29th Annual Symposium of the Hellenic Nuclear Physics Society

24 & 25 September 2021

NCSR Demokritos, Athens, Greece

ΕΕΠΦΕ 1990

HNPS2021

Organized by

INSTITUTE OF
NUCLEAR AND PARTICLE PHYSICS

INRASTES
INSTITUTE OF NUCLEAR & RADIOLOGICAL SCIENCES & TECHNOLOGY, ENERGY & SAFETY

INSTITUTE OF NUCLEAR &
RADIOLOGICAL SCIENCES &
TECHNOLOGY, ENERGY & SAFETY

Hosted & Sponsored by

ΔΗΜΟΚΡΙΤΟΣ

50 ΧΡΟΝΙΑ 1967-2017 ΑΝΤΙΣΕΛ ΑΦΟΙ Α. ΣΕΛΙΔΗ Α.Ε.

FTG FUSION TECHNOLOGY GROUP

http://inp.demokritos.gr/hnps2021/

Organizing Committee
Apostolopoulos George
Axiotis Michail
Karydas Andreas
Lagoyannis Anastasios
Martinou Andriana
Stamatelatos Ion
Vasilopoulou Dora

Day 1: Friday 24/9/2021					
8:30	8:45	Registration			
8:45	9:00	Welcome-Introduction			
SESSION 1			Chairman: Rosa Vlastou		
9:00	9:15	Nikolas Patronis	UoI	NEAR at n_TOF/CERN: Preparing the first multi-foil activation measurement	Online
9:15	9:30	Stylianos Nikas	University of Jyväskylä	Impact of nuclear mass measurements in the vicinity of 132Sn on the r-process nucleosynthesis	Local
9:30	9:45	Maria-Elisso Stamati	CERN/UoI	Preparing Phase 4 of the nTOF/CERN facility	Online
9:45	10:00	Achment Chalil	IRFU CEA	Recent developments in the modeling of (n,γ) reactions with FIFRELIN	Online
10:00	10:15	Sotiris Chasapoglou	NTUA	Cross Section Measurements of (n,x) Reactions at 17.9 MeV Using Highly Enriched Ge Isotopes	Online
10:15	10:30	Veatriki Michalopoulou	NTUA/CERN	Measurement of the 230Th(n,f) cross-section at the CERN n_TOF facility	Local
10:30	10:45	Thanassis Psaltis	TU Darmstadt	Examining neutrino-driven wind nucleosynthesis in core-collapse supernovae with α-induced reactions	Local
10:45	11:15	Coffee Break			
SESSION 2			Chairman: Constantine Kalfas		
11:15	11:45	Lee Packer	Culham Centre for Fusion Energy	Progress in activation of ITER materials at JET during deuterium and tritium operations	Online
11:45	12:00	Pavlos Tsavalas	NCSRD	Investigation of W lamellae after plasma exposure at JET tokamak divertor	Local
12:00	12:15	Vasileios Chatzikos	NCSRD/UoI	Transmutation products in neutron irradiated tungsten	Local
12:15	12:30	Dimitris Mavrikis	NCSRD	A Technique for Metallic Waste Characterization and Segregation in Management Routes	Local
12:30	12:45	Eleni Ntalla	NCSRD	A Comprehensive Study for Radiological Characterization of NORM Waste Associated with Oil Industry by using a LaBr3(Ce) Scintillator	Online
12:45	13:00	Iason Mitsios	NTUA	Development of a computer code for the calculation of self-absorption correction factors in γ-spectrometry applications	Local
13:00	13:15	Theo J. Mertzimekis	NKUA	RAMONES: RadioActivity Monitoring in OceaN EcoSystems	Local
13:15	14:15	Lunch Break			
SESSION 3			Chairman: Eirene Mavrommatis		
14:15	14:45	Jerry Draayer	Louisiana State University	On the dominance of deformation in atomic nuclei as linked to symplectic symmetry with roots in an effective field theory	Online
14:45	15:00	Dennis Bonatsos	NCSRD	Shell Model Foundations of the Proxy-SU(3) Symmetry	Online
15:00	15:15	Andriana Martinou	NCSRD	The microscopic origin of the Interacting Boson Model	
15:15	15:30	Panagioti Georgoudis	GANIL	Unitary limit in heavy nuclei	Online
15:30	15:45	Sofia Karampagia	Grand Valley State University	Spin distribution of the Nuclear Level Density in a Shell Model approach	
15:45	16:00	Vaia Prassa	University of Thessaly	Microscopic analysis of structural evolution in the Pt-Hg region	Online
16:00	16:15	Teo Depastas	NKUA	The Giant Monopole and Dipole Resonances within the Constrained Fermionic Dynamics Framework	Online
16:15	16:45	Coffee Break			
SESSION 4			Chairman: Michael Kokkoris		
16:45	17:15	Artemis Spyrou	Michigan State University	Neutron-capture reactions and the astrophysical i process	Online
17:15	17:30	Georgios Perdikakis	Central Michigan University	Experimental constraints on reaction rates relevant to the radiogenic heating of planets	Online
17:30	17:45	Eleni Vagena	NCSRD	Cross section measurements of proton capture reactions on Sr isotopes for astrophysics applications	Local
17:45	18:00	Pelagia Tsintari	Central Michigan University	Preparation for the first (p,n) reaction measurement at SECAR	Online
18:00	18:15	Athanasios Stamatopoulos	Los Alamos National Laboratory	A new approach for indirect capture measurements: The DICER neutron transmission station at LANSCE	Online
18:15	18:30	Maria Anastasiou	Lawrence Livermore National Laboratory	Measuring the 235U(n,f)/6Li(n,t) cross section ratio in the NIFFTE fissionTPC	Online
18:30	20:30	General Assembly			

Day 2: Saturday 25/9/2021					
SESSION 5				**Chairman: Dennis Bonatsos**	
9:00	9:15	Athena Pakou	UoI	Continuum excitations of weakly bound nuclei at low energies	Online
9:15	9:30	Nikolaos Nicolis	UoI	Validation of Empirical Formulas for Spallation Residue Production in 0.3A-2.6A GeV p + 56Fe Reactions	Online
9:30	9:45	Panagiota Papakonstantinou	IBS/RISP	Constraining the density dependence of the nuclear symmetry energy in the KIDS framework	Online
9:45	10:00	Arsenia Chorozidou	AUTH	The Non-Linear Derivative (NLD) model for the in-medium hyperons & antihyperons dynamics	Online
10:00	10:15	Alkiviadis Kanakis-Pegios	AUTH	Studying the speed of sound of dense nuclear matter via the tidal deformability of neutron stars	Online
10:15	10:30	Polychronis Koliogiannis	AUTH	Rapid uniform rotation of protoneutron stars, hot neutron stars, and neutron star merger remnants: The role of the temperature	Online
10:30	10:45	Pankaj Kumar	Himachal Pradesh University	A Study of Shape Transition and Bubbleness in Ne isotopes	Online
10:45	11:15	**Coffee Break**			
SESSION 6				**Chairman: Anastasios Lagoyannis**	
11:15	11:30	Pavlos Koseoglou	TU Darmstadt	Variable-temperature relative self absorption technique for high-precision level widths' measurements	Local
11:30	11:45	Georgios Souliotis	NKUA	Recent progress in the study of peripheral heavy-ion collisions below the Fermi energy	Online
11:45	12:00	Stergios Koulouris	NKUA	Measurements of projectile fragments from 70Zn (15 MeV/nucleon) + 64Ni collisions with the MAGNEX spectrometer at INFN-LNS	Online
12:00	12:15	Olga Fasoula	NKUA	Study of Multinucleon Transfer Mechanisms in 86Kr-induced Peripheral Collisions at 15 and 25 MeV/nucleon	Online
12:15	12:30	Konstantina Palli	NKUA	Microscopic Description of Multinucleon Transfer in 40Ar +64Ni collisions at 15 MeV/nucleon	Online
12:30	12:45	Polytimos Vasileiou	NKUA	Experimental Study of the Nuclear Structure of 180Hf: Preliminary results	Local
12:45	13:00	Aikaterini Zyriliou	NKUA	Nuclear Structure Investigations in Yb isotopes	Local
13:00	13:30	**Lunch Break**			
13:30	14:30	**Poster Session**			
SESSION 7				**Chairman: Joseph Kehayias**	
14:30	15:00	Drosoula Giantsoudi	Massachusetts General Hospital and Harvard Medical School	Proton therapy: current practice and research perspectives	Online
15:00	15:15	Alexis Papadopoulos	UoI	Microdosimetric investigation of proton quality factor	Online
15:15	15:30	Alexandros Clouvas	AUTH	Performance of NaI(Tl) spectrometers as dosimeters by combination of laboratory and field dose rate measurements and Monte Carlo simulations	Local
15:30	15:45	Prodromos Chatzispyroglou	University of Surrey	Boron-Loaded Organic Semiconductors For Thermal Neutron Detection	Online
15:45	16:00	John Kalef-Ezra	UoI	Suffering in the name of protecting: the case of the Fukushima population	Online
16:00	16:15	Ioannis Kaissas	Greek Atomic Energy Commission (EEAE)	Practical Guidance on the Developing of Radiological Risk Assessment for Educational and Research Laboratories	Local
16:15	16:30	Sofia Kolovi	CNRS / UCA	Radiation exposure of microorganisms living in radioactive mineral springs	Online
16:30	17:00	**Coffee Break**			
SESSION 8				**Chairman: Theo J. Mertzimekis**	
17:00	17:30	Stylianos Chatzidakis	Purdue University	Advances in Cosmic Ray Muon Computed Tomography and Fieldable Spectroscopy	Online
17:30	17:45	Kalliopi Tsampa	NCSRD/NTUA	Macroscopic X-ray fluorescence characterization of Platinum Group Mineral inclusions in archaeological gold	Local
17:45	18:00	Varvara Lagaki	NKUA	MIRACLS: A novel approach for Collinear Laser Spectroscopy	Online
18:00	18:15	Eleni Ntemou	Uppsala University	Assessing Electronic Excitations in Single-crystalline SiC foils by keV ions	Online
18:15	18:30	Ilias Savvidis	AUTH	A large volume spherical proportional counter for WIMPs dark matter detection. The NEWS-G experiment	Online
18:30	18:45	Fotios Maragkos	NTUA	R-matrix Calculations for Proton Elastic Scattering on natMg in the Energy Range E = 2.45 - 4.25 MeV, Suitable for EBS	Local
18:45	19:00	George Savvidis	Queen's University	Multi-anode sensor for the Spherical Proportional Counter (SPC) for the detection of WIMPs and other applications	

19:00	19:15	Stefanos Nanos	UoI	Upgrading the APAPES installation at the tandem accelerator laboratory of NCSR “Demokritos” by developing coincidence techniques	Local
19:15	19:30	**Symposium Closing**			

Poster Session (25/9/2021 13:30-14:30)			
P1	Effrossyni Androulakaki	HCMR	In situ radioactivity measurements and recent applications in the aquatic environment
P2	Zoi Bari	NTUA	Fast neutron activation analysis optimization
P3	Stavros Sotirios Bofos	NKUA	The Nuclear Magnetic Octupole Moment
P4	Konstadinos Bosbotinis	NTUA	Measurement of elastic backscattering differential cross sections for protons on natO in the energy range E= 4- 6 MeV, suitable for EBS
P5	Aristeidis Chiotellis	NCSRD	Targeting the kynurenine pathway for tumour detection and characterization by PET and SPECT
P6	Marios Davis	NTUA	Simulation of a MicroMegas detector for low-energy α-particle and fission fragment tracking using Garfield++
P7	Margarita Efstathiou	NKUA	Gamma spectrometry studies of tap water from Greece
P8	Evangelia Eleftheriou	NCSRD	Advanced XRF Tools and Methodologies for the Revisualization of Vanished Ancient Polychrome
P9	Zinovia Eleme	UoI	The 241Am(n,f) reaction study at the n_TOF/CERN facility
P10	Georgios Gkatis	NTUA	Study of the 3H(p,n)3He neutron producing reaction at N.C.S.R. “Demokritos” – Application on the 232Th(n,f) reaction
P11	Eleftheria Ioannidou	AUTH	Heavy metals and Pb-210 in Finland Air for the years 2000 - 2005
P12	Antigoni Kalamara	NCSRD	Fast Neutron Beam Dosimetry Characterization for Biomedical Sample Irradiations
P13	Vasiliki Kanavou	NTUA	Thermochronomentry of metamorphic rock complexes on the SE Peloponnese, Greece, using thermoluminescence (TL)
P14	Myrto Karagiannakidou Samsarelou	AUTH	Investigation of aged dental zirconia reinforced lithium silicate for personal dosimetry applications
P15	Polychronis Karpodinis	NKUA	Fast neutron reactions with 241Am: a detailed TALYS study
P16	Michael Kokkoris	NTUA	Measurement of the fission cross-section of 232Th with quasi-monoenergetic neutron beams at NCSR “Demokritos” implementing Micromegas detectors
P17	Kostas Korakas	UoI	Empirical Description of Isotope Production in 0.01-2.5 GeV p + natFe Reactions
P18	Vikesh Kumar	Himachal Pradesh University	Nuclear shape evolution of even-even isotopic chains of Sn, Te, and Xe using PCX interaction
P19	Aristotelis Kyriakis	NCSRD	Hellenic Society for the Study of High Energy Physics (HeSSHEP) Activities
P20	Alexandros Liapatis	NTUA	Comparison between digitizers and analog circuitry in nuclear spectroscopy experiments
P21	Angelos Markopoulos	NCSRD	Comparison of Real and Generated by MCNP Simulation Spectrums for Validation of Neutron Activation Calculations
P22	Georgia Mavrokefalou	NCSRD	Dose rate assessment of 137Cs to mussels and pelagic fish from the combined use of field measurements, satellite data and the ERICA Assessment Tool
P23	Eleni Mitsi	NCSRD	Time and temperature resolved resistivity recovery of irradiated metals
P24	Marios Anagnostakis	NTUA	In depth analysis of a sediment core from North Aegean Sea
P25	Sofia Pantousa	NCSRD/NKUA	Effects of Fe+ ion irradiation at 300 oC on Fe-Cr films
P26	Stefanos Papagiannis	NCSRD	PM2.5 chemical speciation and source apportionment by PMF, in the capital on Tajikistan, Dushanbe
P27	Dimitrios Papoulias	UoI	Coherent and Incoherent neutrino-nucleus and WIMP-nucleus scattering
P28	Stavros Patas	NTUA	Activation Cross Section Measurement of the (n,2n) Reaction on 203Tl
P29	Stefanos Pelonis	NKUA	Spectroscopic studies in 152-154Gd
P30	Maria Peoviti	UoI	Characterisation of the new HPGe detectors at INPP/NCSR “Demokritos...and future (n,2n) reactions to be studied
P31	Elektra Poulopoulou	NTUA	Technical-Economic Trends Review for Currently Operating Nuclear Power Reactors
P32	Marilia Savva	NCSRD	Compton Suppressed Gamma Spectrometry for activation analysis of materials irradiated at JET

P33	Lakhdar Sek	University of Biskra	Duffin Kemmer Petiau Oscillator under the effect of an External Magnetic Field in Non-Commutative Space
P34	Konstantinos Stefanopoulos	NCSRD	Neutron Scattering from Porous Materials and Confined Fluids: Applications to CO2 Sequestration and Oil Recovery
P35	Evangelia Taimpiri	NTUA	Differential cross section measurements of the 6Li (d, nγ1-0)7Be, 6Li (d, pγ1-0)7Li, 7Li (d, dγ1-0)7Li and 19F (d, pγ1-0)20F reactions suitable for d-PIGE applications
P36	Virender Thakur	Himachal Pradesh University	Investigation of Ground state observables of even-even Lead (Pb) isotopes in heavy mass region based on Covariant Density Functional Theory
P37	Theofanis Tsakiris	NTUA	Differential Cross-section Measurements for Deuteron Elastic Scattering on 11B
P38	Eleni Tsivouraki	NTUA	Study of the 176Hf(n,2n) and 180Hf(n,nγ) Cross-Sections at 18.9MeV
P39	Theodora Vasilopoulou	NCSRD	NCSRD activities at JET in support to ITER nuclear analyses
P40	Anastasia Ziagkova	NTUA	Differential cross section measurements of the 7Li (p,p'γ1-0) 7Li reaction suitable for PIGE applications

Measuring the $^{235}U(n,f)/^{6}Li(n,t)$ cross section ratio in the NIFFTE fissionTPC *

Maria Anastasiou for the NIFFTE Collaboration[1],

[1] *Lawrence Livermore National Laboratory, Livermore, California 94550, USA*
Presenting author email: anastasiou2@llnl.gov

While nuclear data play an important role in nuclear physics applications, it has become important to have a better understanding and try to minimize their uncertainties. In particular, there is a need for precision neutron-induced fission cross section measurements on fissile nuclei. Neutron-induced fission cross sections are typically measured as ratios, with a well-known standard in the denominator. While the $^{235}U(n,f)$ standard is well measured, some light particle reactions are also well-known and their use as reference can provide information to remove shared systematic uncertainties that are present in an actinide-only ratio. The NIFFTE collaboration's fission time projection chamber (fissionTPC) is a $2\times2\pi$ charged particle tracker designed for measuring neutron-induced fission. Detailed 3D track reconstruction of the reaction products enables evaluation of systematic effects and corresponding uncertainties which are less directly accessible by other measurement techniques. This work focuses on the recent measurement of the $^{235}U(n,f)$ using as a reference the standard $^{6}Li(n,t)$ reaction. Preliminary data of the $^{235}U(n,f)/^{6}Li(n,t)$ measurement deployed at the Los Alamos Neutron Science Center will be presented.

* LLNL-ABS-800573. This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

In situ radioactivity measurements and recent applications in the aquatic environment

C. Tsabaris[1], D.L. Patiris[1], E.G. Androulakaki[1,2], G. Eleftheriou[1], F.K. Pappa[1,3], S. Alexakis[1]

[1] Hellenic Centre for Marine Research, Institute of Oceanography, Anavyssos, Greece
[2] National Technical University of Athens, Department of Physics, Zografou, Athens, Greece
[3] University of the Aegean, Department of Marine Sciences, Mytilene, Lesvos, Greece
Presenting author email: frosso.androulakaki@hcmr.gr

The national authorities require radioactivity measurements in different matrices (e.g. soil/sediments, water/seawater, atmosphere) to assess the variability and determine baseline values regarding the radionuclides concentration in different areas (e.g. industrial coastal zones, ports hosting nuclear powered vessels, regions with NORMs). The last years the in situ method has proven advantageous compared to laboratory measurements (e.g. cost and time effectiveness) and may provide an early warning in a potential nuclear accident event and/or estimate the concentration levels. The Marine Environmental Radioactivity Laboratory (MERL) of HCMR holds and maintains three in-situ detection systems, based on low and medium resolution scintillation crystals (NaI(Tl),$CeBr_3$), namely KATERINA [1], GeoMAREA [2] and KATERINA-D [3] which can reach a high depth of deployment of approximately 4500 m. These systems are implemented worldwide for various applications at specific aquatic areas. The efficiency calibration is performed experimentally in a water tank using reference sources. The calibration extension to a wider energy range is performed via Monte Carlo simulations (GEANT4, MCNP5/-CP and FLUKA). Moreover, a developed methodology combining transfer efficiency calculations and partial MC simulations is applied, reducing the computing time and enabling the calibration extension to different gamma-ray detectors and sources. Recent applications of the three systems in different scientific disciplines (e.g. beach sand mapping, groundwater characterization, radioactivity monitoring in rainfall and gas flows identification) are presented along with the expedition's details and the main results.

Figure 1: Gamma-ray spectrometers of MERL for in situ measurements.

References

[1] C.Tsabaris et al., Appl. Radiat. Isot. **66**, 1419 (2008)
[2] C.Tsabaris et al., J Environ. Radioact. **204**, 12 (2019)
[3] C.Tsabaris et al., Appl. Radiat. Isot. **142**, 120 (2018)

Abstract submitted to HNPS2021

Fast neutron activation analysis optimization

Z. Bari[1,3], S. Chasapoglou[3], A. Kalamara[1], T. Vasilopoulou[1], M. Axiotis[2], A. Lagoyannis[2], M. Kokkoris[3], R. Vlastou[3] and I.E. Stamatelatos[1]

[1] *INRASTES, NCSR Demokritos, Aghia Paraskevi, Athens, Greece*

[2] *INPP, NCSR Demokritos, Aghia Paraskevi, Athens, Greece*

[3] *National Technical University of Athens, Department of Physics, Athens, Greece*

Presenting author email: zwh_mparh@hotmail.com

Fast Neutron Activation Analysis (FNAA) using particle accelerator produced neutron beams has been applied for elemental analysis in a range of materials despite of its poorer sensitivity as compared to nuclear reactor based Neutron Activation Analysis techniques. Scope of this work was the optimization of the FNAA parameters at the NCSRD Tandem accelerator facility. Neutron Activation Analysis and Prognosis (NAAPRO) code [1] was employed for the prediction of activation products, induced activities, count rates, dose rates from the sample, as well as minimum detection and quantification limits on the basis of the simulated spectrum of the activation products for specified analysis conditions. Simulations were performed for samples of biological and geological materials irradiated at a 14 MeV neutron beam. The predictions were compared against the results of a preliminary experiment performed at the NCSRD Tandem accelerator irradiating IAEA reference material samples (Soil-7, A-13). The results of the study demonstrated the fast neutron analytical capabilities of the NCSRD Tandem accelerator and, moreover, allowed optimization of the FNAA parameters, while avoiding the performance of difficult and time-consuming experimental tests at the accelerator facility.

References

[1] V. K. Basenko, et al., J. Radioanal. Nucl. Chem., 271, 353–361 (2007)

* We acknowledge support of this work by the project CALIBRA/EYIE (MIS 5002799), which is implemented under the Action “Reinforcement of the Research and Innovation Infrastructures,” funded by the Operational Program “Competitiveness, Entrepreneurship and Innovation” (NSRF 2014– 2020) and co-financed by Greece and the European Union (European Regional Development Fund).

Abstract submitted to HNPS2021

The Nuclear Magnetic Octupole Moment

S.S. Bofos, T.J. Mertzimekis

Department of Physics, National Kapodistrian University of Athens, GR-15784, Athens, Greece
Presenting author: stbofos@gmail.com

The nuclear magnetic octupole moment is revisited as a potentially useful observable for nuclear structure studies. The magnetic octupole moment, Ω, is examined in terms of the nuclear collective model including weak and strong coupling. Single-particle formulation is additionally considered in the overall comparison of theoretical predictions with available experimental data. The symmetry of the nuclear force in mirror nuclei is also examined in terms of the magnetic octupole moment isoscalar and isovector terms.

Abstract submitted to HNPS2021

Shell Model Foundations of the Proxy-SU(3) Symmetry

Dennis Bonatsos

Institute of Nuclear and Particle Physics, National Centre for Scientific Research "Demokritos", Aghia Paraskevi, GR-15310 Attiki, Greece

Presenting author email: bonat@inp.demokritos.gr

Proxy-SU(3) symmetry is an approximation scheme extending the Elliott SU(3) algebra of the sd shell to heavier shells, in order to make possible the application of the symmetry properties in cutting down the size of the required calculations. When introduced [1] in 2017, the approximation had been justified by calculations carried out within the Nilsson model, an elementary shell model based on a 3-dimensional harmonic oscillator with cylindrical symmetry, applicable to deformed nuclei. Recently our group managed [2] to map the cartesian basis of the Elliott SU(3) model onto the spherical shell model basis, fully clarifying the approximations used within the proxy-SU(3) scheme and paving the way for using the proxy-SU(3) approximation in shell model calculations for heavy nuclei. As a by-product, the relation of the 0[110] Nilsson pairs used in proxy-SU(3) to the earlier used de Shalit-Goldhaber pairs and Federman-Pittel pairs has been clarified. The connection between the proxy-SU(3) scheme and the spherical shell model has also been worked out [3] in the original framework of the Nilsson model, with identical results.

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, Phys. Rev. C **95**, 064325 (2017)

[2] A. Martinou, D. Bonatsos, N. Minkov, I.E. Assimakis, S.K. Peroulis, S. Sarantopoulou, and J. Cseh, Proxy-SU(3) symmetry in the shell model basis, review article, Eur. Phys. J. A **56**, 239 (2020)

[3], D. Bonatsos, H. Sobhani, and H. Hassanabadi, Shell model structure of proxy-SU(3) pairs of orbitals , Eur. Phys. J. Plus **135**, 710 (2020)

Measurement of elastic backscattering differential cross sections for protons on ^{nat}O in the energy range E= 4- 6 MeV, suitable for EBS

K. Bosbotinis[1], M. Kokkoris[1], A. Lagoyannis[2], F. Maragkos[1], E. Taimpiri[1,2]

[1] *Department of Physics, National Technical University of Athens, 15780, Zografou, Athens, Greece*
[2] *Tandem Accelerator Laboratory, Institute of Nuclear and Particle Physics, NCSR "Demokritos", 15341 Agia Paraskevi, Athens, Greece*

Presenting author email: kostasbosbo@hotmail.com

Oxygen is a highly reactive non-metal and thus can easily form oxides with other elements and penetrate or diffuse deeply inside several matrices. Therefore, it is of paramount importance to make an accurate depth profiling in order to determine the exact concentration variations of oxygen in various samples, like superconductors or, e.g., in biological and geological materials. For this purpose, Ion Beam Analysis (IBA) methods have proven to be very effective, and more specifically, among them, the proton elastic backscattering technique (EBS), which is currently widely used for the detection of almost all light elements. For the implementation of EBS, evaluated differential cross sections are required, provided by the online R-matrix SigmaCalc 2.0 calculator (http://sigmacalc.iate.obninsk.ru/). In the particular case of oxygen, the current evaluated data for protons cover the energy range between 100 and 4080 keV. However, in order to investigate oxygen concentrations at larger depths, it is extremely important to go beyond this limit and this task is currently impeded by the lack of experimental and, consequently, evaluated data for higher proton beam energies.

In this study we present the experimental cross sections of the $^{nat}O(p,p_0)$ elastic scattering, determined via the relative measurement technique, in the proton energy range E_{lab}=4- 6 MeV, at six backscattering detector angles between 120^o and 170^o, with a 10^o step. A special target, manufactured *in situ* was used in this experiment, which consisted of three layers. The one on top was an ultra-thin layer of Au for corrosion protection and normalization purposes. The second was the main, thin Na_2HPO_4 (oxygen rich) target and the third one was a self-supporting carbon foil on which the other layers were deposited via the evaporation technique. The measurements were performed using the Van de Graaff Tandem 5.5 MV Accelerator of N.C.S.R. "Demokritos" in Athens, Greece.

Recent developments in the modelling of (n,γ) reactions with FIFRELIN

A. Chalil[1], T. Materna[1], O. Litaize[2], A. Chebboubi[2]

[1]*IRFU, CEA, Université Paris-Saclay, 91191, Gif-sur-Yvette, France*

[2]*CEA, DES, IRESNE, DER, Cadarache F-13108 Saint-Paul-Lez-Durance, France*

Presenting author email: achment.chalil@cea.fr

The FIFRELIN Monte Carlo code [1,2] has been developed for the evaluation of fission data and has been proven very successful in making accurate predictions, especially for neutron and gamma properties. FIFRELIN allows for modelling the de-excitation of a large number of isotopes, providing an essential tool for various applications. In the STEREO experiment, the interaction of neutrinos in the liquid scintillator is signed by a n-capture on a Gd atom. The FIFRELIN predictions of the Gd γ-cascades were shown to significantly improve the Data/MC agreement [3]. In the CRAB method, lately proposed to calibrate cryogenic particle detectors at low energy (100 eV), the FIFRELIN cascades of the W and Ge isotopes played a central role in the feasibility study of the method [4].

FIFRELIN employs a Monte Carlo Hauser-Feshbach framework based on Bečvár's algorithm [5,6]. A sample of nuclear level schemes is generated for a specific isotope of interest, taking into account the uncertainties from nuclear structure. FIFRELIN accounts for the lower energy part of the level scheme from the RIPL-3 database (rel. 2020) [7]. For the higher energy part, a combination between known levels and theoretical nuclear models (level densities, γ-strength functions, spin/parity distributions) is used, to account for the unknown part of the true level scheme of the nucleus of interest.

In this work, new improvements on the FIRELIN de-excitation process are reported. Angular correlations of γ-rays in the de-excitation process have been implemented in order to provide a more accurate description of the γ-ray cascades. The anisotropy of the γ-rays with respect to the axis of a previously emitted γ-ray is modelled using the angular correlation formalism [8], which requires input of the spins and multipolarities of the states involved in the FIFRELIN cascade. Furthermore, the simulation of primary γ-rays emitted from (n,γ) reactions has been updated using the EGAF database [9].

