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Contents

Session 1

Multifaceted character of shape coexistence phenomena in atomic nuclei

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We present a recent survey of decay properties of excited 0^+ states in regions of the nuclear chart well known for shape coexistence phenomena, focusing, in particular, on even-even nuclei around the Z=20 (Ca), 28 (Ni), 50 (Sn), 82 (Pb) proton shell closures and along the Z=36 (Kr), Z=38 (Sr) and Z=40 (Zr) isotopic chains [1]. The aim is to identify examples of *extreme shape coexistence*, namely, coexisting deformed and spherical (or close-to-spherical) nuclear states, with wave functions well separated in the Potential Energy Surface (PES) with coordinates in the deformation space. Such a wave function separation may result in a substantially hindered transition between the corresponding structures. This is in analogy to the 0^+ fission shape isomers in the actinides region and to the superdeformed (SD) states at the decay-out spin in medium/heavy mass systems. In the survey, the Hindrance Factor (HF) of the E2 transitions de-exciting 0^+ states or SD decay-out states is a primary quantity which is used to differentiate between types of shape coexistence.

It is found that a limited number of 0^+ excitations (in the Ni, Sr, Zr and Cd regions) exhibit large HF values (>10), few of them being associated with a clear separation of coexisting wave functions, while in most cases the decay is not hindered, due to the mixing between different configurations. A brief discussion will be devoted to the case of the relatively light ^{64,66}Ni nuclei, where shape- isomer-like structures, of prolate deformed nature, have been observed at spin zero by performing gamma-spectroscopy investigation with different types of reaction mechanisms (i.e., proton and neutron transfer, neutron capture and Coulomb excitation) [2,3]. An analogous situation is expected to occur in $^{112-116}$Sn isotopes, for which preliminary results will be presented from experiments performed at IFIN-HH (Magurele, Romania) with ROSPHERE, and at Legnaro National Laboratory (Padua, Italy) with the AGATA tracking array. The experimental data will be interpreted in the light of state-of-the-art Monte Carlo Shell Model (MCSM) calculations [4], according to which the action of the monopole tensor force plays a relevant role in stabilizing and deepening isolated, deformed local minima in the PES, thus leading to a significant separation of the wave functions of states residing in these minima and, eventually, to shape isomerism.

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Session 1

Parity-violating asymmetry and dipole polarizabilities in atomic nuclei: how do they reconcile with each other?

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In the recent years, attention has been paid to a careful measurement of the dipole polarizability and parity violating asymmetry in medium and heavy mass nuclei such as ^{48}Ca and ^{208}Pb [1-4]. These two observables, as it already happened for the neutron skin thickness, are thought to be particularly sensitive to the properties of the nuclear equation of state at densities around nuclear saturation [5]. Hence, the interest in the low energy nuclear physics community to foster the needed experimental and theoretical developments to accurately study these two observables.

In this contribution I will briefly overview our past and recent theoretical analysis of the parity violating asymmetry and electric dipole polarizability [6-10].

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Session 1

Physics opportunities with relativistic rare ion beams at R3B/FAIR

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R3B is a scientific collaboration of FAIR working towards the realization of an apparatus, located at the end of the High-Energy Branch of this facility, that will receive exotic isotopes of any chemical element from Hydrogen up to Uranium moving at energies around 1 A GeV. R3B will allow us to explore the limits of the nuclear shell model, to study exotic (barionic and strange) nuclear matter and to reproduce in the laboratory some relevant astrophysical scenarios as neutron stars.

In this talk, we will present the state of progress of the project and give a comprehensive overview of the planned research programme. Preliminary results from the Phase-0 experiments will also be discussed.

Session 2

Multiple shape coexistence around ^{80}Zr region

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Neutron-deficient nuclei around mass number A∼80 are of great interest in nuclear structure and nuclear astrophysics (this region, e.g., is explored in the rp-process nucleosynthesis). Although shape-coexistence is becoming a rather common feature along the nuclear chart [1], the region of medium-mass N∼Z nuclei is expected to show several collective structures associated to distinctive shapes present at the mean-field approximation, i.e., multiple shape coexistence [2].

One of the best suited theoretical tools to study these phenomena is the projected generator coordinate method (PGCM, also referred to as symmetry conserving configuration mixing, or multireference energy density functional methods) [3]. In this contribution I will discuss the application of the PGCM method with the Gogny energy density functional in the description of multiple shape coexistence in N=Z nuclei from ^{56}Ni to ^{100}Sn.

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Session 2

The AGATA physics campaign at Legnaro National Laboratories

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In April 2022, AGATA, the European Ge-array at the forefront of gamma detection technology [1,2] was installed at LNL. Based on the new concept of gamma-ray tracking, it can identify the gamma interaction points (pulse shape analysis) and reconstruct via software the trajectories of the individual photons (gamma-ray tracking). Shortly thereafter a physics campaign has started using stable beams ranging from hydrogen to lead, delivered by the Tandem-ALPI-PIAVE accelerator complex at energies from 20-25 MeV/u (lightest ions) to about 7-8 MeV/u (heaviest ions). In the first phase AGATA has been coupled to the PRISMA heavy-ion magnetic spectrometer to access the study of exotic nuclei produced in multi-nucleon transfer and fusion-fission reactions. Different silicon detector arrays for light charged particles and ions have also been used. The physics cases under study involve shell evolution and configuration mixing in key regions of the nuclear chart, such the N=20 island of inversion and the nuclei around the doubly-magic ^{78}Ni, quadrupole and octupole shapes and collectivity across a wide range of nuclear masses, as well as measurements of astrophysical interest. Several Coulomb-excitation experiments investigated shape coexistence along the Z=40 and Z=50 lines. In this presentation, the current status of the physics campaign ant its main results will be discussed.

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Session 2

Nuclear Shapes and their Coexistence at the Islands of Inversion

Alfredo Poves[1]

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I shall discuss the meaning of the "nuclear shape" in the laboratory frame proper to the Spherical Shell Model, and the algebraic models that make its foundations.

Shape coexistence, shape mixing and shape entanglement will be illustrated with relevant physics cases, In particular I shall show that shape coexistence acts as a portal to the Islands of Inversion at N=20-28 and N=40-50 for very neutron rich nuclei.

Session 2

Spin dynamics of triaxial nuclei with a quasiparticle alignment

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The dynamics of nuclei with a triaxial core and a non-axial rigid quasiparticle alignment is described in a semiclassical setting [1,2]. This includes the investigation of the spin dependence of the stationary points and the derivation of the existence conditions for distinct dynamical phases. Additionally, an intuitive visualization of the classical orbits is used to show the classical motion of the total angular momentum vector. Quantum observables to be compared with experimental data, are extracted from a Schrödinger equation constructed from the classical picture, retaining thus a connection to the classical phenomenology. The use of the total angular momentum projection as a continuous variable and the separation of the potential energy allows the interpretation of the spectra in terms of anharmonic wobbling oscillations and tilted axis rotations. Therefore, the concept of wobbling is expanded to non-axial alignments [3] as well as to higher spins by the consistent inclusion of the anharmonicities [4,5]. The experimental realization of the model is presented for the $h_{11/2}$ quasiparticle bands of ^{105}Pd, ^{133}La and ^{135}Pr nuclei. Numerical applications also provided a new understanding for the dynamics of the 133La nucleus, which exhibits a novel tilted-axis wobbling mode [3].

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Session 2

High Multipolarity Tetrahedral Symmetry Shapes Predicted in Nuclei with Nucleon Numbers around Z=N=40

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In collaboration with Jerzy DUDEK, University of Strasbourg.

There is an increasing interest in exotic symmetries predicted to occur in atomic nuclei, yet in the past traditionally associated with molecular structures. This tendency is witnessed by growing number of publications in this domain. Tetrahedral and octahedral symmetries can be considered among the most exotic since they are predicted to produce 4-fold degeneracies of the nucleonic levels in contrast to the standard 2-fold (Kramers) degeneracies.

Following Ref. [1], the presence of tetrahedral symmetry is expected to occur in groups of nuclei throughout the nuclear chart. In this project we examine systematically the exotic symmetry properties of Zirconium nuclei, since $Z = N = 40$ are predicted to be among the leading tetrahedral magic numbers. Our interest was strengthened by the experimental identification of the tetrahedral and octahedral symmetries published in Ref. [2].

It is well known that the molecular symmetry nuclear surfaces can be parametrised with the help of the standard spherical harmonics, $\{Y_{\lambda,\mu}\}$ with only a small sub-families of them contributing. In particular it can be shown, cf. e.g. Ref. [3], that tetrahedral symmetry shapes can be generated, up to two lowest orders by spherical harmonics with multipolarities $\lambda = 3$ and 7. We have systematically examined the tetrahedral symmetry shell effects around $Z = N = 40$ magic gaps discovering that, in contrast to the usual expectations, the strongest tetrahedral shell gaps are predicted as the effect of the 7^{th} order multipolarity. We will present the results performed using a realistic, phenomenological mean-field approach with the new parametrisation of the Hamiltonian tested for the absence of parametric correlations and thus expected to be stable.

To our knowledge, these are the first theory predictions using realistic mean-field Hamiltonians suggesting very low-lying potential energy minima of the 7^{th} order multipolarity. We discuss in detail the experimental verification criteria.

In addition, the new internet service MeanField4Exp (https://meanfield4exp.ifj.edu.pl) allowing to confront the theoretical elementary structure properties of atomic nuclei with experiment and developed under the EURO-LABS Project, will be presented.

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Session 3

Multinucleon Transfer Reactions: Recent Insights from Experiments at LNL-INFN

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Transfer reactions are pivotal in nuclear structure and reaction studies. In heavy-ion transfer reactions, multiple nucleons can be transferred in a single collision along with significant energy and angular momenta from the relative motion to the intrinsic degrees of freedom [1,2]. This establishes multinucleon transfer reactions as an essential tool for probing a wide array of topics, from nucleon-nucleon correlations to reaction dynamics [3].

Recent experiments performed at the Legnaro National Laboratories (LNL, INFN) with the large solid angle magnetic spectrometer PRISMA have focused on studying nucleon-nucleon correlations with heavy-ion beams on medium-mass targets [4,5]. Transfer cross sections were measured across various range of energies in inverse kinematics, from near to far below the Coulomb barrier. Interpretations were derived from excitation functions, extending to large distances of closest approach, where nuclear absorption is minimal. Further studies targeted the production mechanism of neutron-rich nuclei [6-8], highlighting transfer processes as a competitive method for producing exotic species, especially heavy neutron-rich nuclei.

This presentation offers an overview of these experiments, focusing on key results, challenges, and recent advancements, especially in connection with the AGATA array currently coupled to PRISMA.

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Session 3

Exploring the secrets of the atomic nucleus with the COLLAPS setup at CERN

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The COLLAPS experiment stands at the forefront of collinear laser spectroscopy, a field dedicated to the precise measurement of unique nuclear characteristics in short-lived and exotic radioactive nuclei. By analyzing hyperfine structures and isotope shifts, it determines nuclear spins, electromagnetic moments, and charge radii.

At its core, COLLAPS seeks to unravel the mysteries surrounding nuclear existence: the boundaries defining it, the emergence of simple patterns within complex nuclear structures, and the possibility of previously unknown structural forms in regions far from stability. To explore these questions, the COLLAPS collaboration employs highly precise and sensitive laser spectroscopy techniques.

This presentation will introduce the COLLAPS setup and highlight some of the most recent discoveries and results from the experiment.

Session 3

β-decay study of ^{76,77}Cu

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Nuclei in the vicinity of doubly-magic nuclei, such as ^{78}Ni, are of considerable interest for studying the evolution of shell structure within the nuclear shell model. Understanding this evolution is essential for accurately describing exotic nuclear phenomena. In particular, the shape coexistence in ^{79}Zn makes this region especially intriguing, given that such a phenomenon is uncommon in the vicinity of doubly-magic nuclei. Additionally, ^{78}Ni and its neighboring nuclei exhibit high neutron-to-proton ratios, making them particularly significant in the field of astrophysics due to their role in the rapid neutron-capture process (r-process). Exploring these neutron-rich nuclei provides crucial insights into the mechanism underlying the r-process.

The nuclear structure of ^{77}Zn has been studied through the β decay of ^{77}Cu at ISOLDE. Copper isotopes were produced via neutron-induced fission on a UC$_x$ target. ^{77}Cu ions were laser ionized, accelerated, mass-separated and implanted into an aluminized mylar tape on the ISOLDE Decay Station (IDS), where the experimental setup was installed. We report on the decay scheme with newly discovered transitions and levels, the branching ratio of the βn process and, for the first time, the half-lives of two excited states in ^{77}Zn.

We also investigated the controversial existence of the ^{76}Cu isomeric state. According to our data, the scenario remains unclear.

Session 3

Shell-model study of 28Si: shape coexistence and superdeformation

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We study the shape coexistence in the nucleus ^{28}Si with the nuclear shell model using numerical diagonalizations complemented with variational calculations based on the projected generator-coordinate method. Although the ground-state oblate rotational band is well described in the sd shell by the USDB interaction, the second excited 0^+ state and higher-energy levels lack the features of a prolate rotational band, in contrast to experiment. Thus, guided by the quasi-SU(3) model, we slightly lower the energy of the $d_{3/2}$ orbital, which leads to a good description of the prolate band. Alternatively, we extend the configuration space to also include the pf shell, finding that the prolate band appears naturally using the SDPF-NR interaction. Finally, we address the possibility of superdeformation in ^{28}Si within the $sdpf$ space. Our results disfavour the appearance of superdeformed states with excitation energy below 20 MeV.

Session 3

Various facets of shape coexistence in neutron-rich nuclei within a beyond-mean-field approach

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Neutron-rich nuclei in the A=100 mass region display a large variety of shape coexistence phenomena dominating their structure and dynamics. Multifaceted impact of shape coexistence is revealed in the structural evolution with spin, excitation energy, and neutron number, the appearance of the isomeric states, their exotic decay including allowed and first-forbidden β decay. We studied the effects of shape coexistence in ^{96}Y and ^{96}Zr on the allowed and first-forbidden β decay of low- and intermediate-spin isomers and exotic features of the populated states as well as on the first-forbidden β decay of the 0− ground state of ^{92}Rb to 0+ ground state and 2+ states in ^{92}Sr and the properties of the involved states.

Aiming to a simultaneous description of the impact of shape coexistence and mixing on different exotic phenomena we investigated the structure and dynamics of the involved neutron-rich nuclei in the frame of the beyond-mean-field complex Excited Vampir variational model using the effective interaction derived from a nuclear matter G matrix based on the charge-dependent Bonn CD potential in a large model space. Recent results on the comprehensive treatment of different identified characteristics concerning the structure and dynamics of these nuclei manifesting multiple shape coexistence will be presented and compared to available experimental data.

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Session 4

New half-lives measurements for r-process in A~225 Po-Fr nuclei

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The astrophysical rapid-neutron capture process (r-process) of explosive nucleosynthesis is responsible for the formation of half of the heavy nuclei above Fe. Actinides are produced towards the end of this process, when the neutron flux is expected to be minimal, and it is supported also by fission processes. Given that the r-process path runs far away from the accessible species, in this heavy region of the chart of nuclides, experimental inputs on β decay for nuclei beyond N=126 are particularly useful to test predictions of global nuclear models.

In this paper results from a recent experiment performed at GSI-FAIR (Darmstadt, Germany) within the HISPEC-DESPEC experimental campaign, as part of the FAIR Phase-0 program, will be discussed. The experiment populated 220 <A<230 Po-Fr nuclei in a relativistic fragmentation reaction induced by a 1 GeV ^{238}U beam. The species were selected and identified using the FRagment Separator (FRS) and implanted in the DEcay SPECtroscopy (DESPEC) station to study their subsequent β decay. The DESPEC station is composed of a stack of Double Sided Silicon-Strip Detectors (DSSD) sandwiched between two plastic scintillator detectors, surrounded by a hybrid γ-detection array consisting of high-resolution HPGe and fast timing $LaBr_3$(Ce).

The extracted β-decay half-lives are discussed with the help of recent theoretical models, to assess the impact of the measured values in the predictions of the r-process. Perspectives of future measurements in the region will be provided.

