Reflections on the atomic nucleus

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Book of abstracts

Can we use nuclear structure to constrain the sites of the r-process?

Ani Aprahamian

Nuclear Science Laboratory
University of Notre Dame
Notre Dame, IN 46556

The site of the rapid neutron capture process (r-process) is one of the open challenges in all of physics today. The r process is thought to be responsible for the creation of more than half of all elements beyond iron. The scientific challenges to understanding the origin of the heavy elements beyond iron lie in both the uncertainties associated with astrophysical conditions that are needed to allow an r-process to occur and a vast lack of knowledge about the properties of nuclei far from stability. One way is to disentangle the nuclear and astrophysical components of the question. On the astrophysics side, various astrophysical scenarios for the production of the heaviest elements have been proposed but open questions remain. On the nuclear physics side, there is great global competition to access and measure the most exotic nuclei that existing facilities can reach. Access to the very rich nuclei far from stability is a worldwide quest. The challenge is to determine which nuclei have the greatest impact on the r-process. While we don't know the properties of specific nuclei far from stability, we do know the nuclear properties that are important for the r-process. These include nuclear masses, -decay rates, n-capture rates, and -delayed neutron emission probabilities. I will report on sensitivity studies of the various nuclear properties to determine the most impactful nuclei to measure for the r-process.

Nuclear physics with ion traps

Juha Äystö

Helsinki Institute of Physics, Helsinki, Finland and University of Jyväskylä, Jyväskylä, Finland

In this talk I will present an overview of the experimental programme carried out using the JYFLTRAP at the IGISOL facility. In particular, the focus of the talk will be on the physics subjects that gain particularly from the high-precision provided by the Penning trap technique. Examples chosen will be the mass measurements of exotic neutron-rich nuclei of relevance for astrophysics, precision Q-value measurements of the superallowed beta decays for testing the unitarity of the CKM matrix, as well as the Q-values of currently relevant double beta decay experiments.

Nuclear Physics Experiments with High-Power Lasers and Brilliant Gamma Beams at the ELI-NP Facility *

Dimiter L. Balabanski

ELI-NP, "Horia Hulubei" National Institute for Physics and Nuclear Engineering,
30 Reactorului Street, RO-077125 Măgurele, jud. Ilfov, Romania

Abstract: The Extreme Light Infrastructure (ELI) Pan-European facility initiative represents a major step forward in quest for extreme electromagnetic fields. Extreme Light Infrastructure – Nuclear Physics (ELI-NP) is one of the three pillars of the ELI facility, that aims to use extreme electromagnetic fields for nuclear physics and quantum electrodynamics research. At ELI-NP, high-power laser systems together with a very brilliant gamma beam are the main research tools. Their targeted operational parameters will be described. The emerging experimental program of the facility will be reported, with an emphasis on the IGISOL beam line, which is being designed at ELI-NP. The related experimental areas will be presented, together with the main directions of the research envisioned. The different instruments which are considered to operate in the ELI-NP experimental halls will be discussed, with an emphasis on the instrumentation which is designed for nuclear structure, reactions and astrophysics research.

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The shell structure and stability of super-heavy nuclei

Michael Bender

Université Bordeaux, Centre d'Etudes Nucléaires de Bordeaux Gradignan, 33175 Gradignan, France
and CNRS/IN2P3, Centre d'Etudes Nucléaires de Bordeaux Gradignan, 33175 Gradignan, France

The ongoing experimental efforts for the synthesis and spectroscopic study of the heaviest elements are accompanied by theoretical studies. Mean-field models are the tools of choice for the simultaneous description of their bulk and spectroscopic properties [1]. These approaches come in two different forms, *macroscopic-microscopic models* on the one hand, and *self-consistent mean-field models* on the other hand. This presentation will focus on some recent results obtained with the latter.

Going up in mass from the well-deformed heavy actinides to the expected "island of stability" of spherical nuclei, three topics will be addressed. The first one is the sensitivity of excitation spectra to details of the modeling and the difficulty to reach detailed agreement with the ever increasing body of spectroscopic data for nuclei in the region around ^{254}No [2]. The second topic is the appearance and disappearance of deformed shell closures when increasing the proton and/or neutron number [1]. Finally, it will be shown that either shape coexistence or, alternatively, the mixing of different shapes might be a feature of most, if not all, the very heaviest nuclides presently known [3].

