BOOK of ABSTRACTS

HINPW4

4th Workshop of the Hellenic Institute of Nuclear Physics

on "New Aspects and Perspectives in Nuclear Physics"

Ioannina, 5-6 May 2017

BOOK of ABSTRACTS

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PREFACE

Dear colleagues, dear friends,

Following a series of successful HINP Workshops, we are pleased to welcome you to the 4th Workshop of the Hellenic Institute of Nuclear Physics (HINPW4), in Ioannina, from May 5 to 6, 2017.

We hope that HINPW4 will provide a lively forum for leading scientists and graduate students of the Greek Universities and Institutes to share the most recent advancements on various topics related to Nuclear Physics, thus offering a unique platform to exchange ideas and keep track of new aspects and perspectives in the area. The workshop sessions will cover the topics of Nuclear Structure and Nuclear Reactions, Hadron Physics and Environmental, Medical and Archaeometry Applications, with emphasis on Nuclear Reactions.

This year, we have the honour and pleasure to host distinguished colleagues from abroad, invited to present their work and collaborate with us on special topics to be decided during the sessions.

We would like to thank all of you, for your presence and especially those who contribute with oral presentations in HINPW4, generating a vibrant scientific programme.

Financial support from our sponsors – the University of Ioannina and VECTOR Technologies Ltd – is gratefully acknowledged.

We wish to all of you a fruitful workshop and a pleasant stay in Ioannina.

On behalf of the Organizing Committee,

Athena Pakou

PROGRAMME

PROGRAMME

Friday, 5th of May

8:30 – 9:00 *Registration*
9:00 – 9:10 *Welcome address from the Rector of the University of Ioannina*
9:10 – 9:20 *Welcome address from the Dean of the School of Sciences*
9:20 – 9:30 *Welcome address from the President of HINP*

Session I: Chair George Lalazissis

9:30 - 10:20 **Peter Ring** (TUM-Germany)
Covariant density functionals and their microscopic origin
10:20 - 11:00 **Nicolas Alamanos** (IRFU/CEA/SACLAY-France)
Evolution of ideas in direct and fusion reactions

11:00 - 11:30 coffee break

Session II: Chair Panagiotis Misaelides

11:30 - 12:10 **Krzysztof Rusek** (HIL-University of Warsaw-Poland)
Everything is coupled: reactions with weakly bound projectiles
12:10 - 12:50 **Nicholas Keeley** (NCBJ-Poland)
Light charged particle production in reactions induced by weakly-bound projectiles: Still an open question
12:50 - 13:30 **Dimitra Pierroutsakou** (INFN Napoli- Italy)
The EXOTIC project at INFN-LNL

13:30 - 15:00 Workshop photo / lunch break

Session III: Chair Dennis Bonatsos

15:00 - 15:40 **Francesco Cappuzzello** (University of Catania & INFN - Italy)
The nuclear matrix elements of 0νββ decay and the NUMEN project at INFN-LNS
15:40 - 16:10 **Charalampos Moustakidis** (AUTH - Greece)
Speed of sound bounds, tidal polarizability and gravitational waves from neutron stars
16:10 - 16:40 **Theodoros Gaitanos** (AUTH - Greece)
Momentum-dependent mean-field dynamics for in-medium Y-interactions
16:40 - 17:10 **Konstantinos Karakatsanis** (AUTH – Greece)
Spin-orbit splittings of neutron states in N = 20 isotones from covariant density functionals and their extensions

17:10 - 17:40 coffee break

Session IV: Chair Charalampos Moustakidis

17:40 - 18:10 **Dennis Bonatsos** (NCSR "Demokritos" - Greece)
A new symmetry for heavy nuclei: Proxy-SU(3)
18:10 - 18:25 **Ioannis Assimakis** (NCSR "Demokritos" - Greece)
Proxy-SU(3) symmetry in heavy nuclei: Foundations

18:25 - 18:40 **Adriana Martinou** (NCSR "Demokritos" - Greece)
Parameter-independent predictions for shape variables of heavy deformed nuclei in the proxy-SU(3) model
18:40 - 18:55 **Smaragda Sarandopoulou** (NCSR "Demokritos" - Greece)
Prolate dominance and prolate-oblate shape transition in the proxy-SU(3) model
18:55 Closing of Day 1 of the Workshop

20:00 – 23:00 ***Social Dinner***

Saturday, 6th of May

Session I: Chair Efstathios Stiliaris

9:00 - 9:40 **Aldo Bonasera** (Texas A&M - USA & INFN-LNS - Italy)
Nuclear Physics Using Lasers
9:40 - 10:20 **Martin Veselsky** (Institute of Physics, SAS, Slovakia)
EoS studies in nucleus-nucleus collisions: from Coulomb barrier to LHC
10:20 - 10:50 **George Souliotis** (NKUA - Greece)
Production of Neutron-Rich Rare Isotopes toward the astrophysical r-process path
10:50 - 11:15 **Nikolaos Nicolis** (UOI – Greece)
Fission in high-energy proton induced spallation reactions

11:15 - 11:40 coffee break

Session II: Chair George Souliotis

11:40 - 12:10 **Efstathios Stiliaris** (NKUA -Greece)
AMIAS: A Model Independent Analysis Scheme - From Hadronics to Medical Imaging
12:10 - 12:25 **Lefteris Markou** (CyI – Cyprus)
On Proton Deformation: A Model Independent Extraction of EMR from Recent Photoproduction Data
12:25 - 12:40 **Loizos Koutsantonis** (CyI - Cyprus)
Employing a Novel Analysis Method in the field of Tomographic Image Reconstruction for Single Photon Emission Computed Tomography (SPECT)
12:40 - 12:55 **Aristotelis-Nikolaos Rapsomanikis** (NKUA - Greece)
PhoSim: A Simulation Package designed for Macroscopic and Microscopic Studies in the Time-Resolved Optical Tomography
12:55 - 13:15 **Maria Zioga joint talk with Maria Mikeli** (NKUA - Greece)
Mastering Conic Sections for a Direct 3D Compton Image Reconstruction

13:15 - 14:30 lunch break

Session III: Chair Xenofon Aslanoglou

14:30 - 15:00 **Panagiotis Misaelides** (AUTH - Greece)
Study of organic-rich limestones of the Epirus region (Greece) using nuclear and synchrotron radiation techniques
15:00 - 15:30 **Konstantinos Stamoulis** (UOI - Greece)
Paleoseismology: Defining the seismic history of an area with the use of the OSL dating method

15:30 - 15:45 **Chrysoula Betsou** (AUTH - Greece)
^{210}Pb and ^{7}Be concentrations in moss samples from the region of Northern Greece

15:45 - 16:00 **Angeliki Asimakopoulou** (NKUA - Greece)
Systematic studies of proton-induced spallation reactions with microscopic and phenomenological models

16:00 - 16:15 **Sofia Papadimitriou** (NKUA - Greece)
Microscopic description of neutron-induced fission with the Constrained Molecular Dynamics (CoMD) Model: recent progress