Session 4

Anomalous $B_{4/2}$ ratio in the yrast band of ^{167}Os

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Spectroscopic properties of exotic nuclei are powerful tools to obtain a better insight on the evolution of nuclear structure far from the stability. Mid-shell nuclei are expected to exhibit collective behaviour which is typically reflected in the observation of low excitation energies of the first excited states and high transition probabilities. Moreover, the collectivity is expected to increase with the spin, causing both the $R_{4/2} = E_X(4^+)/E_X(2^+)$ to be higher than 2 and the $B_{4/2} = B(E2; 4^+ \rightarrow 2^+)/B(E2; 2^+ \rightarrow 0^+)$ to be higher than the unit.

However, an increasing number of mid-shell nuclei had been found to present a $B_{4/2} < 1$. This has already been observed in two neutron-deficient regions, one located close to the $Z = 50$ shell closure and one in the rare-earth region.

In particular, the osmium isotopic chain presents cases both in even-even nuclei, such as ^{168,170}Os, and one in an even-odd nucleus, ^{169}Os, where the $B_{4/2}$ ratio has been redefined as $B(E2; 21/2^+ \rightarrow 17/2^+)/B(E2; 17/2^+ \rightarrow 13/2^+)$. According to theory, this anomaly could only be explained by a change from collective to seniority-like regimes or by phenomena such as shape coexistence. However, this change in structure has not been predicted by theory in the osmium isotopic chain, which remains an open question.

In this context, lifetime measurements of the excited states of these nuclei can provide a meaningful insight on the structure of the low-lying bands.

An experiment aimed at performing lifetime measurements in ^{167}Os was performed at the Accelerator Laboratory of Jyväskylä (Finland), where the nucleus of interest was populated in a fusion-evaporation reaction. The selection of the channel was performed using the alpha-recoil tagging technique and the gamma rays emitted by the recoil were detected using the Jurogam3 array. The lifetimes were extracted using the Recoil Distance Doppler Shift method.

From the measured lifetimes, it was possible to extract the reduced transition probabilities of the low-lying states and the $B_{4/2}$ ratio. The experimental results were then compared to potential energy surface calculations in order to shed light on the role of the unpaired neutron. In this contribution, a summary of the performed experiment, the new results and the comparison with theory are presented.

Session 4

Probing the rapid onset of deformation below ^{68}Ni through the beta decay of ^{67}Mn

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One of the best-known divergences from the independent-particle shell model description is the existence of islands of inversion [1]. The IoI of the region N=40 draws particular attention since the neutron number 40 was postulated as a non-traditional “magic” number and N = 40 represents the boundary between the negative-parity pf shell and the positive-parity g shell. In stable nuclei, the neutron $g_{9/2}$ orbital is close enough to the pf shell to reduce this shell gap resulting in a more stable subshell closure at N = 50. Measurements of B(E2) values and E(2^+) in the neutron-rich region show increased collectivity through the N = 40 shell gap, with the clear exception of ^{68}Ni [2,3].

Deformation and shape coexistence have been identified in the area, LNPS calculations predict triple shape coexistence for ^{67}Co (N=40), with three rotational bands [4]. And, recent experiments on ^{67}Fe (N=41) propose a spin-parity of $5/2^+$ or $1/2^-$ for its ground state [5] which indicates a significant deformation. In addition, shape coexistence is also expected for ^{67}Fe. Despite the high interest in the region, very limited information is available, to this end, an experiment was performed at the TRIUMF-ISAC facility utilizing the GRIFFIN spectrometer [6], where the β and βn decay of ^{67}Mn populated the ^{67,66}Fe, ^{67,66}Co and ^{67,66}Ni isotopes.

This data set contains orders of magnitude more statistics than previous studies allowing us to build for the first time a complete level scheme of ^{67}Fe and ^{67}Ni, and to improve upon the known β-decay level schemes of ^{67}Co, by expanding the number of transitions and levels, as well as by improving the precision of branching ratios and ground-state half-life measurement. In addition, measurements of level lifetimes down to the picosecond range will allow us to investigate the band structure in these nuclei. For the ^{67}Fe isotope, a good level of statistics will make it possible to measure the energy of the identified isomeric state and improve the lifetime measurement.

These results can provide further insight into the structure of the states by comparison to simple models and large-scale shell model calculations to confirm or refute the shape coexistence picture predicted by LNPS calculations and the shrinking of the N=40 gap just one proton below ^{68}Ni. Preliminary results from the analysis will be presented and discussed.

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Session 4

Exotic Decays of Extremely Proton-rich Nuclei in sd-shell and Related Topics

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In the past ten years, a series of experiments have been done at the HIRFL-RIBLL1 facility for studying the exotic decays of extremely proton-rich nuclei in sd-shell. Beta-delayed proton and two-proton decays from $^{20;21}$Mg, $^{22;23}$Al, $^{22;23;24}$Si, $^{26;27}$P, $^{27;28;29}$S have been measured by the continuous implantation-decay method using silicon array combined with gamma-ray detectors [1]. With high detection efficiency, low energy threshold and good statistics, a great number of new decays have been observed and rich information on the γ-decay spectroscopy (e.g. half-life, decay energy, branching ratio, etc.) has been obtained. Some interesting results related topics will be addressed, including: 1) the beta-delayed two-proton decay of ^{22}Si as well as its mass [2], and large isospin asymmetry in ^{22}Si/^{22}O mirror Gamow-Teller transitions [3]; 2) the branching ratios of proton and gamma decays from the low-lying excited state of ^{27}P and ^{26}Si [4,5], as well as astrophysical reaction rates of ^{26}Si(p, γ) [6] and ^{25}Al(p, γ)[5] related to the abundance issue of ^{26}Al in the Milky Way, 3) strongly isospin-mixed doublet in ^{26}Si observed in beta-delayed two-proton decay of ^{26}P [7], and so on. More details will be presented in the conference.

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Session 5

Probing the fission-landscape and the structure of superheavy nuclei

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Superheavy nuclei (SHN) with an extremely large number of protons (e.g., up to Z = 126) remain to be one of the main topics in nuclear physics [1]. One of the ultimate goals of this research is to explore the fission stability of SHN at around Z = 114 – 126 and N = 184, where the next shell closures are predicted to occur [1]. The fission half-lives of those SHN were predicted to be much longer than the half-lives of neighboring ones. Accordingly, the fission-landscape of SHN regarding the half-lives should form an island in a sea of instability.

To date, SHN with Z up to 118 and neutron numbers up to N = 177 are known [2,3]. They were synthesized mostly in heavy-ion induced reactions with atom-at-a-time rates and were identified predominantly by their α-particle emission and rarely by fission. Corresponding experimental data, e.g., partial half-lives of these radioactive decays, confirm the concept of the island of stability.

However, still many properties of the SHN, such as their shell structure and its impact on their radioactive decay modes, which are necessary for building a more complete picture of the nuclear stability-landscape are poorly known [4-7]. This circumstance has a primary reason, which is the lack of comprehensive experimental spectroscopy data on their nuclear decays, such as the β-decay, α-decay fine structure and fission.

Intensive programs aimed at exploring the fission-landscape and the shell structure of SHN are on-going worldwide, including the SHE-Chemistry department at GSI, Germany [8].

I will present the status and recent results of exploring the fission-landscape of SHN.

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Session 5

Multinucleon Transfer Reactions for fission study

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The MNT reaction allows us to produce many fissioning nuclei, including neutron-rich nuclei, which cannot be populated by other reactions. Also, excitation energy of compound nucleus distributes widely. These properties are used to obtain fission-fragment mass distribution (FFMDs) for many nuclides as well as their excitation-energy dependence [1,2,3]. The experiments were carried out at the JAEA tandem facility using ^{18}O beam and various radioactive target nuclei. From the data, the probability of each multi-chance fission (fission after neutron emission) was quantified for the first time [4,5]. From the threshold of the excitation function of fission probably, fission barrier height was derived [6], one of the key observables to verify fission models.

Our setup for MNT-induced fission allows us to obtain data for MNT mechanism itself. From the fission-fragment angular distribution relative to the rotational axis, we have determined the average angular momentum for each MNT channel [7]. The value is useful to determine the survival probability of compound nucleus to derive the cross sections of neutron-rich evaporation residues generated in MNT reactions.

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Session 5

Single-particle states in fp-shell nuclei through ^{50}Ca(d, p)^{51}Ca transfer reaction.

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Neutron-rich Ca isotopes towards neutron number N = 34 are pivotal for exploring the evolution of the fp-shell orbitals [1]. Beyond the N = 28 shell gap at ^{48}Ca, new magic numbers at N = 32 and 34 were established through spectroscopy of low-lying states [2] and mass measurements [3]. Most recently, the spatial extension of the $1f_{7/2}$ and $2p_{3/2}$ neutron orbitals was determined via a one-neutron knockout reaction from ^{52}Ca [4], while the single-particle $2p_{1/2}$, $1f_{5/2}$ and $1g_{9/2}$ orbitals defining the shell gaps at N = 32, 34 remain to be established experimentally. The ^{50}Ca(d, p)^{51}Ca transfer reaction presents itself as well suited-method to access spectroscopic factors in the fp-shell, where the angular distribution of the reaction products allow for deduction of the angular momentum transfer.

In Decemeber of 2022 the SHARAQ12 experiment was performed at the RIKEN Nishina Center, aiming to study the single-particle structure of ^{51}Ca via the (d, p) reaction using a ^{50}Ca secondary beam. The secondary beam was produced at the BigRIPS separator and then degraded to approximately 15 MeV/nucleon at the OEDO [5] beamline. Beam-tracking has been performed with the recently developed Strip-Readout PPAC detectors [6], recoiling protons coming from the interaction of the beam with the secondary target of CD2 (260 µg/cm2) have been identified with the detector setup TINA2 [7], while the heavy recoils have been identified at the QQD SHARAQ spectrometer. In this contribution, I will present the experiment, current status of the analysis, and the implications on the structure of neutron-rich Ca isotopes.

Session 5

The influence of dissipation on the quasielastic barrier distributions of the ^{20}Ne+^{92,94,95}Mo systems

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The Coupled Channels (CC) model successfully explained the strong enhancement of sub-barrier fusion cross sections as well as the observed structures in the barrier distributions for many systems. However, there are several mechanisms whose influence on the fusion is still not clear, as the role of weak (non-collective excitations) reaction channels. The experimental barrier distributions of some systems turned out to be without any structure, in contradiction to theoretical predictions [1,2,3]. Such an effect is caused by a dissipative mechanism, where part of the kinetic energy is dissipated into the excitation of a multitude of internal non-collective levels of the system. This experimental evidence led to the development of a new model able to include the non-collective excitations in the fusion reactions by extending the CC method using the random matrix theory (RMT) [4,5].

Very recently at the Heavy Ion Laboratory (HIL) of the University of Warsaw, a comparative study of the quasielastic barrier distributions of the ^{20}Ne + ^{92,94,95}Mo systems was performed, aiming to study the influence of dissipation due to single-particle excitations on the barrier distribution structure. The theoretical calculations performed within the CC+RMT model are in good agreement with the experimental data, supporting the hypothesis that non-collective excitations can alter the structure of the barrier distributions. However, the ^{94}Mo shows a smoother and wider structure in comparison to the ^{95}Mo, despite the higher-level density of the latter. This difference might be due to another mechanism of dissipation, being the projectile-target transfers of light particles. In this perspective, the transfer cross sections for different transfer channels will be measured in a separate experiment at HIL. The measurement would clarify the role of transfer couplings on the shape of barrier distribution and the dynamic of the reactions of the three systems. Details on the recent results and plans for fusion and transfer cross-section measurements at HIL will be discussed in this contribution.

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Session 5

Recent data on fusion far below the barrier for ^{12}C + ^{28}Si

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Heavy-ion fusion reactions are essential to investigate the fundamental problem of quantum tunnelling of many-body systems in the presence of intrinsic degrees of freedom. Studying the fusion of light systems with Q > 0, and the identification of hindrance [1] requires challenging measurements. The investigation of slightly heavier cases allows a reliable extrapolation towards the lighter astrophysical systems.

We measured the fusion excitation function of ^{12}C + ^{28}Si down to hundreds of nanobarn, using ^{28}Si beams from the XTU Tandem accelerator of LNL. The combined setup of the γ-spectrometer AGATA [2] and two DSSD [3] around the target, was used. The fusion-evaporation charged particles were detected by the DSSD. The prompt γ-rays emitted by the evaporation residues (ER) were detected by AGATA. The fusion cross-sections are obtained from the coincident events between γ-rays and charged particles.

The light-charged particles have been identified through pulse shape discrimination, using their energy E_{part} vs the rise time of the signal *psd* (left figure). The matrix on the right combines the coincidence events between the energies of γ-rays and charged particles, detected by one ring of the forward DSSD, at E_{lab}=50 MeV. The main transitions from the ER are identified. Neutron evaporation could not be observed, but it is calculated to be not more than a few per cent for this system in the measured energy range.

Preliminary analyses provide very promising results in the study of fusion cross sections for ^{12}C +^{28}Si and other light systems at deep sub-barrier energies. The final results of this experiment will be shown.

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Session 6

Microscopic description of induced fission dynamics

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The dynamics of induced fission is described using a consistent microscopic framework that combines the time-dependent generator coordinate method (TDGCM) and time-dependent nuclear density functional theory (TDDFT). While the former presents a fully quantum mechanical approach that describes the entire fission process as an adiabatic evolution of collective degrees of freedom, the latter models the dissipative dynamics of the final stage of fission by propagating nucleons independently toward scission and beyond. The two methods, based on the same nuclear energy density functional and pairing interaction, are integrated and employed in a study of the charge distribution of yields and total kinetic energy for induced fission. The saddle-to-scission dynamics, the timescale for the formation of a neck between the nascent fragments, and the subsequent mechanism of scission into two or more independent fragments are explored.

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Session 6

The NUMEN project: nuclear response to weak interaction investigated by nuclear reactions

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The physics of neutrinoless double beta (0νββ) decay has important implications on particle physics, cosmology and fundamental physics. It is the most promising process to access the effective neutrino mass. To determine quantitative information from the possible measurement of the 0νββ decay half-lives, the knowledge of the Nuclear Matrix Elements (NME) involved in the transition is mandatory.

The possibility of using heavy-ion induced double charge exchange (DCE) reactions as tools toward the determination of the NME is at the basis of the NUMEN project [1]. The basic points are that the initial and final state wave functions in the two processes are the same and the transition operators are similar, including in both cases a superposition of Fermi, Gamow-Teller and rank-two tensor components. Full understanding of the DCE reaction mechanism is fundamental to disentangle the reaction part from the nuclear structure aspects relevant for the 0νββ decay NMEs. One of the most debated aspect in the DCE and SCE nuclear reactions is the competition between the direct process, proceeding via the meson-exchange paths, and the sequential ones proceeding through the transfer of several nucleons.

The availability of the MAGNEX large acceptance magnetic spectrometer [2] for high resolution measurements of the DCE reactions is essential to obtain high resolution energy spectra and accurate cross sections at very forward angles, including zero degree, and allows the concurrent measurement of the other relevant reaction channels (elastic and inelastic scattering, one- and two-nucleon transfer and single charge exchange reactions). The strategy applied to study such a full net of reactions is to measure the experimental data in the same experimental conditions and analyze them using state-of-the-art nuclear structure and reaction theories in a unique comprehensive and coherent theoretical framework. This multichannel approach has been recently applied to analyze some nets of nuclear reactions, for example involving the $^{18}O + ^{40}Ca$ system. Moreover, the absolute cross sections of some DCE reactions populating nuclei of interest for the 0νββ decay have been measured for the first time. These results will be presented and discussed at the Conference.

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Session 6

Study of the 14B nuclear structure and the tensor force contribution in the O isotopic chain using QFS reactions

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The motivations for studying nuclei far from the valley of stability are manifold: from the study of the role played by the different parts of the nuclear force in the evolution of shell gaps, to the appearance of halo nuclei and clusters in a variety of isotopic chains linked to the proximity of the continuum, including the reordering of the neutron/proton shells as we move toward the corresponding drip line.

An experiment has been recently performed using the R^3B setup at GSI, within the FAIR Phase-0 program. Some of the scientific goals are to study the role of the tensor force when approaching the neutron drip line and the complex facets of neutron rich boron isotopes such as the weakly bound halo nucleus candidate ^{14}B. During this experiment 2 different "cocktail" of nuclei, among which ^{22}O, ^{14}B and ^{15}B were sent on a 5 cm LH2 target surrounded by tracking detectors and the CALIFA calorimeter [1]. This calorimeter allows to detect gamma-rays and light particles from the QFS reactions in inverse kinematics. To study the spectroscopy of unbound states with an unprecedented energy resolution, this new setup includes the high resolution and granularity neutron detector NeuLAND [2].

