13th International Spring Seminar on Nuclear Physics
”Perspectives and Challenges in Nuclear Structure after 70 Years of Shell Model”
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Book of Abstracts

View of the Island of Ischia from the sea, Plate XXX, from "Campi Phlegraei: Observations on the Volcanoes of the Two Sicilies", by Sir William Hamilton. Naples : P. Fabris, 1776.

Ab-initio electroweak reactions with nuclei

Content

The past decade has witnessed tremendous progress in the theoretical and computational tools that produce our understanding of the nucleus as a compound object of interacting protons and neutrons. A number of ab initio calculations of nuclear electroweak properties that started from interactions and currents obtained from chiral effective field theory have successfully described key experimental observables, yielding a complete picture of how nuclei interact with electroweak probes. The level of accuracy and confidence reached by ab initio calculations opens up the concrete possibility of using nuclear theory to help address open questions in other sub-fields of physics, such as neutrino physics.

In this talk we will present our recent results for the charge and weak form factors of the 40Ar nucleus and for electron- and neutrino-nucleus cross section for 16O and 40Ca.

Primary author: BACCA, Sonia (Johannes Gutenberg University)

Presenter: BACCA, Sonia (Johannes Gutenberg University)

Multiple shape coexistence in the Cd isotopes

Content

Recent detailed spectroscopy of ^{110,112}Cd via β decay measurements focused on the observation of weak, low-energy decay branches from levels at high excitation energy [1,2]. Combined with level lifetimes (or limits) determined using the (n,n$'\gamma$) reaction, $B(E2)$ values were deduced for a large number of transitions, permitting the assignment of levels into rotational-like bands. In particular, bands built on excited 0^+ states were assigned, and candidates for "$K = 2$" structures built on the ground and 0_2^+ states were also suggested. These results were interpreted through comparison with beyond-mean-field calculations that predicted the 0^+ states in ^{110,112}Cd possess shapes ranging from deformed prolate, oblate, and triaxial, and the excitations built on them are rotational in nature. Other studies [3] of the lighter Cd isotopes have also suggested a multiple shape coexistence scenario. Examining the systematics of the levels across the Cd isotopic chain, it is suggested that multiple shape coexistence may be present in many of the Cd isotopes [4].

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CLUSTER STRUCTURE OF LIGHT NUCLEI

Content

The cluster structure of light nuclei will be examined. Analytic formulas to describe energy levels, electromagnetic transition rates and form factors in kα-structures with k=2-5 will be presented. These formulas depend on the geometric arrangement of the constituent particles. Formulas appropriate to k=2 (linear with Z_2 symmetry), k=3 (equilateral triangle with D_{3h} symmetry) [1-2], k=4 (tetrahedron with T_d symmetry) [3-4] and k=5 (bi-pyramid with D_{3h} symmetry) [5] will be given and experimental evidence for the occurrence of these symmetries in ^{8}Be, ^{12}C, ^{16}O and ^{20}Ne will be presented.
In the second part of the presentation, current work on clustering in kα-structures + x-neutrons or protons, specifically k=2, x=1 (^{9}Be and ^{9}B) [6], k=3, x=1 (^{13}C and ^{13}N) [7], k=4, x=1 (^{17}O and ^{17}F) and k=5, x=1 (^{21}Ne, ^{21}Na) [8] will be discussed. This work includes the determination of intrinsic states, χ_Ω, and energies, ϵ_Ω, in cluster potentials with Z_2, D_{3h} and T_d symmetry, which form the basis for a cluster shell-model (CSM) [9], and the construction of the rotation-vibration energy levels built on top of these intrinsic states.
The work presented in this talk provides further evidence for the role of symmetries in nuclei.

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Direct measurement of the $^{13}C(\alpha,n)\ ^{16}O$ reaction in the Gamow window of the s-process nucleosynthesis

Content

The $^{13}C(\alpha,n)\ ^{16}O$ reaction is the main neutron source for the slow-neutron-capture s-process in Asymptotic Giant Branch stars. Direct measurements at astrophysical energies in above-ground laboratories are hindered by the extremely small cross-section and cosmic-ray induced background. By using the high-intensity LUNA 400 accelerator installed at Gran Sasso National laboratory we obtained an accurate cross section measurements in energy range from $E_{c.m.}$= 233 keV up to 306 keV with an uncertainty better than 20%.
In this talk the experimental techniques and the results of the LUNA measurement will be presented, together with the astrophysical impact of new revised reaction rate.

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Studies of Heavy Pear-Shaped Nuclei at ISOLDE

Content

For certain combinations of protons and neutrons it is expected that the shape of atomic nuclei can undergo octupole deformation, which would give rise to reflection asymmetry or a "pear shape". In this talk I will describe how recent experiments carried out at CERN using REX-ISOLDE [1] and HIE-ISOLDE [2,3,4] and the Miniball gamma-ray spectrometer have provided evidence that several radium and radon isotopes have either stable pear shapes or are octupole vibrational in nature. I will show that our data on transition moments present some challenges for theory. I will also briefly talk about the relevance of our measurements for atomic EDM searches, and discuss the future prospects for this field.

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Primary author: BUTLER, Peter

Presenter: BUTLER, Peter

^{33}Cl spectroscopic factors via the ^{32}S(^{3}He, d)^{33}Cl one-proton transfer reaction

Content

The structure of light-to-medium mass nuclei is crucial to understand exotic phenomena in nuclear structure, including the appearance of molecular effects in light nuclei and their impact in nuclear astrophysics. In this talk, a new experiment to probe one-proton spectroscopic factors of bound and unbound states in the sd-nucleus ^{33}Cl is discussed. The experiment exploits the reaction ^{32}S(^{3}He, d)^{33}Cl* at 9.68 MeV bombarding energy. This reaction is suitable to probe the single-particle structure of ^{33}Cl states with respect to the population of $1d_{3/2}$, $1f_{7/2}$ and $2p_{3/2}$ shells. Crucial aspects of the investigation are the use of an enriched, high-purity, ^{32}S target and a new generation hodoscope with improved angular resolution, allowing to obtain high-precision angular distribution of the differential cross section in a broad angular range. Results are interpreted by means of finite-range DWBA and coupled-channel calculations. The talk will also discuss recent developments of hodoscopes for the detection of light charged particles particularly useful to perform similar studies.

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Presenter: DELL'AQUILA, Daniele (Istituto Nazionale di Fisica Nucleare)

Possible evidence for a toroidal electric dipole mode in 58Ni

Content

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There are nuclear collective excitations which owe their existence to the quantum nature of finite-particle systems. Examples are the orbital M2 twist mode [1] and the toroidal E1 mode [2]. Their experimental verification is of general interest since their existence invalidates fluid-dynamical interpretations of giant resonances. A toroidal E1 mode in nuclei with vortex current distributions is predicted by semiclassical [3] as well microscopic [4] models as a general phenomenon in all but the lightest nuclei. Detection of the mode is complicated by the strong mixture with the excitation of the giant dipole resonances and - in heavy nuclei with neutron excess - with the pygmy dipole resonance. Thus, possible proof is presently indirect at best [5]. Clearly, transverse electron scattering is the most promising experimental observable to demonstrate the existence of such a mode [6]. Recent theoretical studies suggest that in lighter nuclei without a pygmy dipole resonance on can find rather pure toroidal excitations amongst the lowest E1 transitions [7]. The present work reports a combined analysis of the low-energy E1 strength in 58Ni with high-resolution (p,p') [8], (γ,γ') [9] and (e,e') [10] experiments, which allows to uniquely identify such candidates and demonstrate their transverse nature in electron scattering.

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Microscopic optical potentials: recent achievements and applications.

Content

Nucleon elastic scattering is a very important process to understand nuclear interactions in finite nuclei. Even if this process has been extensively studied in the last years, a consistent microscopic description is still under development.
In this perspective, our long term project was to study the domain of applicability of microscopic two- and three-body chiral forces in the construction of an optical potential (OP) with the ultimate goal to obtain a consistent description of both the target and the projectile-nucleus dynamics.
In general, the OP is obtained as the first-order term within the spectator expansion of the multiple scattering theory and adopting the impulse approximation.
As a first step, we derived a nonrelativistic theoretical optical potential from nucleon-nucleon chiral potentials at fourth (N3LO) and fifth order (N4LO). We checked convergence patterns and establish theoretical error bands for Wolfenstein amplitudes and the cross sections, analyzing powers, and spin rotations of elastic proton scattering off some light nuclei at an incident proton energy of 200 MeV [1,2]. Then, we extended our analysis to the cross sections and analyzing powers of calcium, nickel, tin, and lead isotopes exploring the range $156 \leq E \leq 333$ MeV, where experimental data are available. In addition, we provided theoretical predictions for ^{56}Ni at 400 MeV, which is of interest for the experiments at EXL [3].
In the last years we explored the impact of three-body forces [4] and how the developed formalism could be applied to non-zero spin targets [5].
In conclusion, we also performed some predictions for antiproton elastic scattering off nuclei at energies close to 200 MeV [6], in remarkable agreement with experimental data. Recent works in connection with the Ab-Initio Self-Consistent Green Functions method will also be presented [7]. Our results clearly indicate that microscopic optical potentials derived from nucleon-nucleon chiral potentials can provide reliable predictions for the cross section and the analyzing power of stable and exotic nuclei.

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Collective states with platonic shapes and 1p1h configurations in the heavy nucleus 208Pb

Content

About fifty neutron bound states in ^{208}Pb are excited in a collective manner. The majority (about 80%) is described by the shell model as 1p1h configurations.
At least three excited 0^+ states are known but are not expected in the shell model. About 500 states at $E_x < 8.0$MeV (below the proton threshold) are known [1-4]. They have spins from 0^- to 14^- and 1^+ to 12^+.
A recent experiment with the Q3D magnetic spectrograph at Garching (Germany) revealed states up to E_x = 7.6 MeV (shortly above the neutron threshold) with spins from 0^- to 6^-.
Collective states with spins 10^+, 12^+, 15^+, 18^+ are newly recognized as icosahedral configurations [5]. A dozen tetrahedral configurations were recognized by comparison to ^{16}O [6] and ^{40}Ca.
Excitation energies calculated by the shell model using SDI [7-8] deviate from observation for most states by less than 0.1 MeV. Evidence is given for the discrepant deviation of the excitation energy for several yrast and yrare states from shell model calculations [3-4].
The coupling of the collective 3^- yrast state with 1p1h configurations describes two dozen states at $E_x \approx 6.0$ MeV [9]. The weak coupling model (WCM) introduced by de-Shalit describes highly excited states in ^{208}Pb by couples of collective excitations and 1p1h configurations [10].
The three lowest members of the tetrahedral rotation band were recognized recently [6]. Six members of the icosahedral rotation band were identified by the knowledge of available experimental data [1,3-4] and recognizing the congruence the very selective occurrence of spins in molecules [11] within the heavy nucleus ^{208}Pb [5].
In nearly thirty levels observed by deep inelastic scattering on ^{208}Pb [12] at $E_x < 7$ MeV states are identified. Spin and composition are described by the weak coupling of tetrahedral and icosahedral collective excitations and up to three 1p1h configurations. Several identifications from [12] were changed by the recognition of icosahedral configurations [5]. The mean deviation of the calculated excitation energy from observations is $\langle \Delta E_x \rangle = -0.02$ MeV.