16:15 - 16:30 **Athanasios Papageorgiou** (NKUA - Greece)
Neutron-rich rare isotope production with stable and radioactive beams in the mass range A = 40-60 at 15 MeV/nucleon

16:30 - 16:45 **Onoufrios Sgouros** (UOI - Greece)
Study of ^{7}Be+^{28}Si at near barrier energies: Elastic scattering and alpha production

16:45 - 17:00 **Vasileios Soukeras** (UOI - Greece)
A global study of the ^{6}Li+p system at near barrier energies in a CDCC approach

17:00 Announcement of HINPW5 / Workshop closing

ABSTRACTS

(In programme order)

Covariant density functionals and their microscopic origin

Peter Ring*

Physics Department, Technical University of Munich, 85748 Garching, Germany
Contact e-mail: ring@ph.tum.de

The description of the structure of nuclei in the framework of effective mean-field models are remarkably successful over almost the entire periodic table. Relativistic and non-relativistic versions of this approach enable an effective description of the nuclear many-body problem as an energy density functional. Such theories are used with great success in all quantum mechanical many-body systems. In Coulombic systems, density functional theory is exact and can be derived from the bare Coulomb force without additional phenomenological parameters. In nuclear physics with spin and isospin degrees of freedom, the situation is much more complicated due to the strong nucleon-nucleon and three-body forces. At present, all attempts to derive these functionals directly from the bare forces do not reach the required accuracy. In recent years, however, there have been several attempts to derive semi-microscopic functionals. They start with microscopic Brueckner-Hartree-Fock calculations in nuclear matter. These results are then mapped on a Walecka model to adjust in this way basic properties of the covariant density functionals. Only very few additional, phenomenological parameters are necessary to for a finetuning and in this way universal covariant density functionals have been derived which provide an excellent description of ground states and excited states all over the periodic table with a high predictive power.

These semi-microscopic functionals suffer from the fact, that there form is not directly derived from ab initio calculations, only there parameters are adjusted. Therefore, recently, Relativistic Brueckner-Hartree-Fock theory in finite nuclei has been used to derive the self-consistent mean field and the ground state properties of spherical doubly closed shell nuclei. Starting from a realistic bare nucleon-nucleon (NN) force adjusted to nuclear scattering data, the relativistic G-matrix is obtained as an effective interaction by solving the Bethe-Goldstone equation in a self-consistent basis. This G-matrix is inserted in a relativistic Hartree-Fock code for finite nuclei and in each step of the iteration a new G-matrix is calculated by solving the Bethe-Goldstone equation for the Pauli-operator derived from the corresponding Fermi surface in the finite system. The self-consistent solution of this iteration process allows to calculate ground state properties of finite nuclei without any adjustable parameters. No three-body forces are used. First results are shown for the doubly magic nuclei ^{4}He, ^{16}O, and ^{48}Ca. Their ground state properties, such as binding energies, charge radii, or spin-orbit splittings are largely improved as compared with the results obtained from non-relativistic Brueckner-Hartree-Fock theory. It is discussed that this theory provides a method to study also the ground state properties of heavy nuclei in *ab initio* calculations.

* Work supported by the DFG (Germany) cluster of excellence “Origin and Structure of the Universe” (www.universe-cluster.de)

Evolution of ideas in direct and fusion reactions

N. Alamanos

CEA-Saclay, DAPNIA-SPhN, Gif-sur-Yvette, France

The evolution of our ideas in the domain of elastic and inelastic scattering as well as of direct and fusion reactions at near- and sub-barrier energies will be presented briefly. Start point will be our first attempts to describe elastic and inelastic scattering via the JLM model, without adjustable parameters, up to recent analyses using this model and aiming to obtain experimental matter radii. This new observable, "matter radii", will be compared to state-of-the-art ab-initio calculations and challenge their predictive strength Fusion of very neutron-rich nuclei may be important to determine the composition and heating of the crust of accreting neutron stars. The evolution of our ideas in this domain will be discussed. Near- and sub-barrier fusion results will be compared to modern theoretical calculations (DCCC, density-constrained Hartree-Fock calculations). Personal ideas for both direct and sub- or near-barrier fusion reactions will be given, responding to the questions "where do we stand? What is next?".

Everything is coupled; reactions with weakly bound projectiles

Krzysztof Rusek

Heavy Ion Laboratory, University of Warsaw, Pasteura 5A, 02-093 Warsaw, Poland

Weakly bound light nuclei are ideal to study the importance of coupling effects in scattering and reactions. These effects are clearly observed in the analysis of experiments devoted to elastic scattering, transfer reactions and fusion, providing that the measurements are precise (small error bars).

Coupling to the continuum (to the breakup channel) affects strongly the elastic scattering differential cross section at forward scattering angles and contributes to the generation of analysing powers. The effect of transfer reactions on the elastic scattering is opposite to that of the breakup and it is especially strong at the backward scattering angles. Direct reaction channels (breakup, transfer) may significantly affect the fusion cross section with respect to the predictions based on a simple potential model (e.g. enhance the predicted fusion cross section below the Coulomb barrier and suppress it above). In experiments investigating Coulomb barrier distribution, breakup tends to broaden the distribution and to increase its average energy while the transfer acts in the opposite way.

The best way to investigate coupling effects is to perform a series of complementary experiments and collect a variety of data. So far not many data sets exist that cover all possible reaction channels for a given pair of scattered nuclei. However, one good example of such a set is the data for ^{6,7}Li + ^{28}Si collected by prof. Athena Pakou and her team.

This contribution is not meant as a broad review of the field but rather as a presentation of a few examples of reactions where the couplings of different reaction channels play an important role.

Light charged particle production in reactions induced by weakly-bound projectiles: Still an open question

N. Keeley

National Centre for Nuclear Research, Otwock, Poland

It is often assumed that the large inclusive cross sections for production of alpha particles and other light fragments in reactions induced by weakly-bound projectiles are due to breakup. This is in spite of considerable evidence dating back over forty years that transfer reactions actually play the main role. Some of the evidence available in the literature will be reviewed for the stable weakly-bound nuclei ^{6}Li and ^{7}Li as well as the rather more fragmentary data for radioactive beams like ^{6}He, ^{8}He, ^{8}B etc.

The EXOTIC project at INFN-LNL

D. Pierroutsakou for the EXOTIC collaboration

INFN-Sezione di Napoli, via Cinthia, 80126 Napoli, Italy

I will present the low-energy light Radioactive Ion Beam (RIB) in-flight facility EXOTIC [1-5], operational at the INFN-Laboratori Nazionali di Legnaro (INFN-LNL) and the associated experimental set up [6] designed for nuclear physics and nuclear astrophysics experiments. I will present the outline of the experimental program carried out employing the produced RIBs and discuss few selected recent experiments. Finally, I will give the perspectives of the EXOTIC project.

