Zakopane Conference on Nuclear Physics

47TH IN THE SERIES OF ZAKOPANE SCHOOLS OF PHYSICS

August 27 – September 2, 2012

Extremes of the Nuclear Landscape
ZAKOPANE 2012

ORGANIZED BY:

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The Marian Smoluchowski Institute of Physics, Jagiellonian University
Committee of Physics of the Polish Academy of Sciences (PAN)

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TABLE OF CONTENTS

PROGRAM

MONDAY, AUGUST 27

15:00 – 17:00 Arrival of the Conference participants

18:00 Dinner

19:30 – 20:30 Opening session

19:30 Opening of the Conference

19:45 Baha Balantekin (University of Wisconsin-Madison)
An outlook on nuclear physics

20:30 Welcome reception

TUESDAY, AUGUST 28

7:30 – 8:30 Breakfast

8:30 – 12:50 Morning Session

FRONTIERS OF NUCLEAR THEORY
Witold Nazarewicz, convener

8:30 Joseph Carlson (Los Alamos National Laboratory)
Neutron matter from low to high densities

9:00 Heiko Hergert (Ohio State University)
In-medium similarity renormalization group for finite nuclei

9:15 Thomas Papenbrock (University of Tennessee and ORNL)
Towards model-independent nuclear structure computations

9:45 Jacek Dobaczewski (University of Warsaw)
Effective theory for low-energy nuclear energy density functionals

10:15 Jun Terasaki (University of Tsukuba)
Overlap of QRPA states based on ground states of different nuclei

10:30 Coffee break

11:00 Nicolas Schunck (Lawrence Livermore National Laboratory)
Microscopic description of nuclear fission

11:25 Furong Xu (Peking University)
Recent studies on nuclear shapes of ultrahigh-spin and high-K states

11:50 Charles Horowitz (Indiana University)
Nuclear structure, neutron stars, and gravitational waves

12:20 Andrzej Baran (Maria Curie Skłodowska University)
Stability of superheavy elements in Skyrme HFB approach

12:35 Wojciech Brodziński (NCBJ Świerk)
Prospects for superheavy nuclei with $Z \geq 128$

13:00 Lunch

14:00 – 18:00 Excursion for accompanying persons

14:00 – 17:30 Afternoon Session

EXOTIC GEOMETRICAL SYMMETRIES IN NUCLEI: SELECTED NEW RESULTS
Naftali Auerbach, chairman

14:00 Jerzy Dudek (University of Strasbourg and IPHC)
Symmetries predicted by theory <–> Predictive power of theories

14:30 Lee Riedinger (University of Tennessee)
Search for new symmetries in fast-rotating nuclei

14:55 Michael Jentschel (ILL Grenoble)
Ultra-high resolution gamma-ray spectroscopy search for symmetries

15:20 Toshiyuki Sumikama (Tohoku University)
Decay spectroscopy of neutron-rich nuclei in the vicinity of ^{110}Zr at RIBF

15:45 Hervé Molique (IPHC and University of Strasbourg)
Nuclear Mean Field techniques and the stability of theoretical predictions

16:00 Coffee break

16:20 Artur Dobrowolski (Maria Curie Skłodowska University)
Electric transitions in hypothetical Tetrahedral and Octahedral bands

16:35 David Rouvel (University of Strasbourg)
Superposition of two very distinct symmetries in one quantum state of an atomic nucleus

16:50 Obed Shirinda (iThemba LABS)
Studying chiral bands associated with multi-quasiparticle configuration

17:05 Hideyuki Sakai (RIKEN Nishina Center)
"Einstein was wrong?" – The EPR paradox and a test of Bell inequality by proton pairs

18:00 Dinner

19:00 – 19:40 Evening Session

FEW-NUCLEON INTERACTION DYNAMICS
Reinhard Kulessa, chairman

19:00 Stanisław Kistryn (Jagiellonian University)
Studies of few-nucleon interaction dynamics in new generation experiments

19:25 Barbara Kłos (University of Silesia)
Systematic studies of the three-nucleon system dynamics in the deuteron-proton breakup reaction

20:00 – 22:00 Poster session (in Antałówka Hotel)
Witold Męczyński, chairman

WEDNESDAY, AUGUST 29

7:30 – 8:30 Breakfast

8:30 – 12:55 Morning Session

EVOLUTION OF THE NUCLEAR STRUCTURE IN NEUTRON-RICH AND HEAVY NUCLEI

Robert Janssens, convener

8:30 Guy Savard (University of Chicago and ANL)
Mass measurements of neutron-rich nuclei with CARIBU

8:55 Gerda Neyens (KU Leuven)
Measurements of nuclear moments, spins and charge radii in neutron-rich nuclei: probing structural changes

9:20 Pieter Doornenbal (RIKEN Nishina Center)
Search for the southern and eastern boundaries of the Island of Inversion

9:35 Benjamin Kay (University of York)
Transfer reactions and the structure of neutron-rich nuclei

10:00 Augusto Macchiavelli (Lawrence Berkeley National Laboratory)
Selected aspects of the structure of exotic nuclei and new opportunities with GRETINA

10:30 Coffee break

11:00 Christopher Chiara (University of Maryland and ANL)
Search for intruder states in ^{68}*Ni and* ^{66,67}*Co*

11:15 Igor Celikovic (GANIL)
Lifetime measurements of Zn isotopes around N=40

11:30 Agnieszka Korgul (University of Warsaw)
Beta-decay properties of ^{85,86}*Ge and* ^{86,87}*As*

11:45 George Dracoulis (Australian National University)
Deep-inelastic reactions and K-isomers in neutron-rich nuclei crossing the perimeter of the A=180-190 deformed region

12:10 Emma Wilson (University of Surrey)
Core excitations across the neutron shell gap in the Z=81 ^{207}*Tl nucleus*

12:25 Stanislav Antalic (Comenius University Bratislava)
Nuclear structure studies of heaviest elements measured at SHIP

12:40 Peter Thirolf (Ludwig-Maximilians-University Munich)
Bridging the gap between atomic and nuclear physics: Towards an all-optical access to the lowest nuclear transition in ^{229m}Th

13:00 Lunch
14:00 – 18:00 Excursion to the Tatra Mountains
18:00 Dinner
19:00 – 22:30 Evening Session

NUCLEAR REACTIONS AROUND THE COULOMB BARRIER
Lorenzo Corradi, convener

19:00 Giovanni Pollarolo (University of Torino and INFN)
Aspects of transfer reactions in light and heavy ion collisions

19:30 Suzana Szilner (Ruder Boskovic Institute Zagreb)
Transfer reaction studies with spectrometers

19:50 Felix Liang (Oak Ridge National Laboratory)
Recent results of fusion induced by neutron-rich radioactive beams studied at HRIBF

20:10 Maurits Evers (Australian National University)
Near-barrier nuclear collisions: From coherent quantum-superposition to dissipative dynamics

20:30 Short break

20:45 Marco Mazzocco (University of Padova)
Recent results on reactions with weakly bound nuclei

21:05 Wolfram von Oertzen (Helmholz Zentrum Berlin)
True ternary fission: a new type of radioactive decay of ^{252}Cf

21:30 Simone Bottoni (University of Milano and INFN)
Reaction dynamics and nuclear structure of moderately neutron-rich Ne isotopes by heavy ion reactions

21:45 Valentina Scuderi (INFN Laboratori Nazionali del Sud)
Elastic scattering and direct reactions for the ^{11}Be + ^{64}Zn system close to the Coulomb barrier

22:00 Gloria Marquínez Durán (University of Huelva)
Preliminary results on the scattering of ^{8}He with heavy targets

22:15 Roman Kuzyakin (JINR Dubna)
Isotopic trends of capture cross section and mean-square angular momentum of captured system

THURSDAY, AUGUST 30

7:30 – 8:30 Breakfast

8:30 – 12:45 Morning Session

NUCLEAR STRUCTURE NEAR THE PROTON DRIP LINE
Robert Wadsworth, convener

8:30 Jonathan Billowes (University of Manchester)
Determination of charge radii of ^{74}Rb and other proton-rich nuclei

9:00 Michael Bentley (University of York)
Study of isospin-symmetry breaking in the $f_{7/2}$ shell using knockout reactions

9:30 Torbjörn Bäck (Royal Institute of Technology (KTH))
Study of collectivity in neutron-deficient Te and Sn isotopes

10:00 Yasuhiro Togano (EMMI GSI Darmstadt)
Hindered proton collectivity in the proton-rich nucleus ^{28}S: Possible new magic number at Z=16

10:15 Nadya Smirnova (CENBG Bordeaux-Gradignan)
Isospin symmetry breaking in sd shell nuclei and applications

10:30 Coffee break

11:00 Alexandre Obertelli (CEA Saclay)
Relativistic Coulex measurements in the mass 66 region and the first spectroscopy results on ^{66}Se / ^{65}As

11:25 Krzysztof Miernik (ORNL and University of Warsaw)
Latest results from two proton decay studies

11:50 Marcin Palacz (Heavy Ion Laboratory, University of Warsaw)
Odd parity core excitation of the N=Z=50 core

12:15 Magdalena Matejska-Minda (IFJ PAN Kraków)
Lifetime measurement of high-lying short lived states in ^{69}As

12:30 Valentina Liberati (University of the West of Scotland)
Beta-delayed fission and alpha-decay spectroscopy of the lightest Tl isotopes

13:00 Lunch

14:00 – 18:00 Excursion for accompanying persons

14:00 – 17:50 Afternoon Session

MODERN APPROACH TO SHELL-MODEL AND BEYOND
Morten Hjorth-Jensen, convener

14:00 Takaharu Otsuka (University of Tokyo)
Nuclear structure toward the driplines; understanding many-body forces and correlations

14:30 Christian Forssén (Chalmers University of Technology)
Light nuclei in the ab initio no-core shell model

15:00 Olivier Sorlin (GANIL)
Modifications of shell closures far from stability: evidences, causes and consequences

15:25 Alexandre Lepailleur (GANIL)
Study of nuclear interactions for the weakly bound nucleus of ^{26}F

15:40 Frederic Nowacki (IPHC Strasbourg)
The island of inversion around A=64

16:00 Coffee break

16:20 Mohamad Moukaddam (IPHC Strasbourg)
Evolution of the shell structure in medium-mass nuclei: Search for the $2d_{5/2}$ *neutron orbital in* ^{69}Ni

16:35 Maria Doncel (Royal Institute of Technology (KTH))
Lifetime measurements in neutron-rich Cu isotopes

16:50 Kamila Sieja (IPHC Strasbourg)
Toward a generalized monopole description of atomic nuclei

17:05 Robert Grzywacz (University of Tennessee)
Beta-delayed neutron emission from the r-process nuclei

17:30 Piotr Bednarczyk (IFJ PAN Kraków)
Experimental studies and shell model description of collective structures in fp nuclei at high spin

18:00 Dinner

19:00 – 20:45 Evening session

HIGHLIGHTS IN NUCLEAR ASTROPHYSICS
Michael Hass, convener

19:00 Hendrik Schatz (Michigan State University)
Nucleosynthesis of elements

19:30 Marialuisa Aliotta (University of Edinburgh)
Explosive scenarios, rp-process, X-ray bursts

19:55 B. S. Nara Singh (University of York)
New advances for the $^{3}He(^{4}He, \gamma)^{7}Be$ reaction

20:20 Alain Coc (CSNSM Orsay)
Big Bang nucleosynthesis

21:15 Barbecue at Karczma „Biały Potok"

FRIDAY, AUGUST 31

7:30 – 8:30 Breakfast

8:30 – 12:45 Morning Session

COLLECTIVE MODES IN EXOTIC NUCLEI
Adam Maj, convener

8:30 Peter Ring (Technical University Munich)
Theory of Dipole-Resonances in nuclei close and far from stability

9:00 Angela Bracco (University of Milano and INFN)
The gamma decay of high lying states with inelastic scattering of ^{17}O and with AGATA

9:30 Atsushi Tamii (Osaka University)
Studies of the electric dipole response in nuclei using the scattering of polarized protons

10:00 Tamás Tornyi (University of Oslo and ATOMKI Debrecen)
Study of the γ-ray strength in ^{238}Np

10:15 Paola Marini (GANIL)
Symmetry energy and secondary decay: toward the reconstruction of primary fragments

10:30 Coffee break

11:00 Henry Weller (Duke University and TUNL)
Precise determination of the Isovector Giant Quadrupole Resonance in nuclei

11:30 Nguyen Dinh Dang (RIKEN Nishina Center)
Description of GDR damping in highly excited nuclei

12:00 Concetta Parascandolo (University of Padova and INFN)
Dynamical Dipole mode: a "collective" tool to understand reaction dynamics by using stable and radioactive beams

12:15 Michał Ciemała (IFJ PAN Kraków)
Gamma-decay of the GDR in the GEMINI++ code

12:30 Katarzyna Hadyńska-Klęk (University of Warsaw)
Study of the ^{42}Ca nuclear structure using AGATA and EAGLE spectrometers: Recent results from the Coulomb excitation of the ^{42}Ca experiment

13:00 Lunch

14:00 – 18:00 Excursion to the Tatra Mountains

18:00 Dinner

19:00 – 22:00 Evening session

NUCLEAR SPECTROSCOPY WITH NOVEL TECHNIQUES

Faical Azaiez, convener

19:00 Ari Jokinen (University of Jyväskylä)
Trap assisted nuclear spectroscopy

19:25 Kieran Flanagan (University of Manchester)
Recent advances of laser spectroscopy at ISOLDE

19:50 David Verney (IPN Orsay)
Modern decay spectroscopy with beta-gamma-neutron detectors at ALTO

20:15 Karolina Kolos (IPN Orsay)
Beta decay spectroscopy near ^{78}Ni: level structure of ^{83,84}Ge

20:30 Short break

20:45 Cristina Petrone (NIPNE and University of Bucharest)
Gamma spectroscopy of isomeric states in neutron-rich nuclei: ^{75}Cu and ^{78}Ga

21:00 Lorant Csige (Ludwig-Maximilians-University Munich)
Photofission of ^{238}U induced by quasi-monochromatic, Compton backscattered gamma beam

21:15 Anukul Dhal (Weizmann Institute of Science)
Probing fundamental interactions by an Electrostatic Ion Beam Trap (EIBT)

21:30 Dario Nicolosi (INFN LNS and University of Catania)
Spectroscopy of ^{13}B via the (^{18}O, ^{16}O) two neutron transfer reaction

21:45 Jasmeet Kaur (Panjab University, India)
Quadrupole moment and g-factor measurements of the isomeric states in ^{128,129}Ba

SATURDAY, SEPTEMBER 1

7:30 – 8:30 Breakfast

8:30 – 12:20 Morning Session

DIRECT REACTIONS AND HALO NUCLEI
Thomas Aumann, convener

8:30 Carlos Bertulani (Texas A&M University-Commerce)
BBN and stellar nucleosynthesis from direct reactions

9:00 Takashi Nakamura (Tokyo Institute of Technology)
Coulomb and nuclear breakup of neutron drip line nuclei

9:30 Michael Thoennessen (Michigan State University)
Observation of ground-state two-neutron decay

10:00 Zsolt Vajta (ATOMKI Debrecen)
Study of neutron rich nuclei $^{18\text{-}21}N$ *and* ^{25}F

10:15 Margit Csatlós (ATOMKI Debrecen)
A new method for measuring the neutron-skin thickness

10:30 Coffee break

11:00 Haik Simon (GSI Darmstadt)
Halo nuclei: stepping stones across the drip-lines

11:25 Kathrin Wimmer (Central Michigan University)
Knockout reaction studies, structure and correlations

11:50 Janusz Skalski (NCBJ Warsaw)
Puzzle of third minima in actinides

12:05 Leszek Próchniak (Maria Curie Skłodowska University)
Superdeformed oblate superheavy nuclei in the self-consistent approach

13:00 Lunch

14:00 – 15:30 Afternoon session

SEMINAR SESSION (in Antałówka Hotel)
Rafał Broda, chairman

14:00 Nikolaos Costiris (University of Athens)
The ANN model of Beta-decay half-lives of nuclei in the crust of Neutron Stars

14:15 Ann-Cecilie Larsen (University of Oslo)
Astrophysical reactions rates and the low-energy enhancement in the γ-ray strength

14:30 Magne Guttormsen (University of Oslo)
Observation of large orbital scissors strength in actinides

14:45 Julien Le Bloas (CEA Bruyeres-le-Châtel)
Description of light nuclei (8<Z<20, 8<N<20) with the multiparticle-multihole Gogny energy density functional

15:00 Łukasz Iskra (IFJ PAN Kraków)
High seniority excitations in neutron-rich Sn isotopes

15:15 Oliver Roberts (University of Brighton)
The search for isomeric states in ^{133}Cs and ^{132}Te

15:30 Coffee break

16:00 – 18:00 Special session

IN CELEBRATION OF THE 60TH BIRTHDAY OF MAREK JEŻABEK, DIRECTOR GENERAL OF IFJ PAN

Stanisław Jadach, chairman

16:00 Zbigniew Wąs (IFJ PAN Kraków)
The Higgs boson of Standard Model - its function and signatures

16:30 Tadeusz Lesiak (IFJ PAN Kraków)
Heavy flavour physics

17:00 Jan Kisiel (University of Silesia)
Ideas in neutrino physics

17:30 Mieczysław Witold Krasny (LPNHE Paris)
High intensity gamma beams at the LHC

Closing talk

18:00 Sydney Gales (IPN Orsay)
Summary and outlook: The next 20 years of nuclear physics

20:15 Conference Banquet

SUNDAY, SEPTEMBER 2

7:30 – 9:30 Breakfast

9:00 – 10:30 Departure of the Conference participants

ABSTRACTS

EXPLOSIVE SCENARIOS, rp-PROCESS, X-RAY BURSTS
Marialuisa Aliotta, University of Edinburgh

invited

Novae, supernovae, X-ray bursts are among the most spectacular explosions in the Universe and are believed to be the furnaces where most of the heavy elements (up to and beyond Fe) are synthesised. Typical time scales for such events range from seconds to hours so that the nuclear reactions powering these explosions are critically influenced by the properties of short-lived nuclei that do not normally exist on Earth.

The rapid advances in satellite observations, together with recent developments in stellar models have led to an unprecedented era of progress in astronomy. Similarly, the advent of Radioactive Ion Beam facilities over the last two decades has enabled the direct investigation of many reactions with unstable nuclei, particularly those involved in explosive hydrogen burning. Here, a brief review on recent results for some key reactions will be presented, together with an outlook to future perspectives.

NUCLEAR STRUCTURE STUDIES OF HEAVIEST ELEMENTS MEASURED AT SHIP
Stanislav Antalic, Comenius University, Bratislava

seminar

S. Antalic 1, F. P. Hessberger 2,3, D. Ackermann 2, S. Heinz 2, S. Hofmann 2, Z. Kalaninová 1, B. Kindler 2, M. Leino 4, B. Lommel 2, R. Mann 2, K. Nishio 5, Š. Šáro 1, B. Sulignano 6

1 Comenius University, Bratislava 84248, Slovakia

2 GSI – Helmholtzzentrum für Schwerionenforschung GmbH, 64291 Darmstadt, Germany

3 Helmholtz Institut Mainz, 55099 Mainz, Germany

4 University of Jyväskylä, 40014 Jyväskylä, Finland

5 Japan Atomic Energy Agency, Tokai, Ibaraki 319-1195, Japan

6 CEA-Saclay, DAPNIA/SPhN, 91191 Gif-sur-Yvette Cedex, France

Besides the attempts to synthesize new superheavy elements, nuclear structure research in the fermium region is an important tool helping to reveal the information about heaviest nuclei. Recent developments of experimental techniques suited for alpha, gamma and conversion electron (CE) spectroscopy opened the door to investigate the structure of heaviest nuclei (A > 250). Experiments aimed to investigate them provide crucial information on the structure of heaviest nuclei and are stringent tests for nuclear models. Those studies allow obtaining for example informations on nucleon pairing, single particle levels or deformation changes.

At SHIP in GSI Darmstadt we perform an extensive program aimed at nuclear structure studies of trans-fermium isotopes using alpha-CE and alpha-gamma spectroscopy. We obtained enhanced data for the nuclear structure of several isotopes with Z > 100 what is helping to extend and to improve the single particle level systematics for N=149, N=151 and N=153 isotones. Besides the study via alpha decay the latter ones were studied also by means of beta decay, which was applied for the first time in transfermium region. In addition studies of K isomers were performed, which are very interesting examples of the physics important for production and decay of heaviest nuclei.

This series of experiments at SHIP provided plenty new data. Major results will be presented and discussed within theoretical frameworks, in particular those from the decay study of ^{253}No, ^{253}Md and ^{259}Sg.

STUDY OF COLLECTIVITY IN NEUTRON-DEFICIENT Te AND Sn ISOTOPES

Torbjörn Bäck, Royal Institute of Technology, Stockholm

invited

At the JYFL accelerator facility in Jyväskylä, Finland, the recoil-decay-tagging (RDT) technique has been utilized for several years to study the structure by gamma spectroscopy of many exotic nuclei unstable to alpha decay or proton emission. In the last few years a method combining RDT with a differential plunger has enabled lifetime mesurements in nuclei populated in very weak reaction channels, e.g. in the neutron deficient A=160-190 region. At JYFL, the JUROGAM-II germanium array, in conjunction with the RITU recoil separator and the Köln differential plunger has been used for these experiments. This method was just recently established in the alpha-decay region just above the N=Z=50 shell closure. Here, after presenting the experimental technique, some recent lifetime measurement in neutron deficient Te and I nuclei will be discussed in the context of the nuclear shell model including some comparison with B(E2) data from neutron deficient Sn isotopes.

AN OUTLOOK ON NUCLEAR PHYSICS

Baha Balantekin, University of Wisconsin-Madison

invited

Nuclear Physics aims to understand the nature of nuclear forces, how complex nuclei display simple patterns, how quantum chromodynamics determines the properties of the strongly interacting matter in addition to exploring fundamental symmetries and neutrinos. In this talk an outlook for the nuclear physics and the role it plays in the structure of the Universe will be presented.

STABILITY OF SUPERHEAVY ELEMENTS IN SKYRME HFB APPROACH

Andrzej Baran, Maria Curie Skłodowska University, Lublin

seminar

There are described basic decay properties (α, $\beta^{\pm}$, electron capture and spontaneous fission half-lives) of even-even superheavy elements (SHE) in the region of atomic numbers $108 \leq Z \leq 126$ and neutron numbers $148 \leq N \leq 188$ obtained in a selfconsistent, entirely microscopic, Skyrme Hartree-Fock-Bogoliubov approach. Q–values and spontaneous fission barriers of SHE are shown.

EXPERIMENTAL STUDIES AND SHELL MODEL DESCRIPTION OF COLLECTIVE STRUCTURES IN fp NUCLEI AT HIGH SPIN

Piotr Bednarczyk, IFJ PAN Kraków

invited

In the talk, results from a series of in-beam experiments performed with large germanium detector arrays such as EUROBALL or GASP and aimed at high spin gamma spectroscopy of nuclei lying in the vicinity of doubly magic ^{40}Ca and ^{58}Ni will be summarized.

The use of the Recoil Filter Detector (RFD) - an ancillary device enabling precise Doppler correction of gamma line energies [1] - allowed to extend known rotational bands up to and in some cases beyond band terminating (fully aligned) states. The application of RFD enabled also the Doppler shift attenuation measurements of extremely short lifetimes of states (in the femtosecond range). This method was helpful in tracking the evolution of nuclear deformation along the terminating rotational bands. In particular, it was experimentally demonstrated that strong quadrupole correlations associated with particle-hole excitations in some light fp nuclei [2] cancel at high spins, resulting in a spherical symmetry of the fully aligned state.

The complete spectroscopic information gathered in the experiments will be compared with the results of shell model calculations performed in the extended sdpf configuration space. Particular attention will be paid to the microscopic structure of the 1p-1h excitation in the ^{45}Ti nucleus, where, at high spins, a structure corresponding to the T=0 band in the neighboring N=Z=23 ^{46}V nucleus seems to preserve a large degree of deformation.

Perspectives of extending the experimental and theoretical investigations to highly deformed collective bands in the heavier A ~ 60 mass region will be discussed.

[1] W. Męczyński et al., Nucl. Instrum. Methods Phys. Res. A 580, 1310 (2007).
[2] P. Bednarczyk et al., Eur. Phys. J. A 2, 157 (1998).

STUDY OF ISOSPIN-SYMMETRY BREAKING IN THE $f_{7/2}$ SHELL USING KNOCKOUT REACTIONS

Michael Bentley, University of York

invited

The approximate charge symmetry and charge independence of the nuclear force results in striking symmetries in nuclear behavior between isobaric analogue states (IAS) - states of the same isospin quantum number in a set of nuclei of the same total number of nucleons (an isobaric multiplet). The Coulomb force breaks this symmetry and is the dominating factor in producing the large shifts in absolute binding energy between IAS. The very small differences in excitation energy between the IAS can then be interpreted in terms of Coulomb, and other isospin-non-conserving, effects. The analysis of these energy differences has been shown to be a remarkably sensitive probe of nuclear structure effects as well as providing stringent tests of state-of-the-art shell-model calculations (e.g. [1,2,3]).

New techniques have been applied in the last few years to access excited states in isobaric multiplets of larger isospin – through spectroscopic studies of proton-rich nuclei heading towards the proton drip-line. These techniques include recoil-beta tagging [4,5], decay spectroscopy of isomeric states populated in fragmentation reactions (e.g. [6]) and mirrored double fragmentation reactions using relativistic beams [7]. These latter studies, performed at the NSCL facility, populated isobaric analogue states in isobaric multiplets through "mirrored" knockout reactions.. This has allowed examination, for the first time, of excited states of T_z = –3/2 and –2 nuclei in the fp shell, and the first ever excited states in any T_z = –2 above 2^+. Important new information on isospin-breaking effects has been extracted through comparison with the analogue states in the T_z = +3/2 and +2 nuclei – in particular, the effect and influence of non-Coulomb isospin-breaking effects (e.g. the J=2 anomaly). We take the opportunity, in this presentation, to draw together all the existing data on the J=2 anomaly, to assess the status of this controversial result. The direct nature of the knockout reaction provides a test of recently developed direct two-nucleon knockout calculations [8,9]. We also present new results on the odd-odd T_z = –1 nucleus ^{44}V [10] with particular emphasis on isospin-symmetry breaking in E1 transition strengths.

[1] D. D. Warner, M. A. Bentley and P. Van Isacker. Nature Physics 2, 311 (2006).
[2] S. M. Lenzi and M. A. Bentley, Prog. Part. Nucl. Phys. 59, 497 (2007).
[3] J. Ekman et al., Mod. Phys. Lett. A 20, 2977 (2005).
[4] A. N. Steer et al., Nucl. Instr. and Methods A 565, 630 (2006).
[5] B. S. Nara Singh et al., Phys. Rev. C 75, 061301 (2007).
[6] D. Rudolph et al., Phys. Rev. C 78, 021301 (2008).
[7] J. R. Brown et al., Phys. Rev. C 80, 011306 (2009).
[8] J. A. Tostevin, Eur. Phys. J. Special Topics 150, 67 (2007).
[9] E. C. Simpson et al., Phys. Rev. Lett. 102, 132502 (2009).
[10] M. J. Taylor et al., Phys. Rev. C 84, 064319 (2011).

BBN AND STELLAR NUCLEOSYNTHESIS FROM DIRECT REACTIONS

Carlos Bertulani, Texas A&M University-Commerce

invited

Accurate nuclear reaction rates are needed for primordial nucleosynthesis and hydrostatic burning in stars. The relevant reactions are extremely difficult to measure directly in the laboratory at the small astrophysical energies. Direct reactions have been developed and applied to extract low-energy astrophysical S-factors. I will discuss the major theoretical challenges in extracting quantities of astrophysical interest from direct reactions at the newly existing or under-construction radioactive beam facilities.

DETERMINATION OF CHARGE RADII OF ^{74}Rb AND OTHER PROTON-RICH NUCLEI

Jonathan Billowes, University of Manchester

invited

The measurement of optical isotope shifts offers the only practical way of determining the nuclear charge radii of short-lived isotopes. For nuclides near the proton drip line the measured charge radii are very sensitive to changes in the valence proton wavefunctions. The current status of measurements will be reviewed, particularly for nuclides on the N=Z line above Z=20.

The more recent work on the Rb-74 charge radius was motivated by the interest in testing the unitarity of the Cabbibo-Kobayashi-Maskawa (CKM) matrix which describes the mixing between quarks. A breakdown of the unitarity condition would point to new physics beyond the Standard Model. The most precise value of the up-down quark matrix mixing element is derived from superallowed (0^+ to 0^+) beta decay rates but corrections are necessary. One of these corrections, the isospin symmetry breaking term, requires the mean-square charge radius to help pin down its value. Rb-74 is the heaviest superallowed decay system available for measurement. Attention is now turning to improving the precision of Ga-62 parameters. The status of both measurements will be discussed.

REACTION DYNAMICS AND NUCLEAR STRUCTURE OF MODERATELY NEUTRON-RICH Ne ISOTOPES BY HEAVY ION REACTIONS

Simone Bottoni, University of Milano and INFN, Italy

seminar

Heavy ions play an important role in the study of nuclear reaction mechanisms and nuclear structure. In particular, multi-nucleon transfer reactions allow to investigate the properties of exotic systems, moving away from the valley of stability . A key instrument for these type of studies is the combination of a large acceptance magnetic spectrometer with a high efficiency and a high resolution multi-detector array for γ spectroscopy, since it allows to perform both reaction dynamics and nuclear structure studies of weakly populated channels.

In this work, the heavy ion reaction ^{22}Ne + ^{208}Pb at 128 MeV beam energy is discussed. The experiment has been performed at Laboratori Nazionali di Legnaro of INFN using the PRISMA-CLARA apparatus. The analysis focuses on the study of particle-γ coincidences aiming at the investigation of reaction mechanisms and nuclear structure properties of neutron reach Ne isotopes and neighbouring nuclei. Elastic, inelastic and one nucleon transfer cross sections have been measured and angular distributions have been studied. The data are compared with semiclassical calculations, performed with the code GRAZING and with DWBA predictions obtained with the code PTOLEMY. Global agreement between experiment and theory is obtained. In particular, the angular distribution of the 2^+ state of ^{22}Ne has been analysed by DWBA and a similar calculation has been performed for the unstable ^{24}Ne nucleus, using existing data from the reaction ^{24}Ne + ^{208}Pb at 182 MeV of bombarding energy (measured at SPIRAL with the VAMOS-EXOGAM setup). In both cases the theoretical model gives a good reproduction of the experiment, pointing to a strong reduction of the β2C charge deformation parameter in ^{24}Ne. This follows the trend predicted for the evolution of the quadrupole deformation along the Ne isotopic chain and calls for additional experimental investigation on the collectivity in ^{24}Ne, a nucleus of key importance for understanding the evolution of shell gaps in light systems.

