Zakopane Conference on Nuclear Physics

"Extremes of the Nuclear Landscape"

August 31 – September 7, 2014
Zakopane, Poland

ORGANIZED BY:

The Henryk Niewodniczański Institute of Nuclear Physics PAN
Committee of Physics of the Polish Academy of Sciences (PAN)

BOARD OF CONVENERS:

Dieter Ackermann (GSI)
Angela Bracco (Milano)
Jolie Cizewski (Rutgers)
Bogdan Fornal (Kraków)
Sydney Gales (ELI-NP)
Witold Nazarewicz (MSU)
Tohru Motobayashi (RIKEN)
Berta Rubio (Valencia)
John Simpson (Daresbury)

ORGANIZING COMMITTEE:

CHAIRMAN: Piotr Bednarczyk
CO-CHAIRMAN: Wojciech Królas
SCIENTIFIC SECRETARY: Bartłomiej Szpak

Jerzy Grębosz
Łukasz Iskra
Marcin Jastrząb
Mateusz Krzysiek
Katarzyna Mazurek
Małgorzata Niewiara
Tomasz Pawłat
Bogdan Sowicki
Cecylia Szklarz
Barbara Wasilewska
Jacek Wrzesiński
Mirosław Ziębliński

Table of Contents

Conference Program

Sunday, August 31st

15:00 – 17:30 Arrival of Conference participants

18:00 – 19:30 Dinner

Welcome and Opening Talk

19:30 – 20:30

19:30 **Marek Jeżabek**
Welcome address

19:45 **Bradley Sherrill, Michigan State University**
Prospects for exploring the extremes of the nuclear landscape

20:30 Welcome reception

Monday, September 1st

7:30 Breakfast

Nuclear Theory

08:30 – 13:00

Convener Witold Nazarewicz

8:30 **Nicolas Chamel, Université Libre de Bruxelles**
Recent developments in the modeling of neutron-star crusts

9:00 **Stefano Gandolfi, Los Alamos**
Microscopic calculations of nuclear and neutron matter, symmetry energy and neutron stars

9:30 **Nils Paar, University of Zagreb**
Nuclear energy density functionals and neutron star properties

10:00 **Hans-Werner Hammer, TU Darmstadt**
Three-body forces: from cold atoms to nuclei

10:30 Coffee Break

11:00 **Richard Furnstahl, Ohio State University**
Effective field theory and density functionals

11:30 **Ionel Stetcu, Los Alamos National Laboratory**
Nuclear structure and dynamics with density functional theory

11:45 **Gianluca Colo, University of Milan and INFN**
The nuclear symmetry energy and other isovector observables from the point of view of nuclear structure

12:15 **Anatoli Afanasjev, Mississippi State University**
Nuclear structure theory of the heaviest nuclei

12:45 **Hamidreza Moshfegh, University of Tehran**
The symmetry energy of hot asymmetric nuclear matter

13:00 Lunch

14:00 Mountain Trip

18:00 Dinner

Nuclear Reactions

18:45 – 21:10

18:45 **Valeriy Zagrebaev, JINR Dubna**
Production of exotic nuclei in low-energy multi-nucleon transfer reactions

19:10 **Tea Mijatović, Ruđer Bošković Institute, Zagreb**
Pairing correlation study in the ^{40}Ar + ^{208}Pb multinucleon transfer reaction

19:25 **Diego Ramos, University Santiago de Compostela**
Fission yields of minor actinides at low excitation energy through multi-nucleon transfer reactions of ^{238}U with carbon

19:40 **Daniela Fabris, INFN Padova**
Pre-equilibrium particles emission and its possible relation to alpha-clustering in nuclei

19:55 **Rakesh Kumar, IUAC New Delhi**
Low energy incomplete fusion and the role of input angular momenta

20:10 **Izabela Ciepał, Jagiellonian University , Kraków**
Experimental studies of the Coulomb force effects in deuteron-proton breakup reaction at medium energy regime

20:25 **Sukhjit Kaur, Panjab University**
Structural effects on the peak production of fragments

20:40 **Jelena Vesic, Jozef Stefan Institute, Ljubljana**
Effect of electron screening on nuclear reaction rates

20:55 **Justyna Marganiec, TU Darmstadt**
Coulomb dissociation of ^{27}P

Tuesday, September 2nd

7:30 Breakfast

Nuclear Structure at High Spins - New Developments and Perspectives
08:30 – 10:30

Convener John Simpson

8:30 Ingemar Ragnarsson, Lund University
Theoretical overview of exotic shapes at the highest spins

8:55 Adam Maj, IFJ PAN Kraków
Studies of very elongated nuclear shapes in hot nuclei at very high spins - status and new opportunities with RIBs

9:20 Eddie Paul, University of Liverpool
Recent results at ultrahigh spin: terminating states and beyond in mass 160 rare-earth nuclei

9:45 Yang Sun, Shanghai Jiao Tong University
High-spin physics with the projected shell model

10:00 Navin Alahari, GANIL
First steps towards accessing the high isospin-spin frontier

10:30 Coffee Break

New Results and Opportunities at Radioactive Ion Beam Facilities
11:00 – 13:00

Convener Tohru Motobayashi

11:00 Magdalena Górska, GSI
The last PreSPEC– AGATA campaign

11:25 Peter Doornenbal, RIKEN
Overview of in-beam gamma-ray spectroscopy at the RIBF

11:50 Paweł Napiorkowski, Heavy Ion Laboratory, Warszawa
Coulomb excitation for quadrupole moments measurements

12:15 Thomas Henry, University of York
Mirror Spectroscopy in the upper *fp* shell with GRETINA

12:30 **Bondili Nara Singh, University of York**
A shape study of ^{72}Kr using the REX-ISOLDE/Miniball set-up

12:45 **Ivan Budinčević, KU Leuven**
Collinear Resonance Ionization Spectroscopy of francium isotopes towards the limits of stability

13:00 **Lunch**

Collective Excitation Modes
15:00 – 17:40

Convener Angela Bracco

15:00 **Maria Kmiecik, IFJ PAN Kraków**
GDR width evolution at extreme temperatures

15:25 **Remco Zegers, Michigan State University**
Studies of Gamow-Teller strengths at NSCL and applications in astrophysics and neutrino physics

15:50 **Konstanze Boretzky, GSI**
PDR and dipole polarizability studies at GSI

16:15 **Fabio Crespi, INFN and University of Milan**
Isospin character of low-lying pygmy dipole states via inelastic scattering of ^{17}O

16:40 **Ann-Cecilie Larsen, University of Oslo**
Upbend and M1 scissors mode in neutron-rich nuclei – consequences for r-process (n,γ) reaction rates

16:55 **Sunniva Siem, University of Oslo**
Statistical properties of warm nuclei – observation of a first order pairing phase transition in atomic nuclei

17:10 **Simone Ceruti, University of Milan**
Isospin mixing in ^{80}Zr at finite temperature

17:25 **Nikolay Arsenyev, JINR Dubna**
Effects of phonon-phonon coupling on properties of pygmy resonances in $^{124\text{-}132}$Sn

18:00 **Dinner**

19:30 – 21:00 Poster Session

Wednesday, September 3rd

7:30 Breakfast

Direct Reaction Studies with Radioactive Ion Beams
8:30 – 10:30

Convener Jolie Cizewski

8:30 **Jolie Cizewski, Rutgers University**
Overview of theoretical and experimental nuclear reaction studies with radioactive ion beams

8:45 **Wilton Catford, University of Surrey**
Migration of magic numbers: structure of ^{26}Na via a novel technique using (d, p) with a radioactive ^{25}Na beam

9:15 **Kate Jones, University of Tennessee**
Recent direct reaction experimental studies with heavy-mass radioactive ion beams

9:45 **Francesca Renzi, KU Leuven**
Spectroscopy of ^{7}He by ^{6}He(^{9}Be, ^{8}Be) transfer reaction

10:00 **Guillermo Ribeiro, IEM CSIC Madrid**
Study of the unbound ^{13}Be resonance in a (p, 2p) reaction at GSI

10:15 **Pavel Sharov, JINR Dubna**
Population of ^{10}He continuum in knockout reactions

10:30 Coffee Break

Super-heavy Nuclei

11:00 – 13:00

Convener Dieter Ackermann

11:00 **Yuri Oganessian, JINR Dubna**
Nuclei at the end of the Periodic Table

11:30 **Kosuke Morita, Kyushu University and RIKEN**
Research on superheavy element at RIKEN: status and perspective

12:00 **Andreas Türler, Paul Scherrer Institute and University of Bern**
Recent results from the field of superheavy element research

12:30 **Dariusz Seweryniak, Argonne National Laboratory**
Spectroscopy of very heavy nuclei at ATLAS

13:00 **Lunch**

14:00 **Mountain Trip**

18:00 **Dinner**

Super-heavy Nuclei and Fission

18:45 – 21:10

18:45 **Adam Sobiczewski, NCBJ Warszawa**
Theoretical description of decay chains of the element 115

19:10 **Mikael Sandzelius, University of Jyväskylä**
Prompt in-beam conversion electron and γ-ray spectroscopy at the limit using the SAGE spectrometer

19:25 **Lorant Csige, ATOMKI Debrecen**
Transmission resonance spectroscopy of the doubly odd ^{238}Np in (d, pf) reaction

19:40 **Michał Kowal, NCBJ Warszawa**
Configuration constrained calculations of the potential energy surfaces (PES's) - search for superheavy K-isomers

Super-heavy Nuclei and Fission (cont.)

18:45 – 21:10

19:55 **Anna Bezbakh, JINR Dubna**
Level densities of heaviest nuclei

20:10 **Andreina Chietera, IPHC Strasbourg**
Neutron emission anisotropy in fission

20:25 **Katarzyna Mazurek, IFJ PAN Kraków**
Spontaneous fission of ^{238}U from the self-consistent collective action

20:40 **Eugeny Ryabov, Omsk State University**
Analysis of experimental data from fussion-fission reactions within four-dimensional Langevin dynamics

20:55 **Jean-Francois Lemaitre, CEA/DSM/Irfu Saclay**
Nuclear fission modeling with SPY

Thursday, September 4th

7:30 Breakfast

New Results and Opportunities at Radioactive Ion Beam Facilities II

8:30 – 11:15

8:30 **Tomohiro Uesaka, RIKEN**
RIKEN RIBF overview

8:55 **Marek Lewitowicz, GANIL**
GANIL/SPIRAL 2 – status and future

9:20 **Fabiana Gramegna, Legnaro**
Status of the SPES facility: technological challenges and first day scientific program

9:45 **Magda Zielińska, CEA Saclay**
Deformation of ^{97}Rb studied by low-energy Coulomb excitation

10:00 **Tom Alexander, University of Surrey**
Coulomb excitation of ^{206}Hg with AGATA at GSI

10:15 **Malin Klintefjord, University of Oslo**
Shape transition and coexistence in ^{140}Sm

10:30 **Jack Henderson, University of York**
First spectroscopy of excited states in the drip-line nuclide ^{74}Sr

10:45 **Philipp John, University of Padova and INFN**
Shape evolution in the neutron-rich Osmium isotopes: prompt γ-ray spectroscopy of ^{196}Os

11:00 **Callum Shand, University of Surrey**
Structure of ^{207}Pb populated in deep-inelastic collisions

11:15 Coffee Break

12:00 – 22:00 **Conference Trip and Barbeque Evening**

Friday, September 5th

7:30 Breakfast

Shell Structure at the Extremes of Nuclear Landscape

8:30 – 10:30

Convener Bogdan Fornal

8:30 **Allan Wuosmaa, University of Connecticut**
Light neutron-rich nuclei at and around N=8

9:00 **Robert Janssens, Argonne National Laboratory**
Evolution of shell structure in neutron-rich nuclei from Ca to Ni

9:30 **Gilbert Duchene, IPHC Strasbourg**
Structure beyond the N=50 shell closure in neutron-rich nuclei in the vicinity of ^{78}Ni: The case of N=51 nuclei

9:45 **Silvia Leoni, INFN and University of Milan**
Particle-core couplings close to neutron-rich doubly-magic nuclei

10:15 **Giovanni Bocchi, University of Milano and INFN**
Study of Ca isotopes via neutron capture reactions

10:30 Coffee Break

Beta decay Studies of Exotic Nuclei

11:00 – 13:00

Convener Berta Rubio

11:00 **Maria Borge, IEM Madrid**
Exotic decays in light nuclei

11:25 **Yoshitaka Fujita, Osaka University**
Gamow-Teller excitations studied by the weak and strong interactions

11:50 **Alejandro Algora, University of Valencia**
Beta decay studies using Total Absorption Spectroscopy

12:15 **Vandana Nanal, TIFR Mumbai**
Search for neutrinoless double beta decay in ^{124}Sn

12:40 **Paul Davies, University of York**
Beta decay study of 16^+ and 9^+ spin-gap isomers in ^{96}Cd and ^{98}In

13:00 **Lunch**

Nuclear Structure

15:30 – 17:40

15:30 **Bo Cederwall, KTH Stockholm**
Neutron-proton pair correlations in N=Z nuclei approaching ^{100}Sn

15:55 **Houda Naïdja, IPHC Strasbourg**
Shell-model studies of the neutron rich nuclei beyond ^{132}Sn

16:10 **Timur Shneidman, JINR Dubna**
Cluster effects in the structure of ^{44}Ti

16:25 **Andrzej Staszczak, UMCS Lublin**
A region of rotating toroidal isomers

16:40 **Obed Shirinda, iThemba Labs**
Multiple chiral bands associated with the same strongly asymmetric many-particle nucleon configuration

16:55 **Tomasz Marchlewski, University of Warsaw**
Spontaneous time-reversal symmetry breaking in ^{124}Cs – first observation of a critical frequency

17:10 **Robert Carroll, University of Surrey**
Blurring the boundaries of the nuclear landscape with multiparticle spin-trap isomers at the proton drip line

17:25 **Dimitar Tarpanov, University of Warsaw**
Spectroscopic properties of energy density functionals

18:00 **Dinner**

Beta decay Studies of Exotic Nuclei II

18:45 – 21:10

18:45 Miguel Madurga, CERN ISOLDE
Beta-delayed Neutron Spectroscopy of Ga Isotopes with VANDLE

19:10 Sonja Orrigo, IFIC CSIC University of Valencia
First observation of beta-delayed gamma-proton decay in the *fp*-shell, the beta decay of ^{56}Zn

19:25 Agnieszka Czeszumska, LLNL and University of California, Berkeley
Beta-delayed neutron spectroscopy with trapped fission products

19:40 Giuseppe Lorusso, RIKEN Nishina Center
Measurement of 20 new beta decay half-lives into the r-process path and the physical conditions of the r-process

19:55 Chiara Mazzocchi, University of Warsaw
Beta decay of the most neutron-rich isotopes close to ^{78}Ni

20:10 Krzysztof Miernik, University of Warsaw
Experimental observation of a large beta-delayed two-neutron emission probability in the decay of ^{86}Ga

20:25 Asénath Etilé, CSNSM Orsay
Structure of the odd-odd N=49 isotope ^{82}As from beta decay: first evidence of low lying intruder states

20:40 Marek Karny, University of Warsaw
Beta decay measurements of ^{86}Br, ^{89}Kr, and ^{139}Xe by means of Modular Total Absorption Spectrometer

20:55 Frank Browne, University of Brighton
Gamma-ray spectroscopy in the vicinity of ^{108}Zr

Saturday, September 6th

7:30 Breakfast

Beyond Nuclear Physics
8:30 – 11:00

Convener Sydney Gales

8:30 **Michel Spiro, CEA Saclay**
Dark matter, dark energy and the future of high energy physics

9:00 **Andrzej Rybicki, IFJ PAN Kraków**
Using the nuclear remnants as a new source of information on the space-time evolution of ultrarelativistic heavy ion collisions

9:15 **Calin Ur, ELI-NP Bucharest-Magurele**
New frontiers in Nuclear Physics research at ELI–NP

9:45 **Sylvain David, IPN Orsay**
Future scenarios for fission based reactors: breeding and waste transmutation using U or Th cycle

10:15 **Aleksandra Wrońska, Jagiellonian University**
Gamma emission in hadron therapy – experimental approach

10:30 **Sydney Gales, ELI-NP Bucharest-Magurele**
Physics against cancer: NUPECC report on nuclear medicine

11:00 Coffee Break

Closing Talk
11:30 – 12:15

11:30 **Alexander Wolszczan, Pennsylvania State University**
The astronomical future of humankind

13:00 Lunch

14:00 Mountain Trip

19:00 Conference Banquet

Sunday, September 7th

7:30	Breakfast
9:00 – 10:00	Departure to Kraków

Sunday

August 31st

PROSPECTS FOR EXPLORING THE EXTREMES OF THE NUCLEAR LANDSCAPE

Bradley M. Sherrill, Facility for Rare Isotope Beams, East Lansing, USA

INVITED

Sunday 19:45

The extremes of the nuclear landscape offer great insight into the nature of the interactions that are responsible for the stability and origin of atomic nuclei. They represent laboratory examples that have features related to astrophysical objects such as neutron stars. Recent theoretical estimates are that there are perhaps 7000 possible isotopes for elements from 2 to 120 [1]. What are our prospects for exploring this nuclear landscape? Other than observation of a bit more than 3100 of these isotopes have been produced and observed [2], but only about 2000 have known properties [3]. Next generation accelerator facilities have the capability to open significant new vistas. There are compelling reasons to produce and study nuclides at the very extremes of this landscape. Some recent extreme examples that have drawn theoretical attention are, e.g., the N-Z = -1 ^{159}Hg [4] and ^{240}Mt.This talk will provide an overview, from the experimental perspective, of the prospects for exploration of the nuclear landscape of very neutron-rich and very proton-rich nuclei. Some of the current experimental programs, the progress, and some of the valuables we have discovered so far will be reviewed. The possibilities for reaching the limits of the landscape at the next generation of facilities will also be discussed.

This work is supported by the National Science Foundation and Michigan State University.

REFERENCES

[1] J. Erler, N. Birge, M. Kortelainen, W. Nazarewics, E. Olsen, A.M. Perhac and M. Stoitsov, Nature 486 509 (2012).
[2] M. Thoennessen, http://www.nscl.msu.edu/~thoennes/isotopes/.
[3] A.A. Sonzogni, NuDat 2.6, NNDC Brookhaven National Laboratory, http://www.nndc.bnl.gov/nudat2/help/index.jsp .
[4] E. Olsen, et al., Phy. Rev. Lett. 110 222501 (2013).
[5] S. Goriely, J.-L. Sida, J.-F. Lemaitre, S. Panebianco, N. Dubray, S. Hilaire, A. Bauswein, and H.-J. Janka, Phy. Rev. Lett. 111 242502 (2013).

Monday

September 1st

RECENT DEVELOPMENTS IN THE MODELING OF NEUTRON-STAR CRUSTS

Nicolas Chamel, Université Libre de Bruxelles, Brussels, Belgium

N. Chamel[1], J. M. Pearson[2], A. F. Fantina[1], S. Goriely[1], R. L. Pavlov[3]

1 Institut d'Astronomie et d'Astrophysique, CP-226, Université Libre de Bruxelles, 1050 Brussels, Belgium
2 Département de Physique, Université de Montréal, Montréal, Québec, H3C 3J7 Canada
3 Institute for Nuclear Research and Nuclear Energy, Bulgarian Academy of Sciences, 72 Tsarigradsko Chaussee, 1784 Sofia, Bulgaria

Observations from ground- and space-based instruments have lead to the discovery of remarkable astrophysical phenomena that are thought to be intimately related to the physics of neutron-star crusts like pulsar sudden spin-ups (so called "glitches"), quasi-periodic oscillations in the giant flares from soft gamma-ray repeaters, X-ray bursts and superbursts, or the cooling of quasi-persistent soft X-ray transients. The crust composition is also essential to evaluate the possible contribution of neutron stars to the galactic enrichment in the so-called *r*-process nuclei, whose origin remains one of the major mysteries in astrophysics. Our recent achievements in the understanding of the physics of neutron-star crusts will be briefly reviewed. In particular, models of neutron-star crusts using accurately calibrated nuclear energy density functionals [1-5] will be presented, and discussed in relation with both astrophysical observations and terrestrial experiments.

REFERENCES

[1] J.M. Pearson, S. Goriely, N. Chamel, Physical Review C 83 (2011) 065810
[2] J.M. Pearson, N. Chamel, S. Goriely, C. Ducoin, Physical Review C 85 (2012), 065803
[3] N. Chamel, R. L. Pavlov, L. M. Mihailov, Ch. J. Velchev, Zh. K. Stoyanov, Y. D. Mutafchieva, M. D. Ivanovich, J. M. Pearson, and S. Goriely, Physical Review C 86 (2012), 055804
[4] N. Chamel, Physical Review Letters 110 (2013), 011101
[5] N. Chamel, D. Page, S. Reddy, Physical Review C 87 (2013), 035803

MICROSCOPIC CALCULATIONS OF NUCLEAR AND NEUTRON MATTER, SYMMETRY ENERGY AND NEUTRON STARS

Stefano Gandolfi, Theoretical Division, Los Alamos National Laboratory, Los Alamos, USA

The equation of state of neutron matter at nuclear densities is the bridge between the terrestrial experiments aiming to measure the symmetry energy and the structure of neutron stars. Around nuclear densities, the main role in this connection is played by the three-neutron force, whose form however is not totally understood yet because only weakly accessible in light nuclei. At the same time, astrophysical observations of neutron stars combined with microscopic calculations provide important constraints that can be combined with theoretical models to determine the symmetry energy and its slope.

In this talk, we will present a microscopic study of the equation of state of nuclear and neutron matter using realistic nuclear Hamiltonians. The ground state of the many body system is solved using Quantum Monte Carlo methods. We will discuss properties of the equation of state of neutron matter with a particular focus to the role of three-neutron forces. We will also present new results on the equation of state of nuclear matter and show the qualitative difference with respect to the pure neutron matter case using different nuclear interactions.

NUCLEAR ENERGY DENSITY FUNCTIONALS AND NEUTRON STAR PROPERTIES

Nils Paar, University of Zagreb, Croatia

Nuclear energy density functional (EDF) allows universal microscopic description of nuclear bulk properties, excitations and astrophysically relevant processes involving finite nuclei. In conjunction with recent experimental data for collective excitations, EDFs also provide additional constraints on the properties of nuclear equation of state, i.e. the symmetry energy that is of paramount interest for nuclear structure, nuclear reactions and astrophysics. In Ref. [1] we have studied relationships between properties of collective excitations in finite nuclei and the phase transition density n_t and pressure P_t at the inner edge separating the liquid core and the solid crust of a neutron star. A framework that includes the thermodynamic method and relativistic nuclear energy density functionals is employed in a self-consistent calculation of (n_t,P_t) and collective excitations in nuclei. The covariance analysis shows that properties of charge-exchange dipole transitions, isovector giant dipole and quadrupole resonances and pygmy dipole transitions are correlated both with the core-crust transition density and pressure. A set of relativistic nuclear energy density functionals, characterized by systematic variation of the density dependence of the symmetry energy of nuclear matter, is used to constrain possible values for (n_t,P_t). By comparing the calculated excitation energies of giant resonances, energy weighted pygmy dipole strength, and dipole polarizability with available data, the weighted average values are obtained [1]. It is shown that theoretical modeling and accurate measurements of excitation response in nuclei provide important source of information to determine the properties of neutron star crusts.

REFERENCES
[1] N. Paar, Ch. C. Moustakidis, T. Marketin, et al., arXiv:1403.7574 (2014).

THREE-BODY FORCES: FROM COLD ATOMS TO NUCLEI

Hans-Werner Hammer, TU Darmstadt and Extreme Matter Institute, GSI, Darmstadt, Germany

Physical systems close to the unitary limit show universal properties independent of the details of the interaction at short distances. In the case of a large scattering length, they can include the Efimov effect and log-periodic scaling. Such systems can be realized in experiments with ultracold atoms close to a Feshbach resonance, but also occur naturally in nuclear and particle physics. I will give an overview highlighting the role of three-body forces in this area of physics.

REFERENCES
[1] E. Braaten, H.-W. Hammer, Phys. Rep. **428** (2006) 259.
[2] H.-W. Hammer, A. Nogga, A. Schwenk, Rev. Mod. Phys. **85** (2013) 197.

EFFECTIVE FIELD THEORY AND DENSITY FUNCTIONALS

R.J. Furnstahl, The Ohio State University, Columbus, USA

The current use and future prospects of effective field theory (EFT) methods for constructing and analyzing energy density functionals (EDFs) of nuclei will be reviewed. One aspect is to assess whether phenomenological nonrelativistic and covariant EDFs, which have been precisely tuned to experimental data, exhibit signs (such as “naturalness” of the coupling constants) that they are low-energy theories of quantum chromodynamics (QCD), and how such information could be used to advantage. Another aspect is to use basic EFT principles, such as power counting and the need for a complete set of operators, to guide general extensions of existing phenomenology. Specific constructive extensions based on chiral EFT include using improved versions of the density matrix expansion to encode long-distance pion physics in hybrid functionals, as well as more ambitious efforts for a fully ab initio functional. An EFT perspective can also inspire questions about whether density functionals can be unique or universal, or whether there are inevitable scale and scheme dependencies, as well as suggest profitable generalizations of the density functional formalism.

This work is supported in part by the U.S. National Science Foundation under Grant No. PHY-1306250 and the NUCLEI SciDAC Collaboration under U.S. Department of Energy Grant No. DE-SC0008533.

NUCLEAR STRUCTURE AND DYNAMICS WITH DENSITY FUNCTIONAL THEORY

Ionel Stetcu, Los Alamos National Laboratory, Los Alamos, New Mexico, USA

Even in the absence of *ab initio* methods capable of tackling heavy nuclei without restrictions, one can obtain an *ab initio* description of nuclear properties by means of the density functional theory (DFT), and its extension to superfluid systems in its local variant, the superfluid local density approximation (SLDA). Furthermore, information about the properties of excited states can be obtained in the same framework by using an extension to the time-dependent (TD) phenomena. Within this approach, one describes accurately the interaction in both particle-hole and particle-particle channels, the treatment is fully self-consistent, and all symmetries of the Hamiltonian are properly accounted for. Thus, TDSLDA appears formally as a time-dependent self-consistent local mean-field approximation. In the limit of small amplitude limit the same description can be obtained within QRPA, but the power of the TD approach is that it can be extended beyond linear response. Thus, unlike other approaches in which the nuclear structure information is used as a separate input into reaction models, the TD approach treats on the same footing the nuclear structure and dynamics, and is well suited to provide more reliable description for a large number of processes involving heavy nuclei, from the nuclear response to electroweak probes, to nuclear reactions, such as neutron-induced reactions, or nuclear fusion and fission. In this talk, I will present the latest results of a full numerical implementation on leadership class supercomputers of the 3D TDDFT, extended to superfluid nuclear systems, free of any symmetry constraints. In particular, I will concentrate on the description of the process of Coulomb excitation of a ^{238}U nucleus. I will present the characteristic of neutron and gamma emissions up to about 2,500 *fm*/c after collision, and identify the main modes of excitation of the target nuclear system.

THE NUCLEAR SYMMETRY ENERGY AND OTHER ISOVECTOR OBSERVABLES FROM THE POINT OF VIEW OF NUCLEAR STRUCTURE

Gianluca Colò, Università degli Studi di Milano and INFN Sez. di Milano, Italy

During several years, great interest has been devoted to the problem of how to constrain well the isovector part of the nuclear effective force and/or, accordingly, the (a)symmetry part of the nuclear equation of state. This interest has been driven, among other, by the possibility of discussing on equal footing nuclear structure properties, phenomena taking place in nuclear collisions, and some observations of compact astrophysical objects like neutron stars.

In this contribution, we mainly discuss constraints on the symmetry energy that can be extracted by using mean-field (or energy density functional) calculations of masses of asymmetric nuclei, and of giant resonances or other collective states. The focus is on the following problem: there are many ways to infer constraints on the symmetry energy, and one should have tools to judge their reliability and mutual dependence.

We will discuss two main tools. Covariance analysis is a rigorous way to discuss correlations between observed properties and parameters of the nuclear equation of state, through the use of a theoretical model; we shall, however, show that covariance analysis provides different answers on those correlations, depending on the ansatz that are inherent in the models that are used. Macroscopic models like the liquid drop, although not rigorous, can provide a physical guideline to judge whether correlations that emerge correspond to an intuitive physical picture; we shall discuss relationships between the dipole and quadrupole isovector polarizabilities and symmetry energy parameters in this spirit.

We shall attempt an overall conclusion coming from all constraints proposed so far, and discuss possible new lines for research.

NUCLEAR STRUCTURE THEORY OF THE HEAVIEST NUCLEI

A.V. Afanasjev, Mississippi State University, Mississippi State, USA

The questions of the existence limits and the properties of shell-stabilized superheavy nuclei have been a driving force behind experimental and theoretical efforts to investigate the spectroscopy of the heaviest nuclei [1]. Unfortunately, theoretical predictions for superheavy nuclei differ considerably. In such a situation, heavy nuclei of actinide region play a role of testing ground for many theoretical approaches [2]. Systematic study of these nuclei allows to estimate theoretical uncertainties in the description of the properties of superheavy nuclei. The present status of our understanding of heavy and superheavy nuclei (with main emphasis on the results obtained within the covariant density functional theory) will be presented. I will concentrate on several aspects which define the shell structure, physical observables and stability of heavy and superheavy nuclei. These are single-particle degrees of freedom [3], pairing interactions [4], rotational excitations [4] and fission barriers [5,6], particle-vibration coupling in spherical superheavy nuclei [7,8] and the limits of nuclear landscape [9,10].

This work has been supported by the U.S. Department of Energy under the grant DE-FG02-07ER41459.

REFERENCES

[1] A.Sobiczewski and K.Pomorski, Prog. Part. Nucl. Phys. 58, 292 (2007).
[2] A.V.Afanasjev, T.L.Khoo, S.Frauendorf, G.A.Lalazissis and I.Ahmad, Phys. Rev. C 67, 024309 (2003).
[3] A.V.Afanasjev and S.Shawaqfeh, Phys. Lett. B 706, 177 (2011).
[4] A.V.Afanasjev and O.Abdurazakov, Phys. Rev. C 88, 014320 (2013).
[5] H.Abusara, A.V.Afanasjev and P.Ring, Phys. Rev. C 82, 044303 (2010).
[6] H.Abusara, A.V.Afanasjev and P.Ring, Phys. Rev. C 85, 024314 (2012).
[7] E.Litvinova and A.V.Afanasjev, Phys. Rev. C 84, 014305 (2011).
[8] E.Litvinova, Phys. Rev. C 85, 021303(R) (2012).
[9] A.V.Afanasjev, S.E.Agbemava, D.Ray and P.Ring, Phys.Lett. 726, 680 (2013).
[10] S.E.Agbemava, A.V.Afanasjev, D.Ray and P.Ring, Phys. Rev. C 89, 054320 (2014).

THE SYMMETRY ENERGY OF HOT ASYMMETRIC NUCLEAR MATTER

Hamidreza Moshfegh, University of Tehran, Tehran, Iran

H.R. Moshfegh, S. Goudarzi

Department of Physics, University of Tehran, North Karegar, P.O.B. 14395-547, Tehran, Iran

The knowledge of the nuclear symmetry energy of hot neutron-rich matter is important for understanding the dynamical evolution of massive stars and the supernova explosion mechanisms. In particular, the electron capture rate on nuclei and/or free protons in pre supernova explosions is especially sensitive to the symmetry energy at finite temperature. In view of the above, using the lowest order constrained variational method (LOCV) we calculate the symmetry free energy $F_{sym}(\rho,T)$ for hot, isospin asymmetric nuclear matter as a function of the temperature for various values of the baryon density by applying Argonne V18 two-body nucleon-nucleon interaction supplemented by a microscopic three-body force. The resulting density and temperature dependent symmetry free energy is then used to estimate its slope $F_{sym}(\rho,T)$ at normal density ρ_0. It is shown that the symmetry free energy generally increases with increasing temperature while the slope parameter exhibits opposite temperature dependence. The effect of the three-body force on $F_{sym}(\rho,T)$ and $L(\rho,T)$ is also discussed and the results are compared with the others many-body calculations.

PRODUCTION OF EXOTIC NUCLEI IN LOW-ENERGY MULTI-NUCLEON TRANSFER REACTIONS

Valeriy Zagrebaev, JINR, Dubna, Russia

A possibility for the production of exotic (mostly neutron rich) nuclei in low-energy multi-nucleon transfer reactions will be discussed in the talk. Due to the bending of the stability line toward the neutron axis, in fusion reactions of stable nuclei one may produce only short-living proton rich isotopes of heavy elements. For elements with $Z>100$ only neutron deficient isotopes (located to the left of the stability line) have been synthesized so far. That is the main reason for the impossibility to reach the center of the "island of stability" ($Z\sim110\div120$ and $N\sim184$) in fusion reactions with stable projectiles. Multi-nucleon transfer processes at near barrier collisions of heavy (and very heavy, U–like) ions seem to be most realistic reaction mechanism allowing one to produce new neutron enriched heavy nuclei located in the unexplored upper part of the nuclear map. Our predictions for the production of new neutron rich heavy nuclei in multi-nucleon transfer reactions will be discussed (along with dynamics of such processes) and new (most promising) experiments will be proposed. A special attention will be paid to the "inverse" quasi-fission mechanism leading to formation of reaction fragments with masses lighter than projectile and heavier than target masses [1].

Low-energy multi-nucleon transfer reactions are shown to be very effective tool also for the production and spectroscopic study of light exotic nuclei. The corresponding cross sections are found to be significantly larger as compared with high energy fragmentation reactions. Several optimal reactions for the production of extremely neutron rich isotopes of elements with $Z = 6\div14$ are proposed [2].

A new facility (based on selective laser ionization of reaction products) developed currently at the Flerov laboratory (JINR, Dubna) and aimed on the production and study of new neutron rich heavy nuclei produced in the multi-nucleon transfer reactions will be shortly reviewed.

REFERENCES
[1] V.I. Zagrebaev and W. Greiner, Phys. Rev. C 87, 034608 (2013).
[2] V.I. Zagrebaev, B. Fornal, S. Leoni and Walter Greiner, Phys. Rev. C 89, 054608 (2014).

SEMINAR

Monday 19:10

PAIRING CORRELATION STUDY IN THE $^{40}Ar+^{208}Pb$ MULTINUCLEON TRANSFER REACTION

Tea Mijatović, Ruđer Bošković Institute, Zagreb, Croatia

T. Mijatoć[1], S. Szilner[1], L. Corradi[2], D. Montanari[3], S. Courtin[3], F. Hass[3], E. Fioretto[2], A. Gadea[4], A. Goasduff[5], D. Jelavić Malenica[1], D. Mengoni[6], G. Montagnoli[6], G. Pollarolo[7], F. Scarlassara[6], N. Soić[1], A.M. Stefanini[2], C.A. Ur[2], J.J. Valiente-Dobon[2]

1 Ruđer Bošković Institute, Zagreb, Croatia
2 INFN – Laboratori Nazionali di Legnaro, Legnaro, Italy
3 IPHC, CNRS/IN2P3 and University of Strasbourg, Strasbourg, France
4 IFIC, CSIC - University of Valencia, Valencia, Spain
5 CSNSM, CNRS/IN2P3 and University Paris-Sud, Orsay Campus, France
6 INFN and University of Padova, Padova, Italy
7 INFN and University of Torino, Torino, Italy

Transfer reactions play an essential role in the study of collision dynamics and nuclear structure, particularly in the understanding of correlations in the nuclear medium. In the heavy-ion induced transfer reactions [1] the constituents of the collision may exchange many nucleons, thus providing information on the contribution of single particle and correlated particle transfers [2, 3].
The recent revival of transfer reaction studies benefited from the construction of the new generation large solid angle magnetic spectrometers based on ion trajectory reconstruction. One of the major achievements of the last years was the extraction of absolute differential cross sections through a careful study of the response function of the spectrometer [4].
Multinucleon transfer reaction $^{40}Ar+^{208}Pb$ was measured at E_{lab} = 255 MeV (~25% above the Coulomb barrier) at Laboratori Nazionali di Legnaro, Italy. The magnetic spectrometer Prisma was used to detect projectile-like particles in a large range of energies and angles. Coincident γ rays were detected by the γ-array Clara. Mass and charge yields, differential and total cross sections, total kinetic energy loss distributions of different channels produced in the reactions were simultaneously measured. For the first time angular distributions were measured with Prisma by matching different spectrometer angular settings. Absolute cross section was determined by careful evaluation of the spectrometer response function following the procedure discussed in Ref. [4]. The experimental differential cross sections for various transfer channels, corrected for the response of the spectrometer, will be presented. The relative role of the single particle and pair degrees of freedom in transfer processes will be discussed through their comparison with GRAZING calculations [5], placing the emphasis on the neutron-proton correlations.

REFERENCES
[1] L. Corradi, G. Pollarolo, S. Szilner, J. Phys. G 36, 113101 (2009)
[2] S. Szilner et al., PRC 84 014325 (2011)
[3] L. Corradi et al., PRC 84 034603 (2011)
[4] D. Montanari et al., Eur. Phys. J. A 47, 4 (2011)
[5] A. Winther, Nucl. Phys. A 572, 191 (1994); 594, 203 (1995); http://personalpages.to.infn.it/~nanni/grazing/

FISSION YIELDS OF MINOR ACTINIDES AT LOW EXCITATION ENERGY THROUGH MULTI-NUCLEON TRANSFER REACTIONS OF ^{238}U WITH CARBON

Diego Ramos, USC, Santiago de Compostela, Spain

D. Ramos[1], M. Caamaño[1], F. Farget[2], C. Rodriguez-Tajes[2], L. Audouin[3], J. Benlliure[1], J. Bertrand[2], E. Casarejos[4], E. Clement[2], D. Cortina[1], O. Delaune[2], X. Derkx[5], A. Dijón[2], D. Doré[6], B. Fernández-Domínguez[1], G. de France[2], A. Heinz[7], A. Navin[2], C. Paradela[1], M. Rejmund[2], T. Roger[2], M.-D. Salsac[6], C. Schmitt[2]

1 GENP, USC
2 GANIL, CEA/DMS-CNRS/IN2P3
3 IPN Orsay, Université de Paris-Sud XI-CNRS/IN2P3
4 CIMA, UVigo
5 LPC Caen, Université de Caen-ENSICAEN-CNRS/IN2P3
6 CEA Saclay, DSM/IRFU/SPhN
7 Chalmers University of Technology

Fission is the largest scale collective motion of the nucleons inside the nucleus while, at the same time, is strongly influenced by the microscopic structure of the nucleus. At low excitation energy, shell structure and pairing correlations sign the main features of the fission fragment distribution [1,2,3].

The wide range of isotopes produced by the fission facilitates the study of exotic nuclei, which are inaccessible through any other reaction. Predicting the fission properties of these exotic nuclei is of importance for the design of new-generation nuclear power plants and for the incineration of nuclear waste. The measured yields can also be useful for RIB production.

Experimental access to full isotopic fragment distributions is very important to determine the features of the fission process. However, the complete identification of the fission fragments proved to be a challenge so far. A solution based on the use of inverse kinematics to study transfer-induced fission of minor actinides was carried out in GANIL in 2008, and again in 2011, resulting in the first experiment accessing the full identification of a collection of fissioning systems and their corresponding fission fragments distribution [4,5].

In these experiments, a 238-U beam at 6.1 AMeV impinged on a 12-C target to produce fissioning systems from Am to U by transfer reactions. These actinides were identified and their excitation energy deduced from the detection of the recoil nucleus in an angular DE-E stripped silicon telescope. The use of the VAMOS spectrometer allowed the identification of the fragments, as well as the reconstruction of the emission angle in the fission decay [6].

This contribution presents the first results concerning the fission yields for the different transfer channels as well as for the fusion-fission channel and its evolution with the excitation energy. Others observables will be also discussed, such as the neutron excess and the total kinetic energy of the fission products.

REFERENCES

[1] J. L. Sida et al., Nucl. Phys. A 502, 233c (1989).
[2] S. Steinhauser et al., Nucl. Phys. A 634, 89 (1998).
[3] C. Böckstiegel et al., Nucl. Phys. A 802, 12 (2008).
[4] M. Caamaño et al., Phys. Rev. C 88, 24605 (2013).
[5] C. Rodríguez-Tajes et al., Phys. Rev. C 89, 24614 (2014).
[6] S. Pullanhiotan et al., Nucl. Instr. Meth. A 593, 343 (2008).

PRE-EQUILIBRIUM PARTICLES EMISSION AND ITS POSSIBLE RELATION TO A-CLUSTERING IN NUCLEI

Daniela Fabris, INFN Sezione di Padova, Italy

D. Fabris[1], F. Gramegna[2], T. Marchi[2],M. Degerlier[3], O.V. Fotina[4,5], V.L. Kravchuk[6], M. D'Agostino[7], L. Morelli[7], S. Appannababu[2], G. Baiocco[7], S. Barlini[8], M. Bini[8], A. Brondi[9], M. Bruno[7], G. Casini[8], M. Cinausero[2], N. Gelli[8], R. Moro[9], A. Olmi[8], G. Pasquali[8], S. Piantelli[8], G. Poggi[8], S. Valdrè[8], E. Vardaci[10]

1 INFN sezione di Padova, Padova, Italy
2 Laboratori Nazionali di Legnaro, Legnaro (PD), Italy
3 Nevsehir Haci Bektas University, Science and Art Faculty, Physics Department, Nevsehir, Turkey
4 Physical Department, Lomonosov Moscow State University, Moscow, Russia
5 Skobeltsyn Institute of Nuclear Physics, Lomonosov Moscow State University, Moscow, Russia
6 National Research Center "Kurchatov Institute", Moscow, Russia.
7 Dipartimento di Fisica, Università di Bologna and INFN sezione di Bologna, Bologna, Italy
8 Dipartimento di Fisica, Università di Firenze and INFN sezione di Firenze, Firenze, Italy
9 Dipartimento di Fisica, Università di Napoli and INFN sezione di Napoli, Napoli, Italy
10 Dipartimento di Fisica, Università di Caserta and INFN sezione di Napoli, Napoli, Italy

The study of nuclear states built on clusters bound by valence neutrons in their molecular configurations is a field of large interest: in particular clustering will become important at the drip–line, where weakly bound systems will prevail [1]. Although for light nuclei at an excitation energy close to the particle separation value there are experimental evidences of such structure effects, this is still not the case for heavier nuclear systems. Many attempts have been done using preformation alpha clustering models, but there is still a lack of experimental data capable to give a direct feedback [2].

In the past we have studied the reactions 250, 192 and 130 MeV ^{16}O + ^{116}Sn, observing a significant increase in the fast emitted α-particle yield. This effect was ascribed to the presence of pre-formed α-clusters in the ^{16}O projectile nucleus [3].

To further investigate these aspects, a new experimental campaign has been performed with the GARFIELD + RCo multi-detection system at LNL [4], by comparing two different reaction entrance channels at the same beam velocity: ^{16}O + ^{65}Cu and ^{19}F + ^{62}Ni leading to the same ^{81}Rb* compound nucleus. The angular distributions and the light charged particles emission spectra in coincidence with evaporation residues have been measured and analyzed.

We will present the preliminary results of the data analysis together with theoretical model interpretations.

It would be interesting to extend these type of studies to the neutron-rich nuclei produced by the SPES facility, employing reactions in which a double-magic nucleus like ^{132}Sn interacts with an α-cluster structured target, for example ^{12}C or ^{28}Si.

REFERENCES

[1] W. von Oertzen et al., Phys. Rep. 432, 43-113(2006) and M. Freer Rep.prog. Phys. 70 (2007) 2149-2210.

[2] H. Horiuchi, Proc. of the VII Int. Conf. on Clustering Aspects of Nuclear Structure and Dynamics, Rab, Croatia, 1999, World Scientific, Singapore, River Edge, NJ, 405(2000).

[3] O.V. Fotina et al., Int. Journ. Mod. Phys. E 19, 1134(2010).

[4] F. Gramegna et al., Proc. of 2004 IEEE Nucl. Science Symp., Rome, Italy, 0-7803-8701-5/04/ ; M. Bruno et al. EPJA 49 (2013)12.

LOW ENERGY INCOMPLETE FUSION AND THE ROLE OF INPUT ANGULAR MOMENTA

Rakesh Kumar, Inter University Accelerator Centre, New Delhi, India

R. Kumar[1], Vijay R. Sharma[2], Abhishek Yadav[2], Pushpendra P. Singh[3], S. Appannababu[4], A. Aggarwal[5], B. P. Singh[2], S. Mukherjee[6], R. Ali[2] and R.K. Bhowmik[1]

1 Inter University Accelerator Centre (IUAC), Aruna Asaf Ali Marg, New Delhi – India
2 Accelerator Laboratory, Department of Physics, A.M. University, Aligarh-India
3 Department of Physics, Indian Institute of Technology Ropar, Panjab -140 001, India
4 INFN-Laboratori Nazionali di Legnaro, I-35020 Legnaro, Italy
5 Department of Physics, Bareilly College, Bareilly - 243 005, India
6 Department of Physics, M.S. University of Baroda, Vadodara - 390 002, India

The dynamics of incomplete fusion (ICF), where only a part of projectile fuses with target nucleus, has been extensively investigated and is found to compete with complete fusion (CF) at low incident energies, i.e., $E_{lab} \approx$ 4-7 MeV/A. However, the complex mechanism of incomplete mass transfer is still not well understood and, thus, continues to be an active area of investigation. Recent reports suggest that the probability of ICF depends on alpha-Q-value of projectile [1-2], and the ICF events at low incident energies are found to be originated from the high input angular momenta imparted into the system due to non-central collisions[3]. Apart from the well documented existence of low energy ICF, a strong contradiction on previously established mass- asymmetry systematics has been noticed recently. It has found that the ICF fraction increases with entrance channel mass-asymmetry for the individual projectiles [1-2]. It may, however, be pointed out that the conclusion drawn in these reports are based on the results obtained with α-cluster beams (e.g., ^{12}C, ^{16}O, and ^{20}Ne). The fact that the α-cluster nuclei easily breakup into constituent α-clusters which may eventually lead to fusion incompleteness. Nevertheless, how does ICF show up for non-α-cluster beams is an interesting puzzle, and is not yet fully understood. For better insights into the onset and strength of ICF in terms of various entrance channel parameters, an inclusive experiment has been performed at IUAC New Delhi with non-α-cluster beams ^{14}N. Excitation functions of individual evaporation residues produced in $^{14}N(E_{lab}$=4-7MeV/nucleon)+^{169}Tm are measured, and analyzed in the framework of equilibrated compound nucleus decay model. The ICF strength function is deduced from the analysis of experimental excitation functions and the present results are compared with nearly systems. The effect of an additional np-pair over α-cluster configuration of ^{12}C beam on the onset and strength of ICF is studied. Further, an attempt has been made to calculate ICF probability using a **M**ulti-step p**A**rtial **R**eaction **C**ross-section (**MARC**) model code [4]. It has been found that the code MARC reasonably predicts the ICF cross-sections for the studied energy range. MARC calculations employs an empirical function which depends on input angular momenta of the system. Details of the MARC calculations and experimental results will be presented.