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Primary author: HEUSLER, Andreas

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Evidence of the Triaxial Structure of 129Xe at the Large Hadron Collider

Content

The interpretation of the emergent collective behavior of atomic nuclei in terms of deformed intrinsic shapes is at the heart of our understanding of the rich phenomenology of their structure, ranging from nuclear energy to astrophysical applications across a vast spectrum of energy scales. A new window into the deformation of nuclei has been recently opened with the realization that nuclear collision experiments performed at high-energy colliders, such as the CERN Large Hadron Collider (LHC), enable experimenters to identify the relative orientation of the colliding ions in a way that magnifies the manifestations of their intrinsic deformation [1]. In this work, we apply this technique to LHC data on collisions of ^{129}Xe nuclei to exhibit the first evidence of nonaxiality in the ground state of ions collided at ultrarelativistic energies [2].

More precisely, we first perform state-of-the-art beyond-mean-field calculations for the nuclei ^{129}Xe and ^{208}Pb exploring the variational space of triaxial Bogoliubov quasi-particle states projected onto a good number of particles and a good angular momentum [3]. The nuclear Hamiltonian is taken to be the SLyMR1 parametrization of a phenomenological Skyrme-type pseudopotential [4]. Then, we use the knowledge of the structural properties of these nuclei to perform Monte Carlo simulations of millions of high-energy ^{129}Xe + ^{129}Xe and ^{208}Pb + ^{208}Pb collisions. Finally, comparing our results with LHC data obtained by the ATLAS Collaboration [5], we demonstrate that the later are only compatible with a triaxial deformation ($\beta \approx 0.2$, $\gamma \approx 30°$) for the ground state of ^{129}Xe, which is in good agreement with our nuclear structure calculations as well as recent experimental results from Coulomb excitation of the adjacent isotope ^{130}Xe [6].

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Zr isotopes as a case study for intertwined quantum phase transitions

Content

The zirconium isotopes with $A = 92-110$ have one of the most complicated evolutions of structure in the nuclear chart.
In this talk I will discuss our latest work on these isotopes, where we explain their structural evolution using the notion of intertwined quantum phase transitions (IQPTs), for which a QPT involving a crossing of two configurations (Type II QPT) is accompanied by a shape evolution of each configuration with its own separate QPT (Type I QPT). We find that the Type I QPT takes place within the intruder configuration, which changes from weakly deformed to prolate deformed and finally to γ-unstable. Alongside the Type I QPT, we also find the occurrence of Type II QPT between the normal and intruder configurations, where both Types I and II have a critical-point near $A \approx 100$. By using a definite symmetry-based framework, the interacting boson model with configuration mixing (IBM-CM), we compare our calculation to a large range of experimental data, such as energy levels, two neutron separation energies, $E2$ and $E0$ transition rates, isotope shifts and magnetic moments. The good agreement of our calculation with the vast empirical data along the chain of isotopes demonstrates the relevance of IQPTs to the zirconium isotopes and can serve as a case study to set path for new investigations of IQPTs in other nuclei.

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FISSION ISOMERS STUDIES WITH THE FRS ION CATCHER

Content

The potential energy landscape in actinide nuclei ($Z = 92 - 97$, $N = 141 - 151$) shows a second minimum with $\beta_2 \sim 0.6$. The ground state in this minimum is called a fission isomer, as it will preferably decay via isomeric (delayed) fission with so far observed lifetimes between 5 ps and 14 ms [1].

In previous studies direct reactions (e.g., (d, pf)) have been used to populate fission isomeric states, projectile fragmentation reactions can be a promising alternative. The fragmentation reactions at relativistic energies offer rapid and universal production, hence access to isomers with short half-lives, and most importantly, high-purity beams of exotic nuclei and event-by-event identification. For the reasons illustrated above, the fragmentation method has been used for the first time for fission isomer studies.

At GSI a $1GeV/u$ ^{238}U beam was used, it fragmented on a Be target and resulting projectile fragments were filtered from the reaction product cocktail by the fragment separator (FRS) and then implanted into a scintillation detector or slowed down and thermalized in the Cryogenic Stopping Cell (CSC) before being extracted onto Multiple-Reflection Time-of-Flight Mass Spectrometer (MR-TOF-MS). In this diagnostic section a Special α-ToF detector [2] was installed as it reduces background noise and allows alpha spectroscopy and time-of-flight mass spectrometry at the same time.

One of the fission isomers of interest is ^{235}U, it is particularly suited for this production method due to its isomeric half-life of $11(3)$ ms that has recently been reported from older data [3] and needs independent confirmation. Moreover, the excitation energy of this latest discovered fission isomer is only coarsely known with $2.4(6)$ MeV [3] and needs to be improved in new studies.

To measure ^{235}U and other isomers with ms half-live range at the FRS Ion Catcher Facility [4], a major overhaul of the CSC has been done enabling shorter extraction times, higher rates of the incoming beam and higher resolving power.
In this talk, recent studies, technical improvement and status of data analysis on fission isomers will be presented.

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Comments:

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Manifestation of cluster structure of light nuclei in direct nuclear reactions

Content

The cross sections for nuclear reactions involving light nuclei may not always be described using existing standard methods,e.g., the distorted wave Born approximation. The main ingredients used in DWBA calculations, i.e. the global optical potentials of the input and output channels, as well as the spectroscopic amplitudes, tend to underestimate the experimental data on the differential scattering cross section. Or vice versa, if the theoretical curves are adjusted to the experimental differential cross sections, then the potentials usually turn out to be non-standard, and the amplitudes with large values. To fully understand the mechanisms of nuclear reactions involving light nuclei, more sophisticated theoretical approaches should be applied that take into account the internal structure of light nuclei.

The Coupled reaction channels (CRC) method is one of the most suitable method for the analysis of nuclear reactions. In contrast to DWBA, CRC makes it possible to take into account all possible transfer mechanisms in direct nuclear reactions. Within the CRC framework, in this work, we studied the mechanisms of nuclear reactions involving light nuclei such as ^{6}He, ^{6}Li, ^{9}Be, and ^{13}C. The structureless projectiles, d, $^{3-4}$He, were chosen so that the research would focus only on the target nuclei.

Within the framework of the Double folding model, more realistic interactions of colliding nuclei were obtained on the basis of the three-body wave functions for the nuclei ^{6}He, ^{6}Li, ^{9}Be. Elastic and inelastic scattering channels for the reactions d + ^{9}Be, d + ^{13}C, $^{3-4}$He + ^{9}Be were analyzed within the framework of the CC method. The deformation parameters and optical potentials were extracted, and the contributions of the spin-reorientation effects to the cross sections of inelastic channels are given.

One-step and two-step transfer mechanisms in elastic transfer channels for the systems $2n$ and d were proposed. In particular, the transfer of the $2n$ system corresponds to the reaction α(^{6}He, α)^{6}He, and the d transfer to α(^{6}Li, α)^{6}Li, were studied. Moreover, cluster transfers resulting from the ^{3}He+^{9}Be collision have been investigated. In this case, the analysis of transfer to the output channels ^{7}Be + ^{5}He, ^{6}Li+^{6}Li, ^{6}He+^{6}Be indicates a pronounced cluster structure of the ^{9}Be nucleus.

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Shell-model Study of Nuclear Weak Rates relevant to Astrophysical Processes in Stars

Content

We have evaluated nuclear weak rates relevant to the study of astrophysical processes in stars with the use of new shell-model Hamiltonians that prove to be successful in describing spin responses in nuclei. Electron (e)-capture and β-decay rates in sd-shell [1] and pf-shell [2] in stellar environments are applied to study nuclear URCA processes in degenerate ONeMg cores in stars with 8-10 solar masses [1] and synthesis of iron-group nuclei in type Ia supernovae [2], respectively.
Here, we investigate the weak rates for nuclei, where two-major shells are concerned. We first discuss the weak rates for the nuclear pair with A=31, ^{31}Mg-^{31}Al, in the island of inversion, which have been pointed out to be important for the cooling of neutron star crusts [3]. Neutron-rich nuclei in the island of inversion (sd-pf shell) are studied by shell-model calculations with the EEdf1 interaction [4] obtained by the extended Kuo-Krenciglowa (EKK) method starting from chiral EFT N^{3}LO and Fujita-Miyazawa 3N interaction [5]. Low-lying energy levels in ^{31}Mg are calculated to be positive parity states consistent with the experimental observation, in contrast to conventional shell-model calculations. The weak rates induced by the Gamow-Teller transitions between the low-lying states in the nuclear pair lead to a nuclear Urca process.
Electron-captures in neutron-rich nuclei along and near the N=50 closed neutron shell are important for core-collapse process in stars [6]. The transition strengths and e-capture rates for ^{78}Ni at densities ρY_e = 10^{10} -10^{12} g cm^{-3} (Y_e = proton fraction) and temperatures T = (1-5)×10^{10} K are evaluated by shell-model with full pf-sdg shells including up to 5p-5h excitations outside filling configurations of ^{78}Ni. The shell-model calculation has been done with the use of a modified A3DA interaction [7]. Dominant contributions come from the spin-dipole transitions. Results obtained are compared with RPA calculations and the effective rate formula [6]. Un-blocking of the GT transitions at high temperatures [8] is not considered here.
Electron-capture rates for a forbidden transition ^{20}Ne (0^+, g.s.) $\longrightarrow$ ^{20}F (2^+, g.s.) in stellar environments are evaluated by the multipole expansion method of Walecka [9] as well as the Behrens-Buhring method [10] within sd-shell with the use of the USDB. Difference in the rates between the two methods is found to be rather small as far as the conserved-vector-current (CVC) relation is used for the evaluation of the transverse E2 matrix element. Possible important contributions of the forbidden transition to heating of the ONeMg core by double e-captures on ^{20}Ne in a late stage of the evolution of the core and implications on the final fate of the core, whether core-collapse or thermonuclear explosion, are discussed [11,12,13].