The present work demonstrate the validity of heavy ion reaction studies for both dynamics and nuclear structure studies, providing a fruitful method which could be further exploited in the future for the investigation of very exotic species.

THE GAMMA DECAY OF HIGH LYING STATES WITH INELASTIC SCATTERING OF ^{17}O AND WITH AGATA

Angela Bracco, University of Milano and INFN

invited

The gamma decay from high-lying states in ^{208}Pb populated with inelastic scattering of ^{17}O has been measured using the AGATA set up. The excitation of few states in the region of the pygmy resonance was possible. Comparison of the present results with data obtained using other probes will be made. Interesting is the comparison with the results obtained with inelastic scattering of alpha particles. The response of AGATA to high energy gamma-rays from nuclei with high velocity will be also presented. Ongoing and future work on the gamma decay of the giant quadrupole resonance also in other nuclei will be briefly presented.

PROSPECTS FOR SUPERHEAVY NUCLEI WITH $Z \geq 128$

Wojciech Brodziński, NCBJ Świerk

seminar

Wojciech Brodziński, Janusz Skalski
NCBJ Warsaw

We study limits of nuclear chart for $Z \geq 128$ by both micro-macro and Hartree-Fock-BCS methods. Triaxial configurations turn out crucial for stability against fission in this region and we calculate appropriate energy landscapes. An interplay between macroscopic and shell-correction patterns provides sufficient barriers only for selected Z and N combinations while most nuclei are predicted unstable.

NEUTRON MATTER FROM LOW TO HIGH DENSITIES

Joseph Carlson, Los Alamos National Laboratory

invited

We review understanding of neutron matter from the lowest to the highest densities. At very low densities, neutron matter is a very strongly-paired superfluid, and can be compared to theory and experiment for cold atoms. Recently, we have determined that the equation of state is universal not only for zero effective range, but for finite but small effective range as well. This should allow cold atom experiments to more closely mimic neutron matter.

At higher densities, neutron matter becomes more repulsive very quickly. Part of this repulsion is connected to the three-neutron interaction. The recent observation of a two solar mass neutron star puts strong constraints on the possible mass-radius relationships for neutron stars. We compare recent results for the neutron matter equation of state with mass-radius relationships extracted from observations of neutron stars.

LIFETIME MEASUREMENTS OF Zn ISOTOPES AROUND N = 40
Igor Celikovic, GANIL

seminar

I. Čeliković 1,2, A. Dijon 1, E. Clément 1, G. de France 1, P. Van Isacker 1, J. Ljungvall 3, C. Franzen 4, G. Georgiev 3, A. Görgen 5, A. Gottardo 6, M. Hackstein 4, T. W. Hagen 5, C. Louchart 7, P. Napiorkowski 8, A. Obertelli 7, F. Recchia 9, W. Rother 4, S. Siem 5, B. Sulignano 7, P. Ujić 1,2, J. J. Valiente-Dobón 6 and M. Zielińska 7

1 GANIL, CEA/DSM-CNRS/IN2P3, BP 55027, 14076 Caen, France

2 Institute of Nuclear Sciences “Vinča”, University of Belgrade, 11 000 Belgrade, Serbia

3 CSNSM, CNRS/IN2P3, 91400 Orsay, France

4 Institut für Kernphysik, Universität zu Köln, 50937 Köln, Germany

5 Department of Physics, University of Oslo, 0316 Oslo, Norway

6 LNL (INFN), Laboratori Nazionali di Legnaro, 35020 Legnaro, Italy

7 CEA Saclay, IRFU, SPHN, 91191 Gif-sur-Yvette, France

8 Heavy Ion Laboratory, Warsaw University, 02-097 Warsaw, Poland

9 Dipartimentito di Fisica dell’Università and INFN, 35131 Padova, Italy

The region located in the immediate neighborhood of ^{68}Ni has attracted much attention in the last years. This is because some of its properties reveal a “magic” character while others do not. One particularly interesting aspect is the rapid structure evolution in this area. Indeed, removing two protons from the closed shell at Z=28 leads to a rapid onset of collectivity in n-rich Fe isotopes [1,2] toward N=40. On the other hand, when pairs of protons are added (leading to Zn, Ge and Se isotopes) a sudden decrease of the first 2^+ states is observed, which is accompanied by an increase of the associated B(E2) transition probabilities [3]. Similarly, adding neutrons beyond the N=40 shell (i.e. into the $1g_{9/2}$ shell) leads to an increased collectivity and to an interplay between collective and single particle degrees of freedom. These rapid changes indicate complex structures and make of this region an ideal case for testing theoretical calculations.

In this context, we have measured lifetimes of the yrast states in the Zn isotopes around N=40 using the Recoil Distance Doppler-Shift method. The nuclei of interest were populated in deep-inelastic reactions induced by a ^{238}U beam at an energy of 6.8 AMeV impinging on an 800 μg/cm^2 ^{70}Zn target. The target-like reaction products were unambiguously identified on an event-by-event basis in the detection system of the large-acceptance VAMOS spectrometer, while Doppler-shifted gamma rays were detected with the EXOGAM array. The lifetimes of the $^{69-72}$Zn isotopes were extracted from two target-degrader distances. New transitions have also been identified and the $E(4^+)/E(2^+)$ and $B(E2, 4^+ \rightarrow 2^+)$ / $B(E2, 2^+ \rightarrow 0^+)$ ratios give a qualitative idea of the collective properties characterizing low-energy nuclear structure in the Zn isotopes.

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SEARCH FOR INTRUDER STATES IN ^{68}Ni AND ^{66,67}Co*

Christopher Chiara, University of Maryland and Argonne National Laboratory

seminar

C. J. Chiara 1,2, W. B. Walters 1, M. Albers 2, M. Alcorta 2, P. F. Bertone 2, M. P. Carpenter 2, C. R. Hoffman 2, R. V. F. Janssens 2, T. Lauritsen 2, A. M. Rogers 2, D. Seweryniak 2, S. Zhu 2, F. G. Kondev 2, R. Broda 3, B. Fornal 3, L. Iskra 3, W. Królas 3, T. Pawlat 3, J. Wrzesinski 3, N. Larson 4, S. N. Liddick 4, C. Prokop 4, S. Suchyta 4

1 University of Maryland, College Park MD 20742, USA

2 Argonne National Laboratory, Argonne IL 60439, USA

3 Institute of Nuclear Physics PAN, Kraków, Poland

4 National Superconducting Cyclotron Laboratory and Michigan State University, East Lansing MI 48824, USA

In the ^{68}Ni region, competition between states associated with near-spherical shapes and with deformed proton-intruder configurations, which results in distinctive isomers, has been proposed recently for ^{64,66}Mn [1], ^{66,67}Co [2-3], and ^{68}Ni [4]. In ^{66}Co, two 1^+ states below 1 MeV were identified and attributed to spherical and deformed intruder configurations [2]; in ^{67}Co, observed $1/2^-$, $3/2^-$, and $5/2^-$ levels were suggested to be low-lying members of a collective $K^\pi = 1/2^-$ band (of proton $p_{3/2}$ intruder origin) amid the spherical states [3]; and the proposed isomer in ^{68}Ni was attributed to a proton 2p2h intruder 0^+ state [4]. The intruder nature of these states was not confirmed, however. Doing so would provide valuable input for tuning the single-particle energies and interactions needed for large-scale shell-model calculations of nuclei requiring the full $fpg_{9/2}$ (or even larger) model space, particularly addressing excitations across the Z=28 shell gap.

Deep-inelastic reactions between a 440-MeV ^{70}Zn beam and thick ^{208}Pb and ^{238}U targets were studied with Gammasphere at ATLAS. The aim was to search for evidence at higher spins supporting the assignment of intruder configurations for low-lying states in ^{66,67}Co and to seek prompt gamma rays feeding the proposed isomeric 0^+ state in ^{68}Ni. Beam timing of one pulse every ~410 ns allowed the data to be separated into prompt and delayed time regions with which gamma-ray coincidences above, across, and below isomers could be examined. Furthermore, cross-coincidences between the beam-like and target-like reaction products are observable in combinations of prompt/delay gating in our data. In this way, the level schemes of ^{66,67}Co can be extended to higher spins despite a lack of known high-spin coincidences within the Co nuclei themselves, and sensitivity to isomers in ^{68}Ni permits examination of the proposed intruder 0^+ state. No evidence of the latter isomer was found. Results of this search will be presented.

* Supported in part by the US DoE, Office of Nuclear Physics, under Grant No. DE-FG02-94-ER40834 and Contract No. DE-AC02-06CH11357.

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GAMMA-DECAY OF THE GDR IN THE GEMINI++ CODE
Michał Ciemała, IFJ PAN Kraków

seminar

M. Ciemała 1, M. Kmiecik 1, A. Maj 1, K. Mazurek 1, R. Charity 2, D. Mancusi 3
1 IFJ PAN Krakow, Poland
2 Washington University, St. Louis, USA
3 CEA Saclay, France

The GEMINI++ simulation code [1] has been extensively used for the description of charged particle decay and fission fragment emission following the heavy-ion fusion-reactions. In this paper we report on enhancing the capabilities of this code by adding the possibility of emission of high-energy gamma rays from the Giant Dipole Resonance (GDR).

This new feature, combined with experimental detector positions filter of simulated results, allows for comparison of charged particle and high-energy gamma-ray spectra with the experimental results.

This code was used to describe the experimental results for the decay of ^{88}Mo compound nucleus, measured using the combined HECTOR and GARFIELD arrays [2]. The hot rotating ^{88}Mo compound nucleus was produced in the reaction of 300, 450 and 600 ^{48}Ti beam impinging on ^{40}Ca target, at 125, 194 and 260 MeV excitation energies rsp.

The calculated charged particle spectra, filtered by the experimental conditions, agree quite well with the experimental data. Simultaneously obtained spectra of high-energy gamma-rays were also consisted with the measured ones, and allowed to fit the GDR parameters.

This shows a satisfactory performance of the modified GEMINI++ code of describing the decay of compound nucleus at very high excitation energies, up to 260 MeV.

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BIG BANG NUCLEOSYNTHESIS
Alain Coc, CSNSM Orsay

invited

Primordial nucleosynthesis (or BBN) is one of the three observational evidences for the Big-Bang model. There is indeed a good overall agreement between primordial abundances of D, ^{3}He, ^{4}He and ^{7}Li either deduced from observation or primordial nucleosynthesis calculations. However, there remains a tantalizing discrepancy of a factor of 3-5 between the primordial ^{7}Li abundances either calculated or deduced from observations. Solutions to this problem have been proposed, involving non standard models of the Big-Bang or stellar physics, but first, possible nuclear physics solutions have to be investigated.

Nuclear reactions, candidates for the destruction of ^{7}Be/^{7}Li, have been proposed and nuclear physics experiments have been (or are being) conducted to determine their cross-sections. An additional source of neutrons would alleviate the lithium problem by destroying ^{7}Be, as shown by the unexpected sensitivity of ^{7}Li production to the n(p, γ)d reaction. Such an effect suggest to extend the network in search of other unexpected effects on ^{7}Li and in addition explore ^{6}Li, Be, B and CNO BBN production and associated uncertainties. CNO production in BBN could affect the evolution of the very first stars but its calculation relies on hundreds of thermonuclear reaction rates including many for which very little experimental data is available. We extended our network to over 400 reactions and pointed out the few uncertain reaction rates that can have a significant impact on BBN LiBeB and CNO production.

THE ANN MODEL OF β^--DECAY HALF-LIVES OF NUCLEI IN THE CRUST OF NEUTRON STARS

Nikolaos Costiris, University of Athens

seminar

N. J. Costiris 1, E. Mavrommatis 1, K. A. Gernoth 2, J. W. Clark 3
1 Department of Physics, Section of Nuclear & Particle Physics, University of Athens, Greece
2 School of Physics & Astronomy, The University of Manchester, Manchester, U.K.
3 McDonnell Center for the Space Sciences and Dept. of Physics, Washington University, St. Louis, USA

Lately the crust of neutron stars is under intense investigation. Neutron-rich nuclei play a significant role [1]. Assuming nuclear and beta equilibrium (cold catalyzed matter) they determine the composition and properties of the crust. Moreover, neutron star crust under certain conditions is considered one of the possible sites of r-process nucleosynthesis. Since experimental information of the properties of neutron-rich nuclei is still limited, theoretical models are needed. We focus on their β^--decay half-lives ($T\beta^-$). A number of useful approaches to modeling $T\beta^-$ has been proposed and applied. We have developed a statistical global model for the systematics of β^- lifetimes of the ground state of nuclei that decay exclusively by this mode in the form of a fully connected, multilayer feed-forward Artificial Neural Network (ANN) [2] using data from Nubase2003 [3]. Several tests of its performance have been made as reported in Ref. [2]. We have recently checked its predictive performance for the $T\beta^-$ of all neutron-rich nuclides that have been experimentally studied after Nubase2003 has been published. The conclusion is that in predictive performance the ANN model can match or even surpass that of established theoretical and phenomenological approaches based on quantum theory and can therefore provide a valuable complementary tool for explaining β^--decay systematics. In this work we give predictions of the ANN model for the $T\beta^-$ half-lives of neutron-rich nuclides that are considered to be present in the crust of neutron stars built from cold catalyzed matter. We also present some of the results from our study of $T\beta^-$ of nuclei synthesized via the r-process [4] that refer to the crust. A comparison is made of the ANN Tβ- values with available ones from conventional QRPA based approaches [5]. The study of other properties of neutron-rich nuclides relevant to the physics of neutron stars crust with artificial intelligence techniques is in progress.

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A NEW METHOD FOR MEASURING THE NEUTRON-SKIN THICKNESS

Margit Csatlós, ATOMKI Institute of Nuclear Research, Debrecen

seminar

M. Csatlós 1, A. Krasznahorkay 1, L. Stuhl 1, A. Algora 1, J. Gulyás 1, J. Tímár 1, N. Paar 2, D. Vretenar 2 and the R3B and EXEL Collaborations
1 ATOMKI Institute of Nuclear Research, H-4001 Debrecen, Hungary
2 Physics Departement, Faculty of Science, University of Zagreb, Croatia

The neutron skin, is the difference between the neutron and proton root-mean square (rms) radii, which may provide fundamental nuclear structure informations [1]. A precise knowledge of the neutron-skin thickness may constrain the symmetry-energy term of the nuclear equation of state. Neutron-skins in heavy nuclei and the crust of neutron stars are both built from neutron-rich nuclear matter and one-to-one correlations were drawn between the neutron-skin thickness in nuclei and specific properties of neutron stars [2].

In one of our previous works on inelastic α-scattering, excitation of the isovector giant dipole resonance (IVGDR) was used to extract the neutron-skin thickness of nuclei [3]. The cross section of this process depends strongly on the neutron-skin thickness. Another tool, we developed earlier, for studying the neutron-skin thickness, is the excitation of the isovector spin giant dipole resonance (IVSGDR). The L=1 strength of the IVSGDR is sensitive to the neutron-skin thickness [3].

In a recent experiment we performed at GSI Darmstadt in the frame of the R3B collaboration the γ-decay of the anti-analog of the giant dipole resonance (AGDR) was measured. The AGDR was excited in the ^{124}Sn(p, n) reaction in inverse kinematics. The energy of the ^{124}Sn beam was 600 MeV/nucleon. 2 mm and 5 mm thick CH_2 and 2 mm thick C targets were used. This allowed us to subtract the contribution of the C target to yield measured from CH_2 during the analysis. The ejected neutrons were detected by a low energy neutron array (LENA) TOF spectrometer, which was designed and constructed in Debrecen. The energy of de-exciting γ-transitions was measured by six large (3.5”x8”) $LaBr_3$ assembled in Milano. The n-γ coincidence measurements delivered a precise value for the centroid energy of the AGDR.

The difference in excitation energy of the AGDR and isobar analog state (IAS) was also calculated with the fully self-consistent relativistic proton-neutron quasiparticle random phase approximation (pn-RQRPA) as a function of the neutron skin thickness. The theoretical values of the E(AGDR) – E(IAS) show linear decrease with the increase of the neutron skin. By comparing the theoretical E(AGDR) – E(IAS) value with the measured one we could deduce the $\Delta r_{np} = 0.18\pm0.02$ fm for ^{124}Sn. This value is in good agreement with the previous results for ^{124}Sn.

The present method provides a new possibility for measuring neutron skin thickness of very exotic nuclei.

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PHOTOFISSION OF ^{238}U INDUCED BY QUASI-MONOCHROMATIC, COMPTON BACKSCATTERED GAMMA BEAM

Lorant Csige, Ludwig-Maximilans-University Munich

seminar

Using highly brilliant gamma beams, which will be soon available at the MEGa-Ray facility (Livermore, United States) and at ELI-NP (Bucharest, Romania), a new experimental campaign on photofission studies can be envisaged to study extremely deformed nuclear states of the light actinides and their multiple-humped potential energy surface in a highly-selective way. The experimental technique of these studies is based on the observation of transmission resonances in the prompt fission cross section. Transmission resonances appear, when directly populated states in the first minimum energetically coincide with states in the second or in the third potential minimum. The fission decay channel thus can be expressed as a tunneling process of these gateway states through the multiple-humped fission barrier.

So far, mainly light-particle induced nuclear reactions have been performed to study the transmission resonances with charged particle, conversion electron or gamma ray spectroscopy, resulting in a statistical population of the states in the 2nd and 3rd minimum with a very limited probability, leading to typical isomer intensities of 1/sec. Moreover, these measurements suffered from a dominating background from prompt fission. In contrast, by using monochromatic gamma beams, the states in the higher-lying minima can be populated directly with considerably increased probabilities, leading to a much suppressed background and due to the strong spin-selectivity very clean spectra can be measured.

Until now all photofission measurements at sub-barrier energies have been performed with bremsstrahlung photons, where the fission cross-section was folded by the increasing gamma-ray spectrum. Compared to the presently available gamma bandwidth of 200 keV, the soon available improved energy resolution of 1 keV will allow resolving the “isomeric shelf” in the photofission cross-section into underlying predicted individual resonances.

The results of the first, non-bremsstrahlung, exploratory photofission experiment at a Compton backscattered gamma beam facility (HIgS, Duke University, U.S.A.) will be presented. The aim of this demonstration experiment was to search for transmission resonances in the photofission cross-section of ^{238}U at sub-barrier excitation energies down to 4.5 MeV.

DESCRIPTION OF GDR DAMPING IN HIGHLY EXCITED NUCLEI

Nguyen Dinh Dang, RIKEN Nishina Center

invited

The evolution of the giant dipole resonance’s (GDR’s) width and shape as varying temperature and angular momentum is described within the framework of the phonon damping model (PDM), proposed and developed by the author and collaborators.

The PDM generates the damping of GDR through the couplings of GDR to particle-hole (ph) configurations, which cause the quantal width, and to particle-particle (pp) and/or hole-hole (hh) configurations, which cause the thermal width. The quantal width decreases slightly as temperature T increases, whereas the thermal with increases with T and saturates at high T. This leads to an overall increase in the GDR's total width at low and moderate T, and its saturation at high T. At very low T (below 1 MeV) the GDR's width remains nearly constant because of thermal pairing.

The PDM description is compared with the established experimental systematic obtained from heavy-ion fusion and inelastic scattering of light particles on heavy target nuclei, as well as with predictions by other independent theoretical approaches. In a recent development, the PDM has been extended to include the effect of angular momentum and its description is compared with the most recent preliminary experimental results of GDR in hot rotating Mo-88 nucleus. The predictions by PDM and the heavy-ion fusion data are also employed to predict the viscosity of hot medium and heavy nuclei.

PROBING FUNDAMENTAL INTERACTIONS BY AN ELECTROSTATIC ION BEAM TRAP (EIBT)

Anukul Dhal, Weizmann Institute of Science, Israel

seminar

A. Dhal 1, S. Vaintraub 1,2, T. Trivedi 1, O. Aviv 2, T. Hirsh 1,2, M. L. Rappaport 1, D. Melnik 2, O. Heber 1, D. Schwalm 3, D. Zajfman 1, K. Blaum 3, M. Hass 1

1 Weizmann Institute of Science, Rehovot 76100, Israel

2 Soreq Nuclear Research Center, Yavne 81800, Israel

3 Max-Planck-Institut für Kernphysik, D-69117 Heidelberg, Germany

One of the possibilities to study fundamental interactions and the underlying symmetries is via precision measurements of the parameters of beta decay of trapped radioactive atoms and ions. For example, determining the beta-neutrino angular correlation coefficient in a trap can probe the minute experimental signal that originates from possible tensor or scalar terms in the weak interaction, thus probing possible new physics of beyond-the-standard-model nature. For precision measurements of this correlation traps are mandatory for since the recoiling nuclei, subsequent to the beta decay, are at sub-keV energies.

We have embarked to an experimental scheme to establish a novel experimental set-up to study the beta-neutrino correlation by allowing to decay the trapping light radioactive ion beam inside an Electrostatic Ion Beam Trap (EIBT). This method exhibits several advantages compared to other trapping schemes in terms of concept, efficiency and ease of operation. The first nuclide under study is ^{6}He, to be produced using neutron-induced reactions and subsequent ionization in an electron ion beam source/trap (EIBT) for ionization. The $^{6}He^{+}$ radioisotopes will be stored in an electrostatic ion beam trap (EIBT), commonly used in atomic and molecular physics. The entire apparatus has been built at the Weizmann Institute. The method, the present status of the setup and future plans would be discussed during the presentation.

EFFECTIVE THEORY FOR LOW-ENERGY NUCLEAR ENERGY DENSITY FUNCTIONALS

Jacek Dobaczewski, University of Warsaw

invited

Methods based on nuclear energy density functional (EDFs) have already become the standard tool in describing nuclear ground states and low-energy excited states [1,2]. In the present contribution, I will focus on recent developments related to the quest for new-generation functionals that might provide us with increased precision of global description of nuclear data and link low-energy phenomena to ab-initio properties of nuclear matter and nuclear interactions. The main line of generalizations will be in expansions of EDFs in series of higher-order corrections related to derivatives of densities and fields [3]. I will also discuss generalizations of momentum-dependent interactions, like the Skyrme force, to higher orders [4] and derivations of quasilocal higher-order functionals from nonlocal ones [5]. Finally, I will present ideas related to introducing new functionals based on regularized zero-range forces [6].

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ELECTRIC TRANSITIONS IN HYPOTHETICAL TETRAHEDRAL AND OCTAHEDRAL BANDS

Artur Dobrowolski, Maria Curie Skłodowska University, Lublin

seminar

Within this work we are modeling the electric B(E) transition probabilities between nuclear collective states of well defined transformation properties with respect to the high-rank point symmetry groups, e.g. tetrahedral (Td) or octahedral (O). Particularly these two groups are known to have one- two- and three- dimensional irreducible representations. It implies that in the intrinsic reference frame associated with a nucleus the collective states can be 1-, 2-, 3-times degenerated. However, due to the uniqueness condition (so called, symmetrization of collective states) in the laboratory frame this degeneracy can not be observed. For simplicity we apply the adiabatic separation of vibrational and rotational motions what allows us to construct the full collective solution as the simple product of pure vibrational and pure rotational parts being independently the eigensolutions of vibrational and rotational Hamiltonians.

The vibrational part of a state depending on multipole deformation parameters is constructed as the zero- or one-phonon solution of required parity of the 9-dimensional quadrupole+octupole harmonic oscillator Hamiltonian with the adjustable parameters corresponding to the inverse of the quadrupole and octupole collective potential widths. A reasonable fit of these parameters within the macroscopic-microscopic method based on realistic Woods-Saxon mean-field ensures that the energy values and B(E)'s calculated using these states can stay in good agreement with the experimental data.

The rotational component as function of the Euler angles with given angular momentum contains no free parameters and is given as the appropriate combination of Wigner functions. Obviously, the rotational multiplets have to transform according to the "Td" or "O" group. Both the vibrational and rotational parts are coupled in this way that the full product wave function transforms with respect to the scalar representation of the symmetrization group.

Constructed in this work collective states can produce at this stage a crude estimates of electric transition probabilities for hypothetical collective bands of tetrahedral or octahedral symmetries. Moreover, what is more promising for the future of the TETRANUC project, these solutions can be also considered as the basis in which the collective eigensolutions of more realistic high-rank symmetric Hamiltonians can be developed.

LIFETIME MEASUREMENTS IN NEUTRON-RICH Cu ISOTOPES
Maria Doncel, University of Salamanca

seminar

M. Doncel 1, E. Sahin 2, A. Görgen 3, A. Gadea 4, G. de Angelis 2, B. Quintana 1, J. J. Valiente-Dobón 2, C. Louchart 3, W. Korten 3, M. Albers 5, S. Aydin 6, D. Bazzacco 7, M. Bostan 8, E. Clément 9, L. Corradi 2, A. Dewald 4, G. Duchene 10, M. N. Erduran 8, E. Farnea 7, E. Fioretto 2, G. de France 9, C. Fransen 5, R. Gernhäuser 11, A. Gottardo 2, M. Hackstein 5, T. Huyuk 4, S. Klupp 11, A. Kusoglu 8, S. Lenzi 7, J. Ljungvall 12, S. Lunardi 7, R. Menegazzo 7, D. Mengoni 7, C. Michelagnoli 7, T. Mijatovic 16, G. Montagnoli 7, D. Montanari 2, O. Möller 13, D. R. Napoli 2, A. Obertelli 3, R. Orlandi 14, A. Prieto 1, G. Pollarolo 15, F. Recchia 7, W. Rother 5, M-D Salsac 3, F. Scarlassara 7, M. Schlarb 11, M. Sferrazza 15, P. P. Singh 2, A. Stefanini 2, B. Sulignano 3, S. Szilner 16, C. Ur 7
1 LRI, University of Salamanca, Spain 2 INFN, Laboratori Nazionali di Legnaro, Italy
3 CEA Saclay, IRFU/SPhN, France 4 IFIC, University of Valencia, Spain
5 IKP, University of Köln, Germany 6 University of Aksaray, Turkey
7 Università di Padova and INFN, Padova, Italy
8 Department of Physics, Istanbul University, Turkey
9 GANIL, CEA/DSM-CNRS/IN2P3, Caen, France
10 IPHC, IN2P3/CNRS et Université Louis Pasteur, Strasbourg, France
11 Technische Universität München, Germany
12 CSNSM Orsay, IN2P3/CNRS, Orsay, France
13 Institut für Kernphysik, TU Darmstadt, Darmstadt, Germany
14 IEM - CSIC, Madrid, Spain
15 Dipartimento di Fisica Teorica, Universitá di Torino, Italy
16 Ruder Boskovic Institute, Zagreb, Croatia

We present the results obtained in the experiment: "Lifetime measurements in neutron-rich Cu isotopes" performed at Laboratori Nazionali di Legnaro (Italy). The aim of the experiment has been to measure the lifetime of excited states in neutron-rich nuclei in the region of ^{78}Ni, in particular, in the ^{71}Cu isotope, through the recoil distance Doppler shift method (RDDS) using the AGATA Demonstrator coupled to the PRISMA spectrometer and to the plunger device provided by the University of Cologne. This is the first time this setup has been used together in an experimental measurement. The states have been populated in a multi-nucleon transfer reaction between a ^{76}Ge beam of 577 MeV energy and a ^{238}U target of 1.5 mg/cm^2 together with a 1.4 mg/cm^2 thick Ta backing. The target was mounted together with a Nb degrader foil of 4.2 mg/cm^2 thickness in a compact Plunger device. The projectile-like reaction partners were identified using the PRISMA magnetic spectrometer, which was positioned at 55º with respect to the beam axes, close to the grazing angle, while the gamma rays were detected by the AGATA Demonstrator located at backward angles sensitive to their Doppler shift.

The measured value for the reduced transition probability, obtained through the lifetime determination of the 7/2$^-$ excited sate in ^{71}Cu, is in good agreement with large shell-model theoretical calculations. The results of the work will be discussed in detail at the talk.

SEARCH FOR THE SOUTHERN AND EASTERN BOUNDARIES OF THE ISLAND OF INVERSION

Pieter Doornenbal, RIKEN Nishina Center

seminar

While in the past extensive research focused on the western and northern borderlines of the Island of inversion, a region of neutron rich Ne, Na, and Mg isotopes, in which neutron $f_{7/2}$ states intrude into the sd-shell, only very little is known about the evolution towards the eastern and southern regions. In an attempt to locate these borderlines, very neutron rich secondary beams with proton number Z=10-14 were produced via in-flight separation by the BigRIPS fragment separator of the Radioactive Isotope Beam Factory. The beams were incident on a thick secondary target and reaction products as well as excited states identified via in-beam gamma-ray spectroscopy.

In my presentation I will report on recent results on the very neutron-rich fluorine and magnesium isotopes and discuss their deformation and placement inside or outside of the Island of Inversion. In particular, direct experimental evidence towards an extension to the fluorine isotopes will be presented.

DEEP-INELASTIC REACTIONS AND K-ISOMERS IN NEUTRON-RICH NUCLEI CROSSING THE PERIMETER OF THE A=180-190 DEFORMED REGION

George Dracoulis, Australian National University

invited

The region of deformed nuclei near Z=72 and N=104 is prolific in multi-quasiparticle high-K isomers, formed by combining high-omega orbitals near the proton and neutron Fermi surfaces. Many more are predicted to occur in stable and neutron-rich isotopes but few are accessible by conventional fusion-evaporation reactions. Multi-nucleon transfer or “deep-inelastic” reactions with heavy energetic beams offer an alternative, although non-selective, means of production [1], complementing the broader reach of fragmentation reactions (see, for example Ref. [2]).

We have carried out a series of systematic studies extending, to date, from the well deformed Tm isotopes, through the neutron-rich W and Os region where the nuclei become gamma-soft, to some of the Ir and Au isotopes. The results are from measurements made using 6 MeV per nucleon, pulsed and chopped Xe-136 beams provided by the ATLAS facility at Argonne National Laboratory, incident on a range of enriched targets Gamma-rays were detected with Gammasphere.

I will cover part of the background to the formation of simple, deformed multi-particle isomers in the Hf region, associated questions of K-quantum number purity and dilution, as well as some of the technical aspects of discovery, assignment and characterization.

Selected level schemes and isomers identified in osmium, iridium and gold isotopes [3,4] will then be discussed in the context of the soft tri-axial structures predicted by configuration-constrained potential energy-surface calculations, and also dynamical effects such as oblate alignment [6]. An emerging issue is that very low-lying states associated with the 12^+, $i_{13/2}$ two-neutron-hole configuration are persistently predicted. These could result in long-lived beta-decaying isomers. Prospects for their identification through storage-ring mass measurements [6] will be briefly outlined.