References

[1] O. Litaize *et al.*, Nuclear Data Sheets 118, 216 (2014)

[2] O. Litaize *et al.*, Eur.Phys. J. A 51 1 (2015)

[3] H. Almazan *et al.*, EPJ A 55 183 (2019)

[4] L. Thulliez *et al.*, arXiv:2011.13803v3

[5] F. Bečvár, NIM A, 417 434 (1998)

[6] D. Regnier *et al.*, Comp. Phys. Comm. 201 19 (2016)

[7] R. Capote *et al.*, Nuclear Data Sheets 110 3107 (2009)

[8] R. M. Steffen, K. Alder, W. D. Hamilton (Ed.), "The Electromagnetic interaction in nuclear spectroscopy", North Holland, Amsterdam (1975)

[9] Evaluated Gamma Activation File, https://www-nds.iaea.org/pgaa/egaf.html (accessed: 2021)

Cross Section Measurements of (n,x) Reactions at 17.9 MeV Using Highly Enriched Ge Isotopes

S. Chasapoglou[1], M. Axiotis[2], G. Gkatis[1], S. Harissopulos[2], M. Kokkoris[1], A. Lagoyannis[2], C. Lederer-Woods[4], V. Michalopoulou[1], M.I. Savva[3], I.E. Stamatelatos[3], A. Stamatopoulos[1], T. Vasilopoulou[3], R. Vlastou[1]

[1] *Department of Physics, National Technical University of Athens, 157 80 Athens, Greece*
[2] *Tandem Accelerator Laboratory, Institute of Nuclear and Particle Physics, NCSR Demokritos, 153 10 Aghia Paraskevi, Greece*
[3] *Institute of Nuclear and Radiological Sciences, Energy, Technology & Safety, NCSR Demokritos*
[4] *School of Physics and Astronomy, University of Edinburgh, United Kingdom*
Presenting author email: sotirischasapoglou@mail.ntua.gr

Accurate cross section measurements of neutron induced reactions on Ge isotopes are of major importance for both practical applications, as well as fundamental research in the Nuclear Physics field. Practical applications include dosimetry, nuclear medicine, astrophysical projects, reactor and detector technology. From a fundamental research point of view, some (n,x) reactions produce residual nuclei in high spin isomeric states, whose decay is governed by the spin distribution of the continuum phase space and the spins of the discrete levels involved. The five isotopes of natural Ge can reveal very interesting systematics, on a plethora of reaction channels, the accurate experimental measurement of which, can act as a very sensitive test for the optimization of input parameters in statistical model calculations.

Cross sections of neutron induced reactions on a natural Ge target have been studied in the past by our group [1-2], implementing the $^{3}H(d,n)^{4}He$ reaction for the production of the neutron beam. When natural Ge targets are used, neutron induced reactions in neighbouring isotopes existing in the natural target, lead to the production of the same residual nuclei as the one produced from the measured reaction, thus acting as a contamination. The need for theoretical corrections based on Hauser-Feshbach calculations then arises, to compensate for the contribution of these reactions. These corrections, insert their own uncertainties in the analysis. In the case of measurement of the same reactions with highly enriched mono-isotopic Ge targets, these corrections are no longer needed, since no reactions acting as a contamination take place. In this scope, five mono-isotopic Ge samples of ~2g each that have become available from CERN have been used, with enrichment levels reaching up to ~97.71%. The irradiations were carried out at the 5.5 MV Tandem Accelerator Laboratory of NCSR Demokritos and the quasi monoenergetic neutron beam at 17.9 MeV was produced via the $^{3}H(d,n)^{4}He$ reaction. The Ge samples were placed between two high purity Al reference foils during the irradiations. The use of highly enriched Ge targets, yields more accurate cross section results, that could also improve the existing theoretical models.

References

[1] Gkatis, G., *et al*. (2020). Cross Section Measurements of (n,p) Reactions on Ge Isotopes. *HNPS Advances in Nuclear Physics, 27*, 185-188. doi:http://dx.doi.org/10.12681/hnps.2998

[2] R. Vlastou, *et. al* (2020). Isomeric cross section study of neutron induced reactions on Ge isotopes. *EPJ Web Conf.* 239 01028, doi: https://doi.org/10.1051/epjconf/202023901028

Advances in Cosmic Ray Muon Computed Tomography and Fieldable Spectroscopy

Stylianos Chatzidakis

School of Nuclear Engineering, Purdue University, IN 47906
Presenting author email: schatzid@purdue.edu

A recent example of successful technology transition from high energy physics to practical engineering applications is cosmic ray muon tomography. Cosmic ray muon tomography, is a promising non-destructive technique that has been recently utilized to monitor or image the contents of dense or well shielded objects, typically not feasible with conventional radiography techniques, e.g., x-ray or neutron. Cosmic ray muon tomography has been used with various levels of success in spent nuclear fuel monitoring, volcano imaging, and cargo container imaging. Further, knowledge of cosmic ray muon momentum spectrum has the potential to significantly improve and expand the use of a variety of recently developed muon-based radiographic techniques. However, existing muon tomography systems rely only on muon tracking and have no momentum measurement capabilities which reduces the image resolution and requires longer measurement times. A fieldable cosmic ray muon spectrometer with momentum measurement capabilities for use in muon tomography is currently missing. In this presentation, we will discuss and explore recent advances in cosmic ray muon computed tomography and spectroscopy and their applications to engineering including a new concept for measuring muon momentum using multiple gaseous Cherenkov radiators. By varying the pressure of multiple gas Cherenkov radiators, a set of muon momentum threshold levels can be selected that are triggered only when the incoming muon momentum exceeds that level. As a result, depending on the incoming muon momentum, none to all Cherenkov radiators can be triggered. By analyzing the signals from each radiator, we can estimate the actual muon momentum.

Transmutation products in neutron irradiated tungsten

V. Chatzikos[1,2], M.I. Savva[1], T. Vasilopoulou[1], K. Mergia[1], I.E. Stamatelatos[1], D. Terentyev[3], A. Stankovskiy[3], S. Messoloras[1]

[1] *Institute of Nuclear & Radiological Sciences and Technology, Energy & Safety, NCSR Demokritos, Aghia Paraskevi, 15341, Greece*

[2] *Department of Physics, School of Sciences, University of Ioannina, 45110, Greece*

[3] *SCK-CEN, Institute for Nuclear Material Sciences, B-2400 Mol, Belgium*

Presenting author email: v.chatzikos@ipta.demokritos.gr

Fusion energy production relies on the nuclear reaction of deuterium and tritium, in the form of plasma heated to temperatures in excess of 100 million degrees Celsius, releasing highly energetic neutrons of 14 MeV. Neutrons interact with the fusion reactor materials, resulting in the formation of lattice defects and the creation of transmutation products through neutron capture reactions. The produced damage affects the physical and mechanical properties of the reactor's materials and poses one of the most serious impediments for the realization of fusion energy production. Tungsten is the prime candidate plasma facing material for future fusion reactors due to its high melting point, high thermal conductivity, low coefficient of thermal expansion, high sputtering threshold energy, low tritium retention and low neutron activation properties.

The aim of this work is to determine the inventory of transmutation products in single crystalline tungsten after fission neutron irradiation. High purity single crystal tungsten samples were irradiated at the BR2 research reactor, at SCK-CEN, in Belgium, at the dose of 0.12 displacements per atom (dpa) and four different positions, corresponding to irradiation temperatures of 600, 800, 900 and 1200 °C, respectively. Gamma spectroscopy measurements were performed on the irradiated tungsten samples which enabled the determination of the specific activities of the radioactive isotopes of tungsten (W), rhenium (Re) and tantalum (Ta). The experimental values of the specific activities were compared to the calculated ones, performed with the FISPACT-II radionuclide inventory code by employing the EAF-2010 and TENDL-2019 cross section libraries. A satisfactory agreement between the experimental and calculated specific activity, for both nuclear libraries, was found for the majority of the nuclides. The origin of the discrepancy in the experimental specific activity of ^{188}W with the calculated one using EAF-2010 and TENDL-2019 libraries is discussed. Re, Os and Ta concentration is found in the range of 0.38 to 0.42, 6.1×10^{-3} to 7.7×10^{-3} and 1.5×10^{-3} to 1.7×10^{-3} at%, respectively, for the case of the TENDL-2019 cross section library, depending on the irradiation position. This work contributes to the evaluation of the isotopic inventory of tungsten for future fusion energy applications.

Acknowledgements: This work has been carried out within the framework of the EUROfusion Consortium and has received funding from the Euratom research and training programme 2014-2018 and 2019-2020 under Grant Agreements No. 633053. The views and opinions expressed herein do not necessarily reflect those of the European Commission. The author also acknowledges support of this work by the project "NCSRD – INRASTES research activities in the framework of the national RIS3" (MIS 5002559) which is implemented under the "Action for the Strategic Development on the Research and Technological Sector", funded by the Operational Programme "Competitiveness, Entrepreneurship and Innovation" (NSRF 2014-2020) and co-financed by Greece and the European Union (European Regional Development Fund).

Boron-Loaded Organic Semiconductors For Thermal Neutron Detection

P. Chatzispyroglou

University of Surrey
Presenting author email: prochatz@hotmail.com

The use of neutron sensors is a key requirement across many technology areas, including medical particle accelerators, nuclear power technologies, personnel dosimetry, national defence, and a wide range of scientific experiments. With zero electric charge, neutrons present particular challenges for their effective detection. Here, I report the first demonstration of a solid-state, direct conversion sensor for thermal neutrons based on a polymer/inorganic nanocomposite. Sensors were fabricated from ultra-thick films of poly(triarylamine) (PTAA) semiconducting polymer, with thicknesses up to 100 μm. Boron nanoparticles were dispersed throughout the PTAA film to provide the neutron stopping power arising from the high thermal neutron cross-section of the isotope ^{10}B. To maximise the quantum efficiency of the sensor to thermal neutrons, a high volume fraction of homogeneously dispersed boron nanoparticles was achieved in the thick PTAA film using an optimised processing method. Thick active layers were realised using a high molecular weight of the PTAA (Mw=350 kg/mol), so that molecular entanglements provide a high cohesive strength. A non-ionic surfactant was used to stabilise the boron dispersion in solvent and hence suppress the formation of agglomerates and associated electrical pathways. Boron nanoparticle loadings of up to 17 vol.% were achieved, with thermal neutron quantum efficiency estimates up to 6 % resulting. The sensors' neutron responses were characterised under a high flux (10^6 - 10^7 n cm^{-2}s^{-1}) thermal neutron exposure, showing a linear correlation between the response current and the thermal neutron flux. The sensitivity reached up to 194 pC per 10^7 thermal neutrons. Polymer-based boron nanocomposite sensors offer a new neutron detection technology that uses low-cost, scalable solution processing, and provides an alternative to traditional neutron sensors that use rare isotopes, such as ^{3}He.

Targeting the kynurenine pathway for tumour detection and characterization by PET and SPECT

Angeliki S. Foscolos[1], Maria Georgiou[2], Stylianos Gkionis[2], Ioanna Roupa[2], Ioannis Pirmettis[2], Minas Papadopoulos[2], Aristeidis Chiotellis[2]*

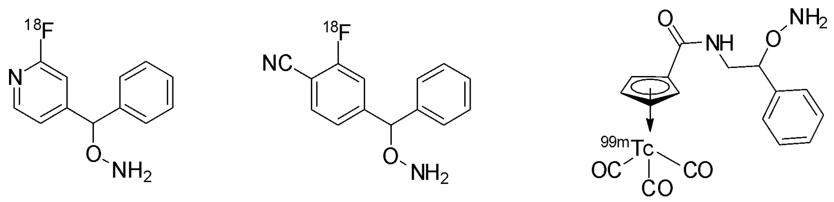
[1]*School of Health Sciences, Department of Pharmacy, Division of Pharmaceutical Chemistry, National and Kapodistrian University of Athens Panepistimioupoli-Zografou, 15784 Athens, Greece*

[2]*Institute of Nuclear & Radiological Sciences & Technology, Energy & Safety, National Center for Scientific Research "Demokritos", 15310 Athens, Greece*

Presenting author email: angelique.lumiere@windowslive.com

The heme-containing enzymes, indoleamine 2,3-dioxygenase 1 (IDO1), indoleamine 2,3-dioxygenase 2 (IDO2) and tryptophan 2,3-dioxygenase (TDO) are cytosolic heme-containing enzymes that catalyze the initial and rate-limiting step of the *L*-tryptophan catabolism through the kynurenine pathway (KP). Enhanced tryptophan catabolism in human cancers, mediated by activation of these enzymes, has been shown to be fundamental in the ability of tumours to breach the defence mechanisms of the immune system. Therefore, KP blockade is an attractive approach for cancer immunotherapy and recent efforts have been focusing on the development of dual IDO1/TDO and/or pan-inhibitors. However, there are no currently available biomarkers for routinely monitoring response to KP-targeted therapies which hampers the development of efficacious anticancer regimes. In this work, we report on the pre-clinical development of PET and SPECT tracers as possible tools for the non-invasive imaging of KP in cancer with potential applications for tumour detection and characterization.

The designed ^{18}F-PET tracers **1** and **2** and ^{99m}Tc-SPECT tracer **3** (Figure below) are based on the pharmacophore structure of diaryl hydroxylamines whose potential for dual and/or pan inhibition was recently shown.[2] Reference compounds and precursors for radiolabelling were synthesized by following multi-step synthetic procedures. Enzyme-based assays identified the references of **1** and **2** as dual IDO1/TDO inhibitors (IC_{50}: 0.37μM and 0.57μM for IDO1, 16.1μM and 9.9μM for TDO) while **3** was identified as an IDO1 inhibitor (IC_{50}: 10μM). Cell-based assays for IDO1 support these results. Preliminary radiosynthesis showed successful ^{18}F-radiolabelling for **1**. On-going efforts are focusing on the radiosynthesis of **2** and **3** and the *in vivo* evaluation of **1-3** in tumour bearing mice.



1 **2** **3**

* "This research is co-financed by Greece and the European Union (European Social Fund- ESF) through the Operational Programme «Human Resources Development, Education and Lifelong Learning 2014-2020» (MIS 5047830)."

References

[1] M. Winters *et. al.*, Eur. J. Med. Chem. **2019**, *162*, 455-464

The Non-Linear Derivative (NLD) model for the in-medium hyperons & antihyperons dynamics

A. Chorozidou [1], T. Gaitanos [1]

[1] *Department of Physics, Aristotle University of Thessaloniki*
email: achoro@auth.gr

The in-medium properties of hyperons and antihyperons are studied with the Non-Linear Derivative (NLD) model and focus is made on the momentum dependence of strangeness optical potentials[1]. The NLD model is based on the Relativistic Mean Field (RMF) approximation to Relativistic Hadrodynamics (RHD) approach of nuclear systems, but it incorporates an explicit momentum dependence of mean-fields. The extension of the NLD model to the baryon and antibaryon octet is based on SU(6) and G-parity arguments. It is demonstrated that with a proper choice of momentum cut-offs, the Λ and Σ optical potentials are consistent with recent studies of the chiral effective field theory and Ξ optical potentials are consistent with Lattice-QCD calculations, over a wide momentum region. We also present NLD predictions for the in-medium momentum dependence of $\overline{\Lambda}$-, $\overline{\Sigma}$- and $\overline{\Xi}$- hyperons. This work is important for future experimental studies, like CBM, PANDA at FAIR and is relevant to nuclear astrophysics as well.

References

[1] T. Gaitanos, A. Chorozidou , Nucl. Phys. **A1008**, 122153 (2021)

Performance of NaI(Tl) spectrometers as dosimeters by combination of laboratory and field dose rate measurements and Monte Carlo simulations.

A. Clouvas[1], S. Xanthos[2], A. Boziari[3], F. Leontaris[1], I. Kaissas[3], M. Omirou[1]

[1] *Department of Electrical and Computer Engineering, Aristotle University of Thessaloniki, GR-54124 Thessaloniki, Greece.*

[2] *International Hellenic University, GR-57001 Thessaloniki, Greece*

[3] *Greek Atomic Energy Commission, GR-15310 Agia Paraskevi, Greece.*

Presenting author email: clouvas@ece.auth.gr

In the framework of the IAEA Coordinated Research Project (CRP) J0212 on "Advancing Radiation Detection Equipment for Detecting Nuclear and Other Radioactive Material Out of Regulatory Control" the properties of two commercial instruments (a) InSpector 1000 analyzer (Canberra), with a 2"x 2" inches NaI(Tl) scintillator and (b) RIIDEYE M-G3 analyzer (Thermo Scientific), with a 3"x 3" inches NaI(Tl) scintillator, were evaluated as dosimeters by laboratory and field measurements. In the Ionizing Radiation Calibration Laboratory (IRCL) of the Greek Atomic Energy Commission, the NaI(Tl) spectrometers were tested in order to measure Ambient gamma Dose Equivalent Rate (ADER). The NaI(Tl) scintillators were irradiated in a homogeneous field with 662 keV photons with different ADER values from 0.17 to 100 μSv h^{-1} at zero degree incidence (irradiation field perpendicular to the detector's front window) and at 90^0 degree incidence. For each irradiation, the measured ADER by the spectrometers and the "true" ADER values (provided by the IRCL) were compared. In addition, the angular dependence (0 to 359 degrees) of the ADER response of the spectrometers was studied with a Eu-152 source placed at one, two and three meters from the spectrometers. The ADER dependence as function of the distance from the Eu-152 source (at zero degree incidence) measured by the two detectors, was compared with the theoretical one. The calculation of ADER values due to unscattered radiation from the source is straightforward. On the contrary, the calculation of ADER values due to scattered radiation from floor , walls and ceiling cannot be determined analytically, and Monte Carlo simulations were performed. In the field studies, ADER was measured by the spectrometers at seven locations belonging to the Greek Early Warning System Network (which is based on Reuter-Stokes ionization chambers). These locations have different ADER values ranging from 20 to 120 nSv h^{-1}. In these locations, gamma ADER were also deduced 1) by in-situ gamma spectrometry measurements with portable Germanium HPGe detectors 2) by the Reuter-Stokes ionization chambers (by subtraction of the cosmic radiation). Gamma dose measurements were also performed with the InSpector 1000 and RIIDEYE M-G3 detectors in 25 locations (beaches) of Northern Greece and compared with the ADER values deduced by sand sample analysis with gamma spectroscopy. Beaches with sand are good candidates for such type of measurements since they are commonly flat and in principle the natural radionuclides are homogenously distributed.

* This work is supported by the IAEA Coordinated Research Project J0212, under contract No 23240.

Simulation of a MicroMegas detector for low-energy α-particle and fission fragment tracking using Garfield++

M. Davis, M. Diakaki, M. Kokkoris, V. Michalopoulou-Petropoulou, R. Vlastou

Department of Physics, National Technical University of Athens, 15780, Zografou, Athens, Greece
Presenting author email: davismarios247@gmail.com

The main purpose of this work has been the implementation of Garfield++, an object-oriented toolkit for the detailed simulation of particle detectors based on ionization measurements in gases or semiconductors, currently widely used in high-energy physics, for studies tuned according to the needs of nuclear physics applications. The choice of this particular code is based on the following advantageous characteristics: (a) The algorithm performs Monte-Carlo calculations and combines the microscopic approach for the tracking of the produced electrons inside the detector, with the macroscopic and the semiclassical ones for ion tracking and for the calculation of the electron transport parameters respectively (b) The code offers a variety of options concerning the accurate description of the detector geometry, materials and signal calculation (c) Moreover, since the toolkit is linked to ROOT, there exists an active supporting community, which constantly updates Garfield++ and helps with any kind of occurring issues. In the present work, the simulated detector is a MicroMegas gaseous one, regularly being used for neutron-induced fission studies at NCSR "Demokritos". The initial code tests involved the linear response of the detector with respect to the energy deposition of 5 MeV α-particles. This study was carried out in two distinct steps: First by collecting simulated data for the deposited charge in the anode electrode for different particle trajectories, as well as, for the same trajectory, but for different gas pressures, ranging between 0.8 and 1.2 atm and then by comparing them with the corresponding results obtained by SRIM2013 regarding the α-particle energy losses inside the detector, using the same set of parameters. Finally, a simulated spectrum of 5 MeV α-particles, having trajectories randomly distributed within the whole detector volume, has been obtained using Garfield++ and has been compared to an experimental one. The similarities and discrepancies observed are discussed and analyzed.

The Giant Monopole and Dipole Resonances within the Constrained Fermionic Dynamics Framework

T. Depastas[1], G.A. Souliotis[1], K. Palli[1], H. Zheng[2] and A. Bonasera[3,4]

[1] *Laboratory of Physical Chemistry, Department of Chemistry, University of Athens, Greece,*
[2]*School of Physics and information Technology, Shaanxi Normal University, Xi'an, China,*
[3]*Cyclotron Institute, Texas A&M University, College Station, Texas, USA*
[4]*Laboratori Nazionali del Sud, INFN, Catania, Italy*
Presenting author email: tdepastas@chem.uoa.gr

The Constrained Molecular Dynamics model (CoMD) has been used extensively in the recent years to describe low energy aspects of nuclear dynamics [1-3]. The CoMD model is based on an effective interaction of Skyrme type, while the nucleons are represented by parameterized Gaussian wave-packets. The evolution of the nuclear system is determined by Hamiltonian equations in the Wigner representation for each nucleonic wave packet [1]. The fermionic nature of the system is taken into account by the constraint of the available phase-space of each nucleon.

The Giant Resonances (GR) are some of the most interesting aspects of near-ground-state dynamics. They correspond to collective modes that arise from multipolar excitations of the nuclear radius. In this work [4], we have studied with the CoMD model the isovector Giant Dipole Resonance (GDR) and the isoscalar Giant Monopole Resonance (GMR) of various near shell-closure systems, along with their corresponding soft modes, representing neutron skin oscillations. Within the CoMD model, the GRs are studied through an initial perturbation and the subsequent evolution of the system. By applying a Fourier transformation to the perturbation trajectory, we extract the spectrum of the GR.

Our calculated spectra are in fair agreement with experimental data [5,6]. Studying the effect of the model parameters to the GDR and GMR spectra, we conclude that a compressibility K=308 MeV appears to improve the GDR energy, while leaving the GMR energy almost unchanged.

References

[1] M. Papa, T. Maruyama, A. Bonasera, Phys. Rev. C 64, 024612 (2001)
[2] G. Giuliani, H. Zheng, A. Bonasera, Prog. Part. Nucl. Phys. 76, 116 (2014).
[3] N. Vonta, G.A. Souliotis et al., Phys. Rev. C 92, 024616 (2015).
[4] T. Depastas, G. Souliotis *et al.*, Eur. Phys. J. Web of Conferences, accepted (Jul. 2021)
[5] J.S. Wang, W.Q. Shen *et al.*, Eur. Phys. J. A 7, 355 (2000)
[6] X. Sun, Phys. Rev. C 103, 044603 (2021)

On the dominance of deformation in atomic nuclei as linked to symplectic symmetry with roots in an effective field theory

J. P. Draayer

Department of Physics and Astronomy, Louisiana State University, Baton Rouge, LA 70803-4001, USA
Presenting author email: draayer@lsu.edu

A brief review of the important role symmetries have played in our gaining a deeper understanding of nuclear structure will be presented. We will then focus our attention on the special role that symplectic symmetry plays in exposing the "dominance of deformation" as found via enhanced B(E2) rates across the Chart of the Nuclides. Additionally, we will show how the No-Core Symplectic Shell Model (NCSpM) emerges naturally from a Symplectic Effective Field Theory, which prepares a way forward for gaining a truly ab initio understanding of the structure of atomic nuclei. Examples will be used throughout to illustrate excitation spectra, strongly enhanced B(E2) transition rates, and nuclear radii of various light to medium-mass nuclei.

Gamma spectrometry studies of tap water from Greece

M. Efstathiou, K. Moustikiadis, K. Papadopoulou, T.J. Mertzimekis

Department of Physics, National and Kapodistrian University of Athens, 15784, Athens, Greece

Natural radioactivity levels in water have been a major objective in various studies worldwide. Besides water resources in the natural environment, it is also important to study processed water that is aimed for consumption by human population in terms of natural or artificial radioisotopes concentrations. In a dedicated study, γ-ray spectroscopy using an apparatus of two 3”x3” NaI(Tl) detectors was used to study approximately 80 samples of tap water from various locations in Greece. The spectrometers were calibrated using standard point sources and their absolute efficiency was determined. From the measurements of the samples, radiological maps were prepared for the naturally occurring isotopes (U-series, Th-Series, ^{40}K) detected. Using the UNSCEAR model [1], dose rates were calculated further to examine the variation of the received dose from drinkable water, received by the general population. From the present results, a distinct uniformity has been observed countrywide, attributed possible to the standards applied by state authorities during water transfer, storage, disinfection and distribution.

References

[1] UNSCEAR Report, vol. 1 (2000)

Advanced XRF Tools and Methodologies for the Revisualization of Vanished Ancient Polychrome

Evangelia Eleftheriou[1], Claudia Caliri[2, 3], Francesco Paolo Romano[2], Kalliopi Tsampa[1], Sofia Sotiropoulou[4] and Andreas Germanos Karydas[1, 2]

[1]*Institute of Nuclear and Particle Physics, NCSR "Demokritos", 153 10 Athens, Greece*
[2]*Instituto di Scienze per il Patrimonio Culturale-CNR, 95125 Catania, Italy*
[3]*Laboratori Nazionali del Sud-INFN, 95123 Catania, Italy*
[4]*IESL-FORTH – Hellas, P.O. Box 1527, GR-711 10 Heraklion, Greece*
Presenting author email: evalftheriou@gmail.com

X-ray Fluorescence (XRF) spectrometry is a versatile, multi-elemental and nondestructive analytical technique, widely used nowadays for in-situ analyses of cultural heritage materials/artifacts using a broad typology of developed instrumentation. For example, handheld XRF (HHXRF) analyzers can offer easy access for fast and efficient measurements under different excitation conditions, whereas the emerging macroscopic XRF (MA-XRF) imaging using novel mobile X-ray scanners [1] can visualize the distribution of chemical elements on entire macro-surfaces.

The aim of this work is to demonstrate the capabilities of advanced MA-XRF measurement and analysis tools to re-visualize the remaining traces of polychrome on the Early Cycladic II (2600-2300 BC) Cycladic figurines and vessels [2]. The in-situ measurements were carried out at the National Archaeological Museum and the Museum of Cycladic Art in the framework of the multidisciplinary project *'The Technology of Early Cycladic Marble'*. Twelve figurines and three vessels were examined, in total. The MA-XRF imaging of the artefacts surface (~cm^2) revealed clear evidences of the use of specific pigments, but also traces of other, non-correlated with pigments, materials. The interpretation of the obtained results was further supported and enhanced by the application of elemental correlation graphs and of a Monte Carlo simulation tool used to to reconstruct the experimental MA-XRF spectra.

Acknowledgements: Dr. Katia Manteli, curator of the Collection of Prehistoric Antiquities of the National Archaeological Museum, and Dr. Nikolas Papadimitriou, curator of Cycladic and Ancient Greek Art Collections of the Museum of Cycladic Art for the coordination of the in-situ MA-XRF analyses at the two museums under the INSTAP project entitled: "The Technology of Early Cycladic Marble" which provided also partial funding support.

References

[1] Romano F.P., Caliri C., Nicotra P., Di Martino S., Pappalardo L., Rizzo F., Santos H., Real time elemental imaging of large dimension paintings with a novel mobile macro X-ray fluorescence (MA-XRF) scanning technique, Journal of Analytical Atomic Spectrometry, 2017;32(4):773-781
[2] Birtacha K., 2016, Examining the paint on Cycladic figurines, Early Cycladic Sculpture in Context Ch. 35:491-502

Abstract submitted to HNPS2021

The ^{241}Am(n,f) reaction study at the n_TOF/CERN facility

Z. Eleme [1], N. Patronis [1], A. Stamatopoulos [2], A. Tsinganis [3], M. Kokkoris [2], V. Michalopoulou [2,3], M. Diakaki [2,4], R. Vlastou [2], L. Tassan-Got [2,3,5], N. Colonna [6], J. Heyse [7], M. Barbagallo [3,6], M. Mastromarco [3,8], D. Macina [3], E. Chiaveri [3,8,9], G. Sibbens [6], A. Moens [6], D. Vanleeuw [6] and the n_TOF Collaboration[10]

[1] Department of Physics, University of Ioannina, Greece
[2] Department of Physics, National Technical University of Athens, Greece
[3] European Organisation for Nuclear Research (CERN), Geneva, Switzerland
[4] CEA, DEN/DER/SPRC/LEPh, Cadarache, Saint Paul lez Durance, France
[5] IPN, CNRS-IN2P3, Univ. Paris-Sud, Université Paris-Saclay, F-91406 Orsay Cedex, France
[6] Istituto Nazionale di Fisica Nucleare, Bari, Italy
[7] European Commission JRC, Geel, Belgium
[8] University of Manchester, United Kingdom
[9] Universidad de Sevilla, Spain
[10] www.cern.ch/ntof

Presenting author email: z.eleme@uoi.gr

High accuracy cross section data of neutron -induced reactions of minor actinides are needed over a wide energy range for the feasibility, design and sensitivity studies on innovative nuclear reactors (Accelerator Driven Systems-ADS and Generation IV fast neutron reactors). These systems, in principle, allow the incineration/transmutation of the existing actinides found in nuclear waste. ^{241}Am ($T_{1/2}$ =433 y) representing almost 1.8% of the actinide mass in spent fuel, is considered one of the possible candidates for incineration/transmutation. On top of that, its production rate increases within the spent fuel through the β -decay of ^{241}Pu ($T_{1/2}$ =14.3 y). Consequently, the accurate determination of the fission reaction rate of ^{241}Am over an extended energy range is of prime importance.

In the present work, the ^{241}Am(n,f) reaction cross section was measured with micromegas detectors at the vertical experimental area of the n_TOF facility at CERN using the time-of-flight technique. For the measurement, six ^{241}Am samples were used along with two ^{235}U and two ^{238}U samples that were used as a reference. In this contribution, the experimental setup will be presented along with the applied data -analysis techniques. Also, the preliminary cross section data from the thermal region up to the fission threshold energies will be compared with the existing results in the literature.