References

[1] V.Z. Maidikov et al., Nucl. Phys. A 746 (2004) 389c
[2] D. Pierroutsakou et al., Eur. Phys. J. Special Topics 150 (2007) 47
[3] F. Farinon et al., Nucl. Instr. and Meth. B 266 (2008) 4097
[4] M. Mazzocco et al., Nucl. Instr. and Meth. B 266 (2008) 4665
[5] M. Mazzocco et al., Nucl. Instr. and Meth. B 317 (2013) 223
[6] D. Pierroutsakou et al., Nucl. Instr. and Meth. A 834 (2016) 46

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

Francesco Cappuzzello

INFN Laboratori Nazionali del Sud, via S. Sofia 62, Catania, Italy
Dipartimento di Fisica e Astronomia, Universita di Catania, via S. Sofia 64, Catania, Italy

The physics case of neutrino-less double beta decay and its tremendous implications on particle physics, cosmology and fundamental physics will be introduced. In particular, the crucial aspect of the nuclear matrix elements entering in the expression of the half-life of this process will be deepened.

The novel idea of using heavy-ion induced reactions as tools for the determination of these matrix elements will be then presented. The strengths and the limits of the proposed methodology will be indicated. New data from MAGNEX facility at the INFN-LNS laboratory give first evidences of the possibility to get quantitative results about nuclear matrix elements from experiments.

Finally, the NUMEN project of INFN and the proposed strategy to this research will be sketched in the view of the emerging collaborations with Greek researchers and Institutions. Results from experimental activity done in collaborations will be also presented at the Conference.

Speed of sound bounds, tidal polarizability and gravitational waves from neutron stars

Ch.C. Moustakidis, T. Gaitanos, Ch. Margaritis, G.A. Lalazissis

Department of Theoretical Physics, Aristotle University of Thessaloniki, 54124 Thessaloniki, Greece

The accurate determination of the maximum mass of the neutron stars is one of the most important tasks in Astrophysics. It is directly related with the identification of the black holes in the Universe, the production of neutron stars from the supernovae explosion and the Equation of State (EoS) of dense matter. However, not only the EoS is directly connected with neutron star masses, but also the speed of sound in dense matter is a crucial quantity which characterizes the stiffness of the EoS. The upper bound of the speed of sound imposes strong constraints on the maximum mass of neutron stars. However, this upper bound remains still an open issue. Recent observations, of binary neutron star systems, offer the possibility to measure with high accuracy both the mass and the tidal polarizability of the stars. We study possible effects of the upper bound of the speed of sound on the upper bound of the mass and the tidal polarizability. We conclude that this kind of measurements, combined with recent observations of neutron stars with masses close to 2 Msolar, will provide robust constraints on the equation of state of hadronic matter at high densities. Finally, we explore the possibility to constrain the equation of state from the detection of a signal of gravitational waves from black hole -neutron star and neutron star-neutron star binary systems.

Momentum-dependent mean-field dynamics for in-medium Y-interactions

Th. Gaitanos, A. Violari

Department of Theoretical Physics, Aristotle University of Thessaloniki, Thessaloniki 54124, Greece

We discuss the Lorentz structure of hyperonic interactions in nuclear matter (Y-interactions) as a function of the baryon density and hyperon momentum. We use the Non-Linear Derivative (NLD) mean-field approach for the description of in-medium nucleon- and antinucleon-potentials. We extend the NLD model to the strangeness sector by including hyperon-nucleon (YN) interactions in the spirit of SU(3), however, by accouting for non-linear derivative terms. The non-linear derivative terms induce an explicit momentum dependence, which regulates the high-momentum tails of the YN-optical potentials. At first, we present results for the optical potentials of protons and antiprotons and show the importance of the momentum-dependent cut-off when comparing with the Dirac phenomenology. In fact, the NLD model reproduces the in-medium proton-potentials, and without any additional parameters, the in-medium momentum dependence of the real and imaginary parts of the antiproton-potential. Furthermore, we show preliminary results for the in-medium momentum-dependence of hyperons in nuclear matter and compare with microscopic calculations. This study is important for a deeper understanding of the strangeness sector of the equation of state (EoS) at high Fermi momenta. We conclude the relevance of our results for nuclear astrophysics and for the PANDA-experiments at the forthcoming FAIR-facility (GSI/Darmstadt).

Spin-orbit splittings of neutron states in N = 20 isotones from covariant density functionals and their extensions

Konstantinos Karakatsanis and G. A. Lalazissis

Physics Department, Aristotle University of Thessaloniki, Thessaloniki GR-54124, Greece

Peter Ring

Physik Department, Technische Universität Munchen, D-85747 Garching, Germany

Elena Litvinova

Department of Physics, Western Michigan University,
Kalamazoo MI 49008-5252 USA and
National Superconducting Cyclotron Laboratory,
Michigan State University, East Lansing, MI 48824-1321, USA

The spin-orbit splitting is an essential ingredient for our understanding of the shell structure in nuclei. One of the most important advantages of relativistic mean-field (RMF) models in nuclear physics is the fact that the large spin-orbit (SO) potential emerges automatically from the inclusion of Lorentz-scalar and -vector potentials in the Dirac equation. It is therefore of great importance to compare the results of such models with experimental data. We investigate the size of 2p- and 1f-splittings for the isotone chain ^{40}Ca, ^{38}Ar, ^{36}S, and ^{34}Si in the framework of various relativistic and non-relativistic density functionals. They are compared with the results of non-relativistic models and with recent experimental data.

A new symmetry for heavy nuclei: Proxy-SU(3)

Dennis Bonatsos

Institute of Nuclear and Particle Physics, National Center for Scientific Research "Demokritos", Athens, Greece

The SU(3) symmetry realized by J. P. Elliott in the sd nuclear shell is destroyed in heavier shells by the strong spin-orbit interaction. On the other hand, the SU(3) symmetry has been used for the description of heavy nuclei in terms of bosons in the framework of the Interacting Boson Approximation, as well as in terms of fermions using the pseudo-SU(3) approximation. We introduce a new fermionic approximation, called the proxy-SU(3), and we comment on its similarities and di_erences with the other approaches.

References

[1] D. Bonatsos, I. E. Assimakis, N. Minkov, A. Martinou, R. B. Cakirli, R. F. Casten, and K. Blaum, Proxy SU(3) symmetry in heavy deformed nuclei, submitted.

Proxy-SU(3) symmetry in heavy nuclei: Foundations

Ioannis E. Assimakis

Institute of Nuclear and Particle Physics, National Center for Scientific Research "Demokritos", Athens, Greece

An approximate SU(3) symmetry appears in heavy deformed even-even nuclei, by omitting the intruder Nilsson orbital of highest total angular momentum and replacing the rest of the intruder orbitals by the orbitals which have escaped to the next lower major shell. The approximation is based on the fact that there is an one-to-one correspondence between the orbitals of the two sets, based on pairs of orbitals having identical quantum numbers of orbital angular momentum, spin, and total angular momentum. The accuracy of the approximation is tested through calculations in the framework of the Nilsson model in the asymptotic limit of large deformations, focusing attention on the changes in selection rules and in avoided crossings caused by the opposite parity of the proxies with respect to the substituted orbitals.