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What can we learn from experiments with high-brilliance gamma-ray beams?

Content

An overview of the main directions of present-day studies with quasimonochromatic γ beams will be presented with an emphasis on the research opportunities which will be provided to the users at the Extreme Light Infrastructure Nuclear Physics (ELI-NP) facility at Magurele near Bucharest. Experiments with γ beams at the extremes of high temperature and high neutron-to-proton ratios will be discussed. The opportunities for nuclear structure studies with γ rays with orbital angular momentum (OAM) will be outlined and a few selected physics problems and classes of experiments, related to, e.g., changes of photonuclear cross sections in reactions with OAM photons, as well as the possibility to address nuclear excitations with higher multipolarity will be discussed. The perspectives for studies of exotic nuclei within the Gamma Factory experiment at CERN will be discussed. The expected fission-fragment yields at the Gamma Factory will be presented.

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Heavy-ion induced quasi-elastic reactions in view of the NUMEN project

Content

The presentation aims at describing an overview of the activities related with the NUMEN project at INFN – LNS. NUMEN is an international collaboration which proposes an innovative technique to give information on the nuclear matrix elements entering the expression of the decay rate of double beta decay by cross section measurements of heavy-ion induced Double Charge Exchange (HI-DCE) reactions. The exploration of HI-DCE reactions is of interest not only for double beta-decay investigations, but also for studies of nuclear reaction and nuclear structure. From the experimental side, the characteristically tiny cross sections for HI-DCE processes and the high background generated by other more probable competing reactions is the main challenge, which has hindered HI-DCE spectroscopy until recent years. Modern magnetic spectrometers, such as the MAGNEX spectrometer, have proven to have the requisites to overcome past limitations. From the theory side, the description of the measured HI-DCE cross sections poses manifold challenges. Dealing with processes involving composite nuclei, HI-DCE reactions can, in principle, proceed through several alternative paths. These, in turn, correspond to different reaction mechanisms probing competing aspects of nuclear structure, from mean field to various classes of nucleon-nucleon interactions and correlations. A powerful way to scrutinize the nuclear response to HI-DCE is to consistently link it to the information extracted from the competing quasi-elastic reactions. Indeed, these complementary studies are mandatory in order to minimize the systematic errors in the data analyses and build a many-facets and parameter-free representation of the systems under study.

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Comments:

on behalf of the NUMEN collaboration

Latest results from the CUORE experiment

Content

The Cryogenic Underground Observatory for Rare Events (CUORE) is the first bolometric experiment searching for 0νββ decay that has been able to reach the one-tonne mass scale. The detector, located at the LNGS in Italy, consists of an array of 988 TeO2 crystals arranged in a compact cylindrical structure of 19 towers. CUORE began its first physics data run in 2017 at a base temperature of about 10 mK and in April 2021 released its 3rd result of the search for 0νββ, corresponding to a tonne-year of TeO2 exposure. This is the largest amount of data ever acquired with a solid state detector and the most sensitive measurement of 0νββ decay in 130Te ever conducted, with a median exclusion sensitivity of 2.8×10^25 yr. We find no evidence of 0νββ decay and set a lower bound of 2.2 ×10^25 yr at a 90% credibility interval on the 130Te half-life for this process. In this talk, we present the current status of CUORE search for 0νββ with the updated statistics of one tonne-yr. We finally give an update of the CUORE background model and the measurement of the 130Te 2νββ decay half-life, study performed using an exposure of 300.7 kg·yr.

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Shape coexistence, chirality and octupole collectivity in Cs and Ba nuclei close to the proton drip line

Content

New results on the strongly deformed proton-rich $A \approx 120$ nuclei obtained from an experiment performed using the JUROGAM 3 + MARA setup will be presented. Evidence of shape coexistence and chiral bands in Cs nuclei, as well as the extent of octupole correlations in Ba nuclei will be discussed. Calculations using particle number conserving cranked shell model and quadrupole-octupole collective hamiltonian based on the relativistic
Hartree Bogoliubov model will be presented.

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Valence-space effective interactions and effective operators from the No-Core Shell Model

Content

Derivation of microscopic effective interactions for valence-space shell-model calculations from realistic nucleon-nucleon interactions have been a long standing challenge of nuclear structure. For a few decades many-body perturbation theory dominated the field. In recent years, novel non-perturbative techniques for constructing valence space shell-model Hamiltonians have been developed. We present one of them, which is based on the Okubo-Lee-Suzuki unitary transformation of the No-Core Shell Model (NCSM) solution. We start with the NCSM calculations for A=16-18, performed at Nmax=6 truncation to derive a charge-dependent version of the effective interaction for the sd shell, which allows us to exactly reproduce selected NCSM spectra of A=18 oxygen, fluorine and neon isotopes. Among various nucleon-nucleon potentials investigated, Daejeon16 offers the best agreement with experiment. In addition, we construct effective single-particle matrix elements of electric quadrupole (E2) and magnetic dipole (M1) operators by matching them to the results on electromagnetic transitions and moments for A=17 oxygen and fluorine from the NCSM at Nmax=6. This procedure allows us to obtain state-dependent effective E2 and M1 operators. Systematic comparison of sd shell results on excitation spectra, quadrupole and magnetic dipole observables with the NCSM results confirms the robustness of the procedure.

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Hole States of the Cluster Shell Model *

Content

We discuss applications of the Cluster Shell Model (CSM) of Della Rocca and Iachello [1] to hole states (7Be, 19F) and particle-hole (p-h) states (8Be). We demonstrate a few essential phenomenological features of the CSM: 1) The hole and p-h states lead to rotational structure predicted for the deformed hole and p-h states. 2) The rotational structures resemble the g.s band of 8Be and 20Ne. 3) The predicted parity doublets are observed.

In particular in 8Be, the observed rotational bands at high excitations, resemble the ground state bands of 8Be, 9Be and 9B, with similar moment of inertia. 4) In 8Be all predicted p-h states of the CSM, and only the predicted p-h states, are observed near thresholds and up to 19.5 MeV. 5) In 8Be the p-h states are observed in the predicted order, with positive parity states below negative parity states.

We examine the observed B(M1)s and B(E2)s in the p-h state in 8Be and g.s. of 8Be, 9Be, 9B and the analog states in 8Li. We discuss the emerging rotational structure in 8Be with respect to ab-initio no core shell model calculations that searched for rotational structures at high excitations in beryllium nuclei [2]. The observed rich structure at high excitations in 8Be lead us to propose a study of the structure of 8Be at high excitations using the ISOLDE Solenoid Spectrometer (ISS) [3].

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Nuclear structure investigations in mirror nuclei

Content

Nuclear structure investigations in mirror nuclei
Dimitar Tonev
The investigation of mirror nuclei along the N=Z line is of considerable interest since it addresses directly the charge symmetry of the nuclear forces and the role of the Coulomb effects on nuclear structure.
In the limit of long wavelengths, where the Siegert theorem holds, the E1 transition operator is purely isovector. If the charge symmetry of the nuclear force is exact, E1 transitions between states of equal isospin are forbidden in N = Z nuclei and have equal strength in mirror nuclei. Experimental deviations from these two rules can, therefore, be used to investigate isospin symmetry breaking. The research reported in this paper aims to test the isospin symmetry conservation in the A = 31 region through the comparison of the E1 strengths of the transitions depopulating the 7/2− analogue states, located slightly above 4400 keV, in the mirror nuclei 31S and 31P [1]. We show that a beyond mean field and self-consistent approach is able to reach a very good agreement in reproducing the B(E1) in both nuclei.
Excited states in the mirror nuclei 31P and 31S were populated in the 1p and 1n exit channels of the reaction 20Ne + 12C, at a beam energy of 33 MeV. The 20Ne beam was delivered for the first time by the Piave-Alpi accelerator of the Laboratori Nazionali di Legnaro. Angular correlations of coincident γ -rays and Doppler-shift attenuation lifetime measurements were performed using the multi-detector array GASP in conjunction with the EUCLIDES charged particle detector. In the observed B(E1) strengths, the isoscalar component, amounting to 24% of the isovector one, provides strong evidence for breaking of the isospin symmetry in the A = 31 mass region. The comparison of the B(E1) strengths in the two mirror transitions indicates a violation of the isospin symmetry manifested by the presence of a large induced isoscalar component. Self-consistent calculations using the NNLOsat and the Equation of Motion Phonon Method reproduce well the experimental findings, confirming the breaking of the isospin symmetry originating from the violation of the charge symmetry of the two- and three-body parts of the potential. The result provides evidence for a coherent contribution to isospin mixing, probably involving the isovector giant monopole resonance.
Second experiment represent DSAM lifetime measurements which were carried out with the multi-detector array EUROBALL [2]. The results of the analysis, partly achieved with a precise procedure [3], provide valuable information on the transition strengths in the yrast cascades of the mirror nuclei 47Cr and 47V. The behavior of the transition strengths with spin is well described by full p f shell model calculations. In this way, a test of the isospin symmetry in mirror nuclei is performed on the basis of the determined B(E2) values.
Some experimental findings in both mirror couples with A=31 and A=47 will be compared and discussed in the presentation.
Acknowledgment: The research has been supported by Bulgarian Science Fund under Contract No. KP-06-N44/1, 27.11.2020.
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Nuclear Incompressibility: Does It Depend on Nuclear Structure

Content

The nuclear incompressibility parameter is one of three important components characterizing the nuclear equation of state. It has crucial bearing on diverse nuclear and astrophysical phenomena, including radii of neutron stars, strength of supernova collapse, and collective flow in medium- and high-energy nuclear collisions.

The only direct experimental measurement of this quantity comes from the compression-mode giant resonances—the isoscalar giant monopole resonance (ISGMR) and the isoscalar giant dipole resonance (ISGDR). There have been some experimental results recently suggesting that nuclear structure effects may influence the energy of the isoscalar giant monopole resonance and, hence, the nuclear incompressibility. However, this being a bulk property of nuclear matter, one expects structure effects to play no role in it.

In this talk, I will review the current status of determination of nuclear incompressibility, and critically examine how, and if, nuclear structure effects play a role.

