena (AUTh) : Measurement of the average cross section for 162Er(gamma,n) reaction with bremsstrahlung photons; comparison with theoretical calculations using the TALYS model (15 min)

13:15-13:30 A. Assimakopoulou (NKUA) : Microscopic description of p-induced spallation reactions with the Constrained Molecular Dynamics (CoMD) Model (15 min)

13:30 - 14:30 Lunch break

Session 3 – Chairs D. Bonatsos (NCSRD), A. Pakou (UoI)

14:30 – 15:00 A. Pakou (UoI) : Probing the cluster structure of 7Li via elastic scattering on protons and deuterons, in inverse kinematics (30 min)

15:00 – 15:15 V. Soukeras (UoI) : Influence of resonance and continuum states on elastic scattering of 6Li+p (15 min)

15:15 – 15:30 Ch. Betsou (UoI): The reaction 6Li + p → 3He + 4He at near barrier energies (15 min)

15:30-15:45 O. Sgouros (UoI) : Alpha and 3He - particle production in the reaction 7Be+28Si at near barrier energies (15 min)

15:45-16:05 G. Souliotis (NKUA) : Production of Rare Isotopes toward the Astrophysical r-process path (20 min)

16:05-16:20 N. Vonta (NKUA) : Neutron-Rich Isotope Production in 238-U Projectile Fission at 20 MeV/nucleon (15 min)

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16:30 – 17:00 Coffee break

17:00 – 18:00 Round Table Discussion - Chair: G. Lalazissis (Chair of HINP, AUTh)

Workshop Closing: G. Lalazissis

The 2015 U.S. Long Range Plan for Nuclear Science

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The 2015 Long Range Plan for Nuclear Science [1], released in October 2015 by the U.S. Nuclear Science Advisory Committee, will be reviewed, with emphasis on new directions in the field of nuclear science and new facilities under construction, as well as on manpower, budget, and the broader impacts of nuclear science.

[1] http://science.energy.gov/~/media/np/nsac/pdf/2015LRP/2015_LRPNS_091815.pdf

Speed of Sound Effects on the Upper Bound of Non-Rotating Neutron Star Mass

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Abstract

The estimation of the maximum mass of a neutron star is one of the most important problem in Astrophysics. Observational identification of black holes requires the knowledge of the upper limit on the gravitational mass of a neutron star. The determination of an accurate maximum neutron star mass strongly depends on the employed nuclear equation of state (EoS) up to very high density. In order to derive upper bounds to the maximum allowed mass a few minimal general assumptions have been considered that is: 1) the matter is a perfect fluid described by a one parameter equation of state which relates the pressure P to the energy density ϵ, 2) the density is positive ($\rho > 0$), 3) the matter is microscopically stable ($\frac{\mathrm{d}P}{\mathrm{d}\epsilon} \geq 0$) and 4) the pressure is always positive ($P \geq 0$). Any further principle which restricts the EoS will leads to improvement in the bounds. Such kind of restriction is the condition that the hydrodynamic phase velocity of sound $v_s = \left(\frac{\mathrm{d}P}{\mathrm{d}\epsilon}\right)^{1/2}$ is less that the speed of light, that is $\left(\frac{\mathrm{d}P}{\mathrm{d}\epsilon}\right)^{1/2} \leq c$. However, it has been conjectured that the speed of sound v_s in any medium is $v_s \leq \frac{c}{\sqrt{3}}$. The above statement imposes strong constraints on the EoS and leads to a significant lowering of the predicted maximum mass limit from $3M_\odot$ to less than $2M_\odot$. The existence of neutron stars with masses around two solar masses combined with the knowledge of the EoS of hadronic matter is in contradiction with this bound. In the present work we study the depends of the maximum neutron star mass on the upper bound of the speed of sound by employing various set of modern EoS's. We display the dramatic effects of speed of sound bounds on the EoS and consequently on the upper limit of a neutron star mass. Finally, we study and present some preliminary results concerning the nuclear symmetry energy effects on the estimation of the maximum neutron star mass.