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Precision Measurements of Nuclear Ground-state Properties for Nuclear Structure, Astrophysics and Fundamental Studies

Klaus Blaum

Max-Planck-Institut für Kernphysik, 69117 Heidelberg, Germany.

Atomic physics techniques like Penning-trap mass spectrometry and laser spectroscopy have provided sensitive and high-precision tools for a detailed study of nuclear ground-state properties far from the valley of stability. Mass, moment and nuclear charge radii measurements in long isotopic and isotonic chains have allowed, e.g., to extract nuclear structure information such as shell and subshell closures, the onset of deformation, the coexistence of nuclear shapes at nearly degenerate energies, and so on. This contribution covers the mentioned experimental techniques to study nuclear ground state properties and their impact on nuclear structure, nuclear astrophysics and fundamental studies. Comparisons to modern calculations will be presented as well.

Radioactive Beam Facilities for Tomorrow

Yorick Blumenfeld

Institut de Physique Nucléaire, IN2P3/CNRS, Université de Paris Sud,
91406 Orsay Cedex, France

Since their inception in the 1980s radioactive ion beams (RIB) have transformed the field of nuclear physics. The start of the 21st century has been accompanied by a flurry of new highly ambitious RIB projects throughout the world such as ARIEL in Canada, EURISOL in Europe, FAIR in Germany, FRIB in the US, HIE-ISOLDE at CERN, RIBF in Japan, RISP in Korea, SPES in Italy, SPIRAL2 in France … I will give a brief description of these projects emphasizing how they are moving away from the traditional "post-accelerated ISOL"/In-flight divide towards combining the best of both worlds with new techniques for slowing down and reaccelerating beams produced in-flight as well as fragmenting post accelerated ISOL beams.

While some of these projects are on track others have been plagued by delays or even cancellations. I will overview the status of the projects and attempt to understand some of the technical and logistical problems that are being faced.

Probing beyond Standard Model physics at low energy

Tim Chupp

University of Michigan, Ann Arbor, Michigan

The nucleus, including the neutron, has long been a laboratory for discovery of new interactions and new phenomena from the discovery of the neutrino through the study of weak interactions that form the experimental basis of the Standard Model, which forms a complete description of the interactions of known particles. In spite of its success, strong evidence that the Standard Model is incomplete is provided by the baryon asymmetry of the universe, the abundance of non-baryonic dark matter, and the neutrino flavor oscillations that imply non-zero masses. It is clear that a New Standard Model must emerge and that it must be based on experiment.

One approach is, of course probing at the highest possible energies, the domain of the LHC and possible future colliders, but the nucleus remains an important low-energy laboratory of the key tools has been measurement or search for evidence of observables that violate symmetries of parity (P), time-reversal (T) and charge conjugation (C), because of the possibility to project weaker interactions in the presence of the dominant strong and electromagnetic interaction. Time-reversal invariance is of particular interest, specifically the electric dipole moment (EDM) of a heavy atom or the neutron, which violates P and T. This is because the forces that may have led to the dominance of matter over antimatter in the early universe would also produce an EDM much larger than Standard Model EDMs. A number of planned experiments are poised to push the sensitivity of EDM measurements in the neutron, atoms, molecules and new systems including atoms with octupole deformed nuclei. A context for interpreting this suite of measurements is provided by a new global analysis we have recently reported.

EDM measurements are an example of searching for new physics where the Standard-Model background is small. Another approach is precision measurement of a quantity that is precisely predicted by the Standard Model or by making a set of measurements that over constrains the Standard Model parameters. The measurement of the muon magnetic-moment anomaly (g_μ-2) is an example of probing where the Standard Model prediction is very precise. Neutron-decay correlation coefficients provide a way to over constrain the allowed Standard-Model parameters.

This talk will provide an overview of these opportunities with emphasis on what and how we can learn about new physics possibilities.

Recent developments in detection technology for scientific research applications

James Cocks

Canberra Industries, Harwell Science Campus, Didcot, U.K.

The evolution of nuclear detection technology in the field of experimental nuclear structure has, through improvements in resolving power and detection limit, supported the probing of increasingly-exotic nuclei. A brief history of this evolution will be presented, with a specific focus on gamma-ray spectroscopy. New developments in detection technology relevant to this field will then be presented with a discussion of their potential impact on nuclear physics research. The talk will also summarize recent contributions to other areas of scientific research.