REFERENCES

[1] Abhishek Yadav et al., Phys. Rev C. 85, 064617 (2012).
[2] Vijay R. Sharma et al., Phys. Rev. C 89, 024608 (2014) and references therein.
[3] Pushpendra P. Singh et al., Physics Letters B 671, 20-24 (2009)
[4] R. Kumar et al., Nucl. Phys. Symp. V56 (2011) B81 614. (http://www.sympnp.org/proceedings/)

SEMINAR

Monday 20:10

EXPERIMENTAL STUDIES OF THE COULOMB FORCE EFFECTS IN DEUTERON-PROTON BREAKUP REACTION AT MEDIUM ENERGY REGIME

Izabela Ciepał, Institute of Physics, Jagiellonian University, Kraków, Poland

I. Ciepał[1], B. Kłos[2], St. Kistryn[1], E. Stephan[2], A. Kozela[3]

1 Institute of Physics, Jagiellonian University, Kraków, Poland
2 Institute of Physics, University of Silesia, Katowice, Poland
3 Institute of Nuclear Physics PAN, Kraków, Poland

Experimental study of deuteron-proton breakup reaction can serve as a valid tool for investigation of interaction between nucleons. Especially, the differential cross-section for the breakup process is very sensitive to different pieces of the system dynamics like three-nucleon force (3NF), Coulomb interaction or relativistic effects, which reveal their influence at various parts of the phase-space. In medium energy domain the properties of few-nucleon systems are successfully modeled with the use of the realistic potentials, coupled-channel (CC) method or Chiral Perturbation Theory (ChPT). However, at certain level of precision, much subtle effects can be studied. The calculations, which describe those additional dynamics include the model of 3NF (e.g. Tucson Melbourn TM force) and/or the Coulomb force.

Experiments devoted to study such subtle ingredients of nuclear dynamics were carried out in KVI Groningen [1-4,7] and FZ-Juelich [5,6] with the use of the dp->ppn breakup reaction at 100 [4], 130 [1-6], 160 [7] MeV deuteron beam energy. They contributed immensely to creating a data base for the breakup process, providing high precision data for a differential cross sections and for vector and tensor analyzing powers.

The data are confronted with the set of the modern calculations. Especially the cross-section data [5,6] obtained in the forward angular region (4^{O}-14^{O}) revealed large effects of the Coulomb interaction. In case of the polarization observables the influence of the electromagnetic component is rather moderate. The Coulomb force is theoretically treated within the CC approach [8] as well as the realistic Argonne V18 potential combined with Urbana IX 3NF model [9].

REFERENCES

[1] St. Kistryn at al., Phys. Rev. C 72, 044006 (2005).
[2] St. Kistryn at al., Phys. Lett. B 641, 23 (2006).
[3] E. Stephan at al., Phys. Rev. C 82, 014003 (2010).
[4] E. Stephan at al., Eur. Phys. J. A 49:36 (2013).
[5] I. Ciepał at al., Phys. Rev. C 85, 017001 (2012).
[6] I. Ciepał at al., Few-Body Syst., (2014).
[7] W. Parol at al., Acta Phys. Pol. B, No. 2, Vol. 45 (2014)
[8] A. Deltuva at al:, Phys. Rev. C 72, 054004 (2005).
[9] A. Deltuva, Phys. Rev. C 80, 064002 (2009).

STRUCTURAL EFFECTS ON THE PEAK PRODUCTION OF FRAGMENTS

Sukhjit Kaur, Panjab University, Chandigarh, India

S. Kaur and S. Sood,

Department of Physics, Panjab University, Chandigarh-160014, India

It is well established that the breaking of the nuclei is affected by the incident beam energy, collision geometry as well as by the mass of the reacting partners. In addition to various entrance channels, the initialization of the nuclei in a transport model also affects the dynamics. The structural effects that enter the calculations through the radii of colliding nuclei play crucial role on various phenomena such as fission, fusion, cluster radioactivity, formation of super heavy nuclei, collective flow and multifragmentation etc. In the present study, we check the role of systematic reduction and enhancement in (liquid drop model (LDM) based) nuclear radius on the multiplicities of various fragments within the Isospin-dependent Quantum Molecular Dynamics (IQMD) picture. We find that multiplicities of various fragments are sensitive towards the initial setup of the nucleus. We also study the effect of nuclear radius on the peak center-of-mass energy ($E_{c.m.}^{max}$) and peak multiplicity of the intermediate mass fragments ($\langle N_{IMF}\rangle^{max}$). We find that both $\langle N_{IMF}\rangle^{max}$ and $E_{c.m.}^{max}$ are sensitive towards the nuclear radius.

The authors are thankful to Prof. Rajeev K. Puri for enlightening discussions on the present work.

SEMINAR

Monday 20:25

EFFECT OF ELECTRON SCREENING ON NUCLEAR REACTION RATES

Jelena Vesic, Jozef Stefan Institute, Ljubljana, Slovenia

J. Vesic, A. Cvetinovic, T. Petrovic, M. Lipoglavsek,

Jozef Stefan Institute, 1000 Ljubljana, Slovenia

Reliable cross section data at low energies are crucial for precise determination of thermonuclear reaction rates. However, stellar environments cannot be reproduced in a laboratory and the influence of electronic environment on nuclear reaction rates in such conditions cannot be experimentally deduced. Therefore, it is of significant importance to measure the bare cross sections as well as possible. The problem is that at low energies at which these reactions occur, the cross section depends exponentially on the height of the Coulomb barrier [1]. Even small changes to the barrier caused by inevitable electrons that surround the reacting nuclei in almost all laboratory experiments have a significant effect on the cross section. Consequently, the measured reaction rates are enhanced compared to reaction rates for bare nuclei.

Experimental studies of various nuclear reactions in metallic environments have shown the expected cross section enhancement at low energies [2-4]. However, the enhancements in metallic targets were significantly larger than expected from the adiabatic limit which is thought to provide the theoretical maximum for the magnitude of electron screening. The discrepancy between the measurements and the adiabatic limit is presently not understood under laboratory conditions, therefore the size of electron screening has to be measured for each metallic environment and each target separately.

Although studied for more than two decades, electron screening still poses some open questions. In order to try to find an answer to some of them we studied electron screening in the laboratory for nuclear reactions involving low Z targets. The $^{1}H(^{7}Li,\alpha)^{4}He$ reaction was studied in inverse kinematics at lithium beam energies from 0.3 to 2.1 MeV in different metallic environments, namely hydrogen implanted Pd, Pt, Zn and Ni targets. Large electron screening of a few keV was observed for all studied targets. These results motivated us to continue our experimental campaign with measurements of electron screening potentials in proton induced reactions on high Z targets. However, surprisingly no large electron screening was observed in the following proton capture reactions: $^{55}Mn(p,\gamma)^{56}Fe$, $^{51}V(p,\gamma)^{52}Cr$ and charge exchange reactions: $^{55}Mn(p,n)^{55}Fe$, $^{113}Cd(p,n)^{113}In$, $^{115}In(p,n)^{115}Sn$, $^{50}V(p,n)^{50}Cr$. Furthermore, no shift in resonance energy for metallic relative to insulator environment was observed for the studied (p,n) and (p,γ) reactions. These results rise a question on the validity of the measurements that showed large electron screening potentials in nuclear reactions involving high Z targets [5] and might suggest a dependence of the electron screening on the position of the target nuclei in a metallic lattice.

REFERENCES
[1] H. J. Assenbaum, K. Langanke and C. Rolfs, Z. Phys. A327, 461 (1987).
[2] J. Cruz et al., Phys. Lett. B624, 181 (2005).
[3] J. Kasagi, Prog. Theor. Phys. Suppl. 154, 365 (2004).
[4] F. Raiola et al., Eur. Phys. J. A 19, 283 (2004).
[5] K. U. Kettner et al., J. Phys. G 32, 489 (2006).

COULOMB DISSOCIATION OF ^{27}P

Justyna Marganiec, TU Darmstadt, Germany

J. Marganiec[2], S. Beceiro-Novo[1], S. Typel[2], Ch. Wimmer[3], T. Aumann[2,4], D. Cortina Gil[1], M. Heil[2], K. Sümmerer[2]
and the R^{3}B collaboration

1 Universidade de Santiago de Compostele, Santiago de Compostela, Spain
2 GSI, Darmstadt, Germany
3 Goethe-Universität, Frankfurt am Main, Germany
4 TU Darmstadt, Germany

The rp-process, a sequence of rapid proton captures and beta-decays along the proton-rich side of the chart of nuclides, plays a role in nova, X-ray burst and gamma-ray burst scenarios. Under certain conditions, the proton-capture reaction ^{26}Si(p,γ)^{27}P can be an important part of this process. We have investigated this reaction by the Coulomb-dissociation (CD) method at GSI in Darmstadt, Germany by impinging a 500 AMeV ^{27}P beam onto a Pb target and accounting for nuclear interactions by subtracting properly scaled spectra obtained from using a ^{12}C target. The R^{3}B-LAND setup was used to detect the ejectiles, ^{26}Si and proton, together with gamma-rays in complete kinematics. By applying detailed balance, the differential CD cross sections were converted to radiative-capture cross sections. We will discuss new insights into the nuclear structure of ^{27}P resulting from our experiment and consequences for the astrophysical rp-process.

Tuesday

September 2nd

SHAPE COEXISTENCE, TRIAXIAL SHAPE AND BAND TERMINATIONS AT HIGH SPIN

Ingemar Ragnarsson, Lund University, Sweden

High-spin bands in nuclei with A ≈ 120-170 are interpreted using the cranking formalism where pairing is either neglected (CNS [1,2]) or included (CNSB [3]). The advantage of the unpaired formalism is that configurations can be fixed in a much more detailed way. The combination of these two methods [4] is a very powerful way to get a detailed understanding of observed high-spin states.
Different phenomena will be considered, e.g.

- Triaxial shapes with rotation around different axes [5].
- The competition between triaxial configurations and terminating configurations in A ~ 150-165 nuclei [4].
- The competition between configurations with and without neutrons excited across the N=82 gap in nuclei around ^{125}Xe [6].
- Configurations observed at energies high above yrast

REFERNCES
[1] A. V. Afanasjev, D. B. Fossan, G. J. Lane, and I. Ragnarsson, Phys. Rep. 322, 1 (1999).
[2] B. G. Carlsson and I. Ragnarsson, Phys. Rev. C 74, 011302 (2006).
[3] B. G. Carlsson *et al.*, Phys. Rev. C 78, 034316 (2008).
[4] Hai-Liang Ma, B. G. Carlsson, I. Ragnarsson and H. Ryde, Phys. Rev. C, to be publ.
[5] C.M. Petrache *et al.*, Phys. Rev. C 88, 051303 (2013).
[6] I. Ragnarsson *et al.*, Int. Nucl. Phys. Conf. INPC 2013, contrib. NS187

STUDIES OF VERY ENLOGATED NUCLEAR SHAPES IN HOT NUCLEI AT VERY HIGH SPINS - STATUS AND NEW OPPORTUNITIES WITH RIBS

Adam Maj, IFJ PAN Kraków, Poland

The study of properties of the giant dipole resonance (GDR) at high temperature and angular momentum is one of the central topics in nuclear structure as it provides insight into the behavior of nuclei under extreme conditions. Of special interest are shape changes induced by high angular momentum leading to very elongated nuclear shapes, particularly the predicted Jacobi and Poincare shape transitions. The former one has been experimentally observed in number of nuclei up to mass 90 [1-5]. The latter is predicted [6,7] to occur at extremely very high spins in exotic neutron-rich nuclei formed in fusion-evaporation reactions induced by high-intensity radioactive beams

In the talk the status of experimental findings, their interpretation, and possible connections to the superdeformed and hyperdeformed structures at low temperatures will be overviewed. In addition the outlook of this type of studies will be discussed in the context of soon available radioactive beam facilities. Especially the concept and status of the novel gamma-ray calorimeter PARIS [8] and its role in such investigations will be discussed will be presented.

REFERENCES

[1] M. Kicinska-Habior et al., Phys. Lett. B308, 225 (1993);
[2] A. Maj et al., Nucl. Phys. A731, 319 (2004);
[3] M. Kmiecik et al., Acta Phys. Pol. B38, 1437 (2007);
[4] D. Pandit et al., Phys. Rev. C81, 061302 (2010);
[5] M. Ciemala et al., Acta Phys. Pol. B42, 633 (2011);
[6] A. Maj et al., Int. J. Mod. Phys. E19, 532 (2010);
[7] K. Mazurek et al., Acta Phys. Pol. B42, 471 (2011);
[8] A. Maj et al., Acta Phys. Pol. B40 (2009).

RECENT RESULTS AT ULTRAHIGH SPIN: TERMINATING STATES AND BEYOND IN MASS 160 RARE-EARTH NUCLEI

Edward Paul, University of Liverpool, UK

One of the most intriguing aspects of atomic nuclei is the generation of angular momentum through the delicate interplay between collective and single-particle degrees of freedom. Rare-earth nuclei with a limited number of neutrons above the N = 82 shell closure, and protons above Z = 64, lie in a transitional region where collective behavior varies rapidly with changing particle number. They tend to be susceptible to shape changes in the triaxial γ plane and exhibit energetically favoured non-collective band-terminating states at spins around 40-50ħ due to the limited number of valence particles. Results will be presented for new terminating states in the odd-Z ^{155}Ho, odd-odd ^{156}Ho and even-even ^{156}Er isotopes following experiments with Gammasphere. In addition to these particularly favoured states, the occurrence of collective triaxial strongly deformed (TSD) bands, bypassing the terminating states and extending to over 65ħ, will be reviewed.

HIGH-SPIN PHYSICS WITH THE PROJECTED SHELL MODEL

Yang Sun, Shanghai Jiao Tong University, Shanghai, China

Performing shell model calculations for heavy, deformed nuclei has been a challenging problem in nuclear physics. The projected shell model idea [1] makes it possible to bridge two traditional nuclear physics methods: the deformed mean-field and the shell model. By using the angular-momentum-projection technique, in which one starts with (in principle, any) deformed single-particle states to construct a shell model basis, one can show that this is a simple, yet efficient approach for heavy, deformed nuclei.

The original version of the projected shell model [1] assumes an axial deformation with restricted types of quasi-particle configuration in its model space. We have recently extended the model in the following aspects. (1) The configuration space has been expanded to include 6-qp states for both positive and negative parities [2]. This development enables us to study some interesting high-spin phenomena. As the first application of the Pfaffian algorithm in spectroscopy calculation, we take ^{166}Hf as an example and show that 6-qp states become the main configuration in the yrast band beyond spin I~34, which explains the observed third back-bending in moment of inertia. Multi-qp high-K isomers in ^{176}Hf with different configurations are investigated as another example. Extension of the original projected shell model to a triaxially-deformed basis with three-dimensional angular-momentum-projection has also been done [3,4].

This work was collaborated with J. A. Sheikh, T. Mizusaki, M. Oi, and others, and supported by the National Natural Science Foundation of China (No. 11135005) and by the 973 Program of China (No. 2013CB834401).

REFERENCES

[1] K. Hara, Y. Sun, Int. J. Mod. Phys. E4, 637 (1995).
[2] L.-J. Wang, F.-Q. Chen, Y. Sun, T. Mizusaki, M. Oi, submitted
[3] J. A. Sheikh, G. H. Bhat, Y.-X. Liu, F.-Q. Chen, Y. Sun, Phys. Rev. C 84, 054314 (2011);
[4] J. A. Sheikh, G. H. Bhat, Y. Sun, R. Palit, Phys. Lett. B 688, 305 (2010).

FIRST STEPS TOWARDS ACCESSING THE HIGH ISOSPIN - SPIN FRONTIER

Navin Alahari, GANIL, Caen, France

In the mid eighties there were two major experimental breakthroughs in nuclear physics; one by Tanihata and his collaborators [1] on the existence of the “halo” phenomenon in neutron rich nuclei and the other was by Twin and his collaborators [2] on the existence of very large deformation at high angular momentum. In the last decades great advances have been made in understanding the evolution the many facets of a nucleus *independently* at high angular and at large isospin. The latter exploited the great advances in the resolving power of gamma-ray detectors and used fusion reactions at energies around the barrier and the former is driven by technical advances in the production of high energy secondary short lived beams and first generation re-accelerated beams and their associated instrumentation. One of the question which can be of interest which has not been yet addressed is how this many body system will behave at *both* at large isospin AND large angular momentum. The question is weather we expect to get some new insight by studying of either the underlying collective symmetries or manifestations of the individual nucleons filling nuclear shells at these two extremes simultaneously ?

The natural way to address this would be to use the next generation very high intensity ISOL facilities. As this may take some more time, we have made a first attempt in this direction. In this talk we will present the first steps towards a possible new frontier for nuclear physics namely the physics of high spin *and* isospin, from the measurements of prompt gamma rays in coincidence with fragments, identified in M and Z, produced in fission reactions around the Coulomb barrier using beams far from the dripline (stable beams). Measurements made at GANIL of prompt gamma rays in coincidence with isotopically-identified fission fragments, produced in collisions of ^{238}U on a ^{9}Be target, at an energy around the Coulomb barrier, will be presented. Selected results using this technique, which provides simultaneous access to the spectroscopy of many nuclei, extending to very neutron-rich isotopes and relatively high angular momenta will be presented. The complementarity of the present work with the conventional high-fold gamma-coincidence method will also be discussed. The status of the next phase of the γ-ray tracking detector AGATA, at GANIL, where it is being coupled with VAMOS^{++} will also be briefly presented.

REFERENCES
[1] I. Tanihata *et al.,* Phys. Rev. Lett. 55 2676 (1985).
[2] P.J. Twin *et al.*, Phys. Rev. Lett. 57 811 (1986).

THE LAST PRESPEC - AGATA CAMPAIGN

Magdalena Górska, GSI Darmstadt, Germany

Nuclear structure studies at GSI attracted recently an increased interest for the results from the present activities as well as for the future project FAIR. A broad range of physics phenomena could have been addressed by high-resolution in-beam γ-ray spectroscopy experiments with radioactive beams offered within the PRESPEC-AGATA experimental campaign. It combined the AGATA spectrometer, the HECTOR array, the fragment separator FRS, and the secondary beam identification setup LYCCA. The secondary beams produced at relativistic energies were used for Coulomb excitation or secondary fragmentation experiments to study projectile like nuclei by measuring de-excitation photons. The first and preliminary nuclear structure results of the last campaign will be presented in the framework of various model calculations. The discussion will include quadrantic evolution of the collectivity around ^{208}Pb, the Pygmy Dipole Resonance in the ^{68}Ni region, and isospin-symmetry-breaking phenomena in the $f_{7/2}$ shell. The flexibility of the PRESPEC setup allowed also to perform prove-of-principle slow-down-beam experiment.
Ideas born from the experience with the PRESPEC project will lead to an improved instrumentation for NUSTAR at FAIR. In particular, nuclear structure based on γ-ray spectroscopy will be a main goal of the HISPEC/DESPEC experiments.

OVERVIEW OF IN-BEAM GAMMA-RAY SPECTROSCOPY AT THE RIBF

Pieter Doornenbal, RIKEN Nishina Center, Wako, Japan

At the Radioactive Isotope Beam Factory stable primary beams are accelerated up to 345 MeV/nucleon and incident on a target to produce secondary beam cocktails with the fragment separator BigRIPS ranging from the lightest nuclei up to the uranium region. For in-beam gamma-ray spectroscopy, the secondary beams impinge on a reaction target at energies between 100 and 300 MeV/nucleon. Reaction residues are detected with the ZeroDegree spectrometer and gamma-rays detected with the NaI(Tl) based DALI2 array.

In my presentation I will give an overview of recent experiments performed at the RIBF employing this technique including the first spectroscopy of ^{54}Ca, measurements inside and beyond the "Island of Inversion" as well as investigations around the doubly -magic nuclei ^{78}Ni and ^{132}Sn.

Besides discussing selected results a description of the setup and an overview of in-beam gamma-ray spectroscopy physics program at the RIBF will given.

COULOMB EXCITATION FOR QUADRUPOLE MOMENTS MEASUREMENTS

Paweł J. Napiorkowski, University of Warsaw, Heavy Ion Laboratory, Warszawa, Poland

INVITED

Tuesday 11:50

Almost a half of century ago quadrupole moments of first excited states were studied using the reorientation effect in Coulomb excitation. The angular distribution of gamma-rays measured with a few detectors only allows to determine nuclear deformation.

In the modern COULEX experiments very efficient multi-detector detection systems are employed to study complex structures of nuclei. Extensive sets of matrix elements derived from Coulomb excitation experiments are the basis for a comprehensive analysis of nuclear deformation. The Quadrupole Sum Rules approach [1] makes possible to deduce the quadrupole deformation parameters – the overall deformation as well as triaxiality.

In the analysis of contemporary COULEX experiments appropriate tools are necessary to perform a multi-parametric fit of electromagnetic matrix elements to experimental data. The GOSIA code developed by Czosnyka, Cline and Wu in the eighties [2] still remains a standard in this domain. Its recent development implementing advanced computer technologies, namely genetic algorithms [3], will help to obtain more reliable results in a faster way.

REFERENCES

[1] D.Cline, Annu. Rev. Nucl. Part. Sci 36, 683 (1986).

[2] T. Czosnyka, et al., Bull Amer. Phys.Soc. 28, 745 (1983), http://www.slcj.uw.edu.pl/gosia.

[3] D.A.Piętak et al., Proceedings ECCTD (European Conference on Circuit Theory and Design), Linkoping 29-31 August 2011

MIRROR SPECTROSCOPY IN THE UPPER *fp* SHELL WITH GRETINA

Thomas Henry, The University of York, York, UK

T. Henry[1], R.M. Clark[2], M.A. Bentley[1], H.L. Crawford[2], A.O. Macchiavelli[2], E. Simpson[3], S.M Lenzi[4], V. Bader[5], T. Baugher[5], D. Bazin [5], C.W Beausang[6], J. Berryman[5], A.M. Bruce[8], C. M. Campbell[2], M. Cromaz[2], P. Fallon[2], A. Gade[5], P.J. Davies[1], H. Iwasaki[5], D.G. Jenkins[1], I.Y. Lee[2], A. Lemasson[5], D.N. Napoli[7], A.J Nichols[1], S. Paschalis[2], M. Petri[2], F. Recchia[5], J. Rissanen[2], T. Ross[6], R. Stroberg[5], R. Wadsworth[1], D. Weisshaar[5], A. Wiens[2]

1 University of York, Heslington, York, YO10 5DD, UK
2 Nuclear Science Division, Lawrence Berkeley National Laboratory, Berkeley, California 94720, USA
3 University of Surrey, Guildford, Surrey GU2 7XH
4 Istituto Nazionale di Fisica Nucleare Sezione di Padova, Via Marzolo 8, 35131 Padova, Italy
5 National Superconducting Cyclotron Laboratory, Michigan State University, East Lansing, Michigan 48824, USA
6 University of Richmond, 28 Westhampton Way, University of Richmond, Virginia, United States
7 Laboratori Nazionali di legnaro, Viale dell'Universit, 2, 35020 Legnaro Padova, Italy
8 University of Brighton, Mithras House, Lewes Rd, Brighton, BN2 4AT, UK

The idea of charge independence is related to the concept of isospin where the proton and neutron are treated as the same particle (the nucleon) distinguished by the isospin projection, Tz, on a quantization axis. Isospin symmetry is broken largely by the Coulomb interacting, having accounted for this there may be residual nuclear isospin non conserving effects. Experimentally, to search for such effects, one examines energy differences between Isobaric Analogue States (IAS). These differences are described in terms of isovector and isotensor components.

Previous work on nuclei in the $f_{7/2}$ shell has revealed new and unexpected isospin breaking effects which cannot easily be explored with the Coulomb interaction alone. To investigate such effects in even heavier systems of the upper-*fp* shell, an experiment was carried out at the National Superconducting Cyclotron Laboratory in Michigan State University. A ^{78}Kr primary beam was fragmented with secondary beam particles identified in the A1900 spectrometer, secondary fragmentation took place at the target position of the S800 spectrograph with the GRETINA detector system measuring gamma-rays. New results include: 1) The structure of ^{65}As investigated through mirrored knockout, the selection of observed states will be described by the emission of a $g_{9/2}$ proton from an isomeric state; 2) new states in ^{63}Ge are observed and allow us to measure the A = 63 mirror energy differences. These results will be discussed and further described within the context of shell model calculations; 3) a candidate for the T = 1 $J^{\pi} = 2^{+}$ state in ^{62}Ga has been identified with better agreement to systematics of known odd-odd isobaric states than the candidate suggested in the literature.

A SHAPE STUDY OF ^{72}Kr USING THE REX - ISOLDE/MINIBALL SET - UP

B.S. Nara Singh (for the I478 Collaboration), University of York, Heslington, UK

Experimental studies often encountered prolate deformed nuclei across the nuclear chart. As a consequence, significant information to shed light on the emergence of prolate deformation exists [1]. By contrast, very limited data are available of oblate nuclear states at low spins due to their rarity and therefore, the corresponding mechanism responsible for producing oblate deformation in nuclei is far from being fully understood. The mass ~ 70 region is well known for nuclei exhibiting co-existing shapes having contributions from the oblate shape configurations [2]. The Kr isotopes constitute one such example of an isotopic chain that also includes the special case of the first excited 2^+ state in ^{72}Kr, for which all the existing experimental and the theoretical information indicate an oblate deformation [3, 4]. However, there has been no direct experimental evidence. Therefore, we carried out a low-energy inelastic Coulomb excitation study to determine the shape of ^{72}Kr residing in the 2^+ state utilizing the re-orientation effect [5]. We employed state-of-the art beam production techniques and obtained the radioactive ^{72}Kr nuclei having 2.85 MeV/u energy as a beam with sufficient intensity at REX-ISOLDE. The beam was delivered to the target position of the MINIBALL gamma ray array where a 2 mg/cm^2 ^{104}Pd target was installed. The Coulomb field between the beam and the target caused excitations in the nuclei. The gamma rays following this inelastic scattering reaction were then detected by the MINIBALL array in coincidence with the scattered beam and target recoils detected in an annular CD particle detector. Our analysis of the gamma-ray yields, which contain the information of the shape of the first excited 2^+ state in ^{72}Kr, will be presented. In contrast with the previous expectations [4], our experimental result is consistent with prolate nature for this state. This new evidence will be discussed together with the beyond relativistic mean-field calculations that are in agreement with our measurement and emphasize an important role of triaxiality in the emergence of shape co-existence (e.g., see [6,7,8]).

REFERENCES
[1] P. Möller et al., At. Data Nucl. Data Tables 59, 185 (1995).
[2] K. Heyde and J. L. Wood, Rev. Mod. Phys. 83, 1467 (2011).
[3] A. Gade et al., Phys. Rev. Lett. 95, 022502 (2005).
[4] E. Bouchez et al., Phys. Rev. Lett. 90, 082502 (2003).
[5] A. M. Hurst et al., Phys. Rev. Lett. 98, 072501 (2007).
[6] H. Iwasaki et al., Phys. Rev. Lett. 112, 142502 (2014).
[7] J.M. Yao et al., to appear in Phys. Rev. C (2014).
[8] A.P. Zuker et al., arXiv:1404.0224 v1 (nucl-th) (2014).

COLLINEAR RESONANCE IONIZATION SPECTROSCOPY OF FRANCIUM ISOTOPES TOWARDS THE LIMITS OF STABILITY

Ivan Budinčević, KU Leuven, Belgium

I. Budinčević[1], J. Billowes[2], M.L. Bissell[1], T.E. Cocolios[2], R.P. de Groote[1], S. De Schepper[1], V.N. Fedosseev[3], K.T. Flanagan[2], S. Franchoo[4], R.F. Garcia Ruiz[1], H. Heylen[1], K.M. Lynch[2,5], B.A. Marsh[3], G. Neyens[1], T.J. Procter[2], R.E. Rossel[3,6], S. Rothe[3], I. Strashnov[2], H.H. Stroke[7], and K.D.A. Wendt[6]

1 KU Leuven, Instituut voor Kern- en Stralingsfysica, Celestijnenlaan 200D, B-3001 Leuven, Belgium
2 School of Physics and Astronomy, The University of Manchester, Manchester M13 9PL, UK
3 Engineering Department, CERN, CH-1211 Geneva 23, Switzerland
4 Institut de Physique Nucléaire d'Orsay, F-91406 Orsay, France
5 Physics Department, CERN, CH-1211 Geneva 23, Switzerland
6 Institut für Physik, Johannes Gutenberg-Universität, D-55128 Mainz, Germany
7 Department of Physics, New York University, New York, New York 10003, USA

The newly installed Collinear Resonance Ionization Spectroscopy (CRIS) beam line at ISOLDE, CERN performed its first successful experimental campaign on a long chain of isotopes in October 2012, studying the francium isotopes $^{202\text{-}206,\,218m,219,229,231}$Fr. The CRIS technique combines the high selectivity and efficiency of resonance ionization spectroscopy, with the high resolution of collinear laser spectroscopy. The high efficiency of the technique was demonstrated with a detection-to-production efficiency of 1% for ^{202}Fr [1], enabling the study of this rarely produced neutron-deficient isotope. The currently achieved resolution is 1.5 GHz (due to the linewidth of the 10 kHz Ti:Sa laser used), with developments under way for reaching the <100 MHz range.
The neutron-deficient $^{202\text{-}206}$Fr isotopes present an interesting physics case due to the presence of an isomeric intruder state originating from the lowering of the $(\pi 3s^{-1}{}_{1/2})_{1/2+}$ state for neutron-deficient isotopes above $Z = 82$, with this state predicted to be the ground state in ^{199}Fr[2]. The neutron-rich francium isotopes ^{218m,219,229,231}Fr are located at the border of the actinide region in which nuclei are known to possess reflection-asymmetric shapes [3].
Magnetic dipole moments and changes in mean-square charge radii extracted from the measured hyperfine spectra have allowed conclusions to be drawn on the nuclear structure of these francium isotopes [1,4,5].
Future developments will also be presented.

REFERENCES

[1] K. T. Flanagan et al ., Phys. Rev. Lett. 111, 212501 (2013).
[2] J. Uusitalo et al ., Phys. Rev. C 71, 024306 (2005).
[3] R. K. Sheline, Phys. Lett. B 197, 3 (1987).
[4] K.M. Lynch et al., Physical Review X 4, 011055 (2014)
[5] I. Budinčević et al., submitted to PRC

GDR WIDTH EVOLUTION AT EXTREME TEMPERATURES

Maria Kmiecik, IFJ PAN Kraków, Poland

The Giant Dipole Resonance (GDR) is the collective excitation of nucleus understood as the oscillations of neutrons against protons. The GDR properties studied at high temperature and angular momentum provide important information on nuclei under extreme conditions. Among them are for example, single particle levels evolution, effective shapes of hot nuclei as a function of temperature/spin, damping mechanism and isospin mixing. They can be studied experimentally by the measurement of high-energy gamma rays emitted in the GDR decay. The information on effective nuclear properties is extracted from the measured GDR strength function, the Lorentzian function described by strength, energy and GDR width parameters. In particular, the GDR width dependence on angular momentum and temperature is very important reflecting the role played by quantal and thermal fluctuations in the damping of giant vibrations.

In last years the GDR width has been measured for several nuclei at different temperatures up to 3.7 MeV showing the increase of GDR width as a function of temperature [1]. The very important was evaluation of proper excitation energy of the compound nucleus considering preequilibrium processes that may occur at high energies. The obtained GDR dependence on the temperature was found to be due to the nuclear deformation increase and, at higher temperatures (above 2.5 MeV), the lifetime of compound nucleus.

In the following experiment the high energy gamma rays from the GDR decay have been measured for ^{88}Mo compound nucleus produced at excitation energy of 124 and 261 MeV using fusion evaporation reaction. Maximal transferred angular momentum was above the value corresponding to the fission barrier for ^{88}Mo. The combine HECTOR and GARFIELD arrays were employed to measure except of high-energy gamma rays charged particle spectra. For discrimination of fusion-evaporation and fission events phoswich detectors were used. Experimental data were analyzed and GDR parameters were achieved using the statistical Monte Carlo code GEMINI++. The value of the GDR width was obtained as a function of temperature and compared to the theoretical predictions of LSD liquid drop model including the thermal shape fluctuations and to the Phonon Damping Model.

REFERENCES

[1] O. Wieland et al., Phys. Rev. Lett. 97, 012501 (2006)

INVITED

Tuesday 15:25

STUDIES OF GAMOW-TELLER STRENGTHS AT NSCL AND APPLICATIONS IN ASTROPHYSICS AND NEUTRINO PHYSICS.

Remco G.T. Zegers[1,2,3], **NSCL, East Lansing, USA**

1 National Superconducting Cyclotron Laboratory, East Lansing, MI, USA
2 Department of Physics and Astronomy, East Lansing, MI, USA
3 Joint Institute for Nuclear Astrophysics, MI, USA

The study of Gamow-Teller transition strengths from stable and unstable nuclei provides key feedback on our ability to accurately model transitions mediated by the weak nuclear force. Although electron-capture and b–decay experiments provide direct information about Gamow-Teller transition strengths, only a limited fraction of the full distribution can be studied (if at all) because of Q-value restrictions. However, charge-exchange experiments (mediated by the strong nuclear force) can provide information on the full Gamow-Teller strength distribution because of a proportionality between Gamow-Teller strength and the charge-exchange differential cross section at forward scattering angles.

At NSCL, the focus of the experimental charge-exchange program is on reactions with unstable beams. These include experiments in which the probe is unstable (for example by using the $(t,^{3}He)$ reaction on stable targets) as well as experiments in which the probed nucleus is unstable. In the latter case, experiments are performed in inverse kinematics, for example by utilizing the (p,n) and $(^{7}Li,^{7}Be)$ reactions.

Experiments are aimed at providing information about the evolution of shell-structure across the nuclear chart, but also have important applications in astrophysics and neutrino physics. In astrophysics, the focus is on constraining electron-capture rates in a variety of phenomena, such as core-collapse and thermonuclear supernovae, as well as neutron star crusts. For neutrino physics, important application relate to (neutrinoless) double b-decay, and the response of neutrino detectors.

This work was supported by the US National Science Foundation (PHY-08-22648, PHY-11-02511). Experiments performed with GRETINA at NSCL are supported by the US DOE, Office of Science, under grant DE-AC02-05CH11231 (LBNL).

PDR AND DIPOLE POLARIZABILITY STUDIES AT GSI

Konstanze Boretzky, GSI Darmstadt, Germany

The symmetry energy term of the nuclear equation-of-state, describing fundamental phenomena both in nuclear physics and in astrophysics, is the focus of huge theoretical and experimental efforts. The electric dipole response of nuclei as a function of the neutron-to-proton-asymmetry is driven by the symmetry energy and in particular by its density dependence. Studies of the Pygmy Dipole Resonance (PDR) in exotic nuclei have been used to constrain the symmetry energy or the neutron skin thickness. The electric dipole polarizability α_D, being very sensitive to the low-lying dipole strength, is correlated to the neutron skin thickness in a robust and less model-dependent manner [1]. Recently, for the stable nucleus, ^{208}Pb the neutron skin thickness was extracted from the measured α_D [2].

Here, a first experimental determination of the electric dipole polarizability α_D in an unstable nucleus, namely ^{68}Ni, and the derivation of its neutron-skin thickness will be reported [3].

Coulomb excitation in inverse kinematics at the R^{3}B-LAND setup at GSI allows for the investigation of the dipole strength distribution in the neutron-rich ^{68}Ni with excitation energies spanning the pygmy (PDR) and giant dipole resonance (GDR). The results comprise the resonance parameters for the observed PDR at 9.55(17) MeV and the GDR at 17.1(2) MeV. In combination with the results from Wieland et al. [4] an unexpectedly large direct photon-decay branching ratio of 7(2)% is observed for the PDR. The measured α_D of 3.40(23) fm^3 is compared to relativistic RPA calculations [5] yielding a neutron-skin thickness of 0.17(2) fm for ^{68}Ni.

REFERENCES

[1] P. G. Reinhard and W. Nazarewicz, Phys. Rev. C 81, 051303 (2010).
[2] A. Tamii et al., Phys. Rev. Lett. 107, 062502 (2011).
[3] D. Rossi et al., Phys. Rev. Lett. 111, 242503 (2013).
[4] O. Wieland et al., Phys. Rev. Lett. 102, 092502 (2009).
[5] J. Piekarewicz, Phys. Rev. C 83, 034319 (2011)

ISOSPIN CHARACTER OF LOW-LYING PYGMY DIPOLE STATES VIA INELASTIC SCATTERING OF ^{17}O

Fabio Crespi, University of Milan / INFN, Milano, Italy

The electric dipole (E1) strength in atomic nuclei is almost completely concentrated in the extensively studied isovector giant dipole resonance (IVGDR). For neutron rich nuclei the E1 response is characterized by concentrations of strength, denoted as pygmy dipole resonance (PDR) or pygmy states, around and below the particle separation energy. One important open problem for pygmy states is the cross section sensitivity to transition densities containing the nuclear structure information. To explore this one needs high-resolution measurements and comparison of data obtained with different probes. In particular, nuclei with sizable neutron skin, such as the doubly magic ^{208}Pb, are very interesting.

The γ decay from the pygmy states was measured in ^{208}Pb using the inelastic scattering of ^{17}O at 340 MeV. The emitted γ rays were detected with high resolution with the AGATA demonstrator array and the scattered ions were detected in two segmented ΔE -E silicon telescopes. The multipolarity of the observed gamma transitions was determined with remarkable sensitivity thanks to angular distribution measurements.

Cross sections and angular distributions of the γ rays and of the scattered particles were measured. The results are compared with (γ, γ') and (p, p') data. The data analysis with the distorted wave Born approximation approach gives a good description of the elastic scattering and of the inelastic excitation of the 2^+ and 3^- states. For the dipole transitions, a form factor obtained by folding a microscopically calculated transition density was used for the first time. This has allowed us to extract the isoscalar component of the 1^- excited states from 4 to 8 MeV.

UPBEND AND M1 SCISSORS MODE IN NEUTRON-RICH NUCLEI CONSEQUENCES FOR R-PROCESS (n,γ) REACTION RATES

Ann Cecilie Larsen, Department of Physics, University of Oslo, Oslo, Norway

A.C. Larsen[1], S. Goriely[2], L. A. Bernstein[3], D. L. Bleuel[3], F. Giacoppo[1], M. Guttormsen[1], A. Görgen[1], S. Harissopulos[4], H. T. Nyhus[1], T. Renstrom[1], S. Siem[1], A. Spyrou[5], G. M. Tveten[1], A. V. Voinov[6], and M. Wiedeking[7]

1 Department of Physics, University of Oslo, Oslo, Norway
2 Institut d'Astronomie et d'Astrophysique, ULB, Brussels, Belgium
3 LLNL, Livermore, California, USA
4 Institute of Nuclear Physics, NCSR "Demokritos", Athens, Greece
5 NSCL, Michigan State University, East Lansing, Michigan, USA
6 Department of Physics and Astronomy, Ohio University, Athens, Ohio, USA
7 iThemba LABS, Somerset West, South Africa

An enhanced probability for low-energy γ–emission at high excitation energies (the *upbend*) has been observed for several light and medium-mass nuclei close to the valley of stability [1-3]. Very recently, this unexpected enhancement has been proven to be of dipole nature for ^{56}Fe [4]. Also, two recent theoretical works have proposed it to be of E1 [5] or M1 [6] nature; at present neither of these explanations can be excluded. The impact of this enhancement, if present also in very neutron-rich, exotic nuclei, could greatly increase the (n,γ) reaction rates relevant for r-process conditions away from (n,γ)-(γ,n) equilibrium [7].
Moreover, the so-called *M1 scissors mode* represents another mechanism for enhancing γ-decay probabilities for low-energy γ-rays, and has been rather well studied for stable nuclei [8,9]. However, it has so far not been studied in neutron-rich nuclei, although mass models (e.g. Ref. [10]) predict rather large ground-state deformations, for example for neutron-rich Kr, Sr, and Ru isotopes. Thus, one could find that *both* the upbend and the M1 scissors mode are present in neutron-rich, deformed nuclei, consequently increasing the (n,γ) reaction rates and potentially changing the achieved element abundances in large-network calculations.
In this talk, the present status of the upbend will be presented. Experiments at radioactivebeam facilities that allow for the study of the upbend and possibly the M1 scissors mode will be briefly discussed. Preliminary reaction-rate calculations for (n,γ) r-process rates, including the M1 scissors mode, will be shown for a wide range of elements.

REFERENCES
[1] A. Voinov *et al.*, Phys. Rev. Lett. 93, 142504 (2004).
[2] M. Guttormsen *et al.*, Phys. Rev. C 71, 044307 (2005).
[3] M. Wiedeking *et al.*, Phys. Rev. Lett. 108, 162503 (2012).
[4] A. C. Larsen *et al.*, Phys. Rev. Lett. 111, 242504 (2013).
[5] E. Litvinova and N. Belov, Phys. Rev. C 88, 031302(R) (2013).
[6] R. Schwengner, S. Frauendorf, and A.C. Larsen, Phys. Rev. Lett. 111, 232504 (2013).
[7] A. C. Larsen and S. Goriely, Phys. Rev. C 82, 014318 (2010).
[8] K. Heyde, P. von Neumann-Cosel, and A. Richter, Rev. Mod. Phys. 82, 2365 (2010).
[9] M. Guttormsen *et al.*, Phys. Rev. Lett. 109, 162503 (2012).
[10] S. Goriely, N. Chamel, and J. M. Pearson, Phys. Rev. Lett. 102, 152503 (2009).

STATISTICAL PROPERTIES OF WARM NUCLEI - OBSERVATION OF A FIRST ORDER PAIRINGPHASE TRANSITION IN ATOMIC NUCLEI

Sunniva Siem, University of Oslo, Norway

S. Siem[1], L. Bernstein[2], D. Bleuel[2], T. Eriksen[1], F. Giacoppo[1], A. Görgen[1], M. Guttormsen[1], A.C. Larsen[1], L.G.Moretto[3,4], H.T. Nyhus[1], T. Renstrřm[1], S.J. Rose[1], T.Tornyi[1], G.M. Tveten[1], A. Voinov[3], M. Wiedeking[4], J. Wilson[5]

1 University of Oslo, Norway
2 Lawrence Livermore National Laboratory, USA
3 University of California, Berkeley, USA
4 Lawrence Berkeley National Laboratory, USA
5 Ohio University, Athens, USA
6 iThemba LABS, Somerset West, South Africa
7 Institut de Physique Nucleaire d'Orsay, France

The nuclear physics group in Oslo has developed a unique technique to extract simultaneously the level density and γ-strength function from primary γ-ray spectra [1]. These are fundamental properties of the atomic nucleus and important input parameters in reaction cross-section calculations, used in simulations of nuclear reactors and in astrophysics, in large network calculation of formation of heavy elements in explosive stellar environments. In this talk an overview of the latest results from experiments performed in Oslo will be presented, starting with the latest status of the low energy enhancement of the γ-strength function first seen in Fe and Mo isotopes [2,3].

For the thorium fuel cycle there are still neutron capture cross sections for some isotopes which are poorly known or not measured. At the Oslo Cyclotron we have started a program to study actinides relevant for the thorium fuel cycle, including the incorporation of a PPAC fission detector into our experimental setup. The level densities and gamma strength functions have been measured for $^{231\text{-}233}$Th, ^{232,233}Pa, and $^{237\text{-}239}$U nuclei [4,5]. These nuclei show a strong M1 scissors mode resonance in the gamma strength function that can significantly enhance neutron capture rates. The level densities of these actinide nuclei follow closely a constant-temperature shape as a function of excitation energy. This dependence is unexpected and poorly understood, though is has also earlier been observed in the rare earth nuclei measured in Oslo.

In this talk, a fundamental explanation of the observed constant-temperature behavior in atomic nuclei is presented [6]. It is shown that the experimental data portray a first-order phase transition from a superfluid to an ideal gas of non-interacting quasiparticles and it is completely consistent with the BCS framework.

REFERENCES

[1] A. Schiller et al., Nucl. Instrum. Methods Phys. Res. A 447, 494 (2000).
[2] A. Voinov et al., Phys. Rev. Lett 93, 142504 (2004).
[3] M. Guttormsen et al., Phys.Rev. C 71, 044307 (2005).
[4] M. Guttormsen et al., Phys. Rev. C 88, 024307 (2013).
[5] M. Guttormsen et al., Phys. Rev. C 89, 014302 (2014).
[6] L.G.Moretto et al., submitted to Phys. Rev. Lett.

ISOSPIN MIXING IN ^{80}Zr AT FINITE TEMPERATURE

Simone Ceruti, Univerity of Milano, Italy

S. Ceruti, F. Camera, A. Bracco

AGATA Collaboration, University of Milano

The knowledge of the isospin impurity (i.e. isospin mixing) is important since it affects the properties of the Isobaric Analog States (IAS) and the Fermi decay of the N = Z nuclei near the proton drip-line. Indeed, the effect of the isospin impurity on the decay has implications in the Fermi decay transition rates, and thus on the Cabibbo-Kobayashi-Maskawa matrix. The breaking of isospin symmetry, increasing with Coulomb interaction, can be observed through decays which would be forbidden by selection rules. This is the case of the E1 decay from self-conjugate nuclei in a I=0 configuration. To fully exploit this property, one should go in the region of the Giant Dipole Resonance (GDR), where most of the E1 strength is concentrated. This approach has been employed to measure the isospin mixing in nuclei at finite temperature T, formed in fusion evaporation reactions. In this type of experiments the use of self-conjugate projectile and target nuclei ensures the population of a compound nucleus (CN) with I=0. The hindrance of the GDR gamma decay can be measured and thus the mixing amplitude deduced. A partial restoration of the isospin symmetry is expected at high temperature due to the decreasing of CN lifetime for particle decay. In the present case isospin mixing was measured in the hot CN ^{80}Zr. This is the heaviest N=Z nucleus so far studied and for which only one datum exists at finite temperature [1]. In this mass region the deviations between different predictions are the largest and thus this nucleus provides a good test for theory [2]. The experimental method is based on the analysis of the GDR gamma-ray emission in the fusion reactions ^{40}Ca+^{40}Ca at E_{beam}= 136 MeV. The experiment was performed in Laboratori Nazioni di Legnaro using an array of segmented HPGe detectors and a large volume $LaBr_3$:Ce (AGATA-HECTOR$^+$ array).

From data analysis three relevant results were obtained:

1. The Coulomb spreading width was found not to depend on the excitation energy of the nucleus, in agreement with theory.
2. The comparison between this measurement and that at higher temperature shows clearly the restoration effect of isospin symmetry.
3. The combined analysis of the experimental data allowed to deduce for this nucleus the isospin mixing at T=0, information that in not accessible in other ways. A constraint to theory can thus be given [2].

REFERENCES

[1] A. Corsi et al., Phys. Rev. C 84, 041304(R) (2011)

[2] W. Satula et al., Physcs Review Letters 103, 012502 (2009)

EFFECTS OF PHONON-PHONON COUPLING ON PROPERTIES OF PYGMY RESONANCES IN $^{124-132}$Sn

Nikolay Arsenyev, Joint Institute for Nuclear Research, Dubna, Russia

N.N. Arsenyev[1], A.P. Severyukhin[1], V.V. Voronov[1], Nguyen Van Giai[2]

1 Bogoliubov Laboratory of Theoretical Physics, JINR, 141980 Dubna, Russia
2 Institut de Physique Nucléaire, CNRS-IN2P3, Université Paris-Sud, F-91406 Orsay Cedex, France

The new spectroscopic studies of pygmy dipole resonances (PDR) [1] in neutron-rich nuclei stimulate a development of the nuclear models. One of the successful tools for describing the PDR is the quasiparticle random phase approximation (QRPA) with the self-consistent mean-field derived by making use of the Skyrme effective nucleon-nucleon interaction [2]. Such an approach describes the properties of the low-lying states less accurately than more phenomenological ones, but the results are in a reasonable agreement with experimental data. Due to the ahnarmonicity of vibrations there is a coupling between one-phonon and more complex states. The main difficulty is that the complexity of calculations beyond standard QRPA increases rapidly with the size of the configuration space, so one has to work within limited spaces. Using a finite rank separable approximation for the residual interaction obtained from the Skyrme forces that has been suggested in [3-5] one can overcome this problem. We study the properties of the low-lying 1^--states in the neutron-rich Sn isotopes [6]. The calculations are performed by using Skyrme SLy4 interactions in the particle-hole channel and density-dependent zero-range interactions in the particle-particle channel. The influence of coupling between one- and two- phonon terms in the wave functions leads to the fragmentation of E1 strength. The inclusion of the two-phonon configurations results in an essential increasing of the PDR width. Our results are in reasonable agreement with available experimental data.

