

Program

28-30 Sept 2026



32nd Nuclear Physics Workshop

28-30 September 2026
Lublin, Poland



32nd Nuclear Physics Workshop 2026

D-332

Instytut Fizyki UMCS pl. M. Curie-Skłodowskiej 1 20-031 Lublin

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Monday 28 September

09:00



09:20

Welcome Addresses and Official Opening

Contribution | **Location:** D-332, Instytut Fizyki UMCS pl. M. Curie-Skłodowskiej 1 20-031 Lublin

09:20

Session 1: Monday mornig**Session** | **Location:** D-332, Instytut Fizyki UMCS pl. M. Curie-Skłodowskiej 1 20-031 Lublin

09:20–09:50

Impact of nuclear structure on WIMP-nucleus and coherent elastic neutrino-nucleus scattering**Speaker**

Cedric Simenel

Description

Direct searches for Weakly Interacting Massive Particles (WIMPs) require accurate nuclear structure inputs to reliably interpret experimental data. We present a self-consistent framework based on Skyrme Hartree-Fock-Bogoliubov theory to compute the nuclear form factors entering WIMP-nucleus scattering. The approach provides all relevant spin-independent and spin-dependent responses within a unified description derived from the underlying one-body density matrix. We discuss applications to detector nuclei, including ^{40}Ar , and compare our predictions with shell-model calculations. While excellent agreement is obtained for the dominant spin-independent response, significant differences emerge in spin-orbit and other subleading channels, highlighting the importance of a microscopic treatment of nuclear structure for future dark matter searches. The same nuclear form factors are also employed to compute coherent elastic neutrino-nucleus scattering (CEvNS) cross sections, providing precise Standard Model predictions for next-generation neutrino experiments and demonstrating the versatility of the formalism. Together, these studies establish a common nuclear-structure framework applicable to both dark matter direct detection and low-energy weak-interaction processes, reducing theoretical uncertainties in searches for physics beyond the Standard Model.

09:50–10:20

Octupole and hexadecapole excitations in nuclei**Speaker**

Kosuke Nomura

Description

This presentation highlights recent theoretical investigations on the octupole and hexadecapole correlations, and related collective excitations in medium-heavy and heavy nuclei in the interacting boson model that is based on the microscopic nuclear density functional theory. Octupole correlations are shown to play an important role in predicting low-energy collective states and the relevant E2 and E3 transition rates in a large number of actinide, rare-earth, and lanthanide nuclei with nucleons numbers close to 56, 88, and 136 and in the $N \sim Z \sim 34$ nuclei, in which triaxiality and coexistence of quadrupole shapes are also present. The hexadecapole degree of freedom is shown to have impacts on the systematic of the energy spectra, E2 and E4 transition strengths in nearly spherical and deformed rare-earth nuclei.

10:20–10:40

Octupole instabilities and pairing vibrations in ^{220}Rn **Speaker**

Artur Dobrowolski

Description

Calculations aimed at reproducing the rotational level patterns in the ^{220}Rn nucleus were carried out using a collective quadrupole-octupole approach with a microscopic mass tensor and moments of inertia dependent on the deformation and pairing degrees of freedom. The main objective, however, is to quantitatively confirm known experimental facts, according to which the Rn nucleus transitions from octupole oscillations to octupole deformation under external rotation.

The collective potential in nine-dimensional deformation space is determined using the macroscopic-microscopic method with the Strutinsky shell correction and the BCS method with an approximate particle number projection. The corresponding Hamiltonian is diagonalised based on the projected solutions of harmonic oscillators coupled with the appropriate Wigner functions. Such orthogonalised basis is, in addition, symmetrised with respect to the so-called internal symmetry group, specifically assigned to the collective space under consideration, in order to ensure the unambiguity of the Hamiltonian eigensolutions with respect to the laboratory reference frame.

The response of the deformation and pairing degrees of freedom to external rotation is discussed in a variational framework (the total energy is minimised by the pairing and deformation variables).

As the nuclear spin increases, the proton and neutron evaporation gaps decrease from their equilibrium values to zero (no superfluid solution). Consequently, the corresponding microscopic moments of inertia increase with increasing collective spin (the Coriolis anti-parity effect), resulting in effectively lower rotational energy levels $\hbar\pi$ compared with the $\hbar(l+1)$ pattern characteristic of a solution with a pure rigid rotor.

Compared with previous calculations, the spin-dependent moments of inertia and mass parameters were calculated taking into account the fact that proton and neutron evaporation gaps are, in fact, collective quantities.

A general comparison of the experimental and theoretical schemes for rotational energy levels and the probabilities of dipole, quadrupole and octupole transitions $BE(\lambda)$ in ^{220}Rn is satisfactory.

10:40–11:10

Coffee break

11:10–11:40

Prompt and delayed γ -ray emission as an experimental probe of fission**Speaker**

Jonathan Wilson

Description

Prompt and delayed gamma ray spectroscopy of nuclear reactions inducing fission can reveal a wealth of important information. Gamma ray spectroscopy of the de-exciting fragments after fission occurs not only allows study of the nuclear structure of neutron-rich nuclei, but also provides essential information on the fission process itself [1][2]. Conversely, study of delayed gamma emission can be used to extract isomeric yield ratios [3] and probe rare phenomena such as the population and back-decay of the fission shape isomers – metastable states with very large deformations which sit on the pathway to fission [4].

This presentation will give an overview of recent results on the gamma ray spectroscopy of fission with the nu-Ball2 spectrometer [5] at the ALTO facility of IJC Lab. Several open questions are currently being addressed, such as the evolution of fragment yield distributions in the sub-actinide region [6], the emission of high energy gamma rays in nuclear fission with potential population of collective excitations (PDR, GDR, etc.) in the emerging fragments [7]. The experiments have also explored other outstanding questions, such as the angular momentum carried away by neutron emission [8] and angular correlations between the spins of fission fragment partners and measurements of angular distributions of gamma rays with respect to the fission axis [9][10][11]. An overview of these new studies from the ν -Ball2 experimental campaign will be given and selected results will be presented along with future perspectives.

References

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11:40–12:10

Femосcopy: its concept and selected applications in heavy ion collisions**Speaker**

Zhigang Xiao

Description

Femtoscopy, the technique of extracting space-time information of particle-emitting sources at femtometer scales via two-particle momentum correlations, has become a cornerstone tool in heavy-ion collision physics. This talk will introduce the basic concept of intensity interferometry, the formalism of the correlation function, and the Lednický-Lyuboshitz analytical model that bridges experimental observables to source parameters and the final state interactions. Then I will present three selected experimental highlights in heavy ion collisions, spanning from the Fermi-energy domain to sub-GeV and ultra-relativistic energies, where the isospin dynamics, the hint of n-p short-range correlation and the final state interaction of particle pairs are inferred from the correlation functions.

12:10–12:30

Gamow-Teller Resonance and Double-Beta Decay of ^{48}Ca within the STDA Framework

Speaker

Daria Denisova

Description

Gamow-Teller resonance and double-beta decay of ^{48}Ca are studied within TDA and STDA using realistic chiral interactions. A consistent description of the resonance is achieved, and isospin symmetry is restored. Two-particle-two-hole correlations are shown to impact nuclear matrix elements and contribute to the quenching of g_A .

12:30–12:40

Study of proton-induced excitations of ^{208}Pb using the KRATTA, LaBr₃ and PARIS setup at CCB IFJ PAN

Speaker

Piotr Mróz

Description

This study details the experimental investigation of ^{208}Pb nuclei excitation through the inelastic scattering of a 155 MeV proton beam. The measurements were carried out at the Cyclotron Centre Bronowice (CCB) IFJ PAN, utilizing a multi-detector setup designed to capture the complex decay patterns of the excited targets.

The experimental configuration comprised the KRATTA triple-telescope array (32 detectors) for the detection and identification of scattered protons, complemented by the PARIS phoswich array and four LaBr₃(Ce) scintillators for high-energy gamma-ray spectrometry. The analytical workflow focused on rigorous energy calibration and the synchronization of the timing signals between the different arrays to isolate true coincidence events from the background.