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SYMMETRIES PREDICTED BY THEORY <–> PREDICTIVE POWER OF THEORIES

Jerzy Dudek, University of Strasbourg and IPHC

invited

NEAR-BARRIER NUCLEAR COLLISIONS: FROM COHERENT QUANTUM-SUPERPOSITION TO DISSIPATIVE DYNAMICS

Maurits Evers, Australian National University

invited

M. Evers, D. J. Hinde, M. Dasgupta and D. H. Luong
Department of Nuclear Physics, Research School of Physics and Engineering,
The Australian National University, Canberra, ACT 0200, Australia

Nuclear collisions at energies near the fusion barrier show a range of different phenomena which can affect each other. Excitations of low-lying collective states in the interacting nuclei as well as nucleon transfer leaving the residual nuclei in distinct excited states have been very successfully treated within the coherent quantum coupled-channels framework and lead to excellent agreement with fusion cross section measurements. At higher energies, deep inelastic collisions (DIC) involving multi-nucleon transfer lead to the population of highly excited states in the residual nuclei. These dissipative processes have been linked with the observed suppression of fusion at energies above the barrier [1,2] and cannot be treated within the usual quantum coupled-channels formalism.

We expect in reality a smooth transition from nucleon transfer to low-lying discrete states in sub-barrier collisions to multi-nucleon transfer leading to dissipation in DIC at energies above the barrier. Thus understanding the role of transfer may be a key step towards developing a formalism that correctly describes the suppression of fusion seen both at deep sub-barrier and at above-barrier energies [1,3,4]. Accordingly a renewed interest in transfer has lead to detailed measurements using various reactions with stable and weakly-bound nuclei [5,6,7].

In reactions with stable nuclei, transfer has been shown to lead to high excitation energies in the residual nuclei already at energies below the barrier [8,7]. Furthermore transfer also plays a crucial role in triggering breakup of weakly-bound nuclei, which may affect the probability for complete fusion [6].

Latest measurements performed at the Australian National University on these aspects will be presented. They may hold a key towards developing a model which allows to link dissipative processes such as transfer leading to highly excited states or even breakup, to a coherent quantum description of nuclear collision dynamics.

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RECENT ADVANCES OF LASER SPECTROSCOPY AT ISOLDE

Kieran Flanagan, University of Manchester

invited

The production of rare isotopes at facilities such as ISOLDE is often compromised by the presence of intense isobaric contaminant beams. This has necessitated extensive research and development into cleaner production methods, such as the laser ion source, as well optimization of target materials and design. In a few special cases it has been possible to use these techniques to even produce isomeric beams for spectroscopy and post acceleration. Such selectivity is not possible for all elements and there are still many cases prevented by isobaric contamination. During the last 3 years a new laser spectroscopy experiment CRIS has been established at ISOLDE that aims to produce a more universal method of isotope purification for secondary experiments, such as nuclear spectroscopy. This new technique offers an efficient method for selecting either the ground state or long lived isomeric state.

This talk will report on the successful commissioning of the CRIS beam line and the recent laser spectroscopy results and laser assisted decay spectroscopy.

LIGHT NUCLEI IN THE AB INITIO NO-CORE SHELL MODEL

Christian Forssén, Chalmers University of Technology

invited

The ab initio no-core shell model (NCSM) is a well-established theoretical framework aimed at an exact description of nuclear structure starting from high precision interactions between the nucleons [1]. In the NCSM we consider a system of A point-like, non-relativistic nucleons that interact by realistic inter-nucleon interactions. We consider both semi-phenomenological potentials, as well as more recent chiral interactions. The performance of the NCSM within nuclear-structure physics will be exemplified by showing results from studies of light nuclei [2,3]. In particular, the importance of three-nucleon forces will be highlighted and I will focus on new and valuable insights into the origins of exotic nuclear structure from ab initio methods. Major challenges in the future development of the method will be outlined.

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SUMMARY AND OUTLOOK: THE NEXT 20 YEARS OF NUCLEAR PHYSICS

Sydney Gales, IPN Orsay

invited

BETA-DELAYED NEUTRON EMISSION FROM THE r-PROCESS NUCLEI

Robert Grzywacz, University of Tennessee and ORNL

invited

Beta-delayed neutron emission is a prevalent decay channel for a majority of the very neutron-rich nuclei participating in the r-process. While many nuclear models predict nuclear lifetimes and branching ratios of the r-process nuclei, very little is known experimentally about the energy spectrum of the neutrons from beta-n branches that provide direct information about the unbound states populated through beta decay. These measurements constitute a better test of nuclear models than simply using lifetimes and branching ratios.

The new neutron detector arrays Versatile Array of Neutron Detectors at Low Energy (VANDLE) [1] and 3Hen were commissioned at the Holifield Radioactive Ion Beam Facility (HRIBF). The HRIBF uses proton-induced fission to produce unique, intense and high isotopic purity beams of neutron-rich fission fragments. We have measured neutron energy spectra in key regions of the nuclear chart: near the shell closures at ^{78}Ni and ^{132}Sn, and for the most deformed nuclei at Z=37. Many of these nuclei lie directly on the r-process path [1]. Of the 29 beta-n emitters studied, only 4 relatively long-lived isotopes were previously measured. For some of the most exotic nuclei, narrow and intense peaks in the neutron energy distribution indicate the presence of resonances, which are most likely signatures of the excitation of deeply bound "core" states. Preliminary results from the most prominent measurements will be presented.

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OBSERVATION OF LARGE ORBITAL SCISSORS STRENGTH IN ACTINIDES
Magne Guttormsen, University of Oslo

seminar

M. Guttormsen 1, L. A. Bernstein 2, A. Bürger 1, F. Gunsing 3, A. Görgen 1, A. C. Larsen 1, T. Renstrøm 1, S. Siem 1, M. Wiedeking 4, T. Wiborg Hagen 1, and J. N. Wilson 5
1 Department of Physics, University of Oslo, N-0316 Oslo, Norway
2 Lawrence Livermore National Laboratory, 7000 East Avenue, Livermore, CA 94550, USA
3 CEA Saclay, DSM/Irfu, F-91191 Gif-sur-Yvette, France
4 iThemba LABS, P.O. Box 722, 7129 Somerset West, South Africa
5 Institut de Physique Nucleaire d'Orsay, 91406 Orsay, France

The orbital M1-scissors resonance has been measured for the first time in the quasi-continuum of actinides. Particle-γ coincidences are recorded with deuteron and ^{3}He induced reactions on ^{232}Th at the Oslo cyclotron laboratory. The outgoing charge particles were measured in backward angles with the SiRi particle-telescope system. The γ–ray spectra were recorded for various excitation energies with the CACTUS system consisting of 28 5" x 5" NaI detectors.

The residual nuclei ^{231,232,233}Th and ^{232,233}Pa show an unexpectedly strong integrated γ-ray strength of B(M1) = 11-15 μ^2 in the 1.0-3.5 MeV γ-ray energy region. The results are compared with sum-rule estimates. The presence of the strong scissors resonance has significant impact on (n, γ) cross sections.

STUDY OF THE ^{42}Ca NUCLEAR STRUCTURE USING AGATA AND EAGLE SPECTROMETERS: RECENT RESULTS FROM THE COULOMB EXCITATION OF THE ^{42}Ca EXPERIMENT
Katarzyna Hadyńska-Klęk, Institute of Experimental Physics and Heavy Ion Laboratory, University of Warsaw

seminar

K. Hadyńska-Klęk 1,2, P. Napiorkowski 2, A. Maj 3, F. Azaiez 4, J. J. Valiente-Dobon 5 on behalf of the AGATA and EAGLE collaborations
1 Institute of Experimental Physics University of Warsaw, Poland
2 Heavy Ion Laboratory, University of Warsaw, Poland
3 H. Niewodniczanski Institute of Nuclear Physics, Polish Academy of Sciences, Krakow
4 Institute of Nuclear Physics, Orsay, France
5 INFN Laboratori Nazionali di Legnaro, Italy

The Coulomb excitation experiment to study electromagnetic properties of low-lying states in ^{42}Ca with a focus on a presumably super-deformed band was performed at the Laboratori Nazionali di Legnaro in Italy in 2010 using the γ-ray spectrometer AGATA Demonstrator coupled to the DANTE position sensitive charged particle detector array. Gamma-rays from Coulomb excited ^{42}Ca nuclei were measured in coincidence with calcium projectiles back-scattered on the ^{208}Pb target and detected by three position-sensitive MCP detectors forming the DANTE array. The AGATA Demonstrator spectrometer consisting of three clusters was used for the first time in a nuclear physics experiment.

In the present experiment the transitions deexciting the presumably super-deformed band were observed for the first time following the Coulomb excitation. Low lying states in the yrast band were also populated via multiple COULEX. In both the ground state band and the deformed band it was possible to Coulomb excite levels of spin up to 4^+. Unexpectedly, two unknown γ lines were observed in the spectrum at energies 2048 and 376 keV. The 2048 keV transition was particularly strong and clearly visible. The widths of these two γ-ray lines indicated that they could be emitted from the ^{42}Ca scattered projectile.

To resolve ambiguities concerning the electromagnetic structure of ^{42}Ca, a dedicated fusion-evaporation experiment aiming at investigation of the low spin level scheme in ^{42}Ca was performed at Heavy Ion Laboratory, University of Warsaw, using the EAGLE-II spectrometer in the configuration with 16 HPGe detectors in anti-Compton shielding. A ^{32}S beam with the energy of 86 MeV bombarded a very thick (> 50 mg/cm^2) ^{12}C target. ^{42}Ca was populated in the 2p reaction channel, being one of the strongest channels observed. In addition, states in ^{42}Ca, including the 2424 keV level, were populated in the beta decay of ^{42}Sc, a product of the pn channel. In the off-beam analysis it was possible to observe the 2424 and 899 keV transitions de-exciting the 2424 keV state. In γ-γ matrix, however, there was no sign of the 376 keV transition neither in coincidence with the 2048 keV γ-ray, nor with the 328 keV transition de-exciting the 4^+ (2752 keV) state to the 2^+ (2424 keV).

Preliminary results of the data analysis of both experiments will be discussed.

IN-MEDIUM SIMILARITY RENORMALIZATION GROUP FOR FINITE NUCLEI

Heiko Hergert, Ohio State University

seminar

The Similarity Renormalization Group (SRG) has emerged as a powerful and versatile tool for many-body physics. So far, its primary application in the framework of the nuclear many-body problem is the derivation of effective interactions from underlying realistic NN (and recently 3N) interactions.

A recent development is the In-Medium SRG, where the Hamiltonian is evolved directly in the A-body system (i.e., at finite density). By a suitable choice of generator the ground state is decoupled from particle-hole excitations, and the IMSRG can be considered an Ab-Initio technique for solving the many-body problem. The modest computational effort makes calculations for medium-mass and heavy nuclei feasible.

I will give a brief overview of the method, present results for closed-shell nuclei with NN and 3N interactions, and discuss an effort to generalize the IM-SRG formalism for arbitrary reference states, with the aim of extending our calculations to open-shell nuclei.

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NUCLEAR STRUCTURE, NEUTRON STARS, AND GRAVITATIONAL WAVES

Charles Horowitz, Indiana University

invited

The PREX experiment at Jefferson Laboratory uses parity violating electron scattering to determine the neutron radius of ^{208}Pb in a way that is free from most strong interaction uncertainties. We present first results and discuss future plans including a follow up measurement on ^{48}Ca. The neutron radius constrains the density dependence of the symmetry energy and has important implications for the structure of neutron stars. We review recent observations of neutron star masses and radii and discuss their implications for the equation of state of neutron rich matter. A new energy functional is directly fitted to both properties of finite nuclei and to neutron star masses and radii. This helps constrain neutron matter properties. Predictions of the functional for the drip lines and for very neutron rich heavy nuclei will be presented. Finally we anticipate soon the historic discovery of gravity waves with the operation of the large detectors Advanced LIGO and Advanced VIRGO. We introduce gravity waves and discuss how they probe neutron rich dense matter.

HIGH SENIORITY EXCITATIONS IN NEUTRON-RICH Sn ISOTOPES

Łukasz Iskra, IFJ PAN Kraków

seminar

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

1 Institute of Nuclear Physics PAN, Kraków, Poland

2 Argonne National Laboratory, Illinois, USA

3 University of Maryland, College Park, Maryland, USA

The seniority ν=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. 1,2,3]. The B(E2) values extracted for isomeric transitions reflect in a rather striking way the filling of the $h_{11/2}$ neutron orbital and indicate 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 recently identified structure in ^{128}Sn [4]. In this analysis, complementary data were used from three separate coincidence measurements performed at Argonne National Laboratory with the ATLAS superconducting linear accelerator and the Gammasphere detector array. In the ^{48}Ca + ^{238}U, and ^{48}Ca + ^{208}Pb experiments, the $^{118-128}$Sn isotopes were produced in the fusion-fission reactions, whereas the fission of the ^{238}U target nuclei populated them predominantly in the third selected colliding system: ^{64}Ni + ^{238}U.

Gamma rays located above the known isomers were identified using delayed coincidence techniques in all Sn isotopes with isomeric half-lives shorter than 10 μsec. For long-lived isomers, the analysis of cross-coincidences with gamma rays from respective complementary fission fragments provided the required identification. In this analysis, the observed isotopic distributions of complementary Sm and Te nuclei in reactions with the ^{48}Ca beam on the ^{238}U and ^{208}Pb targets, respectively, were very broad and indicated high numbers (15 and 12, respectively) of evaporated neutrons. Nevertheless, the careful examination of the cross-coincidence events allowed to place unambiguously the most intense higher-lying gamma transitions in isotopes having long-lived isomers.

Gamma transitions identified in ^{118}Sn did not exhibit any delayed (< 3 ns) component and established two separate structures of levels located above the 7^- and 10^+ isomers. On the other hand, in all other even neutron-rich Sn isotopes, strongly populated higher-lying isomers were identified with respective half-lives of 30(3), 143(14), 260(30), 114(12) and 220(30) ns in ^{120}Sn, ^{122}Sn, ^{124}Sn, ^{126}Sn and ^{128}Sn of which only the ^{128}Sn isomer was observed before [4]. The delayed coincidences exploiting the existence of these isomers confirmed the earlier cross-coincidence identifications, and these were further solidified by the observed isomeric gamma-decay branches to the known 7^- and/or 8^+ states in each isotope. These isomeric decays proceed mainly through cascades of three intense gamma transitions to the 10^+ isomers and the competing branches connect to 7^- and 8^+ levels. These weaker branches clearly assign a $I^\pi = 15^-$ spin-parity to all of the new isomers, similarly to the assignment proposed in the ^{128}Sn case. The systematic of the extracted B(E2) values for the $15^- \rightarrow 13^-$ isomeric transitions closely follows the behavior of the B(E2) values established earlier for the 10^+ isomers.

Apart from the 15^- isomers, strongly populated cascades of three prompt transitions observed in all nuclei establish the apparent location of 12^+, 14^+ and 16^+ states of seniority ν=4 excitations involving four $h_{11/2}$ neutrons. The observed decay branches from 16^+ states which feed the 15^- isomers support such assignments. Delayed, double-gated coincidences with respective transitions located below the 15^- isomers served to identify higher-lying gamma transitions which precede in time isomeric decay in each nucleus. The analysis of prompt coincidences for gamma-ray events selected by appropriate delayed transition gates revealed a rich structure of levels located above the isomers and corresponding to excitations with seniority higher than ν=4.

The analysis established also a complex structure of states located in odd-A Sn isotopes above the $27/2^-$ isomers. As this part of the study is still in progress, the present contribution will summarize only the results obtained for even Sn isotopes.

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ULTRA-HIGH RESOLUTION GAMMA-RAY SPECTROSCOPY SEARCH FOR SYMMETRIES

Michael Jentschel, Institut Laue-Langevin Grenoble

invited

The Institut Laue-Langevin is operating crystal spectrometers yielding the highest possible resolution power for gamma rays available today. The gamma rays are obtained from samples irradiated in a through going tangential beam tube in a flux of 5 x 10^{14} neutrons / cm^2 s. The gamma rays are observed after single or double neutron capture of stable isotopes yielding access to a large number of nuclear excitations. The spectrometers are operated in two modes: double flat crystal or single bent crystal geometries.

The double flat crystal geometry yields a resolving power of $\Delta E/E = 10^{-6}$ and the possibility of intrinsic absolute energy calibration with an uncertainty of 10^{-7} independent of the gamma ray energy. This has allowed developing the Gamma Ray Induced Doppler broadening technique for the measurement of nuclear state lifetimes in the range of femto- to picoseconds. The technique uses the fact that secondary gamma rays are Doppler broadened by the recoil induced by a primary gamma ray emission if the lifetime of the intermediate nuclear state is sufficiently short. The extra-ordinary resolving power of the instruments comes with a rather small effective solid angle of only 10-11 deg. This forces the use of massive sample materials of several grams mass and limits therefore in most cases the use of the instrument to natural target material only. The curved crystal spectrometers profit from the focusing character of the crystals, which yields a four orders of magnitude better solid angle. Therefore the use of very small sample masses of a few tens of mg only is possible. On the other hand the resolving power is energy dependent, $\Delta E/E = 10^{-3}$ E [MeV], which makes the instrument an interesting tool for detailed spectroscopy studies below 1 MeV. Further instruments yield an outstanding dynamic range of about 10^6, which is by one order of magnitude higher compared to all other currently used high resolution detector systems. This property is in particular important for search of weak transitions.

The instruments were successfully used in the last decade for the investigation of a number of nuclear symmetries. The talk will shortly review this activity. Further, a more detailed explanation of currently ongoing studies on negative parity bands in the Gadolinium region will be given. In particular results relevant to the search for tetrahedral symmetry in these nuclei will be shown.

TRAP-ASSISTED NUCLEAR SPECTROSCOPY

Ari Jokinen, University of Jyväskylä

invited

Ion trap techniques have traditionally been used for precision studies of fundamental physics and metrology. During recent years these techniques have become also precision tools for nuclear spectroscopy and related applications. In this presentation, basic principles will be described with various physics examples ranging from sensitive nuclear spectroscopic studies to applications related of nuclear technology and safety.

Decay spectroscopy of fission products suffers often from isobaric contamination due to more abundant, less exotic species in the same mass chain. Ion traps can easily provide mass resolving power exceeding 10 000 allowing separation of isobars. With new techniques, like Ramsey cleaning developed at JYFLTRAP, even higher resolving powers can be obtained, allowing separation of isomeric states in many cases. In this presentation, examples of such studies will be given. In precision studies of fundamental physics, like decay studies of super allowed beta decay, the highest purity with high enough statistics is usually needed. For such studies, a multiple injection and cleaning method has been developed. Physics examples will be illustrated. Precision mass measurements over large range of N and Z can be used as complementary information for spectroscopic studies. In this presentation examples of nuclear structure information obtained through atomic mass measurement will be given.

QUADRUPOLE MOMENT AND g-FACTOR MEASUREMENTS OF THE ISOMERIC STATES IN ^{128,129}Ba
Jasmeet Kaur, Panjab University, India

seminar

Jasmeet Kaur 1, V. Kumar 3, R. Kumar 2, A. K. Bhati 1, R. K. Bhowmik 2
1 Centre of Advanced Study in Physics, Panjab University, Chandigarh, India
2 Inter University Accelerator Centre, Aruna Asaf Ali Marg, New Delhi, India
3 Centre for Medical Physics, Panjab University, Chandigarh, India

The transitional nuclei in the A~130 mass region with few valence nucleons near shell closure offer to study rich variety of shapes and structures due to interplay of various multi quasi-particle excitations and the collective behavior of underlying core. Both protons and neutrons occupy the unique parity $h_{11/2}$ intruder orbitals which play an important role in shape driving properties of neutrons and protons [1,2]. Thus, neutron-deficient Ba isotopes are important for investigating the phenomenon of shape coexistence and have been the subject of much experimental and theoretical interest. The electromagnetic moment measurements give insight into the collective and single particle structures of nuclear states.

The isomeric states, 7^- in ^{128}Ba and $9/2^-$ and $23/2^+$ in ^{129}Ba, have been excited through the ^{120}Sn(^{12}C, xn)^{128,129}Ba nuclear reactions. The lifetime of the isomeric states is well suited to employ the time-differential perturbed angular distribution technique to extract the ratio of the quadrupole moments and the g-factors of the isomeric states. Most of the states in these nuclei are known to be neutron states and thus have small g-factors. The recoils are implanted in iron and the internal magnetic field at Ba in iron was calibrated using the known g factor in ^{132}Ba, i.e., $g(10^+) = -0.159(5)$ [3]. The g-factor of 7^- isomeric state in ^{128}Ba is at variance with the earlier results. The results are compared with the particle - triaxial rotor calculations and the evolution of nuclear shape in Ba nuclei is discussed.

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TRANSFER REACTIONS AND THE STRUCTURE OF NEUTRON-RICH NUCLEI
Benjamin Kay, University of York

invited

Probing the structure of short-lived nuclei with single-nucleon transfer reactions is a key focus of existing and emerging radioactive-ion-beam facilities. At Argonne National Laboratory, the ATLAS accelerator provides light neutron-rich beams through the in-flight production method [1] and shortly the CARIBU facility, re-accelerating Cf fission fragments [2]. Studying transfer reactions in this scenario implies they are performed in inverse kinematics where conventional approaches typically suffer from poor resolution due to significant kinematic compression e.g. [3]. The HELIOS spectrometer [4] sidesteps the kinematic-compression problem by transporting the outgoing ions in the strong, homogeneous magnetic field of a large-bore superconducting solenoid. These ions follow helical trajectories before returning to the magnetic axis, where their energy, position, and time-of-flight are measured – the latter providing automatic, energy independent, particle identification via the cyclotron period of the ion. This opens up many exciting opportunities. An overview of the HELIOS spectrometer will be presented along with results from the first measurements with light neutron-rich beams [5,6,7] and with heavy beams close to Z = 50 and N = 82 [8], along with future directions for the study of neutron-rich nuclei using transfer reactions. The latest prospects for a HELIOS-like spectrometer at a European ISOL facility will be discussed.

This work supported by the U.S. Department of Energy, Office of Nuclear Physics under Contract No. DE-AC02-06CH11357 and Grant No. DE-FG02-04ER41320, NSF Grant No. PHY-02-16783, and the UK Science and Technology Facilities Council.

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IDEAS IN NEUTRINO PHYSICS

Jan Kisiel, University of Silesia

invited

One of the most exciting fields of research in astrophysics and particle physics is neutrino physics. Since neutrino "birth" in 1930 by Wolfgang Pauli, several original and intriguing ideas, in both experiment an theory of neutrino physics have been proposed. A subjective choice of them will be presented.

STUDIES OF FEW-NUCLEON INTERACTION DYNAMICS IN NEW-GENERATION EXPERIMENTS

Stanisław Kistryn, Jagiellonian University

invited

Stanislaw Kistryn 1, Elzbieta Stephan 2, Nasser Kalantar-Nayestanaki 3
1 Jagiellonian University, Krakow, Poland
2 University of Silesia, Katowice, Poland
3 Kernfysisch Versneller Instituut, Groningen, The Netherlands

A basic step towards full understanding of nuclear interactions and structure is proper modeling of all details of the few-nucleon system dynamics. Modern nucleon-nucleon

(NN) interaction models, most commonly based on the meson-exchange picture, are able to reproduce the bulk of all NN data with an utmost precision. Their quality can be efficiently probed in the few-nucleon environment by comparing most up-to-date theoretical predictions with the observables measured in precision experiments. Thorough studies of three-nucleon system have led to a conclusion that a proper description of the experimental data cannot be achieved with the use of NN forces alone. This indicates a necessity of including additional dynamics: subtle effects of suppressed degrees of freedom, introduced by means of genuine three-nucleon forces, or, for a long-time neglected, Coulomb force [1-3].

Those findings, and their extensions attempted in the four-nucleon system, would not be possible without a quantitative improvement of the experimental methods. New generation experiments in the middle-energy region are either employing high-resolution magnetic spectrometers or large, multi-detector arrangements, providing data of unprecedented accuracy. Progress in measuring high-rank polarization observables, in covering wide phase-space regions of the three-nucleon scattering in continuum, as well as attacking four-nucleon systems, are creating new challenges to improve modeling of all details of the interaction dynamics into still unexplored regions. In spite of theoretical and experimental improvements there still remain unresolved puzzles, which indicate that our understanding of the complexity of forces acting in the few-body system is not complete.

The talk will review most common approaches to modeling of the few-nucleon interaction dynamics and present their successes and failures in confrontations with the precise data from several recent experiments performed in the energy region of few tens to few hundreds of MeV.

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SYSTEMATIC STUDIES OF THE THREE-NUCLEON SYSTEM DYNAMICS IN THE DEUTERON-PROTON BREAKUP REACTION

Barbara Kłos, University of Silesia

seminar

Barbara Kłos 1, Izabela Ciepał 2
1 University of Silesia, PL-40007 Katowice, Poland
2 Jagiellonian University, PL-30059 Kraków, Poland

Three-nucleon system dynamics can be investigated quantitatively by comparing observables calculated with the use of Faddeev equations with results of precise measurements. The breakup observables can be predicted by modern realistic pairwise nucleon-nucleon (NN) interaction, combined with model of 3N forces. Moreover the two- and three-nucleon interactions can be modeled within the coupled-channel (CC) framework by an explicite treatment of the Δ-isobar excitation. Alternatively, the dynamics is generated by the Chiral Perturbation Theory (ChPT) at the next-to-next-to-leading order with all relevant NN and 3N contributions taken into account. The listed above calculations include different pieces of nucleon-nucleon dynamics like three nucleon force 3NF, the long-range Coulomb interaction or relativistic effects, which reveal their influence at different part of the phase space. Especially, cross section observables are very sensitive to all these effects.

Experiments devoted to study such subtle ingredients of nuclear dynamics were carried out at KVI Groningen [1,2] and FZ-Jülich [3] with the use of the 1H(→d, pp) n breakup reaction at 100 MeV, 130 MeV and 160 MeV deuteron beam energy. The measurements of the breakup reaction were performed at KVI Groningen with the use of the SALAD and BINA detectors covering large part of the reaction phase space. Experiment at FZ-Jülich was devoted to studies at very forward angles, making use of the Germanium Wall detection system. The precise experimental data of the breakup reaction obtained in a wide phase space region at different incident beam energies are very valuable for systematic studies of the effects and for understanding their role in few-nucleon system dynamics. The data can serve as valid tool for verification of rigorous theoretical calculations which currently are vividly developed.

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BETA DECAY SPECTROSCOPY NEAR ^{78}Ni: LEVEL STRUCTURE OF ^{83,84}Ge

Karolina Kolos, IPN Orsay

seminar

Shell structure is a fundamental property of atomic nuclei. One of the most important subjects of modern nuclear physics is to elucidate the shell structure of unstable nuclei with a large neutron-proton asymmetry. While nuclear shell is very static in stable nuclei, showing shell closures at neutron or proton "magic" numbers of 8, 20, 28, 50, 82, and 126, recent studies revealed that the shell structure dynamically evolves as the neutron-proton asymmetry increases, and even quenches shell gaps at classical magic numbers or gives rise to a closure at non-magic numbers. Neutron-rich ^{78}Ni nucleus with a proton number Z=28 and a neutron number N=50 is doubly magic in a classical picture of shell structure. The persistence or disappearance of the shell gaps near ^{78}Ni has a tremendous impact on the understanding of the mechanism of the evolution of nuclear shell, the development of reliable microscopic models in medium mass nuclei and the scenario of nucleosynthesis in the early universe as ^{78}Ni is in the path towards heavier elements.

To learn more about the shell structure of ^{78}Ni we have studied the beta-decay of the neutron-rich ^{84}Ga isotope at the ALTO facility in IPN Orsay (France). The fission fragments were produced in the photo-fission reaction induced by 50 MeV 10 μA electron beam in a thick UC_x target. The gallium atoms were selectively ionized with a newly developed laser ion source. The ionization of the gallium was more than ten times higher compared to the surface ion source previously used by our group. The ions were separated with the PARRNe mass separator and implanted on a movable mylar tape. Two germanium detectors in close geometry were used for the detection of gamma-rays and gamma-gamma coincidence measurement, and a plastic 4PiBeta for beta tagging.

The improved level scheme for ^{83,84}Ge will be presented and compared with the shell model calculations performed with ANTOINE code using "ni78-jj4b" interaction which is the modified version of the residual interaction developed by Sieja et al. with the ^{78}Ni core.

BETA-DECAY PROPERTIES OF ^{85,86}Ge AND ^{86,87}As*
Agnieszka Korgul, University of Warsaw

seminar

A. Korgul 1, C. Mazzocchi 1, K. P. Rykaczewski 2, R. Grzywacz 3, P. Baczyk 1, N. T. Brewer 4, C. J. Gross 2, C. Jost 3, M. Karny 1,5, G. Kepisty 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. Wolinska-Cichocka 2,5, I. N. Borzov 6

1 Faculty of Physics, University of Warsaw, 00-681 Warszawa, Poland
2 Physics Division, Oak Ridge National Laboratory, Oak Ridge, TN 37830, USA
3 Dept. of Physics and Astronomy, University of Tennessee, Knoxville, TN 37996, USA
4 Dept. of Physics and Astronomy, Vanderbilt University, Nashville, TN 37235, USA
5 Oak Ridge Associated Universities, Oak Ridge, TN 37831, USA
6 Joint Institute for Nuclear Research, 141980 Dubna, Russia

The decay studies of radioactive nuclei far away from the valley of beta-stability are often the sole option for probing nuclear models in such exotic nuclear systems, hence helping to extrapolate nuclear properties into unknown territories.

Recent decay studies of ^{238}U fission products performed at the Holifield Radioactive Ion Beam Facility (HRIBF) included the most neutron-rich isotopes of germanium (Z=32) and arsenic (Z=33) known to date. The isobaric contaminants in the beams were suppressed by using molecular beams GeS and AsS. It allowed us to study the decay properties of ^{85}Ge, ^{86}Ge, ^{86}As and ^{87}As. The beta-decay half-life of ^{86}Ge was measured for the first time and the lifetimes of ^{85}Ge, ^{86}As and ^{87}As were determined with much better accuracy and precision. These new half-life values support the recent theoretical modeling of the beta-decay process within the DF3a+CQRPA framework [1].

The beta-decay properties of ^{85,86}Ge and ^{86,87}As and the structure of respective daughter nuclei will be presented and discussed.

* This work was supported by the U.S. Department of Energy Office of Nuclear Physics, by the National Nuclear Security Administration and in part by the Polish National Science Centre (NCN) under grant number 2011/01/B/ST2/02476.

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HIGH INTENSITY GAMMA BEAMS AT THE LHC
Mieczysław Witold Krasny, LPNHE, Universites Paris VI et VII, IN2P3-CNRS

invited

The classical method of generating photon beams in the MeV range is based on the inverse Compton scattering of a laser light on electrons. The intensity of such beams is and will always be limited because the wavelength of the laser photons is significantly smaller than the classical electron radius. In my talk, I shall discuss the use of partially stripped ions as, by far, more efficient boosters of the frequency of the laser-photons. I shall evaluate the feasibility of accelerating and storing beams of partially stripped ions in the LHC storage rings and focus on the potential of such beams to generate high intensity, MeV-range, photon beams. Such beams could open many new domains of basic research and applications. including gamma-proton, gamma-nucleus and gamma-gamma collision physics, axion searches, photo-transmutation of nuclear isotopes, gamma-ray transmission radiography, cancer therapy and production of very intensive beams of polarized positrons.