In the first part of this work, we focus on the evolution of the proton $0p_{1/2}$-$0p_{3/2}$ SO splitting in the O chain, when the neutron $0d_{5/2}$ orbital is filled by 6 neutrons, from ^{16}O to ^{22}O. The vast majority of studies performed so far in stable nuclei of the chart of nuclides shows that the amplitude of the SO splitting scales with approximately A2/3 [3], due to the surface-dominant term of the spin-orbit force.

The present study, that goes well beyond stability, should demonstrate if such a decrease of the SO splitting between ^{16}O and ^{22}O is found and if it is larger than expected. Indeed, the action of tensor forces should lead to a further decrease of the SO splitting, added to the role of SO force.

The $^{22}O(p, 2p)$ QFS knockout reaction provide information on the tensor force contribution to the $0p_{1/2}$-$0p_{3/2}$ SO splitting in the O isotope chain, from N=8 to N=14 shell closure, when the neutron $0d_{5/2}$ orbital is filled. The SO orbit splitting amplitude is planned to be obtained from the energies and spectroscopic factors of the $1/2^-$ and $3/2^-$ states in ^{21}N. In addition, the $^{22}O(p, pn)$ reaction has also been studied in order to determine if 6 neutrons are indeed added in the $0d_{5/2}$ orbital from ^{16}O to ^{22}O, or if a fraction of them are occupying the nearby $1s_{1/2}$ orbital.

In the second part of this analysis, we use the $^{14}B(p, pn)$ and $^{15}B(p, pn)$ QFS knockout reactions to probe the neutron's orbitals occupancies when moving from the magic, N=8, ^{13}B nucleus [4] to the neutron drip line in the B chain. A dominant s-wave contribution for the neutrons added to the ^{13}B magic nucleus [4] would indicate the halo nature of ^{14}B (Sn<1MeV) and ^{15}B, as suggested by new nuclear radius measurements for these nuclei, the neighboring ^{14}Be and the more neutron-rich ^{17}B and ^{19}B nuclei [5,6].

Furthermore, the $^{15}B(p, pn)^{14}B$ reaction populating the bound and unbound states originating from the $\pi(0p_{3/2})^{-1} \times \nu(1s_{1/2})^1$ and $\pi(0p_{3/2})^{-1} \times \nu(0d_{5/2})^1$ couplings allows the identification of the last unbound state from the corresponding multiplet (1^-), which wasn't observed in the previous studies using transfer reactions [7,8]. Finally, the coupling between states of the same J across the continuum is determined using the momentum distribution study.

Preliminary results from these studies will be presented.

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Session 6

The kink effect of the nuclear charge radius in mean-field relativistic models

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The significant alteration in the trend of the nuclear charge radius within certain isotopic families, when plotted against the mass number A, is called the kink effect (KE). The most typical example of the KE is found in the charge radii of Pb isotopes. This kink is reasonably well reproduced by the nuclear relativistic mean-field [1-4] and relativistic Hartree-Fock approximations [5], while non-relativistic Skyrme-Hartree-Fock (SHF) functionals with standard parametrisations [6] or Gogny forces [7] fail to reproduce it. Thus, new non-relativistic density functionals have been proposed to improve the description of the nuclear charge radii [8-16], trying to understand the mechanism responsible for the KE. However, the entire theoretical understanding has yet to be reached.

This communication aims to give a detailed and complete explanation of the KE in the most common relativistic models in the mean-field approximation. To do this, we analyse the contribution of the valence neutrons to the proton central potential. We show that relativistic effects due to the small component of the Dirac spinors are essential in the kink formation and also to achieve a good description of the charge radii in the lead isotopic family. We explain, in particular, why relativistic models tend to be more kinky than non-relativistic ones [16].

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Session 6

Reaction dynamics of proton drip-line nuclei at energies around the Coulomb barrier

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Reaction dynamics induced by proton drip-line nuclei at energies around the Coulomb barrier is one of the most popular topics in nuclear physics. In order to further investigate the reaction mechanisms of proton drip-line nuclei, we performed the complete-kinematics measurements of ^{8}B+^{120}Sn and ^{17}F+^{58}Ni at CRIB, University of Tokyo. Two detector arrays, i.e., the silicon telescope array of STARE and the ionization chamber array of MITA, were designed respectively for the measurements of ^{8}B and ^{17}F. Reaction products were completely identified with the help of these two arrays. For the ^{8}B+^{120}Sn system, the coincident measurement of the breakup fragments was achieved for the first time. The correlations between the breakup fragments reveal that the prompt breakup occurring on the outgoing trajectory dominates the breakup dynamics of ^{8}B. For ^{17}F+^{58}Ni, nearly the exhaustive information on reaction channels, such as quasi-elastic scattering, breakup and total fusion, was derived for the first time. An enhancement of the fusion cross section of ^{17}F+^{58}Ni was observed at the energy below the Coulomb barrier. Theoretical calculations indicate that this phenomenon is mainly due to the coupling to the continuum states. Moreover, different direct reaction dynamics were found in ^{8}B and ^{17}F systems, suggesting the influence of proton-halo structure on the reaction dynamics.

Session 7

Reaction dynamics and nuclear structure of light exotic nuclei

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The nuclear chart corresponding to light radioactive nuclei has yielded many surprising results, among others, the discovery of the halo structures in neutron and proton dripline nuclei. This region of the nuclear chart is also rich of many other phenomena like the appearance of molecular-like structures where α-particle-clusters are bound together by the exchange of neutrons or the existence of cluster configurations where at least one of the clusters is a weakly bound nucleus.

This presentation will focus on the investigation of these particular features of the nuclear structure of light radioactive nuclei and how they influence the reaction dynamics. The availability of post-accelerated radioactive ion beams has opened new opportunities for such studies; future perspectives will also be discussed.

Session 7

Investigating cluster structures in the A=10 mass region via ^{10}B +^{10}B nuclear reactions

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Reveling the details of different states in light nuclei and gaining a complete spectroscopic picture of nuclei close to the A=10 is important for many reasons. In this mass region states of dominantly shell model character are mixed with molecular and cluster states, including rather exotic ones, like Borromean (e.g. ^{9}Be) and halo (e.g. ^{11}Be) states, or even Bose-Einstein condensates (^{11,12}C, ^{11}B). The nuclei of interest have been accessible by ab initio calculations for some time, so they can serve as a testing ground for improving the corresponding models. Furthermore, many of the states close to the A=10 region are important inputs to astrophysical and cosmological models, since light nuclei occur in early nucleosynthesis and every phase of stellar evolution.

The high-energy region of these nuclei exhibits a dense concentration of states with significant overlap, posing a particular challenge for investigation. Well-defined states preferentially populated in specific experimental channels within this high-energy region not only offer insights into structural characteristics but also serve as compelling evidence thereof. While reaching high-spin states is not always feasible, the unique conditions of the experiment presented here, allow for the population of such states in the exit channels.

Results of nuclear reactions ^{10}B + ^{10}B, measured at 72 MeV, will be presented, the most important being new and rarely seen states in the ^{12}C and ^{13}C [1, 2], which motivate targeted future experiments. In particular, a new state of ^{12}C at Ex = 24.4 MeV is strongly populated in the triple α-particle coincidences, while the rarely seen state at Ex = 30.3 MeV is found to be strong in the d+^{10}B decay channel, reinforcing the previous suggestions that it has the exotic 2α+2d molecular structure [3]. Regarding the ^{13}C nucleus, a potentially novel state at Ex = 19.0 MeV is prominently observed in α+^{9}Be coincidences and demonstrates a well-defined cluster structure. Furthermore, so far unobserved alpha decay of two high-energy ^{13}C states at 21.9 and 23.6 MeV is discussed.

In four nucleons transfer reaction channel, excited states of the ^{14}N at Ex = 13.2 and 15.39 MeV were measured. Both of them fit nicely to a recent AMD calculations [4] as the head and the 5+ state of the ^{10}B(3+) + α rotational band (Kπ = 3+).

Lastly, the unique opportunity presented by ^{10}B + ^{10}B reactions to study high-energy, high-spin states in mirror nuclei pairs such as ^{9}Be-^{9}B, ^{10}Be-^{10}C and ^{11}B-^{11}C is explored. Mirror pairs provide information about the charge independence of the nuclear force, and, in certain cases, the Coulomb displacement energy (via so-called Thomas-Ehrman effect), that can lead to a better understanding of underlying nuclear structure. The experimental data on cluster states in light mirror nuclei are still very rare, though it is clear that they can provide very useful insights.

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Session 7

Beta-decay as a probe of the isospin doublet in ^{8}Be

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Since the mid-60s, the presence of a 2^+ doublet in ^{8}Be, constituted by the 16.6 and 16.9 MeV excited states, has been observed [1-3]. An intriguing aspect of this doublet is its status as the best-known instance featuring a complete isospin mixing, where the 16.6 MeV (^{7}Li+p) and 16.9 MeV (^{7}Be+n) levels can be decomposed in an equal mixture of two pure isospin (T=0 and T=1) levels [4]. While indications of this behaviour have hinted through R-Matrix fits in reaction experiments [5], direct confirmation is still pending.

The 2^+ isospin doublet in ^{8}Be, comprising the 16.6 and 16.9 MeV excited states, has been consistently observed [1-3] since the mid-1960s, through reaction experiments. Notably, this doublet stands out as the most well-known instance of a total isospin mixing, where the 16.6 MeV (^{7}Li+p) and 16.9 MeV (^{7}Be+n) levels exhibit an equal mixture of two pure isospin (T= 0) and (T= 1) states [4]. While R-Matrix fits in reaction experiments have hinted at this behaviour [5], direct confirmation remains pending.

The beta decay of the 1-proton halo nucleus ^{8}B into ^{8}Be offers a valuable avenue for probing the isospin composition of the doublet through selective Fermi and Gamow-Teller components. However, resolving the feeding to the 2^+ doublet poses challenges. Within the Q_{EC} window (Q_{EC} = 17.9798(1) MeV), the predominant (≥ 88 %) decay mode leads to a broad (2^+) state at 3 MeV [6], extensively studied due to its significance as a primary source of high-energy solar neutrinos [7]. Additionally, beta decay can occur via electron capture (EC) at 17,640 MeV. Assuming the EC decay occurs in the core with the halo proton as a spectator, the strength of this unobserved branch is estimated from the decay of ^{7}Li to be a branching ratio of $(2.3 * 10^{-8})$ [8].

The IS633 experiment, conducted by the MAGISOL collaboration at the CERN/ISOLDE facility's decay station (IDS), is focused on investigating the 2^+ doublet of ^{8}Be through the beta decay of ^{8}B [9,10]. A mass-separated 50 keV $^8BF_2$ beam was implanted in a (30, mg/cm^2) carbon foil catcher. Through EC/(β^+) decay, ^{8}B feeds the excited states of ^{8}Be, which subsequently break up into two α particles or a proton and a ^{7}Li, depending on the level fed. Detection of the breakup fragments is done through a system of particle telescopes, each comprising a Double-Sided Silicon Strip Detector (DSSD) stacked with a thick Si-PAD detector. These telescopes, arranged in pairs of opposite-facing detectors, enabled precise data collection.

IS633 represents a significant advancement, achieving a two-order-of-magnitude improvement in statistics over the preceding benchmark experiment JYFL08 [9]. High-statistics data from IS633 enabled the resolution of the continuum spectrum of ^{8}Be from 1 MeV up to 17 MeV. Notably, the 16.6 MeV and 16.9 MeV doublet were resolved for the first time in a beta decay study.

This contribution provides a comprehensive description of experiment IS633, including the analysis of excitation spectra using R-matrix methods and an alternative approach based on beta recoil. These complementary analyses have facilitated the determination of isospin mixing in the doublet and the identification of the Fermi and Gamow-Teller components.

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Session 7

Alpha structure of ^{16}O at high excitation energies by ^{3}He+^{13}C nuclear reactions

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^{3}He induced reactions allow to investigate the spectroscopy of high excitation energy regions of light compound nuclei that can be formed in low energy reactions. We performed a new experiment of this type, HELICA, with the solid-state hodoscope OSCAR at the AN-2000 accelerator of the INFN-LNL. In the experiment, a ^{3}He beam, with energies ranging from about 1400 keV to 2200 keV was delivered to a thin ^{13}C target. In particular, ^{13}C(^{3}He, alpha)^{12}C reactions, leading to the C nucleus into several excited states (including the Hoyle state), were correctly identified. In the talk, we show preliminary angular distributions and excitation functions of the cross section for the ^{13}C(^{3}He,a0), ^{13}C(^{3}He,a1), ^{13}C(^{3}He,a2) reactions in a broad angular domain, and discuss the impact on the spectroscopy of ^{16}O. The preliminary values of the branching ratios between the transitions populating the ground state and the Hoyle state show an energy dependence that suggest the occurrence of a strongly clustered state in ^{16}O at about 24 MeV excitation energy.

Session 7

Comparison of ^{18}O+^{12}C at 16.7 MeV/nucleon reaction with the AMD+GEMINI++ model.

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In this talk I will present a comparison between the experimental data and the transport model AMD [1] (Antisymmetrized Molecular Dynamics) coupled with GEMINI++ as afterburner[2] for the reaction ^{18}O+^{12}C at 16.7 MeV/nucleon measured using the GARFIELD+RCo [3] apparatus at LNL. Considering some recent systematics [4,5], in our system the statistical process are only a small part of the total cross section and the presence of dynamical effects in systems with a similar bombarding energy has been already shown in [6]. On the other hand, the bombarding energy and the size of this system is such that we are still not completely in the energetic and mass regime where a dynamical code has been compared and fully validated through the experimental data comparison.

The aim of this comparison is to test for the first time the AMD code at low energy (below 25 MeV/nucleon) with a light system. This work has shown that AMD+GEMINI++ is able to predict all the different mechanisms from which fragments can be produced, but with different cross sections with respect to the experimental ones. In particular, AMD+GEMINI++ fails in populating the velocity region close to the center of mass velocity as already pointed out in [7] for the light systems ^{32}S+ ^{12}C and ^{20}Ne + ^{12}C at 25 MeV/nucleon and 50 MeV/nucleon. The fact that the model prefers less dissipative reactions, where the QP and the QT stay too much similar to the original projectile and target, might be related to the NN cross section or to the clustering and inter-clustering process. A possible optimization of these parameters within AMD to better reproduce also light systems with this code is foreseen.

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Session 8

The study of $^{20}Ne(p,\gamma)^{21}Na$ and $^{21}Ne(p,\gamma)^{22}Na$ reactions at LUNA

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Among the hydrogen burning processes in stars, proton reactions with Ne isotopes are very relevant to constrain the production and abundances of neon and sodium isotopes in massive stars, novae and supernovae. In particular the $^{20}Ne(p,\gamma)^{21}Na$ reaction is the first and slowest reaction of the NeNa cycle and it controls the speed at which the entire cycle proceeds: its rate affects the synthesis of all the elements in the cycle. In the temperature range from 0.1 GK to 1 GK, it is dominated by the Ep= 386 keV resonance and by the direct capture component. On the other hand, The $^{21}Ne(p,\gamma)^{22}Na$ reaction has a relevant role in the production of the radioactive isotope ^{22}Na in novae and supernovae. At T~0.1-0.7GK, the main contributions to the stellar rate are provided by several resonances (Ep=126, 271, 272, 290 and 352 keV). Both reactions have been recently studied at LUNA (Laboratory for Underground Nuclear Astrophysics) using the intense proton beam delivered by the LUNA 400 kV accelerator and a windowless differential-pumping gas target coupled with two high-purity germanium detectors. New resonance strengths and branching ratios have been determined for all the resonances of interest and several new transitions observed for ^{22}Na excited states. The contribution is aimed to summarize the new results and to highlight their impact on Ne-Na cycle.