REFERENCES

[1] D. Savran, T. Aumann, A. Zilges, Prog. Part. Nucl. Phys. 70, 210 (2013).
[2] N. Paar, D. Vretenar, E. Khan, G. Colò, Rep. Prog. Phys. 70, 691 (2007).
[3] Nguyen Van Giai, Ch. Stoyanov, V.V. Voronov, Phys. Rev. C 57, 1204 (1998).
[4] A.P. Severyukhin, V.V. Voronov, Nguyen Van Giai, Phys. Rev. C 77, 024322 (2008).
[5] A.P. Severyukhin, V.V. Voronov, Nguyen Van Giai, Eur. Phys. J. A 22, 397 (2004).
[6] N.N. Arsenyev, A.P. Severyukhin, V.V. Voronov, Nguyen Van Giai, Eur. Phys. J. WC, 38, 17002 (2012).

Wednesday

September 3rd

OVERVIEW OF THEORETICAL AND EXPERIMENTAL NUCLEAR REACTION STUDIES WITH RADIOACTIVE ION BEAMS

Jolie A. Cizewski, Rutgers University, New Brunswick

&

Filomena Nunes, Michigan State University

Nuclear reactions are one of the most powerful probes to study the properties of nuclei, in particular nuclei at the limits of stability. Reactions also play an important role in astrophysics and other applications. In order to extract useful information from reaction measurements, one needs reaction theory. While the last five decades have provided very good qualitative understanding of the processes, the challenge in the field of reaction theory is to have a grasp on the systematic uncertainties, such that predictions can be truly quantitative. The focus of this talk is on deuteron induced reactions and will provide an overview of various ongoing efforts aimed at advancing the theory for (d,p) reactions and reducing the associated uncertainties. An example is the ambiguities in spectroscopic factors that can be reduced by measuring the reaction with two very different beam energies to constrain the bound state parameters of the neutron. One of the largest sources of uncertainties in direct reaction models is the optical potential. The ambiguities of using only data to constrain the optical potential will be discussed, including recent results on the role of non-locality in the optical potentials. The presentation will conclude by summarizing the many challenges and opportunities that remain.

This work is supported in part by the U.S. Department of Energy, National Nuclear Security Administration under the Stewardship Science Academic Alliances.

MIGRATION OF MAGIC NUMBERS: STRUCTURE OF ^{26}Na VIA A NOVEL TECHNIQUE USING (d,pγ) WITH A RADIOACTIVE ^{25}Na BEAM

Wilton N. Catford, University of Surrey, Guildford, UK.

W.N. Catford[1], G.L. Wilson[1], N.A. Orr[2], C.Aa. Diget[3], G. Hackman[4], N.L. Achouri[2], A. Matta[1], I.C. Celik[1] and the TIGRESS and SHARC collaborations

1 Department of Physics, University of Surrey, Guildford, GU2 7XH, UK
2 LPC Caen, IN2P3-CNRS, 14050 Caen Cedex, France
3 Department of Physics, University of York, York, YO10 5DD, UK
4 TRIUMF, 4004 Wesbrook Mall, Vancouver, BC, V6T 2A3, Canada

A significant reduction in the N=20 shell gap, accompanied by an opening of the N=16 gap, has previously been identified in neutron rich nuclei, including our earlier results obtained using (d,p) transfer to populate states of a single-particle nature in ^{25}Ne [1] and ^{27}Ne [2]. This effect is largely driven by the reduction in the proton occupancy of the $0d_{5/2}$ orbital, in the shell model picture. In order to extend our study to probe directly the interaction of an odd 0d5/2 proton with an odd neutron in the *1s0d* and *0f1p* shells, we have now studied states in the odd-odd nucleus ^{26}Na as populated by the (d,p) reaction. The many states populated are almost completely distinct from all of the previously known states in ^{26}Na [3], which have a more complicated structure than those of a single-particle nature selected by (d,p).

A novel feature of the present work is that *gamma-ray coincidence* gating was employed in order to extract the proton differential cross sections and hence the values of the transferred angular momentum and the spectroscopic factors. The observed gamma-ray decay scheme also played a critical role in determining the spins of the strongly populated states.

A beam of up to 3×10^7 pps of pure ^{25}Na was supplied by the ISAC-2 facility at TRIUMF and bombarded a target of 0.5 mg/cm^2 $(CD_2)_n$ mounted inside the SHARC silicon array [4] that was itself mounted inside the TIGRESS HPGe gamma-ray array [5]. Particle singles and particle-gamma coincidences were recorded. A thin scintillator detector (the “trifoil” [6]) was placed downstream, in the beam, and shielded by a passive Al stopping foil that served to stop the products of fusion-evaporation reactions from carbon in the target. The trifoil registered beam particles and ^{26}Na ions arising from (d,p) reaction and was effective in reducing the background. Gamma-ray angular correlation effects were taken into account in the analysis [7]. The deduced levels for ^{26}Na are consistent with shell model calculations using the modified WBP interaction [8] that have also successfully described ^{25,27}Ne [2].

REFERENCES

[1] W.N. Catford et al., Phys. Rev. Lett. 104, 192501 (2010)
[2] S.M. Brown et al., Phys. Rev. C85, 011302(R) (2011)
[3] S. Lee et al., Phys. Rev. C73, 044321 (2006)
[4] C.Aa. Diget et al., J. Inst. 6, PO2005 (2011)
[5] M.A. Schumaker et al., Nucl. Instr. Meths. A570, 437 (2007)
[6] G.L. Wilson et al., J. Phys. G, Conf. Series, 381, 012097 (2012)
[7] W.N. Catford, Euroschool Vol. IV, Lecture Notes in Physics 879, p.67 (Springer, 2014)
[8] E.K. Warburton and B.A. Brown, Phys. Rev. C46, 923 (1992)

INVITED

Wednesday 09:15

RECENT DIRECT REACTION EXPERIMENTAL STUDIES WITH HEAVY-MASS RADIOACTIVE ION BEAMS

Kate L. Jones, University of Tennessee, Knoxville, USA

Direct reaction techniques are powerful tools to study the single-particle nature of nuclei. Performing direct reactions on short-lived nuclei requires radioactive ion beams produced either via fragmentation or the Isotope Separation OnLine (ISOL) method. Some of the most interesting regions to study with direct reactions are close to the magic numbers where changes in shell structure can be tracked. These changes can impact the final abundances of explosive nucleosynthesis. Results will be presented from studies around Z=50, N=50, and N=82.

A series of in-depth transfer reactions studies of nuclei around ^{132}Sn [1,2] and N=50 above Z=28 [3,4] were performed at the Holifield Radioactive Ion Beam Facility. Inverse kinematics (d,p) experiments on beams of ^{130}Sn and ^{132}Sn resulted in very similar properties being observed in excited states of ^{131}Sn from across the N = 82 shell to those seen at low excitations in ^{133}Sn. These states in ^{131}Sn were further studied using the (^{9}Be,^{8}Be) reaction on a beam of ^{130}Sn. The precise locations of the states observed in [2] have been determined [5] from the γ rays measured in the CLARION HPGe array. Known high-spin states in ^{131}Sn observed here have been explained via transfer on the 7^- isomeric component of the ^{130}Sn beam [5].

At the other end of the tin isotopic chain, the region around ^{100}Sn is influenced by the N=Z=50 magic numbers, the N=Z line, and is also close to the proton drip-line, and the end of the rp-process. One important step in understanding the shell structure in this region is to measure the single-particle states, and study how they evolve with decreasing neutron number. Until recently, there were no firm J^{π} assignments for odd-mass tin isotopes lighter than ^{109}Sn.

Residues and γ rays emerging from reactions of ^{108,106}Sn beams on a ^{9}Be target were measured. The experiment used NSCL's high-efficiency γ ray detector array CAESAR. The reaction residues were detected and identified with the S800 focal plane detector system. Momentum distributions of the residues indicate the orbital angular momentum of the knocked-out neutron. Thereby, the spin and parity of the ground and first excited states of ^{105}Sn and ^{107}Sn have been determined [6].

REFERENCES

[1] K.L. Jones, et al. Phys. Rev. C 84, 034601 (2011).
[2] R.L. Kozub et al., Phys. Rev. Lett. 109, 172501 (2012).
[3] J.S. Thomas et al. Phys. Rev. C 71, 021302 (2006) and J.S. Thomas et al. Phys. Rev. C 76, 044302 (2007).
[4] S. Ahn et al., in preparation
[5] A. Bey et al., in preparation.
[6] A. Ayres et al., in preparation.

SPECTROSCOPY OF ^{7}He BY ^{6}He(^{9}Be,^{8}Be) TRANSFER REACTION

Francesca Renzi, Instituut voor Kern- en Stralingsfysica, KU Leuven, Belgium

F. Renzi[1], R. Raabe[1], G. Randisi[1], C. Angulo[3], J. Cabrera[3], E. Casarejos[3], J. L. Charvet[2], D. Escrig[6], A. Gillibert[2], Th. Keutgen[3], V. Lapoux[2], L. Nalpas[2], A. Ninane[3], A. Obertelli[2], N. Orr[4], F. Skaza[2], J. L. Sida[2], S. I. Sidorchuck[5], D. Smirnov[1], R. Wolski[5]

1 KU Leuven, Instituut voor Kern- en Stralingsfysica, Belgium
2 CEA Saclay, DSM/DAPNIA/SPhN, F-91191 Gif sur Yvette Cedex, France
3 Centre de Recherches du Cyclotron, Chemin du Cyclotron, 2, B-1348, Louvain-la-Neuve, Belgium
4 Laboratoire de Physique Corpusculaire, IN2P3-CNRS, ISMRA et Universite' de Caen, F-14050 Caen Cedex, France
5 Flerov Laboratory of Nuclear Reactions, JINR, 141980, Dubna, Russia
6 Instituto de Estructura de la Materia, CSIC, E-28040 Madrid, Spain

Much interest has been devoted to the investigations of the ^{7}He nucleus in recent years. This nucleus is unbound and the identification of excited states is particularly challenging and controversial. Indeed, despite a significant number of experiments, a detailed information about excited states is still lacking, in particular for the first excited 1/2- state [1-5].

In this work the results of a further measurement are discussed. Using the ^{6}He (^{9}Be,^{8}Be)^{7}He transfer reaction, we took advantage of a very clear signature of the ^{8}Be decay to select the reaction channel of our interest. The identification technique by the signature of ^{8}Be decay has been successfully used to study reactions with both stable and radioactive ion beams (RIBs) [6-8]. After the identification of alphas from the decay ^{8}Be ground state, ^{8}Be momentum was calculated, then the excitation energy spectrum of ^{7}He was reconstructed with the missing mass method. The detection system consisted of two arrays of silicon-strip detectors covering two angular ranges, 5 -12 degrees and 22-70 degrees in the laboratory system. The ^{6}He beam had an energy E_{lab} = 16.8MeV. Detailed Geant4 Monte-Carlo simulations of the experimental setup have been carried out in order to accurately determine acceptance and efficiency. Moreover, the simulations have permitted the identification of the various reaction channels leading to ^{8}Be ground state in the final state and, therefore, all background contributions in the excitation energy spectrum of ^{7}He.

The preliminary results of the analysis and the comparison with previous measurements will be presented as well as their interpretation according to theoretical models. This work helps to settle the disagreement over the excited states of ^{7}He; in addition, it confirms that the identification technique by the signature of ^{8}Be is a powerful method, which could be exploited for the studies of other exotic nuclei.

REFERENCES
[1] D. R. Tilley, et al., Nucl. Phys. A 708, 3 (2002)
[2] F. Skaza, et al., Phys. Rev. C 73, 044301 (2006)
[3] G.V. Rogachev, et al., Phys. Rev. Lett. 92, 23 (2004)
[4] N. Ryezayeva, et al., Phys. Lett. B 639, 623 (2006)
[5] A.H. Wuosmaa, et al., Phys. Rev. C 78, 041302 (2008)
[6] G. J. Wozniak, et al., Nucl. Instrum. Methods 120, 29 (1974)
[7] M. Milin, et al., Phys. Rev. C 70, 044603 (2004)
[8] J. M. Allmond, et al., Phys. Rev. Lett. 112, 172701 (2014)

STUDY OF THE UNBOUND ^{13}Be RESONANCE IN A (p, 2p) REACTION AT GSI

Guillermo Ribeiro, IEM(CSIC), Madrid, Spain

G. Ribeiro, O.Tengblad for the R3B Collaboration.

IEM-CSIC, Madrid

The field of nuclear physics is interested in the understanding of the properties of nuclei in and beyond the drip-line, especially the last decade the interest in research on halo and non-bound nuclei has been growing fast [1, 2].
This contribution is about a study of the unbound system ^{13}Be produced from a ^{14}B (p, 2p) reaction at high energy. The experiment was performed in complete kinematics using the R3B setup in Cave C at GSI.
A primary beam of ^{40}Ar at energy 490 MeV/u was let to impinge on a Beryllium target producing a mixed beam, which was separated in the fragment separator (FRS) before reaching the reaction target and the detection setup. As incoming nuclei the ^{14}B was selected and after a p2p knockout reaction on CH_2, the products of the unbound nuclei of interest ^{13}Be was selected in the detector set-up .
The isotope ^{13}Be has a half-life in the order of 10^{-21} s, not allowing us to detect it directly, forcing us to look for the ^{12}Be+n system. The invariant mass technique is used in the analysis in order to reconstruct the relative energy of the ^{12}Be+n system. The reconstructed excitation spectra combined with the measurement of the gamma emitted from the excited ^{12}Be fragments permits us to extract information about the ^{13}Be structure.
In this contribution these results will be explained together with a comparison to the latest published data, [3, 4], in order to reach a conclusion about the shell structure of ^{13}Be.
For the future R3B experiments at FAIR a new calorimeter, CALIFA, optimized for (p, 2p) reaction is being constructed [5]. For the front end-cap of CALIFA a demonstrator CEPA4 [6] is currently being tested. The main results and the future applications of the new detection technique used in the framework of probing unbound nuclei will be discussed.

REFERENCES
[1] H. Simon, Phys., Scr. T 152, 014024 (2013).
[2] T. Baumann et al., Rep. Prog. Phys.75, 036301(2012).
[3] Yu. Aksyutina et al. ,Phys. Rev. C 87, 064316 (2013).
[4] G. Randisi et al., Phys. Rev. C. 89 034320 (2014).
[5] D. Cortina-Gil et al., Technical report for the CALIFA Barrel (2011).
[6] O. Tengblad et al. NIM A 704 19-26(2013).

POPULATION OF ^{10}He CONTINUUM IN KNOCKOUT REACTIONS

Pavel Sharov, JINR Dubna, Russia

P.G. Sharov[1,2], L.V. Grigorenko[1,3,4] and I.A. Egorova[2,5]

1 Flerov Laboratory of Nuclear Reactions, JINR, Dubna, RU-141980 Russia
2 SSC RF ITEP of NRC “Kurchatov Institute”, Moscow RU-117218 Russia
3 GSI Helmholtzzentrum fur Schwerionenforschung, D-64291 Darmstadt, Germany
4 National Research Center "Kurchatov Institute”, RU-123182 Moscow, Russia
5 Bogoliubov Laboratory of Theoretical Physics, JINR, Dubna, RU-141980 Russia

The unbound nucleus ^{10}He [1] has one of the largest relative neutron excess representing the extreme situation of the nuclear matter asymmetry. On the other hand ^{10}He belongs to the so-called true two-neutron emitters. Such features make theoretical and experimental studies of ^{10}He important, interesting, but very complicated task. In the recent years several experiments [2-4] were performed providing controversial conclusions about ^{10}He structure. Experiments based on knockout reactions [2,4] shows the ground state peak at energy 1.2 MeV. However, in the spectrum populated in two-neutron transfer reaction [3] the g.s. peak is observed about 2.1 MeV.

We have investigated theoretically influence of reaction mechanism on population of ^{10}He continuum in the knockout reactions. The dynamics of ^{10}He decay was considered in the 3-body hyperspherical harmonics ^{8}He+n+n decay model [5]. Several approximations for nucleon (cluster) removal and transfer reactions were investigated.

Our theoretical calculations indicate that low energy peak observated in knockout reactions is likely to be a pileup of 1^-, 0^+, and 2^+ excitations with very similar shapes. Moreover, the “soft” 1^- excitation appears to be the lowest one in energy. Such an anomalous continuum response is traced to the halo structure of ^{11}Li providing extreme low energy shift to all the expected continuum excitations.

REFERENCES
[1] A.A. Korsheninnikov *et al.*, Phys. Lett. B326, 31 (1994).
[2] H.T. Johansson *et al.*, Nucl. Phys. A842, 15 (2010).
[3] S.I. Sidorchuk *et al.*, Phys. Rev. Lett. 108, 202502 (2012).
[4] Z. Kohly *et. al.*, Phys. Rev. Lett. 109, 235501 (2012).
[5] L.V. Grigorenko and M.V. Zhukov, Phys. Rev. C 77, 034611 (2008).

NUCLEI AT THE END OF THE PERIODIC TABLE

Yuri Oganessian, Flerov Laboratory of Nuclear Reactions, Joint Institute for Nuclear Research, Dubna, Russia

One of the fundamental outcomes of the nuclear shell model is the prediction of the "stability islands" in the domain of the hypothetical superheavy elements. The enhanced stability has been expected for the deformed nuclei near Z=108 and N=162, yet much stronger effect has been predicted for heavier spherical nuclei close to the shells Z=114 and N=184, next to the doubly-magic nucleus ^{208}Pb (Z=82, N=126).
The talk is devoted to the experimental verification of these predictions – the synthesis and study of both the decay and chemical properties of the superheavy elements.
The synthesis of the heaviest and neutron-rich nuclei has been carried out in the fusion reactions of ^{233,238}U, ^{237}Np, ^{242,244}Pu, ^{245,248}Cm, ^{249}Bk and ^{249}Cf with the ^{48}Ca projectiles, that made it possible to observe the decay of the 48 new neutron-rich nuclides with Z=104-118 and N=161-177.
The decay properties of the new isotopes present direct experimental evidence of the existence of the Island of stability in the region very heavy (superheavy) nuclei that considerably expand the Periodical Table of the chemical elements.
Further progress of SHE research is related to studies of nuclear and atomic structure of SHE, nuclear fission of the neutron-rich nuclides with Z≥104, as well as the synthesis of the new elements and isotopes in close proximity to the magic numbers protons and neutrons. It is directly associated with the development of heavy ion accelerator facilities, new setups and more sophisticated detectors. New experimental potentialities will be presented also.
The presentation includes the results obtained in FLNR (Dubna, Russia) in collaboration with LLNL, (Livermore, USA), ORNL (Oak-Ridge, USA), PSI (Villigen, Switzerland) and Vanderbilt University (Nashville, USA), Cyclotron Institute of the Texas A&M University, as well as in GSI (Darmstadt, Germany) and RIKEN (Tokyo, Japan).

RESEARCH ON SUPERHEAVY ELEMENT AT RIKEN: STATUS AND PERSPECTIVE

Kosuke Morita, Kyushu University and RIKEN Nishina Center, Japan

Research Group for Superheavy Elements at RIKEN Nishina Center, had conducted the experiment for producing and detecting an isotope of the 113th element, ^{278}113, produced in the ^{209}Bi + ^{70}Zn reaction. A ^{70}Zn beam was delivered from the RIKEN Linear Accelerator (RILAC). A GAs-filled Recoil Ion Separator (GARIS) was used. The experiment started at September 5th 2003, and ended at October 1st 2012, taking many interceptions in between. During the net irradiation time of 575 days, 1.39×10^{20} beam particles had irradiated the target. We observed three correlated decay chains in total, all attributed to the subsequent decays originating from the isotope of the 113th element, ^{278}113. The production cross section was deduced to be 22^{+20}_{-13} fb (fb = 10^{-39} cm^2) with a 1 σ error. The first and the second chain consisted of four consecutive alpha decays followed by a Spontaneous Fission (SF). We assigned the decay chains to $^{278}113(\alpha_1) \rightarrow {}^{274}Rg(\alpha_2) \rightarrow {}^{270}Mt(\alpha_3) \rightarrow {}^{266}Bh(\alpha_4) \rightarrow {}^{262}Db(SF)$. The third one consisted of seven consecutive alpha decays. We assigned the decay chain to $^{278}113(\alpha_1) \rightarrow {}^{274}Rg(\alpha_2) \rightarrow {}^{270}Mt(\alpha_3) \rightarrow {}^{266}Bh(\alpha_4) \rightarrow {}^{262}Db(\alpha_5) \rightarrow {}^{258}Lr(\alpha_6) \rightarrow {}^{254}Md(EC) \rightarrow {}^{254}Fm(\alpha_7) \rightarrow {}^{250}Cf$. Since all the decay characteristics following ^{266}Bh agrees very well with the known ones of nuclides ^{266}Bh, ^{262}Db, ^{258}Lr, and ^{254}Fm, we could unambiguously assign the preceding decays to $^{278}113 \rightarrow {}^{274}Rg \rightarrow {}^{270}Mt$, those are unknown previously. Results are reported in reference [1].

The reaction, $^{248}Cm + {}^{48}Ca \rightarrow {}^{296}Lv^*$(Livermorium, Z = 116), has been studied at the RILAC Facility using GARIS. Although this reaction was intensively studied previously [2, 3], the number of observed events is still very small because of the small production cross sections. The first aim of the present study is to observe more events in the region of superheavy nuclei and possibly to obtain new spectroscopic information of those nuclei. The second aim is to examine the performance of the GARIS facility using the relevant reaction for a future project with the ^{50}Ti beam, instead of the ^{48}Ca beam, to search for new heaviest nuclei. Because of the limitation of target nuclear species, one needs to use beams heavier than ^{48}Ca for further investigation of superheavy nuclei. We observed five correlated events during the experiment, all of which terminated by spontaneous fission (SF). Decay characteristics of those events agreed well with previous studies. Two of them were attributed to the decays originating from ^{293}Lv (3n evaporation channel), and three were tentatively attributed to the ones from ^{292}Lv (4n evaporation channel).

In near future, we plan to perform the experiment to measure the evaporation residue cross section for $^{248}Cm + {}^{50}Ti \rightarrow {}^{298}118^*$ reaction. The ion source group at RIKEN Nishina Center is developing the ^{50}Ti beam for future experiment at this moment.

This research was partly supported by a Grant-in-Aid for Specially Promoted Research, 19002005, 2007, from the Ministry of Education, Culture, Sports, Science and Technology, Japan. This work was also partly supported by the RIKEN Strategic Program for R&D.

[1] K. Morita *et al.*: J. Phys. Soc. Jpn. 81 (2012) 103201

[2] Yu. Ts. Oganessian *et al.*: Phys. Rev. C70 (2004) 064609.

[3] S. Hofmann *et al.*: Eur. Phys. A48 (2012) 62.

RECENT RESULTS FROM THE FIELD OF SUPERHEAVY ELEMENT RESEARCH

Andreas Türler, Paul Scherrer Institute and University of Bern, Switzerland

A. Türler on behalf of TASCA collaboration:
GSI – Mainz – JAEA – ORNL – Liverpool – Canberra – Lund – LBNL - LLNL – Nashville – SAHA – Oslo – Jyväskylä – PSI – Bern – IET

With the discovery of six new elements in the past decade an extraordinary expansion of the Periodic Table took place, so that now all elements of the 7th period have been synthesized. This success was possible by exploiting the concept of "warm" fusion using the available, neutron-rich actinide target materials and the tightly bound, doubly magic projectile ^{48}Ca [1]. Most of these discovery experiments were conducted by the Dubna-Livermore collaboration at the Flerov Laboratory in Dubna, Russia and a number of independent experiments have been able to confirm these findings [2-5]. Due to the discovery of relatively long-lived isotopes of copernicium (element 112) and flerovium (element 114) first chemical experiments have successfully been conducted, revealing the special chemical properties of these elements, which can be attributed to the influence of strong relativistic effects [6]. Substantial progress has also been achieved in investigating the lighter heavy actinide and transactinide elements, where new properties of heavy actinide elements and new classes of tansactinide containing compounds have been synthesized. In this contribution I will highlight different nuclear aspects of superheavy element research in the context of experiments performed by the TASCA collaboration.

While in the discovery experiments usually only the alpha-decay chains of the synthesized heavy nuclei are observed, it is nowadays possible to obtain measure further properties such as masses, as for ^{254}No [7], or rotational bands in ^{256}Rf [8]. Noteworthy is also the possible observation of X-rays in the alpha-particle decay chains of element 115 isotopes [9], paving the way towards X-ray fingerprinting of new elements. Attempts to push beyond Z=118 using the reactions ^{50}Ti + ^{249}Bk and ^{50}Ti + ^{249}Cf have failed so far, while reaching rather low upper limit production cross sections. It appears, as if only new, more powerful accelerators and associated experimental equipment would allow the synthesis of even heavier elements in the 8th row of the Periodic Table.

REFERENCES
[1] Yu.Ts Oganessian, J. Phys. G: Nucl. Part. Phys. 34, R165 (2007)
[2] L. Stavsetra et al., PRL 103, 132502 (2009)
[3] Ch.E. Düllmann et al., PRL 104, 252701 (2010)
[4] S. Hofmann et al., EPJA 48, 1 (2012)
[5] J. Khuyagbaatar et al., PRL 112, 172501 (2014)
[6] A. Türler, V.G. Pershina, Chem. Rev. 113, 1237 (2013)
[7] E. Minaya Ramirez et al., Science 337, 1207 (2012)
[8] J Rubert et al., J. Phys.: Conf. Ser. 420, 012010 (2013) ;
[9] D. Rudolph et al., PRL 111, 112502 (2013)

SPECTROSCOPY OF VERY HEAVY NUCLEI AT ATLAS

Dariusz Seweryniak, Argonne National Laboratory, USA

Spectroscopy of trans-fermium nuclei around the Z=100 and N=152 deformed shell gaps has been an active area of research at ATLAS for many years since the pioneering experiments which led to the observation of a rotational band and K-isomers in ^{254}No using Gammasphere and the Fragment Mass Analyzer (FMA). Rotational bands and K-isomers in trans-fermium nuclei provide a ground for stringent tests of nuclear models used to describe properties of super-heavy elements such as for example their magic numbers which define the long sought after island of super-heavy nuclei. Recent highlights include first observation of two fast isomers in the heaviest known even-even N=150 isotone ^{254}Rf employing the digital DAQ and the determination of the fission barrier in ^{254}No from γ-ray energy-spin distributions obtained with Gammasphere. To extend these studies to even heavier nuclei the Argonne Gas-filled Fragment Analyzer (AGFA) was designed and is currently under construction. Due to charge-state focusing AGFA will have a factor of about ten higher efficiency compared to FMA. During the talk recent results on trans-fermium nuclei and research plans with AGFA at ATLAS will be presented.

This work was supported by U.S Department of Energy, Office of Nuclear Physics, under Contract No. DE-AC02-06CH11357.

THEORETICAL DESCRIPTION OF DECAY CHAINS OF THE ELEMENT 115

Adam Sobiczewski, National Centre for Nuclear Research, Warsaw, Poland

There is a big amount of experimental data on the decay chains of isotopes of the superheavy element 115, collected very recently both at JINR-Dubna [1-4] and at GSI-Darmstadt [5-7].

The objective of this paper is a theoretical description of at least a part of these data.

The α-transition energies Q_α^t and the respective half-lives T_α are calculated. The calculations are based on the model assuming that the α-transitions occur between the states of the same structure (the same quantum numbers) [8].

The model may be used both on the phenomenological level, resulting only in the α-transition energies Q_α^t (and in the respective half-lives T_α), and on the microscopic one, producing both α- and γ-transition energies along the decay chains.

REFERENCES

[1] Yu.Ts. Oganessian *et al.*, Phys. Rev. Lett. 104, 142502 (2010).
[2] Yu.Ts. Oganessian *et al.*, Phys. Rev. Lett. 109, 162501 (2012).
[3] Yu.Ts. Oganessian *et al.*, Phys. Rev. C 87, 014302 (2013).
[4] Yu.Ts. Oganessian *et al.*, Phys. Rev. C 87, 054621 (2013).
[5] D. Rudolph *et al.,* Phys. Rev. Lett. 111, 112502 (2013).
[6] D. Rudolph *et al.,* Acta Phys. Pol. B 45, 263 (2014).
[7] J. Khuyagbaatar *et al.,* Phys. Rev. Lett. 112, 172501 (2014).
[8] A. Parkhomenko and A. Sobiczewski, Acta Phys. Pol. B 36, 3095 (2005)

PROMPT IN-BEAM CONVERSION ELECTRON AND γ-RAY SPECTROSCOPY AT THE LIMIT USING THE SAGE SPECTROMETER

Mikael Sandzelius, University of Jyväskylä, Finland

M. Sandzelius[1], K. Hauschild[2], A. Lopez-Martens[2], P.T. Greenlees[1], P. Butler[3], D. Cox[3] R.-D. Herzberg[3], J. Konki[1], P. Papadakis[1], J. Pakarinen[1], P. Rahkila[1], J. Sorri[1]

1 Department of Physics, University of Jyväskylä, Finland
2 CSNSM, IN2P3-CNRS, Orsay, France
3 Department of Physics, University of Liverpool, UK

In recent years in-beam spectroscopy of heavy elements has taken a leap forward with the ability to target previously inaccessible nuclei. Added sensitivity, and selectivity, with existing detectors coupled to novel ancillary detectors has made it possible to perform in-beam studies of heavy nuclei down to a few tenth of nano barn level. The detection of prompt γ-rays and conversion electrons from excited states has revealed a wealth of information of low-lying structures of heavy nuclei. Thereby enabling identification of collective phenomena, extraction of moments of inertia, and determination of the active single-particle orbitals near the Fermi level.
The SAGE (Silicon And GErmanium) spectrometer is a unique device to study prompt in-beam emission of conversion electrons and γ-rays. The capability to detect prompt conversion electrons, in addition to γ-rays, is crucial in the study of heavy elements, where low energy transitions are highly converted and hence excited states tend to decay almost entirely by conversion-electron emission. SAGE offer the possibility to establish coincidences, not only between two γ-rays or two conversion electrons, but also between γ-rays *and* conversion electrons, making for a very potent tool to elucidate low lying structures and their decay patterns.
However, electron spectroscopy is notoriously difficult because of the fragmented nature of the intensity of the emitted conversion electrons depending on from which shell they emanate. Several peaks from K, L, M-shell conversion electrons can have overlapping energies with that of other transitions, all contributing together with delta electrons to a spectrum which looks vastly different from the discrete nature of a Compton suppressed γ-ray spectrum. Therefore, in order to distinguish any features (peaks) in a prompt conversion electron spectrum, gating on a known γ-ray transition can greatly facilitate an analysis in a low statistics experiment.
This talk will present some highlights of recently concluded SAGE experiments, as well as shed some light, using the study of ^{255}Lr as a specific case, on where the cross-section limits are of performing prompt in-beam conversion electron and γ-ray spectroscopy with today's state-of-the-art technology.

TRANSMISSION RESONANCE SPECTROSCOPY OF THE DOUBLY ODD ^{238}Np IN (d,pf) REACTION

Lorant Csige, MTA Atomki, Debrecen, Hungary

The observation of *discrete* γ transitions between hyperdeformed (HD) nuclear states in the region of A=100-130 represents one of the last frontiers of *high-spin* physics. On the other hand, the existence of HD states in the 3rd minimum of the fission barrier is firmly established both experimentally and theoretically in the *actinide region* [1]. Observing resonances in the fission cross section as a function of the excitation energy caused by resonant tunneling through excited states in the 3rd minimum of the potential barrier can specify the excitation energies of the HD states, moreover, the observed states could be ordered into rotational bands. The moments of inertia of these bands can characterize the underlying nuclear shape proving that these states have indeed HD configuration. The measured high resolution fission cross section can also be used to explore the structure of the potential energy landscape of the fissioning nucleus.
After a successful research program on the even-even Uranium isotopes [1] we started an experimental campaign on the *odd-odd nuclei*. Very recently, we observed, for the first time, HD bands in an odd-odd nucleus (^{232}Pa) [2] which suggested us to continue the systematic investigation of the odd-odd actinides. In our latest experiment the fission probability of ^{238}Np was measured as a function of the excitation energy in order to search for HD rotational bands using the (d,pf) transfer reaction on a radioactive ^{237}Np target. The experiment was performed at the Tandem accelerator of the Maier-Leibnitz Laboratory (MLL) at Garching employing the ^{237}Np(d,pf) reaction at a bombarding energy of E_d=12 MeV. The kinetic energy of the ejectiles was analyzed by a Q3D magnetic spectrometer with an energy resolution of ΔE=8 keV (FWHM). Fission fragments were detected by position sensitive avalanche detectors so the angular distribution of the fragments could be extracted with respect to the recoil axis. The preliminary result shows a consistent description of the observed transmission resonances by analyzing both the high-resolution excitation energy spectrum of ^{238}Np and the fission fragment angular distribution, which supports the interpretation of the resonances as *HD rotational bands*. By performing nuclear reaction code (TALYS1.4) calculations, the fission barrier parameter could be extracted with a high precision.

REFERENCES
[1] A. Krasznahorkay, Handbook of Nuclear Chemistry. 2nd edition, Hamburg, Springer Verlag 1 (2011) 281.
[2] L. Csige *et al.*, Phys. Rev C 85 (2012) 054306.

CONFIGURATION CONSTRAINED CALCULATIONS OF THE POTENTIAL ENERGY SURFACES (PES'S) - SEARCH FOR SUPERHEAVY K-ISOMERS.

Michał Kowal, National Centre for Nuclear Research, Warsaw, Poland

M. Kowal[1], W. Brodziński[1], P. Jachimowicz[2] & J. Skalski[1]

1 National Centre for Nuclear Research, Hoża 69, PL-00-681 Warsaw, Poland
2 Institute of Physics, University of Zielona Góra, Szafrana 4a, PL - 65-516 Zielona Góra, Poland
3 Technical University of Łódź, Institute of Physics, Wólczańska 219,PL - 93-005 Łódź, Poland

Experimental methods of producing superheavy nuclei available today i.e. hot & cold fusion reactions have inherent limitations. A challenge is to predict new exotic systems which can be synthesized. Although much has been written on even – even nuclei, the current state of research suffers important deficiencies failing to address odd heavy nuclear systems. A fascinating possibility for their longer life-times is related to *K* isomerism which is especially likely for odd nuclei. High-K intruder states with very unusual properties in comparison to neighboring states impose appropriate configuration conservation in those nuclei. Preserving this exceptional configuration during the decay process reduces transition energy and increase the stability. This is why main effort here will be placed on the searching for such new, special (with high-K intruder states) odd - A and odd - odd nuclear configurations. Science, all these configurations, as constrained equilibria are in principle detectable, the stability analysis against alpha decay and fission seems to be crucial. We are going to predict and describe the mechanisms responsible for the hindrance of different decay channels for such superheavy K-isomers. In the stability analysis especially demanding will be configuration constrained PES's calculations (with blocking) for odd – odd systems. Such results, using macroscopic – microscopic approach (based on the deformed Woods – Saxon potential) carried out in the multidimensional collective deformation space will be shown.

LEVEL DENSITIES OF HEAVIEST NUCLEI

A.N. Bezbakh, Joint Institute for Nuclear Research, Dubna, Russia

A.N. Bezbakh[1], T.M. Shneidman[1,2], G.G. Adamian[1], N.V. Antonenko[1]

1 Joint Institute for Nuclear Research, Dubna 141980, Russia,
2 Institute of Theoretical Physics, CAS, Beijing 100190, China

The nuclear level density is an important characteristic both for the nuclear reaction calculations and for the investigation of the stability of the new supearheavy elements. The intrinsic level densities of nuclei with Z>100 in the alpha-decay chains of $^{296,298,300}120$ nuclei are calculated using the single-particle spectra obtained with the modifed two-center shell model [1,2]. The level density parameters are extracted and compared with their phenomenological values used in the calculations of the survival of excited heavy nuclei. The dependences of the level density parameters on the mass and charge numbers as well as on the ground-state shell corrections are studied. At low excitations the single-particle level densities are closely related to the shell structure and could indicate the position of the island of stability of heaviest nuclei. The level density, as a function of excitation energy, is required to calculate the survival probability and, correspondingly, the production cross section of heavy nucleus.

REFERENCES

[1] G.G. Adamian, N.V. Antonenko, and W. Scheid, Phys. Rev. C 81, 024320 (2010).
[2] G.G. Adamian, N.V. Antonenko, S.N. Kuklin, and W. Scheid, Phys. Rev. C 82, 054304 (2010).

NEUTRON EMISSION ANISOTROPY IN FISSION

A.Chietera, CNRS/IPHC-Université de Strasbourg, France

A.Chietera[1], L. Stuttgé[1], F. Gönnenwein[2], Yu. Kopatch[3],
M. Mutterer[4], I. Guseva[5], A.Gagarski[5], E. Chernysheva[6] , O. Dorvaux[1],
F.J. Hambsch[7], F. Hanappe[8], S. Telezhnikovch[3], Z. Mezentsevah[3]

1 Département de Recherches Subatomiques, CNRS/IPHC-Université de Strasbourg, France
2 Physikalisches Institut, Universität Tübingen, Germany
3 Frank Laboratory of Neutron Physics, JINR, Dubna, Russia
4 Institut für Kernphysik, Technische Universität GSI Helmholtz Zentrum für Schwerionenforschung, Darmstadt, Germany
5 Petersburg Nuclear Physics Institute, Gatchina, Russia
6 Flerov Laboratory of Nuclear Reactions, JINR, Dubna, Russia
7 EC-JRC-Institute for Reference Materials and Measurements, Geel, Belgium
8 PNTPM, Université Libre de Bruxelles, Belgium.

Neutron experimental distributions are investigated in the spontaneous fission process of ^{252}Cf. It is well known that during the fission process the bulk of prompt neutrons is evaporated from the fully accelerated rotating fragments. Neutrons evaporation theory states that this emission is isotropic in the centre of mass of the moving fragments (C.M.) [1], but if one compares experimental angular distributions with a pure isotropic evaporation, discrepancies appear in many different works.

To understand the origin of these deviations it was introduced a contribution to neutron angular distributions due to neutrons ejected at an early stage of the fission process, at the scission point [2]. But even by adding these scission neutrons and taking into account the anisotropy effect due to the kinematical focusing, an excess of neutrons observed at small laboratory angles around heavy and light fragment remains. So it was assumed that an anisotropy appears also in the C.M. of the two fragments and this effect reinforces the kinematical anisotropy in the laboratory system [3].

There are theoretical arguments and calculations that claim that this anisotropy exists, but there isn't any direct observation, because the contribution to the kine-matical focusing due to the C.M. anisotropy is very weak. To show this effect a new method was developed by our collaboration. The CORA experiment was performed for this purpose. It consists in the measurement of triple coincidences between each fission fragment and two ejected neutrons. With this trick we can disentangle in the laboratory system the contribution to the anisotropy due to the kinematical focusing of the effect of the predicted C.M. anisotropy. The experiment is described and the new analysis method is presented.

REFERENCES

[1] V. F. Weisskopf, Statistics and Nuclear Reaction, Phys. Rev., 52, 295 303, 1937
[2] H. R. Bowman et al, Phys. Rev., 126, 2120 (1962).
[3] V. Bunakov et al. Proc. "Int. Sem. ISINN-14" Dubna, Russia, 2006, p.293

SPONTANEOUS FISSION OF ^{238}U FROM THE SELF-CONSISTENT COLLECTIVE ACTION

Katarzyna Mazurek, IFJ PAN, Kraków, Poland

J. Sadhukhan[1], K. Mazurek[1,2], J. Dobaczewski[3,4], W. Nazarewicz[1,3], J. A. Sheikh[1] and A. Baran[1,5]

1 Department of Physics and Astronomy, University of Tennessee, Knoxville, Tennessee 37996, USA and Physics Division, Oak Ridge National Laboratory, P. O. Box 2008, Oak Ridge, Tennessee 37831, USA
2 The Niewodniczański Institute of Nuclear Physics - PAN, PL-31-342 Krakow, Poland
3 Institute of Theoretical Physics, Faculty of Physics, University of Warsaw, ul. Hoża 69, PL-00-681 Warsaw, Poland
4 Department of Physics, P.O. Box 35 (YFL), University of Jyvâskylâ, FI-40014 Jyvâskylâ, Finland
5 Institute of Physics, University of M. Curie-Skłodowska, ul. Radziszewskiego 10, 20-031 Lublin, Poland

Nuclear density functional theory is a microscopic tool of choice to study nuclear fission process. In the present work, the spontaneous fission lifetime of ^{238}U has been obtained by minimization of the action integral in a four dimensional space of collective variables. Apart from the shape coordinates defined by the multipole moments Q_{20}, Q_{22} and Q_{30}, pairing fluctuations have been also considered. The inertia tensor is computed within non-perturbative cranking approach of the adiabatic time-dependent Hartree-Fock-Bogoliubov approximation [1], recently applied to a two-dimensional case of ^{264}Fm [2]. Our formalism is capable of describing competition between pairing, level crossing dynamics, and symmetry breaking effects. We conclude that dynamical pairing fluctuations significantly change the action integral; hence, the fission half-life [3, 4, 5].
A comparison of the static and dynamic fission trajectories will be discussed.

REFERENCES

[1] A. Baran et al. Phys. Rev. C 84, 054321 (2011)
[2] J. Sadhukan et al. Phys. Rev. C 88, 064314 (2014)
[3] L.G. Moretto and R.P. Babinet, Phys. Lett. B 49, 147 (1974)
[4] A. Staszczak et al., Phys. Lett. B 161, 227 (1985)
[5] J. Sadhukan et al. submitted to Phys. Rev. C

ANALYSIS OF EXPERIMENTAL DATA FROM FUSSION-FISSION REACTIONS WITHIN FOUR-DIMENSIONAL LANGEVIN DYNAMICS

Eugeny Ryabov, Omsk State University, Omsk, Russia

E. G. Ryabov, P. N. Nadtochy and G. D. Adeev

Omsk State University, Mira prospekt 55-A, Omsk 644077, Russia

Fission is among the most complex nuclear reaction mechanism: starting from a compact mono-nuclear system, a large-scale amplitude collective motion develops leading to a dramatic change of the shape of the nucleus. Finally, the system splits into two separate fragments. Depending on the composition and excitation energy of the fissioning nucleus, various aspects affect the process. Thus, fission is a relevant laboratory for understanding nuclear properties in general. During the past decades stochastic approach based on multidimensional Langevin equations has been extensively and rather successfully used to elucidate many problems of collective nuclear dynamics in fusion-fission reactions at high excitation energies [1,2]. In order to explain a wide range of experimental data within dynamical fission modeling one have to choose a reasonable set of the collective degrees of freedom, as well as to take into account the particle evaporation process accompanying the fission process. Thus, we have a complex interplay between statical, statistical and dynamical effects [3,4].
Recently, we have performed the extension of the three-dimensional Langevin dynamical model by adding the orientation degree of freedom (K coordinate) [5] and demonstrated the strong influence of the K-coordinate on the dynamical evolution of fissioning nucleus [6]. In the present study we performed systematic investigations of the new four dimensional Langevin dynamics and pay the main attention to the nuclear viscosity strength, both for the nuclear shapes degrees of freedom (k_s) and orientation degree of freedom γ_K [7] using the four-dimensional Langevin model. We investigated the possible deformation dependence of the viscosity coefficient k_s predicted by chaos theory [8] and deformation dependence of the γ_K coefficient predicted in Ref. [5,9]. In the framework of four-dimensional dynamical model we investigated the correlation between dissipation strength and mass, energy and angular distributions of fission fragments. Our calculations demonstrate that the deformation dependent coefficient k_s and γ_K value obtained by Lestone and co-workers in Ref [5] is suitable for description of experimental mass-energy and angular distributions of fission fragments in 4D model for heavy nuclei. In the 4D calculations simultaneous reproduction of $<n_{pre}>$ and σ^2_M is possible with almost similar k_s values, whereas in the 3D calculations for the heaviest nuclei $k_s \approx 0.1$ was needed for the reproduction of σ^2_M and $k_s > 1$ for the reproduction of $<n_{pre}>$.

REFERENCES
[1] Y. Abe et al., Phys. Rep. 275, 49 (1996);
[2] G. D. Adeev et al., Fiz. Elem. Chast. At. Yadra 36, 732 (2005);
[3] P. N. Nadtochy et al., Phys. Rev. C 65, 064615 (2002);
[4] E. G. Ryabov et al., Phys. Rev. C 78, 044614 (2008);
[5] J. P. Lestone et al., Phys. Rev. C 79, 044611 (2009);
[6] P. N. Nadtochy et al., Phys. Rev. C 85, 064619 (2012);
[7] P. N. Nadtochy et al., Phys. Rev. C 89, 014616 (2014);
[8] G. Chaudhuri and S. Pal, Phys. Rev. C 63, 064603 (2001);

NUCLEAR FISSION MODELING WITH SPY

J.F. Lemaître, CEA/DSM/Irfu & CEA/DAM/DIF, France

J.F. Lemaître[1,2], S. Panebianco[1], J.L. Sida[1], S. Hilaire[2], N. Dubray[2]

1 CEA/Saclay DSM/Irfu, 91191 Gif sur Yvette, France
2 CEA/DAM/DIF, F-91297 Arpajon, France

Although discovered 75 years ago, nuclear fission is still under investigation. Indeed, the understanding of this phenomenon still presents theoretical difficulties due to its complexity. This requires a good understanding of the structure of atomic nucleus and at the same time a detailed description of the mechanisms driving the evolution of a fissioning system.

We are developing a new statistical scission point model named SPY (Scission Point Yields) to model the fission mechanism and determine nascent fragments characteristics (yields, kinetic energy, excitation energy). This model is based on the Wilkins approach [1], developed in 1976. It consists in a statistical description of the fission process at the scission point where fragments are completely defined and well separated with fixed properties. The main advance brought by our model is the introduction of microscopic description of the nuclear structure in the calculation of the energy of the system at scission. Therefore, this model can be regarded as a theoretical laboratory for fission modeling since it allows to study the relationship between fission fragments properties and their nuclear structure.

With SPY, we were able to calculate the properties of fragments for about 3000 fissioning nuclei from Z=70 to Z=109 and from proton drip line to neutron drip line. This allowed us identifying global trends and to produce useful results to understand stellar nucleosynthesis in very neutron-rich astrophysical sites. After a general presentation of the model, I will present the most significant results in the actinide region, like the thermal neutron-induced fission of ^{235}U or the ^{252}Cf spontaneous fission. Then, the study of most exotic nuclei like ^{180}Hg [2] will be presented, together with the global trends on the mass splitting over the whole nuclear chart. Finally I will discuss the astrophysical implications [3] of the results and some outlooks.

REFERENCES
[1] B. D. Wilkins *et al*, Phys. Rev. C 14, 1832-1863 (1976)
[2] S. Panebianco *et al*, Phys. Rev. C 86 064601 (2012)
[3] S. Goriely *et al*, Phys. Rev. Lett. 111 242502 (2013)

Thursday

September 4th

RIKEN RIBF OVERWIEV

Tomohiro Uesaka, RIKEN Nishina Center, Wako, Japan

GANIL/SPIRAL 2 – STATUS AND FUTURE

Marek Lewitowicz , GANIL, Caen, France

Recent results related to study of nuclei far from stability obtained at the GANIL facility [1] will be presented. A short-term scientific program of the current facility and, in particular, the AGATA campaign at GANIL will be discussed.

