Shell Model as a Unified View of Nuclear Structure

lundi 8 octobre 2012 - mercredi 10 octobre 2012

Institut Pluridisciplinaire Hubert Curien

Recueil des résumés

Contents

Ab-initio approaches to nuclear structure / 3

The No-Core Shell Model as an Effective Theory

Auteur: Ubirajara van Kolck[1]

[1] *IPN Orsay*

Auteur correspondant vankolck@ipno.in2p3.fr

The No-Core Shell Model is a powerful method to calculate nuclear properties starting from internucleon interactions. As in the traditional Shell Model, effective interactions have to be constructed for the model space where the Schroedinger equation is solved. I discuss how this can be done systematically and consistently with the underlying theory of strong interactions, QCD, using effective field theories for nucleons in a harmonic oscillator potential.

Ab-initio approaches to nuclear structure / 5

Toward an Ab-Initio Description of Exotic Open-Shell Isotopes

Auteur: Barbieri Carlo[1]

[1] *University of Surrey*

Auteur correspondant c.barbieri@surrey.ac.uk

The talk discusses recently achieved proof-of-principle calculation based on Gorkov-Green's function theory. The method allows first principle calculations of truly open shell, semi-magic, nuclei and has been applied successfully up to Ni-78 with soft low-momenutm interactions. The inclusion of three-nucleon forces has also been demonstrated by calculations within the Green's function formalism and provides the last key element for realistic studies of nuclear physics.

The Gorkov approach presented here substantially extends the scope of ab-initio theory in the medium mass region from a few tens of closed shells cases to hundreds of open shell isotopes. The main output of the formalism is the single-particle spectral function which describes processes involving the addition or knonkout of a nucleon and provides a theoretical optical potential for elastic scattering.

We will give some example of applications and discuss first results regarding the implication of three-nucleon forces on the evolution of correlations with proton-neutron asymmetry.

Ab-initio approaches to nuclear structure / 7

Nonmicroscopic investigations of 3-alpha bosonic states in 12C nucleus

Auteur: Marianne DUFOUR[1]

Co-auteur: Rimantas Lazauskas [2]

[1] *Université de Strasbourg*

[2] *IPHC Strasbourg*

The transition from descriptions of nuclear-wave functions in terms of A nucleons (fermions) toward those in terms of n < A composite clusters as e.g. particles (bosons) is far from being obvious. However, it represents a very interesting challenge which can help to point out states in which clustering is expected to be strongly dominant as in so-called condensate state, a typical example being the 0+2 in the 12C nucleus, known as the Hoyle state [1].
During this talk, we will mainly focuss on recent investigations of the 12C nucleus performed with a nonmicroscopic -particle model involving local and nonlocal potentials [2]. Faddeev equations formulated in configuration space are used to solve the 3-body problem for bound and resonant states. We demonstrate that the nonlocal potential developed by Z. Papp and S. Moszkowski appears to be particularly well-adapted to study 3 clustering. We point out 12C states of positive-parity which share common features with the 0+2 Hoyle states and are interpreted as 3-condensate states. Several negative-parity states revealing a clear bosonic - particle structure are also obtained. We will conclude this talk with preliminary results obtained with a similar nonmicroscrocopic approach complemented by microscopic calculations for the 16O nucleus.

1. T. Yamada, Y. Funaki, H. Horiuchi, G. R¨opke, P. Schuck, A. Tohsaki, Lecture Notes in Physics 848 (2012) - Springer, Clusters in nuclei -Vol.2.
2. R. Lazauskas, M. Dufour, Phys. Rev. C 84, (2011)

Double-beta decay and other rare processes / 25

Status of the results of double beta decay experiments

Auteur: Frédéric PERROT[1]

[1] *CNRS/IN2P3/Bordeaux1*

Auteur correspondant fperrot@cenbg.in2p3.fr

In my talk, I will present a status of various double beta decay experiments. Especially, I will focused on the various experimental approaches, the background of these experiments, their results or expected results on double-beta 2 and 0-neutrino half-lives and the corresponding limit on the effective neutrino mass.

Double-beta decay and other rare processes / 1

Recent advances in neutrinoless double beta decay with energy density functional methods

Auteur: Tomás Rodríguez[1]

[1] *Technische Universität Darmstadt*

Auteur correspondant t.rodriguez@gsi.de

In this presentation I will summarize some recent calculations of the nuclear matrix elements (NME) for neutrinoless double beta decay performed within the energy density functional framework. In particular, I will focussed on the role of pairing, deformation and shell effects in the NME values.