ISOTOPIC TRENDS OF CAPTURE CROSS SECTION AND MEAN-SQUARE ANGULAR MOMENTUM OF CAPTURED SYSTEM

Roman Kuzyakin, Joint Institute for Nuclear Research, Dubna

seminar

R. A. Kuzyakin 1, V. V. Sargsyan 1, G. G. Adamian 1, N.V. Antonenko 1, E. E. Saperstein 2, S. V. Tolokonnikov 2,3

1 Joint Institute for Nuclear Research, Dubna, Russia

2 Kurchatov Institute, Moscow, Russia

3 Moscow Institute of Physics and Technology, Moscow, Russia

By using the quantum diffusion approach, the isotopic trends of capture cross sections and mean-square angular momenta of captured systems are studied in the reactions ^{4}He, ^{16}O, ^{36}S, ^{48}Ca + ^{196,200,204,208}Pb. The nuclear parts of the nucleus-nucleus interaction potentials were calculated by using the double-folding procedure with the density-dependent effective NN interaction constructing with an averaging procedure from the TFFS (Theory of Finite Fermi Systems) effective interaction. For density distributions of interacting nuclei, we used the two-parameter symmetrized Fermi functions. For the lead isotopes, the Fermi-distribution parameters were found to fit to the self-consistent density distributions calculated with the DF3-a functional within the EDF (Energy Density Functional) method.

The available experimental data at energies above and below the Coulomb barrier are well described. The isotopic trends are attributed to the deformation effects, neutron transfer, and nucleus-nucleus interaction. As demonstrated in our calculations, in the case of the same deformations of colliding isotopes and minor effect of neutron transfer, the neutron number of the target nucleus strictly influences the height of the Coulomb barrier, but not the width of the barrier. Thus, the height V_b of the calculated Coulomb barrier can be adjusted to the experimental data for the capture cross sections at $E_{c.m.} > V_b$ to take effectively into account the change of nuclear interaction with neutron number. The width of the nucleus-nucleus interaction potential can be calculated with any realistic diffuseness parameter because the width is rather insensitive to its value. Indeed, this procedure is often used for calculating the sub-barrier fusion and capture. It was applied to the reactions ^{16}O + ^{70,72,74,76}Ge.

As found, the increase of the number of neutrons in Pb assists the capture process. The isotopic dependence is rather weak in the reactions with ^{4}He and ^{16}O because the nucleus-nucleus potential weakly depends on the mass number of the target in very asymmetric reactions. In the reactions with ^{36}S and ^{48}Ca the isotopic trend is more pronounced. The slope of the capture cross section at deep sub-barrier energies is not sensitive to the neutron number of the system.

ASTROPHYSICAL REACTIONS RATES AND THE LOW-ENERGY ENHANCEMENT IN THE γ-RAY STRENGTH
Ann-Cecilie Larsen, University of Oslo

seminar

A. C. Larsen 1, A. Bürger 1, S. Goriely 2, M. Guttormsen 1, A. Görgen 1, S. Harrisopulos 3, H. T. Nyhus 1, T. Renstrøm 1, S. Rose 1, A. Schiller 4, S. Siem 1, G. M. Tveten 1, and A. Voinov 4
1 Department of Physics, University of Oslo, N-0316 Oslo, Norway
2 Institut d'Astronomie et d'Astrophysique, ULB, Belgium
3 Institute of Nuclear Physics, NCSR "Demokritos", Athens, Greece
4 Department of Physics and Astronomy, Ohio University, Athens, Ohio 45701, USA

An unexpected enhancement in the low-energy part of the gamma strength function for medium-mass and light nuclei has been discovered at OCL [1, 2, 3]. This enhancement could lead to an increase in the neutron-capture rates up to two orders of magnitude for very exotic, neutron-rich nuclei (see Ref. [4]).

The existence of this enhancement has very recently been confirmed in ^{95}Mo in an experiment at Lawrence Berkeley National Laboratory [5]. However, there is still an open question whether this structure persists when approaching the neutron drip line.

In this talk, the present status of knowledge of the enhancement and possible consequences for the stellar r-process will be discussed. Fresh data on Fe isotopes, including spectra taken with large-volume $LaBr_3$(Ce) detectors borrowed from the INFN-Milan group will also be shown.

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DESCRIPTION OF LIGHT NUCLEI (8<Z<20, 8<N<20) WITH THE MULTI-PARTICLE-MULTIHOLE GOGNY ENERGY DENSITY FUNCTIONAL
Julien Le Bloas, CEA, DAM, DIF France

seminar

J. Le Bloas, N. Pillet and J.-M. Daugas
CEA, DAM, DIF France

In my talk, I will present both excitation energies and gamma transition probabilities for a few sd-shell even-even nuclei [1]. The results have been obtained in the framework of the multiparticle-multihole configuration mixing approach (mp-mh) [2,3] wich consists of a unified variational treatment of nuclear long-range correlations. The same effective nucleon-nucleon interaction, namely the D1S Gogny effective force, is used in both the mean-field and the residual channels.

Energies, B(E2) and B(M1) calculations are performed for sd-shell even-even nuclei with $8 < Z < 20$ and $8 < N < 20$. Low-lying positive-parity states are considered. The results are compared with those of a standard GCM-type method [4] using the same Gogny D1S interaction. An excellent agreement is obtained for the energies except for two cases, the ^{30}Si and its mirror nucleus the ^{30}S, where a global shift (~2 MeV) is obtained. This discrepency is explained in terms of too large neutron-proton matrix elements of the Gogny interaction. Along isotopic and isotonic chains the experimental trend is globally reproduced for the transitions probabilities.

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STUDY OF NUCLEAR INTERACTIONS FOR THE WEAKLY BOUND NUCLEUS OF ^{26}F

Alexandre Lepailleur, GANIL

seminar

Nuclear forces play a decisive role to account for the creation and modifications of shell gaps, to explain deformed nuclei, to permit the development of halo structures and to fix the limits of particle stability. The determination of nuclear forces inside the nucleus from bare forces is a tedious but important task. The neutron-rich ^{26}F is a benchmark nucleus for studying proton-neutron interaction for different reasons. First, as its neutron binding energy amounts to only 0.80(12) MeV [1], its structure is likely to be influenced by drip-line phenomena. Second, it lies close to the ^{24}O doubly magic nucleus [2]. Therefore its nuclear structure at low excitation energy is expected to be rather simple. It is mainly provided by the interaction between a deeply proton $d_{5/2}$ and an unbound neutron $d_{3/2}$ on top of a closed ^{24}O core, leading to $J = 1, 2, 3, 4$ positive parity states.

The structure of this nucleus has been investigated at GANIL by means of the in-beam γ-ray spectroscopy technique using fragmentation reactions of a cocktail of radioactive nuclei, as by the study of its ground and isomeric beta decay to ^{26}Ne. Combining these pieces of information, as well as those obtained from atomic mass measurement [1] and the discovery of unbound states in ^{26}F [3, recent experiment Brown], we observe a reduction by about 30% of the proton-neutron forces as compared to those used in the USD interactions [4] to account for structural evolution closer to the valley of stability. This pinpoints the need of more self-consistent methods to derive nuclear forces for nuclei close to the continuum.

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HEAVY FLAVOUR PHYSICS

Tadeusz Lesiak, IFJ PAN Kraków

invited

Heavy Flavour Physics encompasses studies involving the charm, beauty and top quark and the tau lepton. This branch of modern physics has accomplished enormous progress during the last decades. It provides also the window on the phenomena described by the physics outside the current state of knowledge of the physics of elementary particles and their interactions. A brief review of the history, current knowledge and future of heavy flavour physics is presented at the level tailored for non-specialists.

RECENT RESULTS OF FUSION INDUCED BY NEUTRON-RICH RADIOACTIVE BEAMS STUDIED AT HRIBF

Felix Liang, Oak Ridge National Laboratory

invited

There is little information concerning the influence of neutron excess on compound nucleus formation. The fission-fragment beams at HRIBF provide a unique opportunity for studying the mechanisms of fusion involving nuclei with large neutron excess.

To explore the role of neutron transfer, fusion excitation functions have been measured using neutron-rich radioactive ^{132}Sn beams incident on ^{40}Ca and ^{58}Ni targets. The Q-values for neutron transfer are comparable for the two systems but the sub-barrier fusion enhancement in ^{132}Sn + ^{58}Ni is significantly smaller than that in ^{124}Sn + ^{40}Ca. To better understand the differences in the correlations between transfer couplings and sub-barrier fusion enhancement for Sn+Ca and Sn+Ni systems, the fusion excitation function for ^{124}Sn + ^{46}Ti has been measured. A comparison of the fusion excitation functions for Sn + Ca, Sn + Ti, and Sn + Ni will be discussed.

To explore the amalgamation process, the evaporation residue cross sections for ^{124,126,127,128}Sn + ^{64}Ni and ^{132}Sn + ^{58}Ni have been measured. The fusion probability for these reactions as a function of neutron excess will be examined. The results of studying the inverse fission of uranium by fusing ^{124,132}Sn with ^{100}Mo will be presented.

*This research was supported by the US Department of Energy Office of Nuclear Physics.

BETA-DELAYED FISSION AND ALPHA-DECAY SPECTROSCOPY OF THE LIGHTEST Tl ISOTOPES

Valentina Liberati, University of the West of Scotland, U.K.

seminar

The region of very neutron deficient nuclei in the vicinity of the proton shell gap Z=82 is known for several interesting phenomena, such as shape coexistence, the presence of shell-model intruder states in the Tl isotopes (Z=81) and the beta-delayed fission process. This contribution reports on the recent experimental campaign carried out at the ISOLDE mass-separator in CERN, in which detailed beta-delayed fission (BDF) study and nuclear decay spectroscopy of the lightest neutron-deficient $^{178-184}$Tl isotopes and their alpha-decay daughter $^{174-180}$Au nuclei were performed. First measurements of alpha-decay branching ratios for several Tl and Au isotopes and first unambiguous identification of the alpha decay of some Au isotopes are also presented. In addition the BDF of ^{200,202}Fr, ^{194,196}At and ^{178,180}Tl were discovered in this work.

The experimental details and the obtained results will be discussed in this contribution.

SELECTED ASPECTS OF THE STRUCTURE OF EXOTIC NUCLEI AND NEW OPPORTUNITIES WITH GRETINA*

Augusto Macchiavelli, Lawrence Berkeley National Laboratory

invited

The structure of nuclei far from the stability line is a central theme of research in nuclear physics, both in experiment and theory. Radioactive beam facilities and novel detector systems are unique tools to produce and study these nuclei, and together with new developments in nuclear theory they provide a framework to understand the properties of these exotic nuclei.

In this talk I will present recent results related to the quadrupole collectivity in neutron rich Carbon isotopes, and the evolution of the N=28 and 40 shell closures with isospin. I will end the presentation with a short review of the gamma-ray tracking technique, a status report of GRETINA, and discuss some aspects of the exciting physics campaign that will be carried out at NSCL/MSU.

* Work supported by the US-DOE under contract number DE-AC02-05CH11231

SYMMETRY ENERGY AND SECONDARY DECAY: TOWARD THE RECONSTRUCTION OF PRIMARY FRAGMENTS

Paola Marini, GANIL

seminar

The properties of nuclear matter in the nucleonic regime are determined by the nuclear interaction, which is, in turn, uniquely linked to the nuclear equation of state (EOS). In spite of its key role in determining important properties of exotic nuclei and astrophysical objects such as neutron stars, the equation of state for asymmetric nuclear matter has relatively few constraints. In particular, the density dependence of the potential part of the symmetry energy term of the EOS represents one of the main challenges for the research activities in nuclear physics.

The isotopic distributions of complex fragments produced in reactions at intermediate energies are expected to be a good observable to extract information. However secondary decay is known to distort the signatures of the symmetry energy. We will present the first results in primary fragment reconstruction obtained exploiting the high mass resolution of the VAMOS spectrometer, coupled to the high granularity of the 4π charged particle array INDRA.

PRELIMINARY RESULTS ON THE SCATTERING OF ^8He WITH HEAVY TARGETS

Gloria Marquínez Durán, University of Huelva

seminar

The scattering of ^8He has attracted the interest of the scientific community due to its particular features. Being a skin nucleus with four valence neutrons and similar binding energies for 1n and 2n, it is very different from 2n halo ^6He where the breakup into α+2n is favored. The differences of both helium isotopes are expected to be reflected in the elastic and reaction cross sections for collisions with heavy targets at Coulomb barrier energies.

The elastic scattering of ^8He on ^{208}Pb has been measured at laboratory energies of 16 and 22 MeV at the SPIRAL/GANIL facility at Caen, France, as part of a large experimental project devoted to study radioctive light isotopes by means of nuclear reactions induced at energies around the Coulomb barrier. The heavy nucleus ^{208}Pb provide a strong Coulomb field for the scattering process and the selected energy region is suitable for near-barrier scattering with the mentioned target, as the barrier energy is about 18 MeV. For studying the process, the angular and energy distributions of elastic channel and the ^6He and ^4He yields from the reactions induced by ^8He on ^{208}Pb are measured. Our array of silicon detectors allow us separating the different reaction channels corresponding to lighter ions in the angular range of interest. This compact, large solid angle, position sensitive array was developed at the University of Huelva. Having a very good angular coverage it has been designed to study direct nuclear reactions induced by light radioactive beams at energies around the Coulomb barrier and it was used for first time for the study of the scattering of the system ^8He + ^{208}Pb.

In this contribution elastic ^8He and $^{6,4}He$ fragments angular distributions produced in collisions of ^8He with a ^{208}Pb target at 22 MeV are presented and discussed together with calculations carried out for transfer and break-up processes. The analysis of the experimental data performed so far has shown that the angular distribution of the ^8He elastic scattering follows the trend of ^6He up to the scattering angles around 80 deg. For larger angles the absorption becomes even greater what could be interpreted as an effect of 1n transfer reaction.

LIFETIME MEASUREMENT OF HIGH-LYING SHORT LIVED STATES IN ^{69}As

Magdalena Matejska-Minda, IFJ PAN Kraków

seminar

M. Matejska-Minda 1, P. Bednarczyk 1, M. Ciemała 1, B. Fornal 1, M. Kmiecik 1, M. Krzysiek 1, A. Maj 1, W. Męczyński 1, S. Myalski 1, J.Styczeń 1, M. Ziębliński 1, G. de Angelis 2, T. Huyuk 2, C. Michelagnoli 2, E. Sahin 2, S. Aydin 3, E. Farnea 3, R. Menegazzo 3, F. Recchia 3, C. Ur 3, S. Brambilla 4, S. Leoni 4, D. Montanari 4, G. Jaworski 5, M. Palacz 5, R. Wadsworth 6

1 The Henryk Niewodniczański Institute of Nuclear Physics PAN, Kraków, Poland

2 INFN Laboratori Nazionali di Legnaro, Italy

3 Dipartimento di Fisica e INFN Padova, Italy

4 Dipartimento di Fisica e INFN Milano, Italy

5 Heavy Ion Laboratory, University of Warsaw, Poland

6 University of York, United Kingdom

Nuclei close to the N=Z line in the vicinity of A~70 exhibit a shape instability, that is manifested by a presence of rotational bands being interpreted in terms of moderate elongation $\beta \sim 0.3$ and significant degree of triaxiality $\gamma \sim 30$. This interpretation, however, could not be confirmed since relevant data on electromagnetic properties of such bands at high spins are still unavailable. In order to investigate experimentally an evolution of nuclear deformation in this region, we have performed a measurement of excited-state lifetimes, in a femtosecond range, with the GASP and RFD detection system at LNL INFN. A 95-MeV ^{32}S pulsed beam from the Tandem XTU accelerator was focused on a 0.8 mg/cm^2 ^{40}Ca target. Such reaction lead to the compound nucleus ^{72}Kr and final nuclei around ^{69}As.

Evaporation residues were detected by the segmented Recoil Filter Detector (RFD) in coincidence with gamma rays measured with the GASP germanium detector array. Each segment of RFD provides information on the time of flight and the direction of every individual evaporation residuum with respect to the beam pulse signal thus giving precise Doppler correction of gamma-ray energies. This feature allows to perform line shape analysis and is helpful in determination of exited states lifetimes if they are comparable to or shorter than the transit time of the recoil through the target - in our case these times are in a femtosecond range.

Event-by-event Doppler correction has been applied to the data, under the assumption that the gamma rays were emitted after the nucleus left the target. As seen in the data, the applied correction is appropriate for the 1305 and 2093 keV transitions in ^{69}As, resulting in sharp lines at these energies. In contrast the 1529 and 1930 keV lines the consequtive transitions in the "band 3" (known from previous studies [1]) are not properly corrected what indicates that the corresponding gamma rays were emitted while the recoiling nucleus was still traveling inside the target. Moreover, these lines do not show any trace of the sharp component what points to the cumulative lifetime shorter than 60 fs for the involved states, as indicated by a simulated line-shape. Our result offer an unique opportunity for testing predictions of various theoretical models

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RECENT RESULTS ON REACTIONS WITH WEAKLY BOUND NUCLEI

Marco Mazzocco, University of Padova

invited

The reaction dynamics induced by light weakly bound Radioactive Ion Beams in the energy range around the Coulomb barrier has been one of the most discussed and studied topics in Nuclear Physics for the last twenty-five years at least. Besides earlier measurements, it is now quite established that breakup related effects enhance the reaction cross section rather that the fusion probability. The question has therefore moved towards understanding which direct process (transfer or breakup) is the main responsible for the enhancement of the reaction cross section.

An overview of the most recent results obtained for the interaction of ^{6}He, ^{8}He, ^{7}Be, ^{11}Be, ^{8}B, ^{15}C and ^{17}F projectiles with medium-mass (^{58}Ni, ^{64}Zn) and heavy-targets (^{197}Au, ^{208}Pb, ^{232}Th, ^{238}U) will be given. Several experiments have indicated the 2n-transfer process as the main responsible for the large reaction cross section enhancement observed for the 2n-halo ^{6}He, whereas the breakup channel seems to be the best candidate to determine the enhancement measured for the 1p-halo ^{8}B. If confirmed, this outcome would suggest that p-halo and n-halo nuclei might be characterized by different behaviors in the reaction dynamics induced at near-barrier energies.

Recent results for the system ^{7}Be + ^{58}Ni will also be presented. The experiment was performed at the Laboratori Nazionali di Legnaro (LNL, Italy), where a moderately intense (20-30 kHz) ^{7}Be secondary beam was produced for the first time with the facility EXOTIC. So far, we evaluated the elastic scattering angular distribution at 22.7 MeV. The analysis of breakup related events has recently started.

LATEST RESULTS FROM TWO PROTON DECAY STUDIES

Krzysztof Miernik, ORNL and University of Warsaw

invited

The two-proton radioactivity is a process of simultaneous emission of two protons from the ground state of an atomic nucleus. It occurs in an even-Z nucleus in the vicinity of the proton drip line when, due to pairing interactions between protons, the nucleus is bound against single-proton emission while it is unbound against the emission of two protons. Since the early considerations of the two-proton radioactivity by Goldansky in 1960 it has been a challenge for experimenters to discover and to study this extremely rare decay mode. First experimental evidence for the two-proton radioactivity (an arbitrary half-life low limit of 1 ps for radioactivity was introduced by Goldansky) was reported more than 40 years later for the case of ^{45}Fe.

Today we know several short lived (e.g. ^{19}Mg, ^{8}C, ^{6}Be) and three long lived isotopes (^{45}Fe, ^{54}Zn and the latest ^{48}Ni) of nuclei undergoing this exotic transition. We will discuss the history of two proton emission observations, the detection methods, the theoretical descriptions of the process and the importance of these studies. The results of experiment performed at NSCL facility where ^{48}Ni was studied with the means of Optical Time Projection Chamber which allows to record three dimensional tracks of emitted protons, will be also presented.

NUCLEAR MEAN FIELD TECHNIQUES AND THE STABILITY OF THEORETICAL PREDICTIONS

Hervé Molique, IPHC and Université de Strasbourg

seminar

It is broadly recognised that the concept of the Nuclear Mean Field is one of the most successful approaches to the Nuclear Many-Body Problem. Over the years, the techniques employed in this domain have shown to be very powerful in the description of numerous properties of nuclei all over the chart of the nuclides.

Various terms of the mean-field Hamiltonian are parametrized and the parameters determined by fitting theoretical observables to experimentally determined quantities. The mathematical expressions postulated usually follow certain preconceived ideas, e.g. mean-field spin-orbit interaction is though to result first of all from the spin-orbit two-body interaction; similarly the mean-field tensor-contribution is usually considered representing the tensor two-body force etc. However, the nuclear mean-field neither needs to nor generally follows this scheme. It is by considering the most general form of the mean-field Hamiltonian allowed by the symmetry principles that we can hope to obtain the most general, most `physical' and most stable both definition of the Hamiltonian and its parameterization.

The instability of the theoretical predictions is directly related to what is called an ill-posed inverse problem, the latter mechanism associated in turn with the mutually correlated parameters of the considered Hamiltonian. Indeed, one demonstrates rigourously that the parametric correlations imply illposedeness of the inverse problem and destroy the predictive power of the model - in other words - make the extrapolation of the calculations to the so far unknown domains of interest (e.g. from heavy to super-heavy nuclei) impossible.

We will try to shed some light into the question of constructing the mean-field Hamiltonians by exploring all possibilities allowed by the general symmetry considerations in view of minimising the number of parametric correlations and thus increasing the predictive power and the stability of the related theoretical modelling.

EVOLUTION OF THE SHELL STRUCTURE IN MEDIUM-MASS NUCLEI: SEARCH FOR THE $2d_{5/2}$ NEUTRON ORBITAL IN ^{69}Ni
Mohamad Moukaddam, IPHC Strasbourg

seminar

M. Moukaddam 1, G. Duchêne 1, D. Beaumel 2, J. Burgunder 3, L. Caceres 3, E. Clement 3, D. Curien 1, F. Didierjean 1, B. Fernandez 3, Ch. Finck 1, F. Flavigny 4, S. Franchoo 2, J. Gibelin 5, S. Giron 2, A. Gillibert 4, S. Grevy 3, J. Guillot 2, F. Haas 1, F. Hammache 2, M. N. Harakeh 6, K. Kemper 7, V. Lapoux 4, Y. Matea 2, A. Matta 2, L. Nalpas 4, F. Nowacki 1, A. Obertelli 4, J. Pancin 3, L. Perrot 2, J. Piot 1, E. Pllumbi 2, R. Raabe 3, J. A. Scarpaci 2, N. de Séreville 2, K. Sieja 1, O. Sorlin 3, I. Stefan 2, C. Stoedel 3, J. C. Thomas 3

1 IPHC, CNRS/IN2P3, Universite de Strasbourg, F-67037 Strasbourg, France
2 IPN, CNRS/IN2P3, Universite Paris-Sud, F-91406 Orsay, France
3 GANIL, CEA/DSM-CNRS/IN2P3, F-14076 Caen, France
4 CEA Saclay, IRFU, Service de Physique Nuclaire, F-91191 Gif-sur-Yvette, France
5 LPC, CNRS-ENSI Caen, Universite de Caen, Basse-Normandie, France
6 GSI, Helmholtzzentrum fur Schwerionenforschung GmbH, D-64291 Darmstadt, Germany
7 Florida State University, Tallahassee, Florida 32306, USA

It has been shown that the neutron $2d_{5/2}$ orbital has to be included in shell-model calculations to explain the appearance of large quadrupole collectivity observed in the neutron rich Fe and Cr of the N $\approx$ 40 region. This work initiated by Caurier et al. has been recently revisited. Calculations in a large valence space involving the fp proton shell and the fpgd neutron shells including a strongly reduced $1g_{9/2}$–$2d_{5/2}$ neutron gap down to 1.5 MeV affect the whole N=40 region and point out to a new island of inversion similar to those known for light nuclei around N=8 and N=20. A global mechanism could be deduced, in the frame of the shell-model approach, of the emergence of islands of inversion at Harmonic-Oscillator shell gaps driven by two particle-two hole neutron excitations into quadrupole partner orbitals across these gaps.

Since no $5/2^+$ state has been assigned in previous studies of ^{69}Ni, it is an ideal laboratory to search for the neutron $2d_{5/2}$ orbital. A (d, p) reaction onto a ^{68}Ni beam produced at GANIL has been used to probe the single-particle energy of the $2d_{5/2}$ neutron orbital in ^{69}Ni. Two $5/2^+$ states with important spectroscopic factors lying around 2.5 MeV excitation energy have been observed, for the first time, in ^{69}Ni. The doublet is understood as the mixing of two main configurations of spherical nature. These results are in good agreement with large scale shell-model calculations in which a 2.5 MeV $1g_{9/2}$–$2d_{5/2}$ gap for neutrons is included, and confirm experimentally Caurier's assumption of a reduced $1g_{9/2}$–$2d_{5/2}$ neutron gap at N=40.

COULOMB AND NUCLEAR BREAKUP OF NEUTRON DRIP LINE NUCLEI

Takashi Nakamura, Tokyo Institute of Technology

invited

Nuclei near the neutron drip line often show unique characteristic structures such as halos. Due to the very loosely bound nature, breakup reactions play important roles in spectroscopy of such nuclei. Coulomb breakup, induced by a heavy target, is useful to extract the electric dipole transitions of the halo nuclei. Characteristic large E1 strength distribution at low excitation energies (soft E1 excitation) can be used to extract the halo properties, such as the angular momentum of the valence neutron, separation energy, and dineutron correlation. Nuclear breakup, induced by a light target, is useful in extracting the single particle nature of the valence neutron, which is removed. I will show here the recent breakup experiments on halo nuclei ^{19}B, ^{22}C, ^{31}Ne, and some neutron rich Mg and Si isotopes at the new-generation RI-beam facility, RIBF, at RIKEN. I will demonstrate how these reactions are useful in extracting the structures at the limit of stability.

NEW ADVANCES FOR THE ^{3}He(^{4}He, γ)^{7}Be REACTION

B. S. Nara Singh, University of York

invited

The ^{3}He(^{4}He, γ)^{7}Be reaction captures interest of several groups around the world, both on the experimental and theoretical fronts, even half a century after its first study. Such efforts have been essentially motivated by the need for the accurate input data for the standard solar model in determining the high-energy solar neutrino flux. It also has implications on the bigbang nucleosynthesis calculations. In my talk, I will present an overview of the focussed studies on this reaction in last few years including our new work using two different and complementary techniques. I will also discuss our future plans based on the scenario that emerged from our analysis.

MEASUREMENTS OF NUCLEAR MOMENTS, SPINS AND CHARGE RADII IN NEUTRON-RICH NUCLEI: PROBING STRUCTURAL CHANGES

Gerda Neyens, KU Leuven

invited

The spin, the magnetic dipole moment, the electric quadrupole moment and the mean square charge radii of isotopes provide information about the nuclear wave function and are therefore good probes to study the shell evolution as a function of isospin along a chain of isotopes. I will present recent results from moments measurements on exotic isotopes produced by projectile fragmentation at GANIL and by the ISOL method at ISOLDE, using respectively the beta-Nuclear Magnetic Resonance and collinear laser spectroscopy methods. Cases that have been studied are located near the magic neutron numbers N=20 (Mg and Al isotopes), N=28-32 (K and Ca isotopes) and along Z=28 (Cu and Ga isotopes).

SPECTROSCOPY OF ^{13}B VIA THE (^{18}O, ^{16}O) TWO NEUTRON TRANSFER REACTION

Dario Nicolosi, INFN Laboratori Nazionali del Sud and University of Catania

seminar

D. Nicolosi 1,2, C. Agodi 1, M. Bondi 1,2, F. Cappuzzello 1,2, D. Carbone 1,2, M. Cavallaro 1, A. Cunsolo 1, M. De Napoli 3, A. Foti 1,3, R. Linares 4, S. Tropea 1,2

1 INFN Laboratori Nazionali del Sud, Catania, Italy

2 Università degli Studi di Catania, Italy

3 INFN Sezione di Catania, Italy

4 Universidade Federal Fluminense, Niteroi, Brazil

The rapid evolution of the shell structure in neutron-rich nuclei with the neutron number N=8 has attracted an increasing attention in recent years. The shell closure is pronounced in the semimagic nucleus ^{14}C, while the even-even nucleus ^{12}Be shows the presence of intruder sd-shell configurations already in its ground state. The N=8 nucleus ^{13}B is therefore expected to be on the borderline between these two regimes. Recent results have demonstrated such peculiarity, showing that the ^{13}B isotope exhibits low lying proton and neutron intruder states, indicating a reduced shell gap between p and sd shells [1,2].

In order to get information on ^{13}B excited states, which are still not completely known experimentally, we performed the two neutron transfer reaction (^{18}O, ^{16}O). The experiment has been done at the Catania LNS-INFN laboratory using an 84 MeV energy Tandem beam impinging on a 78 μg/cm^2 thick ^{11}B target. The ^{16}O ejectiles were detected at forward angles by the MAGNEX magnetic spectrometer [3]. Exploiting its large momentum acceptance (20%) and solid angle (50 msr), energy spectra were obtained with a relevant yield up to about 20 MeV excitation energy. Several known states of the residual ^{13}B nucleus were identified in the excitation energy spectrum. A comparison with the excited states studied for the two neutron transfer reaction $^{12}C(^{18}O, ^{16}O)\,^{14}C$ at the same incident energy seems to give us a confirmation of the reduction of the energy gap between p and sd shells, remarking the important role of the ^{13}B isotope as a proof of the rapid shell evolution for the N=8 systems.

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THE ISLAND OF INVERSION AROUND A=64
Frederic Nowacki, IPHC Strasbourg

invited

We study the development of collectivity in neutron-rich nuclei around N=40, where the experimental evidence suggest a rapid shape change from the spherical to the rotational regime, in analogy to the island of inversion known at N=20.

Theoretical calculations are performed within the interacting shell model framework using an enlarged model space outside the ^{48}Ca core, comprising the pf shell for the protons and the $f_{5/2}$, $p_{3/2}$, $p_{1/2}$, $g_{9/2}$, $d_{5/2}$ orbits for the neutrons. The effective interaction is based on realistic two-body matrix elements which are corrected empirically in its monopole part. We find a good agreement between theoretical results and available experimental data. We predict different development of deformation in various isotopic chains, with the maximum of collectivity occurring in the chromium isotopes. The shell evolution responsible for the observed shape changes is discussed in detail, in parallel with the N=20 case. The impact of the new constraint from the recent experimental observation of the $d_{5/2}$ single particle orbit in ^{69}Ni will be discussed.