References

[1] D. Bonatsos, I. E. Assimakis, N. Minkov, A. Martinou, R. B. Cakirli, R. F. Casten, and K. Blaum, Proxy SU(3) symmetry in heavy deformed nuclei, submitted.

Parameter-independent predictions for shape variables of heavy deformed nuclei in the proxy-SU(3) model

Andriana Martinou

Institute of Nuclear and Particle Physics, National Center for Scientific Research "Demokritos", Athens, Greece

Using a new approximate analytic parameter-free proxy-SU(3) scheme, we make predictions of shape observables for deformed nuclei, namely β and γ deformation variables, and compare these with empirical data and with predictions by relativistic and non-relativistic mean-field theories.

References

[1] D. Bonatsos, I. E. Assimakis, N. Minkov, A. Martinou, S. Sarantopoulou, R. B. Cakirli, R. F. Casten, and K. Blaum, Analytic predictions for nuclear shapes, the prolate dominance and the prolate-oblate shape transition in the proxy-SU(3) model, submitted.

Prolate dominance and prolate-oblate shape transition in the proxy-SU(3) model

Smaragda Sarantopoulou

Institute of Nuclear and Particle Physics, National Center for Scientific Research "Demokritos", Athens, Greece

Using a new approximate analytic parameter-free proxy-SU(3) scheme, we make simple predictions for the global feature of prolate dominance and the locus of the prolate-oblate shape transition and compare these with empirical data.

References

[1] D. Bonatsos, I. E. Assimakis, N. Minkov, A. Martinou, S. Sarantopoulou, R. B. Cakirli, R. F. Casten, and K. Blaum, Analytic predictions for nuclear shapes, the prolate dominance and the prolate-oblate shape transition in the proxy-SU(3) model, submitted.

Nuclear Physics Using Lasers

A. Bonasera

Cyclotron Institute, Texas A&M University, College Station, TX-77843, USA;
Laboratori Nazionali del Sud, INFN, via Santa Sofia, 62, 95123 Catania, Italy

The plasma astrophysical S factor for the ^{3}He(d;p)^{4}He fusion reaction was measured for the first time at temperatures of few KeV, using the interaction of intense ultrafast laser pulses with molecular deuterium clusters mixed with ^{3}He atoms. The experiments were performed at the Petawatt laser facility, University of Texas, Austin-USA. Different proportions of D_2 and ^{3}He or CD_4 and ^{3}He were mixed in the gas target in order to allow the measurement of the cross section. The yield of 14.7 MeV protons from the ^{3}He(d;p)^{4}He reaction was measured in order to extract the astrophysical S factor at low energies.

Recent results obtained at the ABC-laser facility, ENEA-Frascati,Italy on the p+^{11}B,^{6}Li+^{6}Li and d+^{6}Li systems will be discussed.

References

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http://physics.aps.org/synopsis-for/10.1103/PhysRevLett.111.082502

EoS studies in nucleus-nucleus collisions: from Coulomb barrier to LHC

M. Veselsky

Institute of Physics, Slovak Academy of Sciences

Investigations of nuclear equation of state in nucleus-nucleus collisisons will be presented in a wide range of incident energies, ranging from Coulomb barrier up to the ultra-relativistic energies at Large Hadron Collider at CERN. In particular, fusion probabilities in reactions leading to super-heavy elements will be investigated at beam energies close to Coulomb barrier and parameters of equation of state will be extracted. Transport model will be employed at intermediate energies and transport coefficients will be determined. Multiplicity of charged particles will be investigated at ultra-relativistic energies and a relation of its trend to topology of phase space will be demonstrated.

Production of Neutron-Rich Isotopes toward the Astrophysical r-process Path

George. A. Souliotis

Laboratory of Physical Chemistry, Department of Chemistry,
National and Kapodistrian University of Athens, Athens 15771, Greece

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. Toward this end we will be discussing plans of continuation of the present work at Texas A&M University (with the MARS separator) at LNS/Catania (using beams from the S800 Cyclotron and the MAGNEX spectrometer) and, in the future, at RISP/Korea (employing beams from the RAON accelerator complex and the KOBRA separator).

References

[1] G.A. Souliotis et al., Phys. Rev. C 84, 064607 (2011)
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Fission in High-Energy Proton-Induced Spallation Reactions

Nikolaos G. Nicolis[1], G.A. Souliotis[2] and A. Asimakopoulou[2]

[1]Department of Physics, The University of Ioannina, Ioannina 45110, Greece
[2]Laboratory of Physical Chemistry, Department of Chemistry, University of Athens, Athens, Greece

A number of projects of current interest such as transmutation of nuclear waste, neutron sources, radiation damage in space etc. require a detailed modeling of spallation reactions induced by high-energy protons. For this purpose, we couple the results of an intranuclear cascade model with evaporation calculations performed with the statistical model code MECO incorporating high-energy fission. Preliminary results of 0.1 – 1.0 GeV protons on ^{181}Ta, ^{197}Au, ^{208}Pb, ^{209}Bi and ^{238}U targets are compared with experimental data and discussed.

AMIAS: A Model Independent Analysis Scheme - From Hadronics to Medical Imaging

E. Stiliaris and C.N. Papanicolas

Department of Physics, National & Kapodistrian University of Athens, Athens, Greece
and
The Cyprus Institute, Nicosia, Cyprus

AMIAS is a novel method for extracting physical parameters from experimental and simulation data. The method is based on statistical concepts and it relies on Monte Carlo simulation techniques. It identifies and determines with maximal precision parameters that are sensitive to the data. The method has been extensively studied and it is shown to produce model independent results. It is applicable to a wide range of scientific and engineering problems. The initial ideas on which the method relies and the further development of the model will be presented. A brief review on the application of AMIAS in the analysis of experimental data in hadronic physics and of lattice QCD correlators, and most recently in the image reconstruction of tomographic data, will be introduced here.

On Proton Deformation: A Model Independent Extraction of EMR from Recent Photoproduction Data

L. Markou[1], C.N. Papanicolas[1,2], E. Stiliaris[1,2]

[1] *The Cyprus Institute, Nicosia, Cyprus*
[2] *Physics Department, National and Kapodistrian University of Athens, Greece*

The most recent γp → pπ^0 [1,2,3] and γp → nπ$^+$ data have been used for Multipole amplitude extraction at the Δ$^+$(1232) resonance. The data have been analyzed in a novel way, utilizing the Athens Model Independent Analysis Scheme (AMIAS), yielding precise results with little, if any, model error. The benchmark quantity in nucleon deformation, EMR = E1+$^{3/2}$/M1+$^{3/2}$, was determined to be:

$$-\left(2.5^{+0.3}_{-0.2}stat\right)\% \text{ and } -\left(2.5^{+0.4}_{-0.3}stat+syst\right)\%,$$

consistent with previous results but for the first time free of model error. Non resonant amplitudes up to L = 5 have also been extracted which test the sophisticated phenomenological model used in nucleon resonance research. The elaborate analysis scheme and its comparison to the traditional methods will be presented at the conference.