A central part of the analysis was the construction of E_X - E_γ coincidence matrices, in which the excitation energy E_X , reconstructed from the kinematics of the scattered protons, was correlated with the energy E_γ of the coincident gamma rays. Gamma-ray energy spectra were extracted for selected excitation-energy intervals, enabling the investigation of transitions connecting excited states of ^{208}Pb with its ground state. The developed calibration and coincidence-selection provide a basis for the extraction of the gamma-decay signal associated with the Giant Quadrupole Resonance (GQR) in ^{208}Pb .

12:40

13:00



14:00

Lunch
Break

15:00

Session 2: Monday evening

Session | **Location:** D-332, Instytut Fizyki UMCS pl. M. Curie-Skłodowskiej 1 20-031 Lublin

15:00–15:30

Impact of Dynamic Shell Evolution on Fusion Dynamics in Superheavy Element Synthesis

Speaker

Yoshihiro Aritomo

Description

At present, the research into the synthesis of superheavy elements is being pursued under two main goals. One goal is to synthesize elements with larger atomic numbers, and the other is to reach the Island of Stability predicted as the next doubly magic nucleus. The periodic table is currently extended up to element 118, Oganesson (Og) [1], and experiments aimed at the synthesis of element 119 are now in progress. Recently, a successful synthesis experiment $^{54}\text{Cr} + ^{238}\text{U} \rightarrow ^{292-x}\text{Lv}$ has been carried out using a Cr beam [2].

In this work, we investigate the synthesis of superheavy elements using neutron-rich radioactive secondary beams. Since the intensity of secondary beams is significantly lower than that of stable beams, it is often questioned whether measurable evaporation-residue cross sections can be achieved. However, our theoretical analyses indicate that neutron-rich beams offer substantial advantages in both the fusion and decay processes, leading to enhanced evaporation-residue cross sections. The reaction dynamics are analyzed using a multidimensional Langevin approach. The presentation will focus on the following two key mechanisms responsible for the enhancement of the evaporation-residue cross sections:

1. Advantage in the survival probability.
2. Enhancement of the fusion probability through the production of neutron-rich nuclei and dynamic shell evolution

In summary, the production of highly excited compound nuclei on the neutron-rich side of the predicted Island of Stability is important for enhancing both the fusion probability and the survival probability. Although radioactive secondary beams have much lower intensities than stable beams, the unique reaction mechanisms associated with neutron-rich systems are expected to compensate for this disadvantage, resulting in larger evaporation-residue cross sections and improving the prospects for the synthesis of new superheavy elements.

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15:30–16:00

Superfluid Dynamics in Nuclear Collisions: Selected Aspects

Speaker

Piotr Magierski

Description

Superfluidity can significantly influence the dynamics of fermionic systems. On the one hand, it produces an excitation gap that suppresses dissipative processes and facilitates large-amplitude collective motion. On the other hand, the spontaneous breaking of U(1) symmetry gives rise to additional collective excitations, including Goldstone and Higgs modes.

In nuclear systems, these phenomena are obscured by finite-size effects and strong coupling to other degrees of freedom. Consequently, disentangling the various underlying mechanisms is particularly challenging in systems comprising no more than a few hundred particles. A realistic description of collision dynamics must therefore incorporate a broad range of relevant physical ingredients to avoid an oversimplified picture of the collision process.

In this talk, I will discuss selected aspects of superfluid dynamics in nuclear collisions.

16:00–16:30

Microscopic description of spontaneous fission in superheavy elements including tensor correlations

Speaker

Rayner Rodriguez-Guzman

Description

An accurate description of nuclear fission still remains a major challenge in today's nuclear structure physics. In this talk, we will discuss recent advances in the microscopic description of spontaneous nuclear fission, including the role of tensor interactions. It will be shown that in the case of super heavy elements, the reduction of the inner barrier heights represents a major tensor-driven mechanism with strong impact on the predicted spontaneous fission half-lives. Illustrative examples of collective potentials and inertias will be presented for the super heavy Rf, Sg, Hs and Ds isotopic chains, and the resulting spontaneous fission half-lives will be discussed as functions of the neutron number.

16:30–17:00

Coffee break

17:00–17:20

Revisiting pxn and axn channels in heavy and superheavy nuclei synthesis**Speaker**

Tomasz Cap

Description

Heavy-ion fusion-evaporation reactions populating nuclei near $Z \approx 85\text{--}90$ reveal an evaporation-channel puzzle: charged-particle channels pxn and axn are enhanced relative to pure neutron evaporation (xn). In several cases the axn channel exceeds xn by up to two orders of magnitude. A weaker but structurally analogous enhancement is predicted for selected superheavy-element reactions — including $^{51}\text{V} + ^{248}\text{Cm}$ forming $Z = 119$ — where axn channels can compete with xn even though the effect is less dramatic. At the vanishingly small cross sections typical of superheavy nuclei synthesis, this competition creates a genuine identification hazard: a decay chain assigned to xn evaporation may instead originate from a charged-particle channel populating an already-known nuclide. This talk examines the mechanism behind the pxn/axn enhancement — equivalently, xn suppression — and traces its consequences for interpreting current and future experiments. For some reactions employing projectiles heavier than ^{48}Ca , pxn emission has already been reported experimentally, underscoring that this is not a marginal correction but a channel demanding quantitative treatment in reaction-model predictions for the heaviest elements.

17:20–17:40

Mass asymmetry impact on the fusion hindrance within 6-dimensional Langevin dynamics**Speaker**

Yannen Jaganathen

Description

In a recent study, we introduced a six-dimensional Langevin-based formalism as a proof of principle for modeling heavy-ion fusion dynamics. This approach, incorporating elongation, neck, and asymmetry variables with fully unrestricted motion, naturally produces overdamped dynamics and rapid neck stabilization. Using a Yukawa-plus-exponential folding potential and Gaussian random forces, we achieved excellent agreement with experimental spin distributions and fusion cross-sections for the reactions $^{64}\text{Ni} + ^{92,96}\text{Zr}$, thereby validating the robustness of the model. In this contribution, we extend this formalism to investigate the impact of entrance-channel mass asymmetry on fusion probability in the collisions of multiple pairs of projectiles and targets, all forming ^{220}Th . We allow mass asymmetry to evolve freely alongside shape and angular variables, enabling the system to dynamically explore optimal fusion pathways. Suppression factors related to the Coulomb parameter $Z_1 Z_2$ and compound nucleus excitation energy are analyzed in detail. Our model includes full mass, diffusion, and friction tensors, accounting for off-diagonal couplings, to capture the complex interplay between neck formation, elongation, and entrance-channel symmetry. We focus on different types of reactions ranging from the highly asymmetric $^{16}\text{O} + ^{204}\text{Pb}$ to more symmetric configurations. The results highlight a strong dependence of spin distributions and fusion probabilities on the projectile-target combination, confirming the predictive power of six-dimensional stochastic dynamics for compound nucleus formation.

17:40–18:00

Systematic study of superheavy nuclei within a microscopic collective Hamiltonian: Impact of quantum shape fluctuations**Speaker**

Rongyan Hu

Description

We study even-even superheavy nuclei ($104 \leq Z \leq 126$, $N \leq 258$) using a five-dimensional collective Hamiltonian based on triaxial relativistic Hartree-Bogoliubov calculations with the PC-PK1 functional, explicitly incorporating quantum shape fluctuations (QSFs) beyond the mean-field. The model accurately reproduces binding, separation, and α -decay energies. A shape evolution from prolate deformation ($N \approx 150, 210$) to γ -soft configurations ($N \approx 176, 246$) and finally to spherical shapes ($N \approx 184, 258$) is revealed. Remarkably, many transitional nuclei lack bound 0^+_{γ} states because shallow fission saddles and QSF-induced zero-point vibrations prevent their stabilization. QSFs also smooth shell gaps, shifting the effective neutron closures from $N=184$ and 258 to $N=182$ and 256. Our results highlight the decisive role of QSFs in the stability of superheavy nuclei.

18:00–18:20

Neck constraint: a useful tool in the description of fission**Speaker**

Hemant Sharma

Description

In the theoretical description of the nuclear fission, the potential energy surface (PES) plays a vital role in analyzing the process. One crucial region of this process is just before scission, where pre-fragments develop their near-final configuration [1]. It has been demonstrated that employing multiple constraints on collective variables can be beneficial in obtaining a more detailed and continuous PES compared to projecting on only one or two collective degrees of freedom, which can lead to discontinuities and less informative fission barriers [2]. Using the necking constraint, along with constraints on multiple moments can help study this specific region and obtain a continuous PES through this approach [3].