Study of Multinucleon Transfer Mechanisms in ^{86}Kr-induced Peripheral Collisions at 15 and 25 MeV/nucleon

O. Fasoula[1], G. A. Souliotis[1], S. Koulouris[1], K. Palli[1],
M. Veselsky[2], S. J. Yennello[3], A. Bonasera[3]

[1] *Laboratory of Physical Chemistry, Dep. of Chemistry, University of Athens. Greece*
[2] *Institute of Exp. and Applied Physics, Czech Technical University, Prague, Czech Republic*
[3] *Cyclotron Institute, Texas A&M University, College Station, Texas, USA*
Presenting Author email: olgafas@chem.uoa.gr

In this talk, after an overview of the production of neutron rich nuclei, we present our recent efforts to study the multinucleon transfer in peripheral collisions in various reactions near the Fermi regime. Specifically, the reactions of a ^{86}Kr beam at 15 MeV/nucleon with targets of ^{124}Sn ,^{112}Sn, ^{64}Ni and ^{58}Ni and reactions of a ^{86}Kr beam at 25 MeV/nucleon with targets of ^{124}Sn and ^{112}Sn. Experimental data on cross sections were employed from the previous work [1] of our group with the MARS spectrometer at the Cyclotron Institute of Texas A&M University.

Our current focus is on the momentum distributions of the projectile-like fragments that were extracted recently from the original experimental data [1]. The momentum distributions are characterised by a narrow quasi-elastic peak and a broader deep-inelastic peak (corresponding to large dissipation). We employed two-body kinematics to characterize the excitation energies of these regions. In addition, we compared the data with model calculations based on a two-step approach in which the dynamical stage is described with either the Deep-Inelastic Transfer Model (DIT) [2], or with the microscopic Constrained Molecular Dynamics model (CoMD) [3]. The de-excitation of the hot projectile-like fragments is performed with the Gemini model [4,5].

Studying these reactions will provide us with a better understanding as to how the energy of the beam and the different targets affect the mechanism of the multinucleon transfer reactions. With the recent work [6,7], our continued efforts in the study of peripheral reactions in the Fermi energy regime delineate new opportunities to elucidate the reaction mechanism(s) of rare isotope production, and may effectively contribute to the study of unexplored regions of the nuclear chart toward the r-process and the neutron drip line.

References

[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).
[4] R. Charity et al., Nucl. Phys. A **483**, 371 (1988).
[5] R. J. Charity, Phys. Rev. C **58**, 1073 (1998).
[6] O. Fasoula, G.A. Souliotis et al., arXiv:2103.10688 (nucl-ex)
[7] S. Koulouris, G.A. Souliotis et al., arXiv:2103.10691 (nucl-ex)

Unitary limit in heavy nuclei*

Panagioti E. Georgoudis

Grand Accélérateur National d'Ions Lourds,
CEA/DRF-CNRS/IN2P3, BP 55027, F-14076 Caen Cedex 5, France
Presenting Author email: panagiotis.georgoudis@ganil.fr

The unitary limit refers to a scattering problem at infinite scattering length where a scattering state becomes bound. Such a limit is experimentally accessible in systems of cold atoms at the vicinity of Feshbach resonances [1]. In nuclear physics, a physical manifestation of the unitary limit is of interest both from the experimental challenge to measure such a limit in nuclei and from the theoretical aspects that accompany that limit such as conformal symmetry, a quantum critical point and the BCS-BEC crossover.

In this talk I will present the application of a symmetry-based approach to the unitary limit [2] in collective states of heavy, even-even nuclei that is performed by means of the Interacting Boson Model of nuclear structure [3] in conjunction with the Feshbach formalism of nuclear reactions. The results of this application [4] start from the determination of what is to be measured in the experiment for the examination of the unitary limit in collective nuclear states. That is the fluctuations of the cross section of the A+2n compound nucleus. The primary theoretical result concerns the representations of conformal symmetry in A+2n compound nuclei via the fluctuations of cross sections. Other theoretical implications will be shortly discussed such as the operator-state correspondence and the BCS-BEC crossover in A+2n compound nuclei.

* This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie Actions, Individual Fellowships, grant agreement No 793900.

References

[1] M Randeria, W. Zwerger and M. Zwierlein, BCS to BEC Crossover and the Unitary Fermi gas, Springer-Verlag, Berlin, 2012.
[2] F. Werner and Y. Castin, Phys. Rev. A 74, 053604, 2006.
[3] F. Iachello and A. Arima, The Interacting Boson Model, Cambridge University Press, 1989.
[4] Panagioti E. Georgoudis, to appear in Nuclear Physics A, 2021, https://hal.archives-ouvertes.fr/hal-02899169.

Abstract submitted to HNPS2021

Proton therapy: current practice and research perspectives

Drosoula Giantsoudi, Ph.D.

Massachusetts General Hospital and Harvard Medical School, Boston, MA, USA

Presenting author email: dgiantsoudi@mgh.harvard.edu

Proton radiation therapy is currently a well-established treatment option for many tumor types and sites, and the number of proton therapy centers opening worldwide is increasing continuously. Better tumor control probability and/or normal tissue complications probability make proton therapy the preferable treatment modality over conventional photon radiation treatment, especially in the pediatric patient population, where the impact of the decreased total absorbed energy in the patient with protons is most significant. However, several questions regarding the accuracy in dose calculation and biological effect are not fully answered yet.

Proton interactions with matter and proton dosimetry are generally well understood for a known geometry and the proton energies used clinically. Nevertheless, when accounting for patient variability, motion, setup, and material composition uncertainties, we realize that there is still room for improvement in order to take full advantage of the potential of the proton beam therapy. Uncertainties in proton range calculation within the patient in the order of 3.5% are considered in clinical practice, preventing the planners from directing the proton beams toward sensitive structures. In addition, although a constant relative biological effectiveness (RBE) of 1.1 is used clinically in proton therapy, it is well known that this value is directly dependent on the proton energy and linear energy transfer (LET) values and inversely dependent on tissue radiosensitivity. Tissue and patient variability makes the calculation of the relative biological effective proton range challenging, however the LET, being a physical quantity directly correlated with RBE, can be accurately calculated using Monte Carlo methods and utilized in treatment planning optimization, complimentary to dose optimization, to limit any adverse effect to healthy tissues.

Principles of proton therapy treatment planning and optimization will be explained along with current challenges and limitations faced in clinical practice, which have determined recent and future research directions both from the physics and clinical perspectives.

Study of the $^{3}H(p,n)^{3}He$ neutron producing reaction at N.C.S.R. "Demokritos" – Application on the $^{232}Th(n,f)$ reaction

G. Gkatis[1], V. Michalopoulou[1,3], S. Chasapoglou[1], R. Vlastou[1], M. Kokkoris[1], M. Axiotis[2], A. Lagoyannis[2]

[1] *Department of Physics, National Technical University of Athens, 157 80 Athens, Greece*
[2] *Institute of Nuclear and Particle Physics, NCSR "Demokritos", 153 10 Aghia Paraskevi, Greece*
[3] *European Organisation for Nuclear Research (CERN), Geneva, Switzerland*
Presenting author email: gkatisg@gmail.com

Studies of neutron induced reactions are of considerable interest, not only for their importance to fundamental research in Nuclear Physics, but also for practical applications such as reactor technology. The study of those reactions is one of the main research interests of the Nuclear Physics Group at the National Technical University of Athens. One of the laboratories used for the experimental measurements of these reactions, is the Institute of Nuclear and Particle Physics of N.C.S.R. "Demokritos", at the 5.5MV Tandem Van de Graaff accelerator. For the production of the neutron beams, several charged particle reactions are being used (protons, deuterons), covering a wide neutron energy range. In the present work, the neutron beams produced via the $3H$(p,n)$3He$ reaction, were studied. For detecting and monitoring the neutrons the following reference reactions $238U$(n,f), $235U$(n,f) and $237Np$(n,f) were used. Furthermore, a systematic study of the parasitic neutrons, produced via reactions on the target constituents, was performed.

At the same time, the cross sections of the $232Th$(n,f) reaction were deduced, in the energy range from 2 to 5.5 MeV. Seven actinide targets were used, coupled with seven Micromegas detectors, one for each target, for the detection of the fission fragments. The target-detector assembly was placed in an aluminum chamber filled with Ar:CO_2 (90:10) in atmospheric pressure and room temperature. The neutrons impinging on each of the seven actinide targets, were estimated via Monte Carlo simulations, implementing the NeuSDesc, SRIM-2013 and MCNP6 codes. Additional Monte Carlo simulations were carried out using the codes FLUKA and GEF, in order to determine the exact masses of the $232Th$ targets and the energy deposition of the fission fragments in the detector gas.

Statistical model calculations, using the EMPIRE code were performed on the data measured in this work as well as on data reported in the literature.

Heavy metals and Pb-210 in Finland Air for the years 2000 - 2005

E. Ioannidou[1], M. Manousakas[2], K. Eleftheriadis[2], J. Paatero[3], A. Ioannidou[1]

[1] *Physics Department, Nuclear Physics Lab., Aristotle University of Thessaloniki, Thessaloniki 54124, Greece*

[2] *E.R.L., Institute of Nuclear & Radiological Sciences & Technology, Energy & Safety, N.C.S.R. Demokritos, 15310 Ag. Paraskevi, Attiki, Greece*

[3] *Finnish Meteorological Institute (FMI), Observation Services, P.O. Box 503, Helsinki FI-00101, Finland*

Presenting author email: eleioann@physics.auth.gr

In the present work 72 weekly filters collected in Helsinki, Finland during 2000 – 2005 underwent energy dispersive X-ray Fluorescense (ED-XRF) analysis for the determination of their content in Pb, Br, Zn, Cu, Ni, Fe, Mn, Cr, V, Ti, Ca, K, Cl, S, Si, Al and Na. More specifically, one weekly filter per month for every year was analyzed.

The analysis results indicated that there is a decline trend with the time for Fe and a slight decrease for Ti, Si. The observed concentrations of Pb remain relative stable throughout the time period 2000 – 2005.

High average concentration of Pb 500 ngr m^{-3} was typical of the air in central Helsinki throughout the '60s, but after '70s was decreased to around 150 ngr m^{-3} [1]. The observed average concentration of lead in the present study equal with 17.7 ngr m^{-3}, reveals a decrease of its concentration of the order of one magnitude since '70s.

Other observed mean concentrations in ng m^{-3}: Cu: 34.5, Zn: 44.9, Br: 15.8, are also lower almost half of those observed during '70s (Cu: 70, Zn: 172, Br: 49 ng m^{-3}).

The high correlation coefficient observed between the Cu – Zn ($R = 0.89$) is an index of traffic source. The relative high correlation coefficient between the Ni – V observed values ($R=0.66$) is an index of heavy oil source. Finally, the relative high correlation coefficient between the three elements (Fe – Si – Ti) is a clear index of soil source.

The Finnish Meteorological Institute has collected daily aerosol samples for the year 2000 – 2005 for radioactivity monitoring purposes. Airborne ^{210}Pb is a decay product of ^{222}Rn emanating from the soil. Due to its long half-life (22.3 years) ^{210}Pb accumulates relatively into the atmosphere. Thus it can be used as an atmospheric tracer for long-range transported air masses. Anthropogenic lead emissions has low content of ^{210}Pb, so the anthropogenic lead emissions tend to decrease the specific activity of ^{210}Pb in the atmosphere. The ^{210}Pb specific activity is the ratio of the ^{210}Pb activity concentration to the total concentration of stable lead. The observed values of this ratio vary between 3.5 – 58 kBq g^{-1} (Figure 1) (present study). Previous reported values in Southern Finland ranged between 0.67 – 39 kBq g^{-1} and between 3.9 – 91 kBq g^{-1} in Northern Finland [2] with minimum values during the cold winter, due to the increased lead emissions from energy production [3].

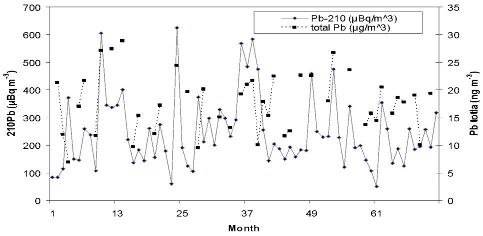


Figure 1: Concentrations for ^{210}Pb and the Pb_{total} for the years 2000 – 2005 in Helsinki, Finland.

References

[1] Mattsson R., Jaakkola T., 1979. An analysis of Helsinki air 1962 to 1977 based on trace metals and radionuclides. Geophysica **16: 1 – 42**.

[2] Kauranen P., Miettinen JK, 1374. Specific activity of ^{210}Pb in the environment. Intern J. Environ Anal Chem. **3: 307 – 316**.

[3] Paatero J., Vaaramaa K., Buyukay M., Kataka J., Lehto J. , 2015. Deposition of atmospheric ^{210}Pb and total beta activity in Finland. J. Radioanal. Nucl. Chem. **303: 2413 – 2420**.

Practical Guidance on the Developing of Radiological Risk Assessment for Educational and Research Laboratories

Ioannis Kaissas[1], Dimitris Mitrakos[2], Costas J. Hourdakis[1]

[1] *Greek Atomic Energy Commission (EEAE), Patriarchou Grigoriou & Neapoleos, 15341, Agia Paraskevi, Attiki*
[2] *National Technical University of Athens (NTUA), 15780, Zografos Campus, Athens, Attiki*
Presenting author email: ioannis.kaissas@eeae.gr

Using ionizing radiation, even in educational and research laboratories, is based on the triplet of principles of: justification, optimization and dose limits. These principles are applicable to the risk assessment that follows the identification of hazards in specific applications. In this work, a practical procedure for the development of the risk assessment is provided for the majority of the research and educational applications, which include the use of unsealed and sealed radioactive sources and apparatus with tubes for the production of ionizing radiation. In addition, the example of the radiological hazard of fire is analysed, in order to classify the severity of the risk of fire on radioactive materials and sources.

The severity of the hazard and consequently of the risk, the probability of the hazard to occur and the detectability of the occurrence are analyzed and combined to yield a risk classification, which induces the management of the measures taken for the emergency preparedness and response. The proposed methodology considers worst case scenarios of external exposure, inhalation and ingestion [1] and compares the doses with criteria like the annual dose limits or the reference band of 20 – 100 mSv [2], in order to initially classify the hazards and therefore the severity on the risk assessment procedure. The results indicate low or medium severity of the risks for most of the educational and research applications. Moreover, specifically the radiological hazard of fire for the public and the first responders is not high due to the relative low or moderate activities in use. Nevertheless the application of the principle of optimization reduces even more the risks with the appropriate measures, like: controlled access, fire detectors and extinguishers, secure storage and keeping of records.

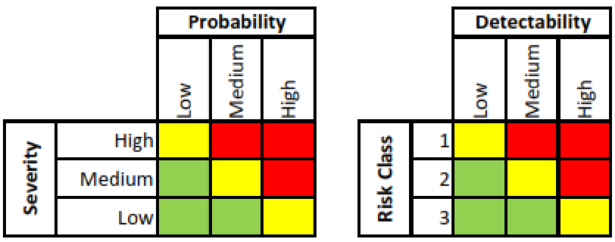


Figure 1: Generic risk assessment classification method. Left: Risk class: Red = 1, Yellow = 2, Green = 3. Right: Risk Priority: Red = High, Yellow = Medium, Green = Low.

References

[1] D. Delacroix, J. P. Guerre, P. Leblanc, C. Hickman, Radionuclide and Radiation Protection Data Handbook 2nd Edition, Radiation Protection Dosimetry, Vol. 98, No 1, (2002)

[2] IAEA, Criteria for Use in Preparedness and Response for a Nuclear or Radiological Emergency, IAEA Safety Standards Series No. GSG-2, IAEA, Vienna (2011)

Fast Neutron Beam Dosimetry Characterization for Biomedical Sample Irradiations

A. Kalamara[1,2], M. Grigalavicius[4], M. I. Savva[1], T. Vasilopoulou[1], A. Lagoyannis[3], K. L. Stefanopoulos[2], T. Theodossiou[4] and I. E. Stamatelatos[1],

[1] *INRASTES, NCSR "Demokritos", 15310 Aghia Paraskevi, Greece.*
[2] *INN, NCSR "Demokritos", 15310 Aghia Paraskevi, Greece.*
[3] *INPP, NCSR "Demokritos", 15310 Aghia Paraskevi, Greece.*
[4] *Institute for Cancer Research, Oslo University Hospital, Oslo, Norway.*
Presenting author email: a.kalamara@ipta.demokritos.gr

The dosimetric properties of fast-neutron beams produced by the p-Li, D-D and D-T reactions at the NCSRD Tandem Accelerator facility were studied using Monte Carlo techniques. Taking into account transport of photons, electrons, protons and alpha particles, depth doses in vials containing photo-sensitizer solutions and biological specimens were calculated. Monte-Carlo simulations were performed by coupling the NeuSDesc and MCNP codes in order to derive the neutron fluence, energy and absorbed dose with depth in the samples under examination for the neutron energy range of 0.5 to 17 MeV. This study contributes data for the characterization of the neutron beam quality and dosimetry characteristics for the irradiations to be performed under the research program FRINGE aiming to investigate neutron generated electronic excitation as a foundation for a radically new cancer therapy.

* Work supported by
Horizon 2020 FET Open No 828922 - FRINGE: Fluorescence and Reactive oxygen Intermediates by Neutron Generated electronic Excitation as a foundation for radically new cancer therapies,
and
CALIBRA project (MIS 5002799) implemented under the Action “Reinforcement of the Research and Innovation Infrastructures” which is funded by the Operational Programme “Competitiveness, Entrepreneurship and Innovation” (NSRF 2014-2020) and co-financed by Greece and the European Union (European Regional Development Fund).

Suffering in the Name of Protecting: The Case of the Fukushima Population

John A. Kalef-Ezra

Medical Physics Laboratory, Medical Department, University of Ioannina, Ioannina, Greece

Presenting author email: e-mail: jkalef@uoi.gr

Major nuclear accidents are rare events causing large and long-lasting medical, environmental, economic, and societal consequences. Justification and optimization are essential in the mitigation of their consequences by actions taken in a timely and safe manner under the existing radiological and no-radiological conditions. Urgent mass evacuation and temporary relocation of the near-by population followed by further evacuations at a later stage and their long-term resettlement after the 1986 Chernobyl and the 2011 Fukushima-1 accidents destabilized both USSR and Japan, two countries with substantial different conditions at that time.

No early radiation-induced somatic effects to public were reported. The collective lifetime effective and thyroid doses to the Japanese population due to the 2011 accident were projected to be ~44.000 man·Sv and ~57,000 man·Gy, respectively. Almost one decade after the accident about ¼ of the ~160.000 evacuees due to the potential radiation risk were still refugees. The thus averted collective dose was ~2,000 man·Sv (on the average ~40 mSv in a group of 18,500 persons, 15 mSv in a group of 35.000, and less than 5 mSv in the remaining), sparing, in theory, about 100 lives with a latency time of decades. The scope of this study was to find retrospectively if the benefit of the evacuation/resettlement procedure was higher than its cost.

The accident-related death toll in the Region of Fukushima has to be differantiated from that due to the earthquaque and the tsunami that trigered the foressen and prevenatble 2011 accident. The ratio of the indirect deaths registered up to 2020 at the heavily impacted by the natural phenoma Regions of Miyagi and Iwate to those directly caused was ~0.10 (1.454/ 14.213) *vs* ~1.43 in Fukushima (2.313/1.414). In addition, the age distribution of the losses differed drastically between them. Among the 2.313 indirect life losses in Fukushima, about 200 could be attributed to either natural phenoma or radiation induced cancers and the remaining, ~2.100, to evacuation/ resettlement. Most of the victims were volunarable pesons, such as patients with chronic diseases, instititionalized individuals, and very poor persons. In addition, migration resulted in increased incidence of pneumonia, mental and psychic disorders (e.g., dipression, suicide attempts, stigmatization), disruption of social networks, insecurity, unemployment, poverty, urbanization, proletarianization, and exploitation. Therefore, the mitigation actions, as designed and implemented, lead in a secondary tragedy larger than that due the accident itself.

The failure to achieve the evacuation/resettlement goals and the revitalization of the abandoned areas in a high-tech country was related in large with the severe limitations of the used decision-aiding tools and decision-making process and the structure of the Japanese society. Many decisions taken the policy-makers were biased by the pressure from people bombarded with overemphasis of the low-dose risks. The decision-makers prioritized short-term planning without taking into account the existing conditions and the power games. Thus, the politically biased processing of probabilities along with the media coverage contributed to the catastrophe.

Only a transparent organization structure totally independent from the interests of the industry and the ruling cycles may assure appropriate decision-making and implementation procedures. In case of departure from such a policy, any well-intended radiation protection scheme may fail.

Studying the speed of sound of dense nuclear matter via the tidal deformability of neutron stars

A. Kanakis-Pegios[1], P.S. Koliogiannis[1], Ch.C. Moustakidis[1]

[1] *Aristotle University of Thessaloniki, 54124 Greece*
Presenting author email: alkanaki@auth.gr

Neutron stars are a natural laboratory for studying dense nuclear matter in its extreme condition. The speed of sound is a microscopic parameter of great interest for studying the equation of state. In this work, we examine possible constraints on the upper bound of the speed of sound. In our study, we use the measured effective tidal deformability from the two recently detected binary neutron star mergers to impose constraints on the equation of state by using the upper bound on the speed of sound [1]. Also, we investigated the maximum mass scenario. To be more specific, in our approach the stiffness of the equation of state is parametrized via two parameters: the speed of sound and the transition density. Moreover, our study is extended in the case of a very massive neutron star, using the recent detection of the GW190814 system [2]. The tidal deformability and the upper bound on the speed of sound for such a massive neutron star are studied, for both individual and binary system cases. According to our study, such a massive neutron star may be existing. Finally, we postulate the kind of future detections that could be useful to impose further constraints and broaden our knowledge on these open problems.

References

[1] A. Kanakis-Pegios *et al.*, Phys. Rev. C **102**, 055801 (2020)
[2] A. Kanakis-Pegios *et al.*, Symmetry **13**, 183 (2021)

Thermochronomentry of metamorphic rock complexes on the SE Peloponnese, Greece, using thermoluminescence (TL)

Kanavou K.V.[1], Athanassas D.C. [1], Stamoulis K.[2], Aslanoglou X.[2], Mouslopoulou V.[3]

[1]*School of Mining and Metallurgical Engineering, NTUA, Greece, kanavouv@mail.ntua.gr;athanassas@central.ntua.gr*
[2] *Department of Physics, University of Ioannina, Greece, kstamoul@cc.uoi.gr; xaslanog@uoi.gr*
[3]*National Observatory of Athens, Greece, vasiliki.mouslopoulou@noa.gr*
Presenting author email: kanavouv@mail.ntua.gr

Many studies have shown that thermochronometry can reveal the thermal history of rocks in the lithosphere by measuring radioactive decay products within the rock, which start to accumulate as soon as the rock passes from different temperatures (cf. Ault et al., 2018). Recently the infrared-stimulated luminescence (IRSL) signal from feldspar grains has been exploited as an alternative low-temperature thermochronometer (e.g. Guralnik et al., 2015; Herman et al., 2010). Nevertheless, typical dose rates encountered in metamorphic rocks limit the application of IRSL to a few hundred ka. In the current study we exploit the thermoluminescence (TL) signal of quartz from metamorphic rocks of the SE Peloponnese to resolve the thermal and exhumation history of the local upper crust. Samples were collected from the center of sizable lumps (a few decimeters in diameter) of quartz cropping out in the «Phyllites-Quartzites» Unit (known also as the «Arna» Unit) of the southern Peloponnese (Tainaro and Neapolis areas). The extremely low-radiation environment predominating in the center of the sampled quartz lumps due to i) the substantially low radioelement concentrations (U ≤ 0.1 ppm, Th ≤ 0.2 ppm and undetectable K) and ii) the insulation effect of the dense and sizable quartz lump against the radioactivity of the surrounding schists, allows the TL signal to grow on longer geological timescales, below saturation levels. By taking advantage of the remarkable stability of the TL signal (i.e. large life-time) and by applying conventional single-aliquot regeneration (SAR) protocols for TL (e.g., Hong et al., 2006; Schmidt et al., 2015) integration of TL spectra between 320°C and 370°C returned unsaturated equivalent doses as high as ~960 Gy. When the very low dose rates of quartz are taken into the calculations the TL dating envelope can be pushed back to the Lower Pliocene, or even to the Late Miocene, rendering TL from quartz a novel thermochronometer for the Neotectonic period (i.e. from the Middle Miocene onwards). The unsaturated TL numerical ages allow to precisely determine the time at which the metamorphic rocks of the SE Peloponnese crossed certain temperatures in the crust (translated into depth based on the geothermal gradient), and calculate the local exhumation rates (Schmidt et al., 2015).

References

[1] Ault *et al.*, Tectonics, **38**, 3705 - 3739 (2018)
[2] B. Guralnik *et al.,* Quaternary Geochronology, **25**,37- 48 (2015)
[3] C. Schmidt *et al.*, Radiation Measurements, **81**, 98-103 (2015)
[4] F. Herman *et al.*, Earth and Planetary Science Letters, Elsevier, **297**,183-189 (2010)
[5] Hong *et al.*, Nuclear Instruments and Methods in Physics Research B, **243**, 174–178 (2006)

Investigation of aged dental zirconia reinforced lithium silicate for personal dosimetry applications

M. Karagiannakidou[1], I. K. Sfampa[1], L. Malletzidou[2], M. Karampiperi[3], E. Kontonasaki[4], G. Kitis[1]

[1] Nuclear and Elementary Physics Laboratory, [2] Advanced Materials and Devices Laboratory, School of Physics, Faculty of Sciences, Aristotle University of Thessaloniki, GR-54124, Thessaloniki, Greece
[3] Laboratory of Archaeometry and Physicochemical Measurements, R.C. 'Athena', P.O. Box 159, Kimmeria University Campus, 67100, Xanthi, Greece
[4] Laboratory of Prosthodontics, Department of Dentistry, School of Health Sciences, Aristotle University of Thessaloniki, GR-54124, Thessaloniki, Greece
Presenting author email: mykaragi@auth.gr

Thermoluminescence (TL) stands as one of the most valuable techniques in the determination of the absorbed dose in dangerous radiation events. Present work studies the differences that may occur after ageing of a glass-ceramic material, specifically zirconia reinforced lithium silicate (ZLS) [1]. Several structural measurements were performed, since mixtures or phases may affect the dosimetric properties. Moreover, the TL properties after each ageing cycle were studied and the affection of ageing over dosimetric properties was estimated.

ZLS specimens were prepared according to manufacturers' instructions. Freshly prepared and *in-vitro* aged samples were examined. The specimens were subjected to different ageing time [2]. TL measurements were carried out using a Risö (model TL/OSL (DA-15)), equipped with a $^{90}Sr/^{90}Y$ beta particle source, delivering a nominal dose rate of 0.0521 Gy/s. A 9635QA photomultiplier tube is used for light detection. All measurements were performed in a nitrogen atmosphere with a low constant heating rate of 2 K/s. X-ray diffraction analysis (XRD) and Fourier transform infrared spectroscopy (FTIR) were performed. The measurements were utilized with a two-cycle Rigaku Ultima$^+$ diffractometer -operating at 40 kV/30 mA-, and a CARY 670 spectrometer -operating in MIR in reflectance mode.

The glow curves were analyzed through a deconvolution method of analysis, using the general kinetic order model (GOK) for all of the specimens under study. Six peaks were used and the evaluated energy for the most prominent of them - at 455 K- is (1.01 ± 0.01) eV. All of the specimens present linear dependence over dose, with slopes equal to 1.00 ± 0.03, and it is independent of the ageing time.

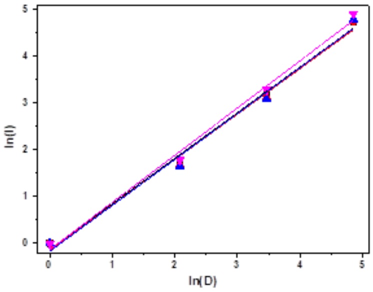


Figure 1: Dose response of the samples A, B, C and D.

References

[1] I.K. Sfampa *et al.,* Appl. Radiat. Isot 157, 109024 (**2020)**

[2] I.K. Sfampa *et al., Radiat. Meas. 125*, 7–14 (**2019**)

Spin distribution of the Nuclear Level Density in a Shell Model approach

Luke Newman[1], Sofia Karampagia[1,2]

[1] *Grand Valley State University, Allendale, Michigan 49401, USA*
[2] *NSCL/FRIB Michigan State University, East Lansing, Michigan 48824-1321, USA*
Presenting author email: karampso@gvsu.edu

Nuclear level densities (NLDs) are key ingredients in calculations of neutron capture rates for neutron rich isotopes in nuclear astrophysics applications. Available experimental NLDs are limited mainly to nuclei near stability. Therefore, theoretical models are employed to predict the NLDs of neutron rich nuclei. Here we present a methodology for calculating spin- and parity- dependent NLDs using methods of statistical spectroscopy, based on the Shell Model. The spin distribution of the NLDs is predicted for nuclei in the sd and pf shells.

References

[1] Roman Sen'kov *et al*., Phys. Rev. **C93**, 064304 (2016)
[2] S. Karampagia *et al*., Int. Jour. Mod. Phys. **E29**, 2030005 (2020)

Fast neutron reactions with ^{241}Am: a detailed TALYS study

Polychronis Karpodinis[1], Theo J. Mertzimekis[1], Sofia Kolovi[2]

[1] *Department of Physics, National and Kapodistrian University of Athens, Zografou Campus, GR-15784 Athens, Greece*
[2] *LPC / CNRS IN2P3, Université Clermont Auvergne, Aubière, France*
Presenting author email: *ckarpodin@gmail.gr*

The relatively large abundance of ^{241}Am in radioactive waste of conventional thermal reactors, combined with its potential hazard for humans, but also the prospect of being used as fuel (e.g. in Radioisotope Thermoelectric Generators), underline the necessity to study its reactions with fast neutrons, which will be of central role in 4th generation fission reactors. In the present work, fast neutron reactions with ^{241}Am are studied by calculating the cross sections of the competing output channels, using the TALYS nuclear reaction simulator.