References

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SU(3) symmetry in deformed nuclei

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01/04/2016

Abstract

SU(3) symmetry emerges in deformed nuclei with equal number of valence protons and neutrons. The deformation appears, when proton and neutron numbers differ perceptibly from magic numbers. The nucleon orbitals are defined by the K[N$n_z\Lambda$] quantum numbers of the Nilsson model. It has been proved, that the spatial overlap among nucleons with differences $\Delta K[\Delta N \Delta n_z \Delta\Lambda] = 0[110]$ is maximum[1]. As a consequense of this observation, an orbital of a valence nucleon can be replaced by its twin orbital. Through this approximation the resulting clump of valence orbitals has SU(3) symmetry. Since a symmetry has been achieved, the Hamiltonian of the nucleus consists of operators which preserve it. Among these operators is a three body interaction operator[2] which succesfully breaks the degeneracy of the β_1 and γ_1 bands, predicted by the IBM[3]. Furthermore the model predicts high values of B(E2) transition probabilities between the γ_1 and the ground state band. Both the cancellation of the degeneracy and the high B(E2) values are in stunning agreement with the experimental results.

References

[1] D. Bonatsos, S. Karampagia, R. B. Cakirli, R. F. Casten, K. Blaum, and L. Amon Susam, Phys. Rev. C 88, 054309 (2013).

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New coupling scheme in heavy nuclei

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1/04/2016

Abstract

The dynamical SU(3) symmetry present in heavy nuclei can be described by a new coupling scheme, which considers the $\Delta K[\Delta N\ \Delta n_z\ \Delta\Lambda]= 0[110]$ Nilsson "partner" orbitals [1,2]. In order to describe the properties of the new Hamiltonian, it is necessary to identify the U(n) symmetry corresponding to each valence shell of the nucleus, its irreducible representations (irreps), and the SU(3) irreps contained in each of them. Once this is accomplished [3], a Hamiltonian can be created, containing the Casimir operators of the proper Lie algebras. The calculation of the eigenvalues of the Casimir operators in a given irrep is a solved group theoretical problem. However, one has further to include the three-body operator Ω and/or the four body operator Λ, which will break the degenaracies among bands belonging to the same SU(3) irrep, without breaking the SU(3) symmetry. The calculation of the eigenvalues of the Λ and Ω operators for nontrivial SU(3) irreps is a formidable group theoretical problem [4-6], receiving attention.

References

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Multi-Strangeness Production in Hadron Induced Reactions

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Abstract

We discuss in detail the formation and propagation of multi-strangeness particles in reactions induced by hadron beams relevant for the forthcoming experiments at FAIR. We focus the discussion on the production of the decuplett-particle Ω and study for the first time the production and propagation mechanism of this heavy hyperon inside nuclear environments. The transport calculations show the possibility of Ω-production in the forthcoming PANDA-experiment, which can be achieved with measurable probabilities using high-energy secondary Ξ-beams. We predict cross sections for Ω-production. We conclude with pointing out the great opportunity of the future activities at FAIR to understand deeper the still little known high strangeness sector of the nuclear equation of state (EoS). Note that the strangeness sector of the equation of state is crucial for our knowledge in nuclear and hadron physics as well as in nuclear astrophysics. For instance, hyperons in nuclei do not experience Pauli blocking within the Fermi-sea of nucleons. Thus they are well suited for explorations of in-medium single-particle dynamics. In highly compressed matter in neutron stars the formation of particles with strangeness degree of freedom is energetically allowed. Of particular interest are hereby the Λ-,Σ-, Ξ- and Ω-hyperons with strangeness S=-1,-2 and -3, respectively. It has been recently shown that these hyperons modify the stiffness of the baryonic EoS at high densities considerably leading to the puzzling disagreement with recent observations of neutron stars in the range of 2 solar masses.

Acknowledgments

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References

[1] T. Gaitanos, C. C. Moustakidis, G. A. Lalazissis and H. Lenske, arXiv:1602.08905 [nucl-th].

Production of Rare Isotopes toward the Astrophysical r-process Path

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Neutron-rich nuclides have traditionally been produced in spallation reactions, fission and “cold" projectile fragmentation. Apart from these main production approaches, the search for new synthetic routes is currently of importance to extend our studies toward the neutron-drip line. To this goal, the production cross sections of projectile-like fragments from the reactions of ^{86}Kr (15 MeV/nucleon) on ^{64}Ni, ^{58}Ni and ^{124}Sn, ^{112}Sn targets were studied in using the MARS recoil separator at the Cyclotron Institute of Texas A&M University [1]. The same reactions were studied earlier at beam energy of 25 MeV/nucleon [2].

In the present work, we present the results of systematic calculations of the nuclear reaction mechanisms for the above collisions employing a hybrid approach. The calculations for the dynamical stage of the projectile-target interaction were carried out using either the microscopic constrained molecular dynamics model (CoMD) [4], or the phenomenological deep-inelastic transfer model (DIT) [3]. Subsequently, for the de-excitation of the projectile-like fragments, the statistical multifragmentation model (SMM) and the binary-decay code GEMINI were employed. A good agreement with the experimental results was observed with the CoMD code, as well as, with a properly modified version of the DIT code [5].