A first phase of the SPIRAL 2 facility [1], an ambitious extension of the GANIL accelerator complex, will be accomplished in 2014/2015. In the frame of this project, a new superconducting linear accelerator delivering high intensity, up to 40 MeV, light (proton, deuteron, $^{3-4}$He) beams as well as a large variety of heavy-ion beams with mass over charge ratio equal to 3 and energy up to 14.5 MeV/nucl. is in the final stage of construction. Two new experimental halls Neutron For Science and S3 will allow for a new class of experiments with a high flux of fast neutron and high intensity heavy -ion beams, respectively. Simultaneously, an important upgrade of the current SPIRAL 1 ISOL facility will be accomplished by 2016/2017 allowing for production and acceleration of RIB of isotopes of about 20 light and medium-light elements. The energies of accelerated RIB will reach up to 7-8 MeV/nucl. for neutron-rich isotopes and 20 MeV/nucl. for neutron-deficient ones. A dedicated new experimental hall called DESIR used for experiments with low-energy RIB provided by SPIRAL1 and S3 is currently in the detailed design phase.

An ambitious scientific program at GANIL/SPIRAL2 imposes a use of the most efficient and innovative detection systems as a new separator/spectrometer S3, the upgraded magnetic spectrometer VAMOS, the 4π gamma-array EXOGAM2 and the European gamma-ray tracking array AGATA as well as charged particle detectors like ACTAR-TPC, FAZIA and GASPARD. A status of the construction of the SPIRAL2 facility and future operation modes of the GANIL/SPIRAL2 complex as a multi-user facility will be shortly presented.

REFERENCES

[1] http://pro.ganil-spiral2.eu/

STATUS OF THE SPES FACILITY: TECHNOLOGICAL CHALLENGES AND FIRST DAY SCIENTIFIC PROGRAM.

Fabiana Gramegna, INFN- LNL, Legnaro(Pd), Italy

F. Gramegna and the SPES collaboration

INFN Laboratori Nazionali di Legnaro

The status of the SPES facility for Radioactive Ion Beam (RIB) production, which is under construction at the INFN Legnaro National Laboratories site, will be reported. SPES will provide mostly neutron-rich exotic beams produced through the proton induced fission on a direct UCx target. The expected SPES beam intensities, quality and energies (up to 11 MeV/A for A=130) together with the up to date experimental apparatuses which are and will be available at LNL will permit to perform forefront research in nuclear structure and nuclear dynamics studies in a region of the nuclear chart far from stability. Both the SPES technological challenges and the First Day Scientific Program, based on the several letters of intents, which have been presented and discussed in National and International Workshops will be described. The quite large and up-to-date scientific program to be considered and studied in the forthcoming years, within International collaborations will concern Beta decay, Coulomb excitation, direct reactions (elastic and inelastic scattering, few and multi-nucleon transfer), fusion evaporation, isospin physics studies, which can be performed with the present and forthcoming SPES Instrumentation.

DEFORMATION OF ^{97}Rb STUDIED BY LOW-ENERGY COULOMB EXCITATION

Magda Zielińska, CEA Saclay, France

C. Sotty[1,2], M. Zielińska[3], G. Georgiev[1], G. Simpson[4], J.M. Daugas[5], D. Balabanski[6], A. Blazhev[7], N. Bree[2], R. Chevrier[5], S. Dasgupta[8], J. Diriken[2], L. Gaffney[9], K. Geibel[6], K. Hadyńska-Klęk[10], F. Kondev[11], T. Kröll[12], B. Lannoo[8], P. Morel[5], P. Napiorkowski[10], J. Pakarinen[13], P. Reiter[6], M. Scheck[12], M. Seidlitz[7], B. Siebeck[7], A. Stuchbery[14], N. Warr[7], F. Wenander[13], and REX-ISOLDE and MINIBALL collaborations

1 CSNSM, Orsay, France; 2 KU Leuven, Belgium; 3 CEA Saclay, France;
4 LPSC, Grenoble, France; 5 CEA/DAM, Bruyères-le-Châtel, France ;
6 INRNE – BAS, Sofia, Bulgaria; 7 Institute for Nuclear Physics, Cologne, Germany;
8 Università di Camerino, Italy ; 9 University of Liverpool, UK ;
10 Heavy Ion Laboratory, Warsaw, Poland; 11 Argonne National Laboratory, USA;
12 Technische Universität Darmstadt, Germany; 13 ISOLDE, CERN, Geneva, Switzerland;
14 ANU, Canberra, Australia

Neutron-rich nuclei in the A~100 mass region have been under extensive investigation in the last four decades, from both the theoretical and experimental points of view, due to the observation of a rapid onset of deformation when going from N=58 to N=60. This effect was initially observed in mass measurements [1] and later confirmed by laser spectroscopy studies of ground state quadrupole moments (e.g. in the Rb isotopes [2]) as well as by significant amount of experimental data on properties of low-lying excited states in neutron-rich Sr and Zr isotopes. Recent mass measurements and Coulomb excitation experiments on Kr isotopes [3,4] have shown a more gradual shape transition in this isotopic chain as compared to what is observed for heavier elements, including neighbouring Rb nuclei. More experimental information on the structure of Rb isotopes seems to be necessary to understand the role of proton orbits in the development of deformation in this mass region.

A low-energy Coulomb excitation experiment to study electromagnetic properties of low-lying excited states in $^{93-99}$Rb has been performed at the REX-ISOLDE facility. Nuclei of interest were post-accelerated to 2.83 MeV/u and Coulomb excited on ^{60}Ni and ^{196}Pt targets. The Miniball array was used for the detection of the gamma-rays of interest in coincidence with scattered particles detected by an annular DSSSD detector placed at forward angles.

Several gamma-ray transitions were observed in ^{97}Rb, where no excited states were previously known. Thanks to gamma-gamma coincidences a level scheme have been constructed, displaying a regular collective structure. Transition probabilities between the observed states were determined using the well-established GOSIA code. Preliminary results concerning the deformation of ^{97}Rb will be presented.

REFERENCES

[1] M. Epherre *et al.*, Phys. Rev. C19, 1504 (1979)
[2] C. Thibault *et al.,* Phys. Rev. C 23, 2720 (1981).
[3] S. Naimi *et al.,* Phys. Rev. Lett. 105, 032502, (2010).
[4] M. Albers *et al.*, Phys. Rev. Lett. 108, 062701 (2012).

COULOMB EXCITATION OF ^{206}Hg WITH AGATA AT GSI

Tom Alexander, University of Surrey, Guildford, UK

T. Alexander[1], Zs. Podolyák[1] , D. Rudolph[2] , J. Gerl[3] , L. G. Sarmiento[2], M. L. Cortés[3] et al.
for the PRESPEC and AGATA collaborations

1 Department of Physics, University of Surrey, Guildford, UK
2 Lund University, Lund, Sweden
3 GSI Helmholtzzentrum fur Schwerionenforschung, Darmstadt, Germany

The region of the nuclear chart surrounding the doubly-magic nucleus ^{208}Pb provides a key area to constrain and develop contemporary nuclear structure models. Energies of most nuclei in this area are well-known, however transition strengths provide a far more stringent constraint on nuclear theories. In order to perform measurements of these aspects of heavy nuclei, we must push the limits of existing experimental techniques, and utilize new technologies.
The nuclei of interest were synthesized in relativistic energy projectile fragmentation at the GSI facility in Germany. They were produced in the fragmentation of a primary ^{208}Pb beam at an energy of 1 GeV per nucleon, and separated and identified using the Fragment Separator. The secondary beams with an energy of ~140 MeV per nucleon were Coulomb excited on a secondary target of 400 mg/cm2 gold. Gamma-rays were detected with the Advanced GAmma Tracking Array (AGATA), and precise particle tracking information for Doppler-correction was determined with position measurements from the Lund-York-Cologne-CAlorimeter (LYCCA). The experiment focused on measurements of B(E2; 0+ → 2+) transition strengths in nuclei in the vicinity of ^{208}Pb, namely ^{198,200,202}Pb, ^{206}Hg and ^{200}Pt.
A significant portion of the incoming beams were in an isomeric state. By replacing the secondary target with a thick plastic stopper, the exact isomeric content of the beam was determined. This isomeric study allowed us to test the consistency and precision of the sophisticated gamma-ray tracking algorithm in a high fragmentation background environment. The analysis of the Coulomb excitation of ^{206}Hg is now at an advanced stage. Its 1068.2 keV 2+ → 0+ transition is now clearly identified in the spectra, and the transition strength will be extracted by utilizing the known value from ^{206}Pb as a calibration point.
This presentation will discuss the specifics of this experimental scenario, the challenges of high-mass relativistic gamma-ray spectroscopy, and the results obtained using these methods.

SHAPE TRANSITION AND COEXISTENCE IN ^{140}Sm

Malin Klintefjord, University of Oslo, Oslo, Norway

M. Klintefjord[1], A. Görgen[1], F. Giacoppo[1,] K. Hadynska-Klek[1],P. Hoff[1], W. Korten[2], A.C. Larsen[1], T. Renstrøm[1], B. Siebeck[3], S. Siem[1], P. Thöle[3], T. Tornyi[1], G.M. Tveten[1], M. Zielinska[2] and the MINIBALL and ISOLDE collaboration.

1 Department of Physics, University of Oslo, Norway
2 IRFU/SPhN, CEA Saclay, France
3 Institut für Kernphysik, Universität zu Köln, Germany

The open-shell nuclei with Z > 50 and N < 82 are known to have some of the largest ground-state deformations in the nuclear chart. The shapes of the nuclei in this region are expected to be prolate, except for a small island of nuclei with Z > 62 and N ≈ 78, which are predicted to be oblate [1]. Nuclei near ^{140}Sm are therefore expected to be located in a transitional region between deformed and spherical shapes (as a function of neutron number) and between prolate and oblate shapes (as a function of proton number), and shape coexistence may be expected to occur. Indeed, the rotational bands built on the isomeric 10^+ states with $\pi(h11/2)^2$ and $\nu(h11/2)^{-2}$ configuration are interpreted as prolate and oblate structures, respectively [2]. Furthermore, a low-lying excited 0^+ state was tentatively assigned in ^{140}Sm [3], which could be interpreted as a sign for shape coexistence. The measurement of spectroscopic quadrupole moments and transition strengths for low-lying states represents a sensitive test for theoretical predictions in this region where nuclear shapes change rapidly.
A Coulomb excitation experiment of ^{140}Sm beam on a ^{94}Mo target was performed at the ISOLDE facility at CERN, using the MINIBALL spectrometer coupled to the DSSSD array. The laser-ionized beam of ^{140}Sm was quasi-pure with an average intensity of $2 \cdot 10^5$ particles per second. At least three excited states in ^{140}Sm were populated during the experiment: the 2^+ and 4^+ states of the ground-state band and the tentatively assigned 0^+ state at 990 keV excitation energy. The statistics collected during the experiment allows the analysis of differential Coulomb excitation cross sections as a function of scattering angle.
To increase the sensitivity of the Coulomb excitation experiment to the spectroscopic quadrupole moment via the reorientation effect, lifetimes of states in the ground-state band were measured in a complementary recoil-distance lifetime measurement at the Heavy Ion Laboratory in Warsaw. The spin assignment of the presumed 0^+ state at 990 keV was investigated in a third experiment at HIL Warsaw by measuring angular correlations following the beta decay of ^{140}Eu. The combination of all three experiments allows a rather complete characterization of the low-lying states in ^{140}Sm. Experimental details and results of the ^{140}Sm Coulomb excitation analysis with GOSIA and GOSIA2 [4] will be discussed.

REFERENCES
[1] J.-P. Delaroche et al., Phys. Rev.C 81, 014303 (2010)
[2] M.A. Cardona et al., Phys. Rev.C 44, 891 (1991)
[3] R.B. Firestone et al., Phys. Rev.C 43, 1066 (1991)
[4] T. Czosnyka, D. Cline, and C.Y. Wu. Bull. Am. Phys. Soc., 28, 745, (1983)

FIRST SPECTROSCOPY OF EXCITED STATES IN THE DRIP-LINE NUCLIDE, ^{74}Sr

Jack Henderson, University of York, York, UK

J. Henderson[1], D. G. Jenkins[1], K. Kaneko[2], P. Ruotsalainen[3], P. Sarriguren[4], K. Auranen[3], M. A. Bentley[1], P. J. Davies[1], A. Görgen[5], T. Grahn[3], P. T. Greenlees[3], A. Hay[1], T. W. Henry[1], A. Herzáň[3], U. Jakobsson[3], R. Julin[3], S. Juutinen[3], J. Konki[3], M. Leino[3], C. McPeake[6], S. Milne[1], A. J. Nichols[1], J. Pakarinen[3], P. Papadakis[3], J. Partanen[3], P. Peura[3], P. Rahikla[3], E. Sahin[5], M. Sandzelius[3], J. Sarén[3], C. Scholey[3], M. Siciliano[7,3], L. Sinclair[1], J. Sorri[3], S. Stolze[3], J. Uusitalo[3] and R. Wadsworth[1]

1 Department of Physics, University of York, Heslington, YorkYO10 5DD, United Kingdom
2 Department of Physics, Kyushu Sangyo University, Fukuoka 813-8503, Japan
3 Department of Physics, University of Jyväskylä, FIN-40014, Finland
4 Instituto de Estructura de la Materia, CSIC, Serrano 123, E-28006 Madrid, Spain
5 Department of Physics, University of Oslo, N-0316, Oslo, Norway
6 Oliver Lodge Laboratory, University of Liverpool, Liverpool L69 7ZE, United Kingdom
7 Dipartimento di Fisica e Astronomia dell'Università di Padova, I-35131 Padova, Italy

The first experimental observation of excited states in the N=Z-2 nuclide ^{74}Sr will be reported. Using the highly selective recoil-beta tagging [1, 2] technique at the University of Jyväskylä, the $2_1^+ \rightarrow 0_1^+$ and $4_1^+ \rightarrow 2_1^+$ transitions are identified. Combining these results with published data for the other nuclides of the A=74 isobar, triplet- and mirror-energy differences (TEDs and MEDs, respectively) are calculated, representing the highest mass for which such data have been extracted.
Through comparison with state-of-the-art shell-model calculations, the need for an additional 100-keV interaction component which is isotensor, J=0 and isospin non-conserving (INC) is found to extend into the A=74 isobar. The implication of this result is that such an INC component is mandated across the nuclear chart, independent of nuclear structure effects, such as which shell-model orbitals are active.
Additionally, a half life for ^{74}Sr is extracted, in good agreement with a measurement performed at the Radioactive Ion Beam Factory at RIKEN [3]. This half life is found to be approximately a factor of two less than that predicted theoretically using systematically calculated Q-values [4]. This raises the possibility that ^{74}Sr is less well-bound than previously supposed, with the implication that both the 2^+ and 4^+ first-excited states may be two-proton unbound.
The extracted TED and MED data therefore not only represent the highest mass for which such information is available, but also possibly the first high-mass case in which one or more of the low J states are unbound.

REFERENCES

[1] A. N. Steer *et al.*, Nucl. Inst. Meth. A 565, 630 (2013)
[2] J. Henderson *et al.*, JINST 8 P04025 (2013)
[3] L. F. Sinclair *et al.*, to be published (2014)
[4] P. Sarriguren *et al.* Phys. Rev. C 83 025801 (2011)

SHAPE EVOLUTION IN THE NEUTRON-RICH OSMIUM ISOTOPES: PROMPT γ-RAY SPECTROSCOPY OF ^{196}Os

Philipp Rudolf John, Dipartimento di Fisica e Astronomia Università degli Studi di Padova and INFN Sezione di Padova, Italy

P.R. John[1], V. Modamio[2], J.J. Valiente-Dobòn[2], D. Mengoni[1], S. Lunardi[1], T.R. Rodrìguez[3,4], and the AGATA collaboration

1 Università di Padova and INFN Sezione di Padova, Padova, Italy
2 INFN Laboratori Nazionali di Legnaro, Legnaro, Italy
3 Technische Universität Darmstadt, Darmstadt, Germany and
4 Universidad Autònoma de Madrid, Madrid, Spain

The nuclei with A~190 between Hf and Pt exhibit a great variety of nuclear phenomena, including K-isomerism, triaxiality and shape transition across the isotopic chain. This region has been in fact a crucial testing ground for the nuclear models aspiring at the description of such complex nuclear phenomena. Of particular interest is the transition from axially symmetric deformed, prolate ($\gamma = 0^{\circ}$) to oblate ($\gamma = 60^{\circ}$) shapes in the neutron-rich Os isotopic chain. While a study by Wheldon et al. [1] of the neutron-rich ^{194}Os nucleus suggests a prolate shape for its yrast states, Podolyàk et al. [2] proposed an oblate shape for ^{198}Os. For the key nucleus in between, ^{196}Os, no γ spectroscopic information exists. To shed light on the shape evolution, ^{196}Os was investigated via in-beam γ-ray spectroscopy using the two-proton transfer reaction ^{198}Pt (^{82}Se, ^{84}Kr)^{196}Os and the binary-partner method: the beam-like recoils were detected and identified in the PRISMA heavy-ion spectrometer [3] and the coincident γ rays were measured by the AGATA demonstrator [4, 5]. The de-excitation of low-lying levels of the yrast band of ^{196}Os were identified for the first time. State-of-the-art beyond mean-field calculations [6] were performed for the even-even $^{188-198}$Os isotopes. The results suggest a smooth transition from predominantly axial rotational behaviour through triaxial nuclei to more vibrational nuclei, when adding pairs of neutrons. The theoretical predictions are in good agreement with the existing and new experimental data. In particular, the newly measured yrast band of ^{196}Os exhibits an almost perfect γ-unstable/triaxial character.

REFERENCES

[1] C. Wheldon et al., Phys. Rev. C63, (2000) 011304(R).
[2] Zs. Podolyàk et al., Phys. Rev. C79, (2009) 031305.
[3] A.M. Stefanini et al., Nucl. Phys. A701, (2002) 217c221c.
[4] S. Akkoyun et al., NIM A668, (2012) 2658.
[5] A. Gadea et al., NIM A654, (2011) 8896.
[6] T. R. Rodrìguez and J. L. Egido, Phys. Rev. C 81 (2010) 064323.

STRUCTURE OF ^{207}Pb POPULATED IN DEEP-INELASTIC COLLISIONS

Callum M. Shand, University of Surrey, Guildford, UK

C.M. Shand[1], E. Wilson[1], Zs. Podolyák[1], B. Fornal[2], R.V.F. Janssens[3], H. Grawe[4], B.A. Brown[5], M. Bowry[1], M. Bunce[1], M.P. Carpenter[3], R.J. Carroll[1], C.J. Chiara[3], N. Cieplicka[2], A.Y. Deo[1], G.D. Dracoulis[6], C.R. Hoffman[3], R.S. Kempley[1], F.G. Kondev[3], G.J. Lane[6], T. Lauritsen[3], M.W. Reed[1], P.H. Regan[1], C. Rodriguez-Triguero[7], D. Seweryniak[3], B. Szpak[2], P.M. Walker[1], S. Zhu[3]

1 Department of Physics, University of Surrey, Guildford, Surrey, GU2 7XH, UK
2 Institute of Nuclear Physics, Polish Academy of Sciences, PL-31342 Kraków, Poland
3 Physics Division, Argonne National Laboratory, Argonne, IL 60439, USA
4 GSI Helmholtzzentrum für Schwerionenforschung, D-64291 Darmstadt, Germany
5 Department of Physics and Astronomy and National Superconducting Cyclotron Laboratory, Michigan State University, East Lansing, MI 48824, USA
6 Department of Nuclear Physics, Australian National University, Canberra ACT 0200, Australia
7 School of Computing, Engineering and Mathematics, University of Brighton, Brighton, BN2 4GJ, UK

^{207}Pb is a one-neutron-hole nucleus with respect to a ^{208}Pb core, the heaviest known doubly-magic nucleus. The region around ^{208}Pb, has been of particular interest in testing the purity of shell-model wave functions. Understanding the structure of nuclei in the aforementioned region is instrumental in calculations of more complex configurations. Accordingly, measurements of a 1446 MeV ^{208}Pb beam impinging on a 75 mg/cm^2 thick ^{208}Pb target were carried out at Argonne National Laboratory using the ATLAS accelerator. Deep-inelastic collisions of the beam and target populated many yrast and near-yrast states within the reaction products. The resulting g rays were detected by Gammasphere, an array of ~100 Compton-suppressed High-Purity Germanium (HPGe) detectors. Among the data collected were transitions populating core-breaking yrast states above the $13/2^+$ $t_{1/2}$=0.806 s isomer in ^{207}Pb. Prior to this work, six of the transitions discussed herein had been tentatively placed in the level scheme up to ~6 MeV [1], with spin and parities purely based on shell model calculations. Analysis of the present data has extended the level scheme of ^{207}Pb up to ~8.9 MeV. Transitions were identified according to coincidences with the previously observed 2485 keV transition, which populates the $13/2^+$ isomeric state in ^{207}Pb. The new yrast and near-yrast transitions have been placed within the level scheme according to their mutual coincidences. Spin and parity assignments of the new states were made based on decay patterns and the first measured angular distributions of these transitions; among these measurements is the first confirmation that the 2485 keV transition has E3 multipolarity. The extended level scheme of ^{207}Pb will be presented and interpreted along with comparisons to two separate shell-model calculations: the Kuo-Herling interaction [2,3] and the M3Y interaction [4].

REFERENCES
[1] M. Schramm, et al., Z. Phys. A. 334, 121 (1992).
[2] T.T.S. Kuo and G.H. Herling, U.S. Naval Research Laboratory Report, No. 2258 (1971).
[3] T.T.S. Kuo and G.H. Herling, Nucl. Phys. A. 181, 113 (1972).
[4] B.A. Brown, Phys. Rev. Lett. 85, 5300 (2000).

Friday

September 5th

STRUCTURE OF LIGHT NEUTRON-RICH NUCLEI STUDIED WITH TRANSFER REACTIONS

Alan H. Wuosmaa, University of Connecticut, Storrs, USA

The properties of light, neutron-rich nuclei are sensitive to many aspects of the nucleon -nucleon interaction that are also important in heavier nuclei, and continue to be a subject of intense study. In particular, with the wide availability of beams of radioactive ions, it is possible to learn about the properties of nuclei far from stability through nucleon transfer reactions. These reactions are highly selective and data for them are relatively straightforward to interpret, making them ideal for assigning quantum numbers, determining spectroscopic factors, and understanding the wave functions of nuclear states. For nuclei around the neutron *p-sd* shell boundary, the evolution of the neutron effective single-particle energies with Z is sensitive to the tensor interaction as well as other features such as nucleon-nucleon residual interactions. I will discuss examples of this behavior, focusing on the neutron-rich boron nuclei $^{12,13,14}B$, studied with the neutron-adding (*d,p*) reaction, and the proton and neutron-proton removing reactions (d,^{3,4}He), in inverse kinematics. Nucleon-adding and removal reactions provide complementary information about the nuclei of interest.

The experiments were performed using beams of ^{13}B, and $^{14,15}C$ from the ATLAS accelerator at Argonne National Laboratory. The short-lived radioactive beams were produced with the in-flight production facility at ATLAS. The reaction products were detected and analyzed using HELIOS (the HELIcal Orbit Spectrometer), a device constructed specifically to analyze the products of transfer reactions done with in inverse kinematics. This approach addresses a number of technical difficulties encountered when studying inverse-kinematic reactions. In the ^{14}B system, the data permit a detailed study of the evolution of the $1s_{1/2}$ and $0d_{5/2}$ single-particle orbitals for N=9 isotones [3]. The selectivity of the (d,^{4}He) reaction has been used to identify so-called “stretched” or aligned states, where the strongest transitions involve protons and neutrons that occupy the same j orbital, with their angular momenta coupled to the maximum possible value. Such states are of interest in nuclei with large neutron-proton imbalance, as one of the two removed particles is typically a deeply-bound nucleon whereas the other may lie close to the Fermi surface. These excitations can have high spin and, despite being at high excitation energy, may be quite narrow. The technical approach, recent experimental results, and interpretations of the data will be presented.

This work was supported by the U. S. Department of Energy, Office of Nuclear Physics under contracts DE-FG02-04ER41320 and DE-AC02-06CH11357, and the U. S. National Science Foundation under Grant No. PHY-1068217.

REFERENCES

[1] A. H. Wuosmaa *et al.*, Nucl. Instrum. and Meth. in Phys. Res. A, 580, 1290 (2007).
[2] J. C. Lighthall *et al.*, Nucl. Instrum. and Meth. in Phys. Res. A 622, 97 (2010).
[3] S. Bedoor *et al.*, Phys. Rev. C 88, 011304R (2013).

EVOLUTION OF SHELL STRUCTURE IN NEUTRON-RICH NUCLEI FROM Ca TO Ni

Robert V. F. Janssens, Physics Division, Argonne National Laboratory, USA

The last decade has witnessed increased interest in structural properties of neutron-rich nuclei in the region located between ^{48}Ca and ^{68}Ni, motivated in part by the prospect of the onset of new subshell closures at neutron numbers $N = 32$ and $N = 34$ as well by questions about the magnitude of the shell gap at $N = 40$.
This presentation will review the available data obtained with a number of experimental techniques. It will compare the observations with recent calculations highlighting the important of three-body forces as well as the role of the occupation of specific orbitals. Evidence for both new subshell closures and the onset of collective behavior will be discussed.

This work is supported by the US Department of Energy, Office of Nuclear Physics, under contract no. DE-AC02-06CH11357.

SEMINAR

STRUCTURE BEYOND THE N=50 SHELL CLOSURE IN NEUTRON-RICH NUCLEI IN THE VICINITY OF ^{78}Ni: THE CASE OF N=51 NUCLEI

Gilbert Duchêne , Institut Pluridisciplinaire Hubert Curien (IPHC), Strasbourg, France

G. Duchêne[1], F. Didierjean[1], D. Verney[2], G. de Angelis[3], C. Fransen[4], R. Lozeva[1], J. Litzinger[4], A. Dewald[4], M. Niikura[2,+], D. Bazzacco[5], E. Farnea[5], S. Aydin[5], A. Bracco[6], S. Bottoni[6], L. Corradi[3], F. Crespi[6], E. Ellinger[4], E. Fioretto[3], S. Franchoo[2], A. Goasduff[1,++], A. Gottardo[5,+++], L. Grocutt[7], M. Hackstein[4], F. Ibrahim[2], K. Kolos[2,*], S. Leoni[6], S. Lenzi[5], S. Lunardi[5], R. Menegazzo[5], D. Mengoni[5], C. Michelagnoli[5,**], T. Mijatovic[8], V. Modamio[3], O. Möller[9], G. Montagnoli[5], D. Montanari[5,***], A. Morales[6], D.R. Napoli[3], F. Nowacki[1], F. Recchia[3], E. Sahin[3,#], F. Scarlassara[5], L. Sengele[1], K. Sieja[1], J. F. Smith[7], A. Stefanini[3], C. Ur[5], J.J. Valiente Dobon[3], V. Vandone[6]

1 IPHC/CNRS-University of Strasbourg, France
2 IPNO/CNRS-University Paris Sud-11, France
3 INFN LNL, Italy
4 IKP University of Cologne, Germany
5 INFN and University of Padova, Italy
6 INFN and University of Milano, Italy
7 University of Paisley, United Kingdom
8 Ruder Boskovic Institute, Croatia
9 IKP, TU Darmstadt, Germany

Recent experimental discoveries have revealed that the neutron effective single-particle evolution above ^{78}Ni shows peculiar or unpredicted behaviours. The aim of this work is to determine the nature of the low-lying yrast or quasi yrast $7/2^+$ states in $32 < Z < 40$, odd-neutron N=51 nuclei in order to assess their collective or υ1g7/2 single-particle origin and better constrain the relative position of the latter with respect to other neutron single-particle states above a ^{78}Ni core. Calculations show that there is a difference of about two orders of magnitude between core-particle coupled state and single-particle state half-lifes.

A Recoil distance Doppler-shift (RDDS) experiment has been performed at LNL (Italy). The neutron-rich nuclei were produced via deep-inelastic, multi-nucleon transfer and induced fission reactions with the ^{82}Se(@ 505 MeV) + ^{238}U system. The setup combined the AGATA demonstrator composed of 5 triple clusters, the PRISMA fragment spectrometer and the Cologne plunger. The number of plunger distances was restricted to only two. This allowed to maximize the statistics for each degrader position while being able to provide the half-life domain (~0.10 ps or several tens ps) of the states of interest, which was sufficient for the main goal of the experiment. This strategy proved to be fruitful, as will be shown in this presentation which gives preliminary results for half-lifes of the lowest-lying 7/2 and 9/2 states of two N=51 nuclei, ^{87}Kr and ^{85}Se.

CURRENT ADDRESSES:

+	*University of Tokyo , Japan*
++	*CSNSM/CNRS-University Paris Sud-11, France*
+++	*IPNO/CNRS-University Paris Sud-11, France*
*	*University of Tenessee , USA*
**	*GANIL, CEA/DSM-CNRS/IN2P3, Caen , France*
***	*IPHC/CNRS-University of Strasbourg, France*
#	*University of Oslo, Norway*

Friday 09:30

PARTICLE-CORE COUPLINGS CLOSE TO NEUTRON-RICH DOUBLY-MAGIC NUCLEI

Silvia Leoni, University of Milano and INFN, Milano, Italy

The coupling between valence particles and core excitations is a very important issue in nuclear structure studies, being a key process at the origin of the quenching of spectroscopic factors, the anharmonicities of vibrational spectra and the damping mechanisms of giant resonances. The investigation of this coupling by using a systematic gamma spectroscopy study of nuclei lying close to the neutron-rich doubly-magic ^{48}Ca, ^{132}Sn and ^{208}Pb cores is of special interest as the phonon excitations are expected to significantly influence the single particle structure in these species. Various reactions have been employed to populate excited states in nuclei lying in close proximity of doubly-magic nuclei: multinucleon transfer with heavy ions, cold neutron capture (n,γ) and neutron induced fission on ^{235}U and ^{241}Pu targets. The measurements were performed at Legnaro National Laboratory and ILL (Grenoble), using complex detection systems based on HpGe arrays, such as CLARA and EXOGAM, coupled to magnetic spectrometers (PRISMA) or fast $LaBr_3$ scintillator detector arrays for lifetime measurements by fast timing techniques. The focus is, in particular, on experimental data on ^{47,49}Ca [1,2], ^{133}Sb and ^{210}Bi, which can be compared with theoretical calculations either based on a particle-phonon coupling approach or on a shell model employing realistic effective nucleon-nucleon interactions. Results on ^{61,65,67}Cu [3,4], obtained at NIPNE (Bucharest), will also be discussed in terms of couplings with the 3^- octupole phonon of the semi-magic ^{60,64,66}Ni cores.

From a broader perspective, the presented data will be used to assess the robustness of the nuclear shell closures in various regions of the nuclear chart, from rather light to heavy systems. They will also serve as a testing ground for state of the art theoretical models.

REFERENCES
[1] D. Montanari et al., Phys. Lett. B697, 288 (2011).
[2] D. Montanari et al., Phys. Rev. C85, 044301 (2012).
[3] G. Bocchi et al., Phys. Rev. C89, 054302 (2014).
[4] C. Nita et al., in print in Phys. Rev. C.

STUDY OF Ca ISOTOPES VIA NEUTRON CAPTURE REACTIONS

Giovanni Bocchi, Università degli Studi di Milano - INFN sezione di Milano, Italy

G. Bocchi[1,2], S. Leoni[1,2], G. Benzoni[1,2], S. Bottoni[1,2,3], A. Bracco[1,2],
M. Jentschel[4], U. Köster[4], P. Mutti[4], T. Söldner[4], A. Blanc[4], G. de France[5],
J.-M. Régis[6], G. S. Simpson[7], W. Urban[8], C. A. Ur[9]

1 Università degli Studi di Milano, Milano, Italy
2 INFN, sezione di Milano
3 KU Leuven, Belgium
4 ILL, Grenoble, France
5 GANIL, France
6 IKP, University of Cologne, Germany
7 University of Western Scotland, UK
8 Institute of Experimental Physics, University of Warsaw, Poland
9 INFN Sezione di Padova, Padova, Italy

Nuclei around doubly closed shells play a crucial role in determining both the nucleonic single-particle energy levels and the two-body matrix elements of the effective nuclear interactions. Of particular importance is the comparison of experimental data with calculations either based on a shell-model approach or taking into account couplings between basic core excitations (such as vibrations) and single particles [1].

In this work we present a detailed γ-spectroscopy study of Ca isotopes, produced by a neutron capture reaction on a ^{48}Ca target. The experiment was performed at the PF1B cold-neutron facility at ILL (Grenoble, France), were the world's brightest continuous neutron flux is delivered with a thermal-equivalent of $2x10^{10}$ n $s^{-1}cm^{-2}$. The experimental set-up consisted of 46 HPGe crystals, belonging to the EXOGAM, GASP and LOHENGRIN collaborations, for a total photopeak efficiency of 6%. The (n,γ) reaction populated excited states of ^{49}Ca within few units of spin, from the ground state up to the neutron binding energy. The same type of information is also obtained for ^{41}Ca and ^{45}Ca, owing to target contaminants of ^{40}Ca and ^{44}Ca. This allows to investigate the nuclear structure of nuclei one nucleon away from the shell closures of ^{40,44,48}Ca, including the possibility to identify the low-spin members of the particle-phonon multiplet (such as the $1/2^+$ and the $3/2^+$ states), arising by coupling the 3^- phonon of the core to the unpaired neutron outside the shell closure [2,3]. A key aspect of the analysis is the accurate measurements of γ–γ angular correlations, which allows to firmly establish the spin and parity of the excited states. Preliminary results will also be shown from a second campaign, where $LaBr_3$ detectors were coupled to the HpGe array, for lifetime measurements via the electronics fast timing technique using LaBr3-LaBr3 coincidences [4,5], with an accuracy of 5 ps between 40 keV and 6.7 MeV.

REFERENCES
[1] A. Bohr, B.R. Mottelson, Nuclear Structure, vols. I and II, W.A. Benjamin, 1975.
[2] D. Montanari et al., Phys. Lett. B 697(2011)288.
[3] D. Montanari et al., Phys. Rev. C 85(2012)044301.
[4] H. Mach, R. L. Gill, M. Moszy´nski, Nucl. Instr. and Meth. A 280 49 (1989)
[5] J.-M. Régis et al., Nucl. Instr. and Meth. A 622 83 (2010)
[6] J.-M. Régis et al., Nucl. Instr. and Meth. A 684 36 (2012)

EXOTIC DECAYS IN LIGHT NUCLEI

G. Borge, María J. ISOLDE-PH, CERN, Switzerland & Instituto de Estructura de la Materia, CSIC, Spain

The beta decay process allows for understanding the interactions and behaviour of the nucleons inside the nucleus. The process is well understood and the interpretation of the data yields a wide variety of spectroscopic information: level energies, spins, parities, widths and level densities.

Often the key nuclei to understand how such a complex system can be constructed from a few ingredients are very neutron or very proton rich. Such exotic systems allow isolating and amplifying specific aspects of the nucleonic interactions, and uniquely display the physics of loosely bound systems governed by the strong interaction. Beta decay can also shed light on some fundamentals of the weak interaction, which it is the main contributor to the process.

Going far from stability the difference in isobaric masses increases quadratically and the binding energy of the last nucleon decreases dramatically, the beta-delayed particle emission becomes dominant near the drip lines. The beta transitions feed unbound excited states and they are followed by delayed particle emission. The high efficiency for the charged particle detection makes the study of the beta delayed particles a unique tool to understand the nuclear structure of very rare species through very exotic decay modes.

In this contribution recent achievements in particle decay studies will be presented. The different techniques developed to do high quality spectroscopy of very low produced exotic nuclei, will be revised.

INVITED

GAMOW-TELLER EXCITATIONS STUDIED BY THE WEAK AND STRONG INTERACTIONS

Yoshitaka Fujita, RCNP & Dept. Phys., Osaka University, Japan

Gamow-Teller (GT) transitions are caused by the spin-isospin ($\sigma\tau$) interaction with $\Delta L = 0$ and they are the most common weak process in the Universe. In addition, GT transitions represent very important nuclear response, because the spin and isospin degrees of freedom are unique in nuclei, where the latter represents the two-fermionic nature of nuclei.

GT excitations are studied by β decays and charge-exchange (CE) reactions. The β decay has a direct access to the absolute GT transition strengths *B*(GT) from the studies of half-lives, *Q*-values and branching ratios, but it can only access states situated lower than decay *Q*-values. In contrast, CE reactions, *e.g.* the (*p*, *n*) and (^{3}He,*t*) reactions, at intermediate beam energies and 0^o, can excite GT states selectively and also up to high excitation energies. Although absolute *B*(GT) values are not derived directly, the strengths of GT excitations can be studied if a proper normalization is obtained from β decay studies due to the proportionality between the cross-sections and *B*(GT) values. Therefore, these two studies are complementary [1].

The comparison of the results from these two processes caused by the weak and strong interactions, respectively, are fruitful if both experiments have comparable quality in their energy resolutions or sensitivity. The developments achieved in these ten years have made such comparisons effective. In the CE reaction side, a resolution of ~30 keV has been realized by a (^{3}He,*t*) reaction at the beam energy of 140 MeV/nucleon at RCNP, Osaka. This resolution was one-order-of-magnitude better compared to pioneering (*p,n*) reactions. Also in the β-decay side the use of Fragment Separators (FRS) made it possible to create and identify short-lived nuclei with a larger quantity, which made it possible to access far-from-stability nuclei.

In the region up to *pf* shell, a direct comparison of GT excitations in a β decay and a (^{3}He,*t*) reaction is possible for the mirror transitions starting from a pair of mass *A* mirror nuclei, where GT transitions form *T*z = -1/2, -1, -3/2, and -2 nuclei [where *T*z = (*N*-*Z*)/2] have been studied in β decays, while those from *T*z =+1/2, +1, +3/2, and +2 nuclei have been studied in (^{3}He,*t*) reactions.

It was found that GT transitions from these mirror nuclei give us valuable information on the symmetry structure in each of these mass *A* system. In addition, by combining the β-decay half-life of a nucleus near the proton-drip-line and the GT strength distribution obtained in the mirror (^{3}He,*t*) reaction, we have shown that fruitful information on GT transitions involved in *rp*-process is available (the merged analysis, see Ref. [2]). Furthermore, the comparison of mirror GT transitions contributed in establishing the existence of low-energy Super GT (phonon) states [3].

An overview will be given for the insights achieved in the combined studies of CE reactions and β decays.

REFERENCES

[1] [1] Y. Fujita, B. Rubio and W. Gelletly, Progress in Particle and Nuclear Physics 66, 549 (2011), and references therein.
[2] [2] Y. Fujita, T. Adachi, B. Rubio et al., Phys. Rev. Lett. 95, 212501 (2005).
[3] [3] Y. Fujita, H. Fujita, B. Rubio et al., Phys. Rev. Lett. 112, 112502 (2014).

Friday 11:25

BETA DECAY STUDIES USING TOTAL ABSORPTION SPECTROSCOPY

Alejandro Algora, IFIC (CSIC-Univ. Valencia), Spain

Beta decay is an important source of information for nuclear structure studies. But in order to obtain that information proper measurements of the beta decay probability to levels in the daughter nucleus are needed.

Total absorption spectroscopy is widely accepted as the only technique that can provide beta decay data free from the so-called Pandemonium effect [1]. In this contribution we will present an overview of recent beta decay studies using the total absorption technique and their implications for nuclear structure, astrophysics and practical applications.

REFERENCES
[1] J.C. Hardy et al., Phys. Lett. B 71, 307 (1977)

SEARCH FOR NEUTRINOLESS DOUBLE BETA DECAY IN ^{124}Sn

Vandana Nanal, Tata Institute of Fundamental Research, Mumbai, India

Neutrinoless Double Beta Decay (NDBD), a lepton number violating process, can occur if neutrinos have mass and are their own antiparticles. The NDBD (0nbb) can provide the information on absolute effective mass of the neutrinos and the true nature of neutrino– whether it is a Dirac or a Majorana particle. After the discovery of neutrino oscillations, which implied that neutrinos have finite mass, there is a renewed interest in the study of the NDBD a variety of novel techniques. The identification of a NDBD event is achieved by a precision measurement of the sum energy of two emitted electrons. Thus, good energy resolution is one of the main considerations for the detector. The cryogenic bolometric detectors, where energy of incident radiation is converted into phonons leading to a measurable temperature rise, have high energy resolution as well as high sensitivity and are suitable for rare event studies like NDBD. In India, efforts have been initiated to search for $0\nu\beta\beta$ in ^{124}Sn at the upcoming underground facility of India-based Neutrino Observatory (INO). The isotope ^{124}Sn with a reasonably high Q value (2292.6±0.39 keV) and a moderate isotopic abundance (5.8%), is a good candidate for search of $0\nu\beta\beta$. Further, Tin becomes superconducting at 3.17 K and can be made into a cryogenic bolometer with high energy resolution, since at temperatures below 100 mK the specific heat has only the phononic contribution. For the development of Sn cryogenic bolometer, a custom built cryogen free dilution refrigerator has been installed at TIFR, Mumbai. Development of NTD Ge sensors for mK thermometry and radiation background studies have also been initiated. This talk will present the status of various aspects of the TIN.TIN (The India-based TIN detector) development.

β-DECAY STUDY OF 16^+ AND 9^+ SPIN-GAP ISOMERS IN ^{96}Cd AND ^{98}In

P. J. Davies, University of York, UK

The self-conjugate nuclides ^{96}Cd and ^{98}In have identified isomeric states of spin-parity 16^+ [1] and 9^+[2], respectively. A recent investigation of the 16^+ spin-gap isomer in ^{96}Cd suggests it exists as a consequence of the T=0 n-p interaction [1], the 9^+ isomer in ^{98}In is expected to arise from the same interaction. The states populated by the β-decay of these isomers, along with the B(GT) strengths and beta-delayed proton branching ratios, will provide a sensitive probe of shell model (SM) calculations in the ^{100}Sn region.

Large-scale SM (LSSM) calculations [1], performed for ^{96}Ag in the *sdg* model space predict the existence of 'resonance-like' states of spin-parity 15^+, 16^+ and 17^+, which sit above the proton separation energy. These calculations indicate that 30% of the B (GT) strength from the decay of the 16^+ isomer in ^{96}Cd should populate these 'resonance-like' states in ^{96}Ag, which are predicted to proton decay to excited states in ^{95}Pd. This is in contrast to the shell model calculations performed in the more restricted *pg* model space, with the Gross-Frenkel interaction, which predict that the 16^+ isomer in ^{96}Cd will only decay to the 15^+ isomer in ^{96}Ag with a B(GT) value of 0.14 .

Previous studies of ^{98}In [2] measured both a fast (32 ms) and a slow (1.02 s) component to the β-decay. It has been suggested the decay of the 0^+ T=1 ground state should be fast [3], hence, the slow component may correspond to the Gamow Teller (GT) decay of the 9+ isomer. SM calculations [2,4] predict the decay of the isomer will populate the 8^+, 9^+, and 10^+ states in ^{98}Cd, of which the 9^+ has yet to be experimentally observed. Furthermore, calculations suggest that the isomer may have a β-delayed proton decay branch.

This presentation will report on results from a recent experiment performed at RIKEN using RIBF and SIMBA. The first evidence of a beta delayed proton decay from the 16^+ isomer in ^{96}Cd will be presented. The beta delayed proton branching ratio has been measured, along with upper and lower limits for the B(GT) strength of the decay from the 16^+ isomer to the 15^+ isomer in ^{96}Ag and the 'resonance-like' states, respectively. These results will be compared to predictions of the latest SM calculations. The β delayed g-ray spectroscopy of the 9^+ isomer in ^{98}In will also be discussed and the measured B(GT) strength will be presented. The latest status of the data analysis will be presented, including the half life of the N<Z nuclide ^{95}Cd.

REFERENCES

[1] B. S. Nara Singh, et al. Phys Rev Lett, 107(17), 172502, (2011)
[2] P. Kienle et al., Prog. Part. Nucl. Phys. 46, 73 (2001)
[3] H. Herndl and B.A. Brown, Nuclear Physics A 627, 35-52 (1997)
[4] T. Faestermann et al. Eur. Phys. J. A 15, 185 (2002)

INVITED

Friday 15:30

NEUTRON-PROTON PAIR CORRELATIONS IN N=Z NUCLEI APPROACHING ^{100}Sn

Bo Cederwall, Department of Physics, KTH – Royal Institute of Technology, Stockholm, Sweden

The talk will review various, mainly experimental, aspects of enhanced neutron-proton correlation phenomena in nuclei along the N=Z line, approaching ^{100}Sn. In this unique region of the nuclear chart a rather complex picture of neutron-proton pair correlations is beginning to emerge. In particular novel approaches to the search for isoscalar BCS-type pairing [1,2] and investigations of the new spin-aligned isoscalar neutron-proton paired phase [3,4] in the A=90-100 mass region will be discussed.

REFERENCES

[1] Engel, J., Langanke, K. & Vogel, P. Pairing and isospin symmetry in proton-rich nuclei. Phys. Lett. B 389, 211–216 (1996)

[2] Civitarese, O., Reboiro, M.& Vogel, P. Neutron-proton pairing in the BCS approach. Phys. Rev. C 56, 1840–1843 (1997)

[3] Cederwall, B. et al. Evidence for a spin-aligned neutron-proton paired phase from the level structure of ^{92}Pd . Nature 469, 68–71 (2011)

[4] Qi, C. et al. Spin-aligned neutron-proton pair mode in atomic nuclei. Phys. Rev. C 84, 021301 (2011)

SHELL-MODEL STUDIES OF THE NEUTRON RICH NUCLEI BEYOND ^{132}Sn

Houda Naïdja, IPHC-Strasbourg, France

H.Naïdja[1,2,3], K.Sieja[1] and F.Nowacki[1]

1 Institut Pluridisciplinaire Hubert Curien (IPHC), F-67037 Strasbourg, France
2 GSI Helmholtzzentrum für Schwerionenforschung GmbH, 64291 Darmstadt, Germany
3 Laboratoire de Physique mathématique et subatomique (LPMS), Constantine 1 University, 25000, Constantine, Algeria

The heavy mass region of neutron-rich nuclei around ^{132}Sn, represents several interesting areas of experimental and theoretical nuclear physics research.
In the theoretical physics, lot of studies have been developped in this region, within the mean field using RPA or QRPA [1, 2, 3], or within the shell model [4, 5, 6]. The astrophysical r- process constitutes one of the important implications, the fact that is responsible of the synthesis of about half of the heavy elements, by multiple neutron captures. However, there is a paucity of the experimental results in this region.
In the present study, our calculations have been performed using shell model code Antoine [9, 8], including the model space $0h_{11/2,}$ $1f_{7/2}$, $0h_{9/2}$, $1f_{5/2}$, $2p_{3/2}$, $2p_{1/2}$, $0i_{13/2}$, for neutrons and $1g_{9/2}$, $1g_{7/2}$, $2d_{5/2}$, $2d_{3/2}$, $3s_{1/2}$ for protons, which are taken above the closed core ^{110}Zr. An effective interaction has been obtained from realistic CD-Bonn potential, renormalized following a $V_{low\text{-}k}$ approach, and adopted to the model space by many-body techniques [10].
We are interested in the spectroscopic properties of the even-even tin isotopes $^{134-138}$Sn. We have focused our calculations on the ground and the excited states 0^+, 2^+, $4^{+,}$ $6^{+,}$ 8^+ energies and on different electromagnetic transitions B(E2, J+2-J). In particular isomeric transitions B(E2, 6+-4+) have been studied, in comparaison to new experimental data obtained in RIKEN [7]. We investigate the effect of core excitations on the structure and transitions rates in the region. The potentiel existence of the N = 90 neutron shell closure in the ^{140}Sn will be discussed. These applications provide a stringent test of our effective interaction used in this heavy mass region very far from stability, and its predictions can be helpful for future experiments.