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A+2n compound nuclei and the unitary limit in nuclear physics

Content

The Interacting Boson Model [1] is diachronically successful in capturing the simplicity out of complexity in the structure of heavy atomic nuclei and predicting new phenomena in nuclear physics such as the Quantum Phase Transitions. Motivated by the exploration of conformal symmetry at the quantum critical points, a new application of the IBM has recently been proposed for the intermediate states of the Feshbach formalism in A+2n compound nuclei [2]. These states emerge after establishing a symmetry-correspondence between the Schrodinger equation of trapped cold atoms [3] and the Schrodinger equation of the IBM's O(6) limit. Feshbach resonances manifest intermediate states in systems of cold atoms during the formation of diatomic molecules and reach the so-called unitary limit under the tuning of the external magnetic field that traps the atoms.
In this talk, I will present how the unitary limit is measurable in a system of nuclear physics such as in a heavy A+2n compound nucleus by emphasizing the tuning of the scattering length between the two neutrons (2n) and the target nucleus (A) via the fluctuation of the cross-section. Moreover, the representations of the one-dimensional conformal group arise as a regularity pattern of the fluctuations of the cross-section in contrast with their usual random appearance in compound nuclei. These results signal the candidacy of the A+2n compound nucleus as a physical laboratory for the BCS-BEC crossover, for an underlying critical point, and algebras with an infinite number of generators.

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Comments:

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Skyrmions as Models for Nuclei

Content

Skyrme proposed an effective field theory of pions, whose Skyrmion solutions are classical precursors of nucleons. Their integer topological twist is identified as the conserved baryon (atomic mass) number. Quantising the Skyrmion's rotational motion gives four basic states – the proton/neutron with spin up/down. Skyrmions have a finite size and a smooth core, so no explicit short-distance cutoff is needed. Quantised Skyrmion-Skyrmion interactions (calculated recently by D. Harland and C. Halcrow using 2nd-order perturbation theory) match most components of the Paris nucleon-nucleon potential, including spin-orbit terms.
Many multi-Skyrmion solutions having various spatial symmetries are known, giving models for many nuclei, though not all. Low-lying vibrational modes and their couplings to rotations need to be quantised. This gives spectra for e.g. Carbon-12 and Oxygen-16 that match experimental data well. In Oxygen-16, the relevant Skyrmion is a tetrahedron of alpha-particle-type constituents, and tunnelling from the tetrahedron to its dual via a square structure accounts for the splitting between the 2^+ and 2^- states near 8 MeV (C. Halcrow, C. King and N.S. Manton). Several multi-Skyrmions with large baryon numbers have icosahedral symmetry, and one has been exploited by A. Heusler to model states of Lead-208 that are not fitted by 1p1h shell model excitations, nor by a tetrahedral rotational band. Isospin quantisation, treated collectively, leads to isospin multiplets, e.g. delta resonances as excitations of nucleons, and Beryllium-7/Lithium-7.
Skyrme's original model gave overstrong binding energies, but various effects reduce these, including the quantisation of vibrational modes, which tends to break-up a compact multi-Skyrmion, and gives the constituents some kinetic energy. There are variants with ρ-meson and ω-meson fields, or with infinitely many heavy vector and axial-vector mesons whose many parameters can be fixed using Sakai and Sugimoto's holographic QCD, as developed by P. Sutcliffe.
The study of Skyrmions is now quite mature. There are websites illustrating in colour numerous multi-Skyrmions and their vibrational modes for modest baryon numbers (C. Halcrow and S.B. Gudnason). World Scientific has just published the author's
book, {\it Skyrmions – A Theory of Nuclei}.

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Studying the Neutron-Rich nuclei in the vicinity of 78Ni

Content

The structure of nuclei in the N>40 and Z>20 region is studied in terms of large-scale shell-model employing a natural extension of the LNPS interaction to the full pf-sdg space. Comparison shows that our results are in a very satisfactory agreement with the available data and supports the confidence in the predictions of our calculations. This, in turn, allows us to comprehensively probe a region of outstanding importance for calculations of astrophysical r-processes path.

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Presenter: Dr RICCARDO, Mancino

Multi-channel experimental and theoretical approach to study the 12C(18O,18F)12B single charge exchange reaction mechanism

Content

Full understanding of the reaction mechanisms involved in double and single charge exchange nuclear reactions is mandatory for the purposes of the NUMEN project [1]. The main goal is to extract data driven information on nuclear matrix elements of neutrinoless double beta decay from measured cross section of heavy ion induced double charge exchange reactions. An interesting benchmark to test the capability of state-of-thr-art nuclear reaction and nuclear structure theories is the network of nuclear reactions involved in the ^{18}O + ^{12}C collision at 15.3 AMeV incident energy. The experiment has been performed at the INFN-LNS using the K800 Superconducting Cyclotron and the MAGNEX magnetic spectrometer. The experimental results and the theoretical analysis for the single charge exchange, elastic and inelastic scattering, one-neutron addition and one-proton removal nuclear reactions will be discussed during the conference.

The main purpose of this work is to describe the newly extracted experimental cross-sections in a full comprehensive theoretical framework in which the reaction channels are treated all together. The many aspects that play a relevant role in the description of the single charge exchange reaction mechanism are the choice and tuning of the optical potential, the role of the couplings with the low-lying excited states of the involved nuclei, the single-particle and many-body properties of the nuclear wave functions and the competition between the direct and the sequential reaction mechanisms.

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Comments:

fo the NUMEN collaboration

Shape evolution in neutron-rich nuclei around mass 100

Content

Nuclei around N=60, Z=40 show a rapid variation in the deformation of their ground state with a rather small change in the neutron number. This feature manifests a subtle interplay between different aspects of the forces in the nucleus and makes this region an ideal testing ground for various nuclear structure theories. As an example, it is established that the ground state of Zr isotopes vary from nearly spherical for N<60 to well deformed after N=60 [1–4]. However, the drastic shape transition in Zr beyond N=60 is still a challenge for the description of different theoretical models [5–11].

Lifetime measurements are an effective way to shed light on the shape evolution in this region of the Segrè chart. For this purpose, a successful experiment was performed in 2017 at GANIL by using the γ-ray tracking array AGATA [12] coupled to the magnetic spectrometer VAMOS [13]. The Orsay Universal Plunger system [14] was installed allowing lifetime measurements in the order
of the picosecond with the Recoil Distance Doppler Shift technique [15]. The data set obtained from this experiment contains hundreds of isotopes and is producing many new lifetime results.

In this contribution I will show preliminary results obtained by applying the Differential Decay Curve Method of analysis [15], both in single gamma and in coincidence gamma-gamma, and the comparison with theoretical calculations.

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Triaxial shapes and rotation modes predicted by CRMs for light nuclei

Content

A quantal, microscopic cranking model Hamiltonian for triaxial rotation (MSCRM3) is derived from the application of a rotation operator (with microscopically-chosen rotation angles) to a deformed nuclear ground-state wavefunction using Hartree-Fock variational method. MSCRM3 Hamiltonian is identical in form to that of the conventional cranking model (CCRM3) plus residual correction terms. However, MSCRM3 angular velocity is not a constant parameter but is microscopically determined resulting in a self-consistent, time-reversal and D2 invariant Hamiltonian. The solution of MSCRM3 (and CCRM3) equations subject to self-consistent deformed harmonic-oscillator potential and constant volume conditions is determined in closed algebraic forms and solved iteratively using the solution of MSCRM3 Newton's equations of motion and Feynman's theorem. MSCRM3 and CCRM3 are used to investigate the stability of nuclear rotational states, and nuclear shapes, rotation modes, and their phase transitions, and non-collective rotational states in the light nuclei 20Ne, 24Mg, and 28Si. The impact of spin-orbit and residuals of the square of the angular momentum and quadrupole-quadrupole interaction is studies. It is shown that MSCRM3 predicts rotational relaxation of the intrinsic system, uniform and triaxial rotation of a triaxial nucleus, the observed reduced rotational-energy-level spacing in 20Ne, and nutating, figure-skater's slow-fast spinning, and tumbling rotations in some rotational states, whereas CCRM3 does not, uniform and figure-skating cases excepted. MSCRM3 rotational states are more unstable than those of CCRM3. MSCRM3 rules out a free self-sustaining rotation.

Primary author: Dr GULSHANI, Parviz (NUTECH Services)

Presenter: Dr GULSHANI, Parviz (NUTECH Services)

Physics Beyond the Standard Model with Nuclei

Content

Nuclear effective field theories allow us to formulate the low-energy effects of interactions beyond those in the Standard Model. I will discuss some of the consequences of the violation of lepton (L) and baryon (B) numbers. Topics include renormalization in (L-violating) neutrinoless double beta decay and deuteron decay with B violation by one and two units.

Primary author: VAN KOLCK, Ubirajara

Presenter: VAN KOLCK, Ubirajara

Challenging Information on Nuclear Dipole Excitations from Tailor-Made Photon Beams

Content

The study of photonuclear reactions in the laboratory has seen a revival during the last decades. This was partly triggered by the advent of new accelerator-based photon sources capable of providing intense quasi-monoenergetic MeV-ranged photon beams from Laser Compton Backscattering and by their usage for nuclear spectroscopy [1]. New experimental approaches to basic research and applications become available [2]. We have recently succeeded in the development of two new approaches exploiting photonuclear reactions with MeV-ranged photon beams with tailored spectral features or polarization.

(i) Nuclear absorption lines will be imprinted in a broadband MeV-ranged photon beam when it passes through matter. This has been exploited for a precision measurement of the $M1$ excitation strength of the 1^+ ground state of ^{6}Li with isospin $T = 0$ to its first excited 0_1^+ state at 3.56 MeV excitation energy with $T = 1$. This self-absorption has been measured to a precision of a few parts in a thousand with the newly developed Relative Self-Absorption (RSA) method [3]. The data reveal the impact of two-body currents on an adequate description of the $M1$ transition strength in ^{6}Li by ab-initio calculations using chiral effective field theory [3].

(ii) The polarization of an MeV-ranged photon beam incident on a sample of nuclei of interest impacts the angular distribution of their resonance fluorescence. Measuring the angular distribution of nuclear resonance fluorescence from the electromagnetic decay of dipole excitations of deformed even-even nuclei into the 0_1^+ and the 2_1^+ states of their $K = 0$ ground state rotational band, allows for precision studies of the dipole excitations' K quantum numbers and their quantum mechanical purity. This way, we have recently measured the (small) K-quantum number-conserving $M1$ excitation strength for the first time. It amounts to $B(M1; \Delta K = 0) \uparrow = 0.008\ \mu_N^2$ in the deformed rare-earth nucleus ^{164}Dy [4]. Very recently, we have been able to study the mixing of K-quantum numbers in the two humps of the $J^\pi = 1^-$ Isovector Giant Dipole Resonance of the deformed rare-earth nucleus ^{154}Sm. The data will be presented and discussed.