We point out that our current understanding of the reaction mechanisms at beam energies below the Fermi energy suggests that such nuclear reactions, involving peripheral nucleon exchange, when employed with high-intensity neutron-rich rare isotope beams will offer a novel route to access extremely neutron-rich rare isotopes toward the astrophysical r-process path, and the neutron drip-line.

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Neutron-Rich Isotope Production in ^{238}U Projectile Fission at 20 MeV/nucleon

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We investigate the possibilities of producing neutron-rich nuclides in projectile fission of heavy beams in the energy range of 20 MeV/nucleon expected from low-energy facilities. We report our efforts to theoretically describe the reaction mechanism of projectile fission following a multinucleon transfer collision at this energy range. Our calculations are mainly based on a two-step approach: the dynamical stage of the collision is described with either the phenomenological Deep-Inelastic Transfer model (DIT) [1], or with the microscopic Constrained Molecular Dynamics model (CoMD) [2,3].

The deexcitation/fission of the hot heavy projectile fragments is performed with the Statistical Multifragmentation Model (SMM)[4]. We compared our model calculations with our previous experimental projectile-fission data of ^{238}U(20 MeV/nucleon)+^{208}Pb [5] and ^{197}Au(20 MeV/nucleon)+^{197}Au [6] and found an overall reasonable agreement. Our study suggests that projectile fission following peripheral heavy-ion collisions at this energy range offers an effective route to access very neutron-rich rare isotopes toward and beyond the astrophysical r-process path.

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Microscopic description of proton-induced spallation reactions with the Constrained Molecular Dynamics (CoMD) Model

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The interaction of a high-energy proton (or neutron) with a heavy target results in the production of a heavy residue or two fission fragments followed by a copious number of nucleons (mostly neutrons). This process, termed “spallation”, has recently gained substantial practical importance due to its application a) in innovative schemes of energy production (e.g. ADS: accelerator driven systems), b) in the transmutation of nuclear waste (ATW: accelerator transmutation of waste) and c) in the use of the produced neutrons as probes for material or biological studies.

A large amount of experimental data on spallation fragment properties has been collected by various groups of the nuclear community. The theoretical description has been traditionally based on a two-step phenomenology: the INC (intra-nuclear cascade) stage and the de-excitation stage, including fission.

In the present work, we initiated a microscopic study of the full dynamics of the spallation process using the code CoMD (Constrained Molecular Dynamics) [1,2]. The code implements an effective interaction with a nuclear-matter compressibility of K=200 (soft EOS) with several forms of the density-dependence of the nucleon symmetry potential. In addition, CoMD imposes a constraint in the phase space occupation for each nucleon (restoring the Pauli principle at each time step of the collision). Proper choice of the surface parameter of the effective interaction has been made to describe the fission/residue competition.

In this talk, we will present preliminary results of spallation for the reactions: p (100-1000 MeV) + ^{173}Ta.^{208}Pb, ^{238}U. Calculated fragment mass distributions and neutron yields will be shown and compared with experimental data. We find that the microscopic code CoMD is able to describe the complicated n-body dynamics of the spallation process. The results are sensitive to the parameters of the effective interaction used. Systematic calculations on the above reactions and extensive comparisons with experimental data are currently in progress.

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[2] N. Vonta, G.A. Souliotis et al , Phys. Rev. C 92, 024616 (2015)

Probing the cluster structure of ^{7}Li via elastic scattering on protons and deuterons, in inverse kinematics

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Abstract

Elastic scattering measurements have been performed for the ^{7}Li + p system in inverse kinematics at the energies of 16, 25, 35 and 38.1 MeV and for the ^{7}Li + d system at 38.1 MeV. The heavy ejectiles were detected by the large acceptance MAGNEX spectrometer at the Laboratori Nazionali del Sud (LNS) in Catania, Italy. The results are considered in a JLM and a CDCC framework. In the last case the cluster structure of ^{7}Li proves to be critical for the theoretical interpretation of the experimental results.