References

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Employing a Novel Analysis Method in the field of Tomographic Image Reconstruction for Single Photon Emission Computed Tomography (SPECT)

L. Koutsantonis[1], C.N. Papanicolas[1,2]

[1] *The Cyprus Institute, Nicosia, Cyprus*
[2] *Physics Department, National and Kapodistrian University of Athens, Greece*

The quality of the tomographic image in Single Photon Emission Computed Tomography (SPECT) is strongly related to the radiation dose injected into the patient. Radiation reduction usually leads to noisy projection data which are further affecting the algorithms involved to reconstruct the inner distribution of radioactivity in the patient. To address this problem, we employ the Athens Model Independent Analysis Scheme (AMIAS), a well suited method for inverse scattering problems, in the field of Medical Image Reconstruction. The method was implemented in HPC environment to be used in the reconstruction of SPECT projections characterized by low scintillation counts. Preliminary results have shown that the method leads to tomographic images of improved diagnostic accuracy in cases where few projections are available and/or characterized by noise and attenuation. A potential success of the method can be exploited to reduce the radiation dose which is injected into the patient and to minimize the duration of the clinical scan.

PhoSim: A Simulation Package Designed for Macroscopic and Microscopic Studies in the Time-Resolved Optical Tomography

A.-N. Rapsomanikis[1], A. Eleftheriou[1,*], M. Mikeli[1], M. Zioga[1], Ch. Pafilis[1,2] and E. Stiliaris[1,3]

[1]*Department of Physics, National and Kapodistrian University of Athens, Greece*
[2] *EEAE, Greek Atomic Energy Commission, Agia Paraskevi, Attica, Greece*
[3] *Institute of Accelerating Systems & Applications (IASA), Athens, Greece*
[*] *Present Address: University of Zurich, Switzerland*

PhoSim is an optical ray tracing Monte-Carlo simulator capable of reproducing the physical processes taking place in a tissue environment when illuminated by Near-Infrared radiation. From a macroscopic point of view this can be accomplished by the proper manipulation of the Henyey-Greenstein phase parameter g, which represents a simple and analytical solution for the fast generation of a random scattering angle photon distribution. Microscopically, the program can simulate certain biological structures by placing a proper density of subcellular organelles inside the volume of interest, proportional to the wavelength of the radiation used at the study (~750-1000 nm). The new version of this software package is able to create different type of phantoms in multilayer environments and it is also equipped with a detailed Fate and Time of Flight information of each traveling photon. ***PhoSim*** is a simple and useful tool for Time-Resolved Optical Tomographic studies; its basic functions and capabilities with optical tomographic examples will be presented in this work.

Mastering Conic Sections for a Direct 3D Compton Image Reconstruction

M. Mikeli[1], M. Zioga[1], A. Eleftheriou[1,*], Ch. Pafilis[1,2], A.-N. Rapsomanikis[1] and E. Stiliaris[1,3]

[1] *Department of Physics, National and Kapodistrian University of Athens, Greece*
[2] *EEAE, Greek Atomic Energy Commission, AgiaParaskevi, Attica, Greece*
[3] *Institute of Accelerating Systems & Applications (IASA), Athens, Greece*
[*] *Present Address: University of Zurich, Switzerland*

Given the complexity of the image reconstruction procedures for Compton Camera events, especially when a 3D image is required for distributed sources in space, a simple, direct algorithmic approach is presented in this work. The recently developed *ComptonRec* package carefully handles the geometry of the conic sections to accumulate ray density distribution in a user defined voxelized volume inside the specified field of interest. Prior to planar reconstruction, the event selection part of the program filters out misidentified coincidence events and other physical background events with unbalanced total energy or inverse interaction sequence with the camera's subsystems. For each accepted event a series of planar reconstructions is performed, where the density distribution is the accumulation product of the conic intersection with all the affected pixels. A 3D image is finally reconstructed by assembling the partial planar information and by taking into account volume effects. The efficiency of this reconstruction method is checked with a plethora of simulated phantoms and results will be presented and discussed.

Study of organic-rich limestones of the Epirus region (Greece) using nuclear and synchrotron radiation techniques

J.T. Tzifas, P. Misaelides

Department of Chemistry, Aristotle University of Thessaloniki, GR-54124 Thessaloniki, Greece

High-resolution gamma-spectroscopic investigation of phosphatised organic-rich limestones from the Epirus region revealed comparably elevated radioactivity mainly attributed to the presence of enhanced uranium concentrations ranging up to 648 mg/kg. Scanning electron microscopy/energy dispersive spectroscopy (SEM/EDS) combined with X-ray diffraction (XRD) showed that the main phases of the geologic material under investigation were apatites (fluoroapatites and carbonate apatites), calcite and organic matter. Micro X-ray fluorescence analysis (μ-XRF) using synchrotron radiation (SR) revealed that the uranium was accumulated in the material parts containing, among others, carbonate apatite and organic matter. Uranium-bearing carbonate apatite crystals were separated from the rock and characterized by Raman spectroscopy and microprobe analysis. The analysis of these crystals also indicated the presence of sodium and sulfur. The UL_{III}-edge of X-ray absorption near edge structure spectra (μ-XANES) showed that the uranium was present in tetravalent form. The uranium presence in the crystals was also visualized, after neutron irradiation and etching, by the observation of the fission tracks. The Epirus samples are classified among the richest U-bearing phosphatized limestones and/or sedimentary phosphorites in the world.

Paleoseismology: Defining the seismic history of an area with the use of the OSL dating method

Stamoulis K.C.[1,2], Tsodoulos I.[1], Papachristodoulou C.[1], Ioannides K.G.[1,2]

[1]*Department of Physics, University of Ioannina, 451 10 Ioannina, Greece*
[2]*Archaeometry Center, University of Ioannina, 451 10 Ioannina, Greece*

Paleoseismology is a subfield of the geological science which is used to study the prehistoric earthquakes of an area. By excavating trenches along seismogenic faults, and mapping structures of deformed geologic deposits, large seismic events can be revealed in a span of few thousands of years. This method is important for the accurate assessment of the seismic hazard of the area and assists civil protection.

A crucial step in dating previous seismic events is the study of the deformed geological features on the walls of an excavated trench across the seismic fault. This can be accomplished by dating carbon remains or human artifacts. In many cases this is impossible because there is no available carbon or artifacts in the excavated trenches. In these cases the Optically Stimulated Luminescence (OSL) dating method can overcome these problems, and provide absolute ages of the geological patterns and consequently dating of past seismic events.

This presentation describes the paleoseismological investigation along an active fault at Gyrtoni, North East Thessaly, which revealed strong earthquakes in the past history of the area. The paleoseismological analysis of the excavated trenches indicated evidence of three surface faulting events in the time span between 1.42 ± 0.06 ka and 5.59 ± 0.13 ka before present. The observed vertical displacement per event of ~0.50 m corresponded to an Mw 6.5 ± 0.1 earthquake. An average fault slip rate of 0.41 ± 0.01 mm/yr and an average recurrence of 1.39 ± 0.14 ka for earthquakes were estimated. The findings documented the activity of the fault and since the return period from the most recent event (minimum age 1.42 ± 0.06 ka) has expired, the possibility for the reactivation of this active structure in the near future should be taken into consideration. This information is extremely valuable for the safety of the population living in the city of Larissa.