We study saddle to the scission region by employing necking constraints using necking operator [4] with the analysis of its parameters: the width and the position of the necking gaussian. This study aims to understand the influence of these parameters on final results. We conduct the study for ^{236}Pu in both asymmetric and super-asymmetric fission modes, as well as for ^{264}Rf in symmetric fission modes. The constrained Hartree-Fock-Bogoliubov model is used with the Gogny D1S parametrization.

In this study, we demonstrate that the position of the minimum neck remains fixed for a given quadrupole deformation, irrespective of the chosen value of the Gaussian width. The minimum neck position can be detected by either using a Gaussian of width 1 fm to precisely capture the local structure of the neck or by performing the calculation with a dynamically determined neck position. However, some discrepancies are observed in the minimum neck position between these two methods.

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18:20–18:40

Flatness of Landscape near the "Island of Stability" of Superheavy Nuclei**Speaker**

Yi-Ming Jiang

Description

The fission barrier height serves as a crucial quantity in understanding the stability of superheavy nuclei and estimating the survival probabilities of a compound nucleus in a heavy ion fusion reaction, while its variation across the nuclear chart characterizes the landscape of the "island of stability" of superheavy nuclei. In this work, we perform the first systematic microscopic calculations of fission barrier heights for even-even superheavy nuclei with triaxiality included. In our calculations, the multidimensionally-constrained relativistic mean-field model is used. Our results reveal that the fission barrier heights remain ~ 5 MeV in the vicinity of the doubly magic nucleus $^{304}120$, indicating a surprising landscape of flatness around the "island of stability". We demonstrate that this flatness originates from the mutually suppressed magicity, whose microscopic origin lies in the distinct density distributions of protons and neutrons, arising from the different orbital angular momenta occupied by nucleons near the Fermi surface. This anomalous behavior is crucial for a quantitative understanding of superheavy nuclear stability and survival. Our findings provide a fresh view of shell evolution and its impact in this region.

18:40

19:00

22:00

Conference Dinner
Break

Tuesday 29 September

09:00

Session 3: Tuesday morning

Session | **Location:** D-332, Instytut Fizyki UMCS pl. M. Curie-Skłodowskiej 1 20-031 Lublin

09:00–09:30 Two avenues to improve nuclear energy density functionals

Speaker

Gianluca Colò

Description

Nuclear Density Functional Theory (DFT) is a widely used theoretical framework that has been developed over several decades and is accurate in describing nuclear ground-state properties such as nuclear masses and radii, as well as excitation spectra, decay properties, reactions, and fission. However, the results often depend on the specific Energy Density Functional (EDF) employed. EDFs that are equally successful for all observables have not yet emerged, and systematic ways to improve them remain unclear.

Nuclear DFT still lags behind electronic DFT in terms of its connection to exact conditions and to more fundamental calculations. I will explain the difference between the nuclear and electronic cases and I will discuss the current status and future perspectives of nuclear DFT grounded in ab initio nuclear theory.

I will then discuss a further topic, that is how DFT could be made efficient for heavy nuclei and for complex, extended systems such as the crust of neutron stars, through the development of orbital-free DFT (OF-DFT).

09:30–10:00

Nucleon Short-Range Correlations and the Equation of State of Dense Matter

Speaker

Bao-Jun Cai

Description

Nucleon short-range correlations (SRCs) and the associated high-momentum tails (HMTs) provide a unique window into the short-range dynamics of nuclear systems and play an important role in determining the equation of state (EOS) of dense, neutron-rich matter. In this talk, I will review recent progress in understanding SRCs and their implications for the EOS of isospin-asymmetric nuclear matter. After a brief overview of the microscopic origin and universal features of SRCs, including the dominance of neutron-proton tensor correlations and the resulting isospin dependence of nucleon momentum distributions, I will discuss how SRC-induced HMTs modify both the kinetic and interaction contributions to the nuclear EOS. Particular emphasis will be placed on the suppression of the kinetic symmetry energy, deviations from the conventional isospin-parabolic approximation, and their implications for dense matter. I will then highlight the impact of SRCs on several areas of nuclear physics and astrophysics, including neutron-star structure and evolution, as well as heavy-ion collisions. Finally, I will briefly discuss several emerging directions and open questions in the study of SRCs and dense matter.

10:00–10:30 Estimating Uncertainties of the Nuclear Mean Field Parameters

Speaker

Irene Dedes

Description

In nuclear structure theory there are two intrinsic facts: so far the exact theory has not been yet found, and (almost) all existing models depend on parameters. This leads us to the following: in order to be able to perform calculations and predictions for the existing and yet-unknown nuclear data, the values of such parameters must be determined, but keeping in mind that such parameters carry uncertainties since the exact theory does not exist (yet).

We wish to present how the parameter optimisation is of great importance in order to obtain the optimal parameter values, by removing "parametric correlations", and show how to obtain parametric uncertainties, and how they eventually propagate to the mean-field predictions, in the individual nucleonic levels, but also in the collective properties.

10:30–11:00 Coffee break

11:00–11:30

Recent advances in nuclear inputs for r-process simulations**Speaker**

Giuliani Samuel A.

Description

The rapid neutron-capture process, or r-process, is responsible for the production of approximately half of the heavy elements beyond iron in the Universe. This process requires environments with high neutron fluxes, such as core-collapse supernovae, neutron-star mergers, and collapsars, where nuclei can rapidly capture neutrons before undergoing radioactive decay. While the main mechanisms responsible for r-process nucleosynthesis are well understood, a quantitative description of abundance patterns and their associated electromagnetic counterparts requires accurate nuclear input.

In this talk, I will discuss some recent progress in the estimation of nuclear properties relevant to the r-process, with a focus on the impact of nuclear masses and fission properties.

11:30–12:00

Dynamical properties of fission in neutron-rich nuclei relevant to r-process nucleosynthesis**Speaker**

Nobuya Nishimura

Description

Nuclear fission plays a crucial role in r-process (rapid neutron capture process) nucleosynthesis in the Universe. However, the theoretical description of fission for neutron-rich nuclei remains incomplete, and many aspects of the underlying physics are still not fully understood. In this talk, I will first review recent progress in astronomical observations and nucleosynthesis studies, highlighting the importance of fission and the types of nuclear data required to advance our understanding of the r-process. I will then discuss how fission properties evolve toward increasingly neutron-rich nuclei, based on dynamical model calculations for uranium isotopes. The calculations are performed using a practical dynamical framework for nuclear fission. Finally, I will present an outlook on the impact that a comprehensive theoretical database of fission properties could have on future studies of r-process nucleosynthesis.

12:00–12:20

Stochastic Bogoliubov-de Gennes Approach to Nonequilibrium Fermionic Superfluidity**Speaker**

Dimitri Lazarou

Description

We formulate a stochastic extension of the time-dependent Bogoliubov-de Gennes formalism to describe thermalization in fermionic superfluids. The approach combines particle-number-conserving fluctuations of the local pairing field with quantum cooling in the particle-particle channel. This framework enables us to model relaxation and thermalization at fixed excitation energy. We investigate the resulting nonequilibrium evolution of the pairing field and analyze the thermodynamic and entanglement entropies of the system to determine whether, and under what conditions, thermalization occurs.

12:20–12:40

Coefficients of Fractional Parentage with Isospin**Speaker**

Algirdas Deveikis

Description

Coefficients of fractional parentage (CFPs) are fundamental ingredients of the nuclear shell model, providing a recursive construction of antisymmetric many-body wave functions and an efficient evaluation of one- and two-body matrix elements. Their calculation in the isospin formalism is considerably more difficult than for identical particles because antisymmetry must simultaneously be satisfied with respect to orbital, spin, and isospin degrees of freedom. Consequently, complete CFP sets with isospin have been available only for limited model spaces. We present a unified computational framework for the calculation of CFPs with isospin together with its extensions to generalized and intrinsic CFPs [1-5]. The method combines a simple enumeration scheme for antisymmetric many-particle states with an efficient construction of the eigenvectors of the antisymmetrization operator, an idempotent matrix whose unit-eigenvalue eigenvectors are precisely the required CFPs. This eliminates repeated diagonalization of large matrices, provides excellent numerical stability, and is naturally suited for parallel implementation [1,2]. The developed algorithms enable large-scale calculations of one-particle and two-particle CFPs for single j-shells with isospin [3]. The methodology has been further extended to generalized CFPs for multishell configurations [4] and to intrinsic two-particle CFPs (CESOs), which combine antisymmetry with translational invariance by eliminating spurious center-of-mass motion [5]. The algorithms avoid costly matrix diagonalizations, are numerically stable, and provide an effective computational foundation for contemporary large-scale nuclear-structure calculations.