* We thank all those who have contributed to the experiments, in particular the accelerator crew, students, and doctoral researchers at the S-DALINAC and at HIγS, TUNL, and those how contributed to the interpretation of the data. In particular, we thank R.V. Jolos, T. Otsuka, R. Roth, A. Schwenk for numerous discussions. We gratefully acknowledge the financial support by the German Research Council (DFG) under grant No.~SFB 1245 (Project ID 279384907), by the German Ministry for Education and Research (BMBF) under grant Nos. 05P18RDEN9, and 05P21RDEN9, by the State of Hesse under the LOEWE grant "Nuclear Photonics" and the Research Cluster ELEMENTS (Project ID 500/10.006).

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Presenter: PIETRALLA, Norbert (TU Darmstadt)

Manifestation of the Berry phase in the atomic nucleus ^{213}Pb

Content

I will present some of our later results on the ^{213}Pb neutron-rich nucleus [1] studied using the unique availability of a primary 1 GeV A ^{238}U beam and of the FRS-RISING setup at GSI. The products of the uranium fragmentation were separated in mass and atomic number and then implanted for isomer decay γ-ray spectroscopy. A level scheme from the decay of the $21/2^+$ isomer, based on γ intensities, γ-γ coincidences and state lifetimes was built up and the $E2$ transition probabilities from the $21/2^+$ isomer to two low-lying $17/2^+$ levels were also deduced.

This experimental data has evidenced one of the best examples of a semi-magic nucleus with a half-filled isolated single-j shell where seniority selection rules are obeyed to a very good approximation. In the most simple shell-model approach ^{213}Pb can be described as five neutrons in the $1\mathrm{g}_{9/2}$ orbital on top of the ^{208}Pb core. Large scale shell-model calculations in the full valence space beyond ^{208}Pb confirm that although the $1\mathrm{g}_{9/2}$ orbital is not isolated in energy, it is found to carry the dominant component in the wave function of the low-energy states. The experimental level scheme and the reduced transition probabilities are in good agreement with the theoretical description that predicts the existence of two $17/2^+$ levels of a very different nature: one with seniority $\upsilon = 3$, while the other with $\upsilon = 5$. The absence of mixing between the two $17/2^+$ states follows from the self-conjugate character of ^{213}Pb, where the particle-hole transformation defines an observable Berry phase that leads to the conservation of seniority for most but not all states in this nucleus.

The Berry phase [2], which is a gauge-invariant geometrical phase accumulated by the wavefunction along a closed path, is a class of observables that are not associated with any operator. It is a key feature in quantum-mechanical systems, that has far reaching consequences, and has been found in many fields of physics since its postulation in the eighties. In the atomic self-conjugate nucleus ^{213}Pb, the quantized Berry phase is evidenced by the conservation of seniority under the particle-hole conjugation transformation. In atomic nuclei no experimental signature of the Berry phase was reported up to now.
I will also present the status of the upcoming physics campaign at Laboratori Nazionali di Legnaro (INFN) with the current forefront Ge γ-ray array in Europe, AGATA [3], which is based on the concept of gamma-ray tracking.

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Presenter: VALIENTE DOBON, Jose' Javier (Istituto Nazionale di Fisica Nucleare)

Electron Scattering for Neutrino Physics at MAMI and MESA

Content

Next generation long-baseline neutrino experiments plan to measure neutrino oscillation parameters at the percent level, definitely establish CP violation in the lepton sector of the Standard Model, and measure astrophysical neutrinos from supernovae. This ambitious program requires a precise knowledge of the neutrino-nucleus interactions over a wide energy range. An alternative approach is the use of electron scattering, which has the advantage of high statistics and complete control over the initial and final states of the reaction. In this contribution, we will describe the plans at the MAMI and MESA facilities for electron scattering experiments aimed at neutrino physics and present preliminary data on carbon and argon nuclei. The planned experiments have also the potential to deepen our knowledge of the nuclear structure enriching the existing data on selected nuclei.

Primary author: DORIA, Luca (Johannes Gutenberg University Mainz)

Presenter: DORIA, Luca (Johannes Gutenberg University Mainz)

Shell Model applications in nuclear astrophysics

Content

In this talk I will review recent applications of the large scale shell model in nuclear astrophysics. Particular emphasis will be put on the description of weak interaction processes relevant for stellar evolution and nucleosynthesis. This include electron capture rates on Iron group nuclei that become relevant during the Iron core collapse of massive stars. I will also discuss the evolution of intermediate massive stars where electron capture processes determine the heating and cooling of the core and the end product of the evolution as either thermonuclear or core-collapse supernova. Finally, I will discuss recent advances on the microscopic description of beta-decay rates for r-process nuclei.

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Neutron/proton matrix elements in the very n-rich Ni isotopes: Fingerprints of a dual quantum liquids phase transition?

Content

The study of neutron rich nuclei with unusually large neutron/proton ratio is challenging the conventional description of the structure of nuclei. The Ni isotopes are in this regard a benchmark of nuclear studies, as they correspond to a proton shell closure (Z = 28), while also exhibiting neutron shell or subshell closures at N = 28, 40 and 50. An intriguing interplay among spherical, prolate and γ-unstable shapes has been predicted in such isotopes driven by the combined effect of the tensor force and different particle configurations 1. Such configuration-dependent shell structure translates into the coexistence of spherical and strongly deformed shapes with shape fluctuations and with a spectrum approaching the symmetry group E(5) with a behavior which has been interpreted as a striking example of phase transitions in dual quantum liquids [1,2]. Nickel isotopes are also an interesting example of partial conservation of the seniority quantum number. Seniority remains a good quantum number for any two-body interaction acting within j shell when j $\leq$7/2, but it needs not be conserved for j $\geq$ 9/2. Partial conservation of the seniority quantum number - most eigenstates are mixed in seniority but some remain pure - has been recently predicted in the neutron rich Ni isotopes, filling the g9/2 shell [3]. Reduced transition probabilities have been recently measured for the most exotic ^{73,74,75}Ni nuclei with relativistic Coulomb excitation performed at the RIKEN Nishina Center [4]. Deformation lengths for n-rich Ni isotopes have been determined from proton inelastic scattering at NSCL using Gretina [5] and neutron/proton matrix elements have been extracted. In this presentation I will discuss the results obtained (^{75}Ni is the most exotic neutron reach Ni isotope presently reachable for such kind of studies) together with the future program at the SPES ISOL radioactive ion beam facility [6].

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The AGATA campaigns at GANIL

Content

AGATA (Advanced Gamma-ray Tracking Array) is a large array to perform high-resolution gamma ray spectroscopy for nuclear structure studies. It is using pulse shape analysis and tracking capabilities, which makes it the most powerful detector together with its equivalent in the US: GRETA. AGATA has been hosted at GANIL for 7 years where it has been coupled to several devices (VAMOS, NEDA/DIAMANT, MUGAST,…) to address specific physics question in the various region of the Segré chart.In this talk a summary of the physics cases covered by these various experimental campaigns will be made.
A special emphasis will be put on the spectroscopy of N~Z nuclei. Indeed, nuclei in the vicinity of the N~Z line form a unique laboratory for studying many different phenomena among which the interplay of T=0 and 1 states at low energy, the role of neutron–proton pairing correlations, the shape coexistence along the N=Z line, the role of isospin symmetry and to which extent it is violated. In the heaviest N=Z nuclei located to the doubly magic N=Z=50, ^{100}Sn nucleus, a key element to adjust the interaction used in shell-model calculations as well as to delineate precisely the proton dripline. In addition, and connected to this latter point, these nuclei lie along the explosive rp-process nuclear synthesis pathway and, hence, their low-lying structure may be of interest in determining reaction rates.
For these numerous motivations, nuclei lying at or close to the N=Z line have been extensively studied at GANIL and in particular using a complex experimental setup consisting of the AGATA array, the NEDA neutron detector and the DIAMANT charged particle detector. This powerful coupling of efficient detectors made it possible to address several of the key questions mentioned above. Some of the main topics will be reviewed in a more detailed way.

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Study of fundamental symmetries in the few-nucleon systems

Content

In this talk, we discuss, first of all, of a rather puzzling anomaly recently observed in the emission of electron-positron pairs in the ^{7}Li(p,$e^{+}e^{-}$)^{8}Be and ^{3}H(p,$e^{+}e^{-}$)^{4}He reactions [1,2]. This anomaly has been interpreted as the signature of a particle not foreseen in the Standard Model (SM) of particle physics (hereafter X17 boson) with mass M=16.8 MeV. The X17 boson could be a mediator of a fifth force, characterized by a strong coupling suppression of protons compared to neutrons [3]. This scenario can explain, at least partially, the long standing anomaly of the magnetic moment of muon found experimentally. Here, we present a recent ab-initio study of the ^{3}H(p,$e^{+}e^{-}$)^{4}He and ^{3}He(n,$e^{+}e^{-}$)4He processes [4]. We analyze the pair production as a purely electromagnetic process in the context of a state-of-the-art approach to nuclear strong-interaction dynamics and nuclear electromagnetic currents, derived from chiral effective field theory (chiEFT). Next, we examine how the exchange of a hypothetical low-mass boson would impact the cross section for such a process. We consider several possibilities, that this boson is either a scalar, pseudoscalar, vector, or axial particle.

We also present the results of the calculation of electric dipole moments (EDMs) of light nuclei, again in the framework of chiEFT. As it is well known, EDMs are related to the violation of the time-reversal symmetry, a key ingredient for understanding
the origing of the observed matter-antimatter asymmetry in the Universe [5]. The sources of time-reversal violation (TRV) in the SM are not sufficient for explaining the observed asymmetry [6] and induce very small EDMs in electrons, atoms, nucleons, and nuclei. Therefore, the observation of EDMs in these systems would highlight TRV effects beyond SM.

In particular, the interest in the study of light-nuclei EDMs is based on the fact that there are proposals for their direct measurement in dedicated storage rings [7].