New developments in nuclear DFT

Jacek Dobaczewski

Institute of Theoretical Physics, University of Warsaw, and
Department of Physics, University of Jyväskylä, Jyväskylä

Energy-density-functional (EDF) methods in nuclear physics are based on the many-body density functional theory and provide a unified description of nuclear ground states as well as low-energy excitations. On the one hand, within the last forty odd years numerous applications thereof have shown a tremendous success of the approach, which allows for a correct description of a multitude of nuclear phenomena. On the other hand, recent analyses indicate that the currently used EDFs have probably reached their limits of accuracy and extrapolability. The question of whether these can be systematically improved appears to be the central issue of the present-day investigations in this domain of nuclear-structure physics. In this talk I will present the status of theoretical developments aiming at improvements of the present-day nuclear EDF approaches. The main lines of current attempts are in expansions based on higher-order derivative corrections and/or including three- or four-body terms. Novel EDFs are often based on zero-range or finite-range pseudopotentials and may have local, quasilocal, or nonlocal character. Some of the new developments have already led to implementations in numerical codes and preliminary applications to finite nuclei are gradually becoming available.

Exploring yrast structures in neutron-rich nuclei with deep-inelastic collisions

Bogdan Fornal

Institute of Nuclear Physics, Polish Academy of Sciences, Kraków, Poland

The usefulness of deep-inelastic reactions for discrete gamma-ray spectroscopic studies was recognized in 1990's, when it was demonstrated that they are amenable to populating yrast structures at relatively high spin in nuclei with large neutron excess. These initial works triggered a series of experimental investigations of neutron-rich nuclei. The technique relies on using processes which occur at incident energies roughly 20% above the Coulomb barrier where the production of neutron-rich species results from a tendency towards N/Z equilibration of the di-nuclear system formed during the collisions. In such reactions, the total reaction yield is spread over many nuclei and characteristic gamma rays from those products can be resolved only by employing efficient gamma-ray detection systems. Indeed, Compton-suppressed germanium arrays (e.g., GASP, GAMMASPHERE, EUROBALL) enabled fruitful studies of discrete gamma rays from deep-inelastic reaction products, especially in measurements carried out with a thick target. Here, an accurate identification of the product nuclei is provided by combining the presence of known gamma rays with the gamma-gamma coincidence technique. By using thick targets with deep-inelastic collisions, yrast and near-yrast structures have been located in many nuclei that were previously inaccessible. In particular, high-spin yrast isomers, with spins as high as 31ħ, were located in neutron-rich nuclei in the neighborhood of the doubly magic ^{208}Pb. With the development of high-intensity, neutron-rich radioactive beams at energies exceeding the Coulomb barrier, deep-inelastic processes may be a unique tool to access yrast structures in nuclei with large neutron excess lying near the radioactive projectile.

Constraining the Neutrinoless Double Beta Decay Matrix Elements using Transfer Reactions

Sean Freeman

School of Physics and Astronomy, University of Manchester

The discovery that neutrinos have finite rest mass has led to renewed interest in neutrinoless double beta decay. The development of large-scale experiments to search for neutrinoless double beta decay has increased the probability of a credible observation of the process in the near future. The reliability of calculations of the associated nuclear matrix elements is likely soon to become a critical issue.

To test the reliability of theoretical models used to predict the nuclear matrix elements for neutrinoless double beta decay, we have undertaken programme of measurements that access properties of the ground-state wave functions of double-beta-decay candidates and associated daughter nuclei. Single-nucleon transfer reactions have been used to deduce the occupancies of valence single-particle orbitals and how they change as a result of the decay process. Pairing properties of these systems have also been investigated by two-nucleon transfer reactions. Progress in this work will be discussed along with recent results.