References

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12:40-12:50

The modification of scattering model at non-spherical nuclei by variable of potential

Speaker

Pavel Krassovitskiy

Description

The model of interaction of neutral particles with non-spherical nuclei has been presented before [1](#). In frame of calculation scheme which presented there, the investigation of transuranic nuclei set has been provided. Comparison of elastic scattering cross sections for isotopes in the prolate spheroid model

The expanding the model's usability is modification of potential with decreasing role of imaging part. The final destination is the reconstruction of model in form where the quite simple potential could be responsible both for the scattering and for the stationary states of the object of scattering.

1. Krassovitskiy P. M., Pen'kov F. M. *Physics* \textbf{6}, 368-375 (2024)

12:50

13:00
14:00

Lunch
Break

15:00

Session 4: Tuesday evening

Session | **Location:** D-332, Instytut Fizyki UMCS pl. M. Curie-Skłodowskiej 1 20-031 Lublin

15:00–15:30

Experimental studies of shape coexistence in $^{94,96}\text{Zr}$

Speaker

Magda Zielinska

Description

Quadrupole deformation of low-lying excited states in zirconium nuclei has attracted considerable attention in the last years. An enhanced $B(E2; 2^+_2 \rightarrow 0^+_{2s})$ value was observed in ^{96}Zr [1], suggesting that an excited deformed configuration coexists with a nearly spherical ground state. This observation has been linked to the type-II shell-evolution mechanism [2], i.e. reorganization of nuclear shells due to specific proton and neutron occupations. The Monte-Carlo shell-model calculations [2] that reproduced well the measured $B(E2)$ strengths in ^{96}Zr , were particularly successful in describing the rapid ground-state shape transition occurring between ^{98}Zr and ^{100}Zr , at the same time predicting a variety of deformed configurations -- prolate, oblate and triaxial ones -- to appear throughout the Zr isotopic chain. A large set of experimental spectroscopic data related to the shape transition in the Zr isotopes was also satisfactorily reproduced in the framework of configuration mixing within the interacting boson model (IBM-CM), invoking an 'intertwined quantum phase transition' [3].

We pursue a broad experimental programme addressing quadrupole and octupole collectivity in even-even Zr nuclei ranging from $A=90$ to 100. To this aim, we combine the powerful Coulomb-excitation technique with high-statistics β decay. The measurements were performed with the GALILEO and AGATA γ -ray spectrometers at LNL (Italy), the GRIFFIN γ -ray spectrometer at TRIUMF (Canada) and Q3D magnetic spectrograph at MLL (Munich, Germany). I will present our recent results firmly establishing coexisting shapes in ^{94}Zr [4] and reevaluating quadrupole in ^{96}Zr [5].

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15:30–16:00

Nuclear Structure of the Zr Isotopes; Collectivity, Phase Transitions, and Shape Coexistence

Speaker

Paul Garrett

Description

The evolution of ground-state shapes usually proceeds smoothly, however for Rb, Sr, Y, and Zr nuclei there are abrupt shape transitions that occur at $N=60$ (see Refs. [1,2] for reviews). Some recent calculations, using the Monte Carlo Shell Model (MCSM) [3] and the Interacting Boson Model employing the Intertwined Quantum Phase Transition (IQPT) [5], have been able to reproduce this abrupt change for the Zr isotopes and predict that shape coexistence occurs both above and below the critical $N=60$ point. The MCSM calculations further predict multiple shape coexistence occurring in the Zr isotopes. Moving towards higher Z , the abruptness of the transition becomes attenuated with a smoother evolution observed in Mo and Ru, for example [2].

Over the past decade, there has been a large number of experimental investigations, using a variety of probes, that are bringing new insights into nuclei in the $N=60$ region. Deformed band structures have been revealed through detailed γ -ray spectroscopy following β -decay [5-7] and fission [8-11]. Coulomb excitation studies have provided important matrix elements and quadrupole moments [12-17] and have been complemented by lifetime measurements [18-21] revealing the collectivity of the band structures. A conversion electron study has provided a measurement of the change in radii of states in ^{98}Zr and ^{100}Zr [22].

We bring additional data to provide a more comprehensive view to the region, focused especially on how the structures in Zr evolve with increasing N from ^{90}Zr . Using our γ -ray spectrometers at the TRIUMF-ISAC facility, we have performed studies of $^{92\text{m}}\text{Nb}$ and $^{98,100}\text{Y}$ decay to study $^{92,98,100}\text{Zr}$, respectively. We have established a collective band in ^{92}Zr [23], and have firmly identified the deformed band built on the 0^+_{-3} state in ^{98}Zr [24]. Our lifetime measurements of levels in ^{100}Zr reveal that the structure built on the 0^+_{-2} state is weakly collective, and bears remarkable similarities with the 0^+_{-2} band in ^{98}Sr [25]. Examining all data available for the Zr isotopes leads us to the suggestion of triple shape coexistence occurring. We place the deformations extracted from these data in the context of the systematics of the wider region.

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16:00–16:30

Experimental studies on shape coexistence in mid-shell Pb region**Speaker**

Joonas Ojala

Description

Shape coexistence refers to a phenomenon where multiple shapes occur within the same nucleus. While this phenomenon has been proposed to exist in almost all nuclei, [1], neutron-deficient Pb isotopes near the $N=104$ mid-shell have been a primary focus for detailed investigations of shape coexistence for decades. In particular, neutron-deficient Pb isotopes, such as $^{184,186,188,190}\text{Pb}$, exhibit experimental evidence of three distinct shapes, [2-4]. Within the shell-model framework, these three shapes are associated with $0p-0h$ (spherical), $2p-2h$ (oblate) and $4p-4h$ (prolate) proton excitation across the $Z=82$ shell.

In the last few years, spectroscopic studies performed at the Accelerator Laboratory of Jyväskylä have advanced the understanding of the shape coexistence phenomenon in neutron-deficient Pb isotopes. These experiments allowed us to reassign states between different collective configurations and provided insight into the mixing between these configurations.

This presentation will go through the experimental techniques employed at Accelerator laboratory of Jyväskylä and observables that can be measured. Some of these techniques have been used for studying the Pb isotopes.

The $^{186,188,190}\text{Pb}$ nuclei have been investigated using two complementary in-beam experimental techniques [5-8]. One utilised a combined γ -ray and conversion electron spectrometer, SAGE, which is sensitive to $E0$ transitions and allow us to assess the mixing between configurations. The other employed a plunger device for measuring lifetimes, which enabled assessment of the collectivity of different structures.

The most recent result at Jyväskylä focused on ^{184}Pb utilising recoil-decay-tagging method in conjunction with the JUROGAMII germanium detector array [9]. This experiment led to the identification of non-yrast structure for ^{184}Pb for the first time. Observing the non-yrast structures in this nucleus is currently at the limit of feasibility, as its production via fusion-evaporation reaction yields low cross-section.

This presentation will summarise the latest in-beam experiments around mid-shell Pb isotopes performed at the Accelerator Laboratory in Jyväskylä. The experimental results will hopefully stimulate new theoretical developments in this region.

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16:30–17:00

Coffee break

17:00–17:30

Exploring emergence of shape coexistence in ^{110}Cd **Speaker**

Katarzyna Wrzosek-Lipska

Description

Mid-shell Cd nuclei were traditionally considered to be the best examples of vibrational nuclei. Recent studies that combined detailed γ -ray spectroscopy with sophisticated beyond-mean-field calculations had suggested [1,2] that the low-lying 0^+_{γ} states in $^{110,112}\text{Cd}$ possessed prolate, triaxial, and oblate shapes with rotational-like bands built upon them. If confirmed, this would have major implications on structural interpretations of nuclei in the $Z = 50$ region, and perhaps beyond. Soon afterwards a similar picture was suggested for ^{106}Cd [3,4].

The low-energy safe Coulomb-excitation technique represents an ideal tool to study nuclear deformation. It enables a direct determination of electromagnetic transition matrix elements between low-lying excited states including spectroscopic quadrupole moments and signs. Those can be further analysed in terms of quadrupole invariants [5,6] yielding model-independent information on shape parameters of individual states. This requires, however, extensive sets of high-precision experimental data.