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Study of highly excited states in ^{8}Be populated in the EC/β^+ decay of ^{8}B

Content

The beta decay of the proton halo nucleus ^{8}B into ^{8}Be has been studied in detail several times during the last decades. Still, there is surprisingly little known experimentally about the beta strength distribution in the full decay. The only transitions observed so far pass through 2+ levels in 8Be that break up into two alpha particles mainly populating the broad 3,030(10) MeV state and hindered by phase space there are a small branch to the 16 MeV 2^+ doublet. However there is within the Q_{EC}-window a well established 1^+ level a 17,640(1) MeV that decays mainly by proton emission. The decay through this level will give a 337 keV proton and a 48 keV recoiling ^{7}Li ion. This so far unobserved transition is highly interesting as a probe of the halo structure of ^{8}B. In a schematic model 1 of a halo nucleus its wave function can be factorised into core and halo, so one could think the β^+/EC decay of ^{8}B as proceeding separately for the core and the halo proton. The decay through the 1^+ level is described by the decay of the core leaving in this case the proton as spectator. The strength of this branch can therefore be estimated from the known decay of the ^{7}Be core nucleus. This gives a BGT = 1,83 corresponding to a branching ratio of 2,3 $\times$ 10^{-8}, see [2] for details. The only experimental information concerning this branch is an upper limit on the beta-delayed proton branch of 2,6 $\times$ 10^{-5} at 95% con dence level [3]. The decay of ^{8}B into the 16.626(3) MeV state has been observed by several groups, but the (mainly EC) decay into the 16.922(3) MeV state was first hinted in a previous JYFL experiment [3], where 5 events were attributed to the breakup from this state.
The 2^+ 16.6 and 16.9 MeV doublet is strongly mixed in isospin [4] so that the states have dominant con gurations ^{7}Li+p and ^{7}Be+n, respectively. The beta decay through them has so far been modeled by assuming that Fermi strength only goes to the T = 1 component and Gamow-Teller strength only to the T = 0. This level mixing has being constrained by alpha scattering data, see [5]]. With this assumption one deduces a model-dependent value of BGT = 2,06. A higher statistics beta-decay spectrum will give further experimental constraints and allows to test whether the feeding of the two levels of the doublet are consistent with what the level mixing model predicts.
To study these high excited states in ^{8}Be at the limit of the decay we performed at experiment at ISOLDE-CERN. The experimental setup consisted in a set of 4 particle-telescopes each formed by a Double Sided Silicon strip Detector (DSSD) of 40-60 μm thickness and stacked with a 1000 μm thick Si-PAD detector. Further, a thick DSSD was placed below the implantation foil to maximize the \beta detection. This was very important in the search of mthe EC-delayed proton branch. At the centre of the setup a carbon foil catcher of 30 μg/cm2 was placed to stop the 50 keV ^{8}B beam. In this presentation we will summarize the results obtained in this high statistic experiment.

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Presenter: G. BORGE, Maria Jose

Beta-decay studies with the projected generator coordinate method

Content

Calculation of single-beta decay properties with mean-field (MF) and beyond-mean-field (BMF) methods is a challenging task for several reasons. Firstly, this process involves the evaluation of wave functions of nuclei with an odd number of particles and performing full-blocking that breaks the time-reversal symmetry at the MF level is mandatory. On the other hand, connecting two quasiparticle vacua with (a priori) different number parities complicates the evaluation of the nuclear matrix elements.

In this talk we will present a method based on the generator coordinate method with particle and angular momentum projected wave functions (PGCM) to compute single-beta-decay nuclear matrix elements. The key point is the proton-neutron mixing in the definition of the quasiparticle states needed to define the final wave functions. To benchmark the method, the results for allowed Gamow-Teller transitions will be compared with exact values provided by large scale shell model calculations in the sd- and pf- valence spaces.

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Presenter: RODRÍGUEZ, Tomás R. (Universidad Autónoma de Madrid)

Study of one-nucleon transfer reactions in 18O + 76Se collision at 275 MeV in the context of the NUMEN project

Content

Heavy-ion one-nucleon transfer reactions are promising tools to investigate single-particle configurations in nuclear states, with and without the excitation of the core degrees of freedom. An accurate determination of the spectroscopic amplitudes of these configurations is essential for the study of other direct reactions as well as beta-decays. In this context, the 76Se(18O,17O)77Se and 76Se(18O,19F)75As one-nucleon transfer reactions give a quantitative access to the relevant single particle orbitals and core polarization transitions built on 76Se. This is particularly relevant, since it provides data-driven information to constrain nuclear structure models for the 76Se nucleus.
The excitation energy spectrum and the differential cross section angular distributions of these nucleon transfer reactions were measured at 275 MeV incident energy for the first time using the MAGNEX large acceptance magnetic spectrometer. The data are compared with calculations based on distorted wave Born approximation, coupled channel Born approximation and coupled reaction channels adopting spectroscopic amplitudes for the projectile and target overlaps derived by large-scale shell model calculations and interacting boson-fermion model.
These reactions are studied in the frame of the NUMEN project. The NUMEN (NUclear Matrix Elements for Neutrinoless double beta decay) project was conceived at the Istituto Nazionale di Fisica Nucleare–Laboratori Nazionali del Sud (INFN-LNS) in Catania, Italy, aiming at accessing information about the nuclear matrix elements (NME) of neutrinoless double beta decay (0νββ) through the study of the heavy-ion induced double charge exchange (DCE) reactions on various 0νββ decay candidate targets. Among these, the 76Se nucleus is under investigation since it is the daughter nucleus of 76Ge in the 0νββ decay process.

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Presenter: CIRALDO, Irene (Istituto Nazionale di Fisica Nucleare)

Comments:

for the NUMEN collaboration

Low-energy enhancement in the gamma-ray strength functions of heavy nuclei*

Content

We report the first theoretical identification of a low-energy enhancement (LEE) in the magnetic dipole gamma-ray strength function (γSF) of heavy nuclei.
The LEE has been the subject of intense experimental and theoretical interest since its discovery, and, if the LEE persists in heavy neutron-rich isotopes, it could have profound implications for our understanding of r-process nucleosynthesis through the enhancement of radiative neutron capture rates. Configuration-interaction (CI) shell model calculations suggest that this enhancement occurs in the magnetic dipole (M1) γSF 1. However, conventional CI shell model calculations are intractable in heavy nuclei, and the existence of a LEE in heavy nuclei has been an open problem.

The shell model Monte Carlo (SMMC) method [2] is a powerful method to calculate thermal observables in model spaces that are many orders of magnitude larger than those that can be addressed in conventional methods, but it cannot be used to calculate directly γSFs. In SMMC, it is only possible to calculate imaginary-time response functions. The standard method to carry out numerically the analytic continuation to real time is the maximum-entropy method whose success depends crucially on a good choice of a prior strength function.

We use the static path plus random-phase approximation (SPA+RPA) [3] to calculate γSFs in the framework of the CI shell model for a pairing plus quadrupole Hamiltonian [4]. We then use the SPA+RPA γSF as a prior in a maximum-entropy method that reproduces the SMMC imaginary-time response function.

The SPA+RPA becomes computationally expensive for the interactions used in SMMC, and instead we use as prior strength the SPA γSF [5].

We applied these methods in chains of samarium [4] and neodymium [5] isotopes and identified a LEE in their M1 γSF. We also observed a scissors mode and a spin-flip mode that are built on top of excited states. We discuss how these modes change in the crossover from spherical to deformed heavy nuclei.

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Presenter: ALHASSID, Yoram (Yale University)

Microscopic Effective Interactions for the Nuclear Shell Model

Content

We present the formalism and numerical implementation of many-body perturbation theory as an approach to derive microscopic valence-space effective interactions for the nuclear shell model. The effective interaction is constructed through Lee-Suzuki similarity transformation and calculated in the framework of time-dependent perturbation theory (the so-called folded-diagram theory). The sd-shell microscopic effective interactions are derived from two-nucleon N3LO, CD-Bonn and Daejeon16 interactions. Our preliminary results confirm that the centroids of the derived microscopic effective interactions are too attractive, which results in too small sub-shell gaps. This deficiency, more pronounced for N3LO and CD-Bonn, leads to overbinding problems in the description of neutron-rich nuclei, and poor spectroscopy of nuclei in the vicinity of sub-shell closures. Further efforts to upgrade the current framework are under way.

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level scheme study of 91,92Mo

Content

Excited states in ^{91,92}Mo are populated through a fusion evaporation reaction, ^{6}Li + ^{89}Y, with a beam energy of 34 MeV at LNL-INFN, Italy. With the gamma rays detected by GALILEO array, $\gamma - \gamma$ matrix and $\gamma - \gamma - \Delta T$ cubes are created and analyzed in the current work. According to the new experimental data, several inter-band transitions between two low-lying seniority bands are found for the first time in ^{92}Mo, and its level scheme has been considerably extended up to high-spin states within 5-10 MeV region. In ^{91}Mo, a new negative band is established on the top of the known $17/2^-_1$ isomer at 2280-keV. On the other hand, the meta-stable states in ^{91,92}Mo with lifetime longer than few nano-seconds are remeasured in this experiment by using different ways, such as mirror symmetric centroid difference (MSCD) method and/or direct slope fitting.

From the theoretical point of view, the level structure in ^{91,92}Mo are calculated with two different effective interactions, $jjglek$ and $jjglem$, corresponding to different model spaces.
Via the comparison between the experimental results and shell model calculations, it is found that in ^{92}Mo, the promotion of $p_{3/2}$ protons across the Z=38 subshell, as well as $1g_{9/2}$ neutron across the N=50 shell closure, could well describe the observed $\sim$ 2 MeV γ rays among high-lying states. %The levels with excitation energy between 7 and 11 MeV were dominated by the excitation of a single neutron across the $N = 50$ shell gap.
Furthermore, the $E1/M2$ mixed nature of several inter-band transitions between two lowing-lying seniority bands with opposite parities in ^{92}Mo could also be described adequately by including the proton $Z = 28$ core-breaking contribution. In ^{91}Mo, the coupling of a single $g_{9/2}$ neutron hole to the known seniority scheme in ^{92}Mo will also be discussed in detail during the presentation.

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Presenter: HUANG, Zhen (University of Padova & Beihang University)

Few-Body Physics in Finite Volume

Content

Simulating quantum systems in a finite volume is a powerful theoretical tool to extract information about them. The pioneering work of Lüscher has shown that the real-world properties of the system are encoded in how its discrete energy levels change with the size of the volume. This approach is relevant not only for nuclear physics, where lattice methods are now able to calculate few- and many-nucleon states, but also for other fields such as simulations of cold atomic systems.

This talk presents recent progress that has been achieved in the field of finite-volume relations and calculations. In particular, it discusses the case of charged particles in a finite periodic box, which is of great relevance for nuclear physics because the vast majority of systems of interest in this field involve more than one charged particle. Moreover, it will present the use of eigenvector continuation as a method for performing robust and efficient extrapolations over a large range of volumes.