The Triangular D3h Symmetry of ^{12}C

Moshe Gai

LNS at Avery Point, University of Connecticut and Yale University

Recent measurements of the structure of ^{12}C [1] using an optical readout TPC (O-TPC) [2] and gamma beams allowed the first study of the rotation vibration spectrum of ^{12}C which appears strikingly similar to the spectrum predicted by a new algebraic cluster model [3] employing a geometrical triangular shape with (D3h) symmetry with predicted recurring rotational bands including the states: 0^+, 2^+, 3^-, (degenerate) 4^+ and 4^-, 5^- etc [4,5]. Such structures and symmetries are common in molecular physics, but have been observed in nuclear physics for the first time. This model also allow us to elucidate the structure of the Hoyle state and as such it is in conflict with ab-initio effective field theory calculations on the lattice [6] that predict a different structure of the Hoyle state. The calculations on the lattice on the other hand use the Hoyle state to conclude the masses of light quarks and the strength of the electromagnetic interaction (within the anthropic view of the universe). Extension of this study to the newly constructed ELI-NP gamma ray facility in Bucharest with a Warsaw-UConn-ELI electronic readout TPC (eTPC) will be discussed.

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Thermodynamic and electromagnetic properties of nuclei

Magne Guttormsen

Department of Physics, University of Oslo, P. Box 1048, N-0316 Oslo

The level density and γ-ray strength function determine the average γ-ray decay probability in the nuclear quasi-continuum. These quantities have been measured simultaneously for each of the $^{231-233}Th$, $^{232,233}Pa$, $^{237-239}U$ and ^{238}Np nuclei at the Oslo Cyclotron Laboratory. All nuclei exhibit a constant-temperature level density and a strong M1 scissors resonance [1-4].

In neutron capture reactions, several decay channels are open above the neutron separation. In particular for the actinides, the γ-decay branching ratio is of crucial importance in the simulations of the nucleosynthesis, fuel cycles in fast reactors and transmutation of nuclear waste.

In order to study the impact of the observed level densities and γ-ray strength functions on the (n, γ) cross section, we have performed statistical Hauser-Feshbach calculations with the TALYS code. The agreements for known cross sections are very good and indicate a high predictive power for many of the actinides where the cross section cannot be directly measured.

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Current challenges in superheavy element research

Rolf-Dietmar Herzberg

Department of Physics, University of Liverpool, L69 7ZE, UK

A growing number of experiments is currently opening up the transfermium region of nuclei for detailed spectroscopic investigations [1,2,3]. In the deformed nuclei in the nobelium region this allows identification and mapping of single particle orbitals closest to the top end of the nuclear chart.

Initial in-beam measurements in the region focussed on γ-ray spectroscopy of even-even nuclei (e.g. ^{252,254}No, ^{250}Fm), studying the ground-state yrast bands and allowing extraction of parameters such as the moments of inertia, and proving the deformed nature of these nuclei. More recently, it has become possible to do combined in-beam gamma ray and conversion electron spectroscopy with the SAGE spectrometer [4]. The first experiments have focused on the study of odd-mass transfermium nuclei and are currently being analysed. These experiments will yield data which can be used to determine the excitation energies and configurations of quasiparticle states in the region, and to compare them to the predictions of various theories.

Experimentally it is important to have a full understanding of the instrument and
GEANT4 simulations play an increasingly important role in the analysis of experimental data [5,6]. An overview of the most recent results and the experimental techniques used will be presented and the SAGE spectrometer in Jyväskylä will be discussed.

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Producing radioactive ion beams through the ISOL method: advances, challenges and opportunities

Mark Huyse

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

Although the production of radioactive ion beams through the Isotope Separation On Line (ISOL) method is more than half a century old, the technical advances of recent years are still placing this production technique at the forefront of radioactive ion beam research. An overview will be given on recent realizations to produce and manipulate intense, pure beams of exotic nuclei tailored for a great variety of experiments in the fields of nuclear and atomic physics, solid-state physics, materials science and life sciences. But new developments are needed to even further extend the possibilities of this technique. The challenges to surpass and the opportunities which are in reach will be discussed in the context of the present and future facilities.

In-beam studies of the structure of exotic nuclei

Rauno Julin

Department of Physics, University of Jyväskylä, P.O. Box 35, FIN-40014 University of Jyväskylä, Finland

The interplay between single-particle motion, collectivity and pairing in nuclei is seen as exotic excitations and coexistence of various structures at low excitation energy. To understand the origin of these structures it is important to extend the systematic spectroscopic studies to nuclei at the extremes of neutron and proton numbers.