^{210}Pb and ^{7}Be concentrations in moss samples from the region of Northern Greece

Ch. Betsou [1], E.Tsakiri [2], J. Hansman [3], M. Krmar [3], A. Ioannidou [1]

[1]Aristotle University of Thessaloniki, Physics Department, Nuclear Physics Laboratory, Thessaloniki 54124, Greece, chbetsou@physics.auth.gr
[2]Aristotle University of Thessaloniki, Biology Department, Division of Botany, Thessaloniki 54124, Greece
[3]University of Novi Sad, Faculty of Science, Physics Department, Trg Dositeja Obradovica 4, 21000 Novi Sad, Serbia

Naturally occurring radionuclides ^{7}Be and ^{210}Pb are a useful tool in studying the environmental processes. The ^{7}Be is formed by spallation reaction between cosmic rays and nuclei of oxygen and nitrogen in the stratosphere and upper troposphere. After production, the ^{7}Be atoms are attached to aerosol particles and the fate of ^{7}Be will become the fate of the carrier aerosols. Since aerosol particles contain most of the air pollutants, the transport of the last ones can be investigated by tracking the ^{7}Be pathway. The radionuclide ^{210}Pb is widely found in the terrestrial environment and it is the final long-lived radionuclide of the ^{238}U chain. It is present in the atmosphere due to the decay of ^{222}Rn diffusing from the ground and its concentration depends on the ability of the radon to leak from the ground and enter the atmosphere.

Terrestrial mosses can be used for investigation and monitoring of airborne radionuclide depositions. Many mosses, obtain most of their nutrients directly from precipitation and dry deposition. The absence or strong reduction of the cuticle and thin leaves allows easy uptake from the atmosphere. Lack of an elaborate rooting system also means that uptake from the substrate is normally insignificant. These properties make mosses an ideal sampling medium for metals and airborne radionuclides deposited from the atmosphere, as they are accumulated by the moss, producing concentrations much higher than those in the original wet or dry deposition. The sample collection is so simple, that a high sampling density can be achieved, in contrast to the conventional precipitation analysis and the air sampling. High resolution gamma spectrometry measurements can be carried out with the moss technique, without any chemical treatment of the samples.

The aim of this study is to measure activities of the natural radionuclides ^{7}Be and ^{210}Pb in mosses and investigate their possible variabilities over different places in Northern Greece. The different meteorological conditions, the wind direction and precipitation can influence the deposition of airborne radionuclides, as well as their activities in mosses.

Samples of *Hypnum cupressiforme* were collected from 90 sampling sites in Northern Greece. All samples were collected in a short time interval during the end of summer 2016. After sampling, mosses were dried at 105°C for 2 hours and all the impurities were removed manually. After the preparation, mosses were put in two cylindrical plastic containers, diameter 67 mm and height 31 mm. They were measured in a low-background HPGe detector with relative efficiency 36%.

Values of ^{7}Be activity concentrations in moss samples vary from 153 to 572 Bq/kg and of ^{210}Pb from 335 to 1374 Bq/kg. Between the concentrations of ^{7}Be and ^{210}Pb there is a good correlation. It can be observed that the major quantity of ^{210}Pb in mosses has arrived from aerosol deposition. A big number of sampling sites was covered and the information obtained using mosses as biomonitors, provide the spatial distribution of the ^{7}Be atmospheric deposition over Northern Greece.

Systematic studies of proton-induced spallation reactions with microscopic and phenomenological models

A. Asimakopoulou[1], G. A. Souliotis[1], A. Bonasera[2,3], M. Veselsky[4]

[1] *Physical Chemistry Laboratory,Department of Chemistry University of Athens, Greece*
[2] *Cyclotron Institute, Texas A &M University, Texas, USA*
[3] *INFN, Catania, Italy,*
[4] *Institute of Physics, Bratislava, Slovakia*

Proton – induced spallation reactions on ^{238}U, ^{208}Pb, ^{181}Ta and ^{197}Au targets at high energies are investigated using the microscopic Contrained Molecular Dynamics (CoMD) [1-3] model and the phenomenological models INC [4] and SMM [5,6]. Total fission cross sections, the ratio fission to residue cross section, mass yield curves, the total number of neutrons emitted, isotopic cross sections of fission fragments as well as the excitation energy of the primary residue as a function of the cross section were calculated using the CoMD , INC and SMM models and compared with experimental data. Also we compared some of the above calculations with the code MECO. Our calculations showed an overall satisfactory agreement with available experimental data. We plan to continue the above systematic studies and we hope that these efforts may contribute to current applications of spallation reactions.

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Microscopic description of neutron-induced fission with the Constrained Molecular Dynamics (CoMD) Model: recent progress

S. Papadimitriou[1], G.A. Souliotis[1], A. Bonasera[2], M. Veselsky[3]

[1] *Laboratory of Physical Chemistry, Department of Chemistry, University of Athens, Athens 15771, Greece*
[2] *Cyclotron Institute, Texas A&M University, College Station, Texas, USA*
[3] *Institute of Physics, Slovak Academy of Sciences, Bratislava, Slovakia*

The microscopic description of the mechanism of nuclear fission is a topic of intense nuclear research nowadays. Understanding of nuclear fission, apart from the theoretical many-body point of view, is of practical importance for energy production, transmutation of nuclear waste, as well as the production of isotopes for medical use. Furthermore, nuclear fission is essentially the process that sets the upper limit to the periodic table of the elements and plays a vital role in the production of heavy elements via the astrophysical rapid neutron-capture process (r-process).In the present work, we initiated a systematic study of neutron-induced fission reactions using the code CoMD (Constrained Molecular Dynamics) of A. Bonasera and M. Papa [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 fission. In this presentation, we show results of neutron-induced fission on ^{235}U at neutron energies 20, 30, 50, 70 and 100 MeV. Calculated mass and energy distributions will be presented and compared with recent experimental data. It appears that the microscopic code CoMD is able to describe the complicated many-body dynamics of the n-induced fission process. Proper adjustment of the parameters of the effective interaction and possible improvements of the code will be implemented to achieve a satisfactory quantitative description of the experiment data, especially at low energies.