Primary author: KOENIG, Sebastian (NC State University)

Co-authors: YU, Hang (NC State University); YAPA, Nuwan (NC State University)

Presenter: KOENIG, Sebastian (NC State University)

An SDD-based spectrometer for beta spectroscopy

Content

We propose to present the status of a project which aims to develop a new detection strategy to perform high-precision, high-accuracy measurements of the energy spectra of beta decays of interest for the physics community, in particular in the field of nuclear physics, double beta decay and reactor neutrinos
The aim is to exploit a relatively novel spectroscopic technique based on Silicon Drift Detectors. An SDD-spectrometer, equipped with all the ancillary detectors required to reject events with only a partial energy deposition in the main sensitive elements, will provide high-statistics and virtually zero-background data. In order to isolate and study the systematic uncertainties, the statistical error on the measured spectra has to be reduced to a negligible level, balancing source activity, measurement duration and background. Reliable and well understood Montecarlo simulations are a key component of this application, as they provide a model for the response functions of the spectrometer, to be deconvolved from the data in order to correctly reconstruct the original spectral shapes.
Thanks to the flexibility of the SDD detector technology, the here presented spectrometer could be coupled to a variety of beta sources, ranging from nuclei deposited on the surface of SDDs to minimise source self-absorpion to short-lived isotopes created and collected at unstable isotope beams like ISOLDE at CERN or the exotic beams at LNS, Catania.
The current status of the technology, with particular focus on the advancements in the detector response modelling to beta electons and related measurements, will be presented and discussed.

Primary author: BIASSONI, Matteo (Istituto Nazionale di Fisica Nucleare)

Presenter: BIASSONI, Matteo (Istituto Nazionale di Fisica Nucleare)

Relativistic Brueckner-Hartree-Fock Theory: an *ab initio* Approach for Nuclear Matter and for Finite Nuclei

Content

Recent years have seen considerable progress with ab-initio calculations of the nuclear structure by non-relativistic many-body methods. Dirac-Brueckner-Hartree-Fock Theory provides a relativistic ab-intio approach, which is able to reproduce saturation properties of symmetric nuclear matter without three-body forces. However, so far, the corresponding equations have been solved only for positive energy states. Negative energy states have been included for forty years in various approximations, leading to differences in the isospin dependence. This problem has been solved only recently by a complete solution of the self-consistent relativistic Brueckner-Hartree-Fock equations in asymmetric nuclear matter. Due to its numerical complexity, however, it is very difficult to extend the Relativistic Brueckner-Hartree-Fock theory to the study of finite nuclear systems. Recent efforts will be discussed to overcome this problem. It will be shown how such calculations can teach us more about the structure of covariant nuclear energy density functionals, particularly the importance of tensor forces.

Primary author: RING, Peter (Technical University Munich)

Presenter: RING, Peter (Technical University Munich)

Nuclear structure and neutrinoless double-beta decay

Content

Neutrinoless double-beta decay in an undiscovered but potentially very exciting decay of an atomic nucleus where only two electrons are emitted while two neutrons turn into two protons. Therefore, the process does not conserve the number of leptons and opens the door to observing physics beyond the standard model of particle physics related to the dominance of matter in the universe, since only two matter particles are created. The nuclear matrix elements governing the decay have to be calculated from nuclear theory, and are sensitive to the nuclear structure of the initial and final nuclei of the decay. I will present recent shell model calculations exploring the value of the nuclear matrix elements, and I will also explore the correlation between neutrinoless double-beta decay matrix elements and other nuclear structure observables, such as double Gamow-Teller transitions and second-order
electromagnetic decays.

Primary author: MENENDEZ, Javier (University of Barcelona)

Presenter: MENENDEZ, Javier (University of Barcelona)

Shape Coexistence far from Stability

Content

I will review the basic physics underlying the phenomenon of shape coexistence at the neutron rich shores and its role as the portal to the Islands of Inversion at N=40 and N=50. Then I will discuss the limitations of our semantics related to the nuclear shape using the Kumar invariants up to Q^6. We introduce the K-plots which show the resulting (invariant) mean values of β and γ and their variances in the β and γ plane. Some unexpected conclusions arise concerning the noticeable softness in β and the extremely large γ softness in medium mass nuclei. Finally I will argue that the use of the term "spherical nuclei" is rather an abuse.

Primary author: POVES, Alfredo (Departamento de Fisica Teoris e IFT-UAM/CSIC)

Presenter: POVES, Alfredo (Departamento de Fisica Teoris e IFT-UAM/CSIC)

Structure of Nuclei near 100Sn

Content

Inevitable progress has been achieved in recent years regarding the available data on the structure of 100Sn and neighboring nuclei. Updated nuclear structure data in the region will be presented using selected examples. State-of-the-art experimental techniques involving stable and radioactive beam facilities have enabled access to those exotic nuclei. The analysis of experimental data has established the shell structure and its evolution towards N = Z = 50 of the number of neutrons, N, and the atomic number, Z, seniority conservation and proton–neutron interaction in the g9/2 orbit, the super-allowed Gamow–Teller decay of 100Sn, masses and half-lives along the rapid neutron-capture process (r-process) path and super-allowed α decay beyond 100Sn. The status of theoretical approaches in shell model will be discussed and their predictive power assessed. The calculated systematics of high-spin states for N = 50 isotopes including the 5- state and N = Z nuclei in the g9/2 orbit is presented for the first time.

Primary author: GORSKA, Magdalena (GSI Darmstadt)

Presenter: GORSKA, Magdalena (GSI Darmstadt)

Beta decay of exotic Tz=-2 and Tz=-1 nuclei

Content

I will present an overview of the physics case of the decay of even-even Tz=-2 and Tz=- 1 nuclei in the fp shell. The experiments started some years ago motivated by the idea of comparing these decays with the mirror charge-exchange reaction process on the mirror stable targets. Experiments have been carried out at GSI, GANIL and RIKEN and reached the most exotic cases where the decay is not dominated by delayed-particle emission. I will present RIKEN experiments with particular emphasis on the decay of ^{64}Se. This case presents a unique feature in the sense that the ground state of the daughter nucleus is the anti-analogue state of the parent. Probably a single case across the nuclide table.

Primary author: RUBIO, Berta (Instituto de Física Corpuscular CSIC-Univ.Valencia)

Presenter: RUBIO, Berta (Instituto de Física Corpuscular CSIC-Univ.Valencia)

Removal of the center of mass in nuclei within the Equation of Motion Phonon Method

Content

We present the Equation of Motion Phonon Method (EMPM). This method constructs and solves iteratively a set of equations of motion to generate a multiphonon basis built of particle-hole or quasiparticle Tamm Dancoff phonons. The basis so obtained is then used to solve the eigenvalue problem in the full multiphonon space.
We have performed several applications of the method in different regions of the nuclear chart. It was adopted, in the particle-hole basis, to investigate the dipole response in the heavy, neutron rich, ^{208}Pb [1] and ^{132}Sn [2], its quasiparticle formulation was used to study low-energy states of the open shell neutron rich ^{20}O[3] and has been extended to odd nuclei with one particle or one hole external to a doubly magic core [4-6].
In this contribution we focus on the issue of the removal of the center of mass in nuclei. We have implemented the Singular Value Decomposition (SVD) method to effectively orthogonalize the multiphonon configuration with respect to the subspace which is contaminated by spurious configurations [7]. We have applied the method to study the effect of the removal of spurious contaminations from the ground and the excited states of ^{4}He using the chiral potential NNLO$_{sat}$[8]. We have shown that the center of mass spouriosity, while having a small impact on the ground state properties once an intrinsic Hamiltonian is adopted, significantly affects the low- and high-energy states producing a theoretical spectrum in fair agreement with the experiment once three-phonons states are included.

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Presenter: VESELY, Petr

iThemba LABS: The South African National Facility for Nuclear Physics and Accelerator Based Sciences

Content

As the sole research infrastructure of the kind in the African continent, iThemba LABS has become the hub to a vibrant research, human capital development, and collaboration network for nuclear science that includes the South African universities, research institutions and international counterparts.
The Facility enjoys a prominent global position and plays a critical role in coordinating the continental contribution to collaborative initiatives with prestigious institutions. Through research in, and production of, accelerator-based radioisotopes, the Facility demonstrates the translation from basic to applied research with innovative real-world solutions, and is a world leader in the accelerator-based production of long-lived radioisotopes for use in a range of medical applications.
The research agenda of iThemba LABS is accomplished largely through the use of a Separated Sector Cyclotron (SSC), a particle accelerator that produces particle beams for research, as well as R&D and production of radioisotopes. The SSC, commissioned in 1985, is an aging research platform with a significant oversubscription of beam time due to increased activities initiated since 2016. To elevate the iThemba LABS contribution to knowledge production, and, consequently, mitigate the key risks to sustainability, the Facility developed a robust strategy articulated through four pillars of its Long-Range Plan. The talk will give as status of the implementation of the Long Range Plan that started 4 years ago.

Primary author: AZAIEZ, faical (IPN-ORSAY/IN2P3)

Presenter: AZAIEZ, faical (IPN-ORSAY/IN2P3)

Fundamental Physics with Nuclei

Content

Next-generation experiments are poised to explore lepton-number violation, discern the neutrino mass hierarchy, understand the particle nature of dark matter, and answer other fundamental questions aimed at testing the validity and extent of the Standard Model. Nuclei are used for these high-precision tests of the Standard Model and for searches of physics Beyond the Standard Model. Without a thorough understanding of nuclei, including electroweak structure and reactions, we will not be able to meaningfully interpret the experimental data nor can we disentangle new physics signals from underlying nuclear effects. To describe nuclear properties, I use many-body nuclear interactions and electroweak currents derived in chiral effective field theory, and Quantum Monte Carlo methods to solve for the nuclear structure and dynamics of the many-body problem for nuclei. This microscopic approach yields a coherent picture of the nucleus and its properties, and indicates that many-body effects are essential to accurately explain the data. In this talk, I will report on recent progress in Quantum Monte Carlo calculations of electron and neutrino interactions with nuclei in a wide range of energy and momentum transfer and their connections to current experimental efforts in fundamental symmetries and neutrino physics.

Primary author: PASTORE, saori (University of South Carolina)

Presenter: PASTORE, saori (University of South Carolina)

Rare weak decays and neutrino mass

Content

The question whether or not neutrinos are Majorana fermions (i.e. their own anti-particles) remains among the most fundamental open questions of subatomic physics. If neutrinos are Majorana particles it would revolutionize our understanding of physics.

Although neutrinoless double beta decay, $0\nu\beta\beta$, was proposed more than 80 years ago to establish the nature of neutrinos, it still remains the most sensitive probe into the non-conservation of lepton number. $0\nu\beta\beta$-decay is a postulated extremely slow and yet unobserved radioactive process in which two neutrons (or protons) inside a nucleus transform into two protons (or neutrons) emitting two electrons (or positrons), respectively, but no neutrinos. Its observation would be a breakthrough in the description of elementary particles and would provide fundamental information on the neutrino masses, their nature, and origin.