Calculations involved the full set of nuclear density models (NLD) and γ-ray strength functions (γSF) being available in TALYS, resulting in the selection and adjustment of those that, along with adjustments of the related fission barriers and Optical Model Potential (OMP) parameters, minimize the residual error between theoretical calculations and experimental data, simultaneously for the output channels *(n,f)*, *(n,γ)*, and *(n,2n)*, but also for the total reaction *(n,tot)*. In addition, a new excitation function is proposed for the inelastic channel *(n,n')*, for which no experimental data are currently available. Finally, the proposed NLD parameters are successfully applied with minor adjustments to the fast neutron reactions with the isotone nucleus ^{239}Np.

Measurement of the fission cross-section of ^{232}Th with quasi-monoenergetic neutron beams at NCSR "Demokritos" implementing Micromegas detectors

V. Michalopoulou[1,2], M. Axiotis[3], S. Chasapoglou[1], G. Gkatis[1], A. Kalamara[1,3], M. Kokkoris[1], A. Lagoyannis[3], A. Stamatopoulos[1], A. Tsantiri[1], R. Vlastou[1]

[1] *National Technical University of Athens, Department of Physics, Zografou Campus, Athens, Greece*
[2] *European Organization for Nuclear Research (CERN), Geneva, Switzerland*
[3] *Tandem Accelerator Laboratory, Institute of Nuclear and Particle Physics, N.C.S.R. Demokritos, Aghia Paraskevi, Athens, Greece*

Presenting author email: kokkoris@central.ntua.gr

Thorium is a naturally occurring element, 3 to 4 times more abundant than uranium, containing mainly the fertile isotope ^{232}Th. The thorium fuel cycle has several advantages compared to the conventional U/Pu one, regarding nuclear safety, waste management of the radioactive waste and nonproliferation. For the research and development of systems based on the thorium cycle, precise nuclear data on neutron-induced reactions on the isotopes present in the thorium cycle are mandatory. More specifically, the neutron induced fission cross-section of ^{232}Th needs to be known with high accuracy, in order to account for the fissions related to ^{232}Th in various systems.

However, discrepancies exist in the available experimental datasets, while only two among them cover the whole fast neutron energy region [1, 2]. Both measurements were performed with the time-of-flight technique and the measurement of Shcherbakov *et al.* is systematically higher than the corresponding one of Lisowksi *et al.*. The aim of this work is to cover the fast neutron energy region, especially between 2.0 and 17.8 MeV, with cross-section points acquired with quasi-monoenergetic neutron beams. In order to achieve this, the experiment was performed at the neutron beam facility of the National Centre for Scientific Research "Demokritos", using the 5.5 MV Van de Graaff Tandem accelerator. The quasi-monoenergetic neutron beams were produced via charged particle reactions, namely the ^{3}H(p,n), ^{2}H(d,n) and ^{3}H(d,n) ones, in order to cover this wide energy region. The detection of the fission fragments was achieved with the use of Micromegas detectors, each coupled to an actinide sample, while the ^{238}U(n,f) and ^{235}U(n,f) reactions were used as reference.

Special attention was given to the study of the parasitic neutrons, present in the experimental area and created via charged particle reactions induced by the beam on the various transport line components and the neutron-producing target, as well as, via neutron scattering in the experimental setup and hall in general.

The whole procedure for data analysis, along with the neutron-induced fission cross-section results for ^{232}Th are presented and discussed.

References

[1] O. Shcherbakov *et al.*, J. Nucl. Sci. Technol. **39(sup2)** 230 (2002)
[2] P. Lisowski *et al.*, Proc. Int. Conf. Nuclear Data for Science and Technology, Mito, Japan (1988)

Rapid uniform rotation of protoneutron stars, hot neutron stars, and neutron star merger remnants: The role of the temperature

P.S. Koliogiannis, Ch.C. Moustakidis

Department of Theoretical Physics, Aristotle University of Thessaloniki, 54124, Greece
Presenting author email: pkoliogi@physics.auth.gr

Hot and dense nuclear matter and the equation of state is mandatory for studying protoneutron stars and neutron star merger remnants [1]. The applied equations of state are derived within the momentum-dependent interaction model and state-of-the-art microscopic data, in order to fulfil the thermodynamic laws. The matter is constructed under the assumptions of finite temperature and beta-equilibrium state, and finite entropy per baryon and varying values of proton fraction. Afterwards, we study the effects of finite temperature and rotation at the mass-shedding limit on the neutron stars properties, including the mass and radius, the moment of inertia, the frequency, the Kerr parameter, the central baryon density, etc. The interplay between the temperature and rotation for protoneutron stars and neutron star merger remnants may shed light in the construction of the equation of state of nuclear matter and apply robust constraints.

References

[1] P.S. Koliogiannis and C.C. Moustakidis, The Astrophys. J. **912**, 69 (2021)

Radiation exposure of microorganisms living in radioactive mineral springs

Kolovi S.[1a] for the TIRAMISU collaboration, Fois G.R.[1], Lanouar S.[1], Chardon P.[1a], Miallier D.[1], Rivrais G.[1a], Alain E.[2a], Baker L-A.[2a-3a], Bailly C.[4a], Beauger A.[2a], Biron DG.[3a], He Y.[4a], Holub G.[5a], Le Jeune A-H.[3a], Mallet C.[3a], Michel H.[6a], Montavon G.[4a], Schoefs B.[7a], Sergeant C.[5a], Maigne L.[1a], Breton V.[1a]

[1] *Laboratoire de Physique de Clermont-Ferrand (LPC) / CNRS IN2P3, Université Clermont Auvergne, Aubière, France*
[2] *Laboratoire de Géographie Physique et Environnementale (GEOLAB) / CNRS, Université Clermont Auvergne, Clermont-Ferrand, France*
[3] *Laboratoire Microorganismes, Génome et Environnement (LMGE) / CNRS, Université Clermont Auvergne, Aubière, France*
[4] *Laboratoire de physique subatomique et des technologies associées (SUBATECH) / CNRS IN2P3, Université de Nantes, Nantes, France*
[5] *Centre d'Etudes Nucléaires de Bordeaux-Gradignan (CENBG) / CNRS IN2P3, Université Bordeaux, Gradignan, France*
[6] *Institut de Chimie de Nice (ICN) / CNRS, Nice, France*
[7] *Metabolism, molecular engineering of Microalgae and applications (MIMMA), Biologie des Organismes Stress Santé Environnement, Le Mans University, Le Mans, France*
[a] *Members of Long-Term Socio-Ecological Research (LTSER) - ZATU»*

Presenting author email: sofia.kolovi@clermont.in2p3.fr

The TIRAMISU collaboration gathers expertise from biologists, physicists and radiochemists within the Zone-Atelier Territoires Uranifères (ZATU) in France to analyze the response of microorganisms living in naturally radioactive mineral springs [1]. Mineral springs are small waterbodies, extremely stable over geological time scales, displaying different physicochemical and radiological parameters compared to their surroundings.

Water and sediment samples collected in 27 mineral springs of the volcanic Auvergne region (Massif Central, France) have been analyzed using α- and γ-spectroscopy, ICP-MS and ICP-MS-HR while also studied for their microbial biodiversity. Among the microorganisms present, microalgae (diatoms), widely used as water quality indicators, have shown to display an exceptional abundance of teratogenic forms in the most radioactive springs studied (Radon activity up to 3700 Bq/L) [2].

ERICA tool was used to estimate the radiological risk to freshwater biota [3]. Most of the sampled mineral springs were highly above the risk threshold of 10 μGy/h due to the large concentrations of Radium in the sediments (up to 50 Bq/g).

The radiological data from the analysis of the water and sediment samples are used as inputs to Monte Carlo simulations [4] at micro- (GATE) and nano-(Geant4-DNA) scale in order to assess the direct and indirect damages on the diatom DNA.

Finally, doses up to 200 Gy are administered using an X-ray irradiator on diatom cultures from the mineral springs, in an effort to disentangle the radiation from other environmental stresses that could induce deformations.

References

[1] Zone-Atelier Territoires Uranifères, https://deims.org/915cb2eb-ed08-4b02-9d16-1f4d688e912b

[2] F. Millan et al., *Botany Letters*, **2020,** 167(1):95-113

[3] J.E. Brown et al., *J. Env. Rad.,* **2008**, 99 (special volume on ERICA tool)

[4] S. Agostinelli et al., *Nucl. Instr. Meth.,* **2003**, A506, 250-303

Empirical Description of Isotope Production in 0.01-2.5 GeV p + ^{nat}Fe Reactions

K. Korakas, T. I. Katsigianni, A. Miliadou, D. Tasioudis and N.G. Nicolis

Department of Physics, The University of Ioannina, Ioannina, Greece

Experimental excitation functions of isotopes produced in $natFe(p,x)$ reactions in a wide energy range are compared with the results of empirical cross section formulas. We consider excitation functions of 16 isotopes (^{36}Cl, ^{38}Ar, ^{42,43}K, ^{44}Ti, ^{46,47,48}Sc, ^{48,51}Cr, ^{52}Fe, ^{52,54}Mn and ^{55,56,57}Co) produced in $natFe(p,x)$ reactions at bombarding energies from threshold up to 2.6 GeV [1]. They are compared with the predictions of the empirical formulas of Rudstam [2], Silberberg-Tsao [3] and SPACS [4]. In the middle-energy range, the formulas provide (in the stated order) a progressively improved description of the experimental excitation functions of the dominant isotopes. This is consistent with a detailed comparison of these formulas with high-resolution measurements of isotopic yields for the reaction $p(56Fe,x)$ [5]. At the highest energies, the limiting values of the dominant excitation functions are well described by the EPAX formula (Version 2.1) [6]. The predictive power of these formulas may be questioned (a) at low energies close to the threshold, (b) for reaction products with a mass much smaller than the target and (c) in natural composition targets, due to problematic contributions from certain target isotopes.

References

[1] R. Michel and N. Otuka, Database for Proton Induced Residual Production Cross Sections up to 2.6 GeV, Available from: < http://www-nds.iaea.org/publications/>.

[2] G. Rudstam, Z. Naturforschg. 21a 1027 (1966)

[3] R. Silberberg and C.H. Tsao, Astrophys J. Suppl. 25 315 (1973); Astrophys J. Suppl. 25 335 (1973)

[4] C. Schmitt, K.-H. Schmidt, A. Kelic-Heil, Phys. Rev. C 90 (2014) 064605; Phys. Rev. C 94 (2016) 039901

[5] N.G. Nicolis, T.-H. Katsigianni, K. Korakas, A. Miliadou, and D. Tasioudis, (Contribution to this Symposium)

[6] K. Suemmerer and B. Blank, Phys. Rev. C 61 034607 (2000)

Abstract submitted to HNPS2021

Variable-temperature relative self absorption technique for high-precision level widths' measurements*

P. Koseoglou[1], M. L. Cortes[1], J. Isaak[1], N. Pietralla[1], V. Werner[1]

[1] *Institut für Kernphysik, Technische Universität Darmstadt, Schlossgartenstrasse 9, Darmstadt, Germany*
Presenting author email: pkoseoglou@ikp.tu-darmstadt.de

Recent state-of-art ab-initio calculations are giving very sensitive results of key observables for the understanding of the nuclear forces. The impact of the effective two-body contributions to transition operators was proved in Ref. [1]. This was possible because of the very precise measurement of the half-life of the state of interest, in the range of attosecond. This shows the importance of measuring nuclear observables with high precision.

Nuclear Resonance Fluorescence (NRF) measurements [2,3] provide insight into several nuclear observables related to the transition strengths. In NRF the measured quantity is related both to the excitation and the de-excitation process of the nucleus. The measured quantity is a product of the ground state transition width (Γ_0) and the branching ratio of the corresponding decay channel, $\sim\Gamma_0\cdot\Gamma_j/\Gamma$ (with Γ_j the level's transition width and Γ the total width of the level). In recent years another technique, the Relative Self-Absorption (RSA) [1,3], has been developed at TU Darmstadt. In RSA the measured quantity is only related to the excitation process, $\sim\Gamma_0$. So one has access directly to the transition strength of the level ($\Gamma_0 \propto$ B(λL)). In the analysis the effective temperature of the target, which is approached with theoretical calculations, plays an important role in the determination of the ground state transition width.

An advanced RSA technique, with the usage of targets in variable temperatures, will be presented. The advantage of this technique is the possibility to overcome the needed theoretical calculations for the effective temperature of the target and in practice the error that they introduce. By cooling the target in very low temperature (approaching the 0K, where the effective temperature becomes ⅜ of the Debye temperature) or heating it up in very high temperatures (where the effective temperature becomes almost equal to the thermodynamical temperature) the systematic error is reduced drastically. Allowing for high-precision measurements of the level widths.

* This work is supported by the State of Hesse within the LOEWE research project Nuclear Photonics and the Deutsche Forschungsgemeinschaft – Project-ID 279384907 – SFB 1245.

References

[1] U. Friman-Gayer et al. Phys. Rev. Lett. 126, 102501 (2021)
[2] U. Kneissl, H.H.Pitz, A.Zilges, Prog. Part. Nucl. Phys. 37 349 (1996)
[3] A. Zilges, D. Balabanski, J. Isaak, N. Pietralla, Prog. Part. Nucl. Phys. (accepted for publication: June 17, 2021)

Abstract submitted to HNPS2021

Measurements of projectile fragments from ^{70}Zn (15 MeV/nucleon) +^{64}Ni collisions with the MAGNEX spectrometer at INFN-LNS

S. Koulouris[1], G. A. Souliotis[1], F. Cappuzzello[2,3], D. Carbone[3], A. Pakou[4], C. Agodi[3], G. Brischetto[2,3], S. Calabrese[3], M. Cavallaro[3], I. Ciraldo[2,3], O. Fasoula[1], J. Klimo[5], K. Palli[1], O. Sgouros[3], V. Soukeras[3], A. Spatafora[2,3], D. Torresi[3], M. Veselsky[6]

[1] Laboratory of Physical Chemistry, Department of Chemistry, National and Kapodistrian University of Athens, Athens, Greece
[2] Dipartimento di Fisica e Astronomia "Ettore Majorana", Universita di Catania, Italy [3] Laboratori Nazionali del Sud, INFN, Catania, Italy
[4] Department of Physics and HINP, The University of Ioannina, Ioannina, Greece [5] Institute of Physics, Slovak Academy of Sciences, Bratislava, Slovakia
[6] Institute of Experimental and Applied Physics, Czech Technical University, Prague, Czech Republic
Presenting author email: stekoul@chem.uoa.gr

The present work is focused on our efforts to produce and identify neutron-rich rare isotopes from peripheral reactions below the Fermi energy [1,2]. High-quality experimental data were obtained from a recent experiment with the MAGNEX spectrometer [3] at INFN-LNS in Catania, Italy. The main goal of this presentation is to describe the adopted identification techniques used to analyze the data from the reaction ^{70}Zn (15 MeV/nucleon) + ^{64}Ni.

The particle identification procedure is based on our novel approach presented in [4]. The approach involves the reconstruction of both the atomic number Z and the ionic charge q of the ions, followed by the identification of the mass. Our method was successfully applied to identify neutron-rich ejectiles from multinucleon transfer generated in the above reaction ^{70}Zn +^{64}Ni at 15 MeV/nucleon. The analysis of the data is ongoing. We expect to obtain the angular and momentum distributions of the fragments, along with their production cross sections. These data, along with comparisons with theoretical models are expected to contribute to a better understanding of the complex reaction mechanisms of multinucleon transfer that dominate this energy regime.

References

[1] G. A. Souliotis, M. Veselsky *et al.*, Phys. Rev. C **84**, 064607 (2011)
[2] P. N. Fountas, G. A. Souliotis, M. Veselsky, A. Bonasera, Phys. Rev. C **90**, 064613 (2014) [3] F. Cappuzzello, C. Agodi, D. Carbone and M. Cavallaro, Eur. Phys. J. A., **52**:167 (2016) [4] G.A. Souliotis, S. Koulouris, F. Cappuzzello *et al.*, Eur. Phys. J. A (submitted)

A Study of Shape Transition and Bubbleness in Ne isotopes

Pankaj Kumar[1], Virender Thakur[1], Shashi K. Dhiman[1]

[1] *Department of Physics, Himachal Pradesh University, Summerhill, Shimla-171005, India*
Presenting author email: *pankajdhiman659@gmail.com*

We have studied shape transition and development of quadrupole deformation in even-even $^{18\text{-}36}$Ne isotopes by employing covariant density functional theory (CDFT) with density-dependent meson exchange (DD-ME2) and density-dependent point coupling (DD-PC1) parameter sets. A sudden shape transition is observed in the Ne isotopic chain and can be related to the evolution of shell structure of single-particle orbitals. The correlations between shape transition and discontinuity in the other physical observables are also examined. Our results for ground-state properties are in good agreement with the available experimental data and the result of various theoretical models. The present calculations infer the neutron drip line at ^{34}Ne. In addition to shape transition, the bubble structure is also studied for magic nuclei in this chain.

Nuclear shape evolution of even-even isotopic chains of Sn, Te, and Xe using PCX interaction*

Vikesh Kumar[1$], Shashi K Dhiman[1]

[1] *Himachal Pradesh University, Summer Hill Shimla INDIA 171005*
[$]Presenting author email: vickyrao955@gmail.com

The primary objective of this research is to analyse the shape evolution of even-even isotopic chains of Sn, Te, and Xe using covariant density functional theory. We have taken the whole even-even isotopic chains of Sn, Te, and Xe, to provide a comparative analysis using PCX interaction. The other properties we included are binding energy per nucleon, quadrupole deformation parameter β_2, one-neutron separation energy, two-neutron separation energy, shell closure parameter $D_n(Z, N)$, differential variation $dS_{2n}(Z, N)$, proton rms-radii, neutron rms-radii, and neutron skin thickness. Theoretically calculated results are discussed and compared with available experimental data[1,2] and other theoretical models[3]. The shape coexistence for these isotopic chains of Sn, Te, and Xe is investigated and discussed in the results section. The adequate resemblance between our calculated results and experimental data provides the experimental background to our studies.

* This work is supported by CSIR vide Ref. No: 09/237 (0163)/2018-EMR-I.

References

[1] Stone, N. J. *Atomic Data and Nuclear Data Tables* **111** (2016): 1-28.
[2] Xia, X. W., et al. *Atomic Data and Nuclear Data Tables* **121** (2018): 1-215.
[3] Möller, P., et al. *Atomic Data and Nuclear Data Tables* **109** (2016): 1-204.

Hellenic Society for the Study of High Energy Physics (HeSSHEP) Activities

Aristotelis Kyriakis[1]

[1] *on behalf of the HeSSHEP*
Presenting author email: kyriakis@inp.demokritos.gr

The Hellenic Society for the Study of High Energy Physics (HeSSHEP) [1] was founded in 1975. The majority of the Greek scientists (both in Greece and abroad) working in this field are members of the Society. Its main objectives are to promote the scientific work of the Greek scientists and to inform the general public and the Greek state on matters concerning the subject of HEP. In this general talk an overview of the activities of HeSSHEP will be presented in both Experiment and Theory.

References

[1] https://www.eesfye.gr/

MIRACLS: A novel approach for Collinear Laser Spectroscopy *

V. Lagaki[1,2,3], P. Fischer[3], H. Heylen[2], I. Belosevic[4], C. Kanitz[2,5], S. Lechner[2,6], F. Maier[2,3], W. Nörtershäuser[7], P. Plattner[2,8], M. Rosenbusch[3,9], L. Schweikhard[3], S. Sels[2], M. Vilen[2], F. Wienholtz[2,3,7], R. N. Wolf[3,10], S. Malbrunot-Ettenauer[2]

[1] *Department of Physics, National and Kapodistrian University of Athens, Zografou Campus, GR-15784, Athens, Greece*

[2] *Experimental Physics Department, CERN, CH-1211 Geneva 23, Switzerland*

[3] *Institut für Physik, Universität Greifswald, 17487 Greifswald, Germany*

[4] *TRIUMF, 4004 Wesbrook Mall, Vancouver BC V6T 2A3, Canada*

[5] *Department für Physik, Friedrich-Alexander-Universität Erlangen-Nürnberg, 91058 Erlangen, Germany*

[6] *Technische Universität Wien, Karlsplatz 13, 1040 Wien, Austria*

[7] *Technische Universität Darmstadt, Karolinenpl. 5, 64289 Darmstadt, Germany*

[8] *Universität Innsbruck, Innrain 52, 6020 Innsbruck, Austria*

[9] *Wako Nuclear Science Center (WNSC), Institute of Particle and Nuclear Studies (IPNS), High Energy Accelerator Research Organization (KEK), Japan*

[10] *ARC Centre for Engineered Quantum Systems, The University of Sydney, Australia*

Presenting author email: vlagaki@phys.uoa.gr

Collinear laser spectroscopy (CLS) is a very powerful tool to measure nuclear ground state properties such as nuclear spins, electromagnetic moments and mean-square nuclear charge radius of short-lived radionuclides far from stability with high precision and accuracy [1]. Conventional CLS is based on the optical detection of fluorescence photons from laser-excited ions or atoms. Due to the employment of fast beams (>30keV) it provides an excellent spectral resolution approaching the natural linewidth [1]. However, its fluorescence-light detection limits its successful application to nuclides with yields of at least a few thousands ions/s, depending on the specific case and spectroscopic transition [2].

To access exotic nuclides with very low production yields far away from stability, more sensitive experimental methods have to be envisioned. For this reason, the Multi Ion Reflection Apparatus for CLS (MIRACLS) is currently being developed at ISOLDE/CERN [3]. This novel approach aims to combine the high resolution of conventional fluorescence based CLS with an experimental sensitivity, increase of a factor of 20 to 600 depending on the mass and lifetime of the studied nuclide. The latter is derived from an extended observation time provided by trapping ion bunches in an Electrostatic Ion Beam Trap, also called Multi-Reflection Time-of-Flight (MR-ToF) device [4] in which the ions are bouncing back and forth between two electrostatic mirrors. Thus, the laser beam probes the ion bunch during each revolution compared to the single passage in conventional CLS. A MIRACLS proof-of-principle apparatus, operating at ~1.5 keV beam energy, has been built around an MR-ToF system which has been upgraded for the purpose of CLS. This setup has successfully demonstrated the functionality of the MIRACLS concept and benchmarked simulations for the design of an upcoming device operating at 30 keV.

This talk will introduce the MIRACLS concept and present CLS measurements with ions of stable magnesium and calcium isotopes. An outlook towards further developments will include the design of a 30-keV MR-ToF device for high-resolution CLS.

* This work has received funding from the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation program under grant agreement No. 679038.

References

[1] K. Blaum, et al., Phys. Scr. T152, 014017 (2013) , P. Campbell et al., Prog. Part. and Nucl. Phys. 86, 127-180 (2016) , R. Neugart, J. Phys. G: Nucl. Part. Phys. 44 (2017)

[2] K. T. Flanagan. Nuclear Physics News 23, 2 24 (2013)

[3] S. Sels et al., Nucl. Instrum. Methods Phys. Res. Section B 2019, 0168-583X., F. Maier et al., Hyperfine interactions 2019, 240:54., S. Lechner et al., Hyperfine Interactions 2019, 240:95, V. Lagaki et al., Acta Physica Polonica B, 51:571–576, 01 2020.

[4] H. Wollnik and M. Przewloka, Int. J. Mass Spectrom. 96, 267 (1990), D. Zajfman et al., Phys. Rev. A 55, 1577 (1997), W. H. Benner, Anal. Chem. 69, 4162 (1997), W. R. Plass et al., Nucl. Instrum. Meth. B 266, 4560 (2008), A. Piechaczek et al., Nucl. Instr. Meth. B 266, 4510 (2008), P. Schury et al., Eur. Phys. J. A 42, 343 349 (2009), J. D. Alexander et al., J. Phys. B 42, 154027 (2009), M. Lange et al., Rev. Sci. Instrum. 81, 055105 (2010), R. N. Wolf et al., Int. J. Mass Spectrom. 349-350, 123-133 (2013), F. Wienholtz et al., Nature 498, 346-349 (2013)

Comparison between digitizers and analog circuitry in nuclear spectroscopy experiments

A.Liapatis[1], M.Axiotis[2]

[1] *Department of Physics , National and Technical University of Athens*
[2] *Tandem Accelerator Laboratory , Institute of Nuclear and Particle Physics , NCSR "Demokritos"*
Presenting author email: alexandrosliapates@gmail.com

High speed , precise analog to digital converters are now available at relatively low cost. This breakthrough evolution in electronics has facilitated the development of a new kind of data acquisition and pulse processing in nuclear physics experiments , for which the pre-amplifier pulse is the first and last analog signal followed only by digitally processed waveforms . The purpose of the present work was to employ this new method using a digitizer and comparing it to analog circuitry. More precisely , the device we used was a CAEN 725S digitizer . The comparison was made by measuring γ-radiation from 60Co , in most cases, and a triple alpha source made of ^{239}Pu , ^{241}Am, ^{244}Cm . We used various detectors for the comparison , such as Sodium Iodide (NaI) , Silicon , HPGe and BGO . The comparison between digital and analog signal processing was based on the resolution of the recorded peaks in the experimental spectra and on the corresponding acquisition dead time . The spectrum visualization and the tuning of parameters for the digitally processed signals (pole-zero adjustment , shaping time, rise time etc.) was accomplished by the software provided by CAEN , namely MC2A Analyzer and CoMPASS . The parameter tuning was carried out by looking at the waveform of the incoming signals using the software we mentioned earlier. Before comparing the two methods , we had to find the optimal settings for the parameters, in order to obtain the best possible resolution . The results showed that the digitizer was as accurate as the analog circuitry , as far as resolution is concerned, and that it was processing the incoming signals faster , resulting in a X times smaller dead time , in some cases.

Comparison of Real and Generated by MCNP Simulation Spectrums for Validation of Neutron Activation Calculations

Angelos Markopoulos[1], Dimitrios Mavrikis[1], Eleni Ntalla[1], Alexandra Ioannidou[2], Anastasia Savidou[1]

[1] *National Center for Scientific Research "Demokritos"; Institute of Nuclear & Radiological Sciences & Technology, Energy & Safety; Radioactive Waste & Material Laboratory*

[2] *Aristotle University of Thessaloniki; Physics Department; Nuclear Physics & Elementary Particle Physics Division*

The objective for decommissioning planning, is to obtain a radiological understanding of the involved installation. The characterization at this stage could be carried out by means of: (a) neutron activation calculations based on reactor design and neutron flux; (b) dose rate measurements; (c) in-situ gamma spectrometry; (d) sampling for determination of the scaling factors in activated and contaminated components.

Neutron activation calculations contains several uncertainties. These uncertainties are based on the input data - such as material data (composition and impurities), neutron flux and energy, nuclear data libraries - and on the methodology of the process and the simulation codes.

Taking into consideration all these modeling uncertainties, this work is focused on the development of a technique for validation of the calculations. A non-destructive gamma spectrometry technique by using MCNP6 simulations is under development for interpretation of the resulting gamma-ray spectra of the radionuclides in activated components. In particular, a spectrum will be produced, based on the activities of the main radionuclides in the activated component and the results of MCNP6 simulations. This spectrum will be compared with the experimental spectrum.

Furthermore, the radiological characterization of activated components, which appeared with surface contamination, is essential for the decision making process during decommissioning. The cutting techniques to be followed in order to reduce the production of secondary waste and limit the doses to personnel and the selection of decontamination techniques should be based on accurate determination of the radionuclides inside the material and/ or in the surface contamination. The proposed method could also be helpful in this case. The activities inside and on the surface of the components could be determined by comparing the experimental spectrum with that produced by MCNP6 simulations, using the arisen activities from the scaling factors and the dose rate measurements.

R-matrix Calculations for Proton Elastic Scattering on ^{nat}Mg in the Energy Range E = 2.45 - 4.25 MeV, Suitable for EBS*

E. Alvanou[1], M. Axiotis[2], N. Bligoura[1], S. Harissopulos[2], M. Kokkoris[1], A. Lagoyannis[2], F. Maragkos[1], E. Ntemou[1, 2], K. Preketes – Sigalas[1, 2]

[1] *Department of Physics, National Technical University of Athens, 15780, Zografou, Athens, Greece*

[2] *Tandem Accelerator Laboratory, Institute of Nuclear and Particle Physics, NCSR "Demokritos", 15341 Agia Paraskevi, Athens, Greece*

Presenting author email: fotismaragkos@mail.ntua.gr

Alloys of natural Magnesium (^{24}Mg 78.99%, ^{25}Mg 10%, ^{26}Mg 11.01%) are widely used in electronics, construction of lightweight materials, superconducting materials and a plethora of other applications due to their remarkable light weight, heat dissipation and damping ability along with wide availability. Thus, the magnesium abundance in scientific and technological materials creates the need for the development of precise techniques for the quantitative determination of its concentration depth profiles. One of the most promising IBA techniques in this regard is p – EBS, however with the current evaluation covering the $E_{p,lab}$ = 0.7 – 2.7 MeV range and with no available experimental datasets for proton energies higher than 2.7 MeV, the analysis of magnesium in deeper layers inside various matrices is currently impeded. In this study a coherent set of data for the differential cross section values of the $^{nat}Mg(p,p_0)^{nat}Mg$ elastic scattering was determined via the relative measurement technique, in the energy range $E_{p,lab}$ = 2700 – 4250 keV for 6 backscattering detection angles, namely 120° – 170°, with a 10° step. The measurements were performed using the Van de Graaff Tandem 5.5 MV Accelerator of N.C.S.R. "Demokritos" in Athens, Greece. The target was produced in the same laboratory and it was comprised of a thin self – supporting carbon foil upon which ^{nat}Mg was evaporated, along with an ultra-thin layer of Au on top for normalization purposes. Based on the characteristics of the compound nucleus of the reaction, the acquired data and the existing evaluation, R-matrix calculations using the AZURE code [1] were performed. These calculations allow the accurate interpolation of differential cross section values for energies between $E_{p,lab}$ = 0.7 to 4.25 MeV for every detection angle between 120° to 170°.