REFERENCES
[1] Terasaki, J. Engel, W. Nazarewicz and M. Stoitsov, Phys.Rev C 66, 054313 (2002).
[2] F. Hofmann and H. Lenske, Phys.Rev C 57, 2281 (1998).
[3] J. Dobaczewski, W. Nazarewicz, T.R. Werner, J.F. Berger, C.R.Chinn, and J.Decharge, Phys. Rev.C 53, 2809 (1996).
[4] M.P.Kartamyshev, T.Engeland, M.Hjorth-Jensen, and E.Osnes Phys.Rev.C 76, 024313 (2007).
[5] S.Sarkar and M.Saha Sarkar, Phys.Rev.C 81, 064328 (2010).
[6] A.Covello, A.Covello, A.Gargano, and N.Itaco, J. Phys. Conf.ser.267, 012019 (2011).
[7] G.S.Simpson and al. submitted in Phys.Rev.Lett.
[8] E. Caurier, G.Martinez-Pinedo, F. Nowacki. A. Poves and A. P. Zuker. Rev. Mod. Phys.77, 427 (2005).
[9] E.Caurier, Shell Model code ANTOINE, CRN, Strasbourg (1989).
[10] M.Hjorth-Jensen, T.T.S.Kuo, E.Osnes, Phy.Rep.261 125-270(1995).

CLUSTER EFFECTS IN THE STRUCTURE OF ^{44}Ti

Timur Shneidman, Joint Institute for Nuclear Research, Dubna, Russia

T.M. Shneidman[1,2], G.G. Adamian[1], N.V. Antonenko[1], R.V. Jolos[1], Shan-Gui Zhou[2]

1 Bogoliubov Laboratory of Theoretical Physics, Joint Institute for Nuclear Research, Dubna, 141980, Russia.
2 State Key Laboratory of Theoretical Physics, Institute of Theoretical Physics, Chinese Academy of Sciences, Beijing 100190, China.

The properties of the ground state and excited bands in ^{44}Ti, including angular momentum dependences of the moments of inertia and multipole transition probabilities, are analyzed in the framework of the dinuclear system model, which is a variant of a cluster model. Previously the model was successfully applied for the description of the excitation spectra of light N=Z nucleus ^{60}Zn [1] and heavier nuclei of rare-earth and actinide mass regions [2,3]. In the proposed model the mass asymmetry variable which describes the partition of nucleons between the clusters is used as a collective coordinate. Due to this, the wave function of the nucleus is treated as a superposition of different cluster configurations including the mononucleus.

REFERENCES

[1] G. G. Adamian et al., Phys. Rev. C67, 054303 (2003).
[2] T.M. Shneidman et al., Phys. Rev. C67, 014313 (2003).
[3] T.M. Shneidman et al., Eur.Phys.J. A 47, 34 (2011).

A REGION OF ROTATING TOROIDAL ISOMERS

Andrzej Staszczak, UMCS Lublin, Poland

A. Staszczak[1] and Cheuk-Yin Wong [2]

1 Institute of Physics, Maria Curie-Skłodowska University, Lublin, Poland
2 Physics Division, Oak Ridge National Laboratory, Oak Ridge, USA

Nuclei as we now know them have the topology of a sphere. Wheeler suggested that under appropriate conditions the nuclear fluid may assume a toroidal shape. Toroidal nuclei are however plagued with various instabilities [1], and the search remains elusive [2-4]. A rotation about the symmetry axis with an angular momentum above a high threshold can stabilize the toroidal nucleus and can lead to an isomeric state at a local energy minimum [5]. However, the angular momentum must take on quantized nontrivial values by aligning the angular momenta of the nucleons along the symmetry axis [6]. From the considerations of both the bulk behaviour and the quantized aligned rotation, we find that rotating toroidal nuclei may have general occurrences, and a large number of rapidly rotating toroidal isomers in the mass region of $28 \leq A \leq 48$ have been located theoretically using cranked constrained Skyrme-Hartree-Fock calculations [7].

REFERENCES
[1] C. Y. Wong, Toroidal and spherical bubble nuclei, Ann. of Phys. (N.Y.) 77, 279 (1973).
[2] G. Royer, F. Haddad, B. Jouault, Rotating bubble and toroidal nuclei and fragmentation, Nucl. Phys. A 605, 403 (1996).
[3] V. Zherebchevsky, et al., Binary fission and coplanar cluster decay of ^{60}Zn compound nuclei at high angular momentum, Phys. Lett. B 646, 12 (2007).
[4] A. Staszczak, C. Y. Wong, Toroidal super-heavy nuclei in Skyrme-Hartree-Fock approach, Acta Phys. Pol. B 40, 753 (2008), and references cited therein.
[5] C. Y. Wong, Rotating toroidal nuclei, Phys. Rev. C 17, 331 (1978).
[6] A. Bohr, B. R. Mottelson, The structure of angular momentum in rapidly rotating nuclei, Nucl. Phys. A 354, 303c (1981).
[7] A. Staszczak, C. Y. Wong, Light rotating toroidal nuclei, arxiv:1312.3413v2.

MULTIPLE CHIRAL BANDS ASSOCIATED WITH THE SAME STRONGLY ASYMMETRIC MANY-PARTICLE NUCLEON CONFIGURATION

Obed Shirinda, iThemba LABS, Cape Town, South Africa

O. Shirinda, E.A. Lawrie

iThemba LABS, P.O. Box 722, Somerset West 7129, South Africa

A nuclear chiral system is formed when the total angular momentum of the nucleus is aplanar, i.e. when it has significant projections along all three nuclear axes [1]. It is revealed by the observation of degenerate $\Delta I = 1$ partner bands [1]. The simplest chiral system is built on a two-quasiparticle configuration, where one quasiparticle has predominantly particle, and the other one has predominantly hole nature, coupled to the rotation of a triaxial core. Up to date, chiral candidates showing two- or multi-quasiparticle partner bands have been observed in several nuclei in A ~ 80, 100, 130 and 190 mass regions. The existence of multiple chiral partner bands (MχD) with large triaxial deformation, but with different particle-hole configuration was proposed in a single nucleus (e.g. see reference [2]). The MχD existence has been experimentally confirmed in ^{133}Ce [3].
Contrary to MχD that differ from each other in their particle-hole configurations and may correspond to different triaxial deformations. We investigated the existence of multiple chiral bands built on the same configuration. Our calculations using the two-quasparticle-plus-triaxial-rotor model (TQPRM) of Semmes and Ragnarsson [4], confirm that more than one pair of chiral bands may exist in a nucleus with the same two-quasiparticle configuration (this was also reported previously in [1,5]). The present work studies the existence and properties of multi chiral bands built on the same many-particle nucleon configuration. We have used the multi-particle-plus-triaxial rotor (MPR) [6] model of Carlsson and Ragnarsson to calculate chiral bands associated with strongly asymmetric configurations in A ~ 100, 130 and 190 mass regions. The quadrupole deformation was set to $\varepsilon_2 = 0.15$, while values of the triaxiality parameter of $\gamma = 30^0$ and $\gamma \neq 30^0$ were considered. The calculations predict multiple chiral bands for both $\gamma = 30^0$ and $\gamma \neq 30^0$. It should be noted how different the layout of the first two pairs of chiral bands is in comparison with that for a two-quasiparticle configuration. Instead of two well identifiable pairs of chiral bands, the four many-particle chiral bands group differently, particularly for $\gamma \neq 30^0$. In that case one of the chiral bands is well separated and lies at lower energy, while the other three group together at similar excitation energy. The results from these calculations will be presented and discussed.

This work is supported by the National Research Foundation, South Africa.

REFERENCES

[1] S. Frauendorf, J. Meng, Nucl. Phys. A 617, (1997) 131
[2] J. Meng et al., Phys. Rev. C 73, (2006) 037303
[3] A.D. Ayangeakaa et al., Phys. Rev. Lett. 110, (2013), 172504
[4] P.B. Semmes and I. Ragnarsson, AIP Conf. Proc. 259, (1992) 566
[5] Q.B. Chen et al., Phys. Rev. C 82, (2010) 067302
[6] B.G. Carlsson and I. Ragnarsson, Phys. Rev. C 74, (2006) 044310

SPONTANEOUS TIME-REVERSAL SYMMETRY BREAKING IN ^{124}Cs FIRST OBSERVATION OF A CRITICAL FREQUENCY

Tomasz Marchlewski, Heavy Ion Laboratory, University of Warsaw, Poland

T. Marchlewski[3], R. Szenborn[1], E Grodner[1], A. A. Pasternak[2], J. Srebrny[3], M. Kowalczyk[1,3], J. Mierzejewski[1,3], M. Kisieliński[4], P. Decowski[5], Ch. Droste[1], J. Perkowski[6], T. Abraham[3], J. Andrzejewski[6], K. Hadyńska-Klęk[3], Ł. Janiak[6], A. Kasparek[1], P. Napiórkowski[3], J. Samorajczyk[6]

1 Faculty of Physics, University of Warsaw, Institute of Experimental Physics, ul. Hoża 69, PL-00681 Warsaw, Poland
2 A. F. Ioffe Physical Technical Institute, 194021 St. Petersburg, Russia
3 Heavy Ion Laboratory, Warsaw University, ul. Pasteura 5A, 02-093 Warsaw, Poland
4 National Centre for Nuclear Research, 05-400, Świerk, Poland
5 Smith College, Northampton, MA 01060, USA
6 Faculty of Physics and Applied Informatics, University of Łódź, ul. Pomorska 149/153, 90-236 Łódź, Poland

Nuclear chirality phenomena, which is connected with time-reversal symmetry, has been studied for more than a decade. Preliminary results of the lifetime evaluation exhibit staggering of B(M1) value along the yrast band which is attributed to spontaneous chiral symmetry breaking. In context of Ref.[1] it confirms the model of new s-symmetry being responsible for chiral gamma-selection rules. These selection rules should appear above certain spin which is called critical frequency [2]. In the most simple case, nuclear chirality is expected to appear above critical frequency in the odd-odd triaxial nuclei where three angular momenta vectors – one of the triaxial core and two of the odd nucleons – form a system with specified handedness. We obtained lifetimes of excited states by means of Doppler Shift Attenuation technique. The ^{124}Cs was produced in the ^{114}Cd(^{14}N,4n)^{124}Cs reaction at the beam energy of 73MeV. The ^{14}N beam was provided by the U200P cyclotron at the Heavy Ion Laboratory of the University of Warsaw [3]. The γ-γ coincidences were measured by the EAGLE [4] array equipped with 15 HPGe detectors obtained from GAMMAPOOL. The DSA analysis was performed with the COMPA, GAMMA and SHAPE codes [5].

REFERENCES
[1] L. Próchniak, S.G. Rohoziński, Ch. Droste, K. Starosta, Acta Phys. Pol. B42 (2011) 465
[2] P. Olbratowski et al., Phys. Rev. Lett 93, 052501 (2004).
[3] *Heavy Ion Laboratory*, www.slcj.uw.edu.pl
[4] J. Mierzejewski et al., Nucl. Instr. and Methods A 659, 84 (2011).
[5] E. Grodner et al., Eur. Phys. J A27, 325 (2006).

BLURRING THE BOUNDARIES OF THE NUCLEAR LANDSCAPE WITH MULTIPARTICLE SPIN-TRAP ISOMERS AT THE PROTON DRIP LINE

Robert Carroll, University of Surrey, Guildford, UK

R. J. Carroll[1], R. D. Page[2], D. T. Joss[2], J. Uusitalo[3], I. G. Darby[2], K. Andgren[4], B. Cederwall[4], S. Eeckhaudt[3], T. Grahn[3], C. Gray-Jones[2], P. T. Greenlees[3], B. Hadinia[4], P. M. Jones[3], R. Julin[3], S. Juutinen[3], M. Leino[3], A.-P. Leppänen[3], M. Nyman[3], D. O'Donnell[2,5], J. Pakarinen[3], P. Rahkila[3], M. Sandzelius[3], J. Sarén[3], C. Scholey[3], D. Seweryniak[6], and J. Simpson[5]

1 Department of Physics, University of Surrey, Guildford, GU2 7XH, United Kingdom
2 Oliver Lodge Laboratory, University of Liverpool, Liverpool, L69 7ZE, United Kingdom
3 University of Jyväskylä, Department of Physics, FI-40014 Jyväskylä, Finland
4 Department of Physics, Royal Institute of Technology, SE-10691 Stockholm, Sweden
5 STFC, Daresbury Laboratory, Daresbury, Warrington WA4 4AD, United Kingdom
6 Argonne National Laboratory, Physics Division, Argonne, Illinois 60439, USA

Identifying the full extent of the nuclear landscape is a long standing issue of fundamental importance in nuclear physics. For odd-Z nuclei, proton emission determines whether a given nuclide will be too short lived to be isolated and studied. In light elements, the lifetimes for proton emission quickly become extremely short with increasing neutron deficiency. For heavier odd-Z elements, the large coulomb barrier means that lifetimes drop more gradually and can be significantly longer than the typical flight time ~1 μs through a recoil separator, an important tool for the identification of nuclei. The separator flight time imposes an experimental limit on the nuclei that can be identified as neutron-deficiency increases, and proton-decay lifetimes decrease.

The occurrence of high-spin isomers could blur the boundary of heavy, proton-rich nuclei that are observable experimentally. Multiparticle spin-trap isomers occur in nuclei with limited numbers of valence nucleons in orbitals with large angular momentum quantum numbers. Isomers provide unique opportunities to observe proton and α decays with larger Δl values than simpler low-lying states. Although the decays of isomers may have greater Q values than those of low-lying states, which would shorten lifetimes, large Δl values inhibit decays so that isomers can have significantly longer half-lives.

Recent results [1] of the discovery of a high-lying spin-trap isomer in the proton-unbound nucleus ^{158}Ta will be reported. This isomer exhibits remarkable stability against proton emission, despite a large Q_p value (3.3 MeV), owing to a large centrifugal barrier. The implications of such isomers on the boundaries of the nuclear landscape will be discussed.

REFERENCES
[1] R. J. Carroll, R. D. Page, D. T. Joss *et al.*, Phys. Rev. Lett. 112, 092501 (2014)

SPECTROSCOPIC PROPERTIES OF ENERGY DENSITY FUNCTIONALS

Dimitar Tarpanov, University of Warsaw, Warsaw, Poland

D.Tarpanov[1,2], J. Toivanen[3], J.Dobaczewski[1,3],B.-G. Carlsson[4]

1 University of Warsaw, ul. Hoza 69, PL-00-681 Warsaw, Poland
2 Institute for Nuclear Research and Nuclear Energy, 1784 Sofia, Bulgaria
3 University of Jyvaskyla , FI-40014 Jyvaskyla , Finland
4 Lund University, Post Office Box 118, S-22100 Lund, Sweden

The aim to construct Hamiltonians with better accuracy in the description of the nuclear systems, lead to the natural requirement for better spectroscopic predictive power of the functionals used in the mean field calculations [1]. In the present study, we examine the possibility to fit the coupling constants of the density functional on the single particle spectrum, taking into account the polarization correction due to the particle to vibration coupling (PVC) effect, as coming from the many body perturbation theory, in a fully self-consistent way. Fitting, of the coupling constants in the particle-particle channel is outside the scope of this work, thus we restrict our considerations on doubly magic nuclei only.
Assuming linear dependence of the single particle energies (SPE) on the coupling constants of the Hamiltonian, one can use the singular value decomposition (SVD) analysis to fit the coupling constants on experimental data sets. In our work we use three different experimental data sets taken from the literature.
The incorporation of PVC correction to the SPE in the calculations, does not lead to a better description of experimental data, even after a refit, remarkably the PVC corrections could be absorbed by parameters of EDF [2].

This work was supported in part by the THEXO JRA within the EU-FP7-IA Project ENSAR (Grant No. 262010)

REFERENCES
[1] M. Kortelainen et al., Phys. Rev. C, 77:064307, Jun 2008.
[2] D. Tarpanov et al., arXiv:1405.4823, May 2014

BETA-DELAYED NEUTRON SPECTROSCOPY OF Ga ISOTOPES WITH VANDLE

Miguel Madurga, CERN, Geneva, Switzerland

M. Madurga[1], S.V. Paulauskas[1], R. Grzywacz[1,2], D. Bardayan[2], J.C. Batchelder[3], N.T. Brewer[4], J.A.Cizewski[5], C.J. Gross[2], S.H. Liu[3], S.V. Ilyushkin[6], B. Manning[5], M. Matos[2], A.J. Mendez II[2], K. Miernik[2,7], D. Miller[1], S.W. Padgett[1], W.A. Peters[3], A. Ratkiewicz[5], K. P. Rykaczewski[2], D.W. Stracener[2], J.A.Winger[8], M. Wolinska-Cichocka[2,7], E.F. Zganjar[9]

1 Dept. of Physics and Astronomy, University of Tennessee, Knoxville, Tennessee 37996, USA
2 Physics Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee 37830, USA
3 Oak Ridge Associated Universities, Oak Ridge, Tennessee 37831, USA
4 Dept. of Physics & Astronomy, Vanderbilt University, Nashville, Tennessee 37235, USA
5 Dept. of Physics and Astronomy, Rutgers University, New Brunswick, NJ 08903 USA
6 Dept. of Physics, Colorado School of Mines, Golden, Colorado 80401, USA
7 Faculty of Physics, University of Warsaw, Warszawa PL 00-681, Poland
8 Dept. of Physics and Astronomy, Mississippi State University, Mississippi 39762, USA
9 Dept. of Physics & Astronomy, Louisiana State University, Baton Rouge, Louisiana 70803, USA

The region in the vicinity of ^{78}Ni (N=50, Z=28) has seen a dramatic increase of experimental and theoretical interest since the observation of rich nuclear properties driven by the proton-neutron imbalance [1,2]. In particular, for nuclei of N>50, the beta-decay half-lives [3] and neutron branching ratios [4] have been consistently observed to be quite different from theoretical predictions [5]. This is not only interesting from the nuclear structure point of view, but for calculations that require this input. For instance, models of nucleosynthesis in explosive astrophysical scenarios have shown that the entire final abundance pattern is sensitive to the beta-decay properties of nuclei at N~50 [3].

A new time-of-flight neutron spectrometer, the Versatile Array of Neutron Detectors at Low Energy (VANDLE), was designed and implemented at the Holifield Radioactive Ion Beam Facility, Oak Ridge National Laboratory, to measure the energy of beta-delayed neutrons. In the commissioning campaign, the neutron energy spectra of 28 nuclei in the N~50 vicinity were measured for the first time. Here, we report the measurement of the delayed neutron emission of the N=52,53 ^{83,84}Ga isotopes. The large decay strength, log(ft)~4.3, deduced from neutrons observed at high energies (2.5 MeV) cannot be explained by the decay of the N>50 valence neutrons. These are energetically allowed to decay only via first forbidden transitions to the *fp* proton shell. This indicates that the population of neutron unbound states is dominated by Gamow-Teller transitions of *fp* neutrons to *fp* protons. We show a simplified shell model calculation using a ^{58}Ni core that correctly predicts the strength distribution in the neutron unbound region.

Development of VANDLE was supported by the National Nuclear Security Administration's Stewardship Science Academic Alliances (DE-FG52-08NA28552).

REFERENCES
[1] T. Otsuka et al., Phys. Rev. Lett. 95, 232502 (2005).
[2] K.T. Flanagan et al., Phys. Rev. Lett. 103, 142501 (2009).
[3] M. Madurga et al., Phys. Rev. Lett. 109, 112501 (2012).
[4] J.A. Winger et al., Phys. Rev. Lett. 102, 142502 (2009).
[5] P. Möller, B. Pfeiffer, and K.-L. Kratz, Phys. Rev. C 67, 055802 (2003).

FIRST OBSERVATION OF BETA-DELAYED GAMMA–PROTON DECAY IN THE *fp*-SHELL, THE BETA DECAY OF ^{56}Zn

Sonja Orrigo, IFIC (CSIC - Valencia University) Valencia, Spain

S. E. A. Orrigo[1], B. Rubio[1], Y. Fujita[2,3], B. Blank[4], W. Gelletly[5], J. Agramunt[1], A. Algora[1,6], P. Ascher[4], B. Bilgier[7], L. Cáceres[8], R. B. Cakirli[7], H. Fujita[3], E. Ganioğlu[7], M. Gerbaux[4], J. Giovinazzo[4], S. Grévy[4], O. Kamalou[8], H. C. Kozer[7], L. Kucuk[7], T. Kurtukian-Nieto[4], F. Molina[1,9], L. Popescu[10], A. M. Rogers[11], G. Susoy[7], C. Stodel[8], T. Suzuki[3], A. Tamii[3], J. C. Thomas[8]

1 Instituto de Física Corpuscular, CSIC-Universidad de Valencia, E-46071 Valencia, Spain
2 Department of Physics, Osaka University, Toyonaka, Osaka 560-0043, Japan
3 Research Center for Nuclear Physics, Osaka University, Ibaraki, Osaka 567-0047, Japan
4 Centre d'Etudes Nucl. de Bordeaux Gradignan, CNRS/IN2P3 Univ. Bordeaux, Cedex, France
5 Department of Physics, University of Surrey, Guildford GU2 7XH, Surrey, UK
6 Inst. of Nuclear Research of the Hung. Acad. of Sciences, Debrecen, H-4026, Hungary
7 Department of Physics, Istanbul University, Istanbul, 34134, Turkey
8 Grand Accélérateur National d'Ions Lourds, BP 55027, F-14076 Caen, France
9 Comisión Chilena de Energía Nuclear, Casilla 188-D, Santiago, Chile
10 SCK.CEN, Boeretang 200, 2400 Mol, Belgium
11 Physics Division, Argonne National Laboratory, Argonne, Illinois 60439, USA

We report the observation of a very exotic decay mode at the proton drip-line, the beta-delayed gamma-proton decay, clearly seen in the beta decay of the T_z = -2 nucleus ^{56}Zn. Here this decay mode, already observed in the *sd*-shell [1], is seen for the first time in the *fp*-shell.

The experiment was performed at the LISE3 facility of GANIL, using a $^{58}Ni^{26+}$ primary beam with an average intensity of 3.7 *em*A, accelerated to 74.5 MeV/nucleon and fragmented on a 200 mm thick natural Ni target. The fragments were selected by the LISE3 separator and implanted into a Double-Sided Silicon Strip Detector 300 mm thick, surrounded by four EXOGAM Ge clovers for gamma detection.

The proton decay of the ^{56}Zn Isobaric Analogue State is normally expected to be isospin forbidden, however both beta-delayed protons and beta-delayed gamma rays have been observed. Similar cases have been seen before. The particularity here is that the states populated in the gamma de-excitation are also proton-unbound, consequently the rare and exotic beta-delayed gamma-proton decay has been observed. In particular, three gamma-proton sequences have been seen after the beta decay [2]. This observation is very important because it does affect the conventional way to determine the Gamow-Teller (GT) transition strength *B*(GT) near the proton drip-line, where the general opinion until now was that the *B*(GT) is simply deduced from the intensity of the proton peaks. On the contrary, the observed proton intensities are due to both direct feeding and indirect feeding coming from the gamma de-excitation. Thus both gamma and proton decays have been taken into account in the estimation of the Fermi and GT strengths.

Evidence for fragmentation of the Fermi strength due to strong isospin mixing is found. The results are compared with the mirror process, the ^{56}Fe(^{3}He,*t*)^{56}Co reaction [3].

REFERENCES

[1] M. Bhattacharya *et al.*, Phys. Rev. C 77, 065503 (2008).
[2] S.E.A Orrigo *et al.*, Phys. Rev. Lett. (2014), in press.
[3] H. Fujita *et al.*, Phys. Rev. C 88, 054329 (2013).

SEMINAR

BETA-DELAYED NEUTRON SPECTROSCOPY WITH TRAPPED FISSION PRODUCTS

Agnieszka Czeszumska, Lawrence Livermore National Laboratory & University of California - Berkeley, USA

A. Czeszumska[1,2], N. D. Scielzo[1], E. B. Norman[1,2], G. Savard[3,4], A. Aprahamian[5], F. Buchinger[6], M. Burkey[4], S. A. Caldwell[3,4], C. J. Chiara[3,7], J. A. Clark[3], C. M. Deibel[8], J. P. Greene[3], J. Harker[3,7], D. Lascar[3,9], A. F. Levand[3], S. T. Marley[5], G. Morgan[10], R. Orford[6], S. Padgett[1], A. Perez Galvan[3], R. E. Segel[9], K. S. Sharma[3,10], K. Siegl[5], M. G. Sternberg[3,4], S. Strauss[5], J. Van Schelt[3,4], R. M. Yee[1,2], B. J. Zabransky[3]

1 Physical and Life Sciences Directorate, Lawrence Livermore National Laboratory, Livermore, California 94550, USA,
2 Department of Nuclear Engineering, University of California, Berkeley, California 94720, USA,
3 Physics Division, Argonne National Laboratory, Argonne, Illinois 60439, USA,
4 Department of Physics, University of Chicago, Chicago, Illinois 60637, USA,
5 Department of Physics, University of Notre Dame, Notre Dame, Indiana 46556 USA,
6 Department of Physics, McGill University, Montreal, Quebec H3A 2T8, Canada,
7 Department of Chemistry and Biochemistry, University of Maryland, College Park, Maryland 20742, USA,
8 Department of Physics and Astronomy, Louisiana State University, Baton Rouge, Louisiana 70803, USA,
9 Department of Physics and Astronomy, Northwestern University, Evanston, Illinois 60208, USA,
10 Department of Physics and Astronomy, University of Manitoba, Winnipeg, Manitoba, Canada

Following β^- decay, a daughter nucleus left in an excitation state above its neutron separation energy may de-excite by emitting a neutron in a process referred to as β-delayed neutron emission (βn). This decay mode influences the abundances of elements calculated in r-process nucleosynthesis models, and βn data are required for nuclear reactor safety analysis calculations. In addition, delayed-neutron energy spectra can illuminate aspects of nuclear structure in neutron-rich nuclei. However, existing data for neutron-rich nuclei are often incomplete or discrepant. A newly developed recoil-ion detection technique [1, 2] to measure the βn spectra and branching ratios avoids the difficulties associated with direct neutron detection. Isobarically-separated ^{252}Cf fission fragments of interest are trapped in a Paul Trap surrounded by a detector array. Detecting β particles, γ rays, and ions emerging from the trap provides three ways of measuring the βn branching ratios. The energy of the recoiling nucleus following β^- decay is measured from its time-of-flight to a microchannel plate detector, and can be used to determine the neutron energy. In a recent experimental campaign that took place at the CARIBU facility at Argonne National Laboratory, data were collected on $^{137-140}$I, $^{144-145}$Cs, and $^{134-136}$Sb. Preliminary results of the experiment will be discussed, in conjunction with plans for future measurements.

This material is based upon work supported by the Department of Energy, National Nuclear Security Administration, under Award Numbers DE-NA0000979 (NSSC), DE-AC52-07NA27344 (LLNL); Office of Nuclear Physics Contract DE-AC02-06CH11357 (ANL), and grants DE-FG02-94ER40834 (University of Maryland), DE-FG02-98ER41086 (Northwestern University); NSERC, Canada, under Application No. 216974; and the Department of Homeland Security. A. Czeszumska acknowledges support from the Lawrence Scholar Program at LLNL.

REFERENCES

[1] R. M. Yee et al., Phys. Rev. Lett. 110, 092501 (2013).
[2] N. D. Scielzo et al., Nucl. Instr. and Meth. in Phys. Res. A681, 94 (2012).

Friday 19:25

MEASUREMENT OF 20 NEW BETA DECAY HALF-LIVES INTO THE R-PROCESS PATH AND THE PHYSICAL CONDITIONS OF THE R-PROCESS

Giuseppe Lorusso, RIKEN, Wako, Japan

The decay of about 20 very neutron-rich nuclei with neutron number N=82 and beyond were studied at the RIBF facility for the elements Ru to Sn. New results include the half-lives of the six r-process waiting points: $^{127}Rh_{82}$, $^{128}Pd_{82}$, $^{131}Ag_{84}$, $^{134}Cd_{86}$, $^{137}In_{88}$, and $^{138}Sn_{88}$. These nuclei determine the formation of the A=130 peak of the solar system abundance pattern and the breakout of the N=82 r-process bottleneck.
The nuclei of interest were produced by in-flight fission of a ^{238}U beam with an energy of 345 MeV/u colliding a Be target. After identification, fission fragments were implanted into the silicon active stopper WAS3ABi working in conjunction with the EURICA HPGe detector array.
The new data are of great significance for both nuclear structure and astrophysics. The unknown evolution of the N=82 shell closure is, in fact, a main challenge for nuclear models, whose predictions across the shell gap are often diverging. In addition, the new measurements allow a more reliable comparison between the solar system abundance pattern and the predictions of stellar models that constrain the r-process path and its conditions. This contribution will present the experiment and will discuss its results, with a particular focus on its astrophysics implications.

SEMINAR

BETA DECAY OF THE MOST NEUTRON-RICH ISOTOPES CLOSE TO ^{78}Ni

Chiara Mazzocchi, University of Warsaw, Poland

C. Mazzocchi[1], A. Korgul[1], K.P. Rykaczewski[2], R. Grzywacz[3,2], P. Bączyk[1], C.R. Bingham[3,2], N.T. Brewer[4], C.J. Gross[2], C. Jost[3], M. Karny[1,5], A. Lis[1], M. Madurga[3], A.J. Mendez II[2], K. Miernik[2,1], D. Miller[3], S. Padgett[3], S.V. Paulauskas[3], D.W. Stracener[2], M. Wolińska-Cichocka[2,5,6], I.N. Borzov[7,8]

1 Faculty of Physics, University of Warsaw, 00-681 Warszawa, Poland
2 Physics Division, Oak Ridge National Laboratory, Oak Ridge, TN 37831, USA
3 Department of Physics and Astronomy, University of Tennessee, Knoxville, TN 37996, USA
4 Department of Physics and Astronomy, Vanderbilt University, Nashville, TN 37235, USA
5 Oak Ridge Associated Universities, Oak Ridge, TN 37831, USA
6 Heavy Ion Laboratory, University of Warsaw, Warsaw, PL 02-093, Poland
7 Joint Institute for Heavy-Ion Research, Oak Ridge, TN 37831, USA
8 Bogoliubov Laboratory of Theoretical Physics, Joint Inst. for Nucl. Res., 141980 Dubna, Russia

The study of decay properties of radioactive nuclei far away from the valley of β-stability contributes vital information for probing and validating nuclear models in such exotic nuclear systems.
Extensive work was carried out recently at the Holifield Radioactive Ion Beam Facility at Oak Ridge National Laboratory [1] to study β-decay properties of fission products in the ^{78}Ni region [2-6]. These studies were enabled by the unique combination of ion-source chemistry and two-stage mass separation [7]. Recently, the β-decay half-life and β-delayed neutron (β-n) probability for the very neutron-rich germanium isotope (^{86}Ge) were measured for the first time, $T_{1/2} = (226\pm21)$ ms [5] and $P_n = (45\pm10)\%$ [6], and several other half-lives were re-measured with improved accuracy. The first spectroscopic information was obtained for decays of ^{85}Ga and ^{86}Ge. The decay schemes of ^{84,85}Ge and ^{87}As and the respective level schemes in their β- and β-n daughter nuclei ($^{83-86}$As, $^{84-87}$Se) were largely expanded, revealing the evolution of the $\nu 3s_{1/2}$ and $\nu 2d_{5/2}$ orbitals in the most neutron-rich N=53 isotones. The results are compared to shell-model predictions for the structure of the β- and βn-daughter nuclei [4] and to updated theoretical models of β decay [8-10].

This work was supported by the DOE Office of Nuclear Physics, under grants DE-AC05-00OR22725, DE-FG02-96ER40983, DE-AC05-06OR23100 and DE-FG05-88ER40407; NNSA Grant DEFC03-03NA00143 and the Polish NCN, Grant 2011/01/B/ST2/02476. I.B. is partially supported by Helmholtz Alliance EMMI and the grant by IN2P3- RFBR under agreement No.110291054.

REFERENCES

[1] J.R. Beene *et al.*, J. Phys. G: Nucl. Part. Phys. 38 (2011) 024002.
[2] M. Madurga *et al.*, Phys. Rev. Lett. 109, (2012) 112501.
[3] S. Padgett *et al.*, Phys. Rev. C 82 (2010) 064314.
[4] A. Korgul *et al.*, Phys. Rev. C 88 (2013) 044330.
[5] C. Mazzocchi *et al.*, Phys. Rev. C 87 (2013) 034315; Phys. Rev. C 87 (2013) 039902(E).
[6] K. Miernik et al., Phys. Rev. Lett. 111 (2013) 132502.
[7] D.W. Stracener, Nucl. Instr. Methods in Phys. Res. B204 (2003) 42.
[8] I.N. Borzov, Phys. Rev. C 67 (2003) 025802.
[9] S.V. Tolokonnikov and E.E.Saperstein. Phys. At. Nucl. 73 (2010) 1684.
[10] N. V. Gnezdilov et al., Phys. Rev. C 89 (2014) 034304.

Friday 19:55

EXPERIMENTAL OBSERVATION OF A LARGE BETA-DELAYED TWO-NEUTRON EMISSION PROBABILITY IN THE DECAY OF ^{86}Ga

Krzysztof Miernik, University of Warsaw, Poland

K.P. Rykaczewski[1], C.J. Gross[1], R. Grzywacz[1,2], M. Madurga[2], D. Miller[2], J.C. Batchelder[3], I.N. Borzov[4], N.T. Brewer[1], C. Jost[3], A. Korgul[5], C. Mazzocchi[5], A.J. Mendez II[1], Y. Liu[1], S.V. Paulauskas[2], J.A. Winger[6], M. Wolińska-Cichocka[3,7]

1 Oak Ridge National Laboratory, Oak Ridge Tennessee 37830 USA,
2 Dept. of Physics and Astronomy, University of Tennessee, Knoxville, Tennessee 37996, USA
3 Oak Ridge Associated Universities, Oak Ridge, Tennessee 37831, USA
4 Joint Institute for Nuclear Research, 141980 Dubna, Russia
5 Faculty of Physics, University of Warsaw, Warsaw PL-00-681, Poland
6 Dept. of Physics and Astronomy, Mississippi State University, Mississippi, 39762, USA
7 Heavy Ion Laboratory, University of Warsaw, Warsaw PL- 02-093, Poland

Beta-delayed neutron emission is one of the main decay modes for exotic neutron-rich nuclei. The delayed neutrons play a major role in reactor physics, and are of importance for astrophysical r-process calculations. It was as early as 1960 when it was realized [1] that multi-neutron emission may appear in very neutron-rich nuclei. This process was observed for the first time in 1979 [2] for the case of β-delayed two-neutron emission (β2n) in the decay of ^{11}Li. So far about 20 β2n emitters have been experimentally found [3]. However, there are only two known cases of β2n emitters in the r-process region, namely ^{98}Rb [4] and ^{100}Rb [5], where the reported branching ratios are too small (0.060(9)% and 0.16(8)%, respectively) to be of importance for astrophysical calculations.

In this contribution we report the first observation of ^{86}Ga β-decay, its half-life, and absolute P_{1n} and P_{2n} values [6]. The β2n decay branch is unambiguously identified by β-neutron-neutron correlations and by observation of a known γ-transition in ^{84}Ge. We report, for the first time in a fission fragment and in a nuclide on the proposed r-process path, a large 20(10)% β2n branch. This result is important for guiding the development of nuclear structure and β-decay models (e.g. [7]), as well as in the simulation of the r-process and its resulting mass abundances.

This research is sponsored by the Office of Nuclear Physics, U. S. Department of Energy under contracts DE-AC05-00OR22725 (ORNL), DE-FG02-96ER41006 (MSU), DE-FG02-96ER40983 (UTK), and DE-AC05-06OR23100(ORAU). The authors from the University of Warsaw acknowledge the support of National Science Center of the Polish Ministry of Science and Higher Education, Grant No. 2011/01/B/ST2/02476.

REFERENCES

[1] V. Goldansky, Nucl. Phys. 19, 482 (1960).
[2] R. Azuma et al., Phys. Rev. Lett. 43, 1652 (1979).
[3] M. Borge, Phys. Scr. T152, 014013 (2013).
[4] P. Reeder, et al., Phys. Rev. Lett. 47, 483 (1981).
[5] B. Jonson et al., CERN Report No. CERN-81-09, p. 265 (1981).
[6] K. Miernik, et al., Phys. Rev. Lett. 111, 132502 (2013).
[7] I. Borzov, et al., Phys. Rev. C 67, 025802 (2003).

SEMINAR

COMMISSIONING OF THE BEDO SETUP AT ALTO AND RE-INVESTIGATION OF THE $^{82}Ge \rightarrow {}^{82}As$

Etilé Asénath, CSNSM, Orsay, France

E. Asénath, D. Verney[2], C. Gaulard[1], G. Audi[1], J.Bettane[2], M. Cheikh Mhamed[2], P.V. Cuong[3], C. Delafosse[2], I. Deloncle[1], F. Didierjean, S. Franchoo[2], A. Goasduff[1], F. Ibrahim[2], K. Kolos[2], C. Lau[2], R. Li[2], M. Niikura[2], J. Peyré[2], S. Roccia[1], P. Rosier[2], B. Roussière[2], A. Saïd[2], D. Testov[2,5] , S. Tusseau-Nenez[2], N.T. Vinh[3] and T. Zerguerras[2]

1 CSNSM, Université Paris-Sud, CNRS/IN2P3, Orsay, France
2 IPNO, Université Paris-Sud, CNRS/IN2P
3, Orsay, France 3 CNP, Institute of Physics, Vietnam Academy of Science and Technology, Hanoi, Vietnam
4 IPHC, Université de Strasbourg, CNRS/IN2P3, Strasbourg, France
5 JINR, Joint Institute for Nuclear Research, Dubna, Russia

The proton single particle order known at stability (^{63}Cu and ^{65}Cu) is $2p_{3/2}$, $1f_{5/2}$, $2p_{1/2}$, $1g_{9/2}$. The β-decay study of ^{69,71,73}Ni [1] gave the first indications of a decrease in the separation energy between the orbitals $\pi 2p_{3/2}$ $\pi 1f_{5/2}$ in neutron rich Cu isotopes. This "monopole drift" was interpreted as being due to the tensor term of the proton-neutron interaction [2]. Recent results from collinear laser spectroscopy studies [5] showed that the ground state spin of ^{75}Cu was 5/2 while for odd lower masses it is 3/2. This was interpreted as the signature of the crossing of the orbitals $\pi 2p_{3/2}$ and $\pi 1f_{5/2}$ between the mass 73 and mass 75.
On the other hand, intriguing structure effect of the N=49 isotonic chain has been revealed several decades ago. First, Hoff and Fogelberg [4] observed the existence of both one-hole and very low-lying (positive parity) one particle-two holes intruder states in the N=49 odd isotones. The second puzzling phenomenon in this region is the considerable amount of very low spin states populated in β-decay which suddenly appears for ^{80}Ga in the sequence of the light odd-odd N=49 isotones from which Kratz *et al.* [5] introduced the concept of “a rapid weakening of the shell strength far from β stability above ^{78}Ni”.
The N=49 odd-odd nuclei should hold the clear fingerprints of the above phenomena: proton level ordering just above ^{78}Ni and the puzzling supposed structure effect between Z= 31 and Z=33. For that reason we have decided to address these questions by studying the N=49 isotonic chain towards ^{77}Ni at ALTO (France). During the commissioning of the new beta decay station BEDO (BEta Decay studies in Orsay), fission fragment beams from ALTO at mass 82 were stopped into the setup. The ion source chosen was a FEBIAD of the MK5-ISOLDE type allowing significant yields for radioactive Ga, Ge, As (A=82) beams. The decay of $^{82}Ge \rightarrow {}^{82}As$ was re-investigated on this occasion.
In this talk we will briefly review the performances of this new BEDO setup. In addition, we propose a new level scheme for ^{82}As. This level scheme is interpreted in the light of simple proton-neutron quasi-particle couplings that explains naturally the observed structures and reveal two major informations: we confirm the filling level of the first proton orbital filled after the Z=28 shell closure : $\pi 1f_{5/2}$, and also show the first evidence of neutron intruder state in an odd-odd nucleus of the N=49 isotonic chain.

REFERENCES
[1] S. Franchoo et al., Phys. Rev. C 64, 054308 (2001)
[2] T. Otsuka et al., Phys. Rev. Lett. 95, 232502 (2005)
[3] K.T. Flanagan et al., Phys. Rev. Lett. 103, 142501 (2009)
[4] P. Hoff and B. Fogelberf, Nuclear Physics A 368, 210 (1981)
[5] K.L. Kratz et al., Phys. Rev. C 38, 278 (1988)

Friday 20:25

BETA DECAY MEASUREMENTS OF ^{86}Br, ^{89}Kr, AND ^{139}Xe BY MEANS OF MODULAR TOTAL ABSORPTION SPECTROMETER

Marek Karny, University of Warsaw, Poland

M. Karny[1], A. Fijałkowska[1], K.P. Rykaczewski[2], M. Wolińska-Cichocka[1], B.C. Rasco[3], C.J. Gross[2], R.K. Grzywacz[2,4], L. Cartegni[4], K.C. Goetz[4], J.W. Johnson[2], J.H. Hamilton[6], C. Jost[5], M. Madurga[4], K. Miernik[1,2], D. Miller[4], S.W. Padgett[4], S.V. Paulauskas[4], A.V. Ramayya[6], M. Al-Shudifat[4], E. Spejewski[5], D. Stracener[2] and E. Zganjar[3]

1 Faculty of Physics, University of Warsaw, Warsaw, PL 00-681, Poland,
2 ORNL, Oak Ridge, TN 37830, USA,
3 Louisiana State University, Baton Rouge, LA 70803, USA,
4 University of Tennessee, Knoxville, TN 37996, USA,
5 ORAU, Oak Ridge, TN 37831, USA,
6 Dept. of Physics and Astronomy, Vanderbilt University, Nashville, TN 37235, USA

Total Absorption Spectrometers (TAS) capable of detecting most of the gamma transitions occurring during the decay process are perfect tools for establishing a true beta feeding pattern. Total Absorption Spectrometry is particularly important for, where the b-strength and thus feeding is distributed over many final states, resulting in weak gamma transitions. Knowledge of the correct beta feeding pattern is important for the analysis of the structure of parent and daughter activities as well as for the determination of the decay heat released by fission products during nuclear fuel cycle [1].

The Modular Total Absorption Spectrometer (MTAS) has been recently constructed at the Holifield Radioactive Ion Beam Facility (HRIBF) at Oak Ridge National Laboratory. It consists of 19 NaI(Tl) hexagonal shape modules, (21 inches long and about 8 inches maximum diameter), and two 1-mm-thick silicon strip detectors for b particle registration. MTAS efficiency for full energy deposition of a single gamma ray approaches nearly 80% around 300 keV.

The decays of over twenty ^{238}U fission products have been studied with MTAS at the HRIBF. Among them seven decays were defined as having the highest priority for decay heat analysis in nuclear reactor by the assessment of OECD Nuclear Energy Agency [2]. Preliminary analysis of ^{89}Br, ^{89}Kr as well as ^{139}Xe showed significant discrepancy between the observed b feeding and the corresponding database values. In this contribution the results of this analysis will be presented.

REFERENCES

[1] A.Algora et al., Phys.Rev.Lett 105, 202501 (2010).

[2] Assessment of Fission Product Decay Data for Decay Heat Calculations, Nuclear Science NEA/WPEC-25 report, NEA No. 6284, OECD (2007).

GAMMA-RAY SPECTROSCOPY IN THE VICINITY OF ^{108}Zr

Frank Browne[1,2], University of Brighton, Brighton, UK

F. Browne[1,2], A. M. Bruce[1], T. Sumikama[3], I. Nishizuka[3], S. Nishumura[2], R. Daido[4], P. Doornenbal[3], G. Lorusso[3], Z. Patel[2,5], S. Rice[2,5], L. Sinclair[2,6], P.-A. Soderstrom[2], H. Watanabe[2,7], J. Wu[2,8], Z. Y. Xu[9] and the EURICA collaboration

1 School of Computing, Engineering and Mathematics, University of Brighton, Brighton BN2 4JG, United Kingdom
2 RIKEN Nishina Center, 2-1 Hirosawa, Wako, Saitama 351-0198, Japan
3 Department of Physics, Tohoku University, Aoba, Sendai, Miyagi 980-8578, Japan
4 Department of Physics, Osaka University, Toyonaka, Osaka 560-0043, Japan
5 Department of Physics, University of Surrey, Guildford GU2 7XH, United Kingdom
6 Department of Physics, University of York, Heslington, York YO10 5DD, United Kingdom
7 Department of Physics, Beihang University, Beijing 100191, China
8 Department of Physics, Peking University, Beijing 100871, China
9 Department of Physics, University of Tokyo, Hongo, Bunkyo-ku, Tokyo 113-0033, Japan

The A~110 region of neutron-rich nuclei is one of rich nuclear structure with theory suggesting competition between several different shapes. To further knowledge in this region, an experiment at the RI Beam Factory (RIBF) in RIKEN has studied $^{102\text{-}108}$Zr and the surrounding region.
The nuclei of interest were produced through the in-flight fission of a 345 MeV/nucleon ^{238}U beam by a ^{9}Be target and selected by the BigRIPS separator. The nuclei were implanted into 5 layers of double-sided silicon strip detectors (WAS3ABi), and γ rays emitted following β decay, or decay of isomeric states were detected in an array of 12 clusters of 7 HPGe detectors (EURICA) augmented with 18 $LaBr_3$ (Ce) detectors. Beta-gamma timing between plastic scintillator detectors, mounted upstream and downstream of WAS3ABi, and the $LaBr_3$ (Ce) array allowed the measurement of nuclear level half-lives in the nanosecond regime. The efficacy of the β-γ timing was tested by measuring the half-life of the 2^+_1 states in ^{102,104} Zr and ^{106,108}Mo.
Information about the energies of low-lying levels and their half-lives will be used to infer the nuclear shape for comparison with model predictions. The preliminary results of this work will be discussed in detail at the talk.

Saturday

September 6th

DARK MATTER, DARK ENERGY AND THE FUTURE OF HIGH ENERGY PHYSICS

Michel Spiro, CEA Saclay, France

Dark matter and dark energy are two major evidences for physics beyond the Standard Model of Particle Physics and maybe the standard model of cosmology. Supersymmetry, axion searches and probing the nature of quantum vacuum are the main avenues to tackle these issues. Affordable future accelerators and ultra high intensity lasers will be crucially needed. The advance of basic knowledge is at stake!

USING THE NUCLEAR REMNANTS AS A NEW SOURCE OF INFORMATION ON THE SPACE-TIME EVOLUTION OF ULTRARELATIVISTIC HEAVY ION COLLISIONS

Andrzej Rybicki, Institute of Nuclear Physics PAN, Kraków, Poland

A. Szczurek[1,2], M. Kłusek-Gawenda[1], I. Sputowska[1]

1 H. Niewodniczański Institute of Nuclear Physics, Polish Academy of Sciences, Kraków, Poland
2 University of Rzeszów, Rzeszów, Poland

In nucleus-nucleus collisions at high energy (typically in the range of a few or more GeV per nucleon pair in the collision c.m.s.), one usually identifies two different "zones" in the reaction: the *participant zone*, created by the nucleons directly participating in the reaction, and the two *spectator systems* – the two nuclear remnants which do not participate directly to the collision.

In the present work, we investigate the possibility of using the *electromagnetic interaction induced by the two spectator systems* as a new source of information on the space-time evolution of particle production in the participant zone. We estimate the effect of this interaction on the *azimuthal anisotropies* characterizing charged pion (p^+ and p^-) production. We find that it induces a charge-dependent, *collective effect of sidewards motion* ("directed flow") of the produced charged pions. This is in good agreement with experimental data on Au+Au collisions at $\sqrt{s_{NN}}$=7.7 GeV reported very recently by the STAR Collaboration [1], as well as data on Pb+Pb reactions at $\sqrt{s_{NN}}$=17.3 GeV reported by the WA98 experiment [2].