Double-beta decay and other rare processes / 14

Neutrinoless double beta decay within the Interacting Shell Model

Auteur: Javier Menéndez[1]

[1] *Technical University Darmstadt*

Auteur correspondant javier.menendez@physik.tu-darmstadt.de

Neutrinoless double beta (0nbb) decay is a unique process because, if detected, it will imply the Majorana nature of neutrinos. Moreover, once an experimental lifetime will be measured, with the nuclear matrix elements (NMEs) very important information about the hierarchy an absolute masses of the neutrinos will be known.

Therefore, a reliable calculation of the NMEs is crucial. Those can be obtained with the Shell Model (SM) for most 0nbb decay candidates, which lie in nuclear mass regions where the SM is able to give a very good spectroscopic description.
I will present some details of these calculations, including the pairing and deformation effects on the NMEs.

I will then explore the problem of the value of the axial-vector coupling g_A, which needs to be quenched in Gamow-Teller and two-neutrino double beta decay calculations, using weak currents based on chiral effective field theory (chiral EFT).

This theory also gives nuclear forces that can be used in nuclear structure calculations.

Nuclear structure at the proton dripline / 11

A PSDPF interaction to describe intruder negative parity states in sd shell nuclei

Auteur: Mouna BOUHELAL[1]

Co-auteurs: Etienne CAURIER [2]; Florent HAAS [3]; Frederic NOWACKI [2]

[1] *Université de Tébessa,Algérie*

[2] *IPHC,Strasbourg*

[3] *IPHC, Srasbourg*

Auteur correspondant florent.haas@iphc.cnrs.fr

In the level scheme of sd shell nuclei,there is generally at relatively low excitation energies,coexistence of 'normal' positive parity states and of 'intruder' negative parity states.The aim of our work is to describe these intruder states in the full p-sd-pf model space with a 4He core and allowing for one nucleon jump between the major shells.To construct our PSDPF interaction,we first modified the p-sd and sd-pf cross-monopole terms and then applied a fitting procedure to adjust all PSDPF parameters by comparing an extended set of experimental and calculated level energies.Results obtained with the new interaction will be compared with experimental data for nuclei throughout the sd shell.

Nuclear structure at the proton dripline / 13

Nuclear structure study of the mirror nuclei 22ne and 22mg around the 21na+proton threshold

Auteur: Mouna Bouhelal[1]

Co-auteurs: ETIENNE CAURIER [2]; FLORENT HAAS [3]; Frederic NOWACKI [2]

[1] *Laboratoire de Physique Appliquée et Théorique, Université de Tébessa, Tébessa, Algérie*

[2] *IPHC Strasbourg*

[3] *IPHC STRASBOURG*

Auteur correspondant m_bouhelal@yahoo.fr

A comparison of the structure properties of 22Ne and 22Mg is interesting because in nucleosynthesis 22Mg can be formed through the capture reaction 21Na(p,gamma) for which the cross sections will depend on spin-parity assignments of the 22Mg states around the proton-emission threshold .
For the pair 22Ne-22Mg, our calculations using the PSDPF interaction predict fifteen states in the excitation energy range up to ~ 6.35 MeV. Experimentally, fourteen states are reported in NNDC with well defined spin and parity for the 22Ne. Twelve of them have positive parity and two of them have negative parity. Concerning the 22Mg, sixteen states are reported, the majority of them having no fixed spin and parity.
In our contribution to the workshop, we will propose based on the shell model calculations a one to one level correspondence between 22Ne and 22Mg. In particular what the negative parity states are concerned, three states are identified in 22Ne: 2- at 5146 keV, 3- at 5910 keV and 0- at ~ 6234 keV, they correspond to the mirror states in 22Mg : 2- at 5006 keV, 3- at 5838 keV and 0- at 6046 keV.
Finally, we will present for the mirror nuclei 22Ne-22Mg, a comparison between the shell model predictions obtained by the interaction PSDPF+Coulomb and the experimental level schemes and electromagnetic transitions.