References

[1] R. Azuma et al., Physical Review C 81 (2010)

Abstract submitted to HNPS2021

The microscopic origin of the Interacting Boson Model *

Andriana Martinou

INPP Demokritos, 15310 Agia Paraskevi, Athens, Greece

Presenting author email: martinou@inp.demokritos.gr

The Interacting Boson Model of Arima and Iachello is the most popular algebraic nuclear model [1]. It treats spherical tensors of degree 0 and 2, namely the *s* and *d* bosons, to construct the U(6) symmetry, from which the nuclear states are generated. The U(6) algebra collapses into three limiting symmetries [2]; the U(5) for spherical nuclei, the O(6) for the γ-unstable and the SU(3) for the deformed nuclei. Although microscopic justification has been provided for the U(5) and the O(6) limits [3], the case of the SU(3) limit is not yet fully understood in the microscopic level. Thus, we propose a microscopic justification of the Interacting Boson Model in its SU(3) limit, in which the *s* and *d* bosons are being constructed by pairs of harmonic oscillator quanta of the valence shell.

* This research is co-financed by Greece and the European Union (European Social Fund- ESF) through the Operational Programme ``Human Resources Development, Education and Lifelong Learning" in the context of the project ``Reinforcement of Postdoctoral Researchers-2nd Cycle" (MIS-5033021), implemented by the State Scholarships Foundation (IKY).

References

[1] A. Arima and F. Iachello, Physical Review Letters, **35**(16), p.1069, (1975).

[2] F. Iachello and A. Arima, *The Interacting Boson Model,* Cambridge University Press, (1987).

[3] F. Iachello and I. Talmi, Reviews of Modern Physics, **59**(2), p. 339, (1987).

A Technique for Metallic Waste Characterization and Segregation in Management Routes

Dimitrios Mavrikis[1], Angelos Markopoulos[1], Eleni Ntalla[1], Alexandra Ioannidou[2], Anastasia Savidou[1]

[1] *National Center of Scientific Research "Demokritos"; Institute of Nuclear & Radiological Sciences & Technology, Energy & Safety; Radioactive Waste & Material Laboratory*

[2] *Aristotle University of Thessaloniki; Physics Department; Nuclear Physics & Elementary Particle Physics Division*

Adequate radiological characterization is important for optimization of metallic waste management.
For decommissioning planning, the objective is to obtain a radiological understanding of the involved installation. The characterization at this stage could be carried out by means of: 1) neutron activation calculations based on reactor design and neutron flux; 2) dose rate measurements; 3) in-situ gamma spectrometry; 4) sampling for determination of the scaling factors in activated and contaminated components. During dismantling, in-situ characterization is carried out to classify and package the generated waste. This is usually achieved by using portable devices to measure dose rates or total counts. Then, the packages are monitored for assessment of activity and determination of the management route.

The radiological characterization of activated components, which appeared with surface contamination, is essential for the decision making process during decommissioning. The selection of cutting and decontamination techniques should be based on accurate determination of the radionuclides inside the material and/ or in the surface contamination. Also, after dismantling, the metallic waste may be activated and/or contaminated with radionuclides which are products of neutron activation or fission. It is important to decide in which cases the decontamination will be efficient as well as to select the appropriate decontamination techniques based on whether the waste is slightly activated or contaminated or both.

A Semi-empirical technique for optimization of determination of contamination and activation of components and metallic waste, is under development based on combination of gamma spectrometry measurements and MCNPX Monte Carlo simulations. Firstly, the technique aims at reduction of the uncertainties related to the density and activity distribution. The specific activities inside and on the surface of the materials could be determined by using the measurement results of the proposed non-destructive technique in combination with the use of the scaling factors for activation and/ or contamination.

Dose rate assessment of ^{137}Cs to mussels and pelagic fish from the combined use of field measurements, satellite data and the ERICA Assessment Tool*

Georgia Mavrokefalou[1,2], Maria Sotiropoulou[1]

[1] *Environmental Radioactivity Laboratory, Institute of Nuclear and Radiological Sciences and Technology, Energy and Safety, NCSR"Demokritos", Patr. Gregoriou E' & 27, Neapoleos str., PO Box 60037, Postal Code GR 153 41, Agia Paraskevi, Athens, Greece (gmavrokefalou@ipta.demokritos.gr , msotirop@ipta.demokritos.gr, eflorou@ipta.demokritos.gr)*

[2] *Department of Nuclear and Elementary Particle Physics, School of Physics, Faculty of Sciences, Aristotle University of Thessaloniki, University Campus, Postal Code GR 541 24, Thessaloniki, Greece (gkitis@physics.auth.gr)*

Presenting author email: gmavrokefalou@ipta.demokritos.gr

Cesium-137 (^{137}Cs) is the most important indicator of radioactive pollution in the marine environment due to its half-life (Tph: 30.2 years), its high fission yield, its solubility (70% in ionic form) and its bioavailability (similar to potassium) [1,2,3]. Soluble radionuclides, like ^{137}Cs, in the seawater are associated with physicogeochemical and biological parameters of the marine environment (e.g. temperature, water density, biota exchange processes, water mass translocation etc.) [4, 5, 6]. Considering this characteristic, we investigate the potential relation between ^{137}Cs activity concentration and sea surface temperature (SST). The parameter of SST is selected, as the element of cesium in the seawater is conservative and its horizontal and vertical dispersion depends on the water mass translocation and water currents. Water mass translocation and water currents are processes that are both governed by the SST [7,8,9]. SST also influences the uptake of ^{137}Cs in some marine organisms as it makes it more bioavailable and affects the biological retention time and the elimination rate [10,11,12].

The study area is the Gulf of Corinth (Greece). Cs-137 in the Gulf of Corinth originates from water runnoff from the land (Chernobyl fallout from 1986) and a small influence exists from the Ionian and Aegean sea water currents. A total of 17 measurements spanning 2004-2005, of ^{137}Cs activity concentrations were retrieved from the Environmental Radioactivity Laboratory (ERL) database of NCSR "D". Furthermore, SST measurements issued from from NASA's Moderate Resolution Imaging Spectroradiometer (MODIS). Databases of ^{137}Cs activity concentrations and SST are used for regression analysis and definition of a linear model. The estimated ^{137}Cs activity concentrations obtained by the model are then compared with the newest measured values obtained by seawater samples from September and November 2018 (a total of 8 seawater samples). Estimated concentrations present a relative difference of about 9% to the measured values.

In order to conduct the risk assessment analysis in the studied area, the dose rates are calculated for marine organisms. The selected marine organisms are mussels and pelagic fish that are abundant in the area and have significant commercial value, with mussels also being an important bioindicator of marine pollution. The total dose rates in these organisms (resulting by both the internal and external exposure) vary from 3.30×10^{1} to 5.40×10^{1} μGy/year for the mussels and from 2.97×10^{-1} to 4.86×10^{-1} μGy/year for pelagic fish, which are much lower that the intervention levels, indicating low impact due to the ^{137}Cs exposure.

* This work is supported by the NCSR"D" and SNF Industrial Fellowship program for Ph.D. students, with the additional financial support of the Geospatial Enabling Technologies (GET) company.

References

[1] G.G. Polikarpov, Radioecology of aquatic organisms (1966)
[2] M.A. Ashraf et al., Crit Rev Environ Sci Technol. **44,** 5 (2014)
[3] M.H. Paller et al., J Environ Radioact. **131** (2014)
[4] G. Lujaniene et al., Environ Res Eng. **2**, 28 (2004)
[5] N. Evangeliou et al., J Environ Radioact. **100** (2009)
[6] R. Delfanti et al., J Mar Syst. **135** (2014)
[7] F.J. Millero, Limnol Oceanogr **14**, 3 (1969)
[8] IAEA, Vol. Safety Series No. 61, (1983)
[9] N. Evangeliou et al., J Environ Radioact. **113** (2012)
[10] K. Pan et al., Chemosphere **163** (2016)
[11] D. M. Thomas et al., J Environ Radioact. **202** (2019)
[12] H.C. Teien et al., Sci Total Environ. **786** (2021)

RAMONES: RadioActivity Monitoring in OceaN EcoSystems

T. J. Mertzimekis for the RAMONES Consortium

Department of Physics, National and Kapodistrian University of Athens, Zografou Campus,
GR-15784, Athens, Greece
Presenting author email: tmertzi@phys.uoa.gr

The EU H2020 FET project RAMONES [1,2] aims to offer new and efficient solutions for *in situ*, continuous, and long–term radioactivity monitoring in harsh subsea environments. We will develop a new generation of submarine radiation instruments, assisted by robotics and artificial intelligence, to understand radiation-related risks near and far from coastal areas and provide data towards shaping new policies for environmental sustainability, economic growth, and human health. The main ambition is to lay a radical new path to close the existing gap in marine radioactivity sampling. RAMONES will provide tools for long-term, rapid deployments, propose new AI-driven and supported methodologies, and offer scaled-up solutions to researchers, policy makers and communities. State-of-the-art equipment from various disciplines will be combined with advanced modelling techniques to support the design of new and effective approaches for the marine environment, provide efficient response to natural and man-made hazards, and shape future policies for the global population, paving the path of Environmental Intelligence across Europe.

RAMONES receives funding from European Union under Horizon 2020
FET Proactive Programme via grant agreement No. 101017808

References

[1] https://cordis.europa.eu/project/id/101017808

[2] https://www.ramones-project.eu

Measurement of the $^{230}Th(n,f)$ cross-section at the CERN n_TOF facility

V. Michalopoulou[1,2], M. Diakaki[1], Z. Eleme[3], M. Kokkoris[1], N. Patronis[3], A. Stamatopoulos[1], A. Tsinganis[4], R. Vlastou[1] and the n_TOF collaboration

[1] *National Technical University of Athens, Department of Physics, Zografou Campus, Athens, Greece*

[2] *European Organization for Nuclear Research (CERN), Geneva, Switzerland*

[3] *University of Ioannina, University Campus, Ioannina, Greece*

[4] *European Commission, Joint Research Centre, Geel, Belgium*

Presenting author email: veatriki.michalopoulou@cern.ch

The study of neutron induced reactions on actinides is of great importance both for the design of advanced nuclear systems and for fundamental research. The design of Generation IV reactors, Accelerator Driven Systems (ADS), as well as the study of alternative fuel cycles, such as the thorium fuel cycle, highlight the need for accurate cross-section data. In addition, fission cross-section data can assist in the study of the fission process and the fission barrier.

Specifically, ^{230}Th is produced from the alpha decay of ^{234}U in the thorium fuel cycle, thus its fission cross-section is required with high accuracy. In addition, in the fission cross-section of thorium isotopes narrow resonances and fine structures are present, which cannot be explained efficiently by the double-humped fission barrier. For ^{230}Th, previous measurements have shown a resonance at ~720 keV with additional fine structures. However, few discrepant experimental data exist in literature covering the energy region from the fission threshold up to 25 MeV.

For this reason, the fission cross-section of ^{230}Th was measured at the CERN n_TOF facility, with the time-of-flight technique in order to cover the energy range of the previous measurements and extend the measurements to higher energies. The measurements were performed with Micromegas detectors, while the high purity ^{230}Th were produced at JRC-Geel in Belgium. The analysis procedure and the preliminary results are presented.

Time and temperature resolved resistivity recovery of irradiated metals *

E. Mitsi[1], A. Theodorou[1,2], Z. Kotsina[3], M. Axiotis[3], G. Apostolopoulos[1]

[1] *Institute of Nuclear and Radiological Science and Technology,Energy and Safety NCSR "Demokritos", 15310 Aghia Paraskevi Attikis, Greece*

[2] *Section of Solid State Physics, Department of Physics, National and Kapodistrian University of Athens, Panepistimiopolis, GR-15784,Zografos*

[3] *Tandem Acceleration Laboratory, Institute of Nuclear Physics, NCSR "Demokritos", 15310 Aghia Paraskevi Attikis, Greece*

Presenting author email: elmitsi@ipta.demokritos.gr

Under high-energy irradiation, defects form in crystals, such as vacancies and self-interstitial atoms (SIAs). These are ultimately responsible for severe degradation of the physical and mechanical properties of materials. Understanding the basic properties of defects is crucial for the development of future next-generation energy systems. Experimentally, defects can be observed mostly indirectly, e.g., by electrical resistivity measurements. The information on defect properties provided by such experiments is both extremely rich and difficult to interpret [1]. Resistivity measurements are typically performed during post-irradiation isothermal or isochronal annealing and the results are analyzed on the basis of simple reaction rate theory. However, a number of strong assumptions has to be made to extract defect parameters such as migration barriers. In many cases these assumptions prove to be inadequate. Furthermore, in metals such as W, where defects are mobile at very low temperature, the validity of classical reaction rate laws comes into question.

In the current contribution we introduce a novel methodology for post-irradiation resistivity measurements combining isochronal and isothermal annealing. Taking advantage of the computer-controlled, high-precision measurement system of the IR2 facility at the TANDEM accelerator of NCSR "Demokritos" [2], we realize a complex post-irradiation annealing and measurement program that reveals aspects of resistivity recovery as a function of both time and temperature. This results in a much more detailed experimental dataset, which can help in reducing the number of assumptions necessary for the classical rate theory analysis. Further, it may provide indications of low temperature quantum effects in defect kinetics. The new method has been tested in measurements of a W single crystal irradiated by 7 MeV protons at 8 K. The observed low temperature resistivity recovery is due to the migration and annihilation of SIA defects, whose properties in W is yet not fully understood. The experimental results obtained with our new method are compared to recent theoretical models of the SIA in W.

* This work has been carried out within the framework of the EUROfusion Consortium and has received funding from the Euratom research and training programme 2014-2018 and 2019-2020 under grant agreement No 633053. The views and opinions expressed herein do not necessarily reflect those of the European Commission.

References

[1] Fu, C.-C., *et al.*, *Nat. Mater.* **4**, 68–74 (2005).
[2] S. Harissopulos *et al., Eur. Phys. J. Plus* **136**, 617 (2021)

Development of a computer code for the calculation of self-absorption correction factors in γ-spectrometry applications

Alafogiannis I.[1], Tugnoli F.[2], Mitsios, I.K.[1], Anagnostakis, M.J.[1]

[1] *Nuclear Engineering Department, School of Mechanical Engineering, National Technical University of Athens, Building K, Zografou Campus, Iroon Polytechneiou 9 Zografou, 15780, Athens, Greece*

[2] *Department of Industrial Engineering, University of Bologna, Via dei Colli 16, Bologna*

Presenting author email: iasoniatis@mail.ntua.gr

Gamma spectroscopic analysis of environmental samples requires careful sampling, sample preparation, gamma spectrum collection and analysis as well as the use of a series of correction factors in order to determine the activity concentration of the detected radionuclides with sufficient accuracy and precision. One of the main effects that need to be considered – especially when using low energy photons – is the self-absorption of the photons within the sample [1], which may be significantly different between the calibration standard and the sample analyzed. This effect is highly dependent on sample volume – especially its thickness – sample density and composition and is dominant for samples containing high Z elements. A common way of dealing with the self-absorption issue is by using Efficiency Correction Factors (ECF), to take into consideration the different absorbing properties between the calibration standard and the sample. In this work, a MATLAB program for the calculation of ECF was developed. For the calculation of the correction factor a method which is based on the calculation of two double integrals which are proportional to the detector efficiency, one integral for the calibration standard material and one for the sample material [2]. The ratio of the two integrals is the correction factor ECF that is used to take account for the different self-absorption between the calibration source material and the sample material [3]. A variety of material matrices and compositions were used for the development of the program, focusing on Naturally Occurring Radioactive Materials (NORM), which may have high density and contain high Z elements [4], thus requiring significant self-absorption corrections. The results of the program were compared with other methods of ECF calculation, such as Monte-Carlo simulation. The results obtained for the materials analysed showed that – contrary to what is often believed – self-absorption corrections may not be required for low energy photons only, but for photon energies higher than 1000keV as well. This is a very important conclusion, as many isotopes of interest in the analysis of environmental materials – especially NORM – emit photons at fairly high energies, often exceeding 1000keV, like ^{40}K (1460keV) and ^{214}Bi (609keV, 1120keV, 1764keV).

References

[1] P. Jodlowski, NUKLEONIKA 21-25, 51 (2006)
[2] K. Debertin, Elsevier Science Publisher B.V. (1988)
[3] M. J. Anagnostakis, S.E. Simopoulos, Environ. Int. 93-99, 22 (1996)
[4] M. F. Attallah *et al.*, IntechOpen 40555 (2012)

In depth analysis of a sediment core from North Aegean Sea

Mitsios, I.K.[1], Pappa, F.K.[2], Patiris D.L.[2], Rouni, P.K.[1], Anagnostakis, M.J.[1], Tsabaris, C.[2]

[1] *Nuclear Engineering Department, School of Mechanical Engineering, National Technical University of Athens, Building K, Zografou Campus, Iroon Polytechneiou 9 Zografou, 15780, Athens, Greece*

[2] *Hellenic Centre for Marine Research, 46,7 km Athens Sounio ave., P.O. Box 712, P.C. 19013 Anavyssos, Attiki, Greece*

Presenting author email: iasoniatis@mail.ntua.gr

In this work a thorough analysis of the vertical distribution of natural and artificial radionuclides and trace elements in a sediment core sample was conducted. The origin of the sample, with code name AEX58, is a deep-sea trench off the coast of Samothrace, Greece. The core was sampled by the Research Vessel AEGAEO, on November 2015, at a depth of 1540m. The sediment core sample was then treated at the Hellenic Centre for Marine Research (HCMR) separated at 1cm increments, ranging from 0cm to 39 cm, dried, and milled. A first analysis of the samples was also conducted at HCMR using gamma spectroscopic techniques. Further spectroscopic analysis continued at Nuclear Engineering Department of the National Technical University of Athens (NED-NTUA) using a Low Energy Germanium Detector (LEGe). The following radionuclides were determined ^{210}Pb, ^{234}Th, ^{226}Ra, ^{228}Ra, ^{228}Th, ^{137}Cs and ^{40}K [1], [2], [3], [4]. Additionally, Instrumental Neutron Activation Analysis (INAA) was used and the following major and trace elements were identified and quantified: Al, Fe, K, Na, Mn, Zn, V, Cr, Rb, Ce, La, Co, As, Ga, Sc, [5], [6]. It is worth mentioning that although the presence of Sm in the samples is strongly indicated, the quantification was not possible due to the strong interference from Uranium photopeaks [7]. Based on the in depth analysis of the sediment core, no specific vertical distribution was observed, neither for the radionuclides nor for the trace elements. Furthermore, significant disruption of radioactive equilibrium between ^{210}Pb and ^{226}Ra was observed in all the increment samples, with ^{210}Pb activity being much higher than that of ^{226}Ra. These findings, together with the presence of ^{137}Cs in all samples, even in the 38-39cm increment, suggest that there is, either high sedimentation rate at the sampling area, or significant mixing of the sediments takes place [4], [8].

References

[1] C. Tsabaris et al., J. Environ. Radioact. 1-8, 144 (2015)
[2] W. Lin et al., Mar. Geol. 424 (2020)
[3] J. A. Alfonso et al., J. Radioanal. Nucl. Chem. 219-224, 300 (2014)
[4] C. Tsabaris et al., Radiat. Prot. Dosim. 474-487, 150 (2012)
[5] A. El-Taher et al., Appl. Radiat. Isot. 171-181, 151 (2019)
[6] T. K. Peppas et al., J. Hazard. Mater. 255-262, 181 (2010)
[7] I. S. Ribeiro et al., J. Radioanal. Nucl. Chem. 299-303, 305 (2015)
[8] C. Tsabaris et al., Environ Earth Sci. 833-843, 67 (2012)

Upgrading the APAPES installation at the tandem accelerator laboratory of NCSR "Demokritos" by developing coincidence techniques *

S. Nanos[1,3], A. Lagoyannis[3], A. Laoutaris[2,3], A. Biniskos[1], E. Menz[4,6], L. Varga[4,7], U. Spillmann[4], P-M. Hillenbrand[4,5], N. Petridis[4], T. Stöhlker[4,6,8], E.P. Benis[1]

[1] *Department of Physics, University of Ioannina, GR-45110 Ioannina, Greece*
[2] *Department of Physics, University of Crete, GR-70013 Heraklion, Greece*
[3] *Tandem Accelerator Laboratory, INPP, NCSR "Demokritos", GR-15310 Ag. Paraskevi, Greece*
[4] *GSI Helmholtzzentrum für Schwerionenforschung, 64291 Darmstadt, Germany*
[5] *Institut fur Kernphysik, Goethe-Universitat, 60438 Frankfurt, Germany*
[6] *Helmholtz-Institut Jena, 07743 Jena, Germany*
[7] *Ruprecht-Karls University Heidelberg, Germany*
[8] *Institut für Optik und Quantenelektronik, Friedrich-Schiller-Universität Jena, 07743 Jena, Germany*
Presenting author email: mbenis@uoi.gr

The APAPES installation at the tandem accelerator laboratory of NCSR "Demokritos" is currently fully operational providing a solid research ground for the field of fast ion-atom collisions based on the ZAPS technique [1]. Fundamental processes such as single electron capture, electron excitation, and electron transfer excitation in multi-electron multi-open shell dynamical atomic systems are at the core of our studies [2-4]. In addition, special techniques have been developed exploiting pre-excited beams that facilitate such investigations [5]. Recently, the upgrade of the installation has been initiated through a collaboration with German Institutes under the support of the IKYDA2020 program [6]. The upgrade will increase the arsenal of the APAPES installation by offering the capability of performing ion-ion and electron-ion coincident measurements. The upgrade will include: (a) a magnetic charge state selector downstream the ZAPS setup, allowing for the detection of the charge change of the projectile measured in coincidence with the electron spectra; (b) an ion TOF spectrometer upstream the ZAPS setup, allowing for the detection of the atomic target charge state or the molecular target fragments in coincidence with the projectile charge state change. The upgrade will extend our research interests to studies concerning the processes of electron loss to continuum (ELC) and electron capture to continuum (ECC) from pre-excited ion beams, never reported in the literature. It will also pave the way to initiate studies concerning molecular fragmentation by fast ion beams. The up-to-date progress of the upgrading and the offered prospects will be presented.

* We acknowledge support of this work by the project IKYDA2020 [6].

References

[1] I. Madesis *et al.*, J. Phys: Conf. Ser. **583** 012014 (2015).
[2] I. Madesis *et al.*, Phys. Rev. Lett. **124** 113401 (2020).
[3] E. P. Benis, X-Ray Spectr. **49**, 54-59 (2020).
[4] T.J.M. Zouros *et al.*, Atoms **8**(3), 61 (2020).
[5] E.P. Benis and T.J.M. Zouros, J. Phys B **49**, 235502 (2016).
[6] https://www.iky.gr/el/upotrofies-gr/2014-12-12-12-09-42/ikyda

Validation of Empirical Formulas for Spallation Residue Production in 0.3A-2.6A GeV $p + {}^{56}Fe$ Reactions

N.G. Nicolis, T. I. Katsigianni, K. Korakas, A. Miliadou, and D. Tasioudis

Department of Physics, The University of Ioannina, Ioannina 45110, Greece

Spallation residue cross sections in bombardments of $56Fe$ with protons are compared with empirical parametric formulas often used in cosmic-ray astrophysics and medical application studies. Experimental mass, charge and isotopic distributions in $56Fe + p$ reactions at 0.3-1.5 GeV/A [1] are compared with cross sections calculated with the formulas of Rudstam (CDMD-G, CDMD) [2], Silberberg-Tsao (S.T.) [3], Silberberg-Tsao-Barghouty (S.T.B) [4], SPACS [5] and the EPAX limit [6]. In this order, these formulas provide on the average a progressively improved description of the experimental data. We comment on the validity of the formulas in lighter and heavier non-fissile systems.

References

[1] C. Villagrasa-Canton et al., Phys. Rev. C 75, 044603 (2007)

[2] G. Rudstam, Z. Naturforschg. 21a 1027 (1966)

[3] R. Silberberg and C.H. Tsao, Astrophys J. Suppl. 25 315 (1973); Astrophys J. Suppl. 25 335 (1973)

[4] R. Silberberg, C. H. Tsao and A. F. Barghouty, Astrophys, J. 501 911 (1998)

[5] C. Schmitt, K.-H. Schmidt, A. Kelic-Heil, Phys. Rev. C 90 (2014) 064605; Phys. Rev. C 94 (2016) 039901

[6] EPAX Version 2.1, K. Sümmerer and B. Blank, Phys. Rev. C 61 034607 (2000)

Impact of nuclear mass measurements in the vicinity of ^{132}Sn on the r-process nucleosynthesis

Stylianos Nikas[1], Anu Kankainen[1], Olga Beliuskina[1], Dmitrii Nesterenko[1], and the IGISOL group[1]

[1] *University of Jyvaskyla, P.O. Box 35 (YFL), FI-40014 University of Jyvaskyla, Finland*
Presenting author email: stynikas@jyu.fi

The creation of the elements is still one of the biggest puzzles in Physics. The rapid (r) and the slow (s) neutron capture processes are thought to create most of the heavy elements in our universe. While the abundances of the s-process can be well modelled based on the currently available experimental data, this is not the case for the r-process. To successfully model the r-process both the astrophysical conditions (entropy, electron fraction) as well as the nuclear properties of nuclei participating in the r – process need to be constrained [1]. The r-process path extends away of stability towards the exotic neutron rich isotopes where experimental data are limited. Cataclysmic events, such as neutron star mergers and supernovae are known to produce r-process elements, however, their exact contributions to the abundances and the exact astrophysical conditions in such events are not yet fully understood.

Nuclear Physics play a crucial role in the effort to understand the origin of elements. One of the most important quantities are the nuclear masses [2]. Precision measurements of nuclear masses with Penning traps, such as JYFLTRAP in the JYFL Accelerator Laboratory in Finland, lead to a better modelling of the needed nuclear reaction rates in order to model the r-process.

In this talk we will focus on the impact of nuclear masses performed with JYFLTRAP on the r-process nucleosynthesis. We will report the atomic masses of $^{113\text{-}124}$Ag, ^{128,130}In, ^{137}Sb, $^{136\text{-}142}$I, the calculated neutron capture rates using a Hauser – Feshbach statistical code and finally their impact on the r-process abundances. In addition, we present a small-scale sensitivity study regarding the reported mass values.

* This work is supported by European Union's Horizon 2020 research and innovation programme (ERC Consolidator Grant 2017), project MAIDEN under grant agreement No. 771036.

References

[1] Cowan JJ, *et al.* Reviews of Modern Physics. **93, no. 1** (2021)
[2] Mumpower, Matthew R., *et al.* Progress in Particle and Nuclear Physics **86** (2016)

A Comprehensive Study for Radiological Characterization of NORM Waste Associated with Oil Industry by using a $LaBr_3$(Ce) Scintillator*

Eleni Ntalla[1,2], Alexandros Clouvas[2], Anastasia Savidou[1]

[1]*Institute of Nuclear & Radiological Sciences & Technology, Energy & Safety, National Center for Scientific Research "Demokritos", Athens, Greece*

[2]*Department of Electrical and Computer Engineering, Aristotle University of Thessaloniki, Thessaloniki, Greece*

Presenting author email: dalla@ipta.demokritos.gr

The last decade $LaBr_3$(Ce) scintillation detectors have become commercially available and are very promising due to their high light yield (> 65000 photons/MeV) that results in a better energy resolution compared to NaI(Tl) detectors (< 3% FWHM at ^{137}Cs), their decay time of 35 ns and their material density (5.29 g/cm^3) [1, 2]. Also, there is no need for cooling comparing to HPGe detectors. Thus, $LaBr_3$(Ce) detectors could be a suitable choice for environmental radiation monitoring [3] and in-situ measurements of NORM [4].

Gamma spectrometry measurements and MCNP-X simulations were combined for the 1.5'x1.5' $LaBr_3$(Ce) scintillator full characterization (FWHM, energy and efficiency calibration). Simulated and experimentally calculated efficiencies were compared in order to determine the accurate dimensions of the $LaBr_3$(Ce) detector crystal. Factors that affect NORM analysis, such as $LaBr_3$(Ce) internal background and peak interferences, were considered in order to select the optimal NORM radionuclides from uranium and thorium radioactive series and the corresponding emitting peak energies that will be used for the analyses.

The development of the method for in-situ NORM characterization is based on the detector efficiency evaluation by MCNP-X simulations after taking into consideration common geometries of containers for NORM originating from Oil Industries and the experimental validation of the MCNP-X models by using waste packages of known radioactivity of NORM. Furthermore, activity inhomogeneity study was performed with the use of reference ^{226}Ra sources.

This methodology can be effectively applied at Oil Industries for fast and cost-effective radiological characterization of NORM.

* This study is supported by the program of Industrial Scholarships of Stavros Niarchos Foundation.

References

[1] Knoll G. F., John Wiley and Sons, 1999.

[2] Quarati, F., Bos, A.J.J.,Brandenburg, S., Dathy, C.,Dorenbos, P., Kraft, S., Ostendorf, R.W., Ouspenski, V., Owens, A. 2007. X-ray and gamma-ray response of a 2´´x 2´´LaBr3:Ce. Nucl. Instr. Meth. Phys. Res. A 574, 115-120.

[3] Ciupek, K., Jednoróg, S., Fujak, M., Szewczak, K. 2014. Evaluation of efficiency for in situ gamma spectrometer based upon cerium-doped lanthanum bromide detector dedicated for environmental radiation monitoring. J. Radioanal. Nucl. Chem. 299, 1345-1350.