Nuclei at the proton drip line and in the region of super-heavy elements can be produced in fusion-evaporation reactions with stable-ion beams and targets. We have shown that highest sensitivity and best resolution in spectroscopic studies of these nuclei are obtained in tagging experiments by combining novel in-beam γ-ray and conversion-electron spectrometer systems with instruments developed for off-beam decay studies. In addition to the γ-ray-, electron- and particle spectrometers, a recoil separator is the key instrument in selecting the very weak reaction channels of interest. The newest developments include a differential-plunger lifetime measurements of excited states in very neutron deficient nuclei and beta-tagging for studies of N = Z nuclei.

New results obtained in tagging experiments carried out at the JYFL Accelerator Laboratory in Jyvaskyla, Finland, will be presented. They include experiments for N = Z nuclei and very neutron deficient nuclei in the Sn and Pb region.

Future plans to improve sensitivity in such measurements include developments of digital electronics, higher efficiency separators and detector arrays, and higher intensity beams. These developments and expected detection limits will be discussed.

Impact of superheavy element research on nuclear theory

Teng Lek Khoo

Argonne National Laboratory, Argonne, IL 60439

Nuclear models are anchored on nuclei for which abundant data exists. Calculations on superheavy elements (SHE), for which there are sparse data, represent true predictions rather than descriptions of existing data. Therefore, SHE provide excellent tests of nuclear theory – beyond an already-interesting check of how well it can quantitatively describe nuclei at the limits of existence in Coulomb instability, spin and excitation energy.

SHE exist only due to shell stabilization, which arises from the single-particle spectrum, especially from gaps. That spectrum constitutes the most critical test of theory. The spectrum also sensitively affects the masses of the ground, yrast and saddle states, as well as the fission barriers, because the shell energy is predominantly responsible for the binding – and existence – of SHE.

Models based on density-functional theory (DFT) and those built on potentials yield quite different predictions of the single-particle spectrum for SHE and, hence, different magic gaps, quasiparticle energies, masses and fission barriers. Comparisons of experiment and theory for these properties discriminate the predictive powers of these theoretical approaches. These comparisons will form the basis of this talk. The macroscopic-microscopic approach with either the Woods-Saxon or folded Yukawa potentials describe simultaneously the single-particle spectrum, quasiparticle energies, fission barriers and masses – *for all nuclei*. While DFT enjoys comparable success for lighter nuclei, they are not yet as accurate for SHE nor as universal in coverage. Although DFT is more fundamental in some sense, its predictive power is still limited by the hunt for a good effective interaction, which is very much in progress. The goal is for a theory which describes *all properties of all nuclei*.

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Couplings between particle and phonons around neutron-rich doubly-magic nuclei

Silvia Leoni

University of Milano and INFN, Milano, Italy

The coupling between valence particles and core excitations is a very important issue in nuclear structure studies: it is a key process at the origin of the quenching of spectroscopic factors, of the anharmonicities of vibrational spectra and of the damping mechanisms of giant resonances. In particular, a systematic investigation of particle-phonon coupled states by gamma spectroscopy study of nuclei lying close to the neutron-rich doubly-magic ^{48}Ca, ^{132}Sn and ^{208}Pb cores is of special interest. Phonon excitations are in fact expected to be quite strong in doubly magic nuclei and to significantly influence the single particle structure of close lying systems. From a broader perspective, such type of information can be used to assess the robustness of the nuclear shell closures in various regions of the nuclear chart, from rather light to heavy systems, providing a testing ground for state of the art theoretical models.

This talk will give an overview of various reactions employed to populate excited states in nuclei lying in close proximity of doubly-magic nuclei: from multinucleon transfer with heavy ions, to cold neutron capture (n,γ) and neutron induced fission on ^{235}U and ^{241}Pu targets. The measurements were performed at Legnaro National Laboratory and ILL (Grenoble), using complex detection systems based on HpGe arrays coupled to magnetic spectrometers (PRISMA) or fast $LaBr_3$ scintillator detector arrays for lifetime measurements. The focus is on experimental data on ^{47,49}Ca [1,2], ^{133}Sb and ^{210}Bi, which are compared with theoretical calculations either based on a particle-phonon coupling approach or on a shell model employing realistic effective nucleon-nucleon interactions. Results on ^{61,65,67}Cu [3,4], obtained at NIPNE (Bucharest), will also be discussed in terms of couplings with the 3^- octupole phonon of the semi-magic ^{60,64,66}Ni cores.

To conclude, perspectives studies with radioactive beams will also be given.