Nuclear structure at the proton dripline / 58

Nuclei at the mirror: study of energy differences between analogue excited states

Auteur: Silvia Lenzi[1]

[1] *University of Padua and INFN*

The study of isospin symmetry in nuclei as a function of angular momentum is a very powerful tool to understand nuclear
properties in rotating nuclei. These studies have become feasible in the last decade due to recent experimental
developments in the identification of proton-rich nuclei produced with very low cross sections. Contemporaneously,
state-of-the-art shell-model codes have been produced for the description of these data. The synergy between theory and
experiment for the study of energy differences of mirror and isobaric analogue nuclei in the mass region between A ~ 30
and A ~ 70 allows the investigation of the evolution of the nuclear wave functions with increasing spin. The alignment
process, changes of the nuclear shape and the intrinsic configuration, together with the evidence of isospin-non-conserving terms of the nuclear interaction are examples of the type of phenomena that can be studied from
the analysis of Coulomb energy differences.
A review of the different results on what we can learn from mirror energy differences will be given, together with an
outlook on current and future developments.

Nuclear structure at the proton dripline / 19

Shell-model description of isospin-symmetry breaking in nuclei

Auteur: Nadya Smirnova[1]

Co-auteurs: ETIENNE CAURIER [2]; Yek Wah Lam [3]

[1] *CENBG*

[2] *IPHC Strasbourg*

[3] *CENBG, France, and TU Darmstadt, Germany*

Auteur correspondant smirnova@cenbg.in2p3.fr

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

We have recently constructed a new empirical sd shell-model Hamiltonian which reproduces accurately splittings of isobaric multiplets [1,2]. The Hamiltonian contains on top of the isospin-conserving realistic sd-shell interaction (USD/USDA/USDB), the Coulomb interaction and a phenomenological term of Yukawa type which models
the isospin-symmetry breaking part of the effective nucleon-nucleon interaction. The latter represents about 1-2% of the residual shell-model interaction. The values of strength parameters are adjusted by a least-squares fit to the experimentally deduced coefficients of the isobaric-mass-multiplet equation (IMME). Thus, solution of the eigenproblem by numerical diagonalization in proton-neutron formalism allows to get nuclear states of mixed isospin. The empirical isospin-nonconserving Hamiltonian represents a modern high-precision version of the previous work [3].

A few applications will be discussed. First, we analyze a particular behaviour of the IMME coefficients as a function of the mass number.
Second, calculation of isospin-symmetry breaking correction to the superallowed 0+ -> 0+ beta-decay for sd-shell emitters in comparison with the existing results [4,5].

[1] Y.H. Lam, Ph.D. thesis, University of Bordeaux 1 (2011).
[2] Y.H. Lam, N.A. Smirnova, E.Caurier, submitted.
[3] W.E. Ormand and B.A. Brown, Nucl. Phys. A491, 1 (1989).
[4] W.E. Ormand and B.A. Brown, Phys. Rev. Lett. 62, 866 (1989)
[5] I.S. Towner and J.C. Hardy, Phys. Rev. C77, 025501 (2008).

Nuclear structure at the proton dripline / 54

Application of Isospin Non-Conserving Hamiltonian for Isospin-Mixing Correction in Superallowed B-Decay

Auteur correspondant lamyihua@gmail.com

Opening / 27

Opening talk

Auteur correspondant k.langanke@gsi.de

Recent progress in shell model and other approaches to nuclear structure / **24**

Shell-model half-lives for r-process waiting point nuclei including first-forbidden contributions

Auteur: Qijun Zhi[1]

Co-auteurs: ETIENNE CAURIER [2]; Gabriel Martínez-Pinedo [1]; J J Cuencag-Garcia [3]; Kamila Sieja [4]; Karlheinz Langanke [3]

[1] *TU Darmstadt*

[2] *IPHC Strasbourg*

[3] *GSI*

[4] *Institute Pluridisciplinaire Hubert Curien*

Auteur correspondant q.zhi@gsi.de

We have performed large-scale shell-model calculations of the half-lives and neutron-branching probabilities of the r-process waiting point nuclei at the magic neutron numbers N=50, 82, and 126. The calculations include contributions from allowed Gamow-Teller and, for the first time, also from first-forbidden transitions. We find good agreement with the measured half-lives for the N=50 nuclei with charge numbers Z=28-32 and for the N=82 nuclei 129Ag and 130Cd. The contribution of forbidden transitions reduce the half-lives of the N=126 waiting point nuclei significantly, while they have only a small effect on the half-lives of the N=50 and 82 r-process nuclei. We also discuss the kexi approximation used in FF transitions and found that it is not a very good approximation when FF should be considered in the half lives.