Session 8

Influence of the tetraneutron on the EoS under core-collapse supernova and heavy-ion collision conditions

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Light (e.g. deuterons, tritons, helions, α−particles), and heavy (pasta phases) nuclei exist in nature in core-collapse supernova matter and neutron star (NS) mergers, where temperatures of the order of 50 to 100 MeV may be attained. In the NS inner crust, that is under different conditions of temperature, density and asymmetry, these heavy clusters should also be present. The appearance of these clusters can modify the neutrino transport, and, therefore, consequences on the dynamical evolution of supernovae and on the cooling of proto-neutron stars are expected. However, a correct estimation of their abundance implies that an in-medium modification of their binding energies is precisely derived. At such temperatures, other exotic degrees of freedom, such as hyperons, Δ−isobars, or even resonant states of four neutrons, may appear. Recently, such a resonant state of four neutrons (tetraneutron) with an energy of $E4n = 2.37\pm0.38(stat) \pm 0.44(sys)$ MeV and a width of $\Gamma = 1.75\pm0.22(stat) \pm 0.30(sys)$ MeV was reported. In this work, we analyze the effect of including such an exotic state on the yields of other light clusters. We use a relativistic mean-field (RMF) formalism, where we consider in-medium effects in a two-fold way – that is, via the couplings of the clusters to the mesons, and via a binding energy shift – to compute the low-density equation of state (EoS) for nuclear matter at finite temperature and fixed proton fraction. We consider five light clusters – namely deuterons, tritons, helions, α−particles, and 6He – immersed in a gas of protons and neutrons, and we calculate their abundances and chemical equilibrium constants with and without the tetraneutron. We also analyze how the associated energy of the tetraneutron would influence such results. We find that the low-temperature, neutron-rich systems are the ones most affected by the presence of the tetraneutron, making NSs excellent environments for their formation. Moreover, its presence in strongly asymmetric matter may increase the proton and α−particle fractions considerably. This may have an influence on the dissolution of the accretion disk of the merger of two NSs.

Session 8

New Isomeric Transition in ^{36}Mg: Merging the N=20 and N=28 islands of inversion

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The N=20 island of inversion, so called due to the sudden onset of deformation at the N=20 neutron magic number, has consistently been one of the most exciting nuclear regions since its discovery 30 years ago. Since then, further experimental, and theoretical studies have explained the origin of this anomaly from the mixing of deformed two-particle two-hole components in the ground state wave function of nuclei in the island of inversion (see e.g. [1]). More recently, the observation of the first 2^+ state in N=28 ^{40}Mg at low energy suggests both the N=20 and N=28 neutron magic numbers disappear in the magnesium isotopic chain [2]. However, deformation in magnesium isotopes between the two neutron magic numbers [3] can be explained due to the increasing occupation of the valence sub-shell, without invoking two-particle two-hole configuration mixing.

The prompt gamma decay of 35 to 38 magnesium isotopes was studied at the National Superconducting Cyclotron Facility, using a 3 clover array of High Purity Germanium detectors. We observed a new isomeric gamma transition at 168 keV in ^{36}Mg, with a half-life of $T_{1/2} = 90(^{+410}_{-50})(\pm 40)_{tran}(^{+800}_{-70})_{sys} ns$, We propose it corresponds to the transition between a new 0^+ state and the previously known first 2^+ state [4]. Our calculations of ^{36}Mg using the SDPF-U-MIX interaction interpret the observed low energy of the second 0^+ state due the small energy separation (pre-diagonalization) between spherical and deformed configurations. This makes ^{36}Mg the crossing point between dominant ground state deformed/superdeformed configuration in ^{32,34}Mg and dominant spherical configuration in ^{38}Mg. We conclude ^{36}Mg bridges the N=20 and N=28 islands of inversion within the so-called Big Island of Deformation encompassing both.

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Session 8

First laser-spectroscopy measurements across N = 32 in the calcium isotopic chain

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Over a decade ago, the first experimental evidence for the N=32 sub shell closure in the calcium isotopic chain emerged [1,2]. Subsequent experimental and theoretical investigations have confirmed this finding. However, in laser spectroscopy measurements extending up to ^{52}Ca (N=32), no indications of this shell gap were apparent [3]. Crossing the shell gap with laser spectroscopy setups has proved difficult due to the simultaneous requirement of a sensitivity of approximately 10 ions/s and a measurement uncertainty on the order of MHz.

This contribution presents the first laser spectroscopy measurements of ^{53}Ca, facilitated by an extension of the collinear laser spectroscopy technique employed at the COLLAPS setup at ISOLDE/CERN. This technique, termed as radioactive detection after optical pumping and state selective charge exchange (ROC), combines the high sensitivity of a particle detection scheme with the high resolution of low-power, continuous wave lasers utilized in a collinear geometry. The methodology of this technique will be explained, followed by the presentation and discussion of preliminary values for the charge radius and magnetic dipole moment of ^{53}Ca in the context of the robustness of the N=32 sub shell closure, as well as the prospects to measure ^{54}Ca.

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Session 8

In-beam gamma-ray spectroscopy and lifetimes of excited states of ^{79}Cu

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In-beam γ-ray spectroscopy of ^{79}Cu was carried out at the Radioactive Isotope Beam Factory of the Riken laboratory during the 2021 Hicari campaign [1]. In-flight fission of 238U at 345 MeV/nucleon produced a wide range of exotic nuclei, including ^{80}Zn. These nuclei were sent through the Bigrips separator onto a beryllium target, where knock-out reactions took place. The emitted γ-rays were detected by an array of germanium detectors positioned around the target, whilst the outcoming fragments were identified in the Zerodegree separator. Among these fragments, our interest was focussed on ^{79}Cu, which contains one proton more than doubly-magic ^{78}Ni. To the extent that the magicity of ^{78}Ni is maintained, the γ-spectra of ^{79}Cu are expected to relate to the single-particle transitions of the last proton [2]. Based on the comparison of the shapes of the energy peaks with simulations, the experiment specifically aimed at the determination of the lifetimes of the de-exciting states, the first results of which show the presence of both collective and single-particle structures at low energy in ^{79}Cu.

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Session 8

Neutrinoless double beta decay in the relativistic framework

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The neutrinoless double beta decay is of fundamental importance for particle physics, nuclear physics, and cosmology. Nuclear matrix element, which encodes the impact of the nuclear structure on the decay half-life, is crucial to interpreting the experimental limits and even more potential future discoveries. However, current knowledge of the nuclear matrix element is not satisfactory due to the unknown short-range contributions to the transition operator [1] and also the complicated nuclear many-body wavefunctions [2].

For the transition operator, we have developed a relativistic framework based on a manifestly Lorentz-invariant chiral Lagrangian [3]. We show that the neutrinoless double-beta decay transition amplitude can be renormalized at leading order without any unknown short-range operators [4]. This enables a model-free determination of the neutrinoless double beta decay operator in nuclear-structure calculations. It also defines a stringent benchmark for the previous estimation of the unknown short- range contributions in the nonrelativistic framework.

For the nuclear many-body wavefunctions, we have established the relativistic configuration-interaction density functional theory [5,6], a novel framework which combines the advantages of nuclear shell model and relativistic density functional theory. It allows a fully microscopic and self-consistent treatment of nuclear triaxiality within a full model space. It provides the first investigation for the triaxial effects on the nuclear matrix elements for both two-neutrino and neutrinoless double beta decays in ^{76}Ge [7]. The triaxiality enhances the nuclear matrix element of the neutrinoless double beta decay significantly by a factor around two.

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Poster Session

Study of multinucleon knockout reactions of exotic nuclei in the region of Nitrogen

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Several works focused on light isotopes [1,2,3] have shown a reduction of the cross sections with respect to the theoretical predictions for single-nucleon knockout reactions. These studies have reached different conclusions regarding the dependence of the reduction factor observed of the spectroscopic factor with respect to the N/Z of the projectile. The study of (p,pX) knockout reactions with the R3B versatile setup is a golden opportunity since the inverse kinematics technique can be used for kinematically complete measurements.

Of particular interest is the systematic study of the probability of cluster formation. The successful experiments on stable Sn isotopes [4] indicating the pre-existence of alpha clusters, which are compatible with theoretical predictions [5], have aroused the interest to study this phenomenon also for other clusters such as d, t or ^{3}He.

This presentation will be focused on deuteron formation and its possible identification with CALIFA [6]. One of the goals is to study the dependence of the cluster formation probability with respect to the mass of the projectile. In addition, the occurrence of deuteron clusters embodies tensor force effects and should be relevant for short-range correlations (SRC) [7].

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Poster Session

First spectroscopic study of ^{51}Ar by the (p,2p) reaction

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The nuclear structure of ^{51}Ar, an uncharted territory so far, was studied by the (p,2p) reaction using γ-ray spectroscopy for the bound states and the invariant mass method for the unbound states. Two peaks were detected in the γ-ray spectrum and six peaks were observed in the ^{50}Ar + n relative energy spectrum. Comparing the results to our shell-model calculations, two bound and six unbound states were established. Three of the unbound states could only be placed tentatively due to the low number of counts in the relative energy spectrum of events associated with the decay through the first excited state of ^{50}Ar. The low cross sections populating the two bound states of ^{51}Ar could be interpreted as a clear signature for the presence of significant subshell closures at neutron numbers 32 and 34 in argon isotopes. It was also revealed that due to the two valence holes, unbound collective states coexist with individual-particle states in ^{51}Ar.

Poster Session

Measurement of $^{27}Al(\alpha, n\gamma)^{30}P$ reaction yields and angular correlations.

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Reactions induced by alpha particles are important in multiple research areas such as nuclear astrophysics, nuclear technologies, dark matter searches and neutrino physics. Accurate data on neutron yields from the interaction of α-particles with nuclei via (α, n) reactions are of particular interest in this context. Despite the existence of experimental data and libraries, they show large discrepances and they are not compatible with the declared uncertainties. In addition, such libraries are only available for a few isotopes, and the spectroscopic information available is limited. The need for new measurements with higher precision has been recently recognized [1]. This work is focused on the reaction $^{27}Al(\alpha, n)^{30}P$, which served as a benchmark to compare measurements from previous experiments and cross check experimental techniques. The measurements are part of a larger project, the Spanish MANY collaboration (Measurement of Alpha Neutron Yields), whose ultimate goal is the measurement of (α, xn) production yields, reaction cross-sections and neutron energy spectra. Here we focus in particular on the measurement of $^{27}Al(\alpha, n)$ reaction yields via activation and $^{27}Al(\alpha, n\gamma)$ production yields. One of the objectives of this work is the commissioning of the new experimental beamline and of the detector systems via a previously measured $^{27}Al(\alpha, n)^{30}P$ reaction. The experiment was carried in two independent beam times at the CMAM (Centro de Micro-Análisis de Materiales) laboratory in Madrid [2], Spain using an array of ten LaBr3(Ce) FATIMA-type [3] detectors placed at selected angles in the laboratory frame. The gamma spectroscopy measurements allow to determine the total reaction yield from the decay of the activation products and the (α, nγ) yield from the de-excitation of the states in the target nuclei. The setup was complemented by a high-resolution HPGe detector to aid gamma-ray identification.

The presentation will address the thick-target yields obtained by activation in the 5 to 15 MeV energy range, the gamma yields resulting for the $^{27}Al(\alpha, n\gamma)$ reaction as a function of energy, and the effect of angular correlations on the experimentally obtained gamma yields.

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Poster Session

Establishing the deformation characteristics of ^{66}Ge

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The presence of both well-deformed prolate and oblate deformations is expected in the $A \approx 70$ mass region because of the surprisingly large single-particle energy gaps at N = 34. Nonetheless, oblate deformations in this region have mostly been inferred from rotational bands (^{68}Se) or model-dependent decay measurements (^{72}Kr [2]). Only recently, Coulomb-excitation measurements have been able to determine the sign of the quadrupole moment in a few proton-rich nuclei in this region; conclusively prolate in ^{74,76}Kr [3] and slightly oblate in ^{70}Se [4,5], although with large uncertainties. As inferred for ^{68}Se, the N = 34 isotone ^{66}Ge is another candidate to possess a large oblate deformation in its ground state.

The measurement of the spectroscopic quadrupole moment for the first 2+ excitation, Q(2+) and shape coexistence in the neutron-deficient isotope of ^{66}Ge have been investigated using the ^{196}Pt(^{66}Ge,^{66}Ge)^{196}Pt Coulomb-excitation reaction at 4.395 MeV/u with the MINIBALL spectrometer and double-sided silicon detectors. To accurately determine the beam purity, the beam was implanted on an aluminium foil and let to decay. Here, we present results from the analysis of the Coulomb-excitation and β-decay data sets, which suggest a strong oblate collectivity with a large E2 strength and a potentially large oblate deformation. As found in previous work [3,6], the triaxial degree of freedom seems to be relevant, as also inferred in this work from beyond mean-field calculations where the collective wave functions go from soft in the ground state to a well-defined minimum as the angular momentum increases.

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Poster Session

Studying the structure of Li-11 via transfer reactions

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The term "halo nucleus" was coined to describe nuclei exhibiting an unusually large spatial extension, deviating from the standard formula $r=r_o{\cdot}A^{1/3}$. The initial empirical observation of this phenomenon arose from scattering experiments involving, among others, lithium isotopes [1]. These experiments, designed to measure the interaction cross-section of neutron-rich nuclei, revealed a significant increase in cross-section as we approach the neutron dripline when going from ^{9}Li to ^{11}Li.This discovery led to the interpretation of a new type of nuclear structure [2], characterized by a compact core and an external set of nucleons (1n for ^{11}Be and 2n for ^{11}Li). Subsequent momentum distribution studies of ^{9}Li from ^{11}Li break-up experiments confirmed this hypothesis [3].

Our focus is on the ^{11}Li isotope, considered the quintessential two-neutron halo. While the ground state of ^{11}Li is well established [4], the same cannot be said about its excitation spectrum, despite multiple experimental attempts [4]; there is no consensus over the energy and number of excited states. Most of these experimental attempts are based on promoting an ^{11}Li nucleus from the ground state to its excited states through reactions, with the only exceptions being [5] and [6], which suffer from a complex experimental setup.

We are undertaking a new experiment to populate the excited states of ^{11}Li using the ^{9}Li(t,p)^{11}Li reaction, as the structure of ^{9}Li is simpler [7]. The experiment, scheduled for 2024, will take place at the Scattering Experiment Chamber (SEC) at CERN-ISOLDE in Switzerland. Our state-of-the-art setup consists of a central tritium target surrounded by a system of five telescopes (PAD+DSSD) forming a pentagon around the target, covering both forward and backward angles. The pentagons are complemented by a system of silicon discs and an S3 at the back, along with an S3-S5 telescope at the front, maximizing angular coverage.

The tritium target will receive a ^{9}Li beam with an energy of 72 MeV/nucleon, populating the excited structure of ^{11}Li through the ^{9}Li(t,p)^{11}Li reaction. Information on the excited states will be gathered from the emitted proton, which will be detected by our setup. To process the data, our DAQ employs compact digitizer cards (64 channels per card) developed by Mesytec. These cards handle all electronic readouts while requiring only two cables (optical link and power), making the setup extremely compact (only six cards are needed).

In this contribution, we present Geant4-MC simulations of the setup and discuss the status of our setup, which is nearing completion.

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Poster Session

Study of exotic nuclei of interest for applied and fundamental nuclear physics with Total Absorption Gamma Spectroscopy (TAGS)

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The study of beta decay of neutron rich nuclei is particularly important for many fields in fundamental and applied physics [1]. In nuclear reactors, fission products, through their decays, produce an additional power called decay heat [2]. The assessment of this energy is essential for nuclear safety since it represents around 7% of the power in an operating reactor and these decays continue after reactor shutdown. Beta decay leads to antineutrino emission and is thus a good tool for fundamental neutrino research [6] but it can also be used for non-proliferation purposes since the antineutrino flux reflects the reactor power and the fuel content. In nuclear astrophysics, the r-process is a nucleosynthesis process [3] at the origin of half of the nuclei heavier than iron. It takes place in hot ($T\sim10^9$K) and highly neutron-dense environments. This process is based on the competition between neutron capture (n,γ), photo-dissociation (γ,n) reactions and beta decays. A precise knowledge of the beta properties can constrain the theoretical models used to understand this nucleosynthesis process. Some of the nuclei involved in these fields of nuclear physics are affected by the pandemonium effect [4]: due to the low efficiency of high-resolution detectors, such as germanium (HPGe), at high gamma energies, some gamma-rays and the corresponding high energy levels can be missed in the decay data leading to a distortion of the beta decay feeding.

New measurements of relevant nuclei for the above mentioned topics have been performed at the IGISOL facility (Jyväskylä, Finland) in September 2022, using Total Absorption Gamma Spectroscopy (TAGS) technique [2]. TAGS is complementary to high resolution gamma-ray spectroscopy and employs a calorimeter to measure the total gamma intensity de-exciting each level of the daughter nucleus providing a direct measurement of the beta feeding. The setup is based on the Rocinante detector, a multi-segmented detector made of 12 barium fluoride (BaF2) crystals, a beta detector acting as a trigger, and a cerium bromine (CeBr3) crystal for identification of contaminants.