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Nuclear Structure Theory: today and tomorrow

Witold Nazarewicz

MSU/ORNL/Warsaw

The long-term vision of nuclear theory is to arrive at a comprehensive and unified description of nuclei and their reactions, grounded in the interactions between the constituent nucleons. Theorists seek to replace current phenomenological models of nuclear structure and reactions with a well-founded microscopic theory that delivers maximum predictive power with well-quantified uncertainties. A new and exciting focus in this endeavor lies in the description of exotic and short-lived nuclei at the limits of proton-to-neutron asymmetry, mass, and charge.

In this talk, theoretical advances in rare isotope research will be reviewed in the context of the main scientific questions. Particular attention will be given to the progress in theoretical studies of nuclei due to the advent of extreme-scale computing platforms. I will also show how to assess the uniqueness and usefulness of an experimental observable, i.e., its information content with respect to current theoretical models.

Dual quantum liquid picture of nuclei and its implication to reflection asymmetry

Takaharu Otsuka

Department of Physics, University of Tokyo

The shell structure and "residual" interaction are two ingredients to determine the nuclear structure in its quantum liquid picture. The shell structure is usually stable in a given nucleus. However, it can be more dynamical in certain situations due to spin-isospin forces, and strong deformation can be created and stabilized. I shall discuss such a mechanism in shape coexistence cases, and extend this idea to reflection asymmetry cases.

Developments in in-beam conversion electron spectroscopy

Janne Pakarinen

Department of Physics, University of Jyväskylä, P.O. Box 35, FIN-40014 University of Jyväskylä, Finland

Over the last few decades, in-beam spectrometers have provided substantial amount of data on observables like transition energy, multipolarity and strength that have significantly extended our understanding of the structure of the atomic nucleus. While majority of the in-beam spectrometers have been dedicated to observation of gamma-rays, the complete picture of nuclear structure can only be obtained if alternative decay paths, ie. conversion electron emissions, for transitions of interest were also measured. This presentation will give an overview of developments of in-beam conversion electron spectrometers and highlight the important milestones en route.

Spin 60 and beyond: Exotic behavior at the limits of angular momentum

Mark Riley

Dept. of Physics, Florida State University

The light rare-earth nuclei near N = 90, are textbook examples of the evolution of nuclear structure with excitation energy and angular momentum. They display a variety of different phenomena, such as, multiple backbends, dramatic shape changes and band termination. However, it has taken several decades before we were able to observe structures beyond band termination. A spectacular return to collectivity has been found to take place extending discrete gamma-ray spectroscopy into the so-called ``ultrahigh-spin regime`` ($I = 50\text{-}70\hbar$). These latter sequences, observed initially in $^{157,158}Er$, were originally interpreted as being associated with a particularly stable and energetically favored strongly deformed triaxial shape minimum. However recent quadrupole moment measurements in erbium nuclei appear to be inconsistent with this early suggestion and now an even more strongly deformed triaxial minimum is preferred. These data have generated a good deal of theoretical discussion along with the suggestion that one of the sequences in ^{158}Er may even be "the highest spin structure ever observed". New results on similar structures in other neighboring nuclei will also be discussed. The latter are beginning to reveal a fascinating spectroscopy in this new exotic shape and spin regime.

Octupole correlations beyond the mean field

Luis Robledo

Dep Fisica Teorica, Universidad Autonoma de Madrid, Madrid

The status of the theoretical description of collective negative parity states both in even-even and odd mass nuclei using techniques based on the mean field approximation will be discussed. Topics include symmetry restoration and fluctuations in the octupole degree of freedom and their impact on observables like excitation energies, transition strengths, mass moments, correlation energies, etc. Other topics relating to clustering phenomena both in light and heavy nuclei will also be considered.

Beta-strength, decay heat and anti-neutrino spectra from Total Absorption Spectroscopy

Krzysztof P. Rykaczewski

Physics Division, Oak Ridge National Laboratory
Oak Ridge, TN 37831, USA

Understanding of processes occurring during the nuclear fuel cycle as well as the analysis of processes involving reactor anti-neutrinos require sufficient knowledge on beta-strength distribution in fission products.