A multi-faceted experimental program to ascertain the deformation of low-energy states in ^{110}Cd has been initiated. We seek to firmly establish the shape of the first three lowest-lying 0^+_{γ} states through the use of the rotation-invariant sum rules for $E2$ transitions. Coulomb-excitation measurements were performed using various reaction partners: ^{14}N and ^{32}S beams with EAGLE at HIL UW (Warsaw, Poland) [7], ^{60}Ni beam with AGATA at LNL (Legnaro, Italy) [8] and ^{110}Cd beam on a ^{208}Pb target with GRETINA at ANL (Argonne, USA). These measurements have been complemented by an experiment performed at TRIUMF-ISAC with the GRIFFIN spectrometer examining the decays of Ag/In that will provide high-precision data on γ -ray branching ratios and transition mixing ratios.

Recent results on quadrupole deformation parameters obtained for the ground and excited 0^+_{γ} states will be presented [7]. These experimental findings will be discussed in the context of new calculations based on the general quadrupole collective Bohr Hamiltonian model involving two variants of interactions: SLy4 and UNEDF0. Information on the $E2$ properties contained in the shape invariants $\langle Q^2 \rangle$ and $\langle Q^3 \cos(3\delta) \rangle$ will be provided, showing which collective parameters are determined by the data, as well as the goodness of collective model descriptions in terms of the emergence of shape coexistence.

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17:30–18:00

Deformation in the vicinity of ^{40}Ca and ^{56}Ni **Speaker**

Katarzyna Hadyńska-Klęk

Description

The concept of magic numbers constitutes a cornerstone of nuclear physics research. Over the past few decades, it has been well established that closed-shell nuclei exhibit spherical shapes in their ground states. However, as nucleons are added to or removed from complete shells, they tend to deform the microscopic mass distribution. Studies of deformed shapes are of key importance for the advancement of nuclear structure physics, especially the origin of the observed enhanced deformation in the vicinity of doubly-magic mass nuclei.

The observation of super-deformed structures (SD) at relatively low excitation energy in the mass $A \sim 40$ around doubly-magic $Z=N=20$ ^{40}Ca nucleus [1], is one of the most important discoveries of modern nuclear physics. Remarkably, the observed SD structures in these lighter nuclei are even less well understood than in heavier regions. Due to the vast reduction of nucleons involved and therefore complexity compared to heavy nuclei, $A \sim 40$ constitutes an ideal ground for investigating exotic structures within various theoretical frameworks. Recently, the electromagnetic structure of the nucleus ^{42}Ca with the advanced AGATA γ -ray tracking array was studied [2]. It was demonstrated for the first time that Coulomb excitation can probe SD structures. This work also provided the first direct experimental evidence for non-axially symmetric or triaxial SD shapes in the $A \sim 40$ neighborhood. The experimental studies of the deformation in this region are ongoing, aiming at investigating the origin of the emerging SD structures coexisting with the normally deformed bands in the Ar-Ca-Ti isotopes.

Going towards the medium mass region, the nickel isotopes offer a unique laboratory to investigate shape evolution in the vicinity of another doubly-magic $N=Z$ nucleus, ^{56}Ni ($Z=N=28$), which should exhibit similar structural properties to those observed in the $Z=N=20$ region. Indeed, observation of the SD structures was also reported in ^{56}Ni , explained as the result of mp-mh excitations like in the case of ^{40}Ca [3]. However, recently, the questions on the validity of $Z/N=28$ as a good magic number have been brought up, triggering the discussion on the deformation in the nickel region, including the signatures of shape coexistence. Microscopic and collective properties in the vicinity of ^{56}Ni shall be evaluated with the dedicated measurements of the deformation and the neighboring nuclei. To this end, the Coulomb excitation studies focused on the structure of $^{58,60,62}\text{Ni}$ isotopes are currently undertaken. These, together with the recent findings from the γ -ray and electron spectroscopy measurements reporting the unexpectedly large $E0$ transition strengths for the $2^+_{\text{g.s.}} \rightarrow 2^+_{\text{1st}}$ transitions of $^{58,60,62}\text{Ni}$ [4], shall bring crucial information enabling the further discussion on the magical properties of Ni isotopes.

In this talk, I will present recent results from measurements designed to approach the well-deformed structures in Ca and Ni isotopes using the Coulomb excitation method, performed at the INFN LNL and IJC Lab, and compare them with state-of-the-art theoretical calculations.

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18:00–18:20

Large-amplitude pairing collective dynamics associated with spontaneously broken global $U(1)$ symmetry

Speaker

Chisato Ruike

Description

The moment of inertia for pair rotation (P-Mol) characterizes the spectral properties of pair rotational collective mode associated with the spontaneous breaking of gauge symmetry in superfluid nuclei. As a collective excitation in the particle-number gauge space, the pair rotation restores the broken symmetry through the phase rotation of the order parameter along the bottom of the Mexican-hat potential. Since the P-Mol is directly connected to the second derivative of the ground-state energy with respect to the particle number, it can be extracted from the two-neutron separation energies of neighboring nuclei using high-precision mass measurements [1].

We have investigated the fundamental properties of the P-Mol of neutrons for proton-magic Ni, Sn, and Pb isotopes using the BCS approximation with a monopole pairing Hamiltonian and HFB approximation with Skyrme energy density functionals [2]. In open-shell nuclei, we find a negative correlation between the PMol and the pair amplitude (magnitude of the pair deformation) [3]. This correlation is in clear contrast to the spatial rotation, where the moment of inertia increases with increasing deformation.

The P-Mol generally increases with neutron number in open-shell Ni and Sn isotopes. We show that this trend originates from the decrease in the pairing force strength and the increase in the single-particle level density near the Fermi energy. The P-Mol is also sensitive to the position of high-j intruder orbits. In the Pb isotopes, the $1i_{13/2}$ orbit located in the middle of the shell accounts for the nearly constant behavior of the experimental P-Mol, which serves as a probe of the shell structure. The P-Mol evaluated with the Belyaev formula deviates from that obtained from the double binding-energy difference near magic numbers. This discrepancy is attributed to the rearrangement effect, i.e., the dependence of the pairing gap on the Fermi energy, which is neglected in the Belyaev inertia. By including an approximate rearrangement correction, the increasing trend of the P-Mol toward magic numbers is reproduced. This analysis provides a useful tool for interpreting mass data in terms of pairing and shell-structure properties.

In addition to P-Mol, we calculate collective masses for pair vibrations to study large-amplitude pairing collective dynamics. We construct a pairing collective Hamiltonian using constrained BCS + local QRPA method, where the pair amplitude serves as the collective variable. The local QRPA enables us to incorporate dynamical effects of the residual interaction, going beyond the Belyaev formula employed in an earlier work [4]. The potential for ^{208}Pb exhibits characteristics of a “critical point” of the pairing phase transition from normal to superfluid nuclei [5]. We calculate pairing collective modes around ^{208}Pb . We will discuss the pair-transfer intensities compared with experimental data. We also extend the analysis to nuclei around ^{48}Ca .

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18:20–18:30

Investigation of pygmy dipole resonances in ^{64}Ni using proton inelastic scattering and the KRATTA, LaBr₃(Ce), and PARIS detector systems at CCB IFJ PAN

Speaker

Kacper Proszowski

Description

This work presents the methodology and results of an experimental study on inelastic proton-induced excitations of a ^{64}Ni target at beam energy $E = 180\text{ MeV}$. The measurements were conducted at the Cyclotron Centre Bronowice (CCB) of the Henryk Niewodniczański Institute of Nuclear Physics PAN in Krakow. The experiment utilized a proton beam to excite the target nuclei, followed by the detection of inelastically scattered proton and gamma-rays emitted during the de-excitation process.

Protons were detected using the 30-detector KRATTA array, while gamma radiation was recorded using a combination of four LaBr₃(Ce) detectors and the PARIS array, which consists of LaBr₃:NaI and CeBr₃:NaI phoswich detectors. The data analysis involved energy and efficiency calibration, time-stability monitoring, and the application of timing corrections for precise coincidence event selection.