The topic of the presentation will be the introduction of Pandemonium effect and the solution our groups choosed to circumvent this effect. Preliminary results of the analysis of the I241 experiment will be presented.

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Poster Session

Superscaling analysis of inclusive electron and (anti)neutrino scattering within the coherent density fluctuation model

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The experimental data from quasielastic electron and (anti)neutrino scattering on ^{12}C are reanalyzed in terms of a new scaling variable $\psi*$ suggested by the interacting relativistic Fermi gas with scalar and vector interactions, which is known to generate a relativistic effective mass for the interacting nucleons. We construct a new scaling function $f^{QE}(\psi*)$ for the inclusive lepton scattering from nuclei within the coherent density fluctuation model (CDFM). The latter is a natural extension of the relativistic Fermi gas model to finite nuclei. In this work, on the basis of the scaling function obtained within CDFM with a relativistic effective mass $m^*_N = 0.8m_N$, we calculate and compare the theoretical predictions with a large set of experimental data for inclusive (e, e′) and (anti)neutrino cross sections. The model also includes the contribution of weak two-body currents in the two-particle two-hole sector, evaluated within a fully relativistic Fermi gas. Good agreement with experimental data is found over the whole range of electron and (anti)neutrino energies.

Poster Session

Pair condensation in excited states of neutron-rich nuclei

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Recently we have analysed two types of excited states generated from a ground state described by a pair condensate.

One type is obtained by breaking a pair from the ground state condensate and replacing it by ”excited” collective pairs built on time-reversed single-particle orbits. The second type is described by a condensate of identical excited pairs. The structure of these excited states is analysed for the valence neutrons of ^{108}Sn. For a state-dependent pairing interaction, the first type of excited states agree well with the J=0 states which are known in ^{108}Sn.

The states corresponding to the excited pair condensate (EPC) appear at low energies, around the energy of the second excited state of the first type, and they do not have a simple correspondence with the exact eigenstates of the pairing Hamiltonian. At a much higher excitation energy, of about 20 MeV, we have found an EPC state which is similar in structure to an exact eigenstate. It is shown that this EPC state has features in common with a giant pairing vibration.

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Session 9

Highlights from the first transfer experiment at GANIL with ACTAR TPC

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Direct reactions are fundamental tools to investigate the structure of exotic nuclei. Studies of nuclei far away from stability are usually performed with secondary radioactive beams, that suf f er from low intensities and need to be compensated with thick targets and high-ef f i cient detection systems to increase luminosity. Active targets are invaluable devices that, among other important features, allow to reconstruct the reaction in three dimensions with- out loss of resolution.

The ACtive TArget and Time Projection Chamber (ACTAR TPC) detector [1,3] has been developed at GANIL to cover a broad physics programme. The device was commissioned in 2018 showing an excellent performance of the detector [4]. Since then, several experiments have been performed at GANIL. In this talk, I will present the results from the single-proton removal reaction ^{20}O(d,^{3}He)^{19}N which aimed at probing the Z=6 shell gap towards the neutron dripline. From all the magic numbers that emerge as a consequence of the spin orbit splitting, the gaps at 6 and 14, were already considered by Goepper-Mayer and Jensen as very weak [5]. However, experimental results published in Nature [6] showed evidence for a Z=6 shell closure. A (p,2p) experiment [7] was performed later and supports a moderate reduction of the 1p1=2 and 1p3=2 splitting. Yet not direct measurement of the gap has been obtained so far.

The goal of the ^{20}O(d,^{3}He)^{19}N [8] experiment at GANIL is twofold: First, the experiment will provide a unique way of determining the gap between the 1p1=2 and 1p3=2 single-particle states in ^{19}N and will bring crucial information on the Z=6 shell gap. Second, this experiment is the first transfer experiment with the new generation of active targets. Originally, these transfer experiments required the use of complex arrays for particle and gamma detection systems to improve selectivity. The use of active targets overcomes the aforementioned difficulties and is specially well adapted to explore new regions of the nuclear chart with unprecedented resolution using a much more compact detection system.

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Session 9

Sub-barrier transfer reactions and the nuclear Josephson effect

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A series of sub-barrier transfer experiments have been recently carried out at LNL, with reaction products detected in inverse kinematic and at forward angles with the large solid angle magnetic spectrometer PRISMA. We measured transfer cross sections far below the Coulomb barrier, making excitation functions down to very low energies. At these low energies, corresponding to very large distances of closest approach, the nuclear absorption is small [1,2,3] and one can probe nucleon-nucleon correlation properties. For the (well Q-value matched) one and two neutron transfer channels in the system ^{60}Ni+^{116}Sn the microscopic calculations very well reproduce the experimental data in the whole energy range, both in magnitude and slope [2]. The fact that most of the cross section of the two neutron transfer channel is in the ground to ground state transition has been further confirmed by a second experiment [4]. Proton transfer channels have been also analyzed [5], showing a large yield in the population of two proton transfer channels, indicating the presence of strong proton-proton correlations.

These kinds of studies, where we followed the behaviour of the transfer probabilities by varying the internuclear distance, turned out to be fundamental to probe nucleon-nucleon correlation effects, where the interaction between the nuclear surfaces plays a fundamental role. In this context, the coupling of the AGATA gamma array to PRISMA offered a unique opportunity to study a nuclear (alternating current (AC)) Josephson-like effect [6], with Cooper-pair tunnelling between superfluid nuclei, whose manifestation has been recently proposed [7] using the data of Refs. [2,4] as a stepping stone. Predictions have been made of a specific gamma strength function associated with the dipole oscillations generated by the, mainly successive, two neutron transfer process. In a very recent experiment, carried out at LNL with PRISMA+AGATA we directly tested for the first time the possible manifestation of this important effect of Cooper pair behaviour, observed to date only in condensed matter physics.

After a general overview on the subject, the talk will focus on new results, addressing the new achievements and the critical issues.

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Session 9

Proton-neutron pairing and α-like quartet condensation in N=Z nuclei

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A specific feature of N = Z nuclei is the occurrence of α -like quartet structures, composed by two neutrons and two protons, which have strong internal correlations and interact weakly with each other. Various studies have shown that the ground states of N=Z systems interacting by proton-neutron pairing interactions can be described by a condensate of α-like quartets [1-9]. This quartet condensate is the analogous of the Cooper pair condensate, commonly employed to treat the neutron or proton pairing correlations. As shown recently, the quartet condensation is also related to the band-like structures of even-even N=Z nuclei [10-11]. More precisely, the low-lying excitations of these nuclei are associated to the breaking of a quartet from the ground state quartet condensate and replacing it with an excited quartet.

In the first part of the talk, I will present an overview of the issues mentioned above. Then I will discuss how the fingerprints of the α-like quartet condensation might show up in the α transfer reactions along a chain of even-even N=Z nuclei [12].

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Session 9

Pair vibrational modes and many-body effects

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We present a theoretical framework for treating the full excitation spectrum of Jπ = 0+ pair addition modes, including the well-known low-lying and bound Pairing Vibration on par with the predicted Giant Pairing Vibration lying in the continuum [1]. Our formalism includes the coupling to low-energy collective quadrupole modes of the core, in such a way that both single-particle self-energy effects and the pairing interaction induced by phonon exchange are accounted for. The theory is applied to the case of the excitation spectrum of 14C, recently populated by two-neutron transfer reactions [2]. We find that the particle vibration coupling drastically modifies the spectrum obtained by conventional pp-RPA calculations. We obtain good agreement with experimental data for bound states. Our calculations pave the way for detailed calculations of two-neutron transfer cross sections.

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Session 9

^{4}He + ^{4}He elastic and inelastic scattering: probing the mysterious properties of the second 0+ state of ^{4}He

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The ^{4}He nucleus is one of the simplest nuclear systems. No bound excited states are present in its level scheme however, a pronounced resonance with the same spin and parity (0^+) as the ground state exists with a centroid slightly above the proton emission energy threshold. The results from several available studies show discrepancies on the determination of the ^{4}He(0_2^+) resonance energy, width and line shape. Furthermore, recent results focusing on the first excited resonant state of ^{4}He nucleus, reveal a puzzling situation potentially calling for missing physics in our best-known nuclear forces and, consequently, in our understanding of the nuclear phenomenology. Into this context, we performed new measurements of the ^{4}He resonance by ^{4}He + ^{4}He scattering at the MAGNEX facility of INFN – Laboratori Nazionali del Sud, featuring data of unprecedented sensitivity and state-of-art analyses of the spectral line shape and the scattering cross sections. Our experimental data on the line shape of the ^{4}He(0_2^+) and on elastic and inelastic differential cross section angular distributions allow for a new insight on the relevant role of the interference between the resonance and the underlying non-resonant continuum. Our data can be reasonably described within the known physics of nuclear interactions and resonance properties, indicating no hint for new physics from ^{4}He resonance properties.

Session 10

Nuclear reactions in the framework of time-dependent density functional theory with pairing correlations

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Superfluidity and superconductivity are remarkable manifestations of quantum coherence at a macroscopic scale. The existence of superfluidity has been experimentally confirmed in many condensed matter systems, in He-3 and He-4 liquids, in nuclear systems including nuclei and neutron stars, in both fermionic and bosonic cold atoms in traps, and it is also predicted to show up in dense quark matter. Pairing correlations in nuclear systems are one of the most important characteristics of non magic atomic nuclei. Various features related to high spin phenomena or to large amplitude collective motion, e.g. fission, indicate that these correlations are crucial for our understanding of nuclear structure and dynamics.

The time dependent density functional theory (TDDFT) is, to date, the only microscopic method which allow to investigate fermionic superfluidity far from equilibrium. In nuclear physics it offers a microscopic description of low energy nuclear reactions, where fermionic degrees of freedom and pairing field dynamics are explicitly taken into account. The local version of TDDFT is particularly well suited for leadership class computers of hybrid (CPU+GPU) architecture. Using the most powerful supercomputers we are currently able to study a real-time 3D dynamics without any symmetry restrictions evolving up to hundred of thousands of superfluid fermions. It represents a true qualitative leap in quantum simulations of nonequilibrium systems, allowing to make quantitative predictions and to reach limits inaccessible in laboratories.

During the talk I will review several applications and results concerning nuclear collisions and induced fission, discussing advantages of this approach.

Session 10

Isomeric states close to ^{78}Ni studied via high-precision mass measurements

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Isomers close to the doubly magic nucleus ^{78}Ni (Z=28, N=50) provide essential information on the shell evolution and shape coexistence far from stability. We have performed high-precision mass measurements of isomeric states close to ^{78}Ni with the JYFLTRAP double Penning trap mass spectrometer at the Ion Guide Isotope Separator On-Line (IGISOL) facility. The existence of a long-lived isomeric state in ^{76}Cu has been debated for a long time. We confirm the existence of such an isomeric state with an excitation energy Ex=64.8(25) keV [2]. Based on the ratio of detected ground- and isomeric-state ions as a function of time, we show that the isomer is the shorter-living state previously considered as the ground state of ^{76}Cu. In addition to 76Cu, we measured the 1/2+ isomeric state of ^{79}Zn. This isomer is known to be strongly deformed [3]. We place it unambiguously at 942(10) keV, slightly below the 5/2+ state at 983(3) keV. Using the state-of-the-art shell-model calculations, the 1/2+ isomer in ^{79}Zn is interpreted as the bandhead of a low-lying deformed structure akin to a predicted low-lying deformed band in ^{80}Zn. The results show the importance of high-precision mass measurements as pinning down the excitation energies of long-living isomeric states and give support for shape coexistence in the ^{78}Ni region.

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Session 10

Coulomb barrier dynamics of nuclear haloes

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Exotic light-nuclei with low particle separation energy can exhibit a very extended matter distribution, the so-called nuclear halo [1, 2]. At collision energies around the Coulomb barrier, the presence of a halo enhances the coupling between the elastic and reaction channels, such as breakup, transfer, and fusion, as compared to stable well-bound nuclei. The Coulomb barrier scattering of single-nucleon halo nuclei such as ^{8}B (1p) and ^{15}C (1n), or two-nucleon haloes such as ^{17}Ne (2p) and ^{6}He (2n), are particularly interesting, due to a complex interplay between nuclear and Coulomb forces and valence nucleon correlations on the dynamical couplings [3, 4, 5, 6]. In this contribution, the characteristic features of low-energy dynamics of nuclear haloes will be presented and discussed, making particular emphasis of latest experimental results and its interpretation in terms of coupled channel calculations.

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Session 10

l-forbidden M1 transitions in semimagic nuclei

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The presence at low energy of pair of nuclear levels differing in orbital angular momentum by two units, which can be ascribed to single-particle states in the shell model, is common place in many odd-mass nuclei located near closed shells. Such single-particle states can be labelled with the radial quantum number n_r, the orbital angular momentum l and the total angular momentum j, and would correspond to $|n_r\ l\ j{=}l{+}1/2\rangle$ and $|n_r{-}1\ l{+}2\ j'{=}l{+}3/2\rangle$, respectively. The pairs $s_{1/2}$ – $d_{3/2}$, $p_{3/2}$ – $f_{5/2}$ and $g_{7/2}$ – $d_{5/2}$ are examples of such orbitals. They are experimentally observed as the ground state and low-lying first-excited state in many odd-A nuclei across the nuclear chart.

Since the magnetic dipole isovector operator does not change the orbital angular momentum, magnetic dipole M1 $\Delta l=2$ transitions between pairs of states of this kind are *l*-forbidden in the extreme shell model picture [1]. Nonetheless these transitions still occur, although with rates typically smaller than those of allowed transitions, or even below the single-particle limit. Consequently, it is anticipated that these transitions arise from the breakdown of *l*-forbiddeness due to nuclear dynamic effects such as core polarization and meson exchange mechanisms [2]. Therefore the investigation of *l*-forbidden M1 transitions may provide insight into the role of these effects within the atomic nucleus [3].

This study is a part of a systematic investigation of *l*-forbidden M1 transitions in semimagic nuclei, making use of available data and our own experimental results. We focus on odd-A N=50 nuclei in the vicinity ^{78}Ni [4] and neutron-rich odd-A Z=50 Sn isotopes [5,6]. The experimental M1 transitions probabilities are obtained from excited level lifetime measurements employing fast-timing methods.

Regarding the N=50 isotopes new results will be presented for ^{83}As and ^{85}Br, obtained from experiments performed at ISOLDE/CERN and ILL, respectively. They will be discussed in the context of other available data for the region. In the case of tin (Z=50), the systematic study of *l*-forbidden transitions in several odd-mass isotopes just below ^{132}Sn will be presented.

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Session 10

Reactions in three- and four-body nuclear and hypernuclear systems

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A rigorous few-body scattering theory as proposed by Faddeev and extended by Yakubovsky and Alt, Grassberger and Sandhas is implemented in the momentum-space framework. Past applications include the nucleon-deuteron scattering, three-cluster nuclear reactions, and four-nucleon scattering. Recent and ongoing extensions of this framework will be presented.

First, we made a two-fold extension of the standard dynamics by developing a new nonlocal form of optical potentials and simultaneously including the excitation of the nuclear core. Example results for nucleon transfer reactions (d,p) and (p,d) and deuteron inelastic scattering (d,d')

^{10}Be and ^{24}Mg nuclei demonstrate a good reproduction of the experimental data and an improved consistency between the two-body (elastic and inelastic nucleon-nucleus scattering) and three-body description [1,2].

Second, the four-nucleon scattering is extended to higher energies. Exact four-body calculations are compared with those based on microscopic optical potential with no-core shell model densities, allowing to evaluate the reliability of the optical potential method [3].

Third, reactions in hypernuclear three-body systems are described fully including the coupling between the nucleon-Lambda and nucleon-Sigma(+,0,-) states, which a highly complicated problem with many thresholds. Various elastic and inelastic cross sections are studied [4].

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Session 11

Advancements in Gamma-ray Spectroscopy: Expanding Sensitivity and Experimental Capabilities

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In recent decades, γ-ray spectroscopy has experienced a significant technological advancement through the technique of γ-ray tracking, achieving a sensitivity almost two orders of magnitude greater than previous Compton-shielded arrays. This leap forward rivals the milestones achieved since the beginning of γ-ray spectroscopy. Combining γ-ray spectrometers with detectors recording complementary reaction products, such as light-charged particles for transfer reactions and scattered ions for Coulomb excitation measurements, further enhances sensitivity.