The Modular Total Absorption Spectrometer (MTAS) has been constructed at Oak Ridge National Laboratory and applied to the decay studies of fission products. MTAS efficiency for full gamma energy absorption is about 78% and 70% for 0.3 MeV and 5 MeV single γ-ray, respectively [1]. MTAS has been used to measure beta-strength function in decays of about forty on-line mass-separated ^{238}U fission products including eleven activities of highest priority for decay heat simulations [2,3]. The examples of MTAS results will be presented and discussed with respect to the beta-strength distribution, decay heat and antineutrino energy spectra. In particular, the problem of so called “reactor anti-neutrino anomaly”, i.e., the deficit of observed reactor anti-neutrinos in single-detector experiments [4,5], will be addressed during my talk.

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Measurement of $B(E3; 0 \rightarrow 3^-)$ strength in strongly octupole correlated nuclei near ^{224}Ra

Marcus Scheck

University of the West of Scotland

In this contribution the physics of strong octupole correlations is introduced. Furthermore, the experimental method of ’safe’ Coulomb excitation using heavy, post-accelerated, radioactive ion beams is outlined using the example of the MINIBALL setup at REX-ISOLDE. The results of a first experimental campaign including ^{220}Rn and ^{224}Ra are shown and their implication for the enhancement of a possible CP-violating Schiff moment in octupole-correlated, odd-mass nuclei discussed. Future prospects for probing octupole collectivity in medium- and heavy-mass nuclei at ISOLDE will also be discussed.

Myths of Collective Structures in Atomic Nuclei

John F. Sharpey-Schafer

University of the Western Cape, South Africa

The liquid drop model of the atomic nucleus and the success of the Weizsäcker mass formula encouraged physicists to interpret the properties of low-lying levels in even-even nuclei in terms of quadrupole and octupole oscillations of the nuclear shape. The rapid increase in accurate information on the properties of such levels, especially in deformed nuclei, does not support some of these interpretations.

The experimental data leading to collective interpretations will be reviewed and major challenges will be discussed.

Coexisting quadrupole shapes in heavy exotic nuclei

Piet Van Duppen

KU Leuven, Instituut voor Kern- en Stralingsfysica
3001 Leuven, Belgium

In a recent review paper [1], it was conjectured that “shape coexistence in nuclei appears to be unique in the realm of finite many-body quantum systems”. It was concluded that in atomic nuclei this phenomenum involves “(sets of) energy eigenstates with different electric quadrupole properties such as moments and transition rates, and different distributions of proton pairs and neutron pairs with respect to their Fermi energies.”

Quadrupole degrees of freedom in atomic nuclei can be probed using different experimental techniques, amongst them laser spectroscopy, life time and angular correlation measurements and Coulomb excitation to name a few. While laser spectroscopy is limited to ground and longer-lived isomeric states, the latter techniques give information on excited states. Recently, initiated by amongst others the availability of (energetic) radioactive beams, these probes have been used in the neutron-deficient lead isotopes. These experimental results give on the one hand new insight in shape coexistence but on the other side invoke new questions.

In this contribution we will present results from Coulomb excitation and decay studies in the neutron-deficient lead region performed at the ISOLDE-CERN facility [2,3] and use them to reflect on shape coexistence in heavy atomic nuclei.

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TSR project at ISOLDE

Fredrik Wenander

BE Department, CERN

The goal of the TSR@ISOLDE initiative is to place the Test Storage Ring (TSR) from MPI-K, Heidelberg, after the HIE-ISOLDE linac to perform experiments with stored exotic nuclides. With the integration of TSR at HIE-ISOLDE it would become the first storage ring at an isotope separator on-line facility. A substantial fraction of the vast number of radioactive beams produced at the ISOLDE facility could be injected into the ring for storage, beam deceleration or acceleration. Apart from decay studies, reaction studies could be carried out using an internal gas-jet being installed at the experimental section of the ring. The cooled ions could also either be slowly or quickly extracted to external setups by means of resonant excitation or kicker extraction. The initiative at its present stage will be summarized, and a tentative layout of the ring and its experimental areas will be introduced. The different operational possibilities and constraints that arise when the ring is connected to an ISOL facility with a successive charge breeder will be addressed.

If you like it you should have put a ring on it

Phil Woods

School of Physics and Astronomy, University of Edinburgh, Edinburgh

The talk will address new developments in studies of explosive nuclear astrophysics with a focus on the present and future role of heavy ion storage ring devices for key measurements in this field.