RELATIVISTIC COULEX MEASUREMENTS IN THE MASS 66 REGION AND THE FIRST SPECTROSCOPY RESULTS ON ^{66}Se / ^{65}As
Alexandre Obertelli, CEA Saclay

invited

TRUE TERNARY FISSION: A NEW TYPE OF RADIOACTIVE DECAY OF ^{252}Cf
Wolfram von Oertzen, Helmholtz-Zentrum Berlin

invited

W. von Oertzen, Yu. V. Pyatkov, D. V. Kamanin et al.
Helmholtz-Zentrum, Berlin
Joint Institute for Nuclear Research, Dubna

True ternary fission with masses (charges) of similar size has not been observed until recently. Earlier and most recent theoretical work for the potentials of the three fragments have shown, that for ternary masses with $Z_3 > 15$ and $A_3 > 30$, the fissioning configurations will be prolate and the fragments will be collinear in the decay. Actually in the search for oblate decays, an upper limit of $1x10^{-8}$ for the occurrence of such decays has been established. True ternary fission with three fragments of comparable size must be collinear!

In recent work with two double arm Time of Fligth (TOF) spectrometers as well as with two Bragg ionization chambers and with PPAC's for timing (placed at 180 degrees), the collinear decay into three clusters has been established for spontaneous fission of ^{252}Cf(ff, fff) and for neutron induced fission of ^{235}U(n, ff, fff) (at a reactor in JINR), which has been named CCT, collinear cluster tri-partition. A specific approach has been applied in order to separate two collinear fragments: multiple scattering in some media: the source backing (50 μg/cm^2) on one side of the two arm spectrometer induces multiple scattering of fragments creating a dispersion of the originally collinear two fragments. With a mesh in front of the ionization chambers one of the two fragments is blocked. We can therefore apply the missing mass method, for the dominant decay mode the decay $^{252}Cf \rightarrow {}^{132}Sn + {}^{50}Ca + {}^{70}Ni$ is obtained (missing Ca). We show, that with the higher Q-values of CCT, and a wide range of mass partitions of the three fragments (and their excitations (level densities) and spins) a large phase space for the ternary decay is obtained. These facts explain, why for the CCT-fission mode a large relative intensity of $3x10^{-3}$ per binary fission is observed. The CCT mode produces a "bump" in the mass distribution similar to the binary decay.

NUCLEAR STRUCTURE TOWARD THE DRIPLINES; UNDERSTANDING MANY-BODY FORCES AND CORRELATIONS

Takaharu Otsuka, University of Tokyo

invited

ODD PARITY CORE EXCITATION OF THE N=Z=50 CORE

Marcin Palacz, Heavy Ion Laboratory, University of Warsaw

invited

M. Palacz 1, J. Nyberg 2, H. Grawe 3, K. Sieja 4
and the the Neutron Wall – EUROBALL collaboration
1 Heavy Ion Laboratory, University of Warsaw
2 Department of Physics and Astronomy, Uppsala University
3 GSI Helmhotzzentrum fur Schwerionenforschung, Darmstadt
4 Universite de Strasbourg, IPHC and CNRS

The region of the Segre chart around the heaviest self-conjugate doubly-magic nucleus ^{100}Sn is, since decades, a subject of extensive experimental and theoretical investigations. One of the key points and questions in the region is the role of the excitations of the N=Z=50 core. Such excitations have been extensively studied in several close Z < 50 neighbors of ^{100}Sn: ^{101}In [1], ^{102}In [2,3], ^{98}Cd [4,5], ^{99}Cd [2], ^{96}Ag [6] and ^{97}Ag [7]. The core excited states in these nuclei are in general successfully interpreted in the Shell Model space consisting of only even parity orbitals, with proton (and neutron) valence holes located in the $g_{9/2}$ orbital and particle-hole excitations across the N=Z=50 gap to the $g_{7/2}$, $d_{5/2}$, $d_{3/2}$, $s_{1/2}$ orbitals. Odd-parity orbitals, for the description of such core excitations, have so far seemed unnecessary, as negative parity core-excited states were not experimentally observed in any of the above mentioned nuclei.

In the present work results are presented of the recent study of excited states of the nucleus ^{96}Pd, which has four valence proton-holes outside ^{100}Sn. States in ^{96}Pd were investigated by gamma-ray spectroscopy methods in a heavy-ion induced fusion evaporation reaction employing the EUROBALL and Neutron Wall detector arrays.

The scheme of excited states in this nucleus was extended up to an excitation energy of 9707 keV and a tentative spin and parity of 19^+. A rich sequence of states interpreted as N=50 core excitations was established. Among those, a negative parity isomeric state was identified, which gives the first evidence of the influence of the odd-parity orbitals on the ^{100}Sn excitations.

Shell Model calculations were performed in four different model spaces. Even parity states of ^{96}Pd are very well reproduced in large scale (LSSM) calculations in which excitations are allowed of up to five $g_{9/2}$ protons and neutrons across the N=Z=50 gap, to the $g_{7/2}$, $d_{5/2}$, $d_{3/2}$, and $s_{1/2}$ orbitals. The odd-parity isomer could be only qualitatively interpreted though, employing calculation in the full fpg shell model space, with just one particle-hole core excitation. Reliability of these calculations is evaluated on the basis of comparison to states in ^{94}Ru, and systematics of states in N=50 isotones below ^{100}Sn is also discussed. A more complete and consistent model is clearly needed to quantitatively reproduce the isomer in ^{96}Pd and its decay, with larger model space, improved interactions in the negative parity orbitals, and more core particle-hole excitations allowed. Role of the negative parity on orbitals on core-excitations in other close neighbors of ^{100}Sn remains an open question.

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TOWARD MODEL-INDEPENDENT NUCLEAR STRUCTURE COMPUTATIONS

Thomas Papenbrock, University of Tennessee and ORNL

invited

This talk presents results from coupled-cluster computations for neutron-rich isotopes of oxygen and calcium, and tools from effective theory for computations in finite oscillator spaces and for deformed nuclei.

DYNAMICAL DIPOLE MODE: A "COLLECTIVE" TOOL TO UNDERSTAND REACTION DYNAMICS BY USING STABLE AND RADIOACTIVE BEAMS

Concetta Parascandolo, University of Padova and INFN

seminar

D. Pierroutsakou 1, C. Parascandolo 2, et al.
1 INFN - Napoli, via Cintia, I-80126 Napoli, Italy
2 Università di Padova and INFN - Padova, via Marzolo 8, I-35131 Padova, Italy

The Dynamical Dipole mode (DD) takes place between interacting ions with a large N/Z asymmetry. During the phase of charge equilibration between the colliding ions, a large amplitude collective dipole oscillation can develop along the symmetry axis of the dinuclear system, and then decays emitting prompt dipole γ-rays [1-4]. A better comprehension of DD mode can give us relevant details about the dynamics of dissipative reactions, in particular for charge equilibration.

The use of radioactive beams permits to reach much larger N/Z asymmetries than previously done with stable beams, allowing to probe the density dependence of the symmetry energy in the Equation of State at sub-saturation densities, where the DD mode is active. Moreover the combination of exotic and stable beams results in a very large number of target-projectile couples in order to perform a systematic study of the DD features. New ideas in this direction are foreseen and will be discussed [5]. As a fast cooling mechanism on the fusion path, the prompt dipole radiation could be of interest for the synthesis of super-heavy elements in hot fusion reactions. The entrance channel charge asymmetry could provide a way to cool down the hot fusion paths, increasing the survival probability. Furthermore, it was predicted in [6] that the DD γ yield decreases in collisions involving heavier ions because reactions with small nuclei are less damped than those involving heavier ones.

Thus, to verify if the DD mode survives in heavier systems, we studied the ^{192}Pb compound nucleus (E*=232 MeV), employing ^{40}Ca + ^{152}Sm and ^{48}Ca + ^{144}Sm reactions at E_{lab} = 440 MeV and 485 MeV, respectively. The DD mode was investigated in both fusion-evaporation and fission events simultaneously for the first time. The experiment was performed at Laboratori Nazionali del Sud (LNS, Italy), by using the $^{40-48}$Ca pulsed beam provided by the Superconducting Cyclotron. The γ-rays and the light charged particles were detected by using the MEDEA apparatus [7], made of 180 BaF_2 scintillators. The heavy reaction fragments were detected by position sensitive Parallel Plate Avalanche Counters placed symmetrically around the beam. Results of this measurement will be showed and compared with results found at different mass regions.

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GAMMA SPECTROSCOPY OF ISOMERIC STATES IN NEUTRON-RICH NUCLEI: ^{75}Cu AND ^{78}Ga

Cristina Petrone, Horia Hulubei National Institute for Physics and Nuclear Engineering, Bucharest and University of Bucharest

seminar

C. Petrone 1,2, J. M. Daugas 3, M. Stanoiu 1, F. Negoita 1, G. Simpson 4, C. Borcea 1, R. Borcea 1, L. Caceres 5, S. Calinescu 1, R. Chevrier 3, L. Gaudefroy 3, G. Georgiev 6, G. Gey 4, C. Plaisir 3, F. Rotaru 1, O. Sorlin 5, J. C. Thomas 5

1 Horia Hulubei National Institute for Physics and Nuclear Engineering, P.O. Box MG-6, 077125 Bucharest-Magurele, Romania

2 University of Bucharest, B-dul Mihail Kogalniceanu nr. 36-46, Bucharest, Romania

3 CEA, DAM, DIF, F-91297 Arpajon, France

4 ILL, F-38042 Grenoble, France

5 Grand Accélérateur National d'Ions Lours (GANIL), CEA/DSM-CNRS/IN2P3, Caen, France

6 CSNSM, CNRS/IN2P3, 91405 Orsay-Campus, France

We present the results of an experiment in which the structure of neutron-rich nuclei located in the vicinity of N=40 was studied. The importance of our results comes from the fact that knowing the behavior of the neutron $g_{9/2}$ orbital with increasing number of neutrons is one of the key points in defining the structure of these nuclei at low excitation energy. The nuclei of interest were produced by fragmentation of a ^{86}Kr beam at 60 MeV/u on a thick Be target at GANIL (France). Preliminary results on ^{75}Cu and ^{78}Ga isomers will be presented together with tentative spin and parity assignments.

ASPECTS OF TRANSFER REACTIONS IN LIGHT AND HEAVY IONS COLLISIONS

Giovanni Pollarolo, University of Torino and INFN

invited

Transfer reactions played a key role in unraveling many properties of the nucleus, in particular they have been essential to define the relevance of the independent particle motion and the role of two-particle correlations in the building of the nuclear spectra. In view of the availability, in the near future, of radioactive beams it is important to summarize some aspect of the transfer processes with light-ions, these will be relevant to define the properties of nuclei close to the neutron and proton drip lines. In the case of heavy-ion collisions the role of the transfer degrees of freedom in defining the cross section for fusion reactions and in the production of neutron rich nuclei will also be discussed.

SUPERDEFORMED OBLATE SUPERHEAVY NUCLEI IN THE SELF-CONSISTENT APPROACH

Leszek Próchniak, Maria Curie Skłodowska University, Lublin

seminar

L. Próchniak and A. Staszczak
Institute of Physics, Maria Curie-Skłodowska University, Lublin

We study the properties of several hypothetical neutron-poor superheavy nuclei with Z=120-126 and N=160-166. The results of a recent paper [1] suggest that they can exhibit a very large oblate deformation (β around –0.50) in their ground state, moreover there are some hints that at least some decay channels are substantially hindered. The model used in [1] is based on the microscopic-macroscopic method with multidimensional deformation space. Our main theoretical tool is the Hartree-Fock-Bogoliubov theory with the Skyrme effective interactions. We do not assume any parametrization of a nuclear shape but instead in order to get the energy dependence on deformation we put constraints on the quadrupole moments of a nucleus. It should be added that the study of properties of oblate minima, in particular fission paths from starting from a minimum, needs taking into account triaxial nuclear shapes.

We made calculations with the SkM* version of the Skyrme interaction and the pairing interaction modelled by the so called "mixed" (volume plus surface) delta interaction. This approach was successfully applied in the region of lighter superheavy nuclei [2]. Our calculations confirm the existence of superdeformed oblate global minima of the potential energy in the considered region. The height of the barrier on the fission path (which leads through a triaxial saddle) is in the range 1-3 MeV. We also present some preliminary results on the fission lifetimes.

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SEARCH FOR NEW SYMMETRIES IN FAST-ROTATING NUCLEI

Lee Riedinger, University of Tennessee

invited

A rich variety of experiments have been performed in the last 30 years on the structure of nuclei from low to high to ultrahigh values of angular momentum, utilizing ever increasing arrays of gamma-ray and associated particle detectors. For example, measured trends of rotational bands coupled with theoretical calculations have taught us much about the physics of normal, extended, and super deformation. These measured trends are also important for looking for subtle discrepancies that might be indicative of new symmetries. For this purpose, we have been pursuing the question of rotational bands at low to medium spins (negative parity) where the expected E2 transition between members of the band is unobserved. This 'missing E2' can result from a reduced E2 transition probability (perhaps due to a tetrahedral symmetry) or an enhanced E1 branching to the ground-state band. One such case is ^{156}Dy. We first performed a spectroscopy measurement on this nucleus using a heavy-ion induced reaction at the ATLAS accelerator and the Gammasphere array of gamma-ray counters. And, in the past year we have performed a measurement of the lifetimes of these negative-parity states, to hopefully lead us to a firm conclusion on this dilemma.

THEORY OF DIPOLE-RESONANCES IN NUCLEI CLOSE AND FAR FROM STABILITY

Peter Ring, Technical University of Munich

invited

Physics Department, Technical University of Munich, 85748 Garching, Germany and
State Key Laboratory of Nuclear Physics and Technology, School of Physics, Peking University,
Beijing 100871, People's Republic of China

The giant dipole resonance has been the first form of collective motion discovered in nuclei and has been discussed in numerous experimental and theoretical papers over the years. With the advent of the radioactive beam facilities in recent years the dipole response in nuclear systems has gained renewed interest. At lower energies, close to the neutron threshold, a new collective mode has been predicted in neutron rich nuclei, which corresponds to the oscillation of the neutron skin against a core with isospin zero. It provides a tool to investigate the size and the properties of the neutron skin in these nuclei. In this talk we discuss general properties of the dipole response in nuclei and we discuss several methods to describe these phenomena in the framework of time-dependent density functional theory, such as sum rules, the influence of the continuum, the effect of nuclear superfluidity and deformation on this motion and the coupling to complex configurations.

THE SEARCH FOR ISOMERIC STATES IN ^{133}CS AND ^{132}TE

Oliver Roberts, University of Brighton

seminar

O. J. Roberts 1, A. M. Bruce 1, F. Browne 1, N. Marginean 2, T. Alharbi 3, T. Alexander 3, L. M. Fraile 4, D. Ivanova 5, S. Kisyov 5, B. Olaziola Mampaso 4, P. J. R. Mason 3, K. Mulholland 6, P. H. Regan 3, J. F. Smith 6, P.-A. Soederstroem 7, C. Townsley 3
1 University of Brighton, U.K., 2 IFIN-HH, Bucharest, Romania
3 University of Surrey, Guildford, U.K., 4 Universidad Compultense de Madrid, Spain
5 University of Sofia, Bulgaria, 6 University of the West of Scotland, Paisley, U.K.
7 RIKEN, Tokyo, Japan

Nuclei in the A~130 region have been shown to demonstrate a variety of nuclear shapes. Indeed, previous work carried out by Koike et al. [1] has shown that the underlying physics of odd-odd Cs isotopes and neighbouring nuclei can be understood through a triaxial structure. Garg et al. [2] demonstrated that the behaviour of odd mass Cs nuclei, such as ^{133}Cs, can be well described by a combination of both the particle-plus-rotor and particle-plus-vibrator models.

Shell effects have also been seen in the neighbouring Te isotopes where previous studies by Jungclaus et al. [3] have probed the shell structure of ^{132}Te, and have shown that for the collective 2^+ state, on average there is quadrupole deformation around a spherical shape due to the mixing of proton and neutron configurations. Discrepancies in the B(E2) strengths and excitation energies around the N=82 shell closure in the systematics of ^{136,134,132}Te have also been identified in this mass region by Terasaki et al. [4].

In order to better understand the low-lying structures of ^{133}Cs and ^{132}Te, an experiment was conducted at IFIN-HH, Bucharest to measure lifetimes in the picosecond to nanosecond regime. A 31.5 MeV beam of ^{7}Li, provided by the TANDEM accelerator, impinged on a ^{130}Te target to exploit the fusion evaporation channels, ^{130}Te(^{7}Li, 4n)^{133}Cs. The population of ^{132}Te was also seen in the mixed incomplete fusion/transfer reaction, ^{130}Te(^{7}Li, αp)^{132}Te, at or near the Coulomb barrier. Gamma-rays were detected using an array of 8 high-purity germanium detectors and 11 lanthanum bromide detectors. The latter providing the capability to measure lifetimes down to ~50 ps.

The level schemes of ^{133}Cs and ^{132}Te observed in this experiment will be compared with previous studies [1-4]. Transition strengths, determined from the measured lifetimes will be used to probe the low-lying structure in these nuclei. This presentation will give preliminary results of the analysis.

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SUPERPOSITION OF TWO VERY DISTINCT SYMMETRIES IN ONE QUANTUM STATE OF AN ATOMIC NUCLEUS

David Rouvel, University of Strasbourg

seminar

The research of exotic symmetries in atomic nuclei, e.g. the nuclear tetrahedral symmetry, has been going on for some years by now. The interest in these new symmetries is principally the idea of the existence of new islands of stability on the chart of nuclides and, possibly, a more adequate and realistic (re)interpretation of experimental data. The tetrahedral symmetry is usually seen in competition with the oblate/prolate or `pear-shape' symmetries. But the quantum nature of the atomic nuclei allows to consider two (or more) symmetries together for instance an axial and tetrahedral symmetry simultaneously. Systematic study of this type states combining very different point-group symmetries in one single collective wave function are new, at least in the nuclear physics context. To take into account competition between several symmetry- and shape- degrees of freedom of the kind discussed, one has to solve the Schrödinger equation for the collective nuclear motion in a riemannian space built at least out of deformation coordinates (α_{20}, α_{22}, α_{30}, α_{32}). This introduces calculations like in general relativity with the mass replaced by a mass tensor depending on the space coordinates and used as metric tensor. We intend to discuss the qualitatively new aspects of the interpretation of the nuclear motion taking into account coexistence of totally different point-group symmetries in one single quantum state.

"EINSTEIN WAS WRONG?" - THE EPR PARADOX AND A TEST OF BELL INEQUALITY BY PROTON PAIRS

Hideyuki Sakai, RIKEN Nishina Center

invited

Nowadays we often hear the words such as 'quantum computation' or 'quantum cryptography'. They are essentially based on the quantum mechanical phenomenon 'entanglement'. The word 'entanglement' was first used in the paper published by Shroedinger after he read the famous paper by Einstein, Podolsky and Rosen (EPR) in 1935. The EPR proposed a thought experiment in which they showed according to quantum mechanics that the result of a measurement of an entangled quantum system performed on earth, for example, can instantaneously influence the result of a measurement performed on the far distant galaxy regardless of the distance. This of course contradicts with the theory of special relativity by Einstein, no information can be transmitted faster than the speed of light. Therefore EPR argued that quantum mechanics must be incomplete. This is called the EPR paradox.

In 1964, Bell found an extremely important inequality which is the embodiment of the EPR arguments. The prediction of the spin-correlation by the Bell's inequality is different from that by the quantum mechanics so that we can test experimentally which assertion is right by the measurement.

We have carried out the spin-correlation measurement of two protons in a spin singlet state aiming to test the EPR paradox. After a short introduction of the EPR paradox, I try to explain how we realized experimentally an almost pure spin singlet state of two protons and how we measured the spin (polarization) correlation of proton pairs. Essential difference from photon pair experiments such as by Aspect will be touched briefly.

MASS MEASUREMENTS OF NEUTRON-RICH NUCLEI WITH CARIBU

Guy Savard, University of Chicago and ANL

invited

NUCLEOSYNTHESIS OF ELEMENTS

Hendrik Schatz, Michigan State University

invited

MICROSCOPIC DESCRIPTION OF NUCLEAR FISSION

Nicolas Schunck, Lawrence Livermore National Laboratory

invited

Since its discovery in the late nineteen thirties, nuclear fission has remained one of the most complex and elusive problems in physics. Powerful phenomenological models have been developed and fine-tuned over the years, which has allowed numerous applications of nuclear fission for civil energy use or national security, in spite of our fragmentary understanding of the fundamental mechanisms involved. However, these empirical approaches are intrinsically limited and their reliability in very neutron-rich or heavy nuclei, where no direct experimental data exists yet, can be questioned. It is, therefore, necessary to develop in complement a microscopic, fully quantum-mechanical, description of fission, where the dynamic of the process is described by many-body methods rooted in the inter-nucleon interaction. The nuclear energy density functional theory (DFT) provides an ideal framework for such a goal, but progress has been slow essentially because of the tremendous computational cost involved. The recent development of leadership computing facilities in the USA, Europe and Japan has introduced a paradigm shift in the field: Calculations that were simply unfeasible only 5 or 10 years ago can now be completed in just a few hours. This talk will review some of the recent advances in the microscopic theory of fission, with special emphasis to the construction of predictive energy functionals, the relevance of high-performance computing in large-scale DFT calculations and the special challenges posed by neutron-induced fission.

ELASTIC SCATTERING AND DIRECT REACTIONS FOR THE ^{11}Be + ^{64}Zn SYSTEM CLOSE TO THE COULOMB BARRIER

Valentina Scuderi, INFN Laboratori Nazionali del Sud, Catania

seminar

A. Di Pietro 1, A. M. Moro 3, L. Acosta 4, F. Amorini 1,2, M. J. G. Borge 5, P. Figuera 1, M. Fisichella 1,6, L. M. Fraile 7, J. Gomez Camacho 3,8, H. Jeppesen 9, M. Lattuada 1,2, I. Martel 4, M. Milin 10, A. Musumarra 1,2, M. Papa 1, M. G. Pellegriti 1,2, F. Perez Bernal 4, R. Raabe 11, G. Randisi 1,2, F. Rizzo 1,2, G. Scalia 1,2, O. Tengblad 5, D. Torresi 1,2, A. Maira Vidal 5, D. Voulot 9, F. Wenander 9, M. Zadro 12

1 INFN-LNS and Sezione di Catania 2 Università di Catania
3 Universidad de Sevilla 4 Universidad de Huelva
5 CSIC Madrid 6 Università di Messina
7 Universidad Complutense Madrid 8 Centro Nacional de Aceleradores Sevilla
9 ISOLDE CERN 10 University of Zagreb
11 KU Leuven 12 Ruder Boskovic Institute, Zagreb

Elastic scattering and direct reactions around the barrier, in collisions induced by halo nuclei, has been the object of many publications in the last years. Elastic scattering, being a peripheral process, allows one to investigate the surface properties of the halo nuclei. Low energy elastic scattering and reaction experiments, involving halo nuclei, have been performed mostly with ^{6}He, which is a 2n-halo nucleus, on several targets over a wide range of energies and masses and only few experiments have been performed with 1n-halo ^{11}Be nucleus. The studies performed using the ^{6}He at low bombarding energy have shown that coupling to the continuum strongly affects the elastic cross-section, especially on heavy targets, with dramatic changes in the elastic cross section from the expected behavior and with an overall increase in the total reaction cross section in favor of direct reaction channels.

Thanks to the availability of a post-accelerated ^{11}Be beam at Rex-Isolde we have measured a high quality quasi-elastic scattering angular distribution for 1n-halo ^{11}Be nucleus. In this contribution, results obtained at Rex-Isolde and LNS Catania concerning different reaction channels for the collisions induced by the three Beryllium isotopes ^{9,10,11}Be on a medium mass ^{64}Zn target at energy close to the Coulomb barrier will be presented. In the case of ^{9,10}Be, elastic scattering angular distributions were measured whereas, in the ^{11}Be case, the quasi-elastic scattering angular distribution was measured. A strong damping of the quasi-elastic cross-section was observed in the ^{11}Be case, in the angular range around the Coulomb-nuclear interference peak. In this latter case a large total reaction cross-section is found. Such a cross-section is more than a factor of two larger than the ones extracted in the reactions induced by the non-halo Beryllium isotopes. A large contribution to the total-reaction cross-section in the ^{11}Be case could be attributed to transfer and/or breakup events.

In this contribution new continuum-discretized coupled channel calculations of the ^{11}Be + ^{64}Zn reaction, performed in the attempt to interpret the effect of coupling with the breakup channels on the measured cross sections, will be also presented. The calculations show that the observed suppression of the Coulomb-nuclear interference peak is caused by a combined effect of Coulomb and nuclear couplings to the breakup channels.

STUDYING CHIRAL BANDS ASSOCIATED WITH MULTI-QUASIPARTICLE CONFIGURATION

Obed Shirinda, iThemba LABS, South Africa

seminar

Nuclear chiral systems are formed when the total angular momentum of the nucleus is aplanar, i.e. when it has significant projections along the three nuclear axes [1]. Chiral symmetry is associated with the observation of degenerate $\Delta I = 1$ partner bands [1] (this is the most revealing feature of strongly broken chiral system).

In this work the chiral fingerprints such as degeneracy in the properties of the chiral partner bands [1], staggering in the B(M1) transition probabilities [2] and a lack of energy staggering [3, 4] associated with chiral partner bands in the mass regions of 100, 130 and 190 were examined using the multi-particle-plus-rotor (MPR) model calculations [5]. A strongly broken chirality for nuclei with large and stable triaxiality and with a suitable chiral configuration was not found for any ideal (a configuration space containing only one orbital for each of the odd valence nucleons) or realistic (a configuration space containing realistically large number of orbitals close to the corresponding Fermi level) configurations. For ideal configuration the angular momentum vectors of these extra valence odd nucleons which are less aligned along the nuclear major axes bring in contributions to the wave functions that correspond to planar geometry which then causes that near degeneracy is not reached. This effect is even stronger for cases which correspond to large configuration space, i.e. realistic configuration. Even though degeneracy was not found, the geometry is on average chiral because the relative orientation of the angular momenta of the proton, the neutron and the core are larger than 700 (for ideal configuration) and 300 (for realistic configuration) even at high spins, confirming that the total angular momentum remains aplanar through the whole calculated spin range. In fact the multi-quasiparticle partner bands with suitable chiral configurations exhibit much worse near-degeneracy than the two-quasiparticle bands investigated in reference [6]. These results, as well as the reliability of using these chiral fingerprints to identify chiral partner bands in real nuclei will be discussed.

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TOWARD A GENERALIZED MONOPOLE DESCRIPTION OF ATOMIC NUCLEI

Kamila Sieja, IPHC Strasbourg

seminar

We discuss a model for the monopole interaction for nuclei in a valence space containing one h.o. shell, based on the invariant decomposition of the effective interaction proposed by Zuker [1-3]. Our model treats empirically the three-nucleon contributions beyond the realistic potential, arising from both core and valence particles. It allows for a correct reproduction of the shell evolution and improves remarkably the spectroscopic description of nuclei with inclusion of only a few parameters beyond the realistic NN potential. We present the results in p and sd-shells, where the rms error for spectroscopy of large sets of nuclei can be reduced by 50% introducing only 4 parameters characterizing three-body monopole corrections.

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HALO NUCLEI: STEPPING STONES ACROSS THE DRIP-LINES
Haik Simon, GSI Helmholtzzentrum für Schwerionenforschung GmbH

invited

The availability of intense secondary beams in conjunction with efficient detection setups allows for a production and study of the most extreme nuclear systems in terms of asymmetry of proton and neutron number in the continuum. Nuclei close to the drip-lines, exhibiting exotic properties themselves, are used as seeds in order to produce them in transfer and knockout reactions depending on beam energies. These nuclear systems challenge nuclear structure theory being open quantum systems far from the valley of beta stability as well as reaction theory while trying to describe their production mechanisms. From experiment momentum distributions, relative energy spectra, and spin alignment during the reaction can be determined and lead to the observation of energy and angular correlations as well as dependent quantities like e.g. the profile function denoting a momentum width in dependence of relative energy. They are determined from fragments and gamma radiation leaving the reaction zone. The link to intrinsic properties of these unbound systems has to be explored by gathering precise knowledge of the properties of the seed nuclei and compare them to the structures observed in the continuum.

In my talk I will try to exemplify the above-mentioned methods, and review the current knowledge on light systems like $^{5,7}H$, ^{7-10}He, $^{10-13}Li$, and the most neutron-rich Beryllium and Oxygen systems.

PUZZLE OF THIRD MINIMA IN ACTINIDES
Janusz Skalski, NCBJ Warsaw

seminar

M. Kowal and J. Skalski
National Centre for Nuclear Research, Hoza 69, 00-681 Warsaw, Poland

Third, hyperdeformed minima in actinides were found first around ^{232}Th and recently in $^{232,234,236}U$. Many theoretical predictions show shallow minima in thorium in agreement with experimental interpretation. Deep IIIrd minima in uranium found by the Munich-Debrecen experiments disagree with all calculations except for those of S. Cwiok et al. within the Woods-Saxon model. We have just showed that in this model the IIIrd minima in uranium disapear after proper nuclear shapes are considered.

Thus, there is a contradiction between experiment and theory. Its resolution is important also for predictions of superheavy nuclei: the orbits that build them at moderate deformations are those that come down at (supposed) hyperdeformed minima in actinides.

ISOSPIN SYMMETRY BREAKING IN SD SHELL NUCLEI AND APPLICATIONS

Nadya Smirnova, Centre d'Etudes Nucléaires de Bordeaux-Gradignan

seminar

N. A. Smirnova 1, Y. Lam 1, and E. Caurier 2
1 CENBG (CNRS/IN2P3 - Universite Bordeaux 1, Chemin du Solarium, BP 120,
F-33175 Gradignan, France
2 Universite Strasbourg, IN2P3, CNRS, F-67037 Strasbourg 2, France

Although the breaking of the isospin symmetry in nuclei is small, there are numerous demands for its accurate description by theoretical models. In particular, the effect of the Coulomb force is vital for understanding of the structure of proton-rich nuclei, relevant for nuclear astrophysics applications, and for description of isospin-forbidden particle emission. Another important issue is calculation of isospin-symmetry breaking corrections to nuclear beta decay in relation to precision tests of the Standard Model on nuclei.

We have recently derived a new empirical *sd* shell-model Hamiltonian which reproduces accurately the isobaric mass multiplets splittings [1, 2]. The Hamiltonian contains apart from the basic USD interaction, the Coulomb interaction and a phenomenological part consisting of Yukawa meson-exchange potentials which models isospin-symmetry breaking of the effective nuclear interaction. The latter represents about 1-2% of the residual shell-model interaction. Solution of the eigenproblem by numerical diagonalization allows to get nuclear states of mixed isospin. The empirical isospin-nonconserving Hamiltonian represents a modern version of the work [3].

Two applications will be discussed. First, we will present branching ratios for a β-delayed proton emission from ^{22}Al in comparison with the previous calculations [4]. Second, calculation of isospin-symmetry breaking correction to the superallowed 0+ → 0+ β-decay for *sd*-shell emitters in comparison with the existing results [5, 6].