Nucleon transfer reactions provide a valuable means to explore the energies of shell model single-particle orbitals and study their energy migration away from stability. Additionally, such measurements permit the estimation of cross sections relevant to stellar evolution and nucleosynthesis. Coincident γ-ray and particle measurements offer insights into decay channels for unbound systems, crucial for astrophysics and nuclear structure near drip-lines.

In this contribution, results and prospects for transfer-reaction experiments utilizing newly developed devices like GRIT and other detectors will be outlined, paving the way for further advancements in γ-ray spectroscopy and nuclear structure studies.

Session 11

PARIS Array – status, first experiments and plans

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PARIS (Photon Array for studies with Radioactive Ion and Stable beams) is an international research project with the aim of developing and building a novel 4π gamma-ray calorimeter, benefiting from recent advances in scintillator technology. It is intended to play the role of an energy-spin spectrometer, a calorimeter for high-energy photons and a medium-resolution gamma-detector. The device is composed of two shells: the scintillators of the most advanced technology (LaBr3:Ce or CeBr3) for the inner volume offering simultaneously high efficiency, excellent time resolution and relatively good energy resolution in a large energy range, and a more conventional scintillator (NaI) for the outer shell. The array can be used in a stand-alone mode, in conjunction with other detection systems, like germanium arrays (e.g., AGATA), particle detectors (e.g., MUGAST, NEDA, FAZIA, ACTAR) or heavy-ion spectrometers (e.g., VAMOS, PRISMA). It will be used in experiments with both intense stable and radioactive ion beams to study the structure of atomic nuclei and new nuclear excitation modes as a function of angular momentum, isospin, and temperature, as well as reaction dynamics. More details can be found on the PARIS web page http://paris.ifj.edu.pl.

In the talk the concept and status of the PARIS project will be presented, as well as selected the results from the first experiments with PARIS in GANIL Caen (France), IJCLab Orsay (France) and IFJ PAN Krakow (Poland) will be shown. In addition, the outlook of the project as well as the ideas for next experiments, among others with AGATA in LNL Legnaro, will be discussed.

Session 11

Microscopic analysis of giant monopole resonance in nuclear isotopic chains

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A systematic study of the isoscalar giant monopole resonance (ISGMR) in a variety of nuclear systems is performed within the microscopic self-consistent Skyrme HF+BCS method and coherent density fluctuation model. The calculations for the incompressibility in finite nuclei are based on several energy density functionals for nuclear matter. This theoretical scheme is successfully proved, for instance, in calculations of the nuclear symmetry energy [1-3], as well as of the ratio of its surface to volume components [4,5]. The good agreement achieved between the calculated centroid energies of the ISGMR and their recent experimental values for various nuclei demonstrates the relevance of the proposed theoretical approach [6]. The latter can be applied to analyses of neutron stars properties, such as incompressibility, symmetry energy, slope parameter, and other astrophysical quantities.

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Session 11

Gamma and Fast-Timing spectroscopy in the ^{128}Cd→^{128}In→^{128}Sn *β*-decay chain

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The isotopic chains close to the nuclei number Z=50 have motivated extensive experimental and theoretical efforts during the last decades. Their structure provide an excellent ground to study shell-evolution along the chain and to investigate the interplay between single-particle and collective degrees of freedom. The systematic study of excited structure of nuclei in the double magic ^{132}Sn region, and specifically the measurement of excited-state lifetimes, provides key observables to get a deeper insight on nuclear structure.

A new experimental camping was carried out at the ISOLDE facility to study the β-decay of neutron- rich cadmium isotopes. High intensity Cd (Z=48) beams were produced after the fission of a thick UC_x target, selectively ionized by the ISOLDE Resonance Ionization Laser Ion Source (RILIS) and sep- arated in mass using the General Purpose Separator (GPS) ISOLDE mass separator. A temperature-controlled quartz transfer line was used to ensure purity of the cadmiun beams.

In this contribution results derived for the A=128 isobaric chain will be discussed [3-5]. Our experi- ment exploited the excellent spectroscopic capabilities provided by the ISOLDE Decay Station (IDS). The fast-timing configuration was employed, which includes 6 highly efficient clover-type HPGe detectors, altogether with two $LaBr_3$(Ce) and three ultrafast β-plastic detectors arranged in a close geometry. This configuration is well suited to measure lifetimes of excited states down to the 10 ps via ultra-fast timing methods [1,2].

The excited structure of ^{128}In was populated via the β-decay of the ^{128}Cd 0^+ ground state. In the case of ^{128}Sn, the excited levels were selectively fed only by the β-decay of the precursor ^{128}In $(3)^+$ ground state, excluding the contribution of others β-decaying states due to selection rules imposed by the parent ^{128}Cd 0^+ state. In this contribution, we will inform on the the expanded level-schemes for both ^{128}In and ^{128}Sn. Additionally, we will report on the first direct measurements lifetimes below the nanosecond range in both nucleus. A discussion will be provided on the derived $B(XL)$ transition rates are discussed, and particularly on the lifetime of the first 4^+ stat in ^{128}Sn and the derived $B(E2; 4^+ \to 2^+)$.

Session 11

Electromagnetic dipole transitions in nuclei at finite temperature

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Describing the properties of highly excited nuclei or atomic nuclei at finite temperatures remains one of the most challenging tasks for both nuclear theory and experiment. Understanding the response of nuclei, particularly electromagnetic dipole transitions, under extreme conditions is not only crucial for nuclear physics but also essential for modelling astrophysical phenomena such as stellar and galactic evolution.

To describe temperature effects in electromagnetic transitions, we developed a self-consistent finite temperature relativistic quasiparticle random phase approximation (FT-RQRPA) based on relativistic energy density functional with point coupling interaction [2-3]. We studied the electric dipole (E1) and magnetic dipole (M1) transitions at temperatures ranging from T=0 to 2 MeV for the calcium and tin isotopic chains. Our study revealed that the E1 and M1 responses exhibit significant dependence on temperature. The E1 strength experiences slight modifications within the considered temperature range, while new low-energy peaks emerge in the low-energy region due to thermal unblocking. The M1 strength also undergo significant shifts towards lower energies due to the decrease in spin-orbit splitting energies and the weakening of the residual interaction with increasing temperature. At high temperatures, we observed an intriguing phenomenon in ^{40,60}Ca nuclei: the emergence of M1 excitations. These excitations, which are typically forbidden at zero temperature due to fully occupied (or fully vacant) spin-orbit partner states, became apparent under these conditions. These findings could play a crucial role in modelling gamma strength functions and their applications in astrophysically relevant nuclear reaction studies.

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Session 12

Nuclear giant resonances studied by a self-consistent Skyrme quasi-particle vibration coupling approach

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Nuclear giant resonances provide deep insight in understanding the structure of atomic nuclei as well as constraining the nuclear equation of state (EoS). The giant monopole resonance (GMR) and giant dipole resonance (GDR) provide effective constraints on nuclear incompressibility and symmetry en- ergy slope parameter, respectively. The giant quadrupole resonance (GQR) gives useful information on nucleon effective mass. The quasiparticle random phase approximation (QRPA) model is the most commonly used microscopic model to study the giant resonances of atomic nuclei. However, due to the lack of higher-order many-body correlations beyond the mean field, the resonance width cannot be given, and serious problems are encountered when describing the GMR energies. In this talk, I will introduce how to solve the above problems by developing a self-consistent quasiparticle random phase approximation + quasiparticle vibration coupling model based on Skyrme density functional which considers higher-order many-body correlations. Furthermore, facing to various modes of nuclear giant resonances, the photonuclear reaction is only limited to the study of nuclear dipole excitations, so I will discuss new possibilities to excite different modes of nuclear giant resonances with vortex photons.

Session 12

Nuclear structure and dynamics of the GDR at low temperatures and its influence in the universal abundance of elements

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Astronomical observations indicate that the abundances of heavy elements from barium to lead in metal-poor stars are consistent with the scaled Solar system abundance pattern for the rapid-neutron capture or r-process, where 50% of the heavy elements beyond iron are expected to be produced in stellar explosions such as neutron star mergers. Given that the Sun formed billions of years after these metal-poor stars, from gas that was enriched by many stellar generations in various ways, such an astounding agreement suggests that the way these elements are produced is universal [1-3]. The origin of such an universal abundance pattern was obscured with a couple of scenarios being suggested: 1) An artifact of nuclear properties such as binding energies and β-decay rates. 2) A single cosmic site with astrophysical conditions that are generated uniformly throughout cosmic time. Here we provide a solution to the universal composition of matter through the decreasing binding energy of nuclei at the temperatures occurring in stellar explosions, which arise from a slight increase in the energy of the giant dipole resonance (GDR), a collective motion of protons and neutrons out of phase, which is responsible for the most of the absorption of photons in nuclei and the nuclear dipole polarization. Such changes narrow down the reaction network for element production in stellar explosions, and explain the long-sought universality of elemental abundances [4].

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Session 12

Shedding new light on the structure of ^{56}Ni using (n,3n) reaction at NFS

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Systematic studies of nuclear reactions are essential to the development of nuclear physics. Understanding and predicting the evolution of nuclear structure and the novel phenomena in atomic nuclei has long been a pursuit of scientific curiosity.

Conventional methods such as charged particle probes, β-decay, Coulombic-excitation, and heavy- ion fusion evaporation reactions have been employed so far in the phase space of Shell structure, magic numbers, angular momentum, and excitation energy. However, the horizon of possibilities expands when we delve into the uncharted territories of fast-neutron probes. The (n,xn) reactions are a long-standing reaction mechanism used in the cross-section data evaluation, but rarely used in the framework of nuclear structure.

This might unveil a treasure trove of reactions, particularly the (n,xn) reactions with high production thresholds, which, until now, have not been looked at from the eye of nuclear structures.

As a result, we know very little about their reaction mechanisms.

While the structure of ^{56}Ni has been previously investigated using charged particle and heavy ions collisions as shown in Fig.1 , a pure neutron probe was never used.

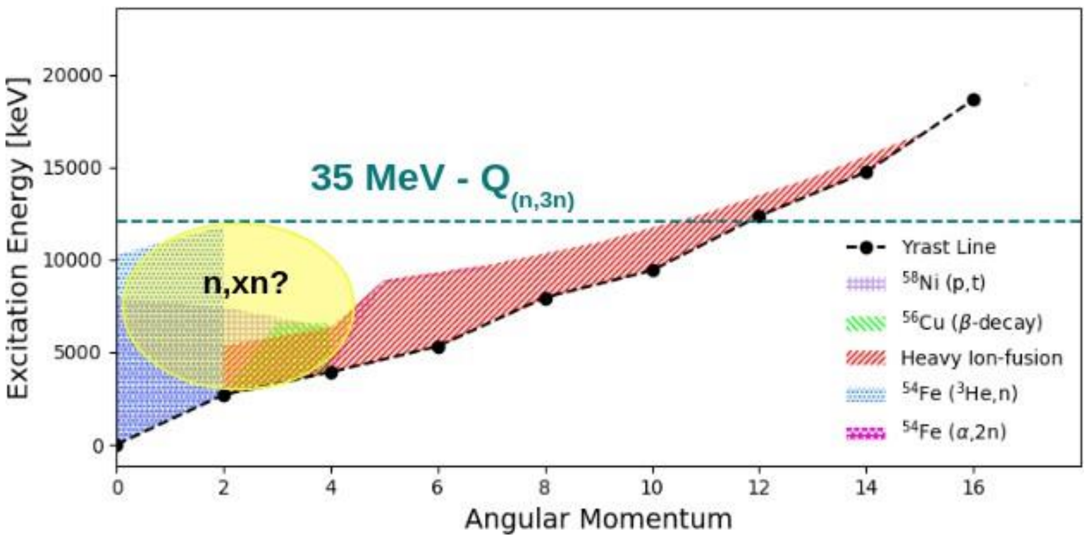

Figure 1: Yrast Diagram

For the first time, using the unprecedented neutron flux at ~20 - 40 MeV at the Neutrons for Science (NFS) facility of GANIL–Spiral2, ^{56}Ni can be populated from ^{58}Ni in a (n,3n) reaction which has a cross-section of 2 mb at ~30 MeV, opening a new probe and possibly new aspects of the nuclear structure of this doubly magic nucleus.

The TALYS cross-section calculation as a function of incident neutron energy is shown in Fig.2.

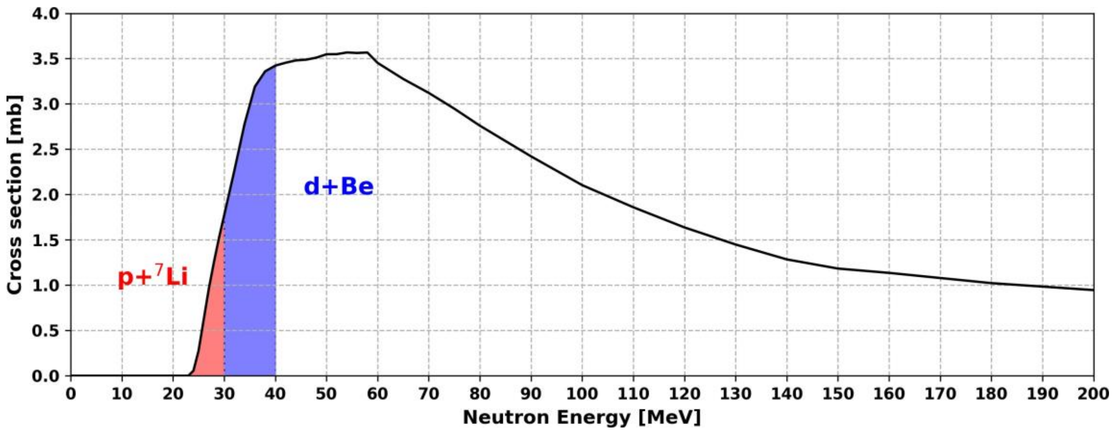

Figure 2: $^{56}Ni\ cross - section$

The maximum cross-section is predicted to be at 40 MeV, slightly higher than the end-point of NFS. p + Li / Be allows reaching the [20-30] MeV range, whereas d + Be allows up to a broader [25-40] MeV range.

With ^{58}Ni target, studying pure neutron channels is the main interest alongside Co isotopes that are produced from (n,p/d/t) reaction.

The nuclei near ^{56}Ni are of particular interest as they are amenable to different microscopic theo- retical treatments while studying the competition between single-particle and collective excitations. The collective states in ^{56}Ni involve multiparticle multi-hole excitations across the $N = Z = 28$ shell gap from the $1f_{7/2}$ shell to the $2p_{3/2}$, $1f_{5/2}$, and $2p_{1/2}$ orbits. Excitation to the higher lying $1g_{9/2}$ orbit are necessary to explain the observed rotational bands in Cu and Zn. At high excita- tion energies, reaction studies have revealed evidence for hyper-deformed resonances in the ^{56}Ni compound.

In this project, we performed prompt-γ spectroscopy of ^{56}Ni using the EXOGAM array at NFS. (From nuclear structure's point of view, the main motivation is the search for low spin J=2 or 4) states from 3 to 10 MeV excitation energy possibly populating the 0^+ states at 3956 keV, 6654 keV and 7903 keV observed only in ^{58}Ni(p,t)^{56}Ni and ^{58}Ni(^{3}He,n)^{56}Ni reactions. New spectroscopic information that will be collected is also relevant for nuclear reaction mechanism formalism (like TALYS) and nuclear data evaluation libraries.

The experiment was carried out in October 2023. During an effective beam time of ~11 days, a high energy neutron beam produced by a primary beam of 10 μAmps of ^{2}H, bombarded a 1mm thick Ni target.

The prompt gamma rays selected on the fastest neutron using the Time of Flight information have been detected by 12 EXOGAM clovers placed at 15 cm off the beam axis.

About 1.6×10^{10} $\gamma\gamma$ coincidences have been sorted after the AddBack procedure.

The ^{56}Ni decay was observed and a large number of $\gamma\gamma$ coincidences for ^{57}Ni and Co isotopes were sorted.

The very preliminary analysis of the experiment, focusing mainly on the pure neutron channels, will be presented.

The (n,2n) channel that produces ^{57}Ni has a much larger cross-section, reaching a maximum of ~90 mb at around 23 MeV, making it easier to study. Additionally, ^{57}Ni is only one neutron away from the doubly magic ^{56}Ni, making spectroscopy of single particle, core-coupled, and collective states of great interest. The primary focus of the talk will be to provide a comprehensive description of its level scheme and excitation functions. This isotope has a half-life of 35.6 hours and undergoes β^+ decay to produce ^{57}Co in the system, which interestingly is also populated by the (n,d) and (n,n$'$p) channels.