As it results from our study, these spectator-induced electromagnetic effects are strongly sensitive to the *distance between the pion emission site and the spectator system.* From the comparison of our calculations to experimental data, we find that this distance decreases with increasing velocity (rapidity) of the emitted pion. This reflects the *longitudinal expansion of the strongly-interacting system responsible for pion emission.* As such, our work proves that the spectator-induced electromagnetic interaction is indeed a *new source of information on the space-time evolution of the system created in the heavy ion collision.* This source is completely independent from other sources such as pion interferometry.

At the same time, our analysis points at the importance of *lower energy nuclear physics characterizing the spectator system* for the interpretation of phenomena observed in nuclear collisions at very high energies. This is particularly important for *fast (high momentum) pions* which appear to be produced close to the spectator system.

More details on this work can be found in [3,4].

REFERENCES

[1] L. Adamczyk *et al.* (STAR Collaboration), Phys. Rev. Lett. 112, 162301 (2014).
[2] H. Schlagheck (WA98 Collaboration), Nucl. Phys. A 663, 725 (2000).
[3] A. Rybicki and A. Szczurek, Phys. Rev. C 87, 054909 (2013).
[4] A. Rybicki and A. Szczurek, arXiv:1405.6860 [nucl-th], to be submitted to Phys. Rev. C.

NEW FRONTIERS IN NUCLEAR PHYSICS RESEARCH AT ELI–NP

Calin Alexandru Ur, ELI–NP/IFIN–HH Magurele–Bucharest, Romania

Extreme Light Infrastructure – Nuclear Physics (ELI–NP) [1] is one of the three pillars of the pan–European ELI [2] initiative, aiming to use extreme electromagnetic fields for nuclear physics research. The pillar, currently under construction at Magurele – Bucharest, will comprise two major research instruments: a high power laser system and a very brilliant gamma beam system. Both systems are at the limits of the present–day's technology. The high power laser system will consist of two 10 PW APPOLON–type lasers based on OPCPA technology with output energy higher than 200 J, pulse duration of 20 – 30 fs and intensities of up to 10^{23} – 10^{24} W/cm^2. The gamma beam, produced via Compton backscattering of a laser beam on a relativistic electron beam, will be characterized by high spectral density of about 10^4 photons/s/eV, a narrow bandwidth (< 0.5%) and tunable energy of up to 20 MeV.

Two scientific communities, high–power lasers and nuclear physics, have joined their efforts to build the new interdisciplinary facility and to define its research program. As a result of this collaboration the scientific interest of ELI–NP is covering a broad range of key topics in frontier fundamental physics and new nuclear physics. The experimental activity of the facility is focused on three directions: high–power laser studies, experiments with gamma beams and combined measurements with high–power lasers and gamma beams. Some of the main research topics of interest are: laser driven nuclear physics experiments, characterization of the laser–target interaction by the means of nuclear physics instruments, photonuclear reactions, exotic nuclear physics and astrophysics. A particular attention is also given to the development of innovative applications based on the use of both high power lasers and brilliant, narrow bandwidth gamma beams.

The status of the project and the overall performance characteristics will be reported. The main research topics proposed to be studied at ELI–NP will be discussed together with the instruments for their investigation.

REFERENCES
[1] ELI–NP http://www.eli-np.ro.
[2] ELI http://www.extreme-light-infrastructure.eu.

FUTURE SCENARIOS FOR FISSION BASED REACTORS: BREEDING AND WASTE TRANSMUTATION USING U OR Th CYCLE

Sylvain David[1,2], Paris, France

1 Institut de Physique Nucléaire, Orsay, France
2 CNRS/IN2P3, Université Paris Sud, France

The coming century will see the end of standard fossile fuels, coal, gas and oil, which represent today 80% of the world energy production. Moreover, their use will have induced important emission of greenhouse gas, and climate change. In this context, nuclear power could be able to respond significantly to the growing world energy demand. Some scenarios consider a nuclear energy production of around 5 Gtoe in 2050, which would represent 25% of the total energy generation.
But a large and significant nuclear energy generation require a development of innovative systems, minimizing the natural resources consumption, the waste production, and increasing the safety and resistance to proliferation.

In this context, future reactor should be able to reduce by a factor 100 the natural uranium consumption by multi-reprocessing plutonium in a fast spectrum. This strategy will lead to high plutonium inventories and high minor actinides production. Alternative strategies, based on transmutation or thorium cycle could help to manage these issues. The presentation will propose a comparison of standard and innovative future systems dedicated to breeding using U or Th cycle, in terms of basic physics parameter, fissile inventories, waste production, and capacity to be deployed. A specific analysis will describe the advantages and drawbacks of minor actinides transmutation.

GAMMA EMISSION IN HADRON THERAPY – EXPERIMENTAL APPROACH

Aleksandra Wrońska, Jagiellonian University, Kraków, Poland

A. Wrońska[1], P. Bednarczyk[2], D. Böckenhoff[3] , A. Bubak[4], S. Feyen[3], A. Konefał[1], K. Laihem[3], A. Magiera[1]

1 Jagiellonian University, Kraków
2 Institute of Nuclear Physics PAN, Kraków
3 RWTH Aachen University, Aachen
4 University of Silesia, Katowice

Hadron therapy is currently a well established treatment technique and in many aspects has reached perfection in clinical use. However, there are still fields requiring further studies and development. One of such topics is a precise determination and monitoring of the ion range in the patient tissue.

Experiment Gamma-CCB proposed at Cyclotron Center Bronowice focuses on investigation of gamma emission in experimental modeling of hadron therapy, searching for a manifestation of the Bragg peak in the gamma spectra. For prompt gamma rays emitted during irradiation human tissue is almost transparent, thus they are a perfect transmitter of information from the place where they are generated. The experimental program comprises a series of measuremets for different energies of the beam accelerated in the cyclotron Proteus C-235, as well as for several phantom materials.

In the talk I will present the experimental environment and technique as well as preliminary results from the pilot measurement performed in November 2013.

The project supported within the POMOST programme of the Foundation for Polish Science, cofinanced from the European Union under the European Regional Development Fund.

PHYSICS AGAINST CANCER: NUPECC REPORT ON NUCLEAR MEDICINE

Sydney Gales ,CNRS Paris, France & ELI-NP Bucharest-Magurele, Romania

THE ASTRONOMICAL FUTURE OF HUMANKIND

Alex Wolszczan, Penn State University, USA

The fact that the long-term survival of the human race is by no means guaranteed should not prevent us from considering the astronomical phenomena that may affect it. Such considerations are also important for research related to life in the Universe and its persistence in face of cosmic evolution. I will review the most relevant astrophysical phenomena that may influence life on Earth, such as stellar evolution, motion of the Solar System around the Galaxy, stellar explosions, galaxy collisions, and, of course, the asteroid strikes, and discuss our chances to survive them.

List of Posters

EXPERIMENT

E1 **Farid Abdullin, JINR Dubna**
Synthesis of neutron-deficient isotopes of Flerovium in the $^{239}Pu+^{48}Ca$ reaction

E2 **Boris Andel, Comenius University, Bratislava**
Decay spectroscopy of (11^{-}) isomeric states in ^{192}Po and ^{194}Po

E3 **Riccardo Avigo , University of Milano and INFN (presented by Simone Ceruti)**
Pygmy dipole resonance in Iron neutron rich isotopes

E4 **Preeti Bansal, Panjab University, Chandigarh, India (presented by Sukhjit Kaur)**
Energy dependence of light charged particles production at intermediate energies

E5 **Sahila Chopra, Panjab University, India (presented by Sukhjit Kaur)**
Non-compound nucleus component in decay of $^{12}C + ^{93}Nb \rightarrow ^{105}Ag^{*}$ reaction with non-coplanar degree of freedom included in dynamical cluster-decay model

E6 **Martha Liliana Cortés, TU Darmstadt**
Evolution of collectivity in the vicinity of ^{208}Pb

E7 **Hanne Heylen, KU Leuven**
Nuclear moments of the neutron-rich Mn isotopes around N=40

E8 **Łukasz Iskra, IFJ PAN Kraków**
High-spin shell model states in odd neutron-rich Sn isotopes populated in fusion-fission reactions

E9 **Ghanshyam Khatri, Jagiellonian University**
Experimental investigation of few-nucleon dynamics in deuteron-deuteron collision at 160 MeV

E10 **Barbara Kłos, University of Silesia**
Experimental study of three-nucleon dynamics in the dp breakup reaction

E11 **Wojciech Krzemień, Jagiellonian University, Kraków**
Search for eta-mesic nuclei with WASA-at-COSY

E12 **Mateusz Krzysiek, IFJ PAN Kraków**
Isospin character of the 'pygmy' states in ^{140}Ce studied via inelastic scattering of ^{17}O

E13 **Clément Mancuso, UCBL-IPNL, Villeurbanne**
Spectroscopic study of neutron rich ruthenium isotopes stemming from EXILL fission campaigns

E14 **Rafał Najman, Jagiellonian University, Kraków**
Properties of freeze-out configuration in the central $^{197}Au + ^{197}Au$ collisions at 23 AMeV

E15 **Jarosław Perkowski, University of Łódź**
Study the $I^{p} = K^{p} = 8^{-}$ isomeric state in ^{184}Pt by combined conversion-electron and gamma spectroscopy

E16 **Damian Ralet, TU Darmstadt**
Analysis of the ^{106}Zr experiment with the PreSPEC-AGATA setup

E17 **Mansi Saxena, University of Delhi, India (presented by Rakesh Kumar)**
Unusual rotational behaviour of midshell Te isotopes

E18 **Jasmine Sethi, Tata Institute of Fundamental Research, Mumbai, India**
Low-lying states near the long lived isomer in ^{108}Ag

E19 **Magdalena Smoleń, University of the West of Scotland**
Characterization of a new structure in octupole-deformed ^{222}Th using gamma-ray and conversion electron spectroscopy

E20 **Roman Szenborn, University of Warsaw**
The disappearance of signature splitting and energy staggering in ^{124}Cs

E21 **Natalia Targosz-Ślęczka, University of Szczecin**
Experimental investigation of nuclear reactions in metals at extremely low energies

E22 **Victoria Truesdale, University of York**
Beta-delayed fission studies of the very neutron-deficient isotopes ^{194,196}At and ^{200,202}Fr at ISOLDE

INSTRUMENTATION

I1 **Jakub Bielecki, IFJ PAN Kraków**
Phillips-Tikhonov regularization with a priori information for neutron emission tomographic reconstruction on JET

I2 **Thifhelimbilu Daphney Bucher, iThemba LABS**
Simulated and measured pulse shape signals of the iThemba LABS 32-fold segmented HPGe clover detector

I3 **Fabien Déchery, IPHC Strasbourg**
Integral simulation of the Super Separator Spectrometer S3

I4 **Agnese Giaz, INFN Milano**
3x3 $LaBr_3$:Ce detector response to monochromatic protons

I5 **Grzegorz Kamiński, JINR Dubna and IFJ PAN Kraków**
The new separator for radioactive beams studies ACCULINNA-2

I6 **Jan Kownacki, NCBJ Świerk, HIL University of Warsaw**
Detection of delayed radiation from uranium samples induced by bremsstrahlung photons

I7 **Ilkka Pohjalainen, University of Jyväskylä**
The current status and future concepts at the new IGISOL-4 facility

I8 **Kseniia Rezynkina, CSNSM Orsay**
First experimental tests of SHELS: a new heavy ion separator at the JINR

I9 **Matthieu Sénoville, CEA Saclay**
CHyMENE, a thin windowless cryogenic hydrogen target

I10 **Jerzy Szerypo, LMU Munich**
Status of the Technological Laboratory at the LMU Munich

I11 **Barbara Wasilewska, IFJ PAN Kraków**
The PARIS cluster coupled to the BaFPro electronic module: data analysis from the NRF experiment at the ELBE facility

I12 **Marzena Wolińska-Cichocka, Heavy Ion Laboratory, University of Warsaw**
The response of Modular Total Absorption Spectrometer tested with $^{142}Ba \rightarrow {}^{142}La \rightarrow {}^{142}Ce$ decay chain

THEORY

T1 **Ismahane Ami, Université M'hamed Bougara de Boumerdès, Algeria**
Excitation energy and nuclear deformation dependence of ^{194}Ir and ^{196}Au effective moment of inertia

T2 **Alexander Andreev, JINR Dubna**
Isospin dependence of mass-distribution shape of fission fragments of Hg isotopes

T3 **Johann Bartel, IPHC Strasbourg**
Fission properties of Po isotopes in different macroscopic-microscopic models

T4 **Artur Dobrowolski, UMCS Lublin**
Nuclear symmetries within a quadrupole-octupole collective approach

T5 **Piotr Jachimowicz, University of Zielona Góra**
Third, hyperdeformed minimum with different nuclear shape parameterizations in ^{232}Th

T6 **Varinderjit Kaur, Mata Gujri College, Fatehgarh Sahib, India (presented by S. Kumar)**
Asymmetry effects in multifragmentation: momentum dependence

T7 **Suneel Kumar, Thapar University, Patiala, India**
Optimization of initialization parameters in transport models: IQMD and QMD

T8 **Suneel Kumar, Thapar University, Patiala, India**
Effect of isospin dependent spatial and momentum constraints on transverse flow

T9 **Suneel Kumar, Thapar University, Patiala, India**
Fragment isotopic content under the influence of isospin-momentum dependent interactions

T10 **Raj Kumari, Panjab University, Chandigarh, India (presented by Sukhjit Kaur)**
Systematic analysis of the fusion barriers for proton and Helium induced reactions using various proximity potentials

T11 **Krzysztof Miernik, University of Warsaw**
Phenomenological model of beta-delayed neutron-emission probability

T12 **Sharma Niyti, Kurukshetra University, India (presented by Sukhjit Kaur)**
Alpha decay in superheavy elements: a key to island of stability

T13 **Gudveen Sawhney, Panjab University, India (presented by Sukhjit Kaur)**
Synthesis of ^{294}118 nucleus in ^{249,250}Cf (^{48}Ca, xn) reactions using the dynamical cluster-decay model

T14 **Agnieszka Szulerecka, UMCS Lublin**
Schematic analysis of electric reduced transition probabilities B(E1) and B(E2) for the quadrupole-octupole model with real deformation parameters

T15 **Michał Warda, UMCS Lublin**
Single-particle structure of neutron skin

T16 **Anna Zdeb, UMCS Lublin**
Spontaneous fission half-lives within semi-empirical model

Abstracts of Posters

SYNTHESIS OF NEUTRON-DEFICIENT ISOTOPES OF FLEROVIUM IN THE ^{239}Pu+^{48}Ca REACTION

F. Sh. Abdullin, Joint Institute for Nuclear Research, Dubna, Russia

Yu.Ts. Oganessian[1], F. Sh. Abdullin[1], C. Alexander[2], J. Binder[2], N. Brewer[2], R.A. Boll[2], S.N. Dmitriev[1], J. Ezold[2], K. Felker[2], J. M. Gostic[3], R. K. Grzywacz[2,4], J. H. Hamilton[5], R. A. Henderson[3], M. G. Itkis[1], K. Miernik[2], D. Miller[4], K. J. Moody[3], A. N. Polyakov[1], A. V. Ramayya[5], J. B. Roberto[2], M. A. Ryabinin[6], K. P. Rykaczewski[2], R. N. Sagaidak[1], D. A. Shaughnessy[3], I. V. Shirokovsky[1], M. V. Shumeiko[1], M. A. Stoyer[3], N. J. Stoyer[3], V. G. Subbotin[1], A. M. Sukhov[1], Yu. S. Tsyganov[1], V. K. Utyonkov[1], A. A. Voinov[1] and G. K. Vostokin[1]

1 Joint Institute for Nuclear Research, RU-141980 Dubna, Russian Federation
2 Oak Ridge National Laboratory, Oak Ridge, TN 37831, USA
3 Lawrence Livermore National Laboratory, Livermore, CA 94551, USA
4 University of Tennessee, Knoxville, TN 37996, USA
5 Vanderbilt University, Nashville, TN 37235, USA
6 Research Institute of Atomic Reactors, RU-433510 Dimitrovgrad, Russian Federation

In 2013-2014 we carried out the experiment aimed at the synthesis of neutron-deficient isotopes of flerovium in the reaction ^{239}Pu(^{48}Ca,2-4n)$^{283\text{-}285}$Fl. At ^{48}Ca energy of 245 MeV (E*=35.7-40.3 MeV), we accumulated the total beam dose of $1.4\text{x}10^{19}$. According to theoretical calculations based on macroscopic-microscopic fission barriers of the nuclei, the cross section of the reactions with evaporation of 2 or 3 neutrons was expected to be about 4 pb. However, we could detect only two decay events that could originate from spontaneous fission of ^{284}Fl with a lifetime of about 0.2 ms. The observed cross section (0.46 pb) appeared to be an order of magnitude lower than the predicted value, while the cross sections of the evaporation channels in the reactions with heavier target isotopes ^{242}Pu and ^{244}Pu amounted 7-13 pb. Such a drastic decrease of the cross section can point to a considerable lowering of the stability of superheavy nuclei when moving away from the N=184 shell, that is caused by a more substantial decrease of nuclear fission barriers than it is predicted by theory.

DECAY SPECTROSCOPY OF (11$^-$) ISOMERIC STATES IN ^{192}Po AND ^{194}Po

Boris Andel, Comenius University in Bratislava, Bratislava, Slovakia

B. Andel[1], A.N. Andreyev[2,3], S. Antalic[1], F.P. Heßberger[4,5], D. Ackermann[4], S. Franchoo[6], S. Hofmann[4,7], M. Huyse[8], Z. Kalaninová[1], B. Kindler[4], I. Kojouharov[4], B. Lommel[4], R. Mann[4], K. Nishio[3], R.D. Page[9], J.J. Ressler[10], B. Streicher[1], B. Sulignano[4], P. Van Duppen[8]

1 Comenius University in Bratislava, Bratislava, Slovakia
2 University of York, York, United Kingdom
3 Advanced Science Research Center, Ibaraki, Japan
4 GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt, Germany
5 Helmholtz Institut Mainz, Mainz, Germany
6 IPN Orsay, Orsay Cedex, France
7 Goethe-Universität Frankfurt, Frankfurt, Germany
8 KU Leuven, Leuven, Belgium
9 University of Liverpool, Liverpool, United Kingdom
10 Simon Fraser University, Burnaby, British Columbia, Canada

Nuclear isomers are valuable probes for the nuclear structure studies. In all even-A polonium isotopes with $196 \leq A \leq 210$, isomeric states with $I^\pi = 11^-$ are present. They have dominant configuration of $\pi(1h_{9/2})\otimes\pi(1i_{13/2})$ and half-lives between 0.5 ns and 1 µs. Excitation energies of the isomers are smoothly decreasing from 2.8 MeV down to 2.5 MeV with decreasing neutron number [1]. Although short-lived isomers were also identified in ^{194,192}Po, their properties are not well known so far. Their excitation energies, de-excitation routes, and even spins and parities are not determined reliably. Tentative decay scheme of the isomer in ^{194}Po was suggested starting at excitation energy of 2.5 MeV [2]. For isomer in ^{192}Po, feeding of the ground state band by 154 keV transition on top of the (10$^+$) level was tentatively suggested with resulting excitation energy of at least 2.3 MeV [3]. In both cases, lack of γ-γ coincidences did not allow firmer assignments into decay schemes.

In this contribution, new γ-ray spectroscopy data for ^{194,192}Po obtained at the velocity filter SHIP at GSI, Darmstadt (Germany) will be discussed. In particular, new γ transitions were identified and γ-γ coincidences in de-excitation of both isomeric states were observed for the first time. On the basis of our observation, changes in existing decay schemes of the isomers are suggested. Cross sections of astatine and polonium isotopes produced in fusion-evaporation reactions will be presented as well.

REFERENCES
[1] L.A. Bernstein et al., Phys. Rev. C 52, 621 (1995).
[2] K. Helariutta et al., Eur. Phys. J. A 6, 289 (1999).
[3] K. Van de Vel et al., Phys. Rev. C 68, 054311 (2003).

PYGMY DIPOLE RESONANCE IN IRON NEUTRON RICH ISOTOPES

Riccardo Avigo, INFN-Università degli Studi di Milano, Milano, Italy

R. Avigo[1,2], O. Wieland[2], F. Camera[1,2], G. Benzoni[2], N. Blasi[2], G. Bocchi[1,2], S. Bottoni[1,2,3], A. Bracco[1,2], S. Brambilla[2], S. Ceruti[1,2], F.C.L. Crespi[1,2], A. Giaz[1,2], S. Leoni[1,2], B. Million[2], A.I. Morales[2], L. Pellegri[2] and PreSPEC - AGATA collaboration

1Università di Milano, Milano, Italy,
2 INFN sezione di Milano, Milano , Italy
3KU Leuven, Leuven, Belgium

The electric dipole (E1) response of nuclei at energies around the particle separation energy is presently attracting large attention, particularly for unstable neutron rich nuclei produced as radioactive beams [1,2]. The investigation of the E1 response is interesting not only to understand how isospin changes the mean field but also for its implications in the astrophysical models predicting the element abundances in the r-process. The E1 response of nuclei and the dipole strength distribution around the binding energy affects strongly the reaction rates in astrophysical scenarios where photodisintegration reactions are important, i.e. in hot stars and stellar explosions [3]. The accumulation of E1 strength around the particle separation energy is commonly denoted as pygmy dipole resonance (PDR) [4] due to the minor size of its strength in comparison with the giant dipole resonance (GDR) which dominates the E1 response and exhausts great part of the Thomas-Reiche-Kuhn (TRK) oscillator sum rule.

In addition the study of the pygmy strength is expected to provide information on the neutron skin and symmetry energy of the equation of state. This information is very relevant for the modeling of neutron stars. Recent works [5,6,7] have derived from the pygmy resonance analysis the value of the derivative of the symmetry energy (denoted by L) and of the neutron skin radius. The obtained values for L agrees fairly well with the values obtained with other techniques such as heavy ion fragmentation reactions. In addition the computed skin radius of ^{208}Pb based on the value of L deduced from ^{132}Sn and ^{68}Ni pygmy experiments lies within the experimental values obtained with different experimental methods.

Recently at GSI laboratories an experiment was performed to study the pygmy resonance in ^{64}Fe and ^{62}Fe by relativistic coulomb excitation and measuring gamma decay to ground state. The measurement was a part of the 2012 and 2014 PreSPEC [8] experimental campaign. The AGATA-HECTOR array system was used for gamma ray detection in order to obtain high energy resolution and efficiency for the measurement of high energy gamma-rays.
The study of E1 response of Iron neutron rich isotopes around the particle separation energy allows to obtain additional information for different nuclei and explore possible model dependences and constraints for the density-dependence of the symmetry energy.

REFERENCES

[1] O. Wieland et al., Phys. Rev. Lett. 102, 092502 (2009)
[2] J. Gibelin et al., Phys. Rev. Lett. 101, 212503 (2008)
[3] S. Goriely, E. Khan, Nucl. Phys. A706, 217 (2002)
[4] A. Richter NPA 731(2004)59
[5] A. Klimkiewicz et al., Phys. Rev. C76, 051603 (2007)
[6] J. Piekarewicz Phys. Rev. C73, 044325 (2006)
[7] A. Carbone et al. Phys. Rev. C 81 (2010) 041301(R)
[8] N. Pietralla et al., EPJ Web of Conferences 66, 02083 (2014)

ENERGY DEPENDENCE OF LIGHT CHARGED PARTICLES PRODUCTION AT INTERMEDIATE ENERGIES

Preeti Bansal, Department of Physics, Panjab University, Chandigarh, India

P. Bansal[1], S. Gautam[2]

1 Department of Physics, Panjab University, Chandigarh-160014, India
2 Department of Physics, Dev Samaj College for Women, Sector 45B, Chandigarh-160047, India

The heavy ion collisions at intermediate energies offer an unique opportunity to study the properties of nuclear matter at extreme conditions of densities and temperatures. Such studies shed light on the equation of state of nuclear matter which is important in the context of nuclear physics as well as astrophysics. Various phenomena such as collective flow and its disappearance, multifragmentation, nuclear stopping and particle production take place at intermediate energies. Out of these, multifragmentation enjoys a special status as it gives insight about the liquid-gas phase transition in nuclear matter. During evolution, various intermediate mass fragments (IMFs), light charged particles (LCPs), heavy mass fragments (HMFs), medium mass fragments (MMFs) and free nucleons are emitted. On the theoretical front, various studies have been done to study the energy dependence of multifragmentation. These studies have revealed rise and fall behavior of the IMFs multiplicity with incident energy of the colliding pair [1-3]. In addition to IMFs, one has copious production of LCPs during heavy ion collisions. A recent study has revealed that LCPs can act as a good probe of the symmetry energy [4] and nuclear dissipation. Therefore, LCPs have significant role in understanding the dynamics of heavy ion reactions. With this in mind, we plan to study the LCPs production as a function of incident energy. We studied the multiplicities of LCPs from semi-central collisions of symmetric reactions of $^{40}Ca+^{40}Ca$, $^{58}Ni+^{58}Ni$, $^{93}Nb+^{93}Nb$, $^{167}Er+^{167}Er$ and $^{197}Au+^{197}Au$. For each system, the multiplicity of LCPs increases with beam energy, reaches a maximum and then decreases. The peak centre-of-mass energy for LCPs production increases linearly with the combined mass of system. The peak multiplicity of LCPs also increases with the system mass. Moreover, peak centre-of-mass energy for LCPs production observed to be higher than the corresponding energy of IMFs production. This is because of much violent nature of collisions at higher incident energies and this in turn breaks the heavy fragments into LCPs.

REFERENCES
[1] Y. K. Vermani and R. K. Puri, J. Phys. G: Nucl. Part. Phys. 36, 105103 (2009).
[2] D. Sisan *et al.*, Phys. Rev. C 63, 027602 (2001).
[3] G. F. Peaslee *et al.*, Phys. Rev. C 49, R2271 (1994).
[4] L. W. Chen, C. M. Ko, and B. A. Li, Phys. Rev. C 68, 017601 (2003).

NON-COMPOUND NUCLEUS COMPONENT IN DECAY OF $^{12}C+^{93}Nb\rightarrow^{105}Ag^*$ REACTION WITH NON-COPLANAR DEGREE OF FREEDOM INCLUDED IN DYNAMICAL CLUSTER-DECAY MODEL

Sahila Chopra, Panjab University, Chandigarh, India

S. Chopra, R. K. Gupta

Department of Physics, Panjab University, Chandigarh-160014, India

A point of interest in this report is the inclusion of non-coplanar degree of freedom (azimuthal angle Φ≠0) and study it's effect on the non-compound nucleus (nCN) component in compound nucleus (CN) decay of $^{105}Ag^*$, formed in $^{12}C+^{93}Nb$ reaction, in our use of the dynamical cluster-decay model (DCM) of Gupta and collaborators. The DCM is worked out in terms of fragmentation coordinate $\eta = (A_1\text{-}A_2)/(A_1+A_2)$ and relative separation R and define the CN decay or the fragments production cross section for ℓ partial waves as

$$\sigma_{(A_1,A_2)}(E_{c.m.},\theta_i,\Phi)=\frac{\pi}{k^2}\sum_{\ell=0}^{\ell_{max}}(2\ell+1)P_0P; \qquad k=\sqrt{\frac{2\mu E_{c.m.}}{\hbar^2}} \qquad (1)$$

Here P_0 is the pre-formation probability of each fragmentation, calculated as the solution of stationary Schrödinger equation in η, and P the penetration probability of the fragment through its confining interaction barrier. In the first phase of our calculation [1] using coplanar nuclei (Φ=0) in DCM, we found an unexpectedly large nCN content in this reaction. For example, at the center of mass energy $E_{c.m.}$=54.205 MeV, the light particle decays 3n and 4n contained almost 100% nCN component (compare, calculated neutron emission cross-section σ_{3n}=0.11 and σ_{4n}=0.0024 with experimental data 398.2 and 203.4 mb, respectively). Adding the Φ degree of freedom, however, does not seem to help resolve this large discrepancy. The new calculated numbers are σ_{3n}=3.95 and σ_{4n}=3.06 mb, which are still only 1-2% of the measured values. Apparently, the repetition of experiment is called for.

REFERENCES

[1] S. Chopra, M. Bansal, M. K. Sharma, and R. K. Gupta, Phys. Rev. C **88,** 014615 (2013).

EVOLUTION OF COLLECTIVITY IN THE VICINITY OF ^{208}Pb

Martha Liliana Cortés, Technische Universität Darmstadt, Darmstadt

T. Alexander[1], M. Reese[2], L.G. Sarmiento[3], J. Gerl[4], N. Pietralla[2], Z. Podolyák[1], D. Rudolph[3] for the S429 PreSPEC-AGATA collaboration

1 University of Surrey, Guildford, United Kingdom
2 Technische Universität Darmstadt, Darmstadt, Germany
3 Lunds Universitet, Lund, Sweden
4 GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt, Germany

Knowledge on the spectroscopic data of nuclei in the region of ^{208}Pb provides key information to probe parameter sets of nuclear models, both shell-model and mean-field based. It also serves as a basis for the extrapolation of any nuclear model into the area of actinides and superheavy nuclei. Since ^{208}Pb is the heaviest doubly-magic nucleus known to date, it is also the last firm anchor point for extrapolations. Surprisingly little data on the fundamental B(E2; $0^+ \rightarrow 2^+$) values for the even-even Pt, Hg, Pb and Po isotopes is available for this region.

Within the PreSPEC-AGATA campaign [1], experiment S429 studied the fragmentation of a ^{208}Pb beam at 1GeV per nucleon on a 2.5 g/cm^2 Be target at GSI Darmstadt. Secondary beams of Pb, Hg and Pt ions were selected and identified by the Fragment Separator (FRS)[2] and focused on a 400 mg/cm^2 thick Au target. Gamma-rays emitted after relativistic Coulomb excitation were detected using AGATA [3] and HECTOR [4] arrays. Outgoing fragments were identified with LYCCA [5].

In our contribution we will present the current status of the complex data analysis.

REFERENCES
[1] N. Pietralla, M. Reese, M.L. Cortes *et al.*, EPJ Web of Conferences 66, 02083 (2014).
[2] H. Geissel *et al.*, Nucl. Instr. Meth. B 70, 286 (1992).
[3] S. Akkoyun *et al.*, Nucl. Instr. Meth. A 668, 26 (2012).
[4] A. Maj *et al.*, Nucl. Phys. A 571, 185 (1994).
[5] P. Golubev *et al.*, Nucl. Instr. Meth. A 723, 55 (2013).

NUCLEAR MOMENTS OF THE NEUTRON-RICH Mn AND Co ISOTOPES AROUND N=40

Hanne Heylen, KU Leuven, Leuven, Belgium

H. Heylen[1], C. Babcock[2], J. Billowes[3], M.L. Bissell[1], K. Blaum[4], I. Budinčević[1], L. Caceres[5], B. Cheal[2], R. P. de Groote[1], V. Fonteinou[6], R. F. Garcia Ruiz[1], Ch. Geppert[7,8], W. Gins[1], J. Papuga[1], O. Kamalou[5], A. Kanellakopoulos[9], K. Kreim[4], I. D. Moore[10], T. Mertzimekis[9], R. Neugart[4,8], G. Neyens[1], W. Nörtershäuser[11], O. Sorlin[5], J.C. Thomas[5], D.T. Yordanov[4]

1. KU Leuven, Inst. voor Kern- en Stralingsfysica, Celestijnenlaan 200D, 3001 Leuven, Belgium
2. Oliver Lodge Laboratory, Oxford Street, University of Liverpool, Liverpool L69 7ZE, UK
3. School of Physics and Astronomy, The University of Manchester, Manchester M13 9PL, UK
4. Max-Plank-Institut für Kernphysik, D-69117 Heidelberg, Germany
5. GANIL, CEA/DSM-CNRS/IN2P3, B.P. 55027, F-14076 Caen Cedex 5, France
6. NCSR Demokritos, Inst. Nucl. Phys., Tandem Accelerator Lab, GR-15310 Athens, Greece
7. GSI Helmholtzzentrum Schwerionenforschung GmbH, D-64291 Darmstadt, Germany
8. Johannes Gutenberg Univ Mainz, Inst Kernchem, D-55128 Mainz, Germany
9. University of Athens, Faculty of Physics, Panepistimiopoli Zografou, 15784 Athens, Greece
10. Department of Physics, University of Jyväskylä, PB 35 (YFL) Jyväskylä, Finland
11. Institut fur Kernphysik, TU Darmstadt, D-64289 Darmstadt, Germany

The region south of ^{68}Ni (Z=28, N=40) is characterized by a rapid shell structure evolution. This results in a competition between single-particle effects due to the stabilizing effect of the Z=28 proton shell gap on one hand and a rapid onset of collectivity when this shell is opened, due to neutron excitations across N=40 on the other hand.

We have studied the neutron-rich $^{51\text{-}64}$Mn (Z=25) and $^{64\text{-}66}$Co (Z=27) isotopes, respectively via collinear laser spectroscopy at ISOLDE and via β-NMR at GANIL. From the laser spectroscopy experiment model-independent information on the ground - and isomeric state spins, as well as their magnetic moments is obtained and this provides unique input for further establishing the level schemes and the changing ground state wave functions of the Mn isotopes towards N=40. In the β-NMR experiment the g-factor is measured and this observable is an excellent probe to the ground state wave function. Our data provide a unique possibility to study the evolution of single-particle and collective behavior as a function of Z and N when approaching N=40.

HIGH-SPIN SHELL MODEL STATES IN ODD NEUTRON-RICH Sn ISOTOPES POPULATED IN FUSION-FISSION REACTIONS

Łukasz Iskra, Institute of Nuclear Physic PAN, Kraków, Poland

Ł. W. Iskra,[1] R. Broda,[1] R. V. F. Janssens,[2] J. Wrzesiński,[1] C. J. Chiara,[2, 3] M. P. Carpenter,[2] B. Fornal,[1] N. Hoteling,[2, 3] F. G. Kondev,[4] W. Królas,[1] T. Lauritsen,[2] T. Pawłat,[1] D. Seweryniak,[2] I. Stefanescu,[2, 3] W. B. Walters,[3] and S. Zhu[2]

[1]Institute of Nuclear Physics, Polish Academy of Sciences, PL-31-342 Kraków, Poland
[2]Physics Division, Argonne National Laboratory, Argonne, Illinois 60439, USA
[3]Department of Chemistry and Biochemistry, University of Maryland, Maryland 20742, USA
[4]Nuclear Engineering Division, Argonne National Laboratory, Argonne, Illinois 60439, USA

The seniority $\nu = 2$ and 3 $(h_{11/2})^n$ 10^+ and $27/2^-$ isomers known in all neutron-rich Sn isotopes were established in a series of deep-inelastic heavy ion reactions [e.g. 1-3]. The *B(E2)* values extracted for isomeric transitions reflected in a transparent way the filling of the $h_{11/2}$ neutron orbital and indicated that the shell is half-filled in the ^{123}Sn isotope. In an extensive analysis, we have now identified higher seniority excitations located above these isomers in the Sn isotopes extending from ^{118}Sn to the ^{128}Sn. While the results obtained for the even-Sn neutron-rich isotopes were already a subject of several conference presentations and were recently published work [4], the present report will summarize results concerning the odd- ^{119,121,123,125}Sn isotopes investigated using the same experimental data.

All of these isotopes were produced in fusion-fission reactions with 6.9-MeV/*A* ^{48}Ca beams on ^{208}Pb and ^{238}U targets and in fission of a ^{238}U target induced by 6.7-MeV/*A* ^{64}Ni beams. Level schemes up to excitation energies in excess of 8 MeV have been established based on multi-fold γ-ray coincidence relationships measured with the GAMMASPHERE array. By exploiting delayed coincidence technique, extensive level schemes have been delineated including the newly observed $23/2^+$ and $35/2^-$ isomers. For most of the identified states unique spin and parity assignments could be proposed. Level schemes and spin-parity assignments were subsequently supported by the theoretical shell-model calculations which were carried out down to ^{123}Sn in the $g_{7/2}$, $d_{5/2}$, $d_{3/2}$, $s_{1/2}$, and $h_{11/2}$ model space of neutron holes with respect to the closed ^{132}Sn core. The calculation results reproduce the experimental level energies and spin-parity assignments rather well. The intrinsic structure of the observed states is discussed on the basis of the calculated wave functions which, in many instances, point to complex configurations.

The systematics of level energies throughout the isotopic chain of neutron-rich Sn isotopes investigated here displays a strikingly regular dependence with mass and this smooth behavior adds further confidence in the experimental results. Even more striking is the regularity observed in the variation of the reduced transition probabilities extracted from the measured isomeric half-lives for a number of *E2* transitions established in the decays of the $19/2^+$ and $23/2^+$ isomers. For these *E2* transitions, the extracted *B(E2)* probabilities have similar values and follow rather precisely the *A* dependence established earlier for the $(h_{11/2})^n$, seniority $\nu = 2,3$ isomers in the full range of $^{116-130}$Sn.

While the present investigation was ongoing, other group independently performed parallel research with the same goal, and their results were reported recently [5]. Apart from the comforting similarity of the results obtained in independent experimental efforts, the level schemes reported here are often more detailed, especially in instances which may turn out to be critical for the interpretation of some of the observed structures.

REFERENCES

[1] R. Broda *et al.*, Phys. Rev. Lett. 68, 1671 (1992).
[2] C. T. Zhang *et al.*, Phys. Rev. C 62, 057305 (2000).
[3] S. Lunardi *et al.*, Z. Phys. A 328, 487 (1987).
[4] Ł. W. Iskra *et al.*, Phys. Rev. C 89, 044324 (2014).
[5] A. Astier *et al.*, Phys. Rev. C 85, 054316 (2012).

EXPERIMENTAL INVESTIGATION OF FEW-NUCLEON DYNAMICS IN DEUTERON-DEUTERON COLLISION AT 160 MeV.

G. Khatri, Jagiellonian University, Kraków, Poland

G. Khatri[1], I. Ciepał[1], St. Kistryn[1], E. Stephan[2] , B. Kłos[2], A. Kozela[3], W. Parol[1], I. Skwira-Chalot[4]

1 Institute of Physics, Jagiellonian University, 30-059, Kraków, Poland
2 Institute of Physics, University of Silesia, 40-007, Katowice, Poland
3 Institute of Nuclear Physics PAN, 31-342, Kraków, Poland
4 Faculty of Physics, University of Warsaw, Warsaw, 00-681, Poland

In the past few decades, the three-nucleon (3N) systems have been studied extensively in both, theoretical and experimental aspects. With the new and improved experimental facilities, the measurement of very subtle effects such as the three-nucleon force (3NF) in the 3N systems has now become possible [1-3]. Theoretical treatment of the 3N systems dynamics have also progressed in parallel to the experimental investigations. Nowadays, there exist several approaches [4-6] to describe the interaction in such systems. The available large set of high precision 3N data is quite well described by the models, at least in the domain of differential cross section. For more complicated systems, those composed of four-nucleon (4N) the knowledge is scarce in both, the theoretical and the experimental aspects. Recently certain progress have been made in calculations of 4N system dynamics, but so far at the energies below the breakup-reaction threshold in the dd collision [4]. In such system the 3NF effects are expected to be enhanced what makes the investigations more attractive. To understand 4N dynamics and to develop further the theoretical approaches, new precise data measured in a wide phase-space region are needed.

To meet the above expectations we have performed an experiment at KVI laboratory (The Netherlands) with use of the BINA detector and 160 MeV deuteron beam impinging on deuteron target. Aim of the measurement was to determine the differential cross-section data for three- (dd->dpn) and four-body breakup (dd->ppnn) reactions. The experiment appears even more important due to the fact that the experimental database for d+d breakup is very limited. Our experiment is a continuation of previous very successful measurements of 3N and 4N systems in continuum at other medium energies [1-3,8,9]. The apparatus is a new-generation construction which offers access to almost full phase-space of the studied breakup process, well suited for such experiments at intermediate energies.

The preliminary results covering sets of differential cross sections for dd->dpn breakup reaction will be presented. The steps following the data analysis will also be discussed briefly.

REFERENCES
[1] St. Kistryn et al., Phys. Rev. C 72 (2005) 044006.
[2] St. Kistryn et al., Phys. Lett. B 641 (2006) 23.
[3] N. Kalantar-Nayestanaki et al., Rep. Progr. Phys. 75 (2012) 016301.
[4] H. Witała et al., Phys. Lett. B 634 (2006) 374.
[5] A. Deltuva et al., Phys. Rev. C 73 (2006) 057001.
[6] E. Epelbaum, Prog. Part. Nucl. Phys. 57 (2006) 654.
[7] A. Deltuva. Few-Body Systems, Springer Link, Nov-2013.
[8] I. Ciepał et al. Few-Body Systems, Springer Link, Jan-2013.
[9] B. Kłos et al. Acta Physica Polonica B ,Vol. 44, No. 3, March 2013, p-345.

EXPERIMENTAL STUDY OF THREE-NUCLEON DYNAMICS IN THE dp BREAKUP REACTION

Barbara Kłos, University of Silesia, Katowice, Poland

B. Kłos[1], I. Ciepał[2] for the WASA-at-Cosy Collaboration

1 University of Silesia, PL-40007 Katowice, Poland
2 Jagiellonian University, PL-30059 Kraków, Poland

An experiment to investigate the 1H(d; pp)n breakup reaction using a deuteron beam of 340, 380 and 400 MeV and the WASA detector has been performed at the Cooler Synchrotron COSY-Jülich. The main goal was the detailed study of various aspects of few-nucleon dynamics in the medium energy region, with particular emphasis on relativistic effects and their interplay with three nucleon forces. Calculations including different pieces of nucleon-nucleon dynamics like the three nucleon force 3NF, the long-range Coulomb interaction or relativistic effects, predict their influence to reveal with different strength at different parts of the phase space. Previous measurements of the cross sections at different deuteron beam energies have demonstrated that an inclusion of 3N and Coulomb forces in the theoretical calculations improves the description of the experimental data [1]. In recent years the relativistic treatment of the breakup reaction in 3N systems was developed using the NN potential [2] and this approach has also been extended for calculations including 3NF [3].The relativistic effects and their interplay with three nucleon forces become more important with increasing available energy in the three nucleon system. Therefore the investigations at high energies are crucial to understand their nature. The almost 4π geometry of the WASA detector gives an unique possibility to study various aspects of dynamics of processes in the three-nucleon reaction. Preliminary results obtained using the WASA detector will presented. The data will be compared to the first obtained theoretical calculations using modern realistic nucleon-nucleon (NN) interactions, combined with a suitable model of 3N forces [4].

REFERENCES

[1] S. Kistryn and E. Stephan, J. Phys. G: Nucl. Part. Phys.40, 063101 (2013)
[2] H. Witała H., R. Skibinski and J. Golak, The EuropeanPhysical Journal A 30, 369 (2006)
[3] H. Witała et al., Phys. Rev. C 83, 044001 (2011)
[4] W. Glöckle , H. Witała, D. Hüber, H. Kamada, J. Golak, Phys. Rep. 274: 107 (1996)

SEARCH FOR ETA-MESIC NUCLEI WITH WASA-at-COSY

Wojciech Krzemień, Jagiellonian University, Kraków, Poland

W. Krzemień[1], P. Moskal[1,2], M. Skurzok[1],
for the WASA-at-COSY collaboration

1 M. Smoluchowski Institute of Physics, Jagiellonian University, 30-059 Kraków, Poland
2 IKP, Forschungszentrum Jülich, D-52425 Jülich, Germany

We search for an evidence of η-mesic He with the WASA detector. Two dedicated experiments were performed at the Cooler Synchrotron COSY-Jülich. The experimental method is based on the measurement of the excitation functions for the two reaction channels: $dd \rightarrow {}^3He\ p\pi^-$ and $dd \rightarrow {}^3He\ n\pi^0$, where the outgoing N-π pairs originate from the conversion of the η meson on a nucleon inside the He nucleus. In this contribution, the experimental method is shortly described and the current status of the analysis will be presented.

ISOSPIN CHARACTER OF THE 'PYGMY' STATES IN ^{140}Ce STUDIED *VIA* INELASTIC SCATTERING OF ^{17}O

Mateusz Krzysiek, Institute of Nuclear Physics PAN, Kraków, Poland

M. Krzysiek[1], M. Kmiecik[1], F.C.L. Crespi[2], A. Maj[1], P. Bednarczyk[1], M. Ciemała[1], B. Fornal[1], J. Grębosz[1], K. Mazurek[1], W. Męczyński[1], M. Ziębliński[1], A. Bracco[2], G. Benzoni[2], N. Blasi[2], C. Boiano[2], S. Brambilla[2], F. Camera[2], A. Giaz[2], S. Leoni[2], B. Million[2], A. Morales[2], R. Nicolini[2], L. Pellegri[2], S. Riboldi[2], V. Vandone[2], O. Wieland[2], G. De Angelis[3], D. R. Napoli[3], J.J. Valiente- Dobon[3], D. Bazzacco[4], E. Farnea[4], A. Gottardo[4], S. Lenzi[4], S. Lunardi[4], D. Mengoni[4], C. Michelagnoli[4], F. Recchia[4], C. Ur[4], A. Gadea[5], T.Huyuk[5], D. Barrientos[5], B. Birkenbach[6], K. Geibel[6], H. Hess[6], P. Reiter[6], T. Steinbach[6], A. Wiens[6], A. Bürger[7], A. Görgen[7], M. Guttormsen[7], A.C. Larsen[7], S. Siem[7]

1 The Niewodniczański Institute of Nuclear Physics, Polish Academy of Sciences, Kraków, Poland
2 Università degli Studi e INFN sezione di Milano, Italy
3 INFN, Laboratori Nazionali di Legnaro, Legnaro, Italy
4 Università di Padova e INFN, sezione di Padova, Padova, Italy
5 IFIC, Valencia, Spain
6 Institut fur Kernphysik der Universitat zu Koln, Germany
7 Department of Physics, University of Oslo, Norway

Giant Resonances are collective modes of excitation of atomic nuclei, which provide useful information on nuclear structure and on the effective nucleon-nucleon interaction [1]. Such resonances can be excited with different probes as for example: photons, charged particles or heavy ions, followed by subsequent decays by emission of particles and γ's [2]. Below Giant Resonance, around particle threshold, a large fraction of highly excited states has been found to be of a dipole nature and it has been associated to so called the 'Pygmy Dipole Resonance', which is considered to be caused by the oscillation of the neutron skin against the inert proton-neutron core.

Main aim of this study is a deeper understanding of the nuclear structure properties of the 'pygmy' states in ^{140}Ce, excited *via* inelastic scattering of a weakly bound ^{17}O projectiles. Important aim will be to further investigate the isospin composition of the PDR. As it was observed in (γ,γ') and (α,α') experiments [3], there is some kind of a 'splitting' of the PDR into two parts: a low-energy isoscalar component dominated by neutron-skin oscillations and a higher-energy component lying on the tail of the giant dipole resonance of rather isovector character. Comparison with previous results for this nucleus, will be helpful for drawing final conclusions.

The experiment was performed at Laboratori Nazionali di Legnaro, Italy. Inelastic scattering of ^{17}O projectiles at 20 MeV/A was used to excite the resonance modes in the ^{140}Ce target (2.5 mg/cm^2 thick). Gamma rays were registered by 5 AGATA triple clusters and 8 large volume scintillators ($LaBr_3$). The detectors were mounted at a distance of about 20 cm from the target position, resulting in a full absorption efficiency of about 0.8% at 10 MeV. The scattered ^{17}O ions were identified by two ΔE-E Si telescopes of the TRACE array mounted inside the scattering chamber. The telescopes consisted of 2 segmented Si-pad detectors, each made of 60 pixels covering an active area of 20x50 mm^2.