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MODIFICATIONS OF SHELL CLOSURES FAR FROM STABILITY: EVIDENCES, CAUSES AND CONSEQUENCES

Olivier Sorlin, GANIL

invited

Magic nuclei are cornerstones of nuclear structure. Due to the presence of large shell gaps between occupied and valence shells, they are spherical, have large excitation energies and weak excitation probabilities. They are often more abundant than other nuclei in the universe, play key roles in explosive nucleosynthesis, and could bind superheavy nuclei despite the large repulsive coulomb interaction.

Our vision of immutable magic numbers, whatever the proton to neutron ratio, has been drastically changed these last years. In particular it has been demonstrated that the neutron magic numbers 8, 20 and 28 were vanishing far from stability. In parallel new magic numbers appear as N=16.

These discoveries arose with the advent of radioactive ion beam facilities worldwide as well as progresses in detection systems. They pose fundamental questions such as: which parts of the nuclear force drive these modifications of shell closures? Are such effects observed throughout the chart of nuclides, or are they limited to medium mass nuclei? What are the consequences of these shell modifications for explosive nucleosynthesis, and for the existence of superheavy nuclei?

The present talk will mainly focus on some important aspects of the nuclear force such as the spin-orbit interaction and the behavior of nuclear forces at drip line.

DECAY SPECTROSCOPY OF NEUTRON-RICH NUCLEI IN THE VICINITY OF ^{110}Zr AT RIBF

Toshiyuki Sumikama, Tohoku University

invited

Shape evolution in the neutron-rich Zr isotopes attracts much attention because prolate, oblate, spherical or exotic-tetrahedral shapes may be stabilized. ^{110}Zr (Z=40 and N=70) is expected to be a spherical shape due to a possible subshell closure at N=70, and be double magic for the exotic tetrahedral shape. Therefore, nuclei in the vicinity of ^{110}Zr are one of the best candidates to search for the shape transition. A tetrahedral shape has a different symmetry from the general quadrupole shape, thus it will be difficult to populate a tetrahedral state. An in-flight-fission reaction of ^{238}U beam is a promising method to produce the tetrahedral shape, and it may become an isomer.

We performed the decay spectroscopy around ^{110}Zr as a first decay experiment at RIBF. The gamma rays from $^{106,108}Zr$ were observed for the first time. The low-lying states of $^{106,108}Zr$ indicate that these two nuclei are well deformed, and the deformation of the Zr isotope reaches maximum at N=64. A new isomer, which was produced as the in-flight-fission fragment, was discovered in ^{108}Zr. The energy of the isomeric state was not determined, but it is the candidate to search for the tetrahedral shape.

The decay spectroscopy using Euroball-RIKEN cluster array (EURICA) will be performed in proton- and neutron-rich regions including neutron-rich Zr isotopes. The EURICA is the high-efficiency-gamma-ray spectrometer consisting of 84 germanium detectors. In this talk, I will show the results of $^{106,108}Zr$ and a future program of the decay spectroscopy with the EURICA around ^{110}Zr.

TRANSFER REACTION STUDIES WITH SPECTROMETERS

Suzana Szilner, Ruder Boskovic Institute, Zagreb

invited

The revival of transfer reaction studies benefited from the construction of the new generation large solid angle spectrometers based on trajectory reconstruction that reached an unprecedented efficiency and selectivity. The coupling of these spectrometers with large gamma arrays allowed the identification of individual excited states and their population pattern.

In transfer reactions one of the most interesting items is how single particle and more complex degrees of freedom act in the transfer process. Via gamma-particle coincidences it is now experimentally possible to measure the transfer strength to specific final states with high efficiency. The individual state yield distribution in the final reaction products reflects a strong interplay between single-particle and collective degrees of freedom that is pertinent to the reaction dynamics.

Specific highlights are the effects of pair transfer degrees of freedom, where with the large solid angle magnetic spectrometers, different (nn), (pp) and (np) correlations, can be studied at once. Of special interest are the studies below the barrier, where the transfer probabilities can be followed up, with sufficient accuracy, to the large internuclear distances in order to understand the role played by nucleon-nucleon correlation.

These two items will be addressed in the presentation, how the individual state yield distribution in the final reaction products reflects a strong interplay between single-particle and collective degrees of freedom and the reaction dynamics via studies of the ^{40}Ar + ^{208}Pb reaction, and the interplay between single and pair transfers far below the Coulomb barrier in ^{96}Zr + ^{40}Ca.

STUDIES OF THE ELECTRIC DIPOLE RESPONSE IN NUCLEI USING THE SCATTERING OF POLARIZED PROTONS

Atsushi Tamii, RCNP, Osaka University

invited

The electric dipole (E1) response is one of the most fundamental responses of atomic nuclei to external fields. Most of the E1 strength is carried by a giant dipole resonance (GDR), which is described as a dipole oscillation between protons and neutrons. Recently a sizable E1 strength concentration has been found in several nuclei at the region of neutron separation energy below GDR, which is called a low-lying dipole resonance or a pygmy dipole resonance (PDR). The nature of the PDR is not understood well but may be interpreted as a dipole oscillation of neutron skin against an isospin-saturated core in theoretical models. The properties of the PDR may shed light on the formation of neutron skins, symmetry energy and equilibrium properties of neutron stars. In addition, recent studies on energy density functionals using Skyrme forces suggest the dipole polarizability, which is an inversely energy-weighted sum of the E1 strength, as an alternative observable to constrain both neutron skin and symmetry energy. Thus complete determination of the E1 response is quite important.

A case of special interest is the doubly magic nucleus ^{208}Pb. We have performed a high-resolution proton inelastic scattering measurement from ^{208}Pb at very forward angles including zero-degrees. The data were taken at the Research Center for Nuclear Physics (RCNP), Osaka University, employing a polarized proton beam at 295 MeV. Differential cross sections were measured at 0-6 degrees and polarization transfer coefficients at 0-2.5 degrees. The measured excitation energy region is 5-22 MeV, which completely covers the GDR and PDR strengths.

The differential cross sections were decomposed into E1, spin magnetic-dipole (spin-M1) and other components by using two independent methods; polarization transfer data analysis and multipole decomposition analysis (MDA) of angular distribution of the cross sections. The two methods have given consistent results on the E1 responses. We have obtained an accurate E1 strength distribution including the PDR region. The dipole polarizability has been determined up to 130 MeV by combining our data and existing data. The measured dipole polarizability and the E1 strength distribution are now compared with theoretically models to discuss the neutron skin thickness and the symmetry energy of the nuclear equation of state. We have also applied the same experimental technique for ^{90}Zr and other targets. In the conference, I will explain the experimental methods and will report on the recent results.

OVERLAP OF QRPA STATES BASED ON GROUND STATES OF DIFFERENT NUCLEI

Jun Terasaki, Center for Computational Science, University of Tsukuba

seminar

The quasiparticle random-phase approximation (QRPA) is applied to two nuclei, and overlap of the QRPA excited states based on the different nuclei is calculated. The purpose is to calculate the overlap of intermediate nuclear states of the double-beta decay. We use the like-particle QRPA after the closure approximation is applied to the nuclear matrix elements. The overlap is calculated as rigorously as possible by making use of the explicit equation of the QRPA ground state - this is rare and the advanced point of our research. The formulation of the overlap is shown, and a test calculation is performed for relatively light nuclei with the Skyrme and volume delta-pairing energy functionals. Efficient truncation is possible keeping good accuracy, therefore, there is no reason any more to avoid the explicit equation of the QRPA ground state.

BRIDGING THE GAP BETWEEN ATOMIC AND NUCLEAR PHYSICS: TOWARDS AN ALL-OPTICAL ACCESS TO THE LOWEST NUCLEAR TRANSITION IN ^{229m}Th*

Peter Thirolf, Ludwig-Maximilians-University Munich

seminar

P. G. Thirolf 1, L. v.d. Wense 1,2, D. Kalb 1, T. W. Haensch 1,2, T. Udem 1
1 LMU München, Germany
2 MPI für Quantenoptik, Garching, Germany

The isomeric first excited state of the isotope ^{229}Th exhibits the lowest nuclear excitation energy in the whole landscape of known atomic nuclei. For a long time this energy was reported as 3.5(5) eV, however, a recent measurement corrected this value to 7.6(5) eV [1], corresponding to a deep-UV transition wavelength of 163(11) nm. Thus for several decades any search for a direct identification of this ground-state transition failed. The isomeric lifetime is ca. 3-5 hours, leading to an extremely sharp relative linewidth of $\Delta E/E \sim 10^{-20}$, 5-6 orders of magnitude smaller than typical atomic relative linewidths. This makes ^{229m}Th an ideal candidate for a nuclear optical clock with very high accuracy [2]. Moreover, in the literature speculations about a drastically enhanced sensitivity of the ground-state transition of ^{229m}Th for potential time-dependent variations of fundamental constants (e.g. fine structure constant alpha) can be found [3,4].

This contribution will report on our experimental efforts towards a first direct identification of the isomeric ground-state transition in ^{229}Th, aiming at improving our knowledge of the transition energy by about an order of magnitude, which is required in order to design a suitable laser system able to directly excite the first excited state. Being a hot topic in nuclear structure as well as in metrology and fundamental physics research, many groups world-wide search for the ground-state deexcitation of ^{229m}Th, using the 2% decay branch in the alpha decay of ^{233}U via the ^{229}Th isomer as population mechanism. Our experimental approach differs from the those pursued by other groups such that we spatially decouple the population of ^{229m}Th from the isomeric deexcitation by placing the ^{233}U source in a buffer-gas stopping cell, extract the recoiling ^{229}Th daughter products and collect the ^{229m}Th ions via a suitable potential on a collection surface behind the gas cell (and a purifying quadrupole mass filter). Thus all prompt decay background occurring in the gas cell is efficiently suppressed. A highly efficient UV optics is employed to focus the deexcitation UV fluorescence onto an MCP detector, where the secondary electrons are accelerated towards a phosphorous screen which is then imaged by a highly sensitive CCD camera. The contribution will review the experimental requirements and the status of the measurements.

*Supported by DFG Cluster of Excellence Munich-Centre for Advanced Photonics (MAP).

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OBSERVATION OF GROUND-STATE TWO-NEUTRON DECAY

Michael Thoennessen, Michigan State University

invited

Neutron decay spectroscopy has become a successful tool to explore nuclear properties of nuclei with the largest neutron-to-proton ratios. Resonances in nuclei located beyond the neutron dripline are accessible by kinematic reconstruction of the decay products. The development of two-neutron detection capabilities of the Modular Neutron Array (MoNA) at NSCL has opened up the possibility to search for unbound nuclei which decay by the emission of two neutrons. Specifically this exotic decay mode was observed in ^{13}Li, ^{16}Be, and ^{26}O.

HINDERED PROTON COLLECTIVITY IN THE PROTON-RICH NUCLEUS ^{28}S: POSSIBLE NEW MAGIC NUMBER AT Z=16

Yasuhiro Togano, Extereme Matter Institute EMMI and GSI

seminar

The reduced transition probability B(E2; GS → 2$^+$) for ^{28}S was determined experimentally using Coulomb excitation at 53 MeV/nucleon [1]. The experiment was performed using the RI Beam Factory accelerator complex at RIKEN Nishina Center. The resultant B(E2) value is smaller than the expectation based on empirical B(E2) systematics [2]. The proton and neutron transition matrix elements, M_p and M_n, for the GS → 2$^+$ transition were evaluated by using the B(E2) values of ^{28}S and the its mirror nucleus ^{28}Mg. The $|M_n/M_p|$ ratio was obtained to be 1.9(2) N/Z, showing the hindrance of proton collectivity relative to that of neutrons. These results indicate the emergence of the magic number Z=16 in the $|T_z|$=2 nucleus ^{28}S.

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STUDY OF THE γ-RAY STRENGTH IN ^{238}Np

Tamás Tornyi, University of Oslo

seminar

T. G. Tornyi 1,2, F. Giacoppo 1, A. Görgen 1, M. Guttormsen 1, T. W. Hagen 1, A. Krasznahorkay 2, A. C. Larsen 1, T. Renstrøm 1, S. J. Rose 1, S. Siem 1, G. M. Tveten 1
1 Department of Physics, University of Oslo, N-0316 Oslo, Norway
2 Institute of Nuclear Research, P.O. Box 51., Debrecen, H-4001, Hungary

An investigation of the γ-ray strength function in different actinide nuclei comparing simulated and observed γ-ray cascades following neutron capture at the n_TOF facility at CERN revealed an excess of low-lying strength for ^{235}U and ^{241}Pu, but not for ^{238}Np [1]. Similar resonances have also been observed in a more direct way using the Oslo method in $^{231-233}$Th and ^{232,233}Pa, and their large strength was interpreted as due to the scissors mode [2]. Scissors-mode resonances can be expected to occur throughout the region of deformed actinide nuclei; it is hence surprising that no indication was found in the n_TOF data for ^{238}Np.

To shed more light on this question, an experiment was performed at the Oslo Cyclotron Laboratory (OCL) to study the γ-strength function in ^{238}Np using the Oslo method and the reaction ^{237}Np(d, p). At the same time the experiment aimed at investigating the competition between (n, γ) and (n, f) cross sections via the so-called surrogate method [3]. For this purpose a new PPAC device was developed at OCL to detect fission fragments in coincidence with scattered particles detected in the ΔE-E silicon telescopes of SiRi and γ-rays detected in the CACTUS array of 28 large-volume NaI detectors. Results for the γ-ray strength function in ^{238}Np will be discussed and the new detector setup for studies of actinides and its performance will be presented.

[1] C. Guerrero et al., Journ. of the Korean Phys. Soc. 59/2, 1510 (2011).
[2] M. Guttormsen et al., to be submitted.
[3] J. N. Wilson et al., Phys. Rev. C 85, 034607 (2012).

STUDY OF NEUTRON RICH NUCLEI $^{18-21}$N AND ^{25}F
Zsolt Vajta, ATOMKI Institute of Nuclear Research, Debrecen

seminar

Zs. Vajta 1, M. L. Achouri 2, T. Aiba 3, J. C. Angélique 2, N. Aoi 4, F. Azaiez 5, H. Baba 4, M. Belleguic 5, D. Bemmerer 6, C. Borcea 7, C. Bourgeois 5, J. M. Daugas 8, F. De Oliveira-Santos 8, Z. Dlouhy 9, Zs. Dombrádi 1, C. Donzaud 5, J. Duprat 5, Z. Elekes 1, T. Furumoto 10, Zs. Fülöp 1, S. Grévy 2, D. Guillemaud-Mueller 5, N. Iwasa 11, Á. Kiss 1, T. Kobayashi 11, Y. Kondo 12, S. Leenhardt 5, M. Lewitowicz 8, M. J. Lopez-Jimenez 8, S. M. Lukyanov 13, W. Mittig 8, T. Motobayashi 4, T. Nakabayashi 12, T. Nannichi 12, Yu.-E. Penionzhkevich 13, M. G. Porquet 14, F. Pougheon 5, P. Roussel-Chomaz 8, M. G. Saint-Laurent 8, Y. Sakuragi 4,10, H. Sakurai 4, H. Savajols 8, Y. Sobolev 13, D. Sohler 1, O. Sorlin 5, M. Stanoiu 5, C. Stodel 8, M. Takashina 15, S. Takeuchi 4, K. Tanaka 4, J. Timar 1, Y. Togano 16, K. Yamada 4, M. Yamaguchi 4, K. Yoneda 4

1 Institute of Nuclear Research, P.O. Box 51., Debrecen, H-4001, Hungary
2 Laboratoire de Physique Corpusculaire, 14000 Caen Cedex, France Caen, 14021 France
3 Niigata University, Niigata 950-2181, Japan
4 The Institute of Physical and Chemical Research (RIKEN), 2-1 Hirosawa, Wako, Saitama 351-0198, Japan
5 Institut de Physique Nucléaire, IN2P3-CNRS, F-91406 Orsay Cedex, France
6 Forschungszentrum Dresden-Rossendorf, Bautzner Landstrasse 128, 01328 Dresden (Rossendorf), Germany
7 IFIN-HH, P.O. Box MG-6, 76900 Bucharest-Magurele, Romania
8 GANIL, B. P. 55027, F-14076 Caen Cedex 5, France
9 Nuclear Physics Institute, AS CR, CZ 25068, Rez, Czech Republic
10 Department of Physics, Osaka City University, Osaka 558-8585, Japan
11 Tohoku University, Sendai, Miyagi 980-8578, Japan
12 Tokyo Institute of Technology, 2-12-1 Oh-Okayama, Megro, Tokyo 152-8551, Japan
13 FLNR, JINR, 141980 Dubna, Moscow Region, Russia
14 CSNSM, IN2P3-CNRS and Université Paris-Sud, F-91405 Orsay Campus, France
15 Research Center for Nuclear Physics (RCNP), Osaka University, Osaka 567-0047,Japan
16 Rikkyo University, 3 Nishi-Ikebukoro, Toshima, Tokyo 171, Japan

The actual question of the experimental nuclear physics is the study of the structure of nuclei close to the drip lines. Shell structure, deformation and excited states of nuclei around ^{24}O have attracted a great interest, since they can give information on the stability of the N = 14 and 16 subshell closures.

Nitrogen and fluorine isotopes located around the heaviest, still bound oxygen isotope ^{24}O have been studied by use of in beam γ-ray spectroscopy. In the case of $^{18-21}N$ the experiment was performed in RIKEN through neutron knockout and proton inelastic scattering, while the ^{25}F was studied in GANIL using single and double step fragmentation reactions. The γ-lines found and the level schemes constructed for the nitrogen isotopes are in good agreement with Ref. [1]. The determined excitation cross sections and the deduced proton and neutron deformation lengths are in accordance with the presence of an N = 14 subshell closure in ^{21}N, while it disappears in ^{20}C. In the case of ^{25}F, several new transitions were identified and based on γγ-coincidence data a level scheme was constructed. It was found that the high-energy states associated with the coupling of the single proton to the 2^+ state of ^{24}O are at several hundred keV lower energy than expected from shell model calculations. This observation is consistent with the fact that the 2^+ energy of the ^{24}O is also at a lower energy than the shell model prediction.

Methods and results of this analysis will be discussed further in the presentation.

[1] D. Sohler et al., Phys. Rev C 77, 044303 (2008).

MODERN DECAY SPECTROSCOPY WITH BETA-GAMMA-NEUTRON DETECTORS AT ALTO

David Verney, IPN Orsay

invited

The IPN Orsay ISOL facility, ALTO, is dedicated to the production of neutron-rich radioactive beams from the interaction of a 50 MeV 10 μA electron beam with a UC_x target (~60 g of ^{238}U). It was dimensioned for 10^{11} fissions/sec and located on the Orsay Tandem premises. While the project was launched some 15 years ago, 2012 is a watershed in progress towards full exploitation as the facility received the full green light for operation from the French nuclear safety authorities. Meanwhile, the ALTO laser ion source was commissioned and successfully used for the selective ionization of neutron rich Ga isotopes. That last subject will be covered by the contribution of K. Kolos to this conference. The construction of a new secondary beamline after the mass separator was completed in May 2012. A new detection setup based on the use of a movable tape station has been designed to accommodate 4 small EXOGAM CLOVER detectors (EXOGAM prototypes). This setup named BEDO (Beta Decay Studies at Orsay) has been optimized for Compton and beta suppression and was recently fully commissioned on-line with radioactive A=83, 84 beams. The BEDO on-line performances will be presented.

In addition, since the very early stages of the project, physics results have been accumulated taking advantage of the beams available during the different commissioning phases. Physics goals were mainly focused on the evolution of the N=50 gap towards Ni-78. An overview of the physics achievements obtained with the PARRNe on-line mass separator from beta-delayed gamma spectroscopy will also be presented.

THE HIGGS BOSON OF STANDARD MODEL – ITS FUNCTION AND SIGNATURES

Zbigniew Wąs, IFJ PAN Kraków

invited

The Higgs boson play a very special role in Standard Model. It interacts weakly with all other elementary fields but at the same time consequences of these interactions are decisive for their basic properties such as masses. This elusive particle, possibly discovered in last summer attracts great attention. It is because it belongs to completely new level of matter construction.

In my talk I will first review fields of the Standard Mode and their The Higgs boson of Standard Model - its function and signatures interactions. Later I will turn to main processes enabling Higgs discovery. In this context I will mention signatures involving tau leptons, where properties of low energy hadronic interactions are used. Participation of physicists from Cracow is of importance in this challenge.

PRECISE DETERMINATION OF THE ISOVECTOR GIANT QUADRUPOLE RESONANCE IN NUCLEI

Henry R. Weller, Duke University and TUNL

invited

The intense, nearly mono-energetic, 100% linearly polarized beams available at the HIGS facility, along with the realization that the E1-E2 interference term that appears in the Compton scattering polarization observable has opposite signs in the forward and backward angles, has been shown to make it possible to obtain an order-of-magnitude improvement in the determination of the parameters of the isovector giant quadrupole resonance (IVGQR) [1]. The first nucleus which was studied was ^{209}Bi. One surprise was that only 56% of the Isovector E2 Energy Weighted Sum Rule was observed. Preliminary results have now been obtained for the case of ^{89}Y. The parameters in this case suggest an A-dependence for the energy, width and sum-rule fraction which is quite intriguing. The method and the results for ^{209}Bi and ^{89}Y will be presented, along with plans for future systematic studies. The possible impact of these results on the nuclear equation of state which is important for our understanding of nuclear matter under extreme conditions will be discussed.

Partially supported by the US Department of Energy grant number DE-FG02-97ER41033.

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CORE EXCITATIONS ACROSS THE NEUTRON SHELL GAP IN THE Z=81 ^{207}Tl NUCLEUS

Emma Wilson, University of Surrey

seminar

E. Wilson 1, Zs. Podolyak 1, M. Bowry 1, M. Bunce 1, R. Kempley 1, M. W. Reed 1, P. H. Regan 1, P. M. Walker 1, B. Fornal 2, N. Cieplicka 2, B. Szpak 2, R. V. F. Janssens 3, M. P. Carpenter 3, C. R. Hoffman 3, T. Lauritsen 3, S. Zhu 3, C. J. Chiara 3,4, F. G. Kondev 5, C. Rodriguez-Triguero 6, G. D. Dracoulis 7, G. J. Lane 7, A. Y. Deo 8, H. Grawe 9

1 Department of Physics, University of Surrey, Guildford, GU2 7XH, UK
2 H. Niewodniczański Institute of Nuclear Physics, Kraków, Poland
3 Physics Division, Argonne National Laboratory, Argonne, IL 60439, USA
4 Department of Chemistry, University of Maryland, College Park, MD 20742, USA
5 Nuclear Engineering Division, Argonne National Laboratory, Argonne, IL 60439, USA
6 School of Computing, Engineering and Mathematics, University of Brighton, Brighton, UK
7 Research School of Physics and Eng., Australian National University, Canberra, Australia
8 Department of Physics, University of Massachusetts Lowell, MA 01854, USA
9 GSI Helmholtzzentrum für Schwerionenforschung GmbH, D-64291 Darmstadt, Germany

A reaction involving the collision of a ^{208}Pb beam on to a ^{208}Pb target led to the production of several neutron-rich isotopes. This experiment took place at Argonne National Laboratory, using the ATLAS accelerator, with a beam energy of 1446 MeV, and the Gammasphere Compton-suppressed, HPGe detector array. Different beam pulsing conditions were used, therefore the experiment was sensitive to both prompt and delayed gamma-rays. Delayed gamma-rays were detected in the beam-off period, which lasted ~300 ns.

^{207}Tl is one proton away from the ^{208}Pb doubly magic nucleus. Its low energy level structure is dominated by single proton hole states $\pi s_{11/2}$, $\pi d_{13/2}$ and $\pi h_{11/2}$. The $11/2^-$ state is isomeric with $T_{1/2}$ = 1.33(11) s [1]. To get to spin levels higher than this isomeric state, the neutron core must be broken.

The reaction partner of ^{207}Tl is ^{209}Bi, which has an additional proton compared to ^{208}Pb, and is relatively well known [2]. Therefore cross-coincidences between these two nuclei were used to establish the levels above the $11/2^-$ isomeric state in ^{207}Tl [3]. Here the level scheme was extended to a spin of approximately 49/2. Tentative multipolarities have been assigned to some transitions, based on theoretical electron conversion coefficients [4]. Additionally, shell model calculations have been produced, and are compared to the tentative experimental level scheme.

The experimental results, as well as their interpretation based on the shell model, will be discussed.

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[2] M. J. Martin, Nucl. Data Sheets 63, 723 (1991).
[3] F. G. Kondev and S. Lalkovski, Nucl. Data Sheets 112, 3 (2011).
[4] T. Kibédi et al, Nucl. Instr. and Meth. A 589, 202 (2008).

KNOCKOUT REACTION STUDIES, STRUCTURE AND CORRELATIONS

Kathrin Wimmer, Central Michigan University

invited

The explanation of the magic numbers for nuclei in the valley of stability was one of the milestones in the understanding of nuclear structure. However, in recent years, several theoretical and experimental investigations found evidence that these magic numbers change when going away from stability towards more exotic nuclei. Nucleon knockout reactions using fast rare isotope beams are a well suited tool to study single-particle properties of exotic nuclei and the evolution of nuclear shell structure towards the drip-lines. Recently, a series of experiments has been performed at the National Superconducting Cyclotron Laboratory at Michigan State University in order to study reaction mechanism in nucleon knockout reactions. Such experiments are key for validation of the theoretical description of the reaction mechanism and use for quantitative spectroscopy of very exotic nuclei. In particular the sudden removal of two protons from an intermediate-energy neutron-rich projectile has been shown to proceed as a direct reaction. In addition to giving spectroscopic information, this type of reaction promises a rather unique tool assign spins by measuring the momentum distributions of the heavy reaction residues. First coincidence measurements of the heavy reaction residues and the removed protons enabled the relative cross sections from each elastic and inelastic nucleon removal mechanism to be determined. These more final-state-exclusive measurements are key for further validation of this direct reaction and its use for quantitative spectroscopy of highly neutron-rich nuclei. The kinematic correlations of the removed protons are also analyzed. Comparisons with phase-space simulations show that a majority of the triple-coincidence events with two protons display correlations consistent with a two-body, diproton-like removal mechanism. This result promises access to a new, more specific probe of the spin and spatial correlations of valence nucleon pairs in exotic nuclei produced as fast beams.

In this talk I will present recent results from experiments at the interplay of nuclear structure and reactions performed at the NSCL.

RECENT STUDIES ON NUCLEAR SHAPES OF ULTRAHIGH-SPIN AND HIGH-K STATES

Furong Xu, Peking University

invited

F. R. Xu, H. L. Liu, Y. Shi, P. M. Walker, J. Dobaczewski, S. Frauendorf, W. Nazarewicz, J.C. Pei, N. Nikolov

School of Physics, Peking University, Beijing 100871, China
Department of Applied Physics, Xi'an Jiaotong University, Xi'an 710049, China
Department of Physics and Astronomy, University of Tennessee, Knoxville, Tennessee, USA
Physics Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee, USA
Institute of Theoretical Physics, Faculty of Physics, University of Warsaw, Poland
Department of Physics, , University of Jyväskylä, Finland
Department of Physics, University of Surrey, Guildford, Surrey GU2 7XH, UK
Department of Physics, University of Notre Dame, Notre Dame, Indiana, USA

Using configuration-constrained Woods-Saxon potential-energy-surface (PES) calculations, we have investigated the effect of deformation on the structures of superheavy nuclei, finding a significant effect from the high-order β_6 deformation [1]. The deformed shell gaps at N=152 and Z=100 are increased due to the existence of β_6 deformation. The inclusion of the β_6 parameter can significantly improve the description of the heaviest high-K isomers. Furthermore, we have investigated possible high-K isomers in the second well of actinide nuclei. Many high-K fission isomers have been predicted [2].

Ultrahigh spins around 65 $\hbar$ have been reached in the nucleus, Er-158; the observed rotational band has a large quadrupole moment [3]. To understand this structure, we carried out self-consistent cranked Skyrme-Hartree-Fock calculations in the tilted-axis-cranking (TAC) variant. Our results suggest that the observed structure can be associated with a triaxial strongly-deformed (TSD) configuration [4]. We demonstrate that one of the two triaxial minima obtained in the principal-axis-cranking method is actually a saddle point.

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2. H. L. Liu et al., Eur. Phys. J. A 47, 135 (2011).
3. X. Wang et al., Phys. Lett. B 702, 127 (2011).
4. Y. Shi et al., Phys. Rev. Lett. 108, 092501 (2012).