The question of whether large germanium volume detectors can be used for γ spectroscopy in a high flux high neutron energy environment will also be addressed.

This experiment is a pioneering work in the study of the nuclear structure studies using large gamma array and fast neutron and is only possible at GANIL-Spiral2 as of today.

If successful, this program will open a new door for nuclear structure studies.

Session 12

Octupole correlations in the neutron-deficient ^{110}Xe nucleus

Andres Illana Sison[1] ; Rosa Maria Perez Vidal[2]

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Octupole correlations near $N = Z = 56$ are unique in sense that they occur between particles in the same orbitals for both neutrons and protons. In this region just above ^{100}Sn, it is expected that enhanced octupole correlations will take place at low and medium spins in the light Te ($Z = 52$), I ($Z = 53$) and Xe ($Z = 54$) nuclei 1. In this region of the nuclear chart, the Fermi surface for both neutrons and protons lies close to orbitals from the $d_{5/2}$ and $h_{11/2}$ subshells; octupole correlations emerge from the interactions of particles in these orbitals with valence neutrons and protons outside the ^{100}Sn core [2, 3]. As a result of the octupole correlations, an enhancement of octupole collectivity is expected to appear. Close to N = Z = 56, a level structure characteristic of octupole correlations, consisting of negative-parity states and enhanced E1 transitions, has been observed in a number of cases including ^{112}Xe [4], ^{114}Xe [5, 6, 7] and ^{118}Ba [8].

With the aim to observe for the first time the octupole band in the neutron-deficient ($N = Z + 2$) ^{110}Xe nucleus, an in-beam experiment was performed at the Accelerator Laboratory of the University of Jyväskylä, Finland. The ^{110}Xe nuclei were produced via the ^{54}Fe(^{58}Ni,2n) fusion-evaporation reaction. The emitted γ rays were detected using the JUROGAM3 γ-ray spectrometer [9], while the fusion-evaporation residues were separated with the MARA separator [10]. In this experiment, we were able to prove the existence of the octupole band via the identification of the low-lying 3^- and 5^- states, and their inter-band E1 transitions between the ground-state band and the octupole band [11]. Hence, this new experimental findings will be presented combined with a detailed study of the systematics of the energy levels and the B(E2)/B(E1) ratios in $^{110-114}$Xe, and a comparison with state-of-the-art theoretical calculations.

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Session 12

Ab initio Green's functions approach for homogeneous nuclear matter

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In this talk, we will present our work at the interface between density functional theory (DFT) and *ab initio* theory. In particular, we will focus on infinite nuclear matter, that we simulate using a description based on a finite number of nucleons, and discuss three research directions [1]:

1. a new *ab initio* Self-consistent Green's function (SCGF) approach, based on the algebraic dia- grammatic construction (ADC) approximation scheme that has proved successful in finite nuclei, is applied to determine the equation of state (EOS) of nuclear matter using chiral interactions [2];
2. we go beyond homogeneous matter, and present results for nuclear matter perturbed by an ex- ternal static potential, the so-called static response problem [3], within the DFT method [4] and, at a preliminary level, within Quantum Monte Carlo;
3. finally, we present our program aimed at the construction of *ab initio*-based energy density func- tionals (EDFs) [1,5], and discuss how the static response offers in principle the possibility to gain information on the surface terms of the EDF *ab initio*.

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Session 13

γ-spectroscopy combining isotopically identified fragments and high fold γ-rays in Nb isotopes - first observation of 1 and 2 phonon γ-vibrational bands in odd-odd nucleus

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The nuclear structure of neutron-rich nuclei around A ∼ 100 shows shape transitions and large defor- mations. Among others, these include ellipsoidal oscillation of the shape (γ-vibrations). One-phonon γ-bands are observed in numerous deformed nuclei, however, observations of two or higher-order phonon γ-bands are rare. While the even-Z nuclei have been well investigated, the spectroscopy of odd-odd nuclei in this region can provide deeper insights into our understanding. As part of a study of the evolution of the structure of even-odd and odd-odd neutron-rich Nb isotopes, the structure of ^{104}Nb was investigated in detail. The Nb nuclei were populated in fission reactions and mea- sured using gamma-ray spectroscopy in two complementary ways using a) isotopically identified fragment produced in beam fusion and transfer induced fission in the ^{238}U+^{9}Be system using the VAMOS++ and the AGATA spectrometer and b) high statistics γ-γ-γ and γ-γ-γ-γ fold data from the spontaneous fission of ^{252}Cf using GAMMASPHERE. The talk will discuss the complementarity of the two methods necessary for studying neutron-rich nuclei at high spin, especially for odd-odd nuclei. The data are then systematically compared with neighboring multi-phonon γ-vibrational bands to address the interesting observation for the first time of multi-phonon vibrational bands in ^{104}Nb.

Session 13

Beta Decay Spectra Measurements for the Study of Reactors' Antineutrino Spectra.

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Recent predictions of reactors $\bar{\upsilon}$ spectra have revealed two irregularities: the Reactor Antineutrino Anomaly (RAA) and the spectral "bump" [1,2,3]. These predictions, calculated with the Huber-Muller Conversion model [4,5], have provoked several doubts about the integrity of experimental data and the accuracy of the models used. In view of this, improved measurements of nuclear data of relevant isotopes, and the use of the Summation Calculation method [6] to determine reactors $\bar{\upsilon}$ spectra, present an alternative to the Conversion model. Calculations of reactors $\bar{\upsilon}$ spectra employing β feedings from standard databases may suffer from the Pandemonium Effect, which can be mitigated by using the Total Absorption Gamma Spectroscopy (TAGS) technique [7].

The decays of a relatively small number of neutron rich fission products contribute the most to reactors $\bar{\upsilon}$ spectra within the regions where the effects of the RAA and the "bump" are stronger [8]. Therefore, to directly determine reliable energy distributions (or shapes) of these β decay spectra, experimental campaigns have been performed at the IGISOL facility (Jyväskylä, Finland) with newly developed telescope detectors. Several β decay spectra of utmost relevance for the study of the RAA and the "bump" have been measured in the I233 (2022) and I233add (2023) experiments.

This presentation is dedicated to introduce the problem of the RAA and the "bump", and how the calculations of reactors $\bar{\upsilon}$ spectra are improved with the use of the Summation method and TAGS β feedings. Preliminary results of the analysis of the data of the I233 experiment will be shown.

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Session 13

TAGS measurements at GANIL with STARS

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Conventional high-resolution techniques for β-decay spectroscopy utilize high-purity germanium detectors to measure individual γ rays emitted after β decay. However, this kind of measurement is affected by the Pandemonium systematic error 1, resulting in many high-energy γ rays and a sig- nificant portion of the β strength being missed. The Total Absorption γ-ray Spectroscopy (TAGS) technique effectively addresses this issue [2, 3]. This method relies on the detection of the full energy of γ cascades following the decay, achieved through the use of large scintillation crystals with high efficiency that act like calorimeters. The TAGS technique allows for a precise determination of the β strength free of Pandemonium. This is a fundamental quantity that depends on the underlying nuclear structure, making it the ideal tool for providing constraints on theoretical models. The tech- nique has been successfully utilized for many years, yielding important results relevant to nuclear structure, nuclear astrophysics, and applications in reactor and neutrino physics (see Ref. [3] for a recent review).

Currently, a new-concept hybrid spectrometer, STARS, is under development within the frame- work of the $(NA)^2$STARS project [4]. STARS will be the first device in the world to combine the large γ efficiency typical of TAGS calorimeters with the excellent energy resolution and timing of $LaBr_3$(Ce) crystals. This unique combination, along with increased segmentation, will enable un- precedented studies further away from nuclear stability, covering a broad range of physics cases and with prospects for use at many international facilities. In particular, our first proposal has al- ready been approved at GANIL: Experiment E891_23 [5], which will be the pioneering measurement performed with STARS. The goal of E891_23 is to measure the β-decay properties of several proton- rich nuclei in the Cr-Zn region, of great interest for nuclear structure (to study isospin symmetry free of Pandemonium in selected Tz=-2 nuclei [6, 7]) and nuclear astrophysics (to constrain reaction rates of interest for the ^{44}Ti nucleosynthesis).

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Session 13

New isomers in ^{213}Tl and ^{215}Tl revealing shell evolution beyond N=126 shell closure

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Experimental data of isomerism in the neutron-rich $N \geq 126$ region are important to test the predictability of shell evolution beyond the N = 126 shell closure by shell-model calculations. Moreover, the predicted properties of more exotic isotopes could affect the abundance of actinides in r-process calculations [1]. However, these information are scarcely available as it is challenging to access this region by current facilities.

We will present new isomeric transitions in the BRIKEN experiment [2] at RIBF, RIKEN Nishina Center. Particle identification of isotopes with mass ranging $200 \lesssim A \lesssim 220$ was confirmed by the BigRIPS separator and the novel silicon dE telescope. For the first time at RIBF, decays of nuclei southeast of ^{208}Pb were measured by the BRIKEN array [3]. New isomers in ^{213}Tl and ^{215}Tl [4] were observed by correlation among implantation, Meitner-Ellis electron [5] and γ events using WAS3ABi active stopper [6] and high-purity germanium (HPGe) clover detector. Our proposed isomeric level schemes [4] are compared to the shell-model calculations [7] to explain shell evolution. Plans to further investigate isomeric transitions and β decays in the same region will be introduced.

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Session 13

Core-breaking effects approaching ^{100}Sn: lifetime measurements in ^{98,100}Cd

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The nuclear structure of doubly magic nuclei such as ^{100}Sn and its neighboring isotopes is of significant interest due to the valuable insights it offers for testing the nuclear shell model. However, describing the nearby Cd isotopic chain poses additional challenges due to the enhanced correlations induced by two proton holes in the $g_{9/2}$ orbit. In particular, ^{98}Cd (Z=48, N=50) stands out as the most proton-rich N=50 isotone for which information about excited states is available, while data on lifetimes remain scarce.

An experimental study with the aim of measuring the lifetimes of low-lying excited states below the 8^+ seniority isomer in the neutron-deficient ^{98,100}Cd isotopes was performed at GSI-FAIR as part of the FAIR Phase-0 program. Ions of interest were populated via a relativistic fragmentation reaction induced by an 839 MeV ^{124}Xe beam. The nuclei were then selected and identified using the FRagment Separator (FRS) and subsequently implanted in the DEcay SPECtroscopy (DESPEC) station. The lifetime measurements were conducted using the FATIMA $LaBr_3$(Ce) array employing the Generalised Centroid Difference (GCD) method.

The obtained results will be discussed and compared with shell model calculations, employing various model spaces and interactions. These comparisons reveal that while ^{98}Cd is consistent with a seniority scheme description, configuration mixing plays a crucial role in describing the measured B(E2) values in ^{100}Cd, with significant contributions from both proton and neutron core excitations.

Session 14

A unified description of the shape phase transitions, shape coexistence and mixing phenomena in nuclei

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The Bohr-Mottelson Hamiltonian [1,2] has been numerically solved for a sextic oscillator potential in the β variable, for both stable and unstable γ-axial deformations [3,4]. The sextic potential, depending on its parameters, presents a single spherical minimum, a flat shape, a single deformed minimum and simultaneously spherical and deformed minima separated by a barrier (maximum) [5,6]. Therefore, the sextic potential is suitable to describe a shape phase transition and its corresponding critical point. Moreover, only by increasing step by step the barrier, which separates the two minima, one can cross from the critical point of the shape phase transition to the shape mixing and coexistence phenomena [7]. The model has also the ability to describe unusually small B(E2) transitions, observed in some nuclei, by assuming that states of the same band have different quadrupole deformation [8,9]. Until now, the model has been applied to a number of nuclei known to manifest such phenomena: ^{238}Pu, ^{152}Nd, ^{170}Hf [3], ^{76}Kr [7], ^{96,98,100}Mo [4], ^{72,74,76}Se [8], ^{74}Ge, ^{74}Kr [10], ^{80}Ge [9] and ^{42,44}Ca [11]. All these results are very promising for future applications and developments of the model.

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Session 14

Shape coexistence and the onset of deformation around A=100: comparing even-even and odd-even cases

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Shape of nuclei is determined by a fine balance between the stabilizing effect of closed shells and the pairing and quadrupole forces that tend to induce deformation [1]. In the mass region around A=100, there exist clear cut examples of the rapid appearance of deformation such as Zr (even-even) [2] and Nb isotopes (odd-even) [3], which can be understood in terms of the coexistence of two different configurations, i.e., shape coexistence. Sr [4] isotopes are also good candidates to study the onset of nuclear deformation and the influence of shape coexistence, while Ru and Mo [5] isotopes seem to be placed at the border of dilution of shape coexistence. In addition, the structural evolution of odd-mass isotopes in this region is significant due to the diversity of configurations and coexisting shapes and to the enhancement of the onset of deformation [3].

In this contribution will be used as framework the Interacting Boson-Fermion Model [6] with Configuration Mixing (IBFM-CM) to introduce a mean-field view (intrinsic state) for studying the evolution of the nuclear deformation in A=100 region, focusing on the case of odd-even Nb isotopes. Two complementary approaches will be used for studying shape evolution: first, an algebraic approach employing a laboratory frame of reference, and secondly, a geometric-oriented method within the context of an intrinsic state formalism. The objective is to compare the onset of deformation in Nb isotopes with the even-even cases, such as Sr and Zr, extracting information from the intrinsic state, but also from spectroscopic properties.

To conclude, by applying the IBFM-CM framework and employing both algebraic and geometric approaches, this contribution aims at providing insights into the evolution of nuclear shapes in even-even and odd-even nuclei in the mass region around A=100.

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Session 14

Mass measurements of N = 50 isotones and its implications in the nuclear structure around ^{100}Sn

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Mass spectrometry is invaluable for probing the essential characteristics of nuclei, particularly their binding energy. The FRS Ion Catcher at GSI employs a Multiple-Reflection Time-of-Flight Mass Spectrometer (MR-TOF-MS) to achieve precise, fast, and sensitive mass measurements, crucial for studying exotic nuclei far from stability. Previous investigations, have scrutinized properties of nuclei surrounding the heaviest N=Z double-magic nucleus, ^{100}Sn [Horn], revealing discrepancies in properties like Q_{ec} and production cross-sections [Hinke, Lubos].

The stability of nuclei along the N=Z line persists up to ^{40}Ca (N=Z=20), beyond which, instability prevails. This increasing divergence from stability poses challenges for both production and measurement techniques in reaching the heaviest N=Z nuclei. In a recent study it was possible to determine the mass value of ^{100}In, based on this and trends in the shifted two-neutron separation energy, the older Q_{ec} value for ^{100}Sn is favoured [Moug]. In the study that will be presented, mass measurements of isotones along the N=50 line (44≤Z≤48) approaching ^{100}Sn were conducted, yielding measurements for 14 ground and two isomeric states [Moll].

The excitation energy of the long-lived isomer in ^{94}Rh was determined for the first time and together with shell model calculations allowed a spin-parity assignment of the observed states.

First direct mass measurement of ^{98}Cd provided a much more accurate and trustful Q_{ec} value than previous mass measurement methods. Systematic investigations of the shifted two-neutron shell-gap, utilizing the newly acquired masses were performed, confirming the results of the previous study, favouring specific Q_{ec} values [Hinke]. Moreover, the Q_{ec} value obtained for ^{98}Cd was also employed to analyze the Gamow-Teller (GT) strength trend along the N=50 isotones, which also has been compared to new state-of-the art calculations utilizing a large-scale shell model (LSSM). This results strongly support the newer Q_{ec} values measured for ^{100}Sn [Lubos].

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Session 14

Lifetime measurements in the A ~ 100 mass region via the coincidence Doppler-shift attenuation method

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The coincidence Doppler-shift attenuation method (CDSAM) is a powerful technique for determining nuclear level lifetimes in the femtosecond regime [1,2].

At the SONIC@HORUS setup [3] at the University of Cologne, several (p,p'γ)- and (α, α'γ)-CDSAM experiments have been performed with a focus on the A ≈ 100 mass region, including Zr, Ru, Pd, Sn, and Te isotopes [4,5,6]. The combined SONIC@HORUS spectrometer allows for coincident detection of γ rays and backscattered beam particles, enabling background reduction, precise transition selection and feeding exclusion. From each experiment, dozens of lifetimes can be determined. Additionally, the analysis of particle-γ-γ coincidences enables thorough and comprehensive spectroscopy. In this contribution, recent results on lifetime determination and spectroscopy will be presented, highlighting the benefits derived from coincidence measurements.