The core of the data treatment was the construction of $E^* - E_{\gamma}$ matrices, correlating the excitation energy determined from proton scattering with the energy of the subsequent gamma-ray de-excitation. These matrices enabled the identification of energy transitions in ^{64}Ni , which were found to be consistent with NNDC database values. As the main results, gamma-ray spectra corresponding to transitions from excited states in ^{64}Ni directly to the ground state are presented. The main technical challenges encountered during the analysis are also discussed. These results serve as a foundational stage for future spectroscopic studies and the investigation of Pygmy Dipole Resonances (PDR) decay in ^{64}Ni .

18:30

19:00
20:00

Dinner

Break

Wednesday 30 September

09:00

Session 5: Wednesday morning

Session | **Location:** D-332, Instytut Fizyki UMCS pl. M. Curie-Skłodowskiej 1 20-031 Lublin

09:00–09:30

Influence of bound electrons and muons on the binding energy of heavy nuclei

Speaker

Anton Repko

Description

The routine calculations of atomic nuclei within Energy-Density Functionals (EDF), such as Skyrme or Gogny, usually don't count with electrons, which however tend to be bound to the experimentally measured nuclei. Besides total electron binding energy, which is indeed subtracted in the modern fits of EDF parametrizations, we should also scrutinize the fact that the inner electron orbitals within superheavy nuclei overlap significantly with the nucleus, and it may become important to account for their shielding effect on the proton-proton interaction in the calculation of nuclear binding energy (and the related energy differences in alpha and beta decay). To properly investigate this point, we will utilize a Dirac-Fock code, constructed with a special care given on the precise numerical evaluation of direct and exchange Coulomb integrals from the interior of nucleus (utilizing the actual proton distribution) up to the boundary of the atom, with possibility to add also muons. The calculated electron (and muon) density is then employed in the nuclear EDF to estimate the effect on nuclear binding energy. The tools developed in this effort are fully relevant also for the muonic atom spectroscopy, which is a subject of reviving attention.

09:30–10:00

Multinucleon transfer in very heavy systems

Speaker

Barbara Sulignano

Description

Multinucleon transfer (MNT) reactions between very heavy nuclei provide a promising pathway to access neutron-rich heavy nuclei that are difficult, or impossible, to produce through conventional fusion-evaporation reactions. In particular, collisions involving actinide nuclei may offer new opportunities to explore the region towards the heaviest elements and to investigate the interplay between nucleon transfer, dissipation and fission.

We will present our experimental programme devoted to the study of MNT reactions in very heavy systems. Results from the $^{136}\text{Xe}+^{238}\text{U}$ reaction studied at Argonne National Laboratory will be discussed, together with other systems investigated to explore the production and structure of heavy nuclei through MNT reactions. An outlook on forthcoming experiments will also be given.

These measurements aim at constraining production yields and reaction mechanisms involving the transfer of several nucleons, while providing spectroscopic information on neutron-rich heavy nuclei. The perspectives offered by MNT reactions for extending our knowledge towards still heavier and more neutron-rich systems will also be discussed.

10:00–10:20

Langevin-Model Analysis of reaction products in Multinucleon Transfer Reactions

Speaker

Kohta Nakajima

Description**Introduction**

The synthesis of neutron-rich heavy nuclei is essential for exploring study of islands of stability and understanding the astrophysical r-process. However, conventional fusion reactions have significant limitations in producing neutron-rich nuclei in the heavy and superheavy mass regions. In recent years, multinucleon transfer (MNT) reactions have therefore attracted considerable attention as a promising alternative method for producing such nuclei [1]. Nevertheless, the reaction mechanism of MNT processes remains poorly understood because of their complex dynamical nature. A quantitative understanding of the reaction dynamics is required to reliably predict the production cross sections and other physical properties of evaporation residues (ERs). In this study, we develop a dynamical model to describe MNT reaction processes and evaluate its validity through comparisons with experimental data. Our goal is to clarify the MNT reaction mechanism and establish a reliable framework for predicting the production of neutron-rich heavy and superheavy nuclei.

Method

In this study, we employ a Langevin-type dynamical model as a theoretical framework for describing MNT reactions. This model describes the time evolution of the nuclear shape, thereby enabling us to follow the reaction dynamics throughout the collision process. It also allows for direct comparisons between the calculated results and experimental data. The nuclear shape is represented using the two-center shell model [2,3], and the corresponding potential energy surface is calculated for each nuclear configuration. The reaction dynamics are then investigated by solving multidimensional Langevin equations to calculate the shape trajectories evolving on the potential energy surface [4].

Result & Discussion

Our model had previously treated only the mass-asymmetry. In the present study, we introduce the charge-asymmetry into the model and perform calculations of the MNT reaction for the $^{136}\text{Xe} + ^{198}\text{Pt}$ system[5]. Comparisons with experimental data demonstrate that the model can reproduce both the mass and charge distributions. In this presentation, in addition to comparing the calculated results with the experimental data, we discuss the effects of the nuclear orientation at contact and the friction acting during the contact stage.

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10:20–10:50

Coffee break

10:50–11:20

Recent Progress in Intermediate-Energy Heavy-Ion Reactions: The Evaporation Filter of Reaction Observables**Speaker**

Jun Su

Description

Intermediate-energy heavy-ion reactions provide essential tools for studying nuclear sizes, fragmentation mechanisms, single-particle strength, and isospin dynamics in stable and exotic nuclei. Traditionally, many inclusive reaction cross sections have been interpreted as rather direct probes of nuclear structure, such as proton radii from charge-changing cross sections, spectroscopic strength from nucleon-removal reactions, and isospin response from charge-pickup reactions. However, recent systematic studies show that the measured final residues are often strongly reshaped by the de-excitation of excited prefragments produced in the fast collision stage.

In this talk, I will discuss recent progress in understanding such reaction observables through the concept of an evaporation filter. Using charge-changing cross sections, elemental fragmentation cross sections, single-nucleon removal, and charge-pickup reactions as representative examples, I will show how charged-particle evaporation, neutron/proton evaporation competition, excitation-energy distributions, and survival probabilities modify the observed cross sections. The transport-plus-de-excitation framework, especially IQMD combined with GEMINI, provides event-history information that helps separate primary production, evaporation feeding, and evaporation loss.

These studies indicate that inclusive cross sections are not always direct structure observables. Instead, they are filtered by reaction mechanisms after the fast collision. Understanding this evaporation filter is therefore essential for extracting reliable nuclear radii, single-particle strength, and neutron-rich surface information from intermediate-energy reaction data.

11:20–11:50

Investigation of collective excitation modes via inelastic proton scattering at the Kraków Cyclotron Centre Bronowice**Speaker**

Michał Ciemala

Description

Atomic nuclei exhibit fundamental collective vibrational modes, such as Giant Resonances (GR) and Pygmy Dipole Resonances (PDR), which provide insights into many-body nuclear dynamics, the nuclear equation of state, and astrophysical processes. In recent years, the proton facility at the Cyclotron Centre Bronowice (CCB) of the Henryk Niewodniczański Institute of Nuclear Physics PAN in Kraków has emerged as active center for investigating these phenomena using fast proton beams with energy ranging from 70 to 230 MeV.

This presentation provides an overview of the research program on collective excitation modes carried out at CCB via inelastic proton scattering. The experimental setup combines the KRATTA triple-telescope array for scattered proton identification and excitation energy (E) determination with high-efficiency scintillation arrays including PARIS clusters and large-volume $\text{LaBr}_3\text{:Ce}$ detectors for high-energy γ -ray spectrometry. Coincidence measurements of E vs. E_γ allow for precise determination of specific decay channels.

The main focus of this contribution will be dedicated to the recent investigation of the Isoscalar Giant Quadrupole Resonance (ISGQR) and Giant Dipole Resonance (GDR) in ^{120}Sn using a 200 MeV proton beam. Experimental data on the γ -decay of the ISGQR are extremely scarce due to strong competition from the dominant neutron emission channel, and they exist only for ^{208}Pb up to now. In addition, to highlight the broader context of the research program at CCB, other studies will be briefly mentioned, including the γ -decay of the GQR in ^{208}Pb and PDR in Ni isotopes.