[4] Mueller, W. F., Ilie, G., Lange, H.J., Rotty, M., Russ, W.R. 2013.In-situ measurements and analysis of naturally occurring radioactive materials.ANIMMA paper #1310

Assessing Electronic Excitations in Single-crystalline SiC foils by keV ions

Ntemou E[1], Holeňak R[1], Primetzhofer D.[1]

[1] *Department of Physics and Astronomy, Uppsala University, 751 20 Uppsala, Sweden*
Presenting author email: eleni.ntemou@physics.uu.se

Accurate knowledge of the energy deposition of ions in matter is crucial for both fundamental and applied science and technology. In fundamental research, studying the stopping of slow ions (~Bohr velocity) is the first step in understanding how dynamic processes such as charge exchange can contribute to target excitation. In applications, knowledge of the specific energy loss is a necessity for materials characterization and modification based on energetic ions.

Silicon carbide (SiC) is an ideal material for use in harsh environments [1] since it exhibits excellent physical and electronic properties. Data on the energy loss in SiC at ion energies below the Bragg maximum is, however, scarce and furthermore largely obtained from a combination of ion implantation and secondary ion mass spectrometry experiments [2].

Experiments were performed using the Time-of-Flight Medium Energy Ion Scattering System at the 350 keV Danfysik Implanter at the Uppsala University [3]. Pulsed beams of H, He and heavier ions, with energies of 60 – 300 keV and with typical pulse length of ~1 ns, were directed on a single-crystalline, self-supporting SiC (100) foil (Norcada Inc.) with nominal thickness of 200 nm. Transmitted ions were detected by a large-angle, position-sensitive detector. The recorded angular distribution is shown in Fig. 1 for transmitted He projectiles with a primary energy of 60 keV.

The energy loss was measured along random and several different channelling trajectories. Data is found to deviate from SRIM predictions [4]. Ions heavier than protons, show a similar discrepancy between electronic stopping along random and channelling trajectories as earlier observed for Si (100) [5].

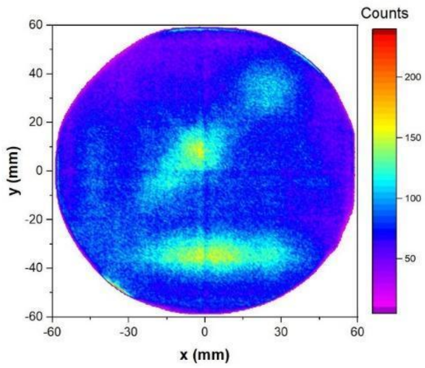


Figure 1 2D distribution of 60 keV He ions transmitted through a SiC self supporting foil (100).

References

[1] Roccaforte F. et al., Microelectronic Engineering 187-188 (2018) p. 66
[2] https://www-nds.iaea.org/stopping/
[3] Sortica et al., NIMB Vol. 463 (2020) p. 16
[4] Ziegler J. F. et al., NIMB Vol. 268, Issues 11-12 (2010) p. 1818
[5] Lohmann S., Primetzhofer D. Phys. Rev. Lett. 124, 096601 (2020)

Progress in activation of ITER materials at JET during deuterium and tritium operations

L. W. Packer[a], P. Batistoni[b], N. Bekris[h], S. C. Bradnam[a], M. Fabbri[e], Z. Ghani[a], M. R. Gilbert[a], R. Kierepko[c], E. Laszynska[d], D. Leichtle[h], I. Lengar[f], S. Loreti[b], J. W. Mietelski[c], C. R. Nobs[a], M. Pillon[b], M. I. Savva[g], I. E.Stamatelatos[g], T. Vasilopoulou[g], A. Wojcik-Gargula[c], A. Zohar[f], and JET Contributors*

[a]*CCFE, United Kingdom Atomic Energy Authority, Culham Science Centre, Abingdon, Oxon, OX14 3DB, UK*

[b]*ENEA - Department of Fusion and Technology for Nuclear Safety and Security via E. Fermi 45, 00044 Frascati (Rome), Italy*

[c]*Institute of Nuclear Physics, Polish Academy of Sciences, PL-31-342 Krakow, Poland*

[d]*Institute of Plasma Physics and Laser Microfusion, 01-497 Warsaw, Poland*

[e]*Fusion for Energy, Josep Pla 2, Torres Diagonal Litoral B3, 08019 Barcelona, Spain*

[f]*Reactor Physics Department, Jozef Stefan Institute, Jamova cesta 39, SI-1000 Ljubljana, Slovenia*

[g]*Institute of Nuclear and Radiological Sciences, Technology, Energy and Safety, NCSR Demokritos, Athens, 15310, Greece*

[h]*Karlsruhe Institute of Technology (KIT), Hermann-von-Helmholtz Platz 1, 76344 Eggenstein-Leopoldshafen, Germany*

**See the author list of J. Mailloux et al. `Overview of JET results for optimising ITER operation' to be published in Nuclear Fusion Special issue: Overview and Summary Papers from the 28th IAEA Fusion Energy Conference.*

Presenting author email: lee.packer@ukaea.uk

The planned high-profile experiments during 2021 at the Joint European Torus (JET), notably including a deuterium-tritium (DT) experimental phase, are expected to produce large neutron yields, in the region of 10^{21} neutrons. The scientific objectives have been linked with a technology programme, WPJET3, to deliver the maximum scientific and technological return from those operations. The data expected to be retrieved under this program will support, develop and improve the radiation transport and activation simulation capabilities via benchmarking and validation in relevant operational conditions. Such capabilities are important and are applied extensively to predict a wide range of nuclear phenomena and impacts associated with components and materials that will be used in ITER operations and more generally in fusion power plant design.

This presentation will discuss progress in collaborative experimental activities conducted at JET within the ACT subproject under WPJET3. The overall aim is to take advantage of the significant 14 MeV neutron fluence expected during JET DT operations to irradiate samples of materials that will be used in the manufacturing of main ITER tokamak components, such as SS316L steels from a range of manufacturers, SS304B, Alloy 660, W, CuCrZr, XM-19, Al bronze, NbTi, Nb_3Sn, and EUROFER. High purity dosimetry foils and a resilient neutron spectrometer activation system developed at NCSRD have been used as supporting diagnostics. Experimental results obtained to date include gamma spectrometry analyses of irradiated samples following the DD JET campaigns in 2015-16 and more recently in 2019. Further ITER material samples have been loaded into the JET environment for the current DT phase, and are expected to be retrieved in 2022, these details will also be discussed. Experimental results are compared to the latest computational simulations using MCNP6 with FISPACT-II performed with fusion-relevant nuclear data libraries.

* This work has been carried out within the framework of the EUROfusion Consortium and has received funding from the Euratom research and training programme 2014-2018 and 2019-2020 under grant agreement No 633053 and from the RCUK Energy Programme [grant number EP/T012250/1]. The views and opinions expressed herein do not necessarily reflect those of the European Commission.

Continuum excitations of weakly bound nuclei at low energies

Athena Pakou[1]

[1] *Department of Physics and HINP, The University of Ioannina*
Presenting author email: apakou@uoi.gr

An overview of our global studies on proton induced reactions at low energies [1-13] with the weakly bound nuclei ^{6}Li,, ^{7}Li and ^{9}Be will be presented. The emphasis will be on continuum excitations via exclusive breakup measurements and their interpretation in a Continuum Discretized Coupled Channel framework. The consequences of this fundamental research to applications will be also given.

References

[1] V. Soukeras et al; Phys. Rev. C **91**, 057601(2015)
[2] V. Soukeras et al; Phys. Rev. C **95**, 054614(2017)
[3] A. Pakou et al; Phys. Rev. C **94**, 014604(2016)
[4] A. Pakou et al; Phys. Rev. C **95**, 044615(2017)
[5] A. Pakou et al; Phys. Rev. C **96**, 034615(2017)
[6] O. Sgouros et al.; Eur. Phys. J A **53**, 165(2017)
[7] N. Keeley et al.; Phys. Rev. C **99**, 014615(2019)
[8] A. Pakou et al; Phys. Rev. C **101**, 024602(2020)
[9] A. Pakou et al.; Acta Physica Polonica B **50**, 1547(2019)
[10] A. Pakou et al.; Nucl. Phys. A **1008**, 122155 (2021)
[11] V. Soukeras et al; Phys. Rev. C **102**, 064622(2020)
[12] A. Pakou et al; Eur. Phys. J A **57**, 25 (2021)
[13] O. Sgouros et al.; Eur.Phys.J. A **57**, 125 (2021)

Microscopic Description of Multinucleon Transfer in ^{40}Ar +^{64}Ni collisions at 15 MeV/nucleon

K. Palli[1], G.A. Souliotis[1], I. Dimitropoulos[1], T. Depastas[1], O. Fasoula[1], S. Koulouris[1], M. Veselsky[2] and A. Bonasera[3]

[1] *Laboratory of Physical Chemistry, Department of Chemistry, University of Athens, Greece,*
[2] *Institute of Experimental and Applied Physics, Czech Technical University, Prague, Czech Republic,*
[3]*Cyclotron Institute, Texas A&M University, College Station, Texas, USA*
Presenting author email: konnapalli@chem.uoa.gr

The production of neutron rich isotopes towards the neutron drip line is a quite fascinating topic in the nuclear physics community nowadays. The study of neutron rich isotopes can give valuable insight in the nuclear structure and additionally can shed light in the astrophysical rapid neutron capture process (r-process), responsible for half of the abundance of heavier than iron nuclei. The main paths to produce neutron-rich isotopes are fission, spallation and high-energy projectile fragmentation, as well as multinucleon transfer reactions at energies from the Coulomb barrier to the Fermi energy (~30 MeV/nucleon).

In this work, we study the reaction of an ^{40}Ar beam with a ^{64}Ni target at 15 MeV/nucleon [1]. The experimental data presented here were obtained with the MARS spectrometer at the Cyclotron Institute of Texas A&M University. Moreover, we present our calculations performed with the phenomenological Deep Inelastic Transfer model (DIT) [3] and with the microscopic Constrained Molecular Dynamics model (CoMD) [4], which is our main focus. The de-excitation of the hot primary fragments is performed with the code GEMINI [5].

This work focuses on the description of the experimental mass and momentum distributions with the CoMD model. We systematically examined the effect of various parameters of the model, such as nuclear compressibility and the effect of the differential nucleon-nucleon scattering cross sections on the calculations for both the fragment production cross sections and the angular distributions of the elastic channel. In the future, we plan to study other multinucleon transfer reactions with the CoMD model, varying projectile, target and energy, that lead to the production of neutron-rich nuclei toward the r-process path and the neutron drip line in hopes to gain valuable information on the reaction mechanisms at Fermi energies.

References

[1] A. Papageorgiou, G.A. Souliotis *et al.*, Journal of Physics G **45**, 095105 (2018).
[2] G. A. Souliotis *et al.,* Phys. Rev. C **84**, 064607 (2011).
[3] L. Tassan-Got and C. Stephan, Nucl. Phys. A 524, 121 (1991).
[4] M. Papa *et al.,* Phys. Rev. C **64**, 024612 (2001).
[4] R. Charity *et al.*, Nucl. Phys. A **483**, 371 (1988).
[6] P.N. Fountas, G.A. Souliotis *et al.*, Phys. Rev. C 90, 064613 (2014).

Effects of Fe+ ion irradiation at 300 °C on Fe-Cr films

S. Pantousa[1,2], E. Manios[1], K. Mergia[1], S. Dellis[1], A. Ionescu[3], C. Kinane[4], S. Langridge[4], A. Caruana[4], U. Kentsch[5], P. Tsavalas[1], A. Lagoyannis[1] and S. Messoloras[1]

[1] *National Centre of Scientific Research "Demokritos", Athens, 15341, Greece*
[2] *Department of Physics, School of Sciences, University of Athens, Athens, 15772, Greece*
[3] *Cavendish Laboratory, University of Cambridge, J J Thomson Avenue 19, Cambridge CB3 0HE, United Kingdom*
[4] *ISIS neutron and muon source, Rutherford Appleton Laboratory, United Kingdom*
[5] *Ion Beam Center, Helmholtz-Zentrum Dresden-Rossendorf, Germany*
Presenting author email: sofia.pantousa@ipta.demokritos.gr

Ferritic – martensitic steels based on Fe-Cr model alloys are candidate structural materials for fusion power plants. These materials will be exposed to extremely high fluxes of energetic neutrons and temperatures of the order of 300 °C. Therefore, the understanding of radiation induced effects on Fe-Cr binary alloys is of major technological importance for the development of radiation resistant materials. The neutron induced radiation damage in the alloys can be imitated by self-ion irradiations, because the dominant lattice damage arises from Fe or Cr knock-on atoms in which the neutron energy is transferred.

Fe-10at%Cr alloy films of thickness 70 nm were fabricated on Si/SiO_2(300nm) substrates employing DC magnetron sputtering and their Cr concentration was verified using X-Ray fluorescence (XRF) and Rutherford Backscattering Spectrometry (RBS) techniques. The films were irradiated at 300 °C and at doses ranging from 0.5 up to 20 displacements per atom (dpa) employing 490 keV Fe+ ions. Dose dependent magnetic effects on the magnetic state of the irradiated samples were found employing Polarised Neutron Reflectivity (PNR) measurements. The magnetization increases with irradiation dose up to about 4 dpa and remains almost constant for higher irradiation doses. This effect is attributed to Cr depletion from the FeCr matrix, caused by radiation induced diffusion enhancement of Cr atoms, which either form Cr-rich bcc precipitates or segregate in the grain boundaries. Cr depletion from the matrix is found to be about 2 at% after the irradiation dose of 20 dpa. Similar effects have been observed in a previous study with Fe+ ion irradiations performed at ambient temperature [1], but at 300 °C the resulting Cr depletion is reduced compared with that after irradiation at ambient temperature.

Acknowledgements: This work has been carried out within the framework of the EUROfusion Consortium and has received funding from the Euratom research and training programme 2014-2018 and 2019-2020 under Grant Agreements No. 633053. The views and opinions expressed herein do not necessarily reflect those of the European Commission. Experiments at the ISIS Neutron and Muon Source were supported by a beamtime allocation from the Science and Technology Facilities Council. The use of the Ion Beam Center facilities at Helmholtz-Zentrum Dresden-Rossendorf is acknowledged.

References

[1] K. Mergia *et al*. (2020). Phase stability of Fe-5at%Cr and Fe-10at%Cr films under Fe+ ion irradiation. *J. Phys.: Condens. Matter*, vol. 32, 185702, doi: 10.1088/1361-648X/ab69a1

Microdosimetric investigation of proton quality factor

A.Papadopoulos[1], I. Kyriakou[1], D. Emfietzoglou[1]

[1] *Medical Physics Laboratory, University of Ioannina Medical School, Ioannina, 45110, Greece.*
Presenting author email: al.papadopoulos@uoi.gr

The health risks from an ionizing radiation exposure depend not only on dose (and dose rate) but also on radiation quality. Microdosimetry offers the physical basis for understanding radiation quality issues in relation to both medical and space radiation exposures. In this work, the variation of the quality factor (Q) of protons (1-100 MeV) is examined using several microdosimetry-based methodologies, namely, the ICRU Report 40 recommendations, the Kellerer-Hahn approximation [1], and the theory of dual radiation action (TDRA) [2]. The stochastic energy deposition spectra and track-related quantities [3] needed as input have been determined for nano- to micro-meter spherical volumes using analytic models [4] which are compared against Monte Carlo simulations [5, 6]. The sensitivity of the results to the different methodologies and target sizes is examined. It is shown that in the energy range 1-100 MeV, the Q values calculated by different Monte Carlo codes, for a fixed proton energy, differ by up to a factor of 1.4 (the difference diminishes with increasing sphere size). Interestingly, for all methodologies and most of the sensitive volumes examined, the analytic- and Monte Carlo-based Q values compare fairly well. The difference between ICRU40 and TDRA methodologies is 50% on average, whereas the difference between ICRU40 and Kellerer-Hahn is less than 10%. Importantly, the widely used LET-based Q values according to the ICRP Report 60 recommendations, differ significantly from the microdosimetry-based predictions.

References

[1] Kellerer and Hahn, Radiat. Res. **114**, 3 (1988)
[2] Kellerer and Rossi, Radiat. Res. **75**, 3 (1972)
[3] ICRU Report 36, J. ICRU. **19**, 1 (1983)
[4] Xapsos et al., Radiat. Meas. **26,** 1 (1996)
[5] Vassiliev et al., Phys. Med. Biol. **64**, 21 (2019)
[6] Liamsuwan et al., Med. Phys. **41**, 8 (2014)

PM2.5 chemical speciation and source apportionment by PMF, in the capital on Tajikistan, Dushanbe

S. Papagiannis[1,2,3], V. Vasilatou[1], K. Eleftheriadis[1], E. Diapouli[1]

[1] *Institute of Nuclear & Radiological Sciences & Technology, Energy & Safety, 15310, Athens, Greece*
[2] *Institute of Nuclear Physics, NCSR Demokritos, 15310, Athens, Greece*
[3] *Department of Materials Science & Engineering, University of Ioannina, 45110, Ioannina*
Presenting author email: s.papagiannis@ipta.demokritos.gr

The aim of the present study is the chemical speciation and source apportionment of atmospheric suspended particulate matter (PM) in the capital of Tajikistan, Dushanbe. Measurements were conducted during the years 2015-16 and 2018-19 at an urban background site, in Dushanbe. $PM_{2.5}$ (particles with diameters up to 2.5 μm) samples were collected daily for an 8-month and a 4-month period respectively. Because of its location and being the capital city where a lot of economic activities are concentrated it suffers from poor air quality, due to variety of emission sources, topography and climatic conditions favoring the accumulation of pollution [1]. A commercial X-Ray fluorescence 3-D optics spectrometer with secondary targets, Epsilon 5, was employed for the elemental analysis of the samples. A multi-wavelength absorption black carbon instrument (MABI) was also used for the determination of the concentration of black carbon (BC) [2]. The Positive Matrix Factorization (PMF) model EPA-PMF 5.0 was applied for source identification and apportionment [3]. The best solution of the PMF model corresponded to eight $PM_{2.5}$ emission sources, namely coal burning (16.9%), secondary sulphates (15.8%), biomass burning (14.3%), aluminum smelter emissions (from the nearby city of Tursunzade) (13.2%), treated wood burning (12.7%), cement plant emissions (10.0%), vehicular traffic (11.6%), and metallurgy plant emissions (from the city of Isfara) (5.5%).

Acknowledgments

We acknowledge support of this work by the project CALIBRA/EYIE (MIS 5002799), which is implemented under Action "Reinforcement of the Research and Innovation Infrastructures," funded by the Operational Programme "Comparativeness, Entrepreneurship and Innovation" (NSRF 2014-2020) and co-financed by Greece and the European Union (European Regional Development Fund).

References

[1] Review, S. (2004). *The Environmental Performance Review of Tajikistan*. (U. N. E. C. for E. (UNECE), Ed.). United Nations Publication.

[2] Kebe, M. *et al.* Source apportionment and assessment of air quality index of pm2.5–10 and pm2.5 in at two different sites in urban background area in senegal. *Atmosphere (Basel).* **12**, 1–16 (2021).

[3] Reff, A., Eberly, S. I. & Bhave, P. V. Receptor Modeling of Ambient Particulate Matter Data Using Positive Matrix Factorization: Review of Existing Methods. *J. Air Waste Manage. Assoc.* **57**, 146–154 (2007).

Constraining the density dependence of the nuclear symmetry energy in the KIDS framework *

Panagiota Papakonstantinou[1]

[1] *Institute for Basic Science, Rare Isotope Science Project, Daejeon 34000, Republic of Korea*
Presenting author email: ppapakon@ibs.re.kr

The properties of very neutron rich nuclear systems are largely determined by the density dependence of the nuclear symmetry energy. Recent and ongoing experiments aiming to measure the neutron skin thickness [1,2] and astronomical observations of neutron stars and gravitational waves [3,4] offer valuable information on the symmetry energy at sub-saturation and supra-saturation densities, respectively.

The Korea-IBS-Daegu-SKKU (KIDS) theoretical framework for the nuclear equation of state (EoS) and energy density functional (EDF) [5,6] offers the possibility to explore the symmetry-energy parameters such as J (value at saturation density), L (slope at saturation), K_{sym} (curvature at saturation), and higher-order ones independently of each other and independently of assumptions about the in-medium effective mass. Within KIDS, any set of EoS parameters can be transposed into a corresponding EDF and get tested in microscopic calculations of nuclear properties [6]. A related study of symmetry-energy parameters based on astronomical observations and bulk nuclear properties was published recently [7] and further work is in progress taking advantage of recent experimental results.

In the proposed talk, I plan to summarize the above activity with emphasis on the emerging important role of the curvature parameter K_{sym} or its droplet-model counterpart K_{τ}, which for the first time are being investigated independently of the other parameters, that is, free of non-physical correlations with them.

* This work is supported by the Rare Isotope Science Project of the Institute for Basic Science funded by the Ministry of Science, ICT and Future Planning and the National Research Foundation (NRF) of Korea (2013M7A1A1075764).

References

[1] T.Aumann *et al*., Phys. Rev. Lett. **119**, 262501 (2017)
[2] D.Adhikari et al., Phys. Rev. Lett. **126**, 172502 (2021)
[3] B.P.Abbott *et al*., Phys. Rev. **X9**, 011001 (2019)
[4] M.C.Miller *et al*., arXiv: 2105.06979
[5] P.Papakonstantinou *et al*., Phys. Rev. **C97**, 014312 (2018); HNPS Adv. Nucl. Phys. **26**, 104 (2019); G.Ahn *et al*., *ibid*., 119
[6] H.Gil et al., Phys. Rev. **C99**, 064319 (2019); Phys. Rev. **C100**, 014312 (2019)
[7] H.Gil et al., Phys. Rev. **C103**, 034330 (2021)

Coherent and Incoherent neutrino-nucleus and WIMP-nucleus scattering*

D.K. Papoulias[1], T.S. Kosmas[1], V.K.B Kota[2], and R. Sahu[3]

[1] *Division of Theoretical Physics, University of Ioannina, GR 45110 Ioannina, Greece*
[2] *Physical Research Laboratory, Ahmedabad 380 009, India*
[3] *National Institute of Science and Technology, Palur Hills, Berhampur 761 008, Odisha, India*
Presenting author email: d.papoulias@uoi.gr

We investigate event rates for neutrino-nucleus scattering and scattering of weakly interacting particles (WIMPs) dark matter candidates with nuclei [1]. They are expected to be measured in appreciably sensitive ton-scale rare-event detectors [2]. The chosen in this study nuclear isotopes constitute detector materials of such experiments, ongoing and/or designed ones, looking for WIMP- and neutrino-nucleus events [2]. Beyond astrophysical neutrinos, such as solar, atmospheric and diffuse supernova neutrinos, we also consider neutrinos emerging from pion-decay at-rest and nuclear reactors as well as Geoneutrinos [3].

The nuclear structure calculations, have been performed within the context of the deformed shell model [4], based on Hartree-Fock intrinsic states with angular momentum projection and band mixing for both the elastic and the inelastic channels [5].

* The research of DKP is co-financed by Greece and the European Union (European Social Fund- ESF) through the Operational Programme «Human Resources Development, Education and Lifelong Learning» in the context of the project “Reinforcement of Postdoctoral Researchers - 2nd Cycle" (MIS-5033021), implemented by the State Scholarships Foundation (IKY).

References

[1] R. Sahu, D. K. Papoulias, V. K. B. Kota and T. S. Kosmas, Phys.Rev.C **102**, 035501 (2020); D. K. Papoulias, T. S. Kosmas, R. Sahu and V. K. B. Kota, Phys.Lett. **B 800**, 135133 (2020).
[2] Marc Schumann, J. Phys. G **46**, 103003 (2019).
[3] T. S. Kosmas, V. K. B. Kota, D. K. Papoulias and R. Sahu, PRC *submitted*
[4] V.K.B. Kota and R. Sahu, “*Structure of Medium Mass Nuclei: Deformed Shell Model and Spin-Isospin Interacting Boson Model*”, CRC Press; 1st edition
[5] T. S. Kosmas, Amand Faessler, R. Sahu and Phys.Rev.C **68**, 054315 (2003)

Activation Cross Section Measurement of the (n,2n) Reaction on ^{203}Tl

S. Patas[1], S. Chasapoglou[1], M.Axiotis[2], G.Gkatis[1], S.Harissopulos[2], M.Kokkoris[1], A.Lagoyannis[2], E. Tsivouraki[1], R.Vlastou[1]

[1]Department of Physics, National Technical University of Athens, Zografou campus, 15780 Athens, Greece
[2]Tandem Accelerator Laboratory, Institute of Nuclear Physics, N.C.S.R. "Demokritos", Aghia Paraskevi, 15310 Athens Greece
Presenting author's email: spatas@physics.auth.gr

Studies of neutron-induced reactions are of considerable significance, both for their importance to basic research in nuclear physics and for practical applications in nuclear technology, medicine and industry. Thallium is widely used in electronics, pharmaceuticals, fiber optics, infrared detectors and nuclear medicine. However, little information is available in literature for neutron induced reactions on Tl isotopes, with many discrepancies among the existing experimental data, especially in the energy region above ~14 MeV.

The aim of the present work was to study the cross-section of the (n,2n) reaction on ^{203}Tl, by irradiating a natural TlCl pellet target with monoenergetic neutron beam at 18.9 MeV. The cross section of the ^{203}Tl(n,2n)^{202}Tl reaction, was measured implementing the activation method, with respect to the ^{197}Au(n,2n)^{196}Au and ^{27}Al(n,α)^{24}Na reference reactions. The monoenergetic neutron beam was generated in the 5.5 MV Tandem accelerator of NCSR Demokritos, using the ^{3}H(d, n)^{4}He reaction. The target and reference foil assembly was placed at approximately 1.5 cm from the tritium target, thus limiting the angular acceptance to ± 23.5°, where the produced neutrons are practically isotropic and monoenergetic. The fluctuation of the neutron beam flux was monitored with a BF3 detector located 3 m from the neutron source. After the irradiation, the induced activity of the samples was measured with a HPGe detector, which was properly shielded with a lead block to reduce the contribution of natural radioactivity. Monte Carlo simulations applying the MCNP code have been performed to take into account the gamma-ray self-absorption results as well as the estimation of the neutron flux through the reference foils. Finally, a comparison of theoretical calculations with the code EMPIRE and experimental data was carried out, with the aim of finding a suitable model for the description of the reaction cross section under study.

Abstract submitted to HNPS2021

NEAR at n_TOF/CERN: Preparing the first multi-foil activation measurement

S. Goula[1], N. Patronis[1], S. Chasapoglou[2], M. Diakaki[2], N. Colonna[3], Z. Eleme[1], E. Georgali[1], M. Kokkoris[2], A. Mengoni[4], V. Michalopoulou[2], M. Peoviti[1], M. E. Stamati[1,5], R. Vlastou[2]

[1] *Department of Physics, University of Ioannina, 45110 Ioannina, Greece*

[2] *Department of Physics, National Technical University of Athens, Zografou Campus, 15780 Athens,Greece*

[3] *Istituto Nazionale di Fisica Nucleare, Sezione di Bari, 70126 Bari, Italy*

[4] *Agenzia Nazionale per le Nuove Tecnologie (ENEA), 40129 Bologna, Italy*

[5] *European Organization for Nuclear Research (CERN), 1211 Geneva, Switzerland*

The n_TOF NEAR Station is a new experimental zone which is located at a distance of only ~3m from the new n_TOF spallation target and just outside the target-moderator assembly's shielding wall [1]. The aim of the n_TOF NEAR Station is to take advantage of the extremely high neutron flux to perform measurements of MACS (Maxwellian Averaged Cross Section) for nuclear astrophysics purposes, as well as for other reaction cross sections (e.g. fusion technology related measurements [2]). In all these cases, the neutron activation technique is going to be used.

Although extensive simulations have been performed to obtain the characteristics of the neutron beam at NEAR, experimentally the newly built experimental area remains unexplored. Therefore, it is of utmost importance to identify the neutron beam flux and energy distribution prior launching the actual research activities. For this reason, a multi-foil activation project has been planned.

In the present work, the preparation of the first multi-foil activation measurements will be presented. The reactions under study were selected according to the cross-section's dependency on neutron energy as well as the product nucleus half-lives. In general various reactions with different resonances have been considered for the characterization of thermal and epithermal energy region while the threshold reactions will be utilized for the characterization of the fast neutron energy range. A tentative plan has been made to measure the induced activities of the samples using a 27% relative efficiency HPGe detector [3].

In this presentation, the newly built experimental area will be presented along with the expected reaction rate calculations and the measurement protocol for a set of the chosen reactions.

References

[1] The new n_TOF NEAR Station, The n_TOF Collaboration (September 2020).
(https://cds.cern.ch/record/2737308?ln=el)

[2] n_TOF: The neutrons time-of-light facility (n_TOF) studies neutron-nucleus interactions for neutron energies ranging from a few meV to several GeV, Alberto Mengoni, The n_TOF Collaboration (July 2021).

[3] Feasibility study for neutron inelastic cross section measurements at n_TOF/CERN using HPGe detectors, M.E. Stamati (2020).

Spectroscopic studies in $^{152\text{-}154}$Gd *

S. Pelonis[1], T. J. Mertzimekis[1], A. Chalil[1,4], F. C. L. Crespi[2], A. Bracco[2], G. Zagoraios[1,5], D. Papaioannou[1,6], N. Florea[3], N. Marginean[3], L. Stan[3], A. Turturica[3]

[1] *Department of Physics, National and Kapodistrian University of Athens, Zografou Campus, Athens, GR-15784, Greece*
[2] *Universita degli Studi di Milano and INFN sez. Milano, I-20122, Italy*
[3] *National Institute for Physics and Nuclear Engineering, Magurele, R-77125, Romania*
[4] *IRFU, CEA, Université Paris-Saclay, Gif-sur-Yvette, FR-91191, France*
[5] *Division of Nuclear Engineering, KTH Royal Institute of Technology, Stockholm, S-11428, Sweden*
[6] *Department of Physics, Uppsala University, S-75237, Sweden*

Presenting author email: pelonisstefanos@outlook.com

The rare-earth mass region has been the focus of various studies because of the strong degrees of collectivity and deformation that are widely present in this part of the nuclear chart. The Gd isotopes belong to this group of nuclei and despite the available spectroscopic information, several open questions about their structure still exist, such as the interband transitions related to shape evolution or the branching ratios in deformed states. Due to strong spin-parity mixing and the presence of high-energy states, studying these nuclei with fusion-evaporation reactions has been proven successful, since they enable the population of high-spin excited states of deformed isotopes. However, production cross-sections of Gd isotopes via other mechanisms, such as 2n-transfer reactions, are largely unknown.