On the other hand, in addition to giving relevant information to be used in the search for double beta decay, single β-decay in medium mass and heavy nuclei itself is still today one of the unsolved problems in nuclear structure. It can also give information about the absolute mass scale of the neutrino spectrum and can be used as an approach to reach sensitivity on neutrino masses in the sub-eV range.

In this talk rare weak decays, in particular double beta decay and extremely low Q-value single beta decay and their connection to neutrino mass, are discussed from theoretical point of view. The current situation is then addressed by combining theoretical results with recent experimental data.

Primary author: KOTILA, Jenni (University of Jyväskylä)

Presenter: KOTILA, Jenni (University of Jyväskylä)

Jacobi no-core Shell Model for p-shell hypernuclei

Content

Nuclear physics with strangeness plays an important role in understanding nuclear interactions from an enlarged $SU(3)$ perspective. A hypernuclues is created when one or several nucleons inside a nucleus are replaced by strange hyperons. In view of the scarcity of hyperon-nucleon (YN) scattering data, Λ hypernuclei especially the light systems are indispensable laboratory for testing microscopic approaches to YN interactions.

In this contribution, we investigate light s- and p-shell Λ hypernuclei up to $A = 7$ baryons employing the Jacobi no-core shell model (J-NCSM) [1] approach in combination with chiral nucleon-nucleon (NN) and YN interactions. In order to speed up the convergence with respect to model space, the employed NN and YN interactions are softened using similarity renormalisation group (SRG) [2]. We first study the predictions of the two practically phase-equivalent YN potentials at next-to-leading order, NLO13 [3] and NLO19 [4], for the Λ separation energies B_Λ of ${}^4_\Lambda\mathrm{He}$, ${}^5_\Lambda\mathrm{He}$ and ${}^7_\Lambda$Li hypernuclei [5]. Possible implications of an increased hypertriton energy $B_\Lambda({}^3_\Lambda\mathrm{H})$ on the energy spectrum of ${}^7_\Lambda$Li [6] are also thoroughly discussed.

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Parity Violating Asymmetry and Dipole Polarizability in 208Pb

Content

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 (see e.g. [1-3]). 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 saturation. Hence, the interest in the low energy nuclear physics community to foster the needed experimental and theoretical developments to accurately study these two observables [4].

In this contribution I will briefly overview our past and recent theoretical analysis of the parity violating asymmetry and electric dipole polarizability in 208Pb [5-8].

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Presenter: ROCA MAZA, JAVIER (Istituto Nazionale di Fisica Nucleare)

Gamow-Teller excitations in the SSRPA approach

Content

The charge-exchange subtracted second random-phase approximation (SSRPA), based on Skyrme functionals,is emplyed to investigate Gamow-Teller resonances in several closed-shell and closed-subshell nuclei, located in different regions of the nuclear chart [1,2]. The amount of Gamow-Teller strength is considerably smaller than in other energy-density-functional calculations and agrees better with the experimental data. These important results, obtained without any *ad hoc* quenching factors, are due to the presence of two-particle–two-hole configurations. Their density progressively increases with excitation energy, leading to a long high-energy tail in the spectrum, a fact that may have implications for the computation of nuclear matrix elements for neutrinoless double-beta decay in the same framework.

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Presenter: GAMBACURTA, Danilo (Istituto Nazionale di Fisica Nucleare)

Persistence of the weak-coupling limit around ^{132}Sn: the case of the 1p-2h ^{131}Sb nucleus

Content

The emergence of collectivity in atomic nuclei is one of the most striking pieces of evidence of self-organization in many-body quantum systems 1. In particular, the quest for the onset of coherent motion of nucleons around a doubly magic core, such as ^{132}Sn and ^{208}Pb, is still attracting much attention, as it provides information on the role of the long-range part of the residual proton-neutron interaction [2,3]. This is intimately related to the underlying shell structure and to the microscopic nature of the nuclear forces, leading to the competition and couplings between single-particle and collective degrees of freedom.
In this work, the lifetime of the first 11/2$^+$ state in the 1p-2h, ^{131}Sb nucleus around doubly-magic ^{132}Sn was measured by fast-timing techniques, yielding τ=5(3) ps, the first such result in neutron-rich, odd-even antimony isotopes approaching the N=82 shell closure. This finding, at the limit of sensitivity of the experimental method, enabled to asses the electric-quadrupole reduced transition probability to the $7/2_1^+$ ground state, providing B(E2) =1.5(9) W.u., similar to the value reported for the first 2$^+$ state of ^{130}Sn (1.18(26) W.u.). The experiment was carried out at Insititut Laue-Langevin (ILL) by using neutron-induced fissions of ^{235}U and the LOHENGRIN spectrometer [4], with a detection setup at the focal plane composed by an ionization chamber, two HPGe detectors and four $LaBr_3$(Ce) fast scintillators for sub-nanosecond lifetime measurements [5].
The experimental results were compared to realistic large-scale shell-model calculations, with a ^{100}Sn core and a two-body effective interaction derived from the CD-Bonn NN potential [6,7]. The latter provides a good description of the structure of ^{131}Sb pointing to a wave function of the 11/2$^+$ state dominated by the $\pi g_{7/2} \otimes 2^+$ (^{130}Sn) configuration. This, along with the experimental results, suggest the validity of the weak coupling limit description in this nucleus, in contrast with the increase of collectivity observed in the neighboring ^{129}Sb system which goes beyond a pure shell model interpretation [2]. Implications on the emergence of collectivity around ^{132}Sn will be discussed.

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Presenter: Dr BOTTONI, Simone (Università degli Studi di Milano and INFN Sez. Milano, Milano, Italy)

Ab-initio description of the monopole resonance in light- and medium-mass nuclei

Content

Giant monopole resonances have a long-standing theoretical importance in nuclear structure. The interest resides notably in the so-called breathing mode that has been established as a standard observable to constrain the nuclear incompressibility. The Random Phase Approximation (RPA) within the frame of phenomenological Energy Density Functionals (EDF) has become the standard tool to address (monopole) giant resonances and extensive studies, mostly in doubly-closed-shell systems, have been performed throughout the years, including via the use of so-called sum rules. A proper study of collective excitations in the *ab-initio* context is, however, missing.

In this perspective, the first systematic ab-initio predictions of (giant) monopole resonances will be presented. *Ab-initio* Quasiparticle-RPA (QRPA) and Projected Generator Coordinate Method (P-GCM) calculations of monopole resonances are compared in light- and mid-mass closed- and open-shell nuclei, which allows in particular to investigate the role of superfluidity from an *ab-initio* standpoint. Sum rules are also employed within both many-body schemes to characterise the fragmentation of the monopole strength. The study further focuses on the dependence of the results on the starting nuclear Hamiltonian derived within the frame of chiral effective field theory.

Monopole resonance represents, thus, the first step towards the investigation of higher multipolarities. Eventually, the mid-term goal to establish P-GCM as a new method to study resonances in the light- and medium-mass region of the nuclide chart will be discussed: interpretation and analysis of resonance data in lighter nuclei is a very demanding task on which ab-initio P-GCM could shed new promising light.

Primary author: PORRO, Andrea (CEA IRFU, Université Paris-Saclay)

Presenter: PORRO, Andrea (CEA IRFU, Université Paris-Saclay)

Lifetime measurement of first 4+ state in 102Sn

Content

The long chain of Sn isotopes is a formidable testing ground for nuclear models studying the evolution of shell structure and interplay between pairing and quadrupole correlations. A transition from superfluid nuclei at midshell to spherical nuclei is also expected approaching the neutron shell closures at N = 50, where the seniority scheme can be adopted to describe the energy spectra. However, the corresponding B(E2 : 0+⟶2+) values have shown a presumed deviation from the expected parabolic behavior. From a theoretical point of view, various attempts have been done to explain the experimental results, in particular by including core-breaking excitations in the shell-model calculations by activating protons and neutrons from the g9/2 orbital to the higher ones. From experimental side, limited data are available beyond 104Sn on this very neutron- deficient region, leading to a difficulty in a firmly establishment of core-braking effect.

In this presentation, we will report on the first lifetime measurement for the 4+ state in 102Sn which is sensitive to the balance between the pairing and quadrupole terms in the nuclear interaction. The experiment is performed at GSI based on the use of hybrid AIDA+HPGe+LaBr3(Ce) array, made available by the HIS- PEC/DESPEC collaboration. The nuclei of interest were separated and identified through the FRS separator, following the production via fragmentation reaction of 124Xe beam incident on a 9Be target. The 102Sn ions are stopped by AIDA array and γ rays emitted from the 6+ seniority isomer are collected by FATIMA array which allows a direct lifetime measurement with a precision up to few tens of ps. The obtained experimental data would be compared with theoretical predictions, shedding light on the detailed wave function and the core breaking contribution.

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Presenter: ZHANG, Guangxin (Istituto Nazionale di Fisica Nucleare)

Application of the Equation of Motion Phonon Method in Exotic Nuclei

Content

We present the extension of Equation of Motion Phonon Method (EMPM) suitable for calculating the structure and energy spectra of single-Λ hypernuclei of various masses. Using an effective ΛN potential, this method was applied to calculate the structure of $^{12}_{\Lambda}$B, which provides a theoretical input to calculate the cross section in electroproduction of $^{12}_{\Lambda}$B. We obtained reasonable agreement with the previous theoretical studies and the experimental data. This allows us to provide theoretical prediction of the cross section in electroproduction of $^{40}_{\Lambda}$K and $^{48}_{\Lambda}$K, the experimental measurement of which is planned.

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Presenter: PETRELLIS, Dimitrios (Nuclear Physics Institute, Czech Academy of Sciences)

Analysis of two-proton transfer reactions in the ^{18}O+^{40}Ca and ^{20}Ne+^{116}Cd collisions

Content

Shell-model calculations have successfully provided excellent descriptions of the nuclear structure for various nuclei. The spectroscopic amplitudes for one- and two-valence particles derived from this structure calculations are essential in transfer reactions dynamics by determining microscopically the integrated or differential transfer cross sections corresponding to the one- and two-particle transfer. Recent results for the two-proton transfer cross sections in ^{40}(^{18}O,^{20}Ne)^{38}Ar reaction at 270 MeV and in the ^{116}Cd(^{20}Ne,^{18}O)^{118}Sn reaction at 306 MeV will be shown in the present analysis. For the ^{20}Ne+^{116}Cd collisions, the effect of correlations between the two transferred protons is compared with the same reaction transferring two neutrons. In both these ^{18}O+^{40}Ca and ^{20}Ne+^{116}Cd collisions, the double charge exchange processes have been measured in the NUMEN project. So, once the transfer of nucleons can contaminate the measured meson charge exchange cross section, it is crucial to evaluate the role played by the transfer process present in the charge exchange reactions.

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