LIST OF POSTERS

Theory

T-1 Andreea-Ioana Budaca (NIPNE Bucharest)
Alpha decay properties of the shell stabilized superheavy nuclei

T-2 M. El-Azab Farid (Assiut University, Egypt)
Theoretical investigations of ^{6,8}*He halo nuclei using Microscopic Optical Potentials*

T-3 Diego Gruyer (GANIL)
Pseudo-Critical behavior of nuclear multifragmentation

T-4 Mahmoud Hassanain (King Khalid University, Saudi Arabia)
An investigation of $^{16}O + ^{16}O$ *elastic scattering by using Cluster Folding Model at high energies*

T-5 Mahmoud Hassanain (King Khalid University, Saudi Arabia)
Elastic scattering analysis of heavy ion at low energy

T-6 Awad Ibraheem (King Khalid University, Saudi Arabia)
Theoretical analysis of Alpha-Nucleus scattering using folded potentials

T-7 Katarzyna Mazurek (IFJ PAN Kraków)
Fission dynamics as a probe of the shape-dependent congruence energy term in the macroscopic models

T-8 Bożena Nerlo-Pomorska and Krzysztof Pomorski
(Maria Curie Skłodowska University)
Rotational bands and masses of heaviest nuclei

T-9 Monika Pieńkos (University of Silesia)
Symmetry energy and structure of a neutron star

E-1 Harith Al-Azri (University of York)
Lifetime measurements of exited states in proton rich ^{108,109}Te isotopes

E-2 Thamer Alharbi (University of Surrey)
Lifetime Measurements of the first excited 6^+ states in N=80 isotones, ^{138}Ce and ^{140}Nd

E-3 Józef Andrzejewski (University of Łódź)
The study of K-isomer in ^{134}Nd by using electron conversion spectroscopy

E-4 Aleksandra Fijałkowska (University of Warsaw and ORNL)
New approach to the decay heat calculations based on the Monte Carlo methods

E-5 Giulia Guastalla (Technical University Darmstadt)
Analysis of the ^{104}Sn experiment at PreSPEC

E-6 Zeren Korkulu (Kocaeli University, Turkey and ATOMKI Debrecen)
^{121}Sb(α, γ)^{125}I, ^{121}Sb(α, n)^{124}I and ^{123}Sb(α, n)^{126}I cross section measurements at the astrophysical energies

E-7 Rafał Najman (Jagiellonian University)
Characteristics of the fragment production in ^{197}Au + ^{197}Au reaction at 23 AMeV

E-8 Kamal Kumar (Aligarh Muslim University, India)
Some interesting trends in incomplete fusion reaction dynamics at energies ~4-7 MeV/nucleon

E-9 Dharmendra Singh (IUAC New Delhi)
Incomplete fusion dynamics by measurement of spin distribution of the Evaporation Residues for the system ^{19}F + ^{154}Sm

Instrumentation

I-1 Dmitry Gorelov (University of Jyväskylä)
A neutron source for new IGISOL facility

I-2 Mateusz Kaczmarski (University of Szczecin)
New accelerator facility for measurements of nuclear reactions at extremely low energies

I-3 Mateusz Krzysiek (IFJ PAN Kraków)
Geant4 and GEMINI++ based simulations of possible application of the Recoil Filter Detector in nuclear structure studies with stable and radioactive beams

I-4 Lianne Scruton (University of York)
Recent results from fast timing polycrystalline diamond detectors as part of the LYCCA-0 array

I-5 László Stuhl (ATOMKI Debrecen)
The application of the Low Energy Neutron Array (LENA)

I-6 Christine Weber (Ludwig-Maximilians-University Munich)
Towards in-trap observation of nuclear decays

I-7 Mirosław Ziębliński (IFJ PAN Kraków)
Testing of the PARIS $LaBr_3$-NaI phoswich detectors with high-energy gamma-rays

ABSTRACTS OF POSTERS

LIFETIME MEASUREMENTS OF EXITED STATES IN PROTON RICH ^{108,109}TE ISOTOPES

Harith Al-Azri, University of York

Harith Al-Azri 1, T. Bäck 2, R. Wadsworth 1, C. Qi 2, B. Cederwall 2, F. Moradi 2, D. Bloor 1, T. Brock 1, A. Johnson 2, R. Liotta 2, R. Wyss 2, T. Grahn 3, P. T. Greenlees 3, K. Hauschild 3, A. Herzan 3, U. Jacobsson 3, P. M. Jones 3, R. Julin 3, S. Juutinen 3, S. Ketelhut 3, M. Leino 3, A. Lopez-Martens 3, P. Nieminen 3, P. Peura 3, P. Rahkila 3, S. Rinta-Antila 3, P. Ruotsalainen 3, M. Sandzelius 3, J. Saren 3, C. Scholey 3, J. Sorri 3, J. Uusitalo 3, S. Go 4, E. Ideguchi 4, D. M. Cullen 5, M. G. Procter 5, T. Braunroth 6, A. Dewald 6, C. Fransen 6, M. Hackstein 6, J. Litzinger 6 and W. Rother 6

1 Department of Physics, University of York, York, UK
2 Department of Physics, Royal Institute of Technology, Stockholm, Sweden
3 Department of Physics, University of Jyväskylä, Jyväskylä, Finland
4 CNS, University of Tokyo, Wako-shi, Saitama, Japan
5 School of Physics and Astronomy, University of Manchester, UK
6 Institut für Kernphysik, Universität zu Koln, Köln, Germany

The structure of nuclei near the doubly magic nucleus ^{100}Sn has been the focus of intensive experimental and theoretical studies. In this region, new and interesting phenomena may arise due to a variety of structural and nucleon interaction effects. An area of specific interest relates to recent studies in the even-even tellurium and xenon isotopes [1,2] which have revealed a striking deviation for the 2^+ and 4^+ energies from the expected trends as the N=Z line is approached. For example, the energy of the first 2^+, 4^+ states is expected to rise for Te, Xe isotopes below the mid-shell point at N~66 as the N=50 shell-gap is approached, since the collectivity is expected to be diminished. However, this is not what is experimentally observed, the energies of the 2^+ and 4^+ states do initially increase as N decreases below mid-shell, but then they start to decrease again, suggesting that an increase in collectivity may be occurring. In order to investigate this unexplained phenomenon, the determination of transition probabilities is important.

Lifetime measurements for low-lying states in ^{108}Te were performed. In addition, we could deduce values for lifetimes of some states in the $h_{11/2}$ decoupled band in ^{109}Te. For these studies a fusion evaporation experiment (utilizing the Koln plunger) has been carried out at Jyväskylä, using the ^{54}Fe+^{58}Ni reaction at a beam energy of 245 MeV. The beam was used to bombard a 1 mg/cm^2 thick ^{58}Ni plunger target. A 1 mg/cm^2 thick ^{24}Mg foil was used as a degrader foil and the technique of recoil decay tagging [3,4] was used to separate out the channels of interest. The fusion evaporation recoils were transported through the RITU spectrometer and implanted into the GREAT DSSSD detectors. Subsequent alpha decays were then recorded and used to select the nuclei of interest.

[1] B. Hadinia et al., Phys Rev C 72, 041303 (2005).
[2] B. Cederwall et al., Phys. Rev. Lett 022501, 99 (2007).
[3] R. Simon et al., Z. Phys. A 325, 197 (1986).
[4] E. Paul et al., Phys. Rev. C 51, 78 (1995).

LIFETIME MEASUREMENTS OF THE FIRST EXCITED 6^+ STATES IN N = 80 ISOTONES, ^{138}Ce AND ^{140}Nd
Thamer Alharbi, University of Surrey

T. Alharbi 1, P. H. Regan 1, P. J. R. Mason 1, Zs. Podolyak 1, M. R. Bunce 1, M. Nakhostin 1, S. Rice 1, J. Lintott 1, R. Britton 1, N. Alazemi 1, C. Townsley 1. E. Willson 1, W. Gelletly 1, N. Marginean 2, D. Filipescu 2, T. Glodariu 2, C. Mihai 2, A. Negret 2, T. Sava 2, R. Marginean 2, D. Ghita 2, D. Deleanu 2, D. Bucurescu 2, L. Stroe 2, A. M. Bruce 3, O. J. Roberts 3, V. Werner 4, G. Ilie 4, N. Cooper 4, M. Zherova 5, S. Kisyov 5, S. Lalkovski 5, S. Liddick 6, J. F. Smith 7, K. Mulholland 7

1 Department of Physics, University of Surrey, Guildford, GU2 7XH
2 Horia Hulubei National Institute for Physics and Nuclear Engineering, Bucharest, Romania
3 School of Engineering and Technology, University of Brighton, Brighton, BN2 4GJ, UK
4 Wright Nuclear Structure Laboratory, Yale University, New Haven, CT 06520, USA
5 Faculty of Physics, University of Sofia, 5 James Bourchier Blvd, 1164 Sofia, Bulgaria
6 National Superconducting Cyclotron Laboratory Michigan State University, USA
7 School of Engineering, University of the West of Scotland, High Street, Paisley PA1 2BE, UK

This work reports on the utilisation of gamma-ray coincidences between germanium and lanthanum bromide $LaBr_3$:(Ce) scintillation detectors for the determination of electromagnetic transition rates in the pico to nanosecond regime. The technique utilises the high-quality full-energy peak resolution of the $LaBr_3$(Ce) detectors [1] coupled with their excellent timing responses in order to study discrete energy gamma-ray cascades from nuclei populated using the ^{130}Te(^{12}C, 4n)^{138}Ce and ^{128}Te(^{16}O, 4n)^{140}Nd fusion-evaporation reactions at beam energy of 56 and 66 MeV respectively. The beam was provided by the Tandem van de Graaff accelerator at Bucharest, Romania [2]. In the first experiment the target consisted of a 1 mg/cm^2 thick enriched ^{130}Te foil on a 20 mg/cm^2 thick ^{208}Pb backing to stop the recoiling nuclei. In the second experiment the target consisted of ^{128}Te 2.24 mg/cm^2 on a thick mylar backing. Extracted Lifetimes for excited states in the N=80 isotones, ^{138}Ce and ^{140}Nd will be presented and reduced transition probabilities have been calculated for the electromagnetic decays from these states and compared with predictions of shell model calculations.

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THE STUDY OF K-ISOMER IN ^{134}Nd BY USING ELECTRON CONVERSION SPECTROSCOPY
Józef Andrzejewski, University of Łódź

J. Andrzejewski 1, T. Abraham 2, W. Czarnacki 3, Ch. Droste 4, E. Grodner 4, Ł. Janiak 1, M. Kisieliński 2,3, M. Kowalczyk 2,4, J. Kownacki 2,3, J. Mierzejewski 2, A. Korman 3, J. Perkowski 1, J. Samorajczyk 1, J. Srebrny 2, A. Stolarz 2, M. Zielińska 2

1 Faculty of Physics and Applied Computer Science, University of Łódź, Poland
2 Heavy Ion Laboratory, University of Warsaw, Poland
3 National Centre for Nuclear Research, Świerk-Otwock, Poland
4 Nuclear Physics Division, IEP, University of Warsaw, Poland

The goal of the series of our measurements was the study of the K selection rule violation for electromagnetic transitions in nuclei with mass number ~130 and neutrons equal 74 by determination of absolute probability transitions from decay of the $I^{\pi} = K^{\pi} = 8^{-}$ isomeric state, which occurs at even-even nuclides. The isomeric half-lives of this isotones vary by six orders of magnitude, from nanoseconds (Xe) to milliseconds (Ce, Ba). Their modes of decay are also different, but decay branches of E1 transitions with a degree of K forbiddingness 7, leading directly to the 8^{+} member of the ground state band with K=0, have been found in Ba-130, Nd-134, Sm-136, and Gd-138. These branches severely violate the K selection rule.

The main goal of the measurements was to determine multipolarities of the gamma transitions de-exciting the $I^{\pi} = K^{\pi} = 8^{-}$ isomeric states in Nd-134 and confirm the existing decay path of this isomer by de-excitation to the gamma band ($8^{-} \rightarrow 5^{+}$). The study of decay of this state in Nd-134 was done by the reaction $^{122}Te(^{16}O, 4n)^{134}Nd$. The ion beam of O-16 with energy of 90 MeV and intensity of 20 enA from Heavy Ion Laboratory cyclotron was used. The experiment was performed in e–γ and γ–γ coincidence modes using an electron spectrometer coupled to the EAGLE gamma-ray array. The spectroscopy of internal conversion electrons in coincidence with gamma-rays allows to determine of multipolarities and furthermore absolute values of the transitions probabilities. The results obtained during 100 hours of the beam time measurements will be presented.

ALPHA DECAY PROPERTIES OF THE SHELL STABILIZED SUPERHEAVY NUCLEI

Andreea-Ioana Budaca, Horia Hulubei National Institute of Physics and Nuclear Engineering, Bucharest

A. I. Budaca and I. Silisteanu
Horia Hulubei National Institute of Physics and Nuclear Engineering, Bucharest, Romania

A standard many-body theory of alpha decay is developed using shell model clustering and resonance scattering amplitudes. Formulas are obtained for the alpha half-lives and applied extensively to known superheavy nuclei. These formulas are combined with measured decay energy to investigate the structure of the decaying states. The work includes formal considerations, as well as practical computational methods, based on self-consistent models for the nuclear structure and reaction dynamics.

THEORETICAL INVESTIGATIONS OF ^{6,8}He HALO NUCLEI USING MICROSCOPIC OPTICAL POTENTIALS

M. El-Azab Farid, Assiut University, Egypt

The elastic angular distributions recently measured for $^{6,8}He$ projectile on ^{65}Cu in the laboratory angular range between 25^{o} and 60^{o} at energies above the coulomb barrier ($E_{lab} = 19.9$, 22.6 and 30.6 MeV) have been examined using microscopically complex optical potential. The microscopic real part has been carried out with the Reid M3Y effective nucleon-nucleon (NN) interactions by using double folding model. Comparative results of two different imaginary part together with the experimental data are presented within the framework of the optical model. The experimental data and total reaction cross section are successfully reproduced using the extracted potentials.

NEW APPROACH TO THE DECAY HEAT CALCULATIONS BASED ON THE MONTE CARLO METHODS
Aleksandra Fijałkowska, University of Warsaw and Oak Ridge National Laboratory

A. Fijałkowska 1,3, M. Dziubiński 1, K. P. Rykaczewski 2, R. K. Grzywacz 2,3, M. Karny 1,2,4, M. Wolińska-Cichocka 2,4

1 University of Warsaw, Warsaw PL 00-681, Poland
2 Oak Ridge National Laboratory, TN 37830, USA
3 University of Tennessee, Knoxville, TN 37996, USA
4 Oak Ridge Associated Universities, TN 37830, USA

The Modular Total Absorption Spectrometer (MTAS) has been recently constructed and commissioned at the Holifield Radioactive Ion Beam Facility (HRIBF) at Oak Ridge National Laboratory [1]. MTAS consists of 19 NaI(Tl) modules of hexagonal shape, with a total weight of about 2200 pounds. Its efficiency for full energy absorption is approaching 90% for 300 keV gamma rays. The scientific program for MTAS focuses on the beta decay studies of fission products. Understanding the energy release following the decay of fission products (so called decay heat) is crucial for the analysis of processes occurring in nuclear fuel in power reactors. The analysis of decay heat is important for the current and next generations of nuclear reactors as well as for the radioactive waste transportation and storage [2-5]. Existing theoretical simulations of decay heat are showing significant deviations from experimental data, compare [2-4]. These discrepancies are believed to be partially due to the incorrect or incomplete decay schemes.

We would like to present a new approach to the decay heat calculations based on the Monte Carlo methods. In this approach average gamma and beta energies used in standard models are replaced by event-by-event calculation with the use of the detailed decay schemes taken from the NNDC database. The impact of potential changes in the decay schemes of the "reactor inventory isotopes" [2] as well as the preliminary results on the decays of mass A=86 and A=87 fission products recently measured with MTAS at the HRIBF will also be presented.

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A NEUTRON SOURCE FOR NEW IGISOL FACILITY

Dmitry Gorelov, University of Jyväskylä

The Ion-Guide Isotope Separator On-Line (IGISOL) is a facility designed for fundamental research of nuclear matter. The key point of such investigations is production of rare isotopes. A general way for the fabrication of neutron-rich isotopes is the fission of heavy nuclei.

Previously, neutron-rich nuclei have been produced at the IGISOL via proton-induced fission. However, preliminary estimations show that neutron-induced fission might be preferable for production of even more exotic nuclei. First of all, the yield of the most neutron-rich isotopes is higher in neutron-induced fission. Secondly, due to lower ionization of the buffer gas used in IGISOL technique, the neutron beam allows the usage of more efficient geometry for fission target. That's why, it was decided to convert primary proton beam into neutrons. This idea is especially relevant due to a high intensity beam available from the new MCC30/15 cyclotron which is coupled to the IGISOL facility.

Various materials and constructions have been considered for the neutron converter target. As result metallic beryllium (Be) target with direct water cooling was chosen for futher development. The test experiment is planing soon in June at The Swedberg Laboratory (Uppsala, Sweden). The actual status of the design and construction will be presented. Also some perspectives of the neutron source usage at the IGISOL facility will be discussed.

PSEUDO-CRITICAL BEHAVIOR OF NUCLEAR MULTIFRAGMENTATION

Diego Gruyer, GANIL, CEA/DSM and CNRS/IN2P3 Caen

D. Gruyer 1, J. D. Frankland 1, M. Płoszajczak 1, A. Chbihi 1, E. Bonnet 1, R. Botet 2

1 GANIL, CEA/DSM and CNRS/IN2P3, Boîte Postale 55027, F-14076 Caen Cedex, France

2 Laboratoire de Physique des Solides Bât. 510 - CNRS UMR8502/Université Paris-Sud, Centre d'Orsay, F-91405 Orsay, France

Nuclear multifragmentation produced in heavy ion collisions can be described in terms of phase transitions and critical phenomena. For this purpose, the size (charge) distribution of the largest fragment produced in each event has been studied in terms of a decomposition into two contributions: one from an ordered and one from a disordered phase. In the theoretical description of aggregation processes (percolation and Smoluchowski models), where the order parameter is the size of the largest cluster, such a decomposition is also observed and allows to define the pseudo-critical domain of the underlying phase transition. By analogy with these models, we use the evolution of the relative population of the two phases with bombarding energy to localize the pseudo-critical domain for experimental multifragmentation data measured with INDRA. In a second step we present a more detailed comparison with the Smoluchowski aggregation scenario to address the timescale of the multifragmentation process.

ANALYSIS OF THE ^{104}Sn EXPERIMENT AT PRESPEC
Giulia Guastalla, Technical University Darmstadt

J. Cederkall 1, D. Di Julio 1, A. Ekström 1, C. Fahlander 1, J. Gellanki 1, P. Golubev 1, R. Hoischen 1, D. Rudolph 1, G. Guastalla 2, N. Pietralla 2, P. Boutachkov 2, E. Merchan 2, M. Górska 3, J. Gerl 3, F. Ameil 3, I. Kojouharov 3, N. Kurz 3, S. Pietri 3, H. Schaffner 3, H.-J. Wollersheim 3 and the PreSPEC collaboration

1 Physics Department, Lund University, Sweden
2 Technical University Darmstadt, Germany
3 GSI, Darmstadt, Germany

The experiments exploring the nuclear shell structure in the vicinity of ^{100}Sn – the heaviest selfconjugate doubly magic nucleus – are an important benchmark for the nuclear shell model. In particular, the reduced transition probability for the first 2^+ state $B(E2:0^+ \rightarrow 2^+)$ along the isotopic chain shows discrepancies between the theoretical and experimental values when approaching ^{100}Sn. The Coulomb excitation measurements of the radioactive beams were utilized to study neutron and proton core polarizations across the shell gap in this region as alternative methods are hampered by the existence of the isomeric 6^+ states. Within the PreSPEC campaign at GSI an experiment has been performed to determine the B(E2) value in ^{104}Sn. The experiment served additionally to disentangle the background contributions occurring along the beam path, both in the fragment separator (FRS) as well after the secondary target. The exotic nuclei of interest were produced in fragmentation reaction of the ^{124}Xe primary beam at 793 MeV/A on a 4 g/cm^2 ^9Be primary target, separated in the FRS and excited via Coulomb excitation on a 400 mg/cm^2 ^{197}Au secondary target.

The state of the art of the preliminary analysis will be presented.

AN INVESTIGATION OF $^{16}O+^{16}O$ ELASTIC SCATTERING BY USING CLUSTER FOLDING MODEL AT HIGH ENERGIES
Mahmoud Hassanain, King Khalid University, Saudi Arabia

An investigation of the elastic scattering angular distribution data of $^{16}O+^{16}O$ system for high energy range from 250-1120 MeV will perform theoretically within the framework of double folding optical model formalism, by using two different versions of effective interaction: the effective α-α cluster interaction and the original M3Y NN realistic interaction, which are independent of the density. Then, to study the effect of the density dependence we will use the density dependence (DD) for the M3Y effective interaction (DDM3Y). Comparative results of our calculation with the experimental data, total reaction cross-section, real and imaginary volume integral are present.

ELASTIC SCATTERING ANALYSIS OF HEAVY ION AT LOW ENERGY

Mahmoud Hassanain, King Khalid University, Saudi Arabia

The elastic scattering angular distribution of ^{32}S projectile on different heavy ion (HI) of targets including the ^{24}Mg , ^{28}Si, ^{32}S, and ^{40}Ca at energy range from 65-160 MeV is described in terms of optical model scattering theory. The microscopic real part of the complex nuclear optical potential have been obtained by using three different approximation methods to treat the single nucleon knock-on exchange term (SNKE) in the optical model. Successful reproduction of data is obtained by all considered forms of potential. It is clear that the effect of Pauli correlation increases with the increases of projectile energy and mass of target. Our calculations are insensitive to the strength of the imaginary potential used in the fit of experimental data except in the case of the identical nuclei. Comparative results of our calculation with the experimental data, total reaction cross-section, real and imaginary volume integral are presented.

THEORETICAL ANALYSIS OF ALPHA-NUCLEUS SCATTERING USING FOLDED POTENTIALS

Awad Ibraheem, King Khalid University, Saudi Arabia

The elastic scattering angular distributions of α particles by ^{12}C, ^{16}O, ^{28}Si, ^{58}Ni and ^{124}Sn over a wide energies range (120-400 MeV) have been analyzed in terms of complex nuclear optical potentials. The real double folding (DF) optical potentials are generated by folding the M3Y, DDM3Y, JLM and DDJLM effective interactions over the suggested density distributions of the two colliding nuclei. The imaginary part expressed in a phenomenological Woods-Saxon (WS) form. The formation of the imaginary part of the optical potentials and the reaction cross sections are also considered. In the case, the imaginary part takes the same radial dependence, the ratio between their depths fitted to the experimental differential cross-section at these different values of energies. Optical potential parameters have been obtained by using the χ^2 minimization method to compare calculations to experiments. The agreement between the theoretical predictions and measured values is quite satisfactory.

NEW ACCELERATOR FACILITY FOR MEASUREMENTS OF NUCLEAR REACTIONS AT EXTREMELY LOW ENERGIES

Mateusz Kaczmarski, University of Szczecin

M. Kaczmarski 1, K. Czerski 1,2, N. Targosz-Ślęczka 1, A. Ihsan Kilic 1, A. Huke 2,4, G. Ruprecht 3,4, D.Weißbach 1,4

1 University of Szczecin, Poland

2 Technical University Berlin, Germany

3 TRIUMF, Vancouver, Canada

4 Institute for Solid State Nuclear Physics, Berlin, Germany

Nuclear reactions at very low energies can be described by tunneling processes through Coulomb barrier. If the projectile energies are low enough the screening effect of Coulomb barrier by surrounding electrons can be observed by means of an exponential-like enhancement of nuclear cross-sections for lowering projectile energies. Recently, this effect has been studied for the ^{2}H(d, p)^{3}H and ^{2}H(d, n)^{3}He reactions taking place in metallic environments which represents a unique model for dense astrophysical plasma. The screening energies determined experimentally as a reduction of the height of the Coulomb barrier turn to be larger by a factor of two that the theoretical predictions. Our new experimental data obtained for the first time under ultra high vacuum (UHV) conditions additionally increase this discrepancy and confirm that the contamination of the target surface plays a crucial role in the screening experiments. These studies are relevant not only for nuclear astrophysics but also for some practical applications of new energy sources based on nuclear fusion.

In order to explain technical, experimental, as well as theoretical problems related to electron screening effect, a new accelerator facility "eLBRUS" is under construction at the University of Szczecin. The facility will consist of a small electrostatic accelerator equipped with a high current ECR ion source and a target chamber operating under UHV conditions. The target chamber has been designed to combine both nuclear reactions methods and analytical methods of surface physics (AES, XPS, ion sputtering, etc.) to overcome difficulties of previous experiments. In addition, construction of a windowless gas-jet target is planed. The accelerator system will be completed by series of devices used for condensed matter (NMR spectrometer, microcalorymeter) and optical (high power lasers) diagnostic methods. The whole system will allow to perform nuclear reaction experiments and necessary preparation and diagnostic work at the same location.

^{121}SB(α,γ)^{125}I, ^{121}SB(α,n)^{124}I AND ^{123}SB(α,n)^{126}I CROSS SECTION MEASUREMENTS AT THE ASTROPHYSICAL ENERGIES

Zeren Korkulu, Kocaeli University, Turkey and ATOMKI Institute of Nuclear Research, Debrecen, Hungary

Z. Korkulu 1,2, N. Özkan 1, R. T. Güray 1, C. Yalçın 1, G. G. Kiss 2, T. Szücs 2, Zs. Fülöp 2, Gy. Gyürky 2, E. Somorjai 2, Z. Halasz 2

1 Department of Physics, Kocaeli University, Umuttepe Kocaeli, 41350, Turkey

2 ATOMKI Institute of Nuclear Research of the Hungarian Academy of Sciences, Debrecen, Hungary

Experimental studies of p-process related reaction cross sections had long been neglected and started, in fact, less than 20 years ago. Today still large uncertainties exist to predict the observed abundances of these p-nuclei. Model calculations of the p-process require large nuclear reaction networks involving about 1800 isotopes and more than ten thousand reaction rates. Almost all of these rates have to be determined theoretically by means of the statistical Hauser-Feshbach (HF) formalism. In order to provide a further test of Hauser-Feshbach predictions and also to be used to optimize input parameters of the codes, alpha captured reaction cross section measurements on natural Sb cross section measurements have been started.

^{121}Sb(α, γ)^{125}I, ^{121}Sb(α, n)^{124}I and ^{123}Sb(α, n)^{126}I reaction cross section measurements have been carried out at cyclotron accelarator of Institute of Nuclear Research of the Hungarian Academy of Sciences (ATOMKI) by using the activation method. The target were produced by vacuum evaporation of natural Sb onto high purity thin aluminum foils. The targets have been irradiated by alpha-beams of typically 0.8 μA and the each irradiation time was about 20 hours. In order to determine ^{121}Sb(α, γ)^{125}I reaction cross section, the yield of the 35.49 keV gamma-line obtained in close geometry by the LEPS (Low Energy Photon Spectrometer) was used. The ^{121}Sb(α, n)^{124}I reaction cross section was also calculated with a 100% relative efficiency HPGe detector in ULB (Ultra Low Background) shielding by counting the yield of 602.73 keV, 722.78 keV and 1690.96 keV gamma-lines. Similarly, for ^{123}Sb(α, n)^{126}I reaction cross section calculations 388.63 keV and 666.33 keV lines were used. The details of the measurements and obtained results will be presented and compared with the Hauser-Feshbach statistical model calculations.

GEANT4 AND GEMINI++ BASED SIMULATIONS OF POSSIBLE APPLICATION OF THE RECOIL FILTER DETECTOR IN NUCLEAR STRUCTURE STUDIES WITH STABLE AND RADIOACTIVE BEAMS

Mateusz Krzysiek, IFJ PAN Kraków

M. Krzysiek 1, P. Bednarczyk 1, M. Ciemała 1, B. Fornal 1, G. Jaworski 2,3, A. Maj 1, M. Matejska-Minda 1, W. Męczyński 1, M. Kmiecik 1, M. Palacz 3, M. Ziębliński 1, Ch. Schmitt 4

1 The Niewodniczanski Institute of Nuclear Physics, Polish Academy of Sciences, Krakow
2 Faculty of Physics, Warsawa University of Technology
3 Heavy Ion Laboratory, University of Warsaw
4 GANIL, CEA/DSM-CNRS/IN2P3 Caen

The Recoil Filter Detector (RFD), which was constructed by the Cracow group [1], allows to select desired nuclei by their time-of-flight and pulse height using a pulsed-beam. It has been already used successfully in gamma-spectroscopy studies as an ancillary detector coupled with OSIRIS [2], GAREL+ [3], EUROBALL IV [4] and GASP [5] Ge arrays allowing filtering out the scattered beam form evaporation residues, and a Doppler correction. In order to choose appropriate experimental conditions and setup it is always necessary to simulate theoretical output of experiments.

The aim of this study was to apply the Geant4 and GEMINI++ based simulations of the RFD performance in nuclear structure studies, firstly, with stable and secondly, radioactive beams. Primary aim is to be achieved by comparing the simulations output with existing experimental data. Evaluation of the simulation tool relevance allows proceeding with the next phase, which is potentially possible adjustment of RFD setup for studies with radioactive beams especially in inverse kinematic reactions.

First part of the present study includes the simulations and comparison of the results with the experimental data obtained in the gamma-spectroscopy experiment using GASP coupled with RFD for the reaction of ^{32}S beam (E = 95 MeV) with ^{40}Ca target (0.8 mg/cm^2) [5]. It is shown, by comparison to experimental data, that our approach can be successfully applied to obtain realistic simulations of experimental conditions.

The second part is devoted to the simulations of possible application of RFD in studies of collective modes of excitation in neutron-rich Ba region via reaction of ^{90}Kr (E = 388 MeV) radioactive beam with ^{48}Ca target (1 mg/cm^2). In the proposed experiment [6], RFD might be possibly coupled with AGATA/EXOGAM2 and PARIS scintillator arrays in SPIRAL2. Possible application in selecting exotic neutron rich Ba isotopes, produced in an inverse kinematics, at very high spin as well as possibility to detect the fission products will be shown and discussed.

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SOME INTERESTING TRENDS IN INCOMPLETE FUSION REACTION DYNAMICS AT ENERGIES ≈ 4-7 MeV/NUCLEON

Kamal Kumar, Aligarh Muslim University, India

At moderate excitation energies the dominating fusion processes are (i) Complete Fusion (CF) and Incomplete Fusion (ICF) [1, 2]. However, in recent years at low projectile energies i.e., near and above the Coulomb barrier (CB), the ICF sets in, where the CF supposed to play a key role to the total fusion cross-section. In order to explain ICF reaction dynamics several dynamical models such as SUMRULE model [3], Break-Up Fusion (BUF) model [4], Promptly Emitted Particles (PEP's) model [5] etc. have been proposed. But none of these models is able to explain the presence of ICF reaction processes at such low incident energies, hence, is a topic of current interest. In general, the CF and ICF reaction processes can be explained on the basis of localization of angular momentum space, where CF supposed to be dominating for $\ell=0$ to ℓ_{crit} and ICF occur for $\ell > \ell_{crit}$. Moreover, Trautmann et al. [6] and Inamura et al. [7] depicted the peripheral nature of ICF processes. Furthermore, some of the effective studies are summarized in an outstanding review by Gerschel [8].

With these motivations, in the present work the excitation functions (EFs) for several evaporation residues produced via ^{16}O + ^{165}Ho interactions have been measured at energies ranging from ≈ 73-105 MeV by employing recoil-catcher technique followed by offline γ-ray spectroscopy. These measured EFs have been analyzed in the framework of statistical model code PACE4 [9]. A significant contribution of ICF has been observed in the production of α-emitting channels. To observe the relative importance of CF and ICF, the ICF fraction has been extracted. In order to find out some systematics the re-analysis of nearby projectile-target combinations, in light of the present data, has been incorporated, and the acquired FICF has been compared for all these systems, and found to be sensitive to the projectile energy and mass asymmetry. However, for some combinations, more mass asymmetric system show less FICF has been observed at same normalized projectile energies. In light of some recent studies [2, 10], projectile structure as well as target deformation [8] both may responsible for this converging trend. The details of the work will be presented.

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FISSION DYNAMICS AS A PROBE OF THE SHAPE-DEPENDENT CONGRUENCE ENERGY TERM IN THE MACROSCOPIC MODELS
Katarzyna Mazurek, IFJ PAN Kraków

K. Mazurek 1, C. Schmitt 2, P. Nadtochy 3, A. Maj 1, P. Wasiak 1, M. Kmiecik 1, B. Wasilewska 1

1 The H. Niewodniczański Institute of Nuclear Physics PAN, Kraków, Poland

2 Grand Accelerateur National d'Ions Lourds, CEA/DSM-CNRS/IN2P3, Caen, France

3 Omsk State University, Department of Theoretical Physics, Omsk, Russia

The fission dynamics described by solving the 3-dimensional Langevin equations [1] is one of the most appropriate methods to verify different macroscopic models. The choice of the macroscopic models has the crucial influence on the charge and mass fragment distribution or emitted particle multiplicity [2]. The potential energy surfaces (PES) obtained with either the Finite Range Liquid Drop Model (FRLDM) [3] or the Lublin-Strasbourg Drop (LSD) [4] formula are very similar for heavy compound nuclei but they differ sizably in the medium mass region.