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Neutron-rich rare isotope production with stable and radioactive beams in the mass range A ~ 40-60 at 15 MeV/nucleon

A. Papageorgiou[1], G.A. Souliotis[1], A. Bonasera[2,3], M. Veselsky[4]

[1] *Laboratory of Physical Chemistry, Department of Chemistry, University of Athens, Athens 15771, Greece*
[2] *Cyclotron Institute, Texas A&M University, College Station, Texas, USA*
[3] *Laboratori Nazionali del Sud, INFN, via Santa Sofia 62, I95123 Catania, Italy*
[4] *Institute of Physics, Slovak Academy of Sciences, Bratislava, Slovakia*

This work reports on our continued efforts to study the production of rare isotopes with heavy-ion beams at energy 15 MeV/nucleon. Our calculations are 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) [2,3,4]. The de-excitation of the hot heavy projectile fragments is performed with the Statistical Multifragmentation Model (SMM) [4]. We first present experimentally acquired production cross sections of neutron-rich nuclides from collisions of a ^{40}Ar stable beam with targets of ^{58}Ni, ^{64}Ni and ^{27}Al [5] and we compare them with our calculations. Then we performed calculations for the same beam (15 MeV/nucleon) with other neutron rich targets such as ^{48}Ca and ^{238}U and find that the multinucleon transfer mechanism leads to very neutron-rich nuclides in mass range A~ 40-60. Motivated by the high production cross section of target 238U, we performed calculation with beam of ^{48}Ca (15 MeV/nucleon). We found that we can produce radioactive beams of ^{46}Ar and ^{54}Ca which can be reaccelerated and hit another target of ^{238}U, participating in reactions of multinucleon transfer which can produce extremely neutron-rich and even new isotopes. We think that our continued progress on the study of multinucleon transfer reactions using beams of 15 MeV/nucleon (below Fermi energy), in combination with enhanced capabilities of present and upcoming low-energy accelerator facilities worldwide can provide new and exciting opportunities in rare isotope research in the near future.

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Study of ^{7}Be+^{28}Si at near barrier energies: Elastic scattering and alpha production

O. Sgouros[1], A. Pakou[1], D. Pierroutsakou[2], M. Mazzocco[3,4], L. Acosta[5,6], X. Aslanoglou[1], Ch. Betsou[1], A. Boiano[2], C. Boiano[7], D. Carbone[8], M. Cavallaro[8], J. Grebosz[9], N. Keeley[10], M. La Commara[2,11], C. Manea[4], G. Marquinez-Duran[12], I. Martel[12], N. G. Nicolis[1], C. Parascandolo[2], K. Rusek[13], A. M. Sanchez-Benitez[12,14], C. Signorini[15], F. Soramel[3,4], V. Soukeras[1], C. Stefanini[3], E. Stiliaris[16], E. Strano[3,4], I. Strojek[10], D. Torresi[3,4]

[1] *Department of Physics and HINP, The University of Ioannina, Ioannina, Greece*
[2] *INFN, Sezione di Napoli, via Cinthia, 80126, Napoli, Italy*
[3] *Dipartimento di Fisica e Astronomia, Universita di Padova, via Marzolo 8, Padova, Italy*
[4] *INFN, Sezione di Padova, via Marzolo 8, Padova, Italy*
[5] *Instituto de Fisica, Universidad Nacional Autonoma de Mexico, Mexico D.F, Mexico*
[6] *INFN, Sezione di Catania, via Santa Sofia 64, Catania, Italy*
[7] *INFN, Sezione di Milano, via Celoria 16, Milano, Italy*
[8] *INFN Laboratori Nazionali del Sud, via Santa Sofia 62, Catania, Italy*
[9] *The Henryk Niewodniczanski Institute of Nuclear Physics (IFJ PAN), Kraków, Poland*
[10] *National Centre for Nuclear Research, ul. Andrzeja Sołtana 7, Otwock, Poland*
[11] *Dipartimento di Scienze Fisiche, Università di Napoli "Federico II", Napoli, Italy*
[12] *Departamento de Ciencias Integradas, Universidad de Huelva, Huelva, Spain*
[13] *Heavy Ion Laboratory, University of Warsaw, Pasteura 5a, Warsaw, Poland*
[14] *Centro de Física Nuclear da Universidade de Lisboa, Lisboa, Portugal*
[15] *INFN, LNL, viale dell'Università 2, Legnaro, Italy*
[16] *Institute of Accelerating Systems and Applications and Department of Physics, University of Athens, Athens, Greece*

The ^{7}Be+^{28}Si system was studied at four near barrier energies: 13.2, 17.2, 19.8 and 22.0 MeV. Angular distribution measurements for the elastically scattered ^{7}Be ions as well as the α and ^{3}He reaction products were performed with the multidetector array EXPADES. The elastic scattering data were analyzed in a double-folding framework and the energy evolution of the optical potential was deduced. The reaction data were analyzed in both statistical model and Distorted Wave Born Approximation frameworks (DWBA) in order to disentangle the degree of competition between direct and compound channels. The energy evolution of the ratio of direct to total reaction cross section was mapped in comparison with similar data for ^{6}Li and ^{7}Li projectiles on a ^{28}Si target, indicating larger transfer contributions for ^{7}Be and ^{7}Li than in the ^{6}Li case. Fusion cross sections for the system under study were deduced and were found to be compatible with systematic. Comparison with previous fusion data for ^{6}Li and ^{7}Li indicate fusion hindrance for ^{7}Li and ^{7}Be compared to ^{6}Li, starting from the barrier and below it. This hindrance is attributed to the existence of large transfer channels.

A global study of the ^{6}Li+p system at near barrier energies in a CDCC approach

V. Soukeras[1], A. Pakou[1], F. Cappuzzello[2,3], L. Acosta[4,5], C. Agodi[2], N. Alamanos[6], S. Calabrese[2,3], D. Carbone[2], M. Cavallaro[2], A. Cunsolo[2], A. Di Pietro[2], J. P. Fernandez-Garcia[2], P. Figuera[2], M. Fisichella[2], A. Foti[3,5], N. Keeley[7], G. Marquinez-Duran[8], I. Martel[8], M. Mazzocco[9,10], D. Pierroutsakou[11], K. Rusek[12], G. Santagati[2,3], O. Sgouros[1], E. Stiliaris[13], E. Strano[9,10], D. Torresi[9,10], K. Zerva[1]

[1] *Department of Physics and HINP, The University of Ioannina, Ioannina, Greece*
[2] *INFN Laboratori Nazionali del Sud, via S. Sofia 62, Catania, Italy*
[3] *Dipartimento di Fisica e Astronomia, Universita di Catania, via S. Sofia 64, Catania, Italy*
[4] *Instituto de Fisica, Universidad Nacional Autonoma de Mexico, Mexico D. F., Mexico*
[5] *INFN - Sezione di Catania, via S. Sofia 64, Catania, Italy*
[6] *CEA-Saclay, DAPNIA-SPhN, Gif-sur-Yvette, France*
[7] *National Center for Nuclear Research, A. Soltana 7, Otwock Warsaw, Poland*
[8] *Departamento di Fisica Aplicada, Universidad de Huelva, Huelva, Spain*
[9] *Departimento di Fisica e Astronomia, Universita di Padova, via Marzolo 8, Padova, Italy*
[10] *INFN - Sezione di Padova, via Marzolo 8, Padova, Italy*
[11] *INFN - Sezione di Napoli, via Cinthia, Napoli, Italy*
[12] *Heavy Ion Laboratory, University of Warsaw, Pasteura 5a, Warsaw, Poland*
[13] *Institute of Accelerating Systems and Applications and Department of Physics, University of Athens, Greece*

Elastic scattering measurements have been performed for the ^{6}Li+p system in inverse kinematics at the energies of 16, 20, 25 and 29 MeV while exclusive breakup measurements have been performed for the same system at the two highest energies. In both cases, the heavy ejectile was detected by the large acceptance MAGNEX spectrometer at the Laboratori Nazionali del Sud (INFN-LNS) in Catania, Italy. The experimental data are considered in a global study within the Continuum Discretized Coupled Channel (CDCC) framework. Good agreement between data and theory is observed, interpreted as evidence for strong coupling to the continuum. The direct and sequential (via the first 3^{+} resonance) breakup cross sections are found to be equally large at the higher incident energies, but the dominant effect on elastic scattering is due to coupling to the sequential breakup. This is true also for the lowest energy at 16 MeV, despite the negligible cross section for excitation of the resonance at this energy.