11:50–12:10

Cosmic-Ray Veto Detector for the FINESSE Experiment at ESS**Speaker**

Hritik Gogoi

Description

The FINESSE program at the European Spallation Source (ESS) in Lund, Sweden, is a high-precision experimental project designed to search for physics beyond the Standard Model. It aims at neutron-to-antineutron ($n \rightarrow \bar{n}$) and neutron-to-sterile/mirror-neutron oscillations ($n \rightarrow n'$), corresponding to baryon number violations of $\Delta B = 2$ and $\Delta B = 1$, respectively. Moreover, searches for axion-like particles (components of dark matter) and neutron electric dipole moment are foreseen as well. To detect these rare processes and weak phenomena, the experiment needs an extremely low-background environment. To suppress the cosmic-ray muons, which are the major background source, a high-efficiency, multi-layer Cosmic-Ray Veto (CRV) detector is being developed at IFJ PAN, Kraków.

This work presents the optional designs of the CRV, Geant4-based Monte Carlo simulations and its performance evaluation. Employed are plastic scintillator modules with light collection by means of wavelength-shifting (WLS) fibers and Silicon Photomultipliers (SiPMs). Detailed Geant4 simulations were performed to model particle interactions, scintillation light transport and its efficient detection for various detector geometries. Overall detection efficiency, timing resolution and spatial resolution of CRV is discussed. Reported will be also the current status of prototype construction and testing, signal processing and future implementation strategies for the full-scale detector system.

12:10–12:20

Machine-learning-based noise suppression for the P-ONE experiment - muon track channel**Speaker**

Gabriel Pietraszek

Description

The Pacific Ocean Neutrino Experiment (P-ONE) is a next-generation neutrino telescope currently under development. It will detect the faint flashes of Cherenkov light produced when high-energy neutrinos interact in seawater. One of the major challenges in neutrino detection is distinguishing genuine physics signals from various sources of optical background noise. In this project, I investigated the application of modern machine learning techniques to suppress detector noise in the muon track reconstruction channel. The work involved analyzing simulated detector data, extracting relevant event features, and training simple machine learning models to classify signal and background events.

12:20–12:30

Monte Carlo simulations of fixed target Ar-Sc and Pb-Pb collisions at $p = 30 \text{ AGeV}/c$ **Speaker**

Paweł Strepikowski

Description

In heavy-ion collisions, primary focus is often given to the participant zone and particles created there. However, recent research demonstrates that spectators that survive the collision play a crucial role in analyzing the Quark-Gluon plasma (QGP) and the trajectories of the particles produced [1,2] due to electromagnetic interaction. Studying de-excitation processes such as evaporation, intermediate-mass fragment (IMF) emission, fission, or multifragmentation provides valuable insight into heavy-ion collisions investigated in experiments such as NA61/SHINE, ALICE or PHENIX.

To analyze the fragmentation of the excited spectator nuclei, the Monte Carlo Abrasion-Ablation model (ABRABLA) [3] was used. Consequently, these simulations are also useful for validating models that describe the de-excitation of exotic nuclei.

In this presentation, results from simulations of spectator de-excitation will be shown, including final product mass/charge distributions, yield distributions across different de-excitation channels, and multiplicity distributions of protons and neutrons emitted by the spectators. The calculations were performed for Ar-Sc and Pb-Pb collisions at $p_{\text{beam}} = 30$ AGeV/c, corresponding to reactions currently analyzed by the NA61/SHINE Collaboration at the CERN SPS.

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12:30-12:40

Monte Carlo analysis of spectator nucleons produced in ultrarelativistic Xe+La collisions

Speaker

Igor Ciarciński

Description

In ultrarelativistic heavy ion collisions, apart from the quark-gluon plasma being produced, part of the projectile or target nucleus may survive the collision without directly participating in the interaction. This nucleus is referred to as a spectator.

The particles could be created within participant zone but also during the deexcitation of the hot spectators. Space-time evolution of these nuclei is difficult to describe, as we do not have sufficient experimental data to compare our results with.

The aim of this work is to simulate and analyze, using abrasion-ablation model, Xe+La collisions at 20 and 150 AGeV/c. Those are reactions from fixed target experiments soon to be conducted at CERN.

12:45

13:00



14:00

Lunch
Break

Session 6: Wednesday evening

Session | **Location:** D-332, Instytut Fizyki UMCS pl. M. Curie-Skłodowskiej 1 20-031 Lublin

15:00–15:30 Shell and pairing energy corrections around scission

Speaker

Krzysztof Pomorski

Description

We investigate the finite-temperature evolution of microscopic free-energy corrections in nuclear fission, focusing on pairing and shell effects near scission. The analysis is based on a finite-temperature BCS treatment combined with the Strutinsky method and is performed for representative deformation points along the fission path. Both pairing and shell contributions exhibit regular thermal attenuation, but their deformation dependencies differ substantially. In particular, pairing remains strongly deformation dependent in the scission region, and its free-energy contribution differs markedly between the constant and surface-dependent pairing-strength prescriptions. The shell correction near scission is also significant at low temperature and is progressively suppressed with increasing excitation energy. These results support the interpretation of odd-even staggering in fragment charge yields as a manifestation of pairing correlations surviving into the strongly deformed pre-scission configuration. They also show that pairing and shell effects should be treated separately in finite-temperature dynamical calculations, with distinct deformation- and temperature-dependent attenuation laws.

15:30–15:50

Comparative Study of Langevin and Random Walk Models for Nuclear Fission in the Overdamped Regime

Speaker

Aleksander Augustyn

Description

Stochastic transport models are a standard tool for describing fission fragment mass distributions, yet the multidimensional Langevin dynamics and the Metropolis random walk are rarely confronted directly within the same framework. We present such a comparison [1] for thermal neutron-induced fission of ^{229}Th , ^{235}U , ^{239}Pu , ^{245}Cm , ^{249}Cf , and ^{255}Fm . Both methods run on identical four-dimensional potential energy surfaces computed in the Fourier-over-Spheroid (FoS) shape parametrization within the macroscopic-microscopic model, ensuring full consistency of the nuclear structure input.

The Metropolis walk corresponds to the overdamped limit of the Langevin equations. We confirm this correspondence numerically: Langevin calculations in the strongly damped regime, with quantum corrections to the random force switched off, produce mass distributions essentially identical to the random walk for the lighter actinides. Systematic deviations develop for the heavier systems, where the Langevin dynamics yields a non-negligible symmetric fission component absent in the random walk. This difference traces back to the kinematic structure of the Metropolis sampling and the residual inertial dynamics retained in the Langevin framework.

A parallel comparison of Langevin calculations with and without the quantum-corrected effective temperature T^* isolates the contribution of zero-point fluctuations and suggests that their standard phenomenological treatment may overestimate their impact. Both approaches reproduce the asymmetric peak positions and their systematic evolution across the actinide chain, while the common narrowness of the predicted distributions points to higher-dimensional deformation modes not included in the present calculations.

Finally, we briefly present preliminary random-walk results obtained on native five-dimensional potential energy surfaces of the Warsaw macroscopic-microscopic model for ten actinide systems --- the first dynamical calculations performed on Warsaw macroscopic-microscopic model surfaces in the FoS parametrization.

[1] A. Augustyn, T. Cap, M. Kowal, and K. Pomorski, submitted to Phys. Rev. C; arXiv:2605.00586

15:50–16:10 Evolution of the fission fragment angular momentum

Speaker

Katarzyna Mazurek

Description

This study [1] explores the role of nucleon exchange for the generation of the fission fragment angular momenta. For a number of typical fission cases, samples of 10,000 shape evolutions are generated by Langevin simulation [2] and, subsequently, for each such evolution, the nucleon exchange transport theory previously developed for damped nuclear reactions [3] is used to obtain the development of the fragment spin-spin distribution within the Fokker-Planck transport framework. The characteristic evolution of both parallel and perpendicular spin components is discussed. A common feature is that the rotational modes fall out of equilibrium before scission when the temperature rises rapidly while the concurrent shrinking of the neck suppresses further exchange. A number of fission observables are extracted from the event ensembles: the distribution of the magnitude of the fragment spin and its orientation relative to the fission axis, as well as the correlation between the two spins and the distribution of their opening angle. The dependence of these observables on the mass asymmetry is also examined.