One of the relevant probes, which we propose to study in this contribution, is the comparison between pre- and post-scission particle multiplicities in addition to the mass, charge and total kinetic energy of the fission fragments and evaporation residua. It turned out, that the shape-dependent congruence energy term, introduces a significant change in the mass distribution of the fission fragments and the multiplicity of emitted particles. It can change the fission barrier by 1-8 MeV, which substantially affects the potential energy surface.

A discussion about how the shape-dependent congruence energy term is phenomenologically implemented in the FRLDM and LSD models will be presented. Constant congruence energy term was already introduced years ago but the discussion of the geometrical factor described the shape-dependence combined to different macroscopic models was not yet studied in the frame of fission dynamics. In addition, fission-fragment charge, mass and energy distributions as well as pre- and post-scission particle multiplicities calculated for excited ^{111}In and ^{252}Fm fissioning nuclei will be compared with experimental data. From the previous calculation [1] for ^{252}Fm we learn then within our model we can reproduce the experimental data but an influence of the various PES into the post-scission emission will be discussed first time.

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CHARACTERISTICS OF THE FRAGMENT PRODUCTION IN ^{197}Au + ^{197}Au REACTION AT 23 AMeV

Rafał Najman, Jagiellonian University

Nuclear dynamics studies have been performed by the BREAKUP group for the system Au + Au at 23 AMeV with two goals: (i) a search for toroidal freeze out configurations predicted to be formed for this heavy system [1]; (ii) an extension of an earlier study carried out at a lower energy of 15 AMeV, in which a new reaction mechanism of violent collinear breakup of non-fusing colliding systems into three and/or four massive fragments was discovered [2-4].

The measurements for the Au + Au reaction were performed in March 2010 using the CHIMERA detector [5] at INFN-LNS. The total number of collected events is of the order of 108. The heavy fragments were identified in charge and mass using DE-E and TOF techniques, respectively.

Characteristics of the charge, mass, energy and angular distributions of identified fragments will be presented. Observables sensitive to the geometry of the decaying nuclear object will compared to static and dynamical model predictions.

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ROTATIONAL BANDS AND MASSES OF HEAVIEST NUCLEI

Bożena Nerlo-Pomorska and Krzysztof Pomorski,
Maria Curie Skłodowska University, Lublin

Investigation of heavy and super-heavy nuclei requires a proper model to reproduce masses and rotational energies. The Yukawa-folded single particle potential and the Lublin Strasbourg Drop (LSD) is taken in our calculations. The macroscopic-microscopic model with the Strutinsky shell-correction and the pairing energy evaluated within the rotating BCS model is used. The moment of inertia is evaluated within the cranking approximation. The equilibrium deformations of Ra-Cn isotopes were determined using the Modified Funny Hills shape parametrization.

The pairing force strengths fitted to positions of the experimental rotational 2^+ states is compared to those which reproduce exactly masses of nuclei. The change of the pairing correlations with rotation is taken into account when evaluating energies of the rotational band members. Our estimates of the ground-state masses and the rotational energies agree well with the experimental data.

SYMMETRY ENERGY AND STRUCTURE OF A NEUTRON STAR
Monika Pieńkos, University of Silesia

I. Bednarek, M. Pieńkos
University of Silesia, Katowice, Poland

The equation of state of dense nuclear matter is the most important factor that determines the parameters and internal structure of a neutron star. In attempt to analyze neutron stars properties related to the isospin asymmetry it is indispensable to determine the density dependence of the symmetry energy. The systematic study of neutron star matter is done within the nonlinear relativistic mean field approach for different parameterizations. The characteristic feature of the considered models is the extended isovector sector which comprises a broad spectrum of mixed vector meson interactions.

The mixed vector meson interactions are very effective in describing asymmetric nuclear matter as they provide modification of the density dependence of the symmetry energy. The obtained parameterization in the isovector sector, which is related to the strength of the particular vector meson couplings, allows one to study the influence of the remodeled symmetry energy on neutron star properties. This has remarkable consequences in the case when the core of a neutron star includes hyperons as the analysis concerns also the influence of the coupling between isovector meson and the hidden strange vector meson. Such enhancement of the isovecor meson sector links the asymmetry of the model with the strangeness content and modifies the properties and composition of dense matter.

RECENT RESULTS FROM FAST TIMING POLYCRYSTALLINE DIAMOND DETECTORS AS PART OF THE LYCCA-0 ARRAY
Lianne Scruton, University of York

L. Scruton, M. A. Bentley, S. P. Fox, B. S. Nara Singh, A. Lohstroh, F. Schirru, D. Di Julio, P. Golubev, R. Hoischen, D. Rudolph, N. Braun, K. Moschner, P. Reiter, J. Taprogge, A. Wendt, F. Ameil, P. Boutachkov, J. Gerl, T. Habermann, N. Kurz, E. Merchan, F. Naqvi, I. Kojouharov, C. Nociforo, S. Pietri, H. Schaffner, H. J. Wollersheim, A. Algora, F. Camera, O. Wieland, V. Stoica, M. Pikna, J. Rudolf, F. Garcia, M. Kalliokoski, E. Tuominen

The very first set of experiments involving the LYCCA-0 array have taken place over the past year and a half using the FRS at GSI as part of the PreSPEC collaboration. The LYCCA-0 array consists of a number of energy and time-of-flight detectors designed to uniquely identify exotic nuclei by both their mass and charge. In order for this to be possible over a relatively short flight path, detectors with very good timing resolution are required.

One such time-of-flight detector used in the first commissioning experiment is made from CVD polycrystalline diamond, a material well known for its fast timing properties and resilience. This detector consisted of six 2 x 2cm diamond wafers, one of the largest area diamond detectors tested to date. After a series of optimisation tests, a prototype of the diamond detector was used in the first commissioning run in September 2010 along with the rest of the LYCCA-0 detectors.

Results from this experiment including the identification of a number of fragments over flight path of 3.4 m shall be presented.

The energy and mass resolution of LYCCA-0 was measured and, from this, the time resolution for the time-of-flight system was extracted. This data will be used to compare the two different time-of-flight solutions that are being considered for time-of-flight "start" detector at the LYCCA target position – fast-plastic or diamond.

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INCOMPLETE FUSION DYNAMICS BY MEASUREMENT OF SPIN DISTRIBUTION OF THE EVAPORATION RESIDUES FOR THE SYSTEM $^{19}F + ^{154}Sm$

Dharmendra Singh, Inter University Accelerator Centre (IUAC), New Delhi

D. Singh 1, H. Kumar 2, R. Ali 2, N. P. M. Sathik 3, M. Afzal Ansari 2, R. Tripathi 4, R. Kumar 1, Indu Bala 1, S. Muralithar 1 and R. P. Singh 1

1 Inter University Accelerator Centre (IUAC), Aruna Asaf Ali Marg, New Delhi, India
2 Department of Physics, Aligarh Muslim University, Aligarh India
3 Department of Physics, Jamal Mohammed College, Trichurapalli, India
4 Radio-chemistry Division, Bhabha Atomic Research Centre, Trombay, Mumbai, India

In order to understand the complete and incomplete fusion dynamics, an experiment have been carried out by using Gamma Detector Array (GDA) coupled with Charged Particle Detector Array (CPDA) at Inter University Accelerator, New Delhi, India. GDA consists of 12 Compton suppressed n-type high purity germanium detectors. The CPDA is a group of 14 Phoswich detectors. In the CPDA scattering chamber, seven CPD were placed on top and seven on bottom of the chamber. A self-supporting 3.1 mg/cm^2 target of ^{154}Sm (enrichment ≈98.6%) prepared with a rolling machine has been used. Spin distributions for various evaporation residues produced via complete and incomplete fusion dynamics have been measured for $^{19}F + ^{154}Sm$ system at projectile energy 110 MeV. It is observed from the experimental results that spin distribution for the evaporation residues produced by complete fusion and incomplete fusion processes are distinctly different. These study show that the yield of incomplete fusion reaction channels are almost constant up to a maximum angular momentum and then falls unlike in complete fusion, where the yield gradually fall with spin. On the basis of above results, it can be inferred that driving input angular momentum J_0 associated with incomplete fusion products are relatively higher than complete fusion products. The observation clearly shows that lower values do not contribute to the incomplete fusion, significantly and hence the production of 'fast' forward PLFs (associated with incomplete fusion reactions) are at relatively higher input angular momentum and hence leads to peripheral interaction.

THE APPLICATION OF THE LOW ENERGY NEUTRON ARRAY (LENA)

László Stuhl, ATOMKI Institute of Nuclear Research, Debrecen

A plastic time-of-flight (TOF) neutron spectrometer (LENA, Low Energy Neutron Array) has been designed and constructed in Debrecen, ATOMKI. The aim of the construction was, to study different type of spin-isospin excitations (giant resonances) in exotic nuclei far from the stability line by using (p, n) charge-exchange reactions in inverse kinematics.

The GEANT4 toolkit was used for simulation the intrinsic efficiency of the scintillator bars as a function of neutron energy. The geometry of the array was optimized, the effects of all surrounding materials were taken into account in the simulation.

The array was designed to measure neutron energies by the time-of-flight (ToF) technique and the laboratory scattering angles with high resolution, and at the same time high detection efficiencies. LENA is an array consisting of 15 single detectors. Each detector consists of plastic scintillator material with a size of 10 × 45 × 1000 mm^3. There are 3 modules; each of them contains 5 single detectors. Details of the design and wrapping procedure, test results about cross scattering effects, time and position resolution as well as the efficiency of the detectors were carefully studied by simulation and also in real experiments. The results will be presented.

In the frame of the R3B collaboration the first (p, n) experiment, using the LENA detector array was performed in last October at the GSI. The aim of the experiments was to measure the neutron-skin thickness of ^{124}Sn. We have used 600 MeV/nucleon ^{124}Sn relativistic heavy-ion beams on 2 and 5 mm thick CH_2 and 2 mm thick C targets and the energy difference of the anti-analog giant dipole resonance (AGDR) and the Isobaric Analog State (IAS) was measured, which depends strongly on the neutron-skin thickness.

We have actually measured the γ-decay of this resonance to the IAS by six large (3.5″×8″) state-of-the-art $LaBr_3$ detectors. The precise energy and efficiency calibration of such detectors have been performed in Debrecen, which results will also be presented.

TOWARDS IN-TRAP OBSERVATION OF NUCLEAR DECAYS

Christine Weber, Ludwig-Maximilians-University Munich

Christine Weber, Jasmin Moazzami-Fallah, Peter Müller, Jurek Szerypo, and Peter Thirolf
Fakultät für Physik, Ludwig-Maximilians-Universität München, 85748 Garching, Germany

A new type of experimental setup, dedicated to in-trap decay spectroscopy in a Penning trap is presently developed at MLL-TRAP/Garching to be implemented in the future MATS facility at FAIR. It combines the high-resolution purification capabilities of a Penning trap with a customized detector trap setup, providing both, ion storage and detection of decay products. In this way, decay-spectroscopy experiments of purified nuclides, free from any background or scattering effects, will become feasible via direct in-situ spectroscopy on a stored ion. For this purpose, the main trapping electrodes are replaced by position-sensitive Si-strip detectors and emitted electrons are efficiently guided by the strong field of the trap magnet towards distant electron detectors. Possible experiments are in-trap alpha-decay experiments of heavy actinides and conversion-electron spectroscopy. Moreover, a coincident detection of an alpha decay with electron detection allows for a reconstruction of the original positions of electron clouds initiated by shake-off as well as from subsequent conversion decay. Via this decay length, the half-lives of excited (2^+) states populated by alpha decay can be derived in a unique type of recoil-distance method. In this presentation, the design of the setup is presented and possible physics experiments are outlined.

Supported by the BMBF (06ML9148), DFG (HA 1101/14-1), and the Maier-Leibnitz-Laboratory (MLL)/Garching.

TESTING OF THE PARIS $LaBr_3$-NaI PHOSWICH DETECTORS WITH HIGH-ENERGY GAMMA-RAYS
Mirosław Ziębliński, IFJ PAN Kraków

M. Ziębliński 1, M. Jastrząb 1, P. Bednarczyk 1, M. Ciemała 1, M. Kmiecik 1, A. Maj 1, M. Dudeło 2, K. Hadyńska-Klęk 2, P. Napiorkowski 2, S. Brambilla 3, B. Genolini 4, Ch. Schmitt 5, W. Catford 6, M. Nakhostin 6, N. Yavuzkanat 7, O. Dorvaux 8
1 IFJ PAN Kraków, Poland
2 SLCJ Warsaw University, Poland
3 INFN Milano, Italy
4 IPN Orsay, France
5 GANIL, France
6 University of Surrey, Guildford, U.K.
7 University of York, U.K.
8 IPHC Strasbourg, France

The PARIS collaboration is developing a dedicated two-shell gamma calorimeter based on a novel phoswich detectors, which consists of optically coupled 2”x2”x2” $LaBr_3$(Ce) to 2”x2”x6” NaI(Tl) scintillator with a common photomultiplier [1]. First two phoswiches, delivered by Saint Gobain, were tested with radioactive sources at IPHC Strasbourg and IPN Orsay. The tests showed that for low energy gamma rays one could deconvolute the complex phoswich signal into the $LaBr_3$ and NaI components. For this purpose the use of digital electronics that in addition can cope with high counting rate and large dynamic range of signals is being tested.

This presentation reports on test measurements performed at IFJ PAN Kraków aimed at evaluation of the phoswich response to high gamma-ray energies. We have used a 6.13 MeV Cm^{13}C source, and the ^{27}Al(p, γ)^{28}Si reaction using a 796 keV proton beam from the Kraków Van de Graff accelerator, in which gamma-rays up to 12 MeV were emitted. The gamma rays were measured using 3 phoswich detectors and one single 2”x2”x2” $LaBr_3$ crystal, being the reference for our measurements. Waveforms were collected with 3 types of commercial digitizers having different sampling rates: 4 GS/s, 1 GS/s, and 250 MS/s. In parallel, an analog Milano “BaF processor“ allowed to distinguish between the fast ($LaBr_3$) and slow (NaI) components on-line. We will discuss the comparison of the two approaches, which will allow for optimization of the pulse shape analysis (PSA). The preliminary results from both approaches show that the time and energy resolution extracted from the phoswich are only slightly worse than those from a single $LaBr_3$ crystal.

LIST OF PARTICIPANTS

Harith Al-Azri	University of York	hmaa501@york.ac.uk
Thamer Alharbi	University of Surrey	t.alharbi@surrey.ac.uk
Marialuisa Aliotta	University of Edinburgh	m.aliotta@ed.ac.uk
Matteo M. Angarano	CAEN Electronic Instrumentation	m.angarano@caen.it
Józef Andrzejewski	University of Łódź	jozefan@uni.lodz.pl
Stanislav Antalic	Comenius University Bratislava	Stanislav.Antalic@fmph.uniba.sk
Naftali Auerbach	Tel Aviv University	auerbach@post.tau.ac.il
Thomas Aumann	Technical University Darmstadt	t.aumann@gsi.de
Faical Azaiez	IPN Orsay	azaiez@ipno.in2p3.fr
Torbjörn Bäck	Royal Institute of Technology (KTH)	back@nuclear.kth.se
Akif Baha Balantekin	University of Wisconsin-Madison	baha@physics.wisc.edu
Andrzej Baran	Maria Curie Skłodowska University	baran@kft.umcs.lublin.pl
Piotr Bednarczyk	IFJ PAN Kraków	piotr.bednarczyk@ifj.edu.pl
Michael Bentley	University of York	michael.bentley@york.ac.uk
Carlos Bertulani	Texas A&M University-Commerce	carlos.bertulani@tamuc.edu
Jonathan Billowes	University of Manchester	j.billowes@manchester.ac.uk
Simone Bottoni	University of Milano and INFN	simone.bottoni@mi.infn.it
Angela Bracco	University of Milano and INFN	Angela.Bracco@mi.infn.it
Rafał Broda	IFJ PAN Kraków	rafal.broda@ifj.edu.pl
Wojciech Brodziński	NCBJ Świerk	wbrodzin@fuw.edu.pl
Andreea-Ioana Budaca	NIPNE Bucharest	abudaca@theory.nipne.ro
Joseph Carlson	Los Alamos National Laboratory	carlson@lanl.gov
Igor Celikovic	GANIL	celikovic@ganil.fr
Christopher Chiara	University of Maryland and ANL	cjc@anl.gov
Michał Ciemała	IFJ PAN Kraków	Michal.Ciemala@ifj.edu.pl
Natalia Cieplicka	IFJ PAN Kraków	Natalia.Cieplicka@ifj.edu.pl
Alain Coc	CSNSM Orsay	Alain.Coc@csnsm.in2p3.fr
Lorenzo Corradi	INFN Laboratori Nazionali di Legnaro	corradi@lnl.infn.it
Nikolaos Costiris	University of Athens	ncost@phys.uoa.gr
Margit Csatlós	ATOMKI Debrecen	margo@atomki.hu
Lorant Csige	Ludwig-Maximilians-University Munich	lorant.csige@physik.uni-muenchen.de
Angelo Cunsolo	INFN Laboratori Nazionali del Sud	cunsolo@lns.infn.it
Konrad Czerski	University of Szczecin	czerski@physik.tu-berlin.de
Nguyen Dinh Dang	RIKEN Nishina Center	dang@riken.jp
Anukul Dhal	Weizmann Institute of Science	anukul.dhal@weizmann.ac.il
Jacek Dobaczewski	University of Warsaw	Jacek.Dobaczewski@fuw.edu.pl
Artur Dobrowolski	Maria Curie Skłodowska University	arturd@kft.umcs.lublin.pl
Maria Doncel	Royal Institute of Technology (KTH)	doncel@usal.es
Pieter Doornenbal	RIKEN Nishina Center	pieter@ribf.riken.jp
George Dracoulis	Australian National University	george.dracoulis@anu.edu.au
Jerzy Dudek	University of Strasbourg and IPHC	Jerzy.Dudek@iphc.cnrs.fr

Maurits Evers	Australian National University	Maurits.Evers@anu.edu.au
M. El-Azab Farid	Assiut University, Egypt	faridme71516@yahoo.com
Aleksandra Fijałkowska	University of Warsaw and ORNL	aleksandra.kuzniak@gmail.com
Kieran Flanagan	University of Manchester	flanagan@cern.ch
Bogdan Fornal	IFJ PAN Kraków	bogdan.fornal@ifj.edu.pl
Christian Forssén	Chalmers University of Technology	christian.forssen@chalmers.se
Sydney Gales	IPN Orsay	gales@in2p3.fr
Dmitry Gorelov	University of Jyväskylä	dmity.a.gorelov@jyu.fi
Andrzej Góźdź	Maria Curie Skłodowska University	Andrzej.Gozdz@umcs.lublin.pl
Jerzy Grębosz	IFJ PAN Kraków	jerzy.grebosz@ifj.edu.pl
Diego Gruyer	GANIL	gruyer@ganil.fr
Robert Grzywacz	University of Tennessee	rgrzywac@utk.edu
Giulia Guastalla	Technical University Darmstadt	g.guastalla@gsi.de
Magne Guttormsen	University of Oslo	magne.guttormsen@fys.uio.no
Katarzyna Hadyńska-Klęk	Heavy Ion Laboratory, University of Warsaw	kasiah@slcj.uw.edu.pl
Michael Hass	Weizmann Institute of Science	michael.hass@weizmann.ac.il
Mahmoud Hassanain	King Khalid University, Saudi Arabia	mho1959@yahoo.com
Heiko Hergert	Ohio State University	hergert.3@osu.edu
Morten Hjorth-Jensen	MSU and University of Oslo	morten.hjorth-jensen@fys.uio.no
Charles Horowitz	Indiana University	horowit@indiana.edu
Awad Ibraheem	King Khalid University, Saudi Arabia	awad_ah_eb@hotmail.com
Łukasz Iskra	IFJ PAN Kraków	lukasz.iskra@ifj.edu.pl
Stanisław Jadach	IFJ PAN Kraków	Stanislaw.Jadach@ifj.edu.pl
Wojciech Janicki	ABE-IPS	wojciech.janicki@abe.pl
Robert V. F. Janssens	Argonne National Laboratory	Janssens@anl.gov
Jerzy Jastrzębski	Heavy Ion Laboratory, University of Warsaw	jastj@slcj.uw.edu.pl
Michael Jentschel	Institut Laue-Langevin Grenoble	jentsch@ill.fr
Marek Jeżabek	IFJ PAN Kraków	marek.jezabek@ifj.edu.pl
Ari Jokinen	University of Jyväskylä	ari.jokinen@jyu.fi
Mateusz Kaczmarski	University of Szczecin	mkaczmarski1@gmail.com
Marcin Kajetanowicz	Nowoczesna Elektronika	Marcin.Kajetanowicz@ne.com.pl
Jasmeet Kaur	Panjab University, India	meetu_a@yahoo.co.in
Benjamin Kay	University of York	benjamin.kay@york.ac.uk
Marta Kicińska-Habior	University of Warsaw	marta@fuw.edu.pl
Jan Kisiel	University of Silesia	Jan.Kisiel@us.edu.pl
Stanisław Kistryn	Jagiellonian University	stanislaw.kistryn@uj.edu.pl
Barbara Kłos	University of Silesia	barbara.klos@us.edu.pl
Maria Kmiecik	IFJ PAN Kraków	maria.kmiecik@ifj.edu.pl
Karolina Kolos	IPN Orsay	kolos@ipno.in2p3.fr
Agnieszka Korgul	University of Warsaw	korgul@fuw.edu.pl
Zeren Korkulu	Kocaeli University	zeren.korkulu@yahoo.com

Mieczysław Witold Krasny	LPNHE Paris	Mieczyslaw.Krasny@cern.ch
Wojciech Królas	IFJ PAN Kraków	wojciech.krolas@ifj.edu.pl
Mateusz Krzysiek	IFJ PAN Kraków	mateusz.krzysiek@ifj.edu.pl
Reinhard Kulessa	Jagiellonian University	kulessa@if.uj.edu.pl
Kamal Kumar	Aligarh Muslim University, India	kamalkumar1908@gmail.com
Roman Kuzyakin	JINR Dubna	kuzyakin@jinr.ru
Ann-Cecilie Larsen	University of Oslo	a.c.larsen@fys.uio.no
Julien Le Bloas	CEA, DAM, DIF Bruyères-le-Châtel	julien.lebloas@cea.fr
Silvia Leoni	University of Milano and INFN	leoni@milano.infn.it
Alexandre Lepailleur	GANIL	lepailleur@ganil.fr
Tadeusz Lesiak	IFJ PAN Kraków	Tadeusz.Lesiak@ifj.edu.pl
Thomas Lesinski	University of Warsaw	tlesinsk@gmail.com
Felix Liang	Oak Ridge National Laboratory	liangjf@ornl.gov
Valentina Liberati	University of the West of Scotland	valentina.liberati@uws.ac.uk
Augusto Macchiavelli	Lawrence Berkeley National Laboratory	aom@lbl.gov
K. Hugo Maier	IFJ PAN Kraków	hugo.maier@t-online.de
Adam Maj	IFJ PAN Kraków	Adam.Maj@ifj.edu.pl
Paola Marini	GANIL	marini@ganil.fr
Gloria Marquínez Durán	University of Huelva	glmarquinez@hotmail.com
Magdalena Matejska-Minda	IFJ PAN Kraków	Magdalena.Matejska-Minda@ifj.edu.pl
Indranil Mazumdar	Duke University	indra@tifr.res.in
Katarzyna Mazurek	IFJ PAN Kraków	mazurek@ifj.edu.pl
Marco Mazzocco	University of Padova and INFN	marco.mazzocco@pd.infn.it
Witold Męczyński	IFJ PAN Kraków	witold.meczynski@ifj.edu.pl
Krzysztof Miernik	ORNL and University of Warsaw	kmiernik@fuw.edu.pl
Hervé Molique	IPHC and University of Strasbourg	Herve.Molique@iphc.cnrs.fr
Tohru Motobayashi	RIKEN Nishina Center	motobaya@riken.jp
Mohamad Moukaddam	IPHC and University of Strasbourg	mohamad.moukaddam@iphc.cnrs.fr
Szymon Myalski	IFJ PAN Kraków	szymon.myalski@ifj.edu.pl
Rafał Najman	Jagiellonian University	rafal3003@interia.pl
Takashi Nakamura	Tokyo Institute of Technology	nakamura@phys.titech.ac.jp
Vandana Nanal	Tata Institute, Mumbai	vnanal@gmail.com
Pawel Napiorkowski	Heavy Ion Laboratory, University of Warsaw	pjn@slcj.uw.edu.pl
B. S. Nara Singh	University of York	narasingh.bondili@york.ac.uk
Witold Nazarewicz	University of Tennessee	witek@utk.edu
Bożena Nerlo-Pomorska	Maria Curie Skłodowska University	pomorska@kft.umcs.lublin.pl
Gerda Neyens	KU Leuven	gerda.neyens@fys.kuleuven.be
Dario Nicolosi	INFN LNS and University of Catania	dario.nicolosi@lns.infn.it
Norbert Niewalda	ABE-IPS	norbert.niewalda@abe.pl
Małgorzata Niewiara	IFJ PAN Kraków	malgorzata.niewiara@ifj.edu.pl
Frederic Nowacki	IPHC Strasbourg	frederic.nowacki@iphc.cnrs.fr

Alexandre Obertelli	CEA Saclay	alexandre.obertelli@cea.fr
Wolfram von Oertzen	Helmholtz Zentrum Berlin	oertzen@helmholtz-berlin.de
Takaharu Otsuka	University of Tokyo	otsuka@phys.s.u-tokyo.ac.jp
Marcin Palacz	Heavy Ion Laboratory, University of Warsaw	palacz@slcj.uw.edu.pl
Thomas Papenbrock	University of Tennessee and ORNL	tpapenbr@utk.edu
Concetta Parascandolo	University of Padova and INFN	concetta.parascandolo@pd.infn.it
Tomasz Pawłat	IFJ PAN Kraków	tomasz.pawlat@ifj.edu.pl
Mihaela-Cristina Petrone	NIPNE and University of Bucharest	cristina.petrone@tandem.nipne.ro
Monika Pieńkos	University of Silesia	monika.pienkos@gmail.com
Giovanni Pollarolo	University of Torino and INFN	nanni@to.infn.it
Krzysztof Pomorski	Maria Curie Skłodowska University	pomorski@kft.umcs.lublin.pl
Leszek Próchniak	Maria Curie Skłodowska University	leszek.prochniak@umcs.lublin.pl
Lee Riedinger	University of Tennessee	lrieding@utk.edu
Peter Ring	Technical University Munich	ring@ph.tum.de
Oliver Roberts	University of Brighton	O.J.Roberts@brighton.ac.uk
David Rouvel	University of Strasbourg	david.rouvel@iphc.cnrs.fr
Krzysztof Rusek	Heavy Ion Laboratory, University of Warsaw	rusek@fuw.edu.pl
Hideyuki Sakai	RIKEN Nishina Center	hidesakai@riken.jp
Guy Savard	ANL and University of Chicago	savard@anl.gov
Hendrik Schatz	Michigan State University	schatz@nscl.msu.edu
Christelle Schmitt	GANIL	schmitt@ganil.fr
Nicolas Schunck	Lawrence Livermore National Laboratory	schunck1@llnl.gov
Lianne Scruton	University of York	ls527@york.ac.uk
Valentina Scuderi	INFN Laboratori Nazionali del Sud	scuderiv@lns.infn.it
Loïc Sengele	IPHC Strasbourg	loic.sengele@iphc.cnrs.fr
Obed Shirinda	iThemba LABS	obed@tlabs.ac.za
Kamila Sieja	IPHC Strasburg	kamila.sieja@iphc.cnrs.fr
Dominik Sierpowski	Nowoczesna Elektronika	Dominik.Sierpowski@ne.com.pl
Haik Simon	GSI Darmstadt	h.simon@gsi.de
Dharmendra Singh	IUAC New Delhi	dsinghiuac@gmail.com
Janusz Skalski	NCBJ Świerk	jskalski@fuw.edu.pl
Helena Śliwińska	IPHC and University of Strasbourg	helena.sliwinska@iphc.cnrs.fr
Nadya Smirnova	CENBG Bordeaux-Gradignan	smirnova@cenbg.in2p3.fr
Olivier Sorlin	GANIL	sorlin@ganil.fr
László Stuhl	ATOMKI Debrecen	stuhl@atomki.hu
Jan Styczeń	IFJ PAN Kraków	jan.styczen@ifj.edu.pl
Toshiyuki Sumikama	Tohoku University	sumikama@lambda.phys.tohoku.ac.jp
Suzana Szilner	Ruder Boskovic Institute, Zagreb	szilner@irb.hr
Cecylia Szklarz	IFJ PAN Kraków	cecylia.szklarz@ifj.edu.pl
Bartłomiej Szpak	IFJ PAN Kraków	bartlomiej.szpak@ifj.edu.pl
Atsushi Tamii	Osaka University	tamii@rcnp.osaka-u.ac.jp

Dimitar Tarpanov	University of Warsaw	dimitert@yahoo.co.uk
Jun Terasaki	University of Tsukuba	terasaki@ccs.tsukuba.ac.jp
Peter Thirolf	Ludwig-Maximilians-University Munich	Peter.Thirolf@physik.uni-muenchen.de
Michael Thoennessen	Michigan State University	thoennessen@nscl.msu.edu
Yasuhiro Togano	ExtreMe Matter Institute EMMI, GSI	Y.Togano@gsi.de
Tamas Tornyi	ATOMKI Debrecen	tornyitom@gmail.com
Zsolt Vajta	ATOMKI Debrecen	vajta@atomki.hu
David Verney	IPN Orsay	verney@ipno.in2p3.fr
Robert Wadsworth	University of York	rw10@york.ac.uk
Zbigniew Wąs	IFJ PAN Kraków	Zbigniew.Was@ifj.edu.pl
Paweł Wasiak	IFJ PAN Kraków	wasiakpp@gmail.com
Barbara Wasilewska	IFJ PAN Kraków	b.a.wasilewska@gmail.com
Christine Weber	Ludwig-Maximilians-University Munich	weber.ch@physik.uni-muenchen.de
Henry R. Weller	Duke University and TUNL	weller@tunl.duke.edu
Emma Wilson	University of Surrey	emma.wilson@surrey.ac.uk
Kathrin Wimmer	Central Michigan University	wimmer@nscl.msu.edu
Jacek Wrzesiński	IFJ PAN Kraków	jacek.wrzesinski@ifj.edu.pl
Furong Xu	Peking University	frxu@pku.edu.cn
Krystyna Zając	Maria Curie Skłodowska University	krystyna.zajac@poczta.umcs.lublin.pl
Mirosław Ziębliński	IFJ PAN Kraków	miroslaw.zieblinski@ifj.edu.pl

Design & DTP: Jolanta Królas