LIST OF PARTICIPANTS

INVITED SPEAKERS

Alamanos Nicolas
IRFU/CEA/Saclay, FRANCE
alamanos@cea.fr

Bonasera Aldo
Texas A&M University, USA
&
Istituto Nazionale di Fisica Nucleare - Laboratori Nazionali del Sud (INFN-LNS), Catania, ITALY
abonasera@comp.tamu.edu

Cappuzzello Francesco
Istituto Nazionale di Fisica Nucleare - Laboratori Nazionali del Sud (INFN-LNS), Catania, ITALY
&
Universita di Catania, Catania, Italy
cappuzzello@lns.infn.it

Keeley Nicholas
National Center for Nuclear Research (NCNR), POLAND
nicholas.keeley@ncbj.gov.pl

Pierroutsakou Dimitra
Istituto Nazionale di Fisica Nucleare (INFN) - Sezione di Napoli, ITALY
pierroutsakou@na.infn.it

Ring Peter
Technical University of Munich (TUM), GERMANY
peter.ring@tum.de

Rusek Krzysztof
Heavy Ion Laboratory, University of Warsaw, POLAND
rusek@slcj.uw.edu.pl

Veselsky Martin
Institute of Physics, Slovak Academy of Sciences (SAS), SLOVAKIA
Martin.Veselsky@savba.sk

PARTICIPANTS

Alexandropoulou Matina
University of Ioannina (UOI), GREECE
matinagucci@gmail.com

Aslanoglou Xenofon
University of Ioannina (UOI), GREECE
xaslanog@cc.uoi.gr

Asimakopoulou Aggeliki
National and Kapodistrian University of Athens (NKUA), GREECE
angie.asim@yahoo.com

Assimakis Ioannis
National Centre for Scientific Research (NCSR) "Demokritos", GREECE
ioasimakis@gmail.com

Betsou Chryssoula
Aristotle University of Thessaloniki (AUTH), GREECE
Chrysam28@hotmail.com

Bonatsos Dennis
National Centre for Scientific Research (NCSR) "Demokritos", GREECE
bonat@inp.demokritos.gr

Eleme Zinovia
University of Ioannina (UOI), GREECE
ph06458@cc.uoi.gr

Gaitanos Theodoros
Aristotle University of Thessaloniki (AUTH), GREECE
tgaitano@auth.gr

Georvassili Stefania
University of Ioannina (UOI), GREECE
stefania_3@windowslive.com

Georgali Efstathia
University of Ioannina (UOI), GREECE
efi.gew9199@gmail.com

Hatzikos Vassileios
National and Kapodistrian University of Athens (NKUA), GREECE
vhatzikos@gmail.com

Ioannides Konstantinos
University of Ioannina (UOI), GREECE
kioannid@cc.uoi.gr

Karakatsanis Konstantinos
Aristotle University of Thessaloniki (AUTH), GREECE
kokaraka@physics.auth.gr

Konstantaki Maria
National and Kapodistrian University of Athens (NKUA), GREECE

Koutsantonis Loizos
The Cyprus Institute (CyI), CYPRUS
l.koutsantonis@cyi.ac.cy

Lalazissis Georgios

Aristotle University of Thessaloniki (AUTH), GREECE
glalazis@auth.gr

Lykiardopoulou Marilena
National and Kapodistrian University of Athens (NKUA), GREECE

Lytrosyggounis Ioannis
National and Kapodistrian University of Athens (NKUA), GREECE

Margaritis Chryssovalantis
Aristotle University of Thessaloniki (AUTH), GREECE
chmargar@gmail.com

Markou Lefteris
The Cyprus Institute (CyI), CYPRUS
l.markou@cyi.ac.cy

Martinou Andriana
National Centre for Scientific Research (NCSR) "Demokritos", GREECE
amartinou@hotmail.com

Mikeli Maria
National and Kapodistrian University of Athens (NKUA), GREECE
mmikeli@phys.uoa.gr

Misaelides Panagiotis
Aristotle University of Thessaloniki (AUTH), GREECE
misailid@chem.auth.gr

Moustakidis Charalampos
Aristotle University of Thessaloniki (AUTH), GREECE
moustaki@auth.gr

Nicolis Nikolaos
University of Ioannina (UOI), GREECE
nnicolis@cc.uoi.gr

Pakou Athena
University of Ioannina (UOI), GREECE
apakou@cc.uoi.gr

Papachristodoulou Christina
University of Ioannina (UOI), GREECE
xpapaxri@cc.uoi.gr

Papadimitriou Sofia
National and Kapodistrian University of Athens (NKUA), GREECE
sofiapap1993@hotmail.gr

Papageorgiou Athanassios
National and Kapodistrian University of Athens (NKUA), GREECE
than-pap@hotmail.com

Patronis Nikolaos
University of Ioannina (UOI), GREECE
npatronis@cc.uoi.gr

Rapsomanikis Aristotelis-Nikolaos
National and Kapodistrian University of Athens (NKUA), GREECE
anrapso@phys.uoa.gr

Sarantopoulou Smaragda
National Centre for Scientific Research (NCSR) "Demokritos", GREECE
smaragda40poulou@yahoo.gr

Sgouros Onoufrios
University of Ioannina (UOI), GREECE
onoufriossgouros@yahoo.gr

Soukeras Vasileios
University of Ioannina (UOI), GREECE
soukerasb@yahoo.gr

Souliotis George
National and Kapodistrian University of Athens (NKUA), GREECE
soulioti@chem.uoa.gr

Stamoulis Konstantinos
University of Ioannina (UOI), GREECE
kstamoul@cc.uoi.gr

Stiliaris Efstathios
National and Kapodistrian University of Athens (NKUA), GREECE
stiliaris@phys.uoa.gr

Violaris Avraam
Aristotle University of Thessaloniki, GREECE

Zerva Konstantina
University of Ioannina (UOI), GREECE
kzerva@staffmail.ed.ac.uk

Zioga Maria
National and Kapodistrian University of Athens (NKUA), GREECE
mzioga@phys.uoa.gr

Zyriliou Aikaterini
National and Kapodistrian University of Athens (NKUA), GREECE

Hellenic Institute of Nuclear Physics

http://hinp.physics.uoi.gr/