Progress in complex data analysis will be discussed. Preliminary results of the angular distributions of the γ-transitions in 'pygmy' energy region confirm its dipole character. Very preliminary results of the Distorted Wave Born Approximation (DWBA) calculations performed in order to investigate the isospin character of the excited 'pygmy' states will be shown and discussed.

REFERENCES
[1] P. F. Bortignon, A. Bracco and R. A. Broglia, Giant Resonances, nuclear structure at finite temperature, Contemporary Concepts in Physics, Harwood Academic Publishers (1998).
[2] J.R. Beene et al., Phys. Rev. C39, 1307(1989).
[3] J. Endres et al., Phys. Rev. C80, 034302 (2009).

SPECTROSCOPIC STUDY OF NEUTRON RICH RUTHENIUM ISOTOPES STEMMING FROM EXILL FISSION CAMPAIGNS

Clément Mancuso, UCBL-IPNL, Villeurbanne, France

C. Mancuso, C. Ducoin, D. Guinet, N. Redon, O. Stezowski
and the EXILL Collaboration

IPNL, Université de Lyon, Université Claude Bernard Lyon1,
and CNRS/IN2P3 F-69622 Villeurbanne, France

For a long time, nuclei have been imagined as being spherical. Nowadays, we know that this is the case for only a minority of them. Neutron rich ruthenium isotopes constitute a particularly interesting research area concerning shape evolution. These isotopes are well known to belong to a region where one can observe a gradual change from spherical [1] to prolate shapes via triaxial deformation [2, 3] by increasing the neutron number. Furthermore, recent Hartree-Fock-Bogolioubov calculation have predicted that ^{120}Ru should be spherical [4].

To understand the behavior of the low-lying states in these Ru isotopes, we have studied Ru isotopes among the fission fragments produced in cold-neutron-induced fission of ^{235}U (November 2012) and ^{241}Pu (April 2013), during the EXILL campaign. For these experiments, a high resolution germanium detector array, mainly made from parts of the EXOGAM array (GANIL), was implemented at the Institut Laue Langevin (ILL). The slow neutrons used allowed to avoid long chain neutron evaporation, and to access neutron rich products among ruthenium isotopes up to ^{115}Ru for ^{241}Pu fission (with a production rate of 10^{-4} nuclei per fission).

In a poster, I will present the experiment, and preliminary results of our analysis.

REFERENCES

[1] B.Kharraja et al., Phys. Rev. C57 (1998) 83
[2] I. Deloncle et al., Eur. Phys. J. A8 (2000) 177
[3] J.A. Shannon et al., Phys. Lett. B336 (1994) 136
[4] S. Hilaire et D. Girod, EPJA 33 (2007) 237

PROSPERTIES OF FREEZE-OUT CONFIGURATION IN THE CENTRAL ^{197}Au + ^{197}Au COLLISIONS AT 23 AMeV

Rafał Najman, Institute of Physics, Jagiellonian University, Kraków, Poland

The results of the measurements performed at INFN-LNS in Catania using the 4π CHIMERA detector for Au + Au system at 23 AMeV will be presented [1]. Global characteristics of the charge, mass, energy and angular distributions of identified fragments will be shown. In order to investigate the reaction scenario, the experimental data will be compared with ETNA and QMD model predictions [2].

Several novel observables sensitive to the geometry of the decaying nuclear object will be used. According to the BUU simulation predictions for a class of events corresponding toroidal configuration most of reaction products should be located in the plane tilted with respect to the reaction plane [3]. Such events will be selected. The indications of the formation of a toroidal freeze-out configuration will be discussed.

REFERENCES

[1] R.Najman et al., Acta Phys.Pol.B.45 (2014) 475.
[2] A.Sochocka et al., Acta Phys. Pol. B40, 747 (2009).
[3] A.Sochocka et al., Int. J. of Mod. Phys. E17, 190 (2008); A.Sochocka et al., Acta Phys. Pol. B39, 405 (2008).

STUDY THE $I^{p}=K^{p}=8^{-}$ ISOMERIC STATE IN ^{184}Pt BY COMBINED CONVERSION-ELECTRON AND GAMMA SPECTROSCOPY

Jarosław Perkowski, University of Łódź, Łódź, Poland

J. Perkowski[1], J. Andrzejewski[1], Ł. Janiak[1], J. Samorajczyk[1], T. Abraham[2], Ch. Droste[3], E. Grodner[3], K. Hadyńska-Klęk[2], M. Kisieliński[2,4], M. Komorowska[2], M. Kowalczyk[2,3], J. Kownacki[2,4], J. Mierzejewski[2,3], P. Napiorkowski[2], A. Korman[4], T. Marchlewski[2], J. Srebrny[2], A. Stolarz[2], M. Zielińska[2,5]

1 Faculty of Physics and Applied Computer Science, University of Lodz, Łódź 90-236, Poland
2 Heavy Ion Laboratory, University of Warsaw, ul. Pasteura 5A, 02-093 Warszawa, Poland
3 Faculty of Physics, University of Warsaw, Warsaw 00-681, Poland
4 The National Centre for Nuclear Research, ul. Andrzeja Sołtana 7, 05-400 Otwock, Świerk, Poland
5 CEA Saclay, Route Nationale, 91400 Gif-sur-Yvette, France

The problem of the K selection rule violation for electromagnetic transitions in nuclei, in spite of being a subject of extensive investigations, is still actual problem [1,2]. One of possible reasons of the phenomenon is the Coriolis interaction, which is responsible for an admixture of wave function components characterized by K values higher than the main one [1-3]. However, the non-axial deformation may cause the same experimental effects. The nuclei with the mass number close to A = 180, exhibiting large triaxiality g around (20 ÷ 30) [3,4], constitute an excellent testing ground to study this phenomenon.

Coincidence gamma-electron measurements allow determining internal conversion coefficients and, in consequence absolute probability transitions descent from of the $I^{p} = K^{p} = 8^{-}$ isomeric state in ^{184}Pt. This isomeric state is observed in nuclei for number of neutrons equal: 74, 106 and 150 or number of protons 74 (tungsten) and it can be interpreted as two quasi particle states [3]. The decay modes of this isomeric state contains E1 transitions with a degree of K forbiddingness n = 7, leading directly to the 8^{+} member of the ground state band with K=0. These branches severely violate the K selection rule.

The main goal of presented experiment was to determine multipolarities of the gamma transitions de-exciting the $I^{p}=K^{p}= 8^{-}$ isomeric state and corresponding their partial half lifes in ^{184}Pt. The determined value of half life (0.571 ± 0.015 ms) doesn't confirm previously measured value equal 1.01 ms [5]. The gamma and internal conversion electron spectroscopy were carried out using the electron spectrometer [6] coupled to the EAGLE array [7] at the Heavy Ion Laboratory of the University of Warsaw.

REFERENCES

[1] P.M. Walker, G.D. Dracoulis, Nature 399 (1999) 35
[2] A.B. Hayes et al., Phys. Rev. Lett. 96 (2006) 042505
[3] F.R. Xu et al., Phys. Rev. C 59 (1999) 731
[4] Y. P. Varshni and S. Bose, Nuclear Phys. A 144 (1970) 645
[5] Coral M. Baglin, Nuclear Data Sheets 111, 275 (2010)
[6] J. Perkowski et al., Rev. Sci. Inst. 85 (2014) 043303
[7] J. Mierzejewski et al., Nucl. Instrum. Methods. Phys. Res. A 659, 84 (2011),

ANALYSIS OF THE ^{106}Zr EXPERIMENT WITH THE PreSPEC-AGATA SETUP

Damian Ralet, TU Darmstadt, Germany

D. Ralet[1], S. Pietri[2], T. Arici[2], T. Alexander[11], T. Back[12], D. Bazzacco[8], B. Bruyneel[9], P. Boutachkov[2], A. Bruce[13], F. Camera[4], B. Cederwal[12], S. Ceruti[5], L. Cortes[1], D. Curien[3], M. Dewald[10], F. Didierjean[3], M. Doncel[12], G. Duchêne[3], M. Hackstein[10], T. Hüyük[6], A. Gadea[6], J. Gerl[2], F. Ghazi[12], N. Goel[2], P. Golubev[7], M. Gorska[2], A. Gotardo[8], H, Grawe[2], T. Habermann[2], A. Jungclaus[14], W. Korten[9], N. Lalovic[2], E. Merchan[2], A. Morales[5], F. Naqvi[15], N. Pietralla[1], Z. Podoliak[11], M. Reese[1], D. Rudolph[7], L. Sengelé[3], C. Stahl[1], P. Thoele[10], O. Wieland,[5] H.J. Wollersheim[2], M. Zielenska[9]

1 Technische Universität, Darmstadt
2 Helmholtzzentrum für Schwerionenforschung GmbH (GSI), Darmstadt
3 IPHC/CNRS-University of Strasbourg, Strasbourg
4 Universta di Milano, Milano, Italy
5 INFN Milano, Milano
6 Instituto di Fisica Corpuscular, Valencia
7 Department of physics Lund University, Lund
8 INFN, Padova
9 CEA-saclay, Paris-Sud
10 Institut für Kernphysik, Universität zu Köln
11 Department of Physics, University of York, York
12 Royal Institute of Technology, Stockholm, Sweden
13 University of Brighton, Brighton
14 Instituto de Estructura de la Materia, Madrid
15 Department of physics Yale University, Yale

In the A=100 region, rapid shape transitions are observed, proof of an evolution of the nuclear collectivity. Nuclear shapes such as oblate, prolate or triaxial are to be expected in the $^{80\text{-}110}$Zirconium isotopes chain. Models are even predicting shape coexistence above an oblate ground state.
The energy levels for the $^{80\text{-}110}$Zr are known but only few B(E2) values have been measured. For example, in the case of the ^{106}Zr, B(E2) values respectively lifetime of (2+) and (4+) levels are unknown.
A gamma-ray spectroscopy experiment for the measurement of excited states lifetimes of ^{106}Zr was performed at GSI using the PreSPEC-AGATA setup. A ^{238}U primary beam from the SIS18 was fissioned on a Beryllium target positioned at the entrance of the FRagement Separator (FRS) to produce ^{107}Nb ions identified, and selected by the FRS. The particles of this secondary beam were fragmented at relativistic energy (beta=v/c~0.5) on a 700 mg/cm^2 thick Beryllium target positioned at the center of the Advanced GAmma Tracking Array (AGATA). The ^{106}Zr reaction products were identified by the Lund York Cologne Calorimeter (LYCCA). The energy and position of the gamma-rays emitted by these ejectiles were measured by 19-AGATA detectors. The position sensitivity of AGATA coupled with LYCCA detectors allow a lifetime determination using the Doppler Shift Attenuation Method (DSAM).
The status of the preliminary analysis will be presented.

UNUSUAL ROTATIONAL BEHAVIOUR OF MIDSHELL Te ISOTOPES

Mansi Saxena, Department of Physics & Astrophysics, University of Delhi, India

M. Saxena[1], R. Kumar[2], A. Jhingan[2], S. Mandal[1], A. Stolarz[3], R. Bhowmik[2], A. Banerjee[1], S. Dutt[4], J. Kaur[5], V. Kumar[6], M. Modou Mbaye[7],Vijay Raj Sharma[8], and H. J. Wollersheim[9]

1 Department of Physics and Astrophysics, University of Delhi, India
2 Inter University Accelerator Centre, New Delhi, India
3 Heavy Ion Laboratory, University of Warsaw, Pasteura 5a, 02-093 Warsaw, Polans
4 Department of Physics, Bareilly College, India
5 Centre for Advanced Studies in Physics, Panjab University, India
6 Department of Physics, SLIET, Sangru 148106, India
7 Cheikh Anta Diop University, Senegal
8 Accelerator Laboratory, Department of Physics, A.M. University, Aligarh 202002, India
10 GSI Helmholtzzentrum fur Schwerionenforschung, Darmstadt, Germany

In recent years the region in the vicinity of tin isotopes has been intensively investigated both from experimental and theoretical perspectives. In particular, the excitation energies and the reduced transition probabilities across the Z = 50 chain has been examined in detail. In tellurium nuclei with two protons outside the major shell, the partial level schemes are dominated by the $1g_{7/2}$ orbit leading to 6^+ isomers in the vicinity of N=82 shell closure. For the mid-shell nuclei ^{120,122,124}Te one observes the expected transition to vibrational-like structure with equal energy spacing between the phonon states. [1]. This observation is quite in contrast to the measured quadrupole moments Q_2^+ for the doubly even Te isotopes [2, 3]. These quadrupole moments can reach 60% of the one predicted by the symmetric rigid rotor.

These sizable quadrupole moments motivated us to measure the reduced transition probabilities connecting the higher lying states which also yield information on the nuclear structure of ^{120,122,124}Te. The main aim of the experiment was to determine the collectivity of ^{120}Te with much higher precision by measuring the B(E2; $0^+ \rightarrow 2^+$). As for the Sn isotopes the data are compared with Large Scale Shell Model (LSSM) [4] calculations. It was also very surprising to find the same neutron number dependence for the 2p states (Te isotopes) and the 2p hole states (Cd isotopes).

A Coulomb excitation experiment was performed to measure the reduced transition probabilities in ^{120,122,124}Te nuclei. The experiment was carried out at IUAC, New Delhi, where stable targets of ^{120,122,124}Te were bombarded with a ^{58}Ni beam. The B(E2; $0^+ \rightarrow 2^+$) = 0.666(20) e^2b^2 was extracted experimentally for ^{120}Te. The B(E2) values to higher lying states were well described by a soft triaxial rotor quite in contrast to the vibrational structure.

REFERENCES
[1] http://www.nndc.bnl.gov/ensdf.
[2] A. Bockisch and A. M. Kleinfeld Nucl. Phys. A261 498-510 (1976).
[3] J. Barrette *et al.,* Phys. Rev. C 10, 3 (1974)
[4] A. Banu *et al.*, Phys. Rev. C 72, 061305(R) (2005).

LOW-LYING STATES NEAR THE LONG LIVED ISOMER IN ^{108}Ag

Jasmine Sethi, Tata Institute of Fundamental Research, Mumbai, India

J. Sethi[1], R. Palit[1], J. J. Carroll[2], S. Karamian[3], S. Saha[1], Z. Naik[4], T. Trivedi[1], S. Biswas[1], M. S. Litz[5], P. Datta[6], S. Chattopadhyay[7], D. Mehta[8], U. Garg[9], H. C. Jain[1], S. Kumar[10], S. Jadhav[1], R. Donthi[1], B.S. Naidu[1], G. H. Bhat[11], J. A. Sheikh[11], S. Sihotra[8], and P. M. Walker[12]

1 Tata Institute of Fundamental Research, Mumbai 400005, India
2 U S Army Research Laboratory, Adelphi, MD 20783, USA
3 Joint Institute for Nuclear Research, Dubna 141980, Russia
4 Sambalpur University, Sambalpur 143005, India
5 Department of Physics, University of Tennessee, Knoxville, TN 37996, USA
6 Ananda Mohan College, Kolkata 700009, India
7 Saha Institute of Nuclear Physics, Kolkata 700064, India
8 Panjab University, Chandigarh 160014, India
9 University of Notre Dame, Notre Dame, IN 46556, USA
10 University of Delhi, Delhi 110007, India
11 Department of Physics, University of Kashmir, Srinagar 190006, India
12 Department of Physics, University of Surrey, Guildford, Surrey GU2 7XH, UK

Study of isomers or metastable states in nuclei is one of the leading areas in nuclear physics research. A variety of isomers arise across the nuclear landscape due to different reasons, for example, the delayed transitions may occur due to shape changes, large spin difference or large difference in K-values [1]. These isomers are storehouses of energy in the range of ~ 100 keV to ~ 1 MeV. Excitation of the isomeric state and the subsequent de-excitation through a depleting pathway motivates the research initiatives to harness the energy stored in the isomer through controlled emission. There are a few nuclei with long-lived isomers where low energy photons can be used to study the feasibility of stimulated emission in nuclei, ^{108}Ag is one such nucleus having a low spin isomer with $T_{1/2}$ = 438 years at 110 keV excitation energy [2].

A comprehensive study of the structure, which includes relative γ-ray intensities, branching ratios, spins and parities of states near the isomer, is essential for evaluation of the depletion pathways of the isomer. To study the structure of the low spin states of ^{108}Ag, an experiment using the reaction ^{100}Mo(^{11}B, 3n) ^{108}Ag at 39 MeV beam energy was carried out, with the Indian National Gamma Array (INGA) comprising of 18 Compton suppressed clover HPGe detectors [3]. From two- and higher-fold coincident data, substantial new information about the structure of ^{108}Ag have been added [4]. For the low spin region, a few new levels and ~ 10 new γ-rays have been established. Three transitions below 420 keV have been identified, whose decay depletes the isomer. The relative γ-ray intensities and branching ratios of low lying states have been extracted. Spins and parities of levels have been assigned based on the angular distribution, DCO (Directional Correlation of Oriented nuclei) ratios and polarization measurements. The spectroscopic information deduced from this experiment will improve the estimation of the energy yield through depletion of the isomer.

REFERENCES
[1] Philip Walker and George Dracoulis, Nature 399, 35 (1999).
[2] J. J. Carroll, AIP Conference Proceedings, 1109 Issue 1, 44 (2009).
[3] R. Palit *et. al.* Nucl. Instrum. Methods A 680, 90 (2012)
[4] J. Sethi *et. al.* Phys. Lett. B 725, 85 (2013)

CHARACTERIZATION OF A NEW STRUCTURE IN OCTUPOLE-DEFORMED ^{222}Th USING GAMMA-RAY AND CONVERSION ELECTRON SPECTROSCOPY

Magdalena Smoleń, University of the West of Scotland, Paisley, United Kingdom

The experiment has been performed (at JYFL Accelerator Laboratory) to characterize a new structure observed in the octupole-deformed light-actinide nucleus ^{222}Th. The new structure appears to be a dipole band, and could represent the first observation of a second alternating-parity band in the even-even actinides. Low-energy transitions in the new structure are studied using combined internal-conversion and gamma-ray spectroscopy using the SAGE-RITU set-up, with the ^{18}O(95 MeV)+^{208}Pb fusion-evaporation reaction.

THE CHIRAL PHASE TRANSITION IN ^{124}Cs – THE EAGLE CAMPAIGN

Roman Szenborn, Heavy Ion Laboratory, University of Warsaw, Poland

E. Grodner[1], A. A. Pasternak[2], J. Srebrny[3], M. Kowalczyk[1,3], J. Mierzejewski[1,3], M. Kisieliński[4], P. Decowski[5], Ch. Droste[1], J. Perkowski[6], T. Abraham[3], J. Andrzejewski[6], K. Hadyńska-Klęk[3], Ł. Janiak[6], A. Kasparek[1], T. Marchlewski[1], P. Napiórkowski[3], J. Samorajczyk[6]

1 Faculty of Physics, University of Warsaw, ul. Hoża 69, PL-00681 Warsaw, Poland
2 A. F. Ioffe Physical Technical Institute, 194021 St. Petersburg, Russia
3 Heavy Ion Laboratory, Warsaw University, ul. Pasteura 5A, 02-093 Warsaw, Poland
4 The A. Sołtan Institute for Nuclear Studies, 05-400, Świerk, Poland
5 Smith College, Northampton, MA 01060, USA
6 Faculty of Physics and Applied Informatics, University of Lódź, ul. Pomorska 149/153, 90-236 Lódź, Poland

The chirality phenomenon in the mass region A=130 has been studied for more than a decade. Characteristic structures in the level schemes known as partner bands have been observed in several nuclei and have been attributed to spontaneous chiral symmetry breaking [1,2,3]. In the most simple case, nuclear chirality is expected to appear in the odd-odd triaxial nuclei where three angular momenta vectors – one of the triaxial core and two of the odd nucleons – form a system with specified handedness. Here, new data related to the ^{124}Cs nucleus, obtained in the $^{114}Cd(^{14}N,4n)^{124}Cs$ experiment performed with the EAGLE array with 12 Phase-I HPGe detectors from the European Gamma Pool, will be presented in the context of the phase transition to nuclear chiral configuration. In Ref. [4], the existence of critical rotational frequency has been predicted. It has been shown that chiral geometry can be attained above the critical frequency forming the point of the phase transition. Spontaneous chiral symmetry breaking will be briefly introduced in the ^{124}Cs example. Energy levels staggering along the partner bands indicating the appearance of the critical frequency in ^{124}Cs will be presented and discussed as a preliminary test of chirality in the nucleus.

REFERENCES

[1] E. Grodner et al., Phys. Rev. Lett. 97, 172501 (2006).
[2] T. Koike et al., Phys. Rev. C 63, 061304 (2001).
[3] K. Starosta et al., Phys. Rev. Lett. 86, 971 (2001).
[4] P. Olbratowski et al., Phys. Rev. Lett 93, 052501 (2004).

EXPERIMENTAL INVESTIGATION OF NUCLEAR REACTIONS IN METALS AT EXTREMELY LOW ENERGIES

Natalia Targosz-Ślęczka, Institute of Physics, University of Szczecin, Poland

Natalia Targosz-Ślęczka[1], K. Czerski[1,2,3], A.I. Kilic[1], D. Weissbach[1,2], A. Huke[2,3], G. Ruprecht[2], M. Kaczmarski[1]

1 Institute of Physics, University of Szczecin, Szczecin, Poland
2 Institute for Solid-State Nuclear Physics, Berlin, Germany
3 Institut für Optik und Atomare Physik, Technische Universität Berlin, Berlin, Germany

Study of the d+d reactions at very low energies in metallic environments in the terrestrial laboratories, enables us to determine the strength of the screening effect in the strongly coupled astrophysical plasma in stars. So far, experimentally determined screening energies were extremely high in comparison to the theoretical predictions, and the reason for the observed discrepancies remained unrecognized.

Here, we present results of new experimental series concerning low-energy fusion reactions in metallic environments performed under ultra-high vacuum conditions in atomically clean targets. New measurements of the $^{2}H(d,p)^{3}H$ and $^{2}H(d,n)^{3}He$ reactions at energies from 6 to 25 keV were performed in Zirconium.

To explain the experimental data it is necessary to include an additional contribution resulting from a hypothetical 0+ threshold resonance in ^{4}He of a single-particle structure. The resonance component can be calculated as a coherent superposition with transition matrix elements for the dd reactions, reducing the value of experimentally obtained screening energy. However, its absolute value still overestimates the theoretical limit and can additionally be influenced by a number of crystal lattice defects of the metallic target.

BETA-DELAYED FISSION STUDIES OF THE VERY NEUTRON-DEFICIENT ISOTOPES ^{194,196}At AND ^{200,202}Fr AT ISOLDE

Victoria Truesdale, University of York, York, United Kingdom

On behalf of the IS466/IS534 collaboration

RILIS-ISOLDE (CERN) – University of York (UK) – UWS, Paisley (UK) – IKS, KU Leuven (Belgium) – Comenius University, Bratislava (Slovakia) – OLL, University of Liverpool (UK)

Beta-delayed fission (βDF) is a rare decay process which couples beta decay and fission. In this two-step process, the parent nucleus undergoes beta decay populating an excited state in the daughter nucleus, close to, or above the fission barrier. The daughter nucleus may then fission in competition with gamma decay to the ground state [1].

βDF is ideally suited to study low-energy fission and is experimentally accessible only in the well-studied uranium region, and lesser studied (by fission) neutron-deficient lead region. A recent study of the βDF of ^{180}Tl showed an unexpected asymmetric fission-fragment split for ^{180}Hg instead of the expected symmetric split to semi-magic ^{90}Zr [2]. This result identified a new region of asymmetric fission in addition to the well known asymmetry in trans-uranium nuclei.

This contribution will present new data for the neutron-deficient nuclides ^{194,196}At and ^{200,202}Fr, which were obtained at the CERN-ISOLDE facility. For At the recently developed laser ionisation scheme for At isotopes was used [3]. Preliminary results of the fission-fragment mass distribution of ^{196}Po, beta daughter of ^{196}At, show a mixture of asymmetric and symmetric fission. This establishes a phenomenon of multimodal fission in this region of nuclei. Similar features have also been identified in the fission of ^{194}Po and ^{202}Rn, indicating a transition region between asymmetric (^{180}Hg) and symmetric (^{204}Rn [4]) fission. The results are compared with predictions from current fission models [5,6].

REFERENCES
[1] A. N. Andreyev, M. Huyse, and P. Van Duppen, Rev. Mod. Phys. 85, 1541 (2013).
[2] A. N. Andreyev *et al.*, Phys. Rev. Letters 105, 252502 (2010).
[3] S. Rothe *et al.*, Nature Comm. 4, 1835 (2013).
[4] K.-H. Schmidt *et al.*, Nucl. Phys. A 665, 221 (2000).
[5] P. Möller *et al.*, Nature (London) 409, 785 (2001).
[6] M. Warda *et al.*, Phys. Rev. C 66, 014310 (2002).

PHILLIPS-TIKHONOV REGULARIZATION WITH A PRIORI INFORMATION FOR NEUTRON EMISSION TOMOGRAPHIC RECONSTRUCTION ON JET

Jakub Bielecki , Institute of Nuclear Physics PAN, Kraków, Poland

J. Bielecki[1], L. Giacomelli[2,3], V. Kiptily[2], M. Scholz[1], K. Drozdowicz[1],U. Woźnicka[1]
and JET EFDA Contributors

1 The H. Niewodniczański Institute of Nuclear Physics PAN, Kraków, Poland
2 JET-EFDA Culham Science Centre, Abingdon, OX14 3DB, UK
3 Dipartimento di Fisica, Università degli Studi di Milano-Bicocca, Italy

A method of tomographic reconstruction of the neutron emissivity in the poloidal cross -section of the Joint European Torus (JET, Culham, UK) tokamak was developed. Due to very limited data set (two projection angles, 19 lines of sight only) provided by the neutron emission profile monitor (KN3 neutron camera) the reconstruction is an ill-posed inverse problem.

The aim of this work consists in making a contribution to the development of reliable plasma tomography reconstruction methods that could be routinely used on existing and future tokamaks. The proposed method is based on Phillips-Tikhonov regularization and incorporates a priori knowledge on the emissivity function and magnetic configuration of the device. The correctness of the solution is checked through the comparison with the electron density profile measured by LIDAR and High Resolution Thomson Scattering JET diagnostics. In contrast with previously developed methods of ill-posed plasma tomography reconstruction problem, the developed algorithms do not include any post-processing of the obtained solution and the physical constrains on the solution are imposed during the regularization process.

The accuracy of the method is evaluated by several tests with synthetic data and then the method is applied to the neutron emissivity reconstruction for JET D plasma discharge. It is demonstrated that this method shows good performance and reliability and it can be routinely used for plasma neutron emissivity reconstruction on JET.

SIMULATED AND MEASURED PULSE SHAPE SIGNALS OF THE ITHEMBA LABS 32-FOLD SEGMENTED HPGE CLOVER DETECTOR

Thifhelimbilu Daphney Bucher, iThemba LABS, Cape Town, South Africa

T. Daphney[1], S. P. Noncolela[1, 2], E. A. Lawrie[1], O. Shirinda[1], J. L. Easton[1, 2]

1 iThemba LABS, P. O. Box 722, 7129, Somerset West, South Africa
2 University of Western Cape, Private Bag X17, 7535, Bellville, South Africa.

Sensitivity to the position of the gamma-ray interaction within the 32-fold segmented HPGe clover detector was investigated through computer simulations and measurements of pulse shape signals. Simulations were performed using ADL [1] and MGS [2] codes which were both successfully implemented at iThemba LABS. The pulse shape response at the inner core and outer contacts was generated for series of different interaction positions in one crystal of the clover detector. Both codes produce traces with similar shapes for the charge collecting signals and the transient induced signals (on neighbouring contacts) for all gamma-ray interaction positions. Small differences in the ADL and MGS pulse shapes depending on the position of the gamma -ray interaction were also observed. The rise-time of the ADL and MGS pulses are almost the same for the gamma-ray interaction positions near the core contacts, but differ slightly for positions near the outer contacts. The cause of these differences in the rise-time is understood to be the charge carrier mobility parameters which are calculated slightly differently in the codes. They can be corrected by extracting the actual parameters from the measured pulse shape signal.

The sensitivity of the detector to the position of the gamma-ray interaction was confirmed by comparing the measured pulse shapes for different gamma-ray interaction positions. Trace data showing the shape of the signals is acquired using the Pixie 16 Digital Gamma Finder (DGF) acquisition system [3]. A computer program is developed at iThemba LABS to read these complex binary data. It utilises CERN ROOT [4] environment to visualize traces from the core and segment contacts. Interesting data, showing traces from segment contacts that correspond to different types of gamma-ray interactions will be shown and discussed in this presentation. For example, single-hit events produce a pulse shape for net charge collection signals, as well as transient induced signals on the neighbouring contacts. The double-hit events though generate signals with more complex features. These signals are often a convolution of charge collection and transient induced signals. Interesting examples of simulated and measured pulse shapes for various gamma-ray interaction positions in the core and segment contacts will be discussed.

REFERENCES
[1] Medina P, Proc. 21st IEEE Inst. & Meas. Tech. (IEEE Cat. No.04CH37510), (2004) 1828.
[2] ADL, http://www.ikp.uni-koeln.de/research/agata/index.php?show=download.
[3] XIA, http://www.xia.com/Manuals/Pixie4_UserManual.pdf.
[4] Brun R., and Rademakers F., Nucl. Inst. & Meth. in Phys. Res. A 389 (1997) 81-86.

INTEGRAL SIMULATION OF THE SUPER SEPARATOR SPECTROMETER S3

Fabien Déchery, Institut Pluridisciplinaire Hubert Curien, Strasbourg, France

From 2015-2016, the linear accelerator of SPIRAL2 at GANIL will provide stable heavy ions beam, from carbon to uranium, at very high intensity (~10^{14} part/s). "The super separator spectrometer S3" will be a powerful device dedicated to the selection and the analysis of very rare events from very low cross section reactions. The project opens new opportunities of the synthesis and the spectroscopy of superheavy elements and exotic nuclei far from stability. S3 will allow various reaction mechanisms: fusion-evaporation, multi-nucleons transfer, deep inelastic scattering... The synthesis and the spectroscopy of superheavy elements is a central axis of the S3 experimental program which lead to major constrains on its technical development. It implies to consider various problematic at the interface of atomic, nuclear, multicharged ions optic, and accelerator physics. Beam target interactions should be well described in order to build realistic emittance profiles that will be used to tune all the electromagnetic fields of the optical structure (dipoles, quadrupoles, sextupoles and octupoles). S3 is a two stages optical system: the first is a momentum achromat for a magnetic rigidity selection which aims to ensure a very high rejection of the primary beam (>99.99%), the second stage is a mass spectrometer which acts like a supplementary selection (>10^{14}) by creating an m/q dispersive focal plane with a mass resolving power of 300. The high order tuning aims to maximize the mass resolution and/or the transmission of the nuclei of interest. The high selectivity of S3 and its large acceptance will ensure a high transmission (<50%) of the nuclei of interest up to various detection systems like the implantation and decay station SIRIUS, *« Spectroscopy and Identification of Rare Isotope Using S3 »*. I will present an integral simulation framework of S3 that has been developed in order to drive technical developments and to estimate performances of the first day experiments proposed by the community.

3”x3” $LaBr_3$:Ce DETECTOR RESPONSE TO MONOCHROMATIC PROTONS

Agnese Giaz, INFN sezione di Milano, Milano, Italy

A. Giaz[1], S. Brambilla[1], B. Szpak[2], M. Ziębliński[2], N. Blasi[1], C. Boiano[1], F. Camera[1,3], S. Ceruti[1,3], B. Million[1], S. Riboldi[1,3] O. Wieland[1], P. Bednarczyk[2], M. Ciemała[2], B. Fornal[2], M. Jastrząb[2], M. Kmiecik[2], M. Krzysiek[2], A. Maj[2], W. Męczyński[2], B. Wasilewska[2], P. Napiorkowski[4].

1 Istituto Nazionale di Fisica Nucleare INFN, Sezione di Milano, Via Celoria 16, 20133 Milano (Mi), Italy
2 Henryk Niewodniczański Institute of Nuclear Physics, Polish Academy of Sciences, Krakow, Poland
3 Univeristà degli studi di Milano Via Celoria 16, 20133 Milano (Mi), Italy.
4 Heavy Ion Laboratory, Warsaw University, Poland.

This $LaBr_3$:Ce detectors are the best scintillators for g-ray detection and spectroscopy, providing energy resolution of 2.7-3.3% at 662keV, time resolution better than 1 ns, good efficiency due to the density of 5.1 g/cm^3. Pulse shape analysis study showed the possibility to discriminate between alpha and gamma rays. In addition, since a few years, large volume crystals are also available (V>1000cm^3).
We investigated the proton response of large volume $LaBr_3$:Ce detectors (3”x3”) by using a proton beam with an energy range of 70-230 MeV. Protons with energies between 70 and 185 MeV are stopped inside the crystal.
The crystal was coupled to a HAMAMATSU R6233-100SEL photomultiplier tube and an active voltage divider especially designed for such large volume $LaBr_3$:Ce detectors. The anode signal was formed with an amplifier (a BAFPRO unit) with a shaping time of approximately 500 ns and then was sent to an CAEN VME-ADC. The pulses of the detector were also digitized by using a 12 bit LeCroy HDO 6054 oscilloscope. The detector was placed at 1.5 m from the target and at an angle of about 10°.
The proton beam was delivered by the CCB cyclotron inside the Niewodniczanski Institute of Nuclear Physics in Krakow (Poland). An elastic scattering reaction was performed on a 23 mg/cm^2 thick titanium foil placed at the end of the beam pipe.
The protons response was measured in terms of energy resolution and linearity. From the data it will be possible to extract also the quenching factor for protons. Moreover, signals from scattered protons and from the 6.13 MeV gamma-rays from a CmC composite source were digitized. This allows the comparison between the gamma rays $LaBr_3$:Ce anode pulses and those of protons of different energies. Data were taken using three different PMT voltages and therefore with three different dynamic ranges of the detector.

THE NEW SEPARATOR FOR RADIOACTIVE BEAMS STUDIES ACCULINNA-2

Grzegorz Kamiński, Institute for Nuclear Physics PAN, Kraków, Poland

G. Kamiński[1,2], A.S. Fomichev[1], S.A. Barayeva[1], A.A. Bezbakh[1], V. Chudoba[1,3], S. Enkhbold[1], M.S. Golovkov[1], V.A. Gorshkov[1], A.V. Gorshkov[1], L.V. Grigorenko[1], A. Knyazev[1], S.A. Krupko[1], M. Mentel[1,5], S. Mianowski[1,4], P. Pluciński[1,5], M. Pfützner[4], P.G. Sharov[1], S.I. Sidorchuk[1], R.S. Slepnev[1], S.V. Stepantsov[1], G.M. Ter-Akopian[1], R Wolski[1,2]

1 Joint Institute for Nuclear Research, Dubna, 141980 Dubna, Russia
2 Institute of Nuclear Physics PAN, 31-342 Krakow, Poland
3 Institute of Physics, Silesian University in Opava, 74601 Czech Republic
4 National Center for Nuclear Research, 05-400 Otwock, Poland
5 AGH University of Sciences and Technology, 30-059 Krakow, Poland

The new project of the in-flight fragment separator ACCULINNA-2 [1] at U-400M cyclotron in Flerov Laboratory of Nuclear Reaction, JINR is under construction (2011-2016). It is expected to be a more universal and powerful instrument in comparison with existing separator ACCULINNA [2]. The beam intensity should be increased by factor 10-15, the beam quality greatly improved and the range of the accessible secondary radioactive beams broadened up to Z~20. The new separator will provide RIBs in the broad range of energies 5÷50 AMeV – the lowest energy range which is attainable for in-flight separators. The new separator complex will be equipped in a cryogenic tritium target [3], neutron detection array [4] and OTPC (Optical Time Projection Chamber) [5]. The current status of the project is reported. The results of the recent experiments carried out at the existing separator ACCULINNA, will be presented. Extensive research program for ACCULLINA-2 will be described.

REFERENCES
[1] A.S. Fomichev et al., Acta Phys. Pol B 41 (2010) 475.
[2] A. M. Rodin et al., Nucl. Instrum. and Meth. B 204 (2003) 114.
[3] A.A. Yukhimchuk et al., Nucl. Instr. Meth. Phys. Res. A 513 (2003) 439.
[4] G. Kamiński et. al., Acta Phys. Pol. B 45 (2014) 519.
[5] K. Miernik et al., Nucl. Instrum. Methods A 581 (2007) 194.

DETECTION OF DELAYED RADIATION FROM URANIUM SAMPLES INDUCED BY BREMSSTRAHLUNG PHOTONS

Jan Kownacki, NCBJ, HIL -Warsaw,Poland

P. Sibczyński[1], J. Kownacki[1,2], A. Syntfeld-Każuch[1], M. Moszyński[1], M. Kisieliński[1], K. Wincel[1], J. Kozieł[1], T. Kozłowski[1], K. Kosiński[1], M. Matusiak[1]

1 National Centre for Nuclear Research (NCBJ), PL 05-400 Otwock, Poland
2 Heavy Ion Laboratory, University of Warsaw, Poland

The detection of delayed neutrons and g-rays emitted by fission products, which are created by photofission of nuclear materials, was performed. The matter of border monitoring and preventing illegal transfer of radioactive and special nuclear materials (SNM) has become very important. Together with delayed neutrons, γ-rays are also emitted some time after SNM irradiation, which can be efficiently detected by large volume organic or inorganic scintillators. Particularly, the measurement of the delayed radiation can reveal information on existence and localization of the nuclear material in cargo containers and plays important role in homeland security and border monitoring [1]. In this investigation an observation of delayed neutrons and g-rays was possible due to irradiation of different uranium samples with bremsstrahlung photons obtained from Siemens Mevatron KD2 and Neptun 10P linear accelerators (LINAC's) at NCBJ-Otwock. A 100 g, highly enriched (HEU) ^{235}U cylinder (92% of enrichment) and an unexploited 393 g fuel element delivered from Maria Pool Reactor containing 313 g of ^{235}U (80% of enrichment), as well as 4.7 kg depleted uranium (DU) sample were irradiated with high energy photons. Previously, the delayed g-ray spectra from the ^{235}U 100 g cylinder were also carefully investigated using 16 HPGe detectors array (EAGLE) [2, 3]. Delayed neutrons emitted from samples after irradiations were detected by high pressure ^{3}He gaseous detector (φ 1.5” x 11.34”) covered with 5.5 cm of polyethylene moderator and 1 mm cadmium foil in order to prevent the detection of thermalized neutrons from background. This geometry was calculated by MCNPX code in order to optimize the delayed neutrons detection efficiency. The counts recorded by ^{3}He counter from fuel element at different distances were measured after irradiation with 15 MeV bremsstrahlung photons. Measurements with 9 MeV bremsstrahlung photons were done with use of the Neptun 10P LINAC. The 100 g HEU sample was irradiated and the delayed gamma rays were registered with φ 3” x 2” EJ-200 and BC-408 plastic scintillators. Sample was placed in the vicinity of the detector, 1 meter from the tungsten converter. Dose rate from the LINAC was set to 54 cGy/min × m. Both for delayed neutrons and gamma rays measurements a special logic gating method allowed avoiding the gamma flash from accelerator and measuring the delayed neutrons between accelerator pulses. During measurements with 6 MeV photons, delayed g-rays were detected by BC-408 (φ 5” x 3”) polyvinyl toluene-based (PVT) plastic scintillator. The 4.7 kg DU was placed 40 cm from the LINAC tungsten converter. The number of counts originated from delayed γ-rays measured for BC-408 is many times larger from that measured for active background. The dose rate set for the LINAC was set to 40 cGy/min × m. Summarizing, the techniques and performance of delayed signatures detection from nuclear materials are presented.

REFERENCES
[1] M. Gmar et al., Appl. Rad. and Isotopes 63 (2005) 613.
[2] J. Mierzejewski et al., NIM A 659 (2011) 84 – 90.
[3] P. Sibczyński et al., Appl. Rad. and Isotopes, 82 (2013) 170-174.

THE CURRENT STATUS AND FUTURE CONCEPTS AT THE NEW IGISOL-4 FACILITY

Ilkka Pohjalainen, University of Jyväskylä, Jyväskylä, Finland

I. Pohjalainen[1], D. Gorelov[1], J. Hakala[1], A. Jokinen[1], J. Koponen[1], I.D. Moore[1], H. Penttilä[1], J. Reinikainen[1], M. Reponen[1], S. Rinta-Antila[1], V. Sonnenschein[1] and A. Voss[1]

1 Department of Physics, University of Jyväskylä, P.O.B. 35 (YFL), FIN-40014 Jyväskylä, Finland.

The Ion Guide Isotope Separator On-Line (IGISOL) facility at the Accelerator Laboratory of University of Jyväskylä has been an active place for fundamental research of the nuclear landscape since the early 1980's using low-energy beams of exotic nuclei [1]. The era of IGISOL-4 began with the recent move of the facility to an extended experimental hall with access to the heavy-ion K130 MeV cyclotron and the new light ion MCC30-15 cyclotron the latter of which will greatly increase the intensity of beams and availability of beam time for experiments. The large area of the new hall enables several improvements to the general facility including more effective beam transportation, installation of off-line test ion sources, and more sophisticated, permanent measurement and beam diagnostic setups. At the front end, the buffer gas purification system has been reconstructed to meet the more stringent gas purity requirements. The laser ion source facility at IGISOL, Fast Universal Resonant laser IOn Source, FURIOS, has been re-designed for better access to the front end with lasers for the utilization of the in-gas-cell and in-gas-jet methods [2].

The past year has been notable not only for important milestones in the IGISOL-4 commissioning phase but also many PAC-approved experiments for which the new IGISOL facility has been able to successfully provide beams. Both of the main experimental workhorses, the collinear laser spectroscopy station [3] and the JYFL Penning trap [4], are operational and have utilized on-line beams. The developments at the new facility are now continuing at the front end with a neutron-induced fission ion source enabling increasingly neutron rich, exotic nuclei for mass, laser and decay spectroscopic studies and with a cryogenic ion guide cooled with a cryocooler for improved efficiency and purity of the stopping gas. Other future developments include a Multi Reflection-TOF Mass Spectrometer and various off-line activities with a dedicated off-line setup. The general overview of the IGISOL-4 facility, status and outlook are presented in this contribution.

REFERENCES
[1] J. Äystö *et al.*, Hyp. Int. 223, 1-3, p1-3, (2014)
[2] M. Reponen *et al.*, Eur. Phys. J. 48, 45, (2012)
[3] B. Cheal, D.H. Forest, Hyp. Int. 223, 1-3, p223-230, (2014)
[4] T. Eronen *et al.*, Eur. Phys. J. 48, 46, (2012)

FIRST EXPERIMENTAL TESTS OF SHELS: A NEW HEAVY IONSEPARATOR AT THE JINR

Kseniia Rezynkina, CSNSM Orsay, Orsay, France

K. Rezynkina[1], K. Hauschild[1], A. Lopez-Martens[1], O. Dorvaux[2], B. Gall[2], F. Déchery[2], H. Faure[2], J. Rubert[2], A.V. Yeremin[3], M.L. Chelnokov[3], V.I. Chepigin[3], A.V. Isaev[3], I.N. Izosimov[3], D.E. Katrasev[3], A.N. Kuznetsov[3], A.A. Kuznetsova[3], O.N. Malyshev[3], A.G. Popeko[3], A.Y. Popov[3], E.A. Sokol[3], A.I. Svirikhin[3]

1 CSNSM, IN2P3-CNRS, UMR 8609, F-91405 Orsay, France
2 IPHC-DRS/ULP, IN2P3-CNRS, F-67037 Strasbourg, France.
3 IFLNR, JINR, 141980 Dubna, Russia

Super Heavy Elements (SHE) are elements with a vanishing Liquid Drop fission barrier. They are entirely stabilized by quantum shell effects, which give them an enhanced stability and therefore much longer lifetimes. Theoretical predictions on the sequence and spacing of single-particle levels vary widely from one model to the other. This is why the heaviest elements provide a unique laboratory to study the behaviour of nuclei under the influence of large Coulomb forces and large mass and test theoretical parameterizations.

The Separator for Heavy ELement Spectroscopy (SHELS) [1] has been developed in a collaboration between French and Russian institutes (respectively the Institut National de Physique Nucléaire et de Physique des Particules (IN2P3) and the Joint Institute for Nuclear Research (JINR)). This collaboration has existed since 2003 and started with the VASSILISSA separator, which was upgraded in 2013 and is now called SHELS. SHELS separates fusion-evaporation residues (ER) from other reaction products on the basis of their velocity and charge state. The ER that pass through SHELS are then implanted into the double-strip silicon detector (DSSD) of the detection system called GABRIELA (Gamma Alpha Beta Recoil Investigations with Electromagnetic Analyzer) [2] - an array of detectors for complete (α, β, γ, CE and X-ray) spectroscopy.

In May 2013 the first commissioning tests of the new separator took place using the old 58×58 mm^2 (48×48 strips) DSSD [3]. In November 2013 transmission tests using a newly developed ^{50}Ti beam were performed. In March-April 2014 we were able to instrument a new 100×100 mm^2 (128×128 strips) DSSD and obtained an excellent improvement in the transmission of ER produced in highly asymmetric reactions.

These tests not only served for the commissioning of the new separator, but also allowed us to obtain some interesting physics results. In particular, we have investigated the decay of known isomers in Ra isotopes produced in the ^{50}Ti+^{164}Dy reaction and explored the fission and α-decay of $^{245/246}$Fm nuclei produced in the ^{40}Ar+^{208}Pb reaction. These results, as well as the outlook for the future, will be discussed.

REFERENCES

[1] SHELS: ANR-06-BLAN-0034-01.

[2] K. Hauschild et al., Nucl. Instr. and Meth. A 560 (2006) 388-394.

[3] A.V. Isaev et al., Instr. and Exp. Techn. 54 (2011) 37. P. Sibczyński et al., Appl. Rad. and Isotopes, 82 (2013) 170-174.

CHyMENE, A THIN WINDOWLESS CRYOGENIC HYDROGEN TARGET

Matthieu Sénoville, CEA Saclay/IRFU/SPhN, Gif-sur-Yvette, France

G. Authelet[1], R. Boudouin[2], A.Gillibert[3], J.M. Gheller[1], P. Graffin[2], J.M. Joubert[2], A. Lukin[4], J.Relland[2], A. Roger[2], M. Sénoville[3], I. Vinyar[4] and the CHyMENE Collaboration

1 CEA, Centre de Saclay, IRFU/SACM, F-91191 Gif-sur-Yvette, France
2 CEA, Centre de Saclay, IRFU/SIS, F-91191 Gif-sur-Yvette, France
3 CEA, Centre de Saclay, IRFU/SPhN, F-91191 Gif-sur-Yvette, France
4 PELIN Laboratory, 27A, Gzhatskaya, Saint-Petersburg, 195220, Russia

Direct binary reactions represent tools of considerable importance in exploring the structure of exotic nuclei. Nuclear reactions on hydrogen CH_2 or CD_2 targets in inverse kinematics are extensively used with radioactive beams, e.g. for transfer reactions or resonant elastic scattering. Pure cryogenic targets may be used to improve the luminosity and remove the contribution of C atoms. However, for low incident beam energies, the thickness of the cryogenic target is a crucial parameter to achieve the detection of the reaction products. The thickness of solid cryogenic targets is usually not below 1 mm.

In this context, we are in the process of developing a new cryogenic hydrogen target with significantly improved characteristics compared to existing systems, with emphasis on the thickness of the target (in the 30-100 μm range), and the purity by removing for the first time Mylar-type windows. The latter aspect is particularly important to suppress additional contributions coming from the windows used to hold the volume of gas before freezing, for example carbon atoms in Mylar windows. Our development strategies involve the integration in detection devices, such as GASPARD or AGATA.

The CHyMENE Project [1] is devoted to produce a thin target by a continuous extrusion technique [2]. The actual design consists in a tank where hydrogen gas is solidified by cooling, and pushed by the rotation of an endless screw. At extrusion process, hydrogen flows through a nozzle which defines the shape and the thickness of the target.