Influence of resonance and continuum states on elastic scattering of ^{6}Li+p

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Abstract

Elastic scattering and breakup measurements have been performed for the ^{6}Li + p system in inverse kinematics at the energies of 16, 20, 25 and 29 MeV. The heavy ejectile was detected by the large acceptance MAGNEX spectrometer at the Laboratori Nazionali del Sud (LNS) in Catania, Italy. Elastic scattering experimental data will be presented and the influence of resonance and continuum states on elastic scattering will be discussed in a continuum discretized coupled channel (CDCC) framework. Preliminary exclusive breakup angular distribution measurements will be also presented.

Acknowledgments

The research leading to these results has received funding from the European Union Seventh Framework Programme FP7/2007-2013 under the Grant Agreement no. 262010-ENSAR.

The reaction ^{6}Li + p $\rightarrow$ ^{3}He + ^{4}He at near barrier energies

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Abstract

Angular distribution measurements were performed for the ^{6}Li + p $\rightarrow$ ^{3}He + ^{4}He reaction in inverse kinematics at near barrier energies, namely 2.7, 3.3, 4.2 and 4.8 MeV/u. The reaction products ^{3}He and ^{4}He were recorded with one telescope of the DINEX array and they were detected over the laboratory angle range θ_{lab} =16^0 to 34^0. The detection of the recoils over this angular range allowed the determination of the angular distribution over a wide angular range in the center-of-mass frame ($\theta_{c.m.} \sim 40^0$ to 140^0). The results clarified previous inconsistencies between existing data sets, while a good consistency of data with compound nucleus model calculations gave ground to useful conclusions for the reaction mechanism.

Acknowledgments

The research leading to these results has received funding from the European Union Seventh Framework Programme FP7/2007-2013 under the Grant Agreement no. 262010-ENSAR.

Alpha and ^{3}He - particle production in the reaction ^{7}Be+^{28}Si at near barrier energies

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Abstract

The production of α and ^{3}He - particles, was studied in the ^{7}Be + ^{28}Si reaction at 3 near-barrier energies, namely at 13, 20 and 22 MeV. Angular distributions were measured at each energy and the data were treated in a statistical model framework in order to disentangle the degree of competition between direct and compound channels and its energy evolution near barrier. Taking into account particle multiplicities and the α - production cross sections due to the compound nucleus formation, fusion cross sections were deduced and will be compared to systematics. The ^{3}He - particle cross sections will be discussed in a DWBA framework.

Acknowledgments

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^{148}Ce 4_1^+ lifetime from EXILL&FATIMA experiment

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Abstract

^{235}U and ^{241}Pu fission fragments were measured by a mixed spectrometer consisting of high-resolution Ge and fast $LaBr_3$(Ce)-scintillator detectors at the high-flux reactor of the ILL. Prompt γ-ray cascades from the nuclei of interest are selected via Ge-Ge-$LaBr_3$-$LaBr_3$ coincidences. The good energy resolution of the Ge allow precise gates to be set, selecting the cascade, hence, the nucleus of interest. The excellent timing performance of the $LaBr_3$ detectors in combination with the General Centroid Difference method [1] allows the measurement of lifetimes in the ps range in preparation for the FATIMA experiment at FAIR. The first results on neutron-rich ^{148}Ce is presented.

Acknowledgments

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References

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Measurement of the average cross section for $^{162}Er(\gamma, n)$ reaction with bremsstrahlung photons; comparison with theoretical calculations using the TALYS model.

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Abstract

Electron linacs accelerate high-energy electron beams to impinge on high Z targets producing high-energy gamma rays (bremsstrahlung photons). In this study, the bremsstrahlung photons have been used to experimentally determine the near threshold photonuclear cross section data of nuclides. First data were obtained for the astrophysically important nucleus ^{162}Er. Moreover, theoretical calculations have been applied using the TALYS code with default parameters. The technique employed, the measured yield from photoactivation of the targets via eight (γ, n) reactions, that allowed the determination of the number of photons from the threshold energy up to the end-point energy of the clinically photon beam used. The diversity of the materials allowed the monitoring of the photon flux in different energy intervals. Analyzing the experimental data, the integrated cross-sections for the photonuclear reaction $^{162}Er(\gamma, n)$ is calculated for 15 MeV bremsstrahlung end-point energy, that is unknown in the literature. To validate the method for the estimation of the average cross-section data of $^{162}Er(\gamma, n)$ reaction, the same procedure has been performed to calculate the average cross-section data of the reaction $^{197}Au(\gamma, n)^{196}Au$ that is commonly used as standard. The present results for both $^{162}Er(\gamma, n)$ and $^{197}Au(\gamma, n)$ are found to be in good agreement with the theoretical values obtained by TALYS 1.6.