Recent progress in shell model and other approaches to nuclear structure / **20**

Complexity, scale invariance and sensitivity in the nuclear shell model

Auteur: Víctor Velázquez[1]

Co-auteurs: A. Frank [2]; E. Landa [3]; R. Fossion [4]

[1] *Universidad Nacional Autónoma de México*

[2] *Instituto de Ciencias Nucleares, Universidad Nacional Autónoma de México & Centro de Ciencias de la Complejidad (C3) , Universidad Nacional Autónoma de México*

[3] *Instituto de Ciencias Nucleares, Universidad Nacional Autónoma de México*

[4] *Centro de Ciencias de la Complejidad (C3) , Universidad Nacional Autónoma de México*

Auteur correspondant vicvela@ciencias.unam.mx

The atomic nucleus is a many-body quantum system, where both the excitation energies and the wave functions can show specific correlations. From Random Matrix Theory, we know that these correlations are related to the underlying nuclear dynamics. In this work, we analyze concepts like complexity, scale invariance and sensitivity in the framework of the nuclear shell model, in the JT-scheme for 8 and 10 particles in the fp shell. In particular, we focus on transitions from pure to mixed states.

Recent progress in shell model and other approaches to nuclear structure / 22

Recent results in quantum chaos and its applications to nuclei and particles

Auteur: Jose Gomez[1]

Co-auteurs: A. Relano [1]; E. Faleiro [2]; J. Retamosa [1]; L. Munoz [1]; R.A. Molina [3]

[1] *Universidad Complutense de Madrid*

[2] *Universidad Politecnica de Madrid*

[3] *CSIC*

In the last decade or so, the study of chaos in nuclei and other quantum systems has been a very active research field. Besides work based on random matrix theory, new theoretical developments making use of information theory, time series analysis, and the merging of thermodynamics and the semiclassical approximation have been published [1]. In this talk, a survey of chaotic dynamics in atomic nuclei is presented, using on the one hand standard statistics of quantum chaos studies, as well as time series analysis methods. We emphasize the energy and isospin dependence of nuclear chaoticity, based on shell-model energy spectra fluctuations in Ca, Sc and Ti isotopes, which are analyzed using standard statistics such as the nearest level spacing distribution P(s) and the Dyson-Mehta Δ3 statistic [2].
We also discuss quantum chaos in general using a new approach based on the analogy between the sequence of energy levels and a discrete time series. Considering the energy spectrum fluctuations as a discrete time series, we have shown that chaotic quantum systems such as 24Mg and 32Na nuclei, quantum billiards, and random matrix theory (RMT) ensembles, exhibit 1/f noise in their power spectrum [3]. Moreover, we show that the spectra of integrable quantum systems exhibit 1/f2 noise [3]. Therefore we suggest the following conjecture:

The energy spectra of chaotic quantum systems are characterized by 1/f noise.

We have also derived an analytic expression for the energy level fluctuations power spectrum of RMT ensembles, and the results confirm the above conjecture [4].
The order to chaos transition has been studied in terms of this power spectrum for several intermediate systems, such as the Robnik billiard [5], the quartic oscillator or the kicked top [6]. A power law 1/f β is found at all the transition stages, and it is shown that the exponent β is related to the chaotic component of the classical phase space of the quantum system.
This approach has also been applied to study the possible existence of chaos remnants in nuclear masses [7], and to characterize the spectral fluctuations of imperfect spectra, with missing or misassigned levels [8].
Finally, we present a recent study of the low-lying baryon spectrum up to 2.2 GeV which has shown that experimental data exhibit a P(s) distribution close to GOE and, on the contrary, quark models predictions are more similar to the Poisson distribution [9]. This result sheds light on the problem of missing baryon resonances.

[1] J.M.G. Gómez, K. Kar, V.K.B. Kota, R.A. Molina, A. Relaño and, J. Retamosa, Phys. Reports 499, 103-126 (2011).
[2] R.A. Molina, J.M.G. Gómez and J. Retamosa, Phys. Rev. C 63, 014311 (2000).
[3] A. Relaño, J.M.G. Gómez, R. A. Molina, J. Retamosa, and E. Faleiro, Phys. Rev. Lett. 89, 244102 (2002).
[4] E. Faleiro, J.M.G. Gómez, R. A. Molina, L. Mu˜noz, A. Rela˜no, and J. Retamosa, Phys. Rev. Lett. 93, 244101 (2004).
[5] J.M.G. Gómez, A. Relaño, J. Retamosa, E. Faleiro, L. Salasnich, M. Vranicar, and M. Robnik, Phys. Rev. Lett. 94, 084101 (2005)
[6] M.S. Santhanam and J.N. Bandyopadhyay, Phys. Rev. Lett. 95, 114101 (2005).
[7] J. Barea, A. Frank, J.G. Hirsch, and P. Van Isacker, Phys. Rev. Lett. 94, 102501 (2005).
[8] R.A. Molina, J. Retamosa, L. Muñoz, A. Relaño, and E. Faleiro, Phys. Lett. B 644, 25 (2007).
[9] C. Fernández-Ramírez and A. Relaño, Phys. Rev. Lett. 98, 062001 (2007).