In this work, we report on an experimental attempt to populate the excited states in the isotopes $^{152\text{-}154}$Gd, by employing the fusion-evaporation reaction ^{18}O + ^{138}Ba in the energy range of 61-67 MeV. The experiment was conducted at the 9 MV FV Pelletron Tandem at the Horia Hulubei National Institute for Physics and Nuclear Engineering (IFIN–HH), employing the ROSPHERE array. Several branching ratios for energy levels in ^{152,153}Gd have been measured, resulting in new or updated experimental values. Furthermore, relative fusion cross-sections to the three Gd isotopes have been measured at different energies and compared with theoretical calculations from the PACE4 algorithm.

* We acknowledge travel support by ENSAR2.

Abstract submitted to HNPS2021

Characterisation of the new HPGe detectors at INPP/NCSR "Demokritos" ...and future (n,2n) reactions to be studied

M. Peoviti[1], M. Axiotis[2], E. Georgali[1], S. Harissopulos[2], A. Lagoyannis[2], N. Patronis[1]

[1] *Department of Physics, University of Ioannina, 45110 Ioannina, Greece*
[2] *Tandem Accelerator Laboratory, Institute of Nuclear and Particle Physics, N.C.S.R. "Demokritos", Aghia Paraskevi, 15310 Athens, Greece*
Presenting author email: marpeoviti@gmail.com

Within the present work, the HPGe detectors of the Institute of Nuclear and Particle Physics at NCSR "Demokritos" were fully characterized in terms of efficiency and resolution. The three n-type 80% relative efficiency HPGe were recently acquired in the framework of the CALIBRA project. All detectors are equipped with carbon fiber windows that allow detection of low energy γ-rays. Besides the efficiency and energy resolution characterization, the three detectors were fully modeled by means of the GEANT4 simulation toolkit. In all cases, the simulated detector geometries were fine-tuned so as to fully reproduce the experimental efficiency data at different source-to-detector distances. Finally, as a demonstration of the new offered abilities, the efficiency characterization and the GEANT4 modeling of the three HPGe detectors were used for a feasibility study of possible/future (n,2n) activation measurements on medium-weight nuclei.

Experimental constraints on reaction rates relevant to the radiogenic heating of planets. *

G. Perdikakis[1], N. Dimitrakopoulos[1], P. Gastis[1], P. Tsintari[1], J. Dissanayake[1], I. Sultana[1], L. Ulbrich[1], T. N. Massey[2], Z. Meisel[2], C.R. Brune[2], A. Voinov[2], Y. Jones-Alberty[2], K. Brandenburg[2], T. Danley[2], R. Giri[2], S. Paneru[2], S. Soltesz[2] and S. Subedi[2].

[1] *Department of Physics, Central Michigan University, Mount Pleasant, MI 48823*

[2] *Edwards Accelerator Laboratory, Ohio University, OH*

Presenting author email: perdi1g@cmich.edu

The quantity of radioactive isotopes in a planet's mantle and the evolution of its heating due to the isotopes' radioactive decay determines the capability of that planet to develop geological features associated with a habitable environment such as surface crust and plate tectonics. One of the major isotopes responsible for the radiogenic heating of our planet and Earth-like exoplanets is 40K. Predicting the amount of 40K enrichment in the solar system of a given exoplanet is key for a reliable calculation of the planet's heating evolution. From a nucleosynthesis point of view, the uncertainty in the abundance of 40K is associated with the reactions that create and destroy 40K in stellar nucleosynthesis processes and the corresponding reaction rates. Our research aims to experimentally constrain the two reaction rates responsible for the destruction of ^{40}K in stars, namely the ^{40}K(n,p) and ^{40}K(n,a). The objective of the research was to deduce both reaction rates through the ^{40}Ar(p,n)^{40}K and ^{37}Cl(a,n)^{40}K reaction cross-section measurements at the Edwards accelerator of Ohio university. The measurements were performed using the swinger facility of Ohio University, the LENDA neutron detector and a setup of two $LaBr_3$ detectors to obtain angular distributions of neutrons and gamma rays. In my talk, I will present details of the measurements so far and will discuss published and preliminary results from our experimental campaign.

* This work is supported by the US Department of Energy under grant no DE-SC 0014285 and by the Office of Research and Graduate studies of Central Michigan University under a Faculty Research and Creative Endeavors grant.

Abstract submitted to HNPS2021

Technical-Economic Trends Review for Currently Operating Nuclear Power Reactors

Poulopoulou E.D., Mitrakos D., Petropoulos N.P.

Nuclear Engineering Laboratory, School of Mechanical Engineering, National Technical University of Athens, 15780 Athens, GREECE

Presenting author email: eleprc@mail.ntua.gr

This work attempts a comprehensive compilation of data regarding the performance and evolution indicators for today's (2021) operating nuclear power reactors. All data were on-line obtained from IAEA's Power Reactor Information System (PRIS) Database, transferred to spreadsheet software, post-processed if necessary, plotted in cognitive graphs and interpreted appropriately in-brief. The aim was to identify past, present and future trends related to the usage of nuclear power for electric energy production. The examined time span covers mainly all currently operating power reactors, the oldest of which have been grid connected in the '70s. Several operational periods could be clearly identified, each one of them with its own properties and characteristics: a) pre Three-Mile-Island, b) post Three-Mile-Island (or pre Chernobyl), c) post Chernobyl (or pre Fukushima), d) post Fukushima and, finally, e) New Build. The mentioned periods are loosely connected to the reactor generations as released and installed, i.e. Gen-II, Gen-III, Gen-III+. Although discussed as early as in the late '90s, Gen-IV reactors have not yet been developed not even on a demonstration basis. Instead, the New Build period involves mainly Gen-III+ types and a controversial long and heavy discussion on the market possibilities of proposed Small Modular Reactors (SMR) and recently of Mini Modular Reactors (MMR). Overall, there are clear indicators that (i) there is no negative trend on the number of active power reactors, (ii) the yearly electrical power produced by nuclear sources is slowly but steadily increasing, (iii) the reactor performance indicators are steadily getting better, (iv) despite their negligible number, the reactor accidents have been the main factors, which prohibited the expansion of nuclear reactors for electricity production, (v) all such accidents were followed by a period of conservative usage of most operating reactors, and, (vi) all such accidents have led to the long-term improvement of the average reactor operational characteristics. Further, it could be supported that renewables have not clearly affected the nuclear reactors operational characteristics, since their role as base power units is further supported by the extensive retirement of fossil fuel - fired conventional power plants.

References

[1] IAEA, International Atomic Energy Agency, Computer Manual Series, Power Reactor Information System (PRIS) Statistics Users Manual, Vienna 2012

[2] IAEA, International Atomic Energy Agency, Operating Experience with Nuclear Power Stations in Member States, 2020 Edition

[3] IAEA, International Atomic Energy Agency, Reference Data Series No. 2, Nuclear Power Reactors in the World, 2021 Edition

Microscopic analysis of structural evolution in the Pt-Hg region

Vaia Prassa[1], and K. E. Karakatsanis[2,3]

[1]*Physics Department, Faculty of Science, University of Thessaly, GR-35100 Lamia, Greece,*
[2]*Department of Physics, Aristotle University of Thessaloniki, GR-54124 Thessaloniki, Greece,*
[3]*Physics Department, Faculty of Science, University of Zagreb, 10000 Zagreb, Croatia*
Presenting author email: vprassa@uth.gr

The phenomena of shape-phase transitions and shape coexistence in neutron deficient even-even Pt and Hg isotopes are investigated, using a five-dimensional collective Hamiltonian (5DCH) based on covariant density-functional theory. The triaxial deformation energy surfaces in Pt isotopes display a transition from prolate (^{188}Pt) to triaxial or oblate ($^{190\text{-}198}$Pt), and to near spherical (^{198}Pt) shapes. The calculations suggest coexisting configurations in ^{190}Hg, γ-soft potential energy surfaces in $^{192\text{-}198}$Hg and a more spherical structure in ^{200}Hg. The corresponding 5DCH model calculations confirm the structural evolution in this region and suggest more increased collectivity than what can be deduced from the data.

*This research was conducted within the Call "Fellowship for Postdoctoral research" implemented by the University of Thessaly and funded by the Stavros Niarchos Foundation

References

[1] V. Prassa and K.E. Karakatsanis, International Journal of Modern Physics E (2021)
[2] X. Q. Yang, L. J. Wang, J. Xiang, X. Y. Wu, and Z. P. Li, Phys. Rev. C 103, 054321 (2021).

Examining neutrino-driven wind nucleosynthesis in core-collapse supernovae with α-induced reactions*

A. Psaltis[1,2], A.A. Chen[2,3], A. Arcones[1,4] and C. Ruiz[5]

[1] *Institut für Kernphysik, Technische Universität Darmstadt, D-64289 Darmstadt, Germany*
[2] *The NuGrid Collaboration, https://nugrid.github.io*
[3] *Department of Physics and Astronomy, McMaster University, Hamilton, Ontario L8S 4M1, Canada*
[4] *GSI Helmholtzzentrum für Schwerionenforschung GmbH, D-64291 Darmstadt, Germany*
[5] *TRIUMF, Vancouver, British Columbia V6T 2A3, Canada*
Presenting author email: psaltis@theorie.ikp.physik.tu-darmstadt.de

Nucleosynthesis in the neutrino-driven wind ejecta of core–collapse supernovae has gained in popularity in recent years. According to the initial composition, two distinct nucleosynthesis processes can operate, namely the νp–process [1] (neutron–deficient ejecta) and the weak r–process (slightly neutron–rich ejecta) [2]. Both scenarios exhibit uncertainties related to the explosion dynamics and the underlying nuclear physics input. For the νp–process, the $^{7}Be(\alpha, \gamma)^{11}C$ reaction has been shown that can affect the production of 90<A<100 neutron-deficient nuclei [3], nevertheless, there is a lack of experimental information about its rate in the relevant temperature range (T= 1.5-3 GK). To constrain this reaction rate, the first direct measurement of resonances with unknown strengths was recently performed at TRIUMF using an intense radioactive ^{7}Be ($t_{1/2}$= 53.24 d) beam and the DRAGON recoil separator [4]. The experimental challenges, preliminary results, and nucleosynthesis calculations to study the effect of the new reaction rate will be discussed. For the weak r–process, the main nuclear physics uncertainty arises from the absence of experimental data from (α,xn) reactions on neutron–rich nuclei, which are currently based on statistical model calculations. A recent sensitivity study identified the most important (α,xn) reactions that can affect the production of "light" heavy elements between strontium and silver under different astrophysical conditions [5]. The current status of weak r-process nucleosynthesis calculations and the planning of studies to experimentally determine (α,xn) reaction rates using the MUSIC detector at Argonne National Laboratory [6] and the SECAR recoil separator at FRIB [7] will be discussed.

* This work is supported by the Natural Sciences and Engineering Research Council of Canada (NSERC), and the ERC Starting Grant EUROPIUM-677912, Deutsche Forschungsgemeinschaft through SFB 1245.

References

[1] C. Frohlich *et al.*, Phys. Rev. Lett **96**, 142502 (2006).
[2] A. Arcones and F. Montes, Astrophys. J. **731**, 5 (2011).
[3] S. Wanajo, H.-T. Janka and S. Kubono, Astrophys. J **729**, 46 (2011).
[4] D. Hutcheon *et al.*, Nucl. Instrum. Methods Phys. Res A **498**, 190 (2003).
[5] J. Bliss *et al.*, Phys. Rev. C **101**, 055807 (2020).
[6] M. L. Avila *et al.*, Nucl. Instrum. Methods Phys. Res A **859**, 63 (2017).
[7] G. Berg *et al.*, Nucl. Instrum. Methods A **877**, 87 (2018).

Compton Suppressed Gamma Spectrometry for activation analysis of materials irradiated at JET

M.I. Savva[1], T. Vasilopoulou[1], C.R. Nobs[2], L.W. Packer[2], I.E. Stamatelatos[1]

[1] *INRASTES, National Centre for Scientific Research Demokritos, Greece*
[2] *Culham Centre for Fusion Energy, Culham Science Centre, Abingdon, Oxon, OX14 3DB, UK*
Presenting author email: m.savva@ipta.demokritos.gr

Compton Suppressed Spectrometry (CSS) provides a method to improve the peak-to-background ratio, and consequently counting statistics and the limit of detection, of a gamma spectrometer. The NCSRD Fusion Technology Group CSS system consists of a NaI detector coupled to a 40% HPGe with Al endcap. The NaI detector consists of two parts: an annulus, surrounding the HPGe, and a plug, which can be removed to allow the positioning of the sample, thus offering the possibility of detection in an almost 4π geometry. The signal processing chain of the configuration allows for the simultaneous collection of both the suppressed and the unsuppressed spectra. During the analysis the Compton continuum of the gamma spectrum is suppressed and in the case of nuclides emitting single gamma photons, the full energy peaks become more prominent. In the case of nuclides that emit gamma rays in cascade, the spectra are affected in a more complex way, since the peak count rate can also be diminished due to the rejection signals produced when a coincident photon interacts with the guard detector [1]. The simultaneous collection of the suppressed and unsuppressed spectra allows the analyst to use the optimum spectrum, depending on the radionuclide to be determined and the emitted photons.

In this work, an assessment of the performance of the NCSRD CSS system for the analysis of different material samples irradiated at the Joint European Torus (JET) Long Term Irradiation Station (LTIS) during the 2019 Deuterium-Deuterium (DD) campaign is presented. Dosimetry foils of different materials as well as VERDI detectors [2] were studied. It was found that the CSS system significantly reduced the Compton continuum and provides better peak identification of weak peaks of nuclides without cascade photon emission that fall into the continuum. In addition, it was shown that the use of the CSS can have a positive or negative effect on the analysis of an isotope, depending on the specific decay scheme. The developed methodology will be applied to study the activation characteristics of materials to be used in the manufacturing of ITER components, after irradiation at the significant 14 MeV neutron yield during the JET DT campaign.

References

[1] O. Sima and I. Osvath, *Appl. Radiat. Isot.*, 81 (2013)
[2] M. I. Savva *et al.*, *Fusion Eng. Des.*, 166 (2021)

Abstract submitted to HNPS2021

A large volume spherical proportional counter for WIMPs dark matter detection. The NEWS-G experiment

Ilias Savvidis

Aristotle University of Thessaloniki (for the NEWS-G collaboration)

A large volume spherical proportional counter developed for low mas WIMPs detection. The detector is made with pure, very low radioactivity materials, to minimize the background and is currently installed at SNO-lab underground laboratory. The WIMPs can be detected via their elastic scattering with the nucleus of the gasses in the detector and the detection of the recoil nucleus. The special advantages of this detector are the following: a) high energy sensitivity to low energy signals down to single electron, b) very low background, c) possibility to use light gasses, which can give detectable signal even for very low mass WIMPs.

The first data of the detector are collected during the first installation at the LSM underground laboratory in Modane (France).

Multi-anode sensor for the Spherical Proportional Counter (SPC) for the detection of WIMPs and other applications

George Savvidis
Aristotle University of Thessaloniki

The NEWS-G experiment employs a very low radio-activity Spherical Proportional Counters (SPC) towards the direct search for light Dark Matter candidates in the 0.1 – 10 GeV mass range. The detector provides high sensitivity to low-energy recoil detection thanks to the choice of various gases and operating pressures. A novel multi-anode sensor, named ACHINOS, at the center of the SPC allows for operation at higher pressures, and higher primary ionization collection efficiency thanks to enhanced electric fields at large radii. The ACHINOS sensor is suitable for detection of sub-keV energies down to single-electrons as well as for the detection of neutrinos, neutrons and alpha particles.

Duffin Kemmer Petiau Oscillator under the effect of an External Magnetic Field in Non-Commutative Space

Lakhdar Sek[1], Mokhtar Falek[1], Mustafa Moumni[1].

[1] *Laboratory of Photonic Physics and Nano-Materials (LPPNNM), Department of Matter Sciences, University of Biskra, 07000 Biskra, Algeria.*

Presenting author email: lakhdar.sek@univ-biskra.dz

In this work**,** we present the study of thermal properties of a relativistic quantum system describing the oscillatory motion of DKP particle (spins 0) under the effect of an external magnetic field in non-commutative space. In this case of spin 0, the motion equation is reduced to the Klein-Gordon problem with the same interaction, where the spectrum energy and wave functions are then deduced. In the end, we analyze the system's thermodynamic properties.

Keywords: DKP Oscillator, Non-Commutative space, Thermodynamic Properties.

References

Y. Nedjadi and R. C. Barrett, The Duffin Kemmer Petiau Oscillator. J.Phys.A:Math.Gen.27, 4301 (1994)

M. Falek and M. Merad, DKP Oscillator in a Non-commutative Space. Commun. Theor. Phys. 50 587 (2008).

Mirza, B., Narimani, R., & Zare, S. Relativistic Oscillators in a Non-commutative Space and in a Magnetic Field. Communications in Theoretical Physics, 55(3), 405–409. (2011)

Recent progress in the study of peripheral heavy-ion collisions below the Fermi energy

G. A. Souliotis[1], T. Depastas[1], O. Fasoula[1], S. Koulouris[1], K. Palli[1], M. Veselsky[2], and A. Bonasera[3]

[1] *Laboratory of Physical Chemistry, Dep. of Chemistry, University of Athens. Greece*
[2] *Institute of Exp. and Applied Physics, Czech Technical University, Prague, Czech Republic*
[3] *Cyclotron Institute, Texas A&M University, College Station, Texas, USA*
Presenting author email: soulioti@chem.uoa.gr

In this talk, we give an overview of our recent experimental and theoretical work on peripheral heavy-ion collisions in the energy range 15-25 MeV/nucleon. The experimental work concerns mass spectrometric measurements of projectile fragments from a) ^{40}Ar and ^{86}Kr projectiles analyzed with the MARS spectrometer at the Cyclotron Institute of Texas A&M University, and b) ^{70}Zn (15 MeV/nucleon) projectile fragments obtained with the MAGNEX spectrometer at INFN-LNS Catania that are currently under analysis. The goal of the work is the production of neutron rich isotopes in multinucleon transfer processes.
Special attention is now been devoted to the study of the momentum distributions. These distributions are characterized by a narrow quasi-elastic peak and a broader deep-inelastic peak. The experimental data are compared with model calculations based on the Deep Inelastic Transfer Model (DIT) [2], and the Constrained Molecular Dynamics model (CoMD) [3]. Presently, we are systematically exploring the capabilities of CoMD in order to obtain a fair description of the channels leading to exotic neutron-rich isotopes [4,5].

The CoMD work on these reactions goes in parallel with studies of the properties of nuclear ground states (binding energies, radii, neutron skins) and the dynamics of GDR and GMR (Giant Dipole and Giant Monopole Resonances) as given by the CoMD. It is our hope that the CoMD will provide a unified description of low energy nuclear dynamics and, furthermore, offer a reliable framework for the production of neutron-rich exotic nuclei.

References

[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).
[4] O. Fasoula, G.A. Souliotis et al., arXiv:2103.10688 (nucl-ex)
[5] S. Koulouris, G.A. Souliotis et al., arXiv:2103.10691 (nucl-ex)

Neutron-capture reactions and the astrophysical i process *

Artemis Spyrou[1,2,3]

[1] *National Superconducting Cyclotron Laboratory, Michigan State University, East Lansing, MI, USA*
[2] *Department of Physics and Astronomy, Michigan State University, East Lansing, MI, USA*
[3] *Joint Institute for Nuclear Astrophysics, Michigan State University, East Lansing, MI, USA*
Presenting author email: spyrou@nscl.msu.edu

If there is one thing we learned about the synthesis of heavy elements in the Universe during the last 10 years, it's that it is complicated business. Three astrophysical processes were proposed initially, since the birth of nuclear astrophysics in the 1950s, to describe the production of all heavy elements. These three processes (p, s, and r) are still strong contributors and still exhibit significant open questions. However, today we understand that other processes may have significant contributions to the production of heavy elements as well.

This talk will present the new complex picture of heavy-element nucleosynthesis, focusing on the astrophysical i-process, which is intermediate between the s- and r-neutron-capture processes. The main focus will be on neutron-capture reactions, the most important nuclear physics input needed to constrain the i process. I will discuss recent experiments performed at the National Superconducting Cyclotron Laboratory at Michigan State University, and at the CARIBU facility at Argonne National Laboratory. Finally, I will present exiting new opportunities that open up at the Facility for Rare Isotope Beams (FRIB) in the near future.

* This work is supported by the National Science Foundation and the Department of Energy, USA

Preparing Phase 4 of the n_TOF/CERN facility

M.E. Stamati[1,2], N. Patronis[2], S. Amaducci[3], M. Bacak[1], A. Casanovas[4], F. Garcia Infantes[1,5], A. Manna[6], A. Mengoni[7], J.A. Pavon Rodriguez[1,8], A.J. Praena Rodriquez[5], M. Spelta[6]

[1] *European Organization for Nuclear Research (CERN), 1211 Geneva, Switzerland*
[2] *Department of Physics, University of Ioannina, 45110 Ioannina, Greece*
[3] *Istituto Nazionale di Fisica Nucleare, Laboratori Nazionali del Sud, Catania, Italy*
[4] *Instituto de Fisica Corpuscular, CSIC-Universidad de Valencia, Spain*
[5] *Universidad de Granada, Spain*
[6] *Dipartimento di Fisica, Universita di Bologna, and Sezione INFN di Bologna, Italy*
[7] *Agenzia nazionale per le nuove tecnologie, l'energia e lo sviluppo economico sostenibile (ENEA), Bologna, Italy*
[8] *Universidad de Sevilla, Spain*
Presenting author email: maria-elisso.stamati@cern.ch

The n_TOF facility at CERN is designed to study neutron induced reactions bearing importance for basic research as well as for nuclear astrophysics and nuclear technology applications (energy, medicine, etc). Besides its excellent time resolution, the n_TOF facility allows for reaction studies in an extended energy range, ranging from the meV up to the GeV energy region.

During CERN's Long Shutdown 2, the n_TOF facility has been largely upgraded. The lead spallation target has been replaced with a new, liquid nitrogen cooled, third-generation lead target. Furthermore, important developments have been implemented in different components of the facility: Beam optics improvements (collimators, sweeping magnet replacement, etc), improvement of the experimental areas' alignment infrastructure as well as DAQ software upgrades.

After these major changes in the facility, the performance of the new target must be inspected thoroughly and the neutron beam in the experimental areas needs to be fully characterised. In this direction, n_TOF is currently being commissioned using a variety of different detection setups ranging from fission to capture, in order to extract the neutron beam flux, energy distribution, beam profile and the resolution function for both experimental areas [2].

In this work, an overview of the facility will be given and the detector setups in use for the commissioning will be described. Additionally, the first experimental results will be presented.

References

[1] https://ntof-exp.web.cern.ch/
[2] J. Praena and the nTOF collaboration, Commissioning of the third-generation spallation target and the neutron beam characteristics of the n_TOF facility, (2020)

A new approach for indirect capture measurements: The DICER neutron transmission station at LANSCE*

A. Stamatopoulos[1], P. E. Koehler[1], A. J. Couture[1,2,3], B. J. DiGiovine[1], G. Rusev[2], J. L. Ullmann[1]

[1] Los Alamos National Laboratory, Physics Division, Los Alamos, 87545, NM USA
[2] Los Alamos National Laboratory, Chemistry Division, Los Alamos, 87545, NM USA
Presenting author email: athanasios.stamatopoulos@lanl.gov

Direct (n,γ) measurements on radioactive nuclei can often be challenging. Substantial effort has been devoted to develop indirect techniques and thus perform measurements on short-lived radionuclides of astrophysical interest. A new indirect technique is being explored at the Los Alamos Neutron Science Center (LANSCE) which enables the calculation of average neuron capture properties from neutron transmission data.

A transmission station has been under commissioning during the last two years at LANSCE. The Device for Indirect Capture Experiments on Radionuclides (DICER) is currently capable of carrying out measurements on stable cylindrical samples with a diameter as small as 1mm and mass as low as a few mg.

The first year of operation indicate that the DICER instrument is ready to perform its first measurement on a radioactive sample (^{88}Zr, $t_{1/2}$=83.4 days) which is planned for the summer of 2021. A description of the apparatus and details on the latest DICER results will be presented.

* This work is funded by Los Alamos National Laboratory, Laboratory Directed Research and Development, Directed Research

Neutron Scattering from Porous Materials and Confined Fluids: Applications to CO_2 Sequestration and Oil Recovery *

Konstantinos L. Stefanopoulos

Institute of Nanoscience & Nanotechnology, NCSR "Demokritos", Ag. Paraskevi Attikis, Athens, Greece
Presenting author email: k.stefanopoulos@inn.demokritos.gr

One of the main advantages of neutrons in comparison to x-rays is their high penetration capability because they have no charge and interact with atomic nuclei with relatively weak interactions. Elastic neutron scattering techniques such as neutron diffraction, total neutron scattering, small-angle neutron scattering (SANS) and ultra-small-angle neutron scattering (USANS) are powerful tools to probe and reveal the structural properties of porous media at length scales from interatomic distances up to a few micrometers. In addition, when fluids are confined in nanoscale pores, their structural, thermodynamic and dynamic properties are different from those of the bulk phases. The reason is that the surface-fluid interactions and the finite pore volume can significantly alter the structural and dynamic properties of confined fluids and strongly influence their phase behaviour. Apart from the theoretical point of view, an in-depth understanding of confined fluids is also important for various applications such as catalysis, gas separations and storage, chromatography, CO_2 sequestration and oil recovery. Again, when neutron scattering is combined with *in situ* gas sorption, valuable information can be obtained about the structure, the phase behaviour and the location of the confined fluid [1-3].

In the current study we present the benefits of utilising *in situ* CO_2 sorption and neutron scattering methods in model porous systems (having definite pore shape and size) and in natural porous systems (having complex pore architecture) to explore the pore morphology as well as the pore accessibility and the structural properties of confined CO_2. This information is of great importance in the case of sedimentary rocks for the design of optimal CO_2 sequestration as well as gas and oil recovery projects.

* This work is supported by CIRA-2019-002 project.

References

[1] Y.B. Melnichenko Small-Angle Scattering from Confined and Interfacial Fluids: Applications to Energy Storage and Environmental Science, Springer, 2015
[2] K.L. Stefanopoulos *et al.*, Phys. Rev. Lett. **116**, 025502 (2016)
[3] K.L. Stefanopoulos *et al.*, Environ. Sci. Technol. **51**, 6515 (2017)

Differential cross section measurements of the ^{6}Li (d, n$\gamma_{1\text{-}0}$)^{7}Be, ^{6}Li (d, p$\gamma_{1\text{-}0}$)^{7}Li, ^{7}Li (d, d$\gamma_{1\text{-}0}$)^{7}Li and ^{19}F (d, p$\gamma_{1\text{-}0}$)^{20}F reactions suitable for d-PIGE applications

E. Taimpiri[1,2], M. Axiotis[2], K. Bosbotinis[1], M. Kokkoris[1], A. Lagoyannis[2], A. Ziagkova[1]

[1] *Department of Physics, National Technical University of Athens, Zografou campus, 15780 Athens, Greece*
[2] *Tandem Accelerator Laboratory, Institute of Nuclear Physics, N.C.S.R. "Demokritos", Aghia Paraskevi, 15310 Athens, Greece*
Presenting author email: evagelia43@gmail.com

Light elements such as lithium and fluorine, are widely used in industry. As a result, their detection and accurate quantification is of great importance. The most effective IBA technique for this purpose is PIGE due to the intense penetration of gamma - rays in mater and the high isotopic selectivity of the method. Despite the fact that proton beams are ideal for quantifying ^{7}Li and ^{19}F, they fail for the case of ^{6}Li due to the lack of an appropriate gamma – ray. In that case, deuteron beams were proposed as a more appropriate approach. However, a survey of the existing literature proves that there is a lack of datasets in higher energies and a rather narrow range of angles covered. In the present work, a thorough study of the reactions ^{6}Li (d, n$\gamma_{1\text{-}0}$)^{7}Be, ^{6}Li (d, p$\gamma_{1\text{-}0}$)^{7}Li, ^{7}Li (d, d$\gamma_{1\text{-}0}$)^{7}Li at a wider energy and angle range is carried out. Results for ^{19}F (d, p$\gamma_{1\text{-}0}$)^{20}F reaction are also presented.

Differential cross section measurements took place at the 5.5MV Tandem Van de Graaff accelerator of NCSR "Demokritos". The deuteron energy beam ranged from 1000 keV up to 2200 keV with a step of 20 keV, at angles of 0˚, 55˚ and 90˚. For the detection of the γ-ray peaks of interest at E_γ=429keV, E_γ=478keV, E_γ=656keV and E_γ=871keV, two different LiF targets were used. The first was a thin layer of ^{nat}LiF evaporated on a thick ^{nat}Ta layer. The second one consisted of a ^{nat}C substrate on top of which a thin ^{6}LiF (95% ^{6}Li, 5% ^{7}Li) layer was created via the same technique, with a top layer of Au. Three High Purity Germanium Detectors (HPGe) of 80% relative efficiency were used for the detection of the studied gamma ray peaks. Additionally, in order to validate the differential cross section measurements, a benchmarking procedure proved necessary, using ^{nat}LiF and $^{6}Li_2CO_3$ thick targets. Comparing the present results with previous datasets from the literature, remarkable discrepancies were found.