This presentation will discuss the development status of the CHyMENE project, in particular the detailed description of the cryostat and the extruder, as well as recent results of production of pure H_2 film obtained in spring 2014. The future outlook for the project will also be briefly addressed.

REFERENCES
[1] CHyMENE Project supported by ANR fundation for Blanc-SIMI 4-Physique
[2] A. Gillibert et al., Eur. Phys. J. A (2013) 49

STATUS OF THE TECHNOLOGICAL LABORATORY AT THE LMU MUNICH

Jerzy Szerypo, LMU Munich, Germany

J. Szerypo, H.-J. Maier, H.U. Friebel and D. Frischke

Faculty of Physics, University of Munich (LMU), D-85748 Garching, Germany

The Technological Laboratory of LMU Munich is undergoing important changes. The Hot-Lab Facility dealing with radioactive target production has been shut down. On the other hand, new developments in the direction of laser physics have taken place. A new laboratory part has been built, which is devoted to development and production of ultra -thin (nm range) free standing Diamond-Like-Carbon (DLC) foils for laser physics applications. One of main applications of such foils is laser-driven charged particle acceleration. It allows to accelerate electrons, protons and 12C ions to relatively high energies, which previously were achievable in big conventional accelerators only. Main advantage of this technique is, that the laser accelerator serving this purpose would have very small size, compared to the conventional one. A very important application of such device would be cancer radiation therapy, allowing for very precise cancer destruction with minimal side effects for the patient's health. Much lower, in comparison to the conventional accelerator, cost of the assembly and small space needs would make it available to a majority of hospitals occupied with cancer treatment.

The DLC-foils are produced by cathodic arc deposition technique in a dust-reduced environment. Production section is supplied with modern foil diagnostic techniques, including, e.g., an Atomic Force Microscope (AFM). The Technological Laboratory will preserve its possibilities of standard thin film deposition by high vacuum evaporation and sputtering techniques, including the production of stable isotope targets.

THE PARIS CLUSTER COUPLED TO THE BaFPRO ELECTRONIC MODULE: DATA ANALYSIS FROM THE NRF EXPERIMENT AT THE ELBE FACILITY

Barbara Wasilewska, IFJ PAN, Kraków, Poland

B. Wasilewska[1], M. Ciemała[1, 2], S. Brambilla[3], A. Mentana[3], R. Schwenger[4], I. Mazumdar[5], A. Maj[1], F. Camera[3, 6], M. Kmiecik[1], P. Bednarczyk[1], C. Boiano[3], O. Dorvaux[7], A. Giaz[3], M. Jastrząb[1], S. Kihel[7], I. Matea[8], R. Massarczyk[4], P. Napiorkowski[9], S. Riboldi[6], B. Sowicki[1]

1 IFJ PAN Cracow, Poland
2 GANIL Caen, France
3 INFN Milano, Italy
4 HZDR Dresden, Germany
5 TIFR Mumbai, India
6 University of Milano, Italy
7 IPHC Strasbourg, France
8 IPNO Orsay, France
9 SLCJ Warsaw, Poland

The Photon Array for studies with Radioactive Ion and Stable beams (PARIS) is an upcoming 4 pi calorimeter for γ-rays in the energy range from ~100 keV up to 40 MeV [1]. It is planned to use PARIS in the constructed RIB facilities in Europe (SPIRAL2, SPES, HIE-ISOLDE, FAIR). PARIS will be ultimately made of more than 200 detectors arranged in clusters, each of 9 detectors. Each detector is a *phoswich*, consisting of 2"x 2"x 2" $LaBr_3$(Ce) backed by 2" x 2" x 6" NaI(Tl) and a common PMT. As light impulses emitted from those materials differ significantly in shape and amplitude it is crucial for good energy resolution to disentangle them and add after proper calibration. Additionally, in the high γ-ray energy range pair production occurs, resulting in 511 keV γ-rays escaping from a detector. If detected in another crystal it is worth to tracing their origin and add them back to attenuate singular and double escape peaks.

In December 2013 the first cluster of PARIS was tested at the γELBE bremsstrahlung facility [2] of Helmholtz-Zentrum Dresden-Rossendorf, Germany, in a Nuclear Resonance Fluorescence (NRF) experiment. The 16 MeV electron beam was converted to a bremsstrahlung γ spectrum ranging up to 16 MeV, which irradiated a target of 11B + C (natural), resulting in the excitation of certain levels in those nuclei and subsequent emission of discrete gammas of energies 2125, 4444, 5020, 7285, 8917 and 15100 keV. Data were taken using the BaFPro [3] electronic module. Hence, 2D matrices of signals' Amplitude vs Charge were possible to build, enabling a discrimination between $LaBr_3$(Ce) and NaI(Tl) components.

Experimental setup will be shown as well as algorithms of decomposing LaBr and NaI signals for proper addback. The time tracing of 511 keV γ-rays will be presented. Conclusive spectra for whole the cluster will be discussed in detail.

REFERENCES

[1] A. Maj et al., *The PARIS Project,* Acta Phys. Pol B, vol. 40, No 3, p. 565-575 (2009)

[2] R. Schwengner et al., NIM A 555, 211 (2005)

[3] C. Boiano et al. *Pulse shape results of LaBr3 and BaF2 scintillator obtained with a 16 ch. fast analog stretcher module*, NSS/MIC, 2010 IEEE, p. 268-270

THE RESPONSE OF MODULAR TOTAL ABSORPTION SPECTROMETER TESTED WITH $^{142}Ba \rightarrow {}^{142}La \rightarrow {}^{142}Ce$ DECAY CHAIN

Marzena Wolińska-Cichocka, Heavy Ion Lab., Univ. of Warsaw, Warsaw, Poland

M.Wolińska-Cichocka[1,2], K.P. Rykaczewski[2], M.Karny[3], A Fijałkowska[3], R.Grzywacz[2,4], C.J.Gross[2], B.C.Rasco[5], K.C.Goetz[4], R.Goans[6], J.Johnson[2], C.Jost[4], M.Madurga[4], K.Miernik[3], D.Miller[4], S.W.Padgett[4], S.V.Paulauskas[4], M.Al-Shudifat[4], E.Spejewski[6], D.Stracener[2], E.Zganjar[5], J.H.Hamilton[7], A.V.Ramayya[7]

1 Heavy Ion Laboratory, University of Warsaw, Warsaw, PL 02-093, Poland
2 ORNL, Oak Ridge, TN 37830, USA
3 Faculty of Physics, University of Warsaw, Warsaw, PL 00-681, Poland
4 University of Tennessee, Knoxville, TN 37996, USA
5 Louisiana State University, Baton Rouge, LA 70803, USA
6 ORAU, Oak Ridge, TN 37830, USA
7 Dept. of Physics and Astronomy, Vanderbilt University, Nashville, TN 37235, USA

The Modular Total Absorption Spectrometer (MTAS) has been constructed and commissioned at the Holifield Radioactive Ion Beam Facility (HRIBF) at Oak Ridge National Laboratory. MTAS measurements, resulting in the true β-strength distribution after the proper de-convolution of MTAS experimental spectrum, are verifying and helping to develop the microscopic description of β-decay in neutron-rich nuclei. In particular, the decay heat release by fission products during a nuclear fuel cycle as well as respective anti-neutrino energy spectra can be determined from the complete β-decay scheme.

MTAS consists of 19 NaI(Tl) hexagonal shape detectors, each one is ~53 cm long and about ~20 cm maximum diameter. The entire MTAS array is surrounded by over 5000 kg of lead and by SWX-227A neutron shielding. Auxiliary detectors include two segmented 1-mm-thick silicon strip detectors placed inside the MTAS array around the tape transporting the activities [1]. The MTAS array is designed to efficiently measure all γ radiation and electrons emitted in the decay of radioactive fission products. The efficiency for full energy deposition of a single γ -ray is about 78% at 300 keV and about 70% at 5 MeV.

Twenty-two decays of ^{238}U fission products measured in 2012 at the HRIBF [1-3] included seven decays of highest priority for decay heat analysis. These measurements included also the decay chain $^{142}Ba \rightarrow {}^{142}La \rightarrow {}^{142}Ce$, where both decays studied previously with total absorption and high energy resolution techniques. The results of new total absorption studies of ^{142}Ba and ^{142}La decay will be presented and compared to previous data [4].

REFERENCES
[1] M. Wolińska-Cichocka et al., NDS 120, 22 (2014)
[2] A. Fijałkowska et al., NDS 120, 26 (2014)
[3] A. Fijałkowska et al., Acta Phys. Pol. B 45, 545 (2014)
[4] R. C. Greenwood et al., Nucl. Instr. Meth. Phys. Res. A390, 95 (1997)

EXCITATION ENERGY AND NUCLEAR DEFORMATION DEPENDENCE OF ^{194}Ir AND ^{196}Au EFFECTIVE MOMENT OF INERTIA

Ismahane Ami[1,2], Université M'hamed Bougara de Boumerdès, Algeria

I. Ami[1,2], M. Fellah[2,3] and N. H. Allal[2,3]

1 Université M'hamed Bougara de Boumerdès.Campus Sud-35000, Boumerdès, Algeria
2 Faculté de Physique,USTHB, BP32, El-Alia, 16111 Bab Ezzouar, Algiers, Algeria
3 Centre de Recherche Nucléaire d'Alger, COMENA, BP 399, Alger-Gare, Algiers, Algeria.

The moment of inertia (MI) plays an important role within both nuclear reaction and spectroscopic studies, with different features underlined within each of these fields [1-5]. Recently, the study of perpendicular and parallel MI has been carried out for some odd-odd nuclei [1]. Furthermore, special attention is paid to the study of the effective MI which is involved in the theory of angular anisotropy of fission fragments. In the present contribution, the effective moment of inertia is evaluated as a function of excitation energy E* and nuclear deformation, in the vicinity of the ground state, for the two deformed nuclei ^{194}Ir and ^{196}Au. The recent evaluation of the cross sections of neutron induced reactions on these nuclei revealed a very high sensitivity to angular momentum parameters and a strong dependence on momentum of inertia parameters [6]. The present study has been carried out including the pairing correlations between like-particles and using cranking model and Feynman path integral method [1-5]. The used single-particle and eigen-states energies are those of a deformed Woods-Saxon mean field. The effective MI has been plotted as a function of the deformation parameters, for various values of the excitation energy (E* ranging from 0 to 20 MeV). As expected, these variations are very sensitive to the deformation but it is also sensitive to the excitation energy. Moreover, it was found that the behavior of the effective MI for these two nuclei as a function of the deformation is very different for any value of E*.

Acknowledgments: This work was performed under a Grant of the Physics Department, Faculty of Sciences, M’hamed Bougara University of Boumerdes, UMBB. We thank V. Avrigeanu and M. Mirea for useful discussions.

REFERENCES

[1] [1] I. Ami, M. Fellah, N. H. Allal and M. R. Oudih, Rom. Journ. Phys. 59, 504 (2014).
[2] [2] N. H. Allal, M. Fellah, N. Benhamouda, and M. R. Oudih, Phys. Rev. C 77, 054310 (2008).
[3] [3] I. Ami, M. Fellah, N. H. Allal, N. Benhamouda, M. Belabbas and M. R. Oudih, Int. J. Mod. Phys. E 20, 1947 (2011).
[4] [4] I. Ami, M. Fellah, N. Benhamouda, N. H. Allal and M. Belabbas, J. Phys.: Conf. Ser. 338, 012019 (2012).
[5] [5] I. Ami, M. Fellah, N. Benhamouda, N. H. Allal, *J. Phys.: Conf. Ser.* 413, 012032 (2013).
[6] [6] M. Avrigeanu, V. Avrigeanu, M. Diakaki and R. Vlastou, Phys. Rev. C85, 044618 (2012).

ISOSPIN DEPENDENCE OF MASS-DISTRIBUTION SHAPE OF FISSION FRAGMENTS OF Hg ISOTOPES

Alexander Andreev, Joint Institute for Nuclear Research, Dubna, Russia

A. V. Andreev, G. G. Adamian, N. V. Antonenko

Joint Institute for Nuclear Research, 141980 Dubna, Russia

Using an improved scission-point model, mass distributions are calculated for induced fission of even Hg isotopes with mass numbers A = 174 to 198. The asymmetric mass distribution of fission fragments of ^{180}Hg observed in the recent experiment is explained. With increasing A of a fissioning ^{A}Hg nucleus the mass distribution evolves from symmetric for ^{174}Hg, to asymmetric for isotopes close to ^{180}Hg, and back to more symmetric for $^{192\text{-}198}$Hg. In the fissioning Hg isotopes their excitation energy weakly influences the shape of the mass distribution.

FISSION PROPERTIES OF PO ISOTOPES IN DIFFERENT MACROSCOPIC-MICROSCOPIC MODELS

Johann Bartel, IPHC, Strasbourg University, Strasbourg, France

J. Bartel[1], K. Pomorski[2], B. Nerlo-Pomorska[2], Ch. Schmitt[3]

1 IPHC, Strasbourg University, Strasbourg, France
2 IPHC, Marie-Curie Sklodowska University, Lublin, Poland
3 IPHC, GANIL, Caen, France

Fission barriers of nuclei in the Po isotopic chain are investigated in several macroscopic-microscopic models, with a special emphasis on our approach that relies on the Lublin-Strasbourg drop for the macroscopic part and the Yukawa folded single-particle potential and a BCS pairing treatment for the microscopic part. The large variety of nuclear shapes encountered in the process are described in our approach a 4-dimensional deformation space with elongation, neck formation, left-right asymmetry and non-axiality degrees of freedom. It is shown that the correct description of fission barriers is a very selective tool to discern between different macroscopic-microscopic models.

NUCLEAR SYMMETRIES WITHIN A QUADRUPOLE-OCTUPOLE COLLECTIVE APPROACH

Artur Dobrowolski, M. Curie-Skłodowska University, Lublin, Poland

A. Dobrowolski, A. Góźdź, A. Szulerecka, A. Pędrak

M. Curie-Skłodowska University, Lublin, Poland

Using the idea of adiabatic separation of vibrational and rotational collective motions in atomic nuclei we construct a zero- and one-phonon multidimensional oscillator-like basis which is applied to diagonalize a realistic collective vibrational-rotational Hamiltonian based on the Woods-Saxon mean field potential energy surface. The generalized symmetrization procedure which is applied to make the basis states unique in the laboratory coordinate system is tightly connected with the symmetrization group of transformations in the intrinsic frame. This symmetry group (which has formally nothing to do with the symmetry of the Hamiltonian) depends, contrarily to some former understandings, on the collective deformation space of the model. The latter is spanned by the quadrupole, octupole (axial and all non-axial) and rotational modes described by standard multipole $\alpha_{\lambda\mu}$ deformation parameters and Euler angles, respectively. The collective eigensolutions of this Hamiltonian would allow us to investigate the symmetries of nuclear shapes including the high rank tetrahedral, octahedral or others symmetries as well as the mechanism of symmetry breaking. As a test of the presented model the most recent experimental B(E1) and B(E2) probabilities in ^{156}Gd, measured in ILL Grenoble, using the ultra-high resolution crystal spectrometers GAMS are reproduced and interpreted in terms of nuclear shape symmetries.

THIRD, HYPERDEFORMED MINIMUM WITH DIFFERENT NUCLEAR SHAPE PARAMETERIZATIONS IN ^{232}Th

Piotr Jachimowicz, Institute of Physics, University of Zielona Góra, Poland

M. Kowal[1], R. Rechciński[2], J. Skalski[1]

1 National Centre for Nuclear Research, Hoża 69, PL-00-681 Warsaw, Poland
2 Technical University of Łódź, Wólczańska 219,PL - 93-005 Łódź, Poland

The topic of third minima in actinides, which are supposedly more deformed than the superdeformed ones, and for this reason sometimes called „hyperdeformed" is surrounded by some uncertainty. A general difficulty in studying very deformed nuclear shapes lies in their effective shape parameterization. Thus additional check of the hypothesis may be obtained by calculating the potential energy surfaces with different shape parameterizations. This is why, we have calculated here the existence of third, hyper deformed minimum in ^{232}Th using the Woods-Saxon microscopic-macroscopic model that very well reproduces first and second minima and fission barriers in actinides with (i) standard spherical harmonic expansion, (ii) modify Funny-Hills parameterization and (iii) three quadratic surfaces parameterization. Since, the mean field concept is inherently connected to the selection of some degrees of freedom that are assumed to be of particular relevance for the specific problem under interest, choice of the collective deformation space is one of the crucial problem for the proper description of the fission process. Obviously, regardless of the adopted parameterization here the selection of the collective variables is slightly different. Despite this, the results in those three cases of nuclear shape parameterizations are fully convergent. We have shown that III'd minimum in ^{232}Th has a depth of roughly 0.4 MeV within each of them. The shapes of fissioning nucleus at the second minimum, second saddle point, third minimum and at the third saddle point are also practically the same in each used parameterization. Our results support the existence of a shallow third minimum in ^{232}Th as in the old experiments of Blons and thus agree with the majority of modern theoretical models.

ASYMMETRY EFFECTS IN MULTIFRAGMENTATION: MOMENTUM DEPENDENCE

Varinderjit Kaur, Mata Gujri College, Fatehgarh Sahib, India

V. Kaur and M. Kaur

PG Department of Physics, Mata Gujri College, Fatehgarh Sahib, India

One of the most important challenges in heavy ion physics is the determination of the nuclear equation of state (NEOS) of asymmetric nuclear matter which plays an important role at low energy phenomena like fusion-fission, nuclear structure etc; intermediate energy phenomena like multifragmentation, fragment flow, nuclear stopping etc; and at last high energy phenomena like pion and kaon production [1]. The momentum dependent interactions are found to be the prominent candidate to study the NEOS of mass asymmetric nuclear matter. It is well known that the dynamics for symmetric and asymmetric reactions is entirely different [2]. When reaction takes place, the formation of participant as well as spectator zone takes place. Participant zone in the presence of momentum dependent interactions (MDI) play very important role. In the participant zone, the projectile nucleons feel strong repulsion due to target nucleons in the presence of MDI. Due to this large density gradient, asymmetric collisions become equally important in the presence of MDI.

Here, our aim is to present a detailed study on the consequences of employing momentum dependent interactions in intermediate mass fragment emission by taking mass asymmetry into account over the entire collision geometry. The simulations have been carried within the framework of Isospin quantum molecular dynamics (IQMD) model [3]. To fulfill this aim, the mass asymmetry of the reaction is varied by keeping the total mass of the system fixed. It has been found that the impact of MDI is different in lighter projectile systems as compared to heavier one.

REFERENCES
[1] Ch. Hartnack, H. Oeschler and J. Aichelin Phys. Rev. Lett 96, 012302 (2006).
[2] V. Kaur and S. Kumar J. Phys. G: Nucl. Part. Phys. 39, 085114 (2012).
[3] C. Hartnack, R. K. Puri, J. Aichelin, J. Konopka, S. A. Bass, H. Stocker, and W. Greiner, Eur. Phys. J. A 1, 151 (1998).

OPTIMIZATION OF INITIALIZATION PARAMETERS IN TRANSPORT MODELS : IQMD AND QMD

Suneel Kumar ,Thapar University ,Patiala, India

Amandeep Kaur, Suneel Kumar

School of Physics and Materials Science, Thapar University, Patiala-147004, Punjab, India

We present here the details of numerical realization of Isospin Dependent Quantum Molecular Dynamics Model (IQMD) [1] and Quantum Molecular Dynamics Model (QMD) [1]. We carry out an extensive survey of the different input parameters used in both the models. Our analysis reveals that the physics parameters are mainly responsible for the difference between observables like multifragmentation, nuclear stopping etc. calculated by using phase space obtained from the two transport models [1]. These parameters correspond to a detailed description of interactions and may be changed within a reasonable range. For the present study, we simulated reactions ^{50}Ca +^{50}Ca, ^{75}Zn +^{75}Zn, ^{100}Zr +^{100}Zr, ^{124}Sn +^{124} Sn, ^{150}Nd +^{150} Nd and ^{197}Au +^{197}Au with fixed N/Z and at fixed colliding geometry i.e., scaled impact parameter b=0.3 where b_{max} = 1.12($A_P^{1/3}$+ $A_T^{1/3}$) fm, where A_T and A_P are the target and projectile mass respectively. The progress till now allows us to state that once the physics parameters are fixed, both the transport models should yield similar results under the constrained conditions.

REFERENCES

[1] C. Hartnack *et al.* Eur. Phys. J. A 1, 151 (1998)

FRAGMENT ISOTOPIC CONTENT UNDER THE INFLUENCE OF ISOSPIN-MOMENTUM DEPENDENT INTERACTIONS

Suneel Kumar, Thapar University, Patiala, India

N. K. Virk[1], K. S. Vinayak[2], S. Kumar[1]

1 Thapar University, Patiala-147004, Punjab, India
2 Variable Energy Cyclotron Centre, Kolkatta-700064, West Bengal, India

Isospin effects of momentum dependent interactions (IMDIs) are analyzed by using the correlation between various observables namely multiplicity, fragment isotopic content ($<R_{n/p}>$), double ratio ($<DR_{n/p}>$), isospin fractionation ratio and the incident energy of the colliding nuclei. The main objective of this work is to extract the best suited observable which can be useful to extract the information regarding the IMDI. To fulfill this aim, simulations have been carried out for the reactions of $^{40}Ca+^{40}Ca$ and neutron-rich nuclei $^{60}Ca+^{60}Ca$ at different incident energies by employing the different momentum dependent interactions (MDIs).

EFFECT OF ISOSPIN DEPENDENT SPATIAL AND MOMENTUM CONSTRAINTS ON TRANSVERSE FLOW

Suneel Kumar, Thapar University, Patiala, India

K. Kaur, M. Kaur, S. Kumar

School of Physics and Materials Science, Thapar University, Patiala -147004, Punjab, India

Directed flow plays a prominent role among all the available observables to determine the nuclear equation of state from the heavy-ion data. It provides the elementary information about the dynamical evolution of the reaction system. In the past few years numerous attempts have been made in order to obtain further insight into the properties of the equation of state and nucleon-nucleon cross-section by studying the directed flow. The cluster recognition method also plays an important role to describe the reaction dynamics under the extreme conditions. In the present study, we aim to investigate the effect of different cluster recognition criteria on the transverse flow of light particles produced from a neutron rich system within the framework of isospin dependent quantum molecular dynamics (IQMD) model. In IQMD model, the fragments are recognized by using minimum spanning tree (MST) method. Two nucleons are allowed to share the same fragment, if their centroids are closer than a distance r_{min}. with $|r_i-r_j|\leq r_{min}$; r_{min}=2 - 4 fm.;

In the present study, an isospin dependence of nucleons has been included within the simple MST method. In this method, the value of r_{min} has been varied depending upon the isospin of nucleon in that fragment. i. e.$|r_i-r_j|\leq r^{pp}_{min}$ OR $r^{np,nn}_{min}$ and $|p_i-p_j|\leq p^{pp}_{min}$ OR $p^{np,nn}_{min}$ where, r^{pp}_{min} varies from 3 to 4 fm and $r^{np,nn}_{min}$ varies from 3 to 6 fm. However, a fix value of p^{pp}_{min}=250 MeV/c and $p^{np,nn}_{min}$= 150 MeV/c is used. The long range Coulomb force between the nucleons is reason for limited range of r^{pp}_{min}.

The transverse momentum dependence of transverse flow for light particles is investigated within the different rapidity regions. Moreover, the comparison of our calculations with the experimental data is expected to provide the better constraints for the values of r^{pp}_{min} and $r^{np,nn}_{min}$.

REFERENCES

[1] C. Hartnack et. al. *Eur. Phys. J. A* 1 151 (1998).

SYSTEMATIC ANALYSIS OF THE FUSION BARRIERS FOR PROTON AND HELIUM INDUCED REACTIONS USING VARIOUS PROXIMITY POTENTIALS

Raj Kumari, Department of Physics, Panjab University, Chandigarh, India

R. Kumari, S. Kaur

Department of Physics, Panjab University, Chandigarh 160014, India

With the advent of advanced and sophisticated heavy-ion accelerators and detectors, a number of new directions have been emerged in nuclear physics. The study of nuclear structure and the interactions among nucleons gives us valuable information about synthesis of super-heavy elements and also helpful in the field of cosmology and astrophysics. The most probable process of fusion at low incident energies ($E < 10$ MeV) has strong dependence upon fusion parameters i.e. fusion barrier heights and positions. The knowledge of these fusion parameters gives valuable information for studying nuclear reaction mechanisms. We first aim to calculate fusion parameters for proton and helium projectiles fusing with different target using proximity potentials and present parameterized forms of the fusion barrier heights and positions. The calculated values of parameterized forms will be compared with the empirical values. Our study reveals that out of various proximity potentials, the parameterized forms derived using Proximity 1977 potential yields values closer to the empirical values and can be used further to directly estimate the barrier parameters for the fusion reactions of proton and helium projectile with any target.

PHENOMENOLOGICAL MODEL OF Β-DELAYED NEUTRON-EMISSION PROBABILITY

Krzysztof Miernik, Faculty of Physics, University of Warsaw, Poland

If the β^--decay energy is larger than the neutron separation energy of the decay daughter a so-called delayed-neutron may be emitted after the β transition. The β-decay strength is generally fragmented over a large number of states, resulting in a complex delayed-neutron energy spectrum. However, often only the total neutron-emission probability (P_n) is of primary interest. The P_n value is in particular used in applications such as r-process nucleosynthesis modeling [1], reactor operation, and nuclear fuel postprocessing [2],

The key issue in determining P_n is modeling the β-strength function. This can be provided by microscopic models such as the shell model [3] or quasiparticle random-phase approximation (QRPA) [4,5]. However, the complexity of the many-body nuclear system at medium excitation energies represents a major difficulty for microscopic theories. In practice, phenomenological descriptions of S_β may better systematize P_n values globally.

In this contribution a phenomenological model of the β-delayed neutron-emission probability, based on a level density function, is presented [6]. The effective level density systematics have been modeled and used to determine β-delayed neutron-emission probabilities. This method is compared to other available models and is found to provide an improved description of the β-delayed neutron-emission probabilities across the entire mass surface.

In addition a multi-neutron emission channels – two (P_{2n}) and three (P_{3n}) β-delayed neutrons – will be discussed in the framework of the effective density model. In particular, the effects of the competition between different decay channels, and its impact on P_{2n} and P_{3n} predictions will be examined and compared with available experimental results [7,8].

REFERENCES

[1] M. R. Mumpower et al., Astrophys. J. 752, 117 (2012).
[2] D. Abriola, B. Singh, and I. Dillman, IAEA, INDC(NDS)-0599, 2011.
[3] Q. Zhi et al., Phys. Rev. C 87, 025803 (2013).
[4] P. Möller, B. Pfeiffer, and K.-L. Kratz, Phys. Rev. C 67, 055802 (2003).
[5] I. N. Borzov, Phys. Rev. C 67, 025802 (2003).
[6] K. Miernik. Phys. Rev. C 88, 041301(R) (2013).
[7] K. Miernik, et al., Phys. Rev. Lett. 111, 132502 (2013).
[8] M. Borge, Phys. Scr. T152, 014013 (2013).

ALPHA DECAY IN SUPERHEAVY ELEMENTS: A KEY TO ISLAND OF STABILITY

Sharma Niyti, Department of Physics, Kurukshetra University, Kurukshetra, India

S. Niyti[1], Amandeep[1], M.K. Sharma[2] , Kirandeep Sandhu[2] and R.K.Gupta[3]

1 Department of Physics, Kurukshetra University, Kurukshetra, India
2 School of Physics and Material Sciences, Thapar University, Patiala, India
3 Department of Physics, Panjab University, Chandigarh, India.

Identification and characterization of decay chains form a crucial part of the nuclide identification and are helpful in the synthesis of super-heavy elements, achieved via cold or hot fusion reactions. Here we obtain the alpha-decay half-lives in the framework of dynamical cluster-decay model (DCM) [1] based on quantum mechanical fragmentation theory, built with the use of preformation probability and penetration probability. In our previous work, α-decay chains of Z=115 isotopes were investigated thorough Preformed cluster model (PCM) using "Hot optimum" orientations by including a constant scaling factor to approach the available data [2]. Recently, the DCM approach was exploited for the first time where temperature dependence was included via recoil energy of the residual nucleus, which in turn takes care of the scaling factor employed in PCM calculations of α-decay. The use of DCM to address α-decay seems justified because the compound nucleus formed is considered to be hot due to its recoil energy after *xn* emission, before the alpha-decay chain starts.
In DCM (ℓ =0), or equivalently, PCM (T≠0), the decay constant/ half-life time is defined as, $\lambda = P_0 \nu_0 P$, $T^{1/2} = \ln 2/\lambda$ where P_0 and P are the pre-formation and penetration probability, respectively, calculated at $R=R_a = R_1+R_2+\Delta R$ for T-dependent potentials $V_R(\eta, T)$ and $V\eta\ (R, T)$.
Decay half-lives of various isotopes of Z=107, 108, 109, 111, 113, 115, 117 and 118 have been calculated and compared nicely with the available experimental data [3-5] to extract extensive information regarding dynamics of the above mentioned superheavy systems and calculations are underway to locate the centre of Island of Stability using this information.

REFERENCES

[1] Niyti and R. K. Gupta, Phys. Rev. C 89, 014603 (2014) and earlier references therein.
[2] R. Kumar, K. Sandhu, M. K. Sharma, and R. K. Gupta, Phys. Rev. C 87, 054610 (2013).
[3] Yu. Ts. Oganessian *et al.*, Phys. Rev. C **87**, 014302 (2013).
[4] Yuri Oganessian, J. Phys. G 34, R165-R242 (2007).
[5] Yu. Ts. Oganessian *et al.*, Phys. Rev. C 87, 034605 (2013).

SYNTHESIS OF ^{294}118 NUCLEUS IN ^{249,250}Cf (^{48}Ca, xn) REACTIONS USING THE DYNAMICAL CLUSTER-DECAY MODEL

Gudveen Sawhney, Panjab University, Chandigarh, India

R. K. Gupta[1], A. Kaur[2], M. K. Sharma[2]

1 Department of Physics, Panjab University, Chandigarh-160014, India
2 School of Physics and Materials Science, Thapar University, Patiala-147004, India

Advancement in heavy ion reactions, to produce nuclei in the superheavy mass region, has created a large excitement for nuclear structure studies. Keeping this in mind, we have studied ^{249,250}Cf + ^{48}Ca → $^{297,298}118^*$ reactions using the dynamical cluster-decay model (DCM) taking Z=126 and N=184 as the possible magic numbers in the superheavy region with reference to [1]. Experimentally, the synthesis of Z =118 element have been carried out at Dubna [2] to investigate the 3n evaporation channel in ^{249}Cf + ^{48}Ca complete fusion reaction at compound nucleus excitation energies E_{CN}^*=29.2 MeV and 34.4 MeV. Also, some theoretical estimates have been recently made available [3, 4] regarding the possibility of synthesizing $^{292\text{-}298}$118 isotopes via $^{249\text{-}252}$Cf + ^{48}Ca reactions. In addition, it was concluded in Ref. [3] that due to the inevitable presence of ^{250}Cf isotope in the ^{249}Cf enriched target, the observed ^{294}118 evaporation residue (ER) cross-sections [2] at the two different beam energies are contributed by three neutrons emission from $^{297}118^*$ and four neutrons emission from $^{298}118^*$ CN, formed in ^{48}Ca induced reactions.

Following Ref. [2], we intend to anaylze in the present work, the decay cross-sections of 3n and 4n ER in the framework of DCM, with a view to see if there is any mixing of ^{249,250}Cf isotopes in the target. The main ingredients of DCM are the preformation probablity P_0 and barrier penetration probability P. The P_0 is calculated by solving a time independent Schrödinger equation in mass asymmetry corodinate [$\eta = (A_1\text{-}A_2)/(A_1+A_2)$] and the barrier penetrability P is worked out using WKB approach. Interestingly, the DCM calculated 3n ER cross sections for ^{249}Cf + ^{48}Ca reaction are found to be in good agreement with the experimental results using both spherical and deformed choice of fragmentation which seems to suggest that contribution by 4n channel in ^{250}Cf + ^{48}Ca reaction may not be significant. It is worth noting that DCM calculations are sensitive to the choice of neck-length parameter ΔR, which represents the time scale at which the neutron emission takes place. For a chosen neck elongation, the relative contribution of 4n decay is negligibly small in comparison to that for 3n decay. This observation is independent of spherical or deformed fragmentation approach as well as the choice of proximity interaction. However, further investitigations regarding appropriate choice of available phase space (neck criteria) may impart more insight regarding the possible existence of 4n channel.

REFERENCES
[1] R. K. Gupta, *et al.*, J. Phys. G: Nucl. Part. Phys. 36, 115105 (2009).
[2] Yu. Ts. Oganessian, *et al.*, Phys. Rev. C 74, 044602 (2006).
[3] G. Mandaglio, *et al.,* Phys. Rev. C 86, 064607 (2012).
[4] T. Cap, *et al.,* Phys. Rev. C 88, 037603 (2013).

SCHEMATIC ANALYSIS OF ELECTRIC REDUCED TRANSITION PROBABILITIES B(E1) AND B(E2) FOR THE QUADRUPOLE-OCTUPOLE MODEL WITH REAL DEFORMATION PARAMETERS

Agnieszka Szulerecka, UMCS Lublin, Poland

A. Szularecka, A. Góźdź , A. Dobrowolski

UMCS Lublin, Poland

We consider the quadrupole-octupole nuclear collective model with the nuclear surface determined by not complex but real deformation parameters as used in many mean-field approaches. The nuclear surface is described by the spherical harmonic expansion:

$R(\theta,\varphi)=R_0\{1+\alpha_{20}Y_{20}(\theta,\varphi)+ \alpha_{22} (Y_{22} (\theta,\varphi)+ Y_{2-2} (\theta,\varphi)) +\alpha_{30}Y_{30}(\theta,\varphi)+ \alpha_{31} (Y_{31} (\theta,\varphi)- Y_{3-1} (\theta,\varphi))+ \alpha_{32} (Y_{32} (\theta,\varphi)+ Y_{3-2} (\theta,\varphi))+ \alpha_{33} (Y_{33} (\theta,\varphi)- Y_{3-3} (\theta,\varphi))\}$.

This model of collective space leads to D_4 point intrinsic group as the symmetrization group. This property determines the form of basis functions. We consider only zero and one phonon vibrations and rotational excitations on top of them. The rotational basis is constructed from standard Wigner functions of the SO(3) group. The vibrational states are projected from harmonic oscillator states with shifted arguments which determine the equilibrium deformation for vibrations. The poster shows preliminary results of the analysis of possible scenarios of transitions for ground states quadrupole and one phonon excited octupole bands.

SINGLE-PARTICLE STRUCTURE OF NEUTRON SKIN

Michał Warda, Maria Curie-Skłodowska University, Lublin, Poland

M. Warda[1], X. Viñas[2], M. Centelles[2], X. Roca-Maza[3]

1 Maria Curie-Skłodowska University, Lublin, Poland
2 University of Barcelona, Spain
3 INFN, Milano, Italy

Neutron skin, defined as a difference of neutron and proton rms radii, may arise from the shift between half-density radii of both types of nucleons (bulk type) and/or from the differences in surface diffuseness (surface type). The relation between the bulk or the surface character of neutron skins of nuclei has been studied [1, 2] using density distribution obtained from self-consistent calculations approximated by the 2 parameter Fermi profile. We have emphasized role of the distinct surface widths of the neutron and proton density profiles [3]. Neutron skin is important as it is closely related to the coefficient L of the slope of the nuclear symmetry energy at saturation [3,4].

A close correlation is found between the quantum numbers of the valence neutrons and the changes in the position and the diffuseness of the nuclear surface, which in turn affect the neutron skin thickness [5]. Neutrons in the valence orbitals with low principal quantum number and high angular momentum mainly displace the position of the neutron surface outwards, while neutrons with high principal quantum number and low angular momentum basically increase the diffuseness of the neutron surface.

REFERENCES
[1] M. Warda, X. Vinas, X. Roca-Maza, M. Centelles, Phys. Rev. C81, 054309 (2010).
[2] M. Centelles, X. Roca-Maza, X. Vinas, M. Warda, Phys. Rev. C82, 054314 (2010).
[3] M. Warda, X. Vinas, X. Roca-Maza, M. Centelles, Phys. Rev. C80, 024316 (2009).
[4] M. Centelles, X. Roca-Maza, X. Vinas, M. Warda, Phys. Rev. Lett 102, 122502 (2009).
[5] M. Warda, X. Vinas, M. Centelles, X. Roca-Maza, Phys. Rev. C89, 064302 (2014).

SPONTANEOUS FISSION HALF-LIVES WITHIN SEMI-EMPIRICAL MODEL

Anna Zdeb, Maria Curie-Sklodowska University, Lublin, Poland

A. Zbeb, M. Warda, and K. Pomorski

Department of Theoretical Physics , Maria Curie-Sklodowska University, Lublin, Poland

Almost 60 years ago W. J. Świątecki [1] has observed a close correlation between spontaneous fission half-lives and ground state masses of nuclei. He has obtained a smooth dependence of logarithms of spontaneous fission half-lives corrected by the ground-state empirical shell effects δM, in a function of fissility parameter. Our goal is to check how good this idea works for newest available experimental data and a modern version macroscopic model. Namely, we have taken the δM correction for each isotope as the difference between the experimental mass and its macroscopic estimate evaluated using the Lublin Strasbourg Drop mass formula [2]. A simple prescription for spontaneous fission half-lives evaluation, dependent only on one adjustable parameter (for even-even nuclei) and the proton number Z of the mother-nucleus was obtained. For odd-systems an additional hindrance factor was introduced. Within our method all existing data for spontaneous fission half-lives in the actinides and super-heavy regions of nuclei were successfully reproduced [3].

REFERENCES
[1] W. J. Świątecki, *Phys. Rev. Lett.* 100, 937 (1955).
[2] K. Pomorski, J. Dudek, *Phys. Rev.* C67, 044316 (2003).
[3] A. Zdeb, M. Warda, K. Pomorski, *Phys. Scr.*, 89 (2014).

List of Participants

Abdullin Farid	JINR Dubna
Ackermann Dieter	GSI
Afanasjev Anatoli	Mississippi State University
Akkus Baki	Istanbul University
Alexander Tom	University of Surrey
Algora Alejandro	IFIC CSIC University of Valencia
Ami Ismahane	University Mhamed Bougara de Boumerdes, Algeria
Andel Boris	Comenius University, Bratislava
Andreev Alexander	JINR Dubna
Arora Sangeeta	Thapar University, India
Arsenyev Nikolay	JINR Dubna
Avetisyan Sergey	JINR Dubna
Baran Andrzej	UMCS Lublin
Bartel Johann	IPHC Strasbourg
Bednarczyk Piotr	IFJ PAN Kraków
Bezbakh Anna	JINR Dubna
Bezbakh Andrey	JINR Dubna
Bielecki Jakub	IFJ PAN Kraków
Bocchi Giovanni	University of Milano and INFN
Boretzky Konstanze	GSI
Bounthong Bounseng	IPHC Strasbourg
Bracco Angela	University of Milano and INFN
Britton Richard	University of Surrey
Broda Rafał	IFJ PAN Kraków
Browne Frank	University of Brighton
Bucher Thifhelimbilu	iThemba Labs
Budinčević Ivan	KU Leuven
Carbone Diana	LNS INFN
Carroll Robert	University of Surrey
Catford Wilton	University of Surrey
Cederwall Bo	KTH-Royal Institute of Technology
Ceruti Simone	University of Milano and INFN
Chamel Nicolas	Université Libre de Bruxelles
Chietera Andreina	IPHC Strasbourg
Chmielowski Wladyslaw	JINR Dubna
Ciemała Michał	GANIL
Ciepał Izabela	Jagiellonian University
Cieplicka Natalia	IFJ PAN Kraków
Cizewski Jolie	Rutgers University
Colò Gianluca	University of Milano and INFN

Cortes Sua Martha Liliana	TU Darmstadt / GSI
Crespi Fabio	University of Milano and INFN
Csige Lorant	MTA Atomki
Czeszumska Agnieszka	Lawrence Livermore National Laboratory / University of California, Berkeley
David Sylvain	CNRS Paris
Davies Paul	University of York
Dechery Fabien	IPHC Strasbourg
Dobaczewski Jacek	University of Warsaw
Dobrowolski Artur	UMCS Lublin
Doornenbal Pieter	RIKEN
Duchene Gilbert	IPHC Strasbourg
Ergun Aysegul	Selcuk University, Konya, Turkey
Ertoprak Aysegul	Istanbul University
Etile Asenath	CSNSM Orsay
Fabris Daniela	INFN Padova
Fornal Bogdan	IFJ PAN Kraków
Fujita Yoshitaka	RCNP Osaka Univeristy
Furnstahl Richard	Ohio State University
Gales Sydney	ELI-NP and IN2P3/CNRS
Gandolfi Stefano	Los Alamos
Garcia Borge Maria Jose	CERN
Ghazimoradi Farnaz	KTH Royal Institute of Technology
Giaz Agnese	INFN Milano
Görgen Andreas	University of Oslo
Górska Magdalena	GSI
Góźdź Andrzej	UMCS Lublin
Gramegna Fabiana	INFN Legnaro
Grębosz Jerzy	IFJ PAN Kraków
Hadynska-Klek Katarzyna	University of Oslo
Hammer Hans-	TU Darmstadt
Henderson Jack	University of York
Henry Thomas	University of York
Heylen Hanne	KU Leuven
Iskra Łukasz	IFJ PAN Kraków
Jachimowicz Piotr	University of Zielona Góra
Janssens Robert V. F.	Argonne National Laboratory
Jastrząb Marcin	IFJ PAN Kraków
Jastrzębski Jerzy	Heavy Ion Laboratory, University of Warsaw

Jeżabek Marek	IFJ PAN Kraków
John Philipp Rudolf	University of Padova and INFN
Jones Kate	University of Tennessee
Kalaninová Zdenka	Comenius University, Bratislava
Kamiński Grzegorz	IFJ PAN Kraków
Karny Marek	University of Warsaw
Kaur Sukhjit	Panjab University, India
Kaur Arshdeep	Panjab University, India
Khatri Ghanshyam	Jagiellonian University
Klintefjord Malin	University of Oslo
Kłos Barbara	University of Silesia
Kmiecik Maria	IFJ PAN Kraków
Konieczka Monika	IFJ PAN Kraków
Kowal Michał	NCBJ Warsaw
Kownacki Jan	HIL, University of Warsaw
Królas Wojciech	IFJ PAN Kraków
Krzemień Wojciech	Jagiellonian University
Krzysiek Mateusz	IFJ PAN Kraków
Kulessa Reinhard	IF UJ
Kumar Suneel	Thapar University, Patiala (Punjab), India
Kumar Rakesh	IUAC New Delhi
Larsen Ann-Cecilie	University of Oslo
Lemaître Jean-François	CEA/DAM/DIF
Leoni Silvia	University of Milano and INFN
Lewitowicz Marek	GANIL
Lorusso Giuseppe	RIKEN Nishina Center
Madurga Flores Miguel	CERN
Maier K. Hugo	IFJ PAN Kraków
Maj Adam	IFJ PAN Kraków
Mancuso Clement	IPN Lyon
Marchlewski Tomasz	Heavy Ion Laboratory, University of Warsaw
Marganiec Justyna	TU Darmstadt
Mazurek Katarzyna	IFJ PAN Kraków
Mazzocchi Chiara	University of Warsaw
Męczyński Witold	IFJ PAN Kraków
Miernik Krzysztof	University of Warsaw

Mijatovic Tea	Ruder Boskovic Institute, Zagreb
Morita Kosuke	Kyushu University
Moshfegh Hamidreza	University of Tehran
Motobayashi Tohru	RIKEN Nishina Center
Naïdja Houda	IPHC Strasbourg
Najman Rafal	Jagiellonian University
Nanal Vandana	Tata Institute, Mumbai
Napiorkowski Paweł	Heavy Ion Laboratory, University of Warsaw
Nara Singh Bondili	University of York
Navin Alahari	GANIL
Nazarewicz Witold	Michigan State University
Nerlo-Pomorska Bożena	UMCS Lublin
Niewiara Małgorzata	IFJ PAN Kraków
Niyti Sharma	Kurukshetra University, India
Nowacki Frederic	IPHC Strasbourg
Oganessian Yuri	JINR Dubna
Orrigo Sonja	IFIC University of Valencia
Paar Nils	University of Zagreb
Paul Edward	University of Liverpool
Pawłat Tomasz	IFJ PAN Kraków
Perkowski Jarosław	University of Łódź
Pohjalainen Ilkka	University of Jyväskylä
Pomorski Krzysztof	UMCS Lublin
Próchniak Leszek	Heavy Ion Laboratory, University of Warsaw
Ragnarsson Ingemar	LTH, Lund University
Ralet Damian	TU Darmstadt
Ramos Diego	University of Santiago de Compostela (USC)
Renzi Francesca	KU Leuven
Rezynkina Kseniia	CSNSM Orsay
Ribeiro Guillermo	IEM-CSIC Madrid
Rubio Berta	IFIC CSIC University of Valencia

Rusek Krzysztof	Heavy Ion Laboratory, University of Warsaw
Ryabov Eugeny	Omsk State University
Rybicki Andrzej	IFJ PAN Kraków
Sandzelius Mikael	University of Jyväskylä
Satuła Wojciech	University of Warsaw
Saxena Mansi	University of Delhi
Senoville Matthieu	CEA Saclay IRFU/SPhN
Sethi Jasmine	Tata Institute, Mumbai
Seweryniak Dariusz	Argonne National Laboratory
Sezen Erkan	Wiener Plein & Baus
Shand Callum	University of Surrey
Sharov Pavel	JINR Dubna
Sherrill Bradley	Michigan State University
Shirinda Obed	iThemba Labs
Shneidman Timur	JINR Dubna
Siem Sunniva	University of Oslo
Siem Sunniva	University of Oslo
Simpson John	STFC Daresbury Laboratory
Smoleń Magdalena	University of the West of Scotland
Sobiczewski Adam	NCBJ Warsaw
Spiro Michel	CEA
Srebrny Julian	Heavy Ion Laboratory, University of Warsaw
Staszczak Andrzej	UMCS Lublin
Stetcu Ionel	Los Alamos National Laboratory
Styczeń Jan	IFJ PAN Kraków
Sun Yang	Shanghai Jiaotong University
Szenborn Roman	University of Warsaw
Szerypo Jerzy	LMU Munich
Szklarz Cecylia	IFJ PAN Kraków
Szpak Bartlomiej	IFJ PAN Kraków
Szulerecka Agnieszka	UMCS Lublin
Targosz-Ślęczka Natalia	University of Szczecin

Tarpanov Dimitar	University of Warsaw
Truesdale Victoria	University of York
Türler Andreas	Paul Scherrer Institute & University of Bern
Uesaka Tomohiro	RIKEN Nishina Center
Ur Calin Alexandru	ELI-NP Magurele-Bucharest
Vesic Jelena	Jozef Stefan Institute, Ljubljana
Warda Michał	UMCS Lublin
Wasilewska Barbara	IFJ PAN Kraków
Wolińska-Cichocka Marzena	Heavy Ion Laboratory, University of Warsaw
Wolszczan Alexander	Pennsylvania State University
Wong Cheuk-Yin	Oak Ridge National Laboratory
Wrońska Aleksandra	Jagiellonian University
Wrzesiński Jacek	IFJ PAN Kraków
Wuosmaa Alan	University of Connecticut
Zagrebaev Valeriy	JINR Dubna
Zając Krystyna	UMCS Lublin
Zdeb Anna	UMCS Lublin
Zegers Remco	Michigan State University
Zielińska Magda	CEA Saclay
Ziębliński Mirosław	IFJ PAN Kraków