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Session 14

Detailed structure of ^{131}Sn populated in the β-decay of isomerically-purified ^{131}In states

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Nuclei with a large N/Z ratio are of great interest to test nuclear models and provide information about single particle states far off stability. During the last two decades there has been a substantial effort directed to gathering information about the region around the neutron-rich ^{132}Sn [1-3]. Lifetimes of excited states provide direct access to the reduced transition probabilities of γ transitions, which play an important role in the investigation of nuclear structure and the nucleon-nucleon effective interaction. The information available for the tin isotopes around ^{132}Sn is scarce.

The excited structure of ^{131}Sn was investigated in detail at the ISOLDE facility at CERN. We profited from the selective ionization by the ISOLDE Resonance Ionization Laser Ion Source (RILIS) [4] to enhance the production of each particular isomer in ^{131}In, and study its decay separately for the first time. This measurement took place at the new ISOLDE Decay Station (IDS), equipped with four highly efficient clover-type Ge detectors, along with a compact fast-timing setup consisting of two LaBr3(Ce) detectors and a fast β-plastic detector [5-8].

In this contribution we will report on the first measurement of subnanosecond lifetimes in ^{131}Sn. A noticeable short half-life was derived for the $\nu 3s_{1/2}^{-1}$ single-hole state, indicating an enhanced l -forbidden M1 behaviour for the $\nu 3s_{1/2}^{-1} \rightarrow \nu 3d_{3/2}^{-1}$ transition [9-11]. The measured half-lives of high-energy states, provided valuable information on transition rates, supporting the interpretation of these levels as core-excited states. In the other hand, the unambiguous separation of the decay provided an unique opportunity to disentangle the decay scheme of each ^{131}In isomer. The extended level-schemes, the position of the $\nu 1h_{11/2}^{-1}$ single-hole state [12], as well as the observed correlation between n/γ competition above the neutron-separation energy and the parent populating indium state will be discussed. Additionally, a revision of β-decay properties, such as log ft of the first-forbidden single-particle transitions, half-lives and P_n values for the three ^{131}In β-decaying states will be addressed.

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Session 14

The shell model in a quantum computer

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The nuclear shell model is one of the prime many-body methods to study the structure of atomic nuclei, but it is hampered by an exponential scaling on the basis size as the number of valence particles increases. I will discuss a quantum circuit design strategy to find nuclear ground states by exploiting an adaptive variational quantum eigensolver algorithm. This circuit implementation is in excellent agreement with classical shell-model simulations for a dozen of light and medium-mass nuclei, including neon and calcium isotopes. Simulated circuits approach the benchmark results with a polynomial scaling in quantum resources for each nucleus. I will also discuss entanglement measures, their connection to nuclear structure observables as well as potential strategies to exploit entanglement forging in nuclear physics. This work paves the way for quantum computing shell-model studies across the nuclear chart.

Session 15

Nuclear structure with AGATA using post-accelerated radioactive beams

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AGATA (Advanced Gamma-ray Tracking Array, www.agata.org) is the European forefront instrument for high-resolution γ-ray spectroscopy based on high-purity segmented germanium detectors. Thanks to its fine segmentation, digital data acquisition electronics and pulse-shape analysis techniques, AGATA can track the path of a gamma ray inside the spectrometer to reconstruct its emission angle as well its full energy. This ensures an unprecedented combination of detection efficiency and resolving power. AGATA is a travelling instrument, used to perform experimental campaigns at leading European nuclear research facilities. Its importance will further increase in the future as AGATA is particularly suited for experimental conditions expected at the future facilities delivering intense radioactive ion beams as well as high-intensity stable ion beams, which are currently under construction in Europe. AGATA is presently its second phase of construction with the goal of constructing a 3-pi array by 2030 [1-3].

AGATA was located between 2014 and 2021 at the GANIL facility, Caen-France. Combined to the high resolution MUGAST charged particle array [4] and the VAMOS magnetic spectrometer, a large campaign of in-beam spectroscopy was performed using the post-accelerated radioactive beams from the SPIRAL1 facility. The physics subjects cover the spectroscopy of un-bound states, astro- physics, shell evolution and the role of the 3-body term in ab-initio calculations. Published and unpublished results will be presented [5].

The current experimental campaign is running at LNL until end of 2026. Beyond that horizon, the AGATA collaboration will decide the next location of the array. Possible candidates are European radioactive beams facilities such as SPES with post-accelerated fission fragments, GANIL with light post-accelerated RIBs from SPIRAL1, GSI/FAIR, and the University of Jyvaskyla or HIE-ISOLDE at CERN. The specific strengths of each of these installations as well as envisaged physics cases are described in the AGATA White Book [3].

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Session 15

Lifetime measurements after transfer reactions with AGATA at LNL

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The lifetimes of nuclear excited states are directly related to electromagnetic transition probabilities and their determination has strong impacts on our understanding of nuclear structure and of a variety of astrophysical scenarios.

At the Legnaro National Laboratories of INFN in the last 2 years an extensive experimental campaign has been carried out with the γ-ray tracking array AGATA [1] coupled to the magnetic spectrometer PRISMA [2] and other ancillary detectors, such as Silicon arrays, MCP detectors and scintillators [3]. In this configuration, one-, two- and multi-nucleon transfer reactions with beam energies between 5 and 10 MeV/u have been largely exploited to populate moderately exotic nuclei along the whole nuclear chart. Following these reactions, the lifetime of selected nuclear excited states, lying in a wide range between 1 fs to 100 ps, has been measured with the Recoil Distance Doppler Shift method or the Dopper Shift Attenuated Method.

In the talk I will present few selected cases from the last experimental campaigns and show the possibilities and performance offered by the set-up, together with some preliminary results. Possible perspectives, also in view of the future experimentation with the radioactive ion beams delivered by SPES [4], will be discussed.

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Session 15

Prompt and delayed gamma-ray spectroscopy of neutron-rich Au isotopes populated from multi-nucleon transfer reaction

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The investigation of neutron-rich nuclei situated below ^{208}Pb is anticipated to unveil a spectrum of phenomena, from shape evolution to the existence of exotic shapes and coexistence, which manifest from nuclear interaction. Additionally, nuclides' vicinity to the N=126 shell closure is linked to understanding the r-process path towards actinides. Although its importance is well recognized, only limited knowledge of the excited states is available, restricting comprehensive understanding. Despite the acknowledged importance of this realm, our understanding remains restricted primarily due to challenges in the production of such isotopes. Furthermore, the available excited states of known isotopes are limited to decay spectroscopy.

To address these limitations, a novel experiment was performed at GANIL aimed at exploring isotopes of interest via multi-nucleon transfer reactions between a 7 MeV/u ^{136}Xe beam and a ^{198}Pt target. The large acceptance VAMOS++ magnetic spectrometer and AGATA Ge tracking array were used to measure excited states of nuclides of interest. Several new experimental techniques were implemented. First, a new second arm ToF spectrometer was installed, which is composed of a 1.2 m long vacuum chamber and large area multi-wire proportional counter to measure the velocity vector of the target-like fragments. Second, a four EXOGAM clover HPGe array was installed at the end of the second arm to measure the delayed gamma rays from the excited states. Finally, a new method to determine particle identification was developed using a machine learning algorithm, where energy and charge states are determined using supervised machine learning, and atomic numbers are determined by the unsupervised learning method.

Among the plethora of populated isotopes, particular attention was devoted to the nuclear structure of odd-mass Au isotopes. The structure of Au isotopes has the longest chain of odd-mass isotopes with excited state information; showcasing proton-hole states with nearly constant energies across varying neutron numbers, but the neutron-rich part of information is limited near the stable isotope ^{197}Au. The preliminary results of several neutron-rich Au isotopes, such as their level structure, will be presented.

Session 15

Some aspects of the structure of neutron-rich F isotopes in the Particle-Rotor Model

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In this talk, we will discuss some aspects of the structure of neutron-rich F nuclei within the frame- work of the particle plus rotor model. Specifically, the low-lying structure of ^{25,27,29}F can be understood in the rotation-aligned coupling scheme with their $5/2^+$ ground states as the bandhead of a decoupled band [1,2].
The excitation energies of the $1/2^+$ and $9/2^+$ states correlate strongly with the rotational energy of the effective core, seen by the odd proton, and allow us to estimate its 2^+ energy. The Nilsson plus PRM picture suggests that the extra proton, with a dominant component in the down-sloping [220]1/2 level polarizes the Oxygens and stabilizes its dynamic deformation. Thus, the effective cores could be interpreted as slightly deformed rotors with a modest $e^2 \approx 0.15$, as compared to the weak vibrational quadrupole collectivity in the real Oxygens.
Relevant to this interpretation are the recent studies of the ^{25}F(p,2p) ^{24}O and ^{25}F(-1n KO)^{24}O reactions carried out at RIBF/RIKEN [3] and NSCL/MSU [4] respectively. Derived spectroscopic factors suggest that the effective core of ^{25}F significantly differs from a free ^{24}O nucleus. The observed fragmentation of the $\pi d_{5/2}$ single-particle strength agrees with the PRM calculations and arises from the effects of deformation and core overlap.
We will also present results of the two-particles plus rotor model for odd-odd ^{28}F [5] and ^{30}F [6] and discuss further experiments that can shed further light on the validity of our interpretation.
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Session 16

In-source laser spectroscopy @ ISOLDE: studies of shape coexistence and shape evolution across the lead region

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Laser spectroscopy is a powerful tool for studying how structures of ground and isomeric states evolve across the chart of nuclides [1]. By measuring isotope shifts and hyperfine structures we can deduce fundamental properties such as nuclear spins, changes in mean-squared charge radii and electromagnetic moments, all in a model-independent way. Such data are excellent tests for theory, providing wide-ranging benchmarks to compare model predictions to [2].

I will introduce the in-source resonance ionisation technique used at CERN's ISOLDE facility [3] – a highly efficient method, which when combined with the sensitivity of decay stations [4] or mass spectrometry devices [5], allows access to exotic nuclides with extremely low production rates. Results will be presented from campaigns of experiments of isotopes in the proton-rich Pb (Z=82) region, a hot bed of nuclear structure phenomena that produce striking changes in nuclear ground-state deformation. Highlights will be given from studies of the charge radii of gold and bismuth isotopes, along with accompanying Hartree-Fock-Bogoliubov calculations that attempt to describe the trends in radii throughout the region [6].

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Session 16

Global properties of nuclei and drip lines at finite temperature

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In stellar environments nuclei appear at finite temperatures, becoming extremely hot in core-collapse supernovae and neutron star mergers. However, due to theoretical and computational complexity, most model calculations of nuclear properties are performed at zero temperature, while those existing at finite temperatures are limited only to selected regions of the nuclide chart. Recently a theoretical framework has been established for the description of properties of hot nuclei, based on the relativistic nuclear energy density functional (RNEDF) and finite temperature relativistic Hartree-Bogoliubov model supplemented by the continuum subtraction procedure. A variety of nuclear properties have been investigated, including nuclear binding energies, neutron emission lifetimes, quadrupole deformations, neutron skin thickness, proton and neutron pairing gaps, entropy and excitation energy. At lower temperatures the nuclear landscape is influenced only moderately by the finite-temperature effects, mainly by reducing the pairing correlations. As the temperature increases, the effects on nuclear structure become more pronounced, reducing both the deformations and the shell effects. It is also important to understand where are the limits of nuclear binding in hot stellar environments. Recently the nuclear drip lines have been mapped at temperatures up to around 20 billion kelvins in the RNEDF framework including treatment of thermal scattering of nucleons in the continuum. With extensive computational effort, the drip lines have been determined using several RNEDFs with different underlying interactions, demonstrating considerable alterations of the neutron drip line with temperature increase, especially near the magic numbers. At temperatures less than around 12 billion kelvins, the interplay between the properties of nuclear effective interaction, pairing, and temperature effects determines the nuclear binding. At higher temperatures, surprisingly the total number of bound nuclei increases with temperature due to thermal shell quenching effect. The nuclear drip lines for hot nuclei appearing in stellar environments should be viewed as limits that change dynamically with temperature. Nuclear excitations and weak interaction processes also display sensitivity on the finite temperature effects.

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Session 16

Lifetime measurements in the N=126 region with the reversed plunger configuration

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A novel technique has been developed to measure lifetimes of heavy neutron-rich nuclei, namely 'the reversed plunger'. In heavy neutron-rich nuclei, information on the lifetimes of low-lying excited states is scarce since these nuclei are difficult to populate. Among different reaction mechanisms, multi-nucleon transfer reactions have shown to be the perfect tool to explore such regions. Therefore, profiting from the kinematics of such reactions and the plunger device in the reversed configuration, lifetimes of excited nuclear states of the order of picoseconds can be measured.

This technique was employed for the first time at Laboratori Nazionali di Legnaro to measure lifetimes of low-lying excited states of nuclei with a mass of around 190, where shape transitions from prolate to oblate are expected to occur along different isotopic chains while approaching the N=126 shell closure.

A beam of ^{136}Xe with the energy of 1134 MeV passed through a degrader foil of ^{93}Nb with a thickness of 3.2 mg/cm^2 and impinged into a ^{198}Pt target 1.4 mg/cm^2 thick. Beam-like fragments entered the PRISMA spectrometer where they were identified in mass, atomic number, and velocity, while the target-like fragments (the heavy nuclei of interest) traveled towards the degrader foil where they were stopped. Gamma rays were measured with the AGATA tracking array composed of 33 segmented HPGe detectors. Among the nuclei populated in this experiment is ^{198}Pt, for which the lifetimes of the low-lying excited states are known, and can be used as a benchmark to validate the use of the proposed technique.

This work reports the lifetimes of the 2^+, 2^+ and the 4^+ states of ^{198}Pt measured with the reversed plunger configuration, employing the standard analysis procedures: the Decay Curve Method and the Differential Decay Curve Method. The agreement of our results with the literature data demonstrates the capability of this technique to further investigate the nuclear structure of heavy neutron- rich nuclei.

Session 16

Double-gamma decays of double-beta decay emitters: can they be measured?

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Recently, some theoretical nuclear structure works have pointed out the relation between the nuclear matrix elements of neutrinoless double-beta decay, a much sought-after nuclear decay that emits two matter particles without antimatter [1,2], and the corresponding matrix elements of double-gamma decay from the double isobaric analog states (DIAS) of the initial double-beta decay nuclei [3,4]. However, the DIAS appear at high excitation energies, and their double-gamma decay competes with faster decay channels such as particle emission or single-gamma decay, making their measurement very challenging.

In this talk I will present recent results [5] comparing the width of the double-gamma decay of DIAS of double-beta emitters and these competing channels, focusing on the lightest ^{48}Ti but also covering heavier nuclei. Our preliminary results support the feasibility of measurements of double-gamma decay of DIAS, which can provide very previous insights on the nuclear matrix elements of neutrinoless double-beta decay.

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Session 16

First Observation of New Isotopes at FRIB: What Comes Next?

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The Facility for Rare Isotope Beams (FRIB) [1] is a US Department of Energy User facility providing primary, heavy-ion beams with energies up to 300 MeV/u (typically 250 MeV/u for most mid-mass beams). Typical beam intensities are 500 pnA with plans to increase to 20,000 pnA. This capability positions FRIB as a pivotal resource for accessing a broad spectrum of rare isotope beams. Herein, we present the first observations of new isotopes at FRIB [2], achieved through the interaction of a ^{198}Pt beam with a carbon target at 186 MeV/u and a beam power of 1.5 kW, which is equivalent to 41 pnA. This discovery, occurring within FRIB's inaugural year, underscores its potential for research with beams of rare isotopes. We detail the particle identification process for reaction products, employing event-by-event analysis of energy loss, time of flight, magnetic rigidity, and total kinetic energy, and compare these findings to those from the National Superconducting Cyclotron Laboratory (NSCL) with a ^{198}Pt beam at 85 MeV/u [3]. Moreover, we discuss the efficacy of a multi-step reaction scheme for probing the neutron-rich region, highlighting the Abrasion-Ablation model's role in predicting production cross sections for previously unobserved isotopes. This discussion integrates the latest theoretical and experimental insights, alongside computational advancements. The evolution of FRIB's capabilities, marked by the transition to full intensity, heralds a new era for the exploration of rare isotopes, promising significant contributions to nuclear physics.

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