Investigation of Ground state observables of even-even Lead (Pb) isotopes in heavy mass region based on Covariant Density Functional Theory

Virender Thakur[1], Pankaj Kumar[1], Smriti Thakur[1], Vikesh Kumar[1], Shashi K. Dhiman[1]

[1] *Department of Physics, Himachal Pradesh University, Summerhill, Shimla-171005, India*

Presenting author email: virenthakur2154@gmail.com

Static nuclear ground state properties have been investigated with the Covariant Density Functional Theory. Investigation is done for even-even isotopes of Lead (Pb) as a representative of the heavy mass range nuclei in the periodic table. The nuclear ground state observables like charge radii, proton radii, neutron radii, root mean square radius and neutron skin thickness reflecting the size of the nucleus are studied. Theoretical results for shell closure parameter dS_{2n} based on two neutron separation energy S_{2n} are also presented. All the theoretical estimates are computed by using Relativistic nuclear density functional based on parameters DD-PCX and DD-ME2 and also compared with the available experimental data. The presented ground state properties with the Covariant DFT are in good agreement with recently available experimental data. DD-PCX parameters are found to be more efficient to reproduce experimental results in the selected heavy mass range region. Theoretical model predictions related to the observables for which experimental data is not available are also presented in this work.

Abstract submitted to HNPS2021

Differential Cross-section Measurements for Deuteron Elastic Scattering on ^{11}B

Th. Tsakiris[1], N. Dimitrakopoulos[1], M. Kokkoris[1], A. Lagoyannis[2], F. Maragkos[1], G. Provatas[3]

[1] *Department of Physics, National Technical University of Athens, Zografou Campus, 15780 Athens, Greece*
[2] *Tandem Accelerator Laboratory, Institute of Nuclear and Particle Physics, N.C.S.R. "Demokritos", Aghia Paraskevi, 15310 Athens, Greece*
[3] *Division of Experimental Physics, Ruđer Bošković Institute, Bijenička cesta 54, 10000 Zagreb, Croatia*
Presenting author email: tsakiristheofanis@gmail.com

The implementation of boron in several fields such as in the creation of p-type semiconductors in electronics and in neutron shielding in nuclear reactor cladding has created the need for the accurate quantitative determination of its depth profile concentrations in near surface layers of various matrices. In the framework of IBA techniques a combination of Elastic Backscattering Spectroscopy (EBS) along with Nuclear Reaction Analysis (NRA) has been proposed in order to address the current needs for boron depth profiling. Unfortunately there is currently a great lack of experimental datasets concerning the deuteron elastic scattering on boron. Thus, in the present work, measurements of the $^{11}B(d,d_0)^{11}B$ differential cross sections were carried out in the energy range $E_{d,lab} = 1300 - 1860 keV$ for the backscattering angles of 150°, 160°, 170°. The study was conducted at the 5.5 MV Tandem Accelerator of the Institute of Nuclear and Particle Physics, National Center of Scientific Research "Demokritos", Athens, Greece. The target was a thin, self-supporting aluminum foil upon which a thin ^{nat}B (isotopic ratio: ^{11}B: 80.1%, ^{10}B: 19.9%) layer was deposited using sputtering methods, followed by the evaporation of an ultra-thin layer of Au on top for normalization purposes. The outgoing particles were detected using silicon surface barrier detectors and the differential cross sections $^{11}B(d,d_0)^{11}B$ were determined from the resulting spectra via the relative technique.

Macroscopic X-ray fluorescence characterization of Platinum Group Mineral inclusions in archaeological gold

Kalliopi Tsampa[1], Claudia Caliri[2,3], Francesco Paolo Romano [3], Jack Davis[4], Sharon R. Stocker[4], Andreas Germanos Karydas[1,3]

[1] Institute of Nuclear and Particle Physics, N.C.S.R. "Demokritos", Patriarchou Grigoriou and Neapoleos 27, Agia Paraskevi, 15341, Athens, Greece

[2] Laboratori Nazionali del Sud, INFN, Via Santa Sofia 62, 95123, Catania, Italy

[3] CNR, Istituto per i Beni Archeologici e Monumentali (IBAM), Via Biblioteca 4, 95124, Catania, Italy

[4] University of Cincinnati, Department of Classics, Blegen Library 410, P.O. Box 210226, Cincinnati Ohio 45221-0226

Presenting author email: tsampa@inp.demokritos.gr

In May 2015, a team from the University of Cincinnati discovered an unlooted Mycenaean grave near the Palace of Nestor in Pylos Messenia. Among the excavated goods, four gold signet rings were found, decorated with Minoan rituals [1, 2]. The holistic macro-XRF (MA-XRF) imaging analysis of the external surface of the rings using the state of art LANDIS-X mobile x-ray scanner [3], offered the unique possibility of identifying several platinum group mineral inclusions (PGMs) containing elements such as Osmium (Os), Iridium (Ir) and Ruthenium (Ru). The presence of PGM inclusions in ancient gold objects is considered a clear indication that the gold and the PGM inclusions became associated as a result of fluvial transport [4]. A detailed characterization of the PGM inclusions in terms of their morphological features and compositional profile was carried out. The presentation will report and discuss obtained results, the analytical possibilities of MA-XRF imaging analysis, as well as the future perspectives in gold provenance studies.

Acknowledgements

The project was partially funded by the project CALIBRA/EYIE (MIS 5002799), which is implemented under the Action "Reinforcement of the Research and Innovation Infrastructures," funded by the Operational Programme "Competitiveness, Entrepreneurship and Innovation" (NSRF 2014–2020) and co-financed by Greece and the European Union (European Regional Development Fund).

References

[1] www.griffinwarrior.org

[2] Davis JL and Stocker SR, The Lord of the Gold Rings - The Griffin Warrior of Pylos, Hesperia 2016;85:627-655

[3] Romano F.P., Caliri C., Nicotra P., Di Martino S., Pappalardo L., Rizzo F., Santos H., Real-time elemental imaging of large dimension paintings with a novel mobile macro X-ray fluorescence (MA-XRF) scanning technique Journal of Analytical Atomic Spectrometry, 2017;32(4):773-781

[4] Meeks N.D. and Tite M.S., The Analysis of Platinum-group Element Inclusions in Gold Antiquities, Journal of Archaeological Science 1980, 7, 267-275

Investigation of W lamellae after plasma exposure at JET tokamak divertor

P. Tsavalas[a,b] , K. Mergia[a], A. Lagoyannis[a], M. Axiotis[a], Z. Kotsina[a], M. Rubel[c], A. Widdowson[d] and JET Contributors**

[a] *National Centre for Scientific Research "Demokritos", 15310 Aghia Paraskevi, Athens, Greece*
[b] *National Technical University of Athens, Department of Physics, Zografou Campus, Athens, Greece*
[c] *Department of Fusion Plasma Physics, Royal Institute of Technology (KTH), 100 44 Stockholm, Sweden*
[d] *EURATOM/CCFE Fusion Association, Culham Science Centre, Abingdon, OX14 3DB, UK*
** *See Joffrin et al 2019 (https://doi.org/10.1088/1741-4326/ab2276) for the JET contributors.*
Presenting author email: ptsavalas@ipta.demokritos.gr

The comprehensive understanding of the interaction between the plasma and the plasma-facing materials constitutes a critical issue for the safe operation of the fusion devices and the prediction of the life time of the inner wall of fusion machines. The most important mechanisms that define plasma-material interaction are the surface erosion, the fuel retention and the migration and deposition of impurities on the free surfaces of the plasma-facing components. The Joint European Torus (JET) tokamak was transformed from a carbon to a full metal wall machine with beryllium in the main chamber and tungsten in the divertor (ITER-like wall), in order to investigate the results of the interaction between the plasma and the plasma facing components for the next generation fusion device, ITER. After the new wall installation, three D – D experimental campaigns (2011/12, 2013/14 and 2015/16) were carried.

In this work, samples from different bulk W lamellae of stack A and C of the JET divertor after the three campaigns were investigated in order to assess material deposition, with emphasis on light elements, and surface morphology. Nuclear reaction analysis (NRA) employing a ^{2}H beam was used to determine the content of beryllium, carbon and oxygen and the depth profile of carbon in the W lamellae. The carbon amount is found between 1.4×10^{17} at/cm^2 and 1.0×10^{18} at/cm^2 in all lamellae apart from the sample from the ILW1-C3 lamella which presents carbon deposition in macroscopic length scale. Additionally, the carbon concentration is reduced drastically with the depth. From the first to the second campaign, a reduction of the carbon amount is observed. Moreover, the beryllium amount is estimated between 1.1×10^{17} at/cm^2 and 1.6×10^{18} at/cm^2 and the oxygen amount between 1.9×10^{17} at/cm^2 and 1.8×10^{18} at/cm^2. The as-fabricated W lamellae installed in JET are characterized by a network of micro-cracks on the surface. After plasma exposure the morphology of their surface as observed by scanning electron microscopy (SEM), shows both mild and strong plasma surface interaction with the density and the width of the micro-cracks being affected in the lamellae from the stack C and after the second campaign. Low-, medium- and high-Z elements (C, N, O, F, Na, Mg, Al, Si, S, Cl, Ar, K, Ca, Ti, Cr, Mn, Fe, Ni, Cu, Mo, W) were detected employing energy dispersive X-ray spectroscopy on the surface of all the samples.

Acknowledgements:
This work has been carried out within the framework of the EUROfusion Consortium and has received funding from the Euratom research and training programme 2014-2018 and 2019-2020 under grant agreement No 633053. The views and opinions expressed herein do not necessarily reflect those of the European Commission.

Abstract submitted to HNPS2021

Preparation for the first (p,n) reaction measurement at SECAR. *

P. Tsintari[1,5], A. Banu[6], G.P.A. Berg[2,5], M. Couder[2,5], N. Dimitrakopoulos[1,5], A. Estrade[1,5], R. Garg[3,5], R. Jain[3,5], C. Marshall[4,5], Z. Meisel[4,5], F. Montes[3,5], G. Perdikakis[1,5], H. Schatz[3,5], and L. Wagner[3,5]

[1]*Department of Physics, Central Michigan University, Mt. Pleasant, MI 48859, USA*
[2]*Department of Physics, University of Notre Dame, Notre Dame, IN 46556, USA*
[3]*Facility for Rare Isotope Beams, Michigan State University, East Lansing, MI48824, USA*
[4]*Department of Physics & Astronomy, Ohio University, Athens, OH 45701, USA*
[5]*Joint Institute of Nuclear Astrophysics - Center for the Evolution of the Elements, Michigan State University, East Lansing, MI 48824, USA*
[6]*Department of Physics and Astronomy, James Madison University, Harrisonburg, Virginia 22807, USA*
Presenting author email: tsint1p@cmich.edu

Neutron-induced reactions are essential to nucleosynthesis of the elements heavier than iron. Recent studies show that key (n,p) reactions, such as the ^{56}Ni(n,p)^{56}Co and ^{64}Ge(n,p)^{64}Ga, regulate the efficiency of the so-called neutrino-p process (νp-process), which is responsible for the formation of elements between nickel (Ni) and tin (Sn) in type II supernovae. Nucleosynthesis in νp-process occurs at slightly proton-rich regions in the neutrino driven wind of core-collapse supernovae, via a sequence of proton-capture reactions and (n,p) reactions. The small abundance of neutrons needed originates from anti-neutrino captures on free protons.

The recoil mass separator, SECAR (SEparator for CApture Reactions) [1] at FRIB, has been initially designed with the required sensitivity to study (p,γ) and (a,γ) reactions, directly at astrophysical energies in inverse kinematics, with radioactive beams of masses up to about A = 65. However, the study of (n,p) reactions via the measurement of the reverse (p,n) reactions in inverse kinematics is as well feasible for SECAR. Although, such proton-induced reactions are particularly challenging, as the recoils and the unreacted projectiles have nearly identical momenta, the SECAR system with its sequence of multipole magnets along with two Wien Filters could overcome such challenges. The preparation of the SECAR system to accommodate its first (p,n) reaction measurement including the development of alternative ion beam optics, and the implementation of in coincidence detection of neutron-recoil pairs will be discussed in this talk.

* This work is supported by the Department of Energy, USA

References

[1] Design of SECAR: a Recoil Mass Separator for Astrophysical Capture Reactions with Radioactive Beams" by G. Berg, M. Couder, M.T. Moran, K. Smith, M. Wiescher, H. Schatz, U. Hager, C. Wrede, F. Montes, G. Perdikakis, X. Wu, A. Zeller, M.S. Smith, D.W. Bardayan, K.A. Chipps, S.D. Pain, J. Blackmon, U. Greife, K.E. Rehm, and R.V.F. Janssens, **Nuclear Instruments and & Methods A 877, (2018) 87-103.**

Abstract submitted to HNPS2021

Study of the ^{176}Hf(n,2n) and ^{180}Hf(n,nγ) Cross-Sections at 18.9MeV.

E. Tsivouraki[1], S. Chasapoglou[1], M. Serris[2], M. Axiotis[3], G. Gkatis[1], S. Harissopulos[3], M. Kokkoris[1], A. Lagoyannis[3], S. Patas[1], R. Vlastou[1]

[1]*Department of Physics, National Technical University of Athens, Zografou campus, 15780 Athens, Greece*
[2]*Department of Naval Architecture, University of West Attica, 122 10 Athens, Greece*
[3]*Tandem Accelerator Laboratory, Institute of Nuclear Physics, N.C.S.R. "Demokritos", Aghia Paraskevi, 15310 Athens, Greece*

Presenting author email: eltsivouraki@yahoo.com

Neutron nuclear reactions can provide significant information in the field of nuclear physics and applications. Hafnium (Hf) is one of the rare-earth isotopes with a relative large neutron total cross-section in the thermal neutron energy region and neutron induced reactions in reactor materials could lead to the production of long-lived isomeric states of Hf isotopes. Thus, the knowledge of neutron cross-sections on Hf isotopes is of great importance for basic research in Nuclear Physics as well as for applications concerning the interaction of neutrons with matter.

In this study measurements of experimental cross section for the ^{176}Hf(n,2n)^{175}Hf and ^{180}Hf(n,n΄γ)^{180m}Hf reactions were carried out, using the activation technique. The neutron beam energy at 18.9 MeV was produced via the ^{3}H(d,n)^{4}He reaction at the 5.5 MeV Tandem Van de Graaf accelerator laboratory of NCSR "Demokritos". A thin metallic foil of natural Hf was used, while for the determination of the neutron flux at the target position a reference foil of Al was placed at the back of the Hf target. The irradiation was continuous for 28 hours leading to a total neutron fluence of 10^{10} n/cm^2 and a BF_3 detector was used for monitoring the neutron flux during the irradiation. After the end of irradiation, the activity of the Hf target and the Al foil were measured off-line by two HPGe detectors. Both detector efficiencies were obtained using a calibrated ^{152}Eu source, placed in the same distance as the target and the reference foil.

The ^{176}Hf(n,2n)^{175}Hf reaction has been corrected from the contribution of ^{177}Hf(n,3n)^{175}Hf and the ^{174}Hf(n,γ)^{175}Hf reactions and the ^{180}Hf(n,n΄γ)^{180m}Hf reaction from the ^{179}Hf(n,γ)^{180m}Hf.

Theoretical calculations of the ^{174}Hf(n,2n)^{175}Hf, ^{176}Hf(n,2n)^{175}Hf and ^{180}Hf(n,n΄γ)^{180m}Hf reaction cross-sections have also been performed using the nuclear statistical code "EMPIRE 3.2.3" and they have been compared with the data.

Cross section measurements of proton capture reactions on Sr isotopes for astrophysics applications

S. Harissopulos[1], E. Vagena[1], P. Dimitriou[1,2], M. Axiotis[1], S. Galanopoulos[1,3], V. Foteinou[1,4], and A. Lagoyannis[1]

[1]*Institute of Nuclear and Particle Physics, NCSR "Demokritos", 153.10 Aghia Paraskevi, Athens, Greece*

[2]*Present address: Nuclear Data Section, International Atomic Energy Agency, Vienna 1400, Austria.*

[3]*Present address: Archimedean Upper Conservatory, 12425 Sunset Dr., Miami, FL 33183, USA.*

[4]*Present address: DTL/RUBION, 40781 Bochum, Germany.*

Presenting author email: vagena@inp.demokritos.gr

Background: Abundance calculations of a certain class of proton-rich isotopes, known as *p* nuclei, require knowledge of the cross sections of thousands of nuclear reactions entering a reaction network. As a result, the solution of the latter relies on the predictions of the Hauser-Feshbach (HF) theory and, hence, on the reliability of the models describing the nuclear parameters entering the HF calculations, notably the optical model potential (OMP), the nuclear level density (NLD) and the γ -ray strength function (γSF). **Purpose:** The present work reports on a systematic study of proton capture reactions on Sr isotopes at energies relevant to the *p* process which is responsible for the production of the *p* nuclei at explosive stellar sites. The purpose of the work reported here is to perform a validity test of the different OMP, NLD, and γSF models through extensive and detailed comparisons between HF calculations and experimental cross section data. This test is necessary to understand the origin of discrepancies between the *p*-nuclei abundances observed in the solar system and those predicted by the different astrophysical models, known as *p*-process models, aiming at describing the nucleosynthesis of the *p* isotopes. **Method:** Cross sections were determined from γ-angular distribution measurements and from angle-integrated γ spectra taken with the 4π γ-summing technique. Cross-section data and the resulting astrophysical *S* factors were compared with Hauser-Feshbach calculations obtained with the latest version 1.95 of the nuclear reaction code TALYS using combinations of global semi-microscopic and phenomenological models of optical potentials (OMPs), nuclear level densities (NLDs), and γ-ray strength functions (γ SFs). **Results:** Total cross sections as well as cross sections to the ground and metastable states were determined for the reactions ^{86}Sr(p,γ)^{87}Y, ^{87}Sr(p,γ)^{88}Y, and ^{88}Sr(p,γ)^{89}Y at incident proton-beam energies from 2.5 to 3.6, 2 to 5, and 1.5 to 5 MeV, respectively. **Conclusions:** The experimental data reported in the present work are in very good agreement with the TALYS 1.95 calculations obtained with the default combination of OMP, NLD, and γSF models. This combination is based on purely phenomenological models. A semimicroscopic proton-nucleus optical model potential was optimized at low energies leading to an equally good agreement between experimental data and theoretical calculations based solely on combinations of fully semimicroscopic models of OMP, NLD, and γSF. Our results highlight the need for a continued effort on the systematic study of proton-capture reactions to reduce the range of uncertainties arising from global nuclear models for as wide a range of relevant nuclei as possible. In this regard, new (p,γ) data at the lowest possible energies below the opening of the neutron channel are of key importance to improve global proton-nucleus optical model potentials.

* We acknowledge support of this work by the project "CALIBRA/EYIE" (MIS 5002799), which is implemented under the Action "Reinforcement of the Research and Innovation Infrastructures," funded by the Operational Programme "Competitiveness, Entrepreneurship and Innovation" (NSRF 2014-2020) and cofinanced by Greece and the European Union (European Regional Development Fund).

References

[1] M. Arnould and S. Goriely, The *p*-process of stellar nucleosynthesis: Astrophysics and nuclear physics status, Phys. Rep. **384**, 1 (2003).

[2] Sotirios V. Harissopulos, Cross-section measurements of capture reactions relevant to *p*-process nucleosynthesis, Eur. Phys. J. Plus **133**, 332 (2018).

[3] W. Hauser and H. Feshbach, The inelastic scattering of neutrons, Phys. Rev. **87**, 366 (1952).

Experimental Study of the Nuclear Structure of ^{180}Hf: Preliminary results*

P. Vasileiou[1], T.J. Mertzimekis[1], A. Chalil[1,4], A. Zyriliou[1], S. Pelonis[1], V. Lagaki[1], G. Siltzovalis[1], M. Efstathiou[1], P. Koseoglou[5], Dennis Bonatsos[2], Andriana Martinou[2], N. Minkov[3], N. Mărginean[6], C. Mihai[6], N. Florea[6], S. Ujeniuc[6], A. Turturica[6], C. Costache[6], R. Mihai[6], L. Stan[6], D. Filipescu[6], S. Toma[6], I. Gheorghe[6], I. Dinescu[6], A. Ionescu[6], L. Stoica[6], S. Calinescu[6], A. Oprea[6], A. Stoica[6], C. Sotty[6], C. Clisu[6], C. Nita[6], C. Neascu[6]

[1] *Department of Physics, University of Athens, Greece*
[2] *Institute of Nuclear and Particle Physics, NCSR "Demokritos", Greece*
[3] *Institute of Nuclear Research and Nuclear Energy, Bulgarian Academy of Sciences, Bulgaria*
[4] *IRFU, CEA, Université Paris-Saclay, France*
[5] *Institut für Kernphysik, Technische Universität Darmstadt, Germany*
[6] *National Institute for Physics and Nuclear Engineering, Romania*
Presenting author email: polvasil@phys.uoa.gr

The structure of ^{180}Hf (Z=72) is of particular interest, as the nucleus features a rotational ground state band, but also several other collective bands, K-isomers, and non-band members [1], which are generally poorly investigated. This work features preliminary results from a recent experimental campaign at IFIN-HH, Romania, aimed at measuring lifetimes of excited states in the neutron-rich ^{180}Hf, by means of the RDDS technique. The ^{181}Ta(^{11}B,^{12}C)^{180}Hf proton pick-up reaction was used to populate excited states in the ^{180}Hf nucleus. The γ transitions depopulating these levels were detected using the ROSPHERE [2] array, in its 25HPGe configuration. The array was coupled to the SORCERER [3] particle detector and a plunger device enabling the study of p-γ and p-γ-γ coinciding events. Six different plunger foil distances were chosen, allowing for the construction of the decay curves of the observed γ transitions, from which the lifetimes of the levels of interest can subsequently be deduced.

References

[1] National Nuclear Data Center, url: https://www.nndc.bnl.gov/
[2] D. Bucurescu *et al.*, NIM A 837, 1 (2016)
[3] T. Beck *et al.*, NIM A 951 (2020)

NCSRD activities at JET in support to ITER nuclear analyses

T. Vasilopoulou[1], M. I. Savva[1], P. Tsavalas[1], A. Lagoyannis[2], V. Ioannou-Sougleridis[3], K. Mergia[1], I. E. Stamatelatos[1] and JET contributors*

EUROfusion Consortium, JET, Culham Science Centre, Abingdon, Oxon, OX14 3DB, UK

[1] *Institute of Nuclear & Radiological Sciences and Technology, Energy & Safety*

[2] *Institute of Nuclear and Particle Physics*

[3] *Institute of Nanoscience and Nanotechnology*

NCSR "Demokritos", 15310, Athens, Greece

** See the author list of E. Joffrin et al. 2019 Nucl. Fusion 59 112021*

Presenting author email: dora@ipta.demokritos.gr

ITER is the key facility on the path to realization of fusion energy and the first-ever fusion device to produce net energy. ITER is expected to achieve its First Plasma by the end of 2025, while it will begin its Deuterium-Tritium Operation by 2035. In view of this goal, a huge combined effort is being made by a globe-spanning collaboration of 35 nations towards the construction and preparation of ITER operation. JET, which is currently the largest operating tokamak in the world and the central research facility of the European Fusion Program, has an important role as a test bed for ITER technologies and plasma operating scenarios. Within this framework, several ITER oriented experiments are being performed at JET, with the objective to validate codes, models, assumptions, procedures and data currently used in ITER nuclear analyses, thus reducing the related uncertainties and the associated risks in ITER operation, maximizing the scientific and technological preparedness and ensuring a successful launch of ITER.

NCSRD fusion technology group contributes to the preparation of ITER operation, participating in both experimental and computational studies that are implemented at JET in direct support to ITER. These studies include radiological characterization of ITER materials, neutron streaming and shutdown dose rate measurements at positions close and far from the plasma source, development of a novel neutron detector capable to measure neutron fluence under the harsh conditions encountered in a fusion device, as well as the investigation of ITER-like plasma facing materials and radiation damage studies of functional materials.

This work provides an overview of the NCSRD activities in support to ITER, focusing on the unique experiments carried out at JET during the recent DD, TT & DT campaigns, and summarizes the significant experience gained from these activities in view of the preparation of ITER operation.

Acknowledgements: This work has been carried out within the framework of the EUROfusion Consortium and has received funding from the Euratom research and training programme 2014-2018 and 2019-2020 under Grant Agreement No. 633053. The views and opinions expressed herein do not necessarily reflect those of the European Commission.

Differential cross section measurements of the $^{7}Li\ (p,p'\gamma_{1\text{-}0})\ ^{7}Li$ reaction suitable for PIGE applications

A. Ziagkova[1,2], M. Axiotis[2], S. Harissopoulos[2], M. Kokkoris[1], A. Lagoyannis[2], F. Maragkos[1], E. Ntemou[1,2]

[1]*Department of Physics, National Technical University of Athens, Zografou campus, 15780 Athens, Greece*
[2]*Tandem Accelerator Laboratory, Institute of Nuclear Physics, N.C.S.R. "Demokritos", Aghia Paraskevi, 15310 Athens, Greece*

Presenting author email: anziagova@windowslive.com

Lithium is one of the lightest elements in nature and its study via the PIGE technique is widely applied in many disciplines. The isotope ^{7}Li is the most abundant one (92.5%) of natural lithium, so the accurate determination of the differential cross sections of the reaction $^{7}Li\ (p,p'\gamma_{1\text{-}0})\ ^{7}Li$ is of great importance. However, due to discrepancies between older experimental datasets and the considerable lack of results corresponding to different angles, a further study of the reaction is carried out in the present work. The measurements of the differential cross sections took place at the 5.5MV Tandem Van de Graaff accelerator of NCSR "Demokritos" for the proton energy beam range of 1010 – 4000 keV and at the detector angles of 0^{o}, 90^{o}, 55^{o} and 165^{o}. The target was a thin LiF layer created via the evaporation technique on a ^{nat}Ta thick layer. The detection of the gamma ray peak of interest, at E_{γ} = 477.6 keV, was accomplished by using four High Purity Germanium Detectors (HPGe) of 16 – 20% relative efficiency. An additional benchmarking experiment also carried out, using a thick LiF target, for the validation of the differential cross section measurements at the detection angles of 0^{o}, 90^{o} and 55^{o}.

SIMNRA v.7.03 and SPECTRW codes were used for the characterization of the target and the integration of the gamma ray peaks, respectively. The obtained results follow the general trend of previous measurements and there is a quite good agreement with two of the previously obtained differential cross datasets in literature at complementary angles.

Abstract submitted to HNPS2021

Nuclear Structure Investigations in Yb isotopes*

A. Zyriliou[1], T. J. Mertzimekis[1], A. Chalil[1,4], P. Vasileiou[1], S. Pelonis[1], E. Mavrommatis[1], Dennis Bonatsos[2], Andriana Martinou[2], S. Peroulis[2], N. Minkov[3], C. Nita[5], N. Mărginean[5], C. Mihai[5], D. Bucurescu[5], D. Filipescu[5], I. Gheorghe[5], R. Lică[5], R. Mărginean[5], A. Negreț[5], L. Stroe[5], S. Toma[5], R. Șuvăilă[5], N.V. Zamfir[5], C.A. Ur[5]

[1]*Department of Physics, National and Kapodistrian University of Athens, Zografou Campus, GR-15784, Athens, Greece*

[2]*Institute of Nuclear and Particle Physics, NCSR "Demokritos", Greece*

[3]*Institute of Nuclear Research and Nuclear Energy, Bulgarian Academy of Sciences, Bulgaria*

[4]*IRFU, CEA, Université Paris-Saclay, France*

[5]*National Institute for Physics and Nuclear Engineering, Romania*

Presenting author email: kzyriliou@phys.uoa.gr

The medium-to-heavy mass ytterbium isotopes ($_{70}$Yb) in the rare-earth mass region are known to be well-deformed nuclei, which can be populated to very high spin. Spectroscopic information becomes scarcer as the neutron number increases, impeding the understanding of nuclear structure in this mass region, where interesting phenomena, such as shape coexistence, have been predicted [1]. The lack of any experimental information on the structure of the neutron-rich ^{180}Yb isotope and the lifetime of the 2_1^+ state of ^{178}Yb have greatly motivated this study, which can offer useful information for the collective behavior of neutrons and protons, the evolution of shape and shape coexistence. A measurement was performed to investigate the population of excited states and a first measurement of the unknown 2_1^+ lifetime of ^{178}Yb by means of a two neutron-transfer reaction ^{176}Yb(^{18}O,^{16}O)^{178}Yb at energies 68-74 MeV using the ROSPHERE [2] array at IFIN-HH, Romania. From the theoretical point of view, in this work, energy levels, deformation parameters β_2, reduced transition probabilities B(E2) and transition quadrupole moments Q for even-even Yb isotopes have been calculated using a Phenomenological Model, the Interacting Boson Model and various other theoretical models, including the recently developed proxy SU(3) model [3]. Along these lines, the results for the even-even $^{164\text{-}180}$Yb isotopes are compared to available experimental data [4,5], serving as benchmarks for more detailed studies in the near future. An overall good agreement was found between available adopted data and theoretical predictions.

References

[1] A. Martinou *et al.*, Eur. Phys. J. A 57, 84 (2021)

[2] D. Bucurescu *et al.*, NIM A 837, 1 (2016)

[3] D. Bonatsos *et al.*, Phys. Rev. 95, 064325 (2017)

[4] B. Pritychenko *et al.*, Atom. Data Nucl. Data Tabl. 107, 1 (2016)

[5] Nudat2, National Nuclear Data Center, url: http://www.nndc.bnl.gov/nudat2