References

- [1] J. Randrup, P. Nadtochy, C. Schmitt, K. Mazurek, Phys. Rev. C 113 (2026) 044605
- [2] G.D. Adeev, A.V. Karpov, P.N. Nadtochii, D.V. Vanin, Phys. Part. Nucl. 36, 378 (2005)
- [3] J. Randrup, Nucl. Phys. A 327, 490 (1979)

16:10–16:30 Microscopic description of spontaneous fission for Fm isotopes
Speaker

Kouhei Washiyama

Description

Nuclear fission plays an important role in various phenomena such as the r -process nucleosynthesis. Spontaneous fission is an important subject for developing a microscopic theory of large-amplitude collective motions. The nuclear energy density functional (EDF) theory can be one such microscopic theory that provides a microscopic description of fission dynamics [1]. Recent EDF-based works on spontaneous fission employ the semiclassical WKB approximation for many-body quantum tunneling [2]. In those works, the collective potential energy has been calculated using a constrained EDF method, while the collective inertia has been calculated with the so-called cranking formula. It is known that the cranking formula ignores dynamical residual effects, and then the cranking formula significantly deviates from the correct inertia.

We have developed a framework to evaluate collective inertia within the local quasiparticle random-phase approximation (QRPA) with the Skyrme EDF [3]. This framework correctly includes the dynamical residual effects on the collective inertia that the former EDF-based works have ignored. We applied the local QRPA to calculate the collective inertia along a spontaneous fission path in actinide nuclei [3,4].

In this contribution, we will show the results of the collective inertia along the fission path in actinide nuclei and the importance of the dynamical residual effects on the collective inertia. We take the triaxiality into account as a collective variable as well as an axially quadrupole moment, and determine the fission path in the two-dimensional collective space. Then, we will discuss the impact of the correct evaluation of the collective inertia on the fission path and fission half-life in spontaneous fission. We will further discuss the isotope dependence of the collective inertia and fission half-life in Fm isotopes.

- [1] N. Schunck and L.M. Robledo, Rep. Prog. Phys. **79**, 116301 (2016).
- [2] J. Sadhukhan et al., Phys. Rev. C **88**, 064314 (2013).
- [3] K. Washiyama, N. Hinohara, and T. Nakatsukasa, Phys. Rev. C **103**, 014306 (2021).
- [4] K. Washiyama, EPJ Web of Conferences **306**, 01026 (2024).

16:30–17:10 Coffee break
17:10–17:40 Microscopic Study of Nuclear Excitation and Fission
Speaker

Zhipan Li

Description

With the commissioning of next-generation radioactive ion beam facilities worldwide, nuclear structure physics has entered a new era of opportunities. The exploration of exotic nuclei far from stability has revealed a variety of unexpected phenomena, including octupole (pear-shaped) deformation, tetrahedral symmetry, and asymmetric fission in the sub-lead region, highlighting the remarkable richness of nuclear many-body systems. These discoveries have significantly broadened our understanding of atomic nuclei while posing stringent challenges to microscopic nuclear theories.

Motivated by these frontier problems, we develop a series of microscopic collective Hamiltonian models based on covariant density functional theory to investigate nuclear collective excitations and fission dynamics:

1. Using the five-dimensional quadrupole collective Hamiltonian (5DCH), we systematically investigate the influence of quantum shape fluctuations on the structure of superheavy nuclei and demonstrate that they substantially reduce the stability of superheavy nuclei in transitional regions [1].
2. By extending the framework to incorporate octupole collective degrees of freedom, we achieve a unified description of negative-parity rotational bands in lanthanide and actinide nuclei [2-4], predict stable tetrahedral configurations around ^{110}Zr , and identify characteristic low-lying spectroscopic signatures to guide future experimental searches [5].
3. Furthermore, a time-dependent extension of the collective Hamiltonian successfully reproduces the recently observed asymmetric fission mode in the ^{180}Hg region and reveals that it originates from the cooperative interplay between the deformed proton shell gap at $Z \approx 36$ and the octupole neutron shell closure at $N \approx 56$ [6,7].

These results establish a unified microscopic framework for describing collective phenomena in exotic nuclei, providing new insights into the emergence of novel nuclear shapes and fission dynamics. They also offer theoretical guidance for experiments at current and next-generation radioactive ion beam facilities.

Reference

- [1] X. Q. Yang, R. Y. Hu, R. N. Mao, J. Xiang, and Z. P. Li, Systematic study of superheavy nuclei within a microscopic collective Hamiltonian: Impact of quantum shape fluctuations, Phys. Lett. B 876, 140382 (2026)
- [2] S. Y. Xia, H. Tao, Y. Lu, Z. P. Li, T. Nikšić, and D. Vretenar, Spectroscopy of reflection-asymmetric nuclei with relativistic energy density functionals, Phys. Rev. C 96, 054303 (2017).
- [3] W. Sun, S. Quan, Z. P. Li, J. Zhao, T. Nikšić, and D. Vretenar, Microscopic core-quasiparticle coupling model for spectroscopy of odd-mass nuclei with octupole correlations. Phys. Rev. C 100, 044319(2019).
- [4] J. Xiang, J. Zhao, Z. P. Li, and D. Vretenar, Microscopic triaxial quadrupole-octupole collective Hamiltonian for low-energy nuclear excitations, Phys. Rev. C 113, 044328 (2026).
- [5] J. Xiang, J. Zhao, Z. P. Li, and D. Vretenar, Tetrahedra symmetry in atomic nuclei, in preparation.
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17:40–18:10

Microscopic Multidimensional Description of Nuclear Fission Dynamics Based on Fourier Shape Parameterization

Speaker

Li Zeyu

Description

Nuclear fission is a nonequilibrium, large-amplitude collective process in which a nuclear many-body system evolves through a multidimensional collective space. The dynamics involve complex quantum fluctuations and correlation effects, while the underlying microscopic mechanism remains incompletely understood [2]. The time-dependent generator coordinate method (TDGCM) represents the nuclear wave function as a superposition of intrinsic states in collective deformation space. By solving time-dependent equations of motion in the collective-coordinate space, TDGCM can incorporate quantum fluctuations during fission. It is therefore one of the principal microscopic approaches to fission dynamics. Multiple collective degrees of freedom are excited cooperatively during fission. Accurately capturing their complex couplings in simulations within a finite-dimensional collective space remains a major theoretical challenge.

Existing microscopic studies generally parameterize nuclear shapes using spherical-harmonic expansions. Recent studies, however, have identified substantial limitations of this approach for highly deformed configurations at late stages of fission [3,4]. To address this issue, we implemented Fourier shape parameterization within point-coupling covariant density functional theory and derived the corresponding deformation operators. We then calculated the potential energy surface and collective mass tensor in a two-dimensional collective space and performed dynamical fission simulations [5]. For ^{226}Th , the Fourier-parameterized collective space converges rapidly and describes highly elongated and scission configurations more effectively. TDGCM calculations in the Gaussian overlap approximation consequently provide an improved description of the fission-fragment distributions.

Recently, we extended the calculations to a three-dimensional deformation space by introducing the neck-size degree of freedom q_4 . We investigated its effects on the topology of the potential energy surface and on energy fluctuations. This extension provides a clear picture of the competition and evolution among multiple fission pathways. The smooth, gently varying three-dimensional potential energy surface and the rapid convergence of higher-order coordinates improve the treatment of quantum fluctuations and dynamical evolution. The calculations reproduce the measured peak positions and widths of the fission-fragment yield distributions. They also substantially improve predictions of the total kinetic-energy distribution.

References

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- [2] V. E. Lewis, Nucl. Phys. A 151, 120 (1970).
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18:10–18:30

Fission of (super)heavy nuclei and its hindrance in odd systems & K -isomers**Speaker**

Janusz Skalski

Description

Heavy and superheavy nuclei show, besides a wide variation of spontaneous fission half-lives, a consistent fission hindrance of 3-5 orders of magnitude for odd-A species (no systematics exists for odd-odd species). There is also some evidence pointing to a similar hindrance in decays from high-K isomers. In contrast to chemistry, a description of collective tunneling in nuclei lacks a firm definition of the mass parameter. A widely used adiabatic approximation that has some rationale for even-even nuclei (due to a paired character of the wave function) breaks down for both odd-A and high-K configurations as the evolution of singly-occupied orbitals becomes undetermined. An assumption of a fixed configuration for the unpaired orbital is unrealistic and leads to a pointwise diverging mass parameter. Some understanding of fission rates from odd-A and high-K states would be desirable in view of their occurrence in superheavy nuclei. We discuss possible ways of a more consistent, instanton-inspired approach that might account for the observed hindrance and illustrate them with some examples.

18:30–18:40

Closing

18:40

19:00



20:00

Dinner
Break