Recent progress in shell model and other approaches to nuclear structure / 6

Mean field theories, recent developments

Auteur: Luis Robledo[1]

[1] *Universidad Autonoma de Madrid*

Auteur correspondant luis.robledo@uam.es

Two items will be addressed in this talk, the first concern
developments to compute the overlaps required for beyond
mean field theories of the HFB type. They are based on the
powerful concept of the Pfaffian of a skew symmetric matrix
and are specially useful for odd-A systems where time
reversal invariance is broken.
The second concerns a recently proposed energy density
functional (denoted BCPM) inspired by microscopic inputs.
It form, fitting strategies and results in finite nuclei
will be discussed.

Shell evolution of neutron rich isotopes II / 0

NEUTRON-RICH LEAD ISOTOPES PROVIDE HINTS ON THE ROLE OF EFFECTIVE THREE-BODY FORCES

Auteur: Jose Javier Valiente Dobon[1]

Co-auteurs: Andrea Gottardo [2]; Giovanna Benzoni [3]

[1] *Laboratori Nazionali di Legnaro (INFN)*

[2] *LNL-INFN*

[3] *Milano-INFN*

Auteur correspondant valiente@lnl.infn.it

Electromagnetic transition rates, in particular for E2 transitions, are a sensitive and well-studied probe of nuclear structure: their dependence on the nuclear wave function offers the possibility of strict tests of theoretical models. Usually, B(E2) rates are calculated in a restricted shell-model space and they are then renormalized with constant effective charges. However, even large-scale shell-model calculations may fall short in reproducing the experimental data, as in the case of proton-rich tin isotopes [1,2]. In this regard, there is a common but bad practice of neglecting effective three-body forces and two-body transition operators when calculating the B(E2) values which could be the origin of the problems encountered [3]. We have performed an experiment to measure the transitions rates from the seniority-isomers of semi-magic neutron-rich lead isotopes and they show indeed discrepancies with shell-model estimates. This region of the nuclide chart has been so far scarcely explored due to its high mass and neutron excess, which oblige to exploit fragmentations reactions with relativistic uranium beams. Consequently, neutron-rich nuclei beyond 208Pb were populated by using a 1 GeV*A 238U beam at GSI. The resulting fragments were separated and analyzed with the FRS-RISING setup [4,5]. Many neutron-rich isotopes were identified for the first time and a significant number of new isomers were hence discovered, enabling to study the structure of these isotopes. The new exotic isotopes observed extend up to 216Pb along the Z=82 shell closure and up to N=134 and N=138 for the proton-hole and proton-particle Tl and Bi nuclei, respectively. New isomers were observed in 212-216Pb, in 217Bi, in 211,213Tl and in 210Hg. In the talk, the experimental results will be presented as well as state-of-the-art shell-model calculations pointing out how the measured isomeric B(E2)s in neutron-rich lead isotopes seem to require state-dependent effective charges to be correctly reproduced. It will be shown how this is related with the aforementioned neglect of

effective three-body forces, whose introduction improves the agreement with the experimental data. The unexpected structure of the very exotic 210Hg isotope will also be discussed.

References

[1] A. Banu et al., Phys. Rev. C 72, 061305(R) (2005).
[2] C. Vaman et al., Phys. Rev. Lett. 99, 162501 (2007).
[3] A. Poves et al., Phys. Lett. B 82, 319 (1979).
[4] H. Geissel et al., Nucl. Instr. Meth. B 70, 286 (1992).
[5] S. Pietri et al., Nucl. Instr. Meth. B 261, 1079 (2007).

Shell evolution of neutron rich isotopes II / 4

Single-particle states around 132Sn by realistic shell-model calculations

Auteur: Angela Gargano[1]

[1] *INFN-Napoli*

Auteur correspondant gargano@na.infn.it

Over the past several years various shell-model studies have been performed for neutron-rich nuclei beyond 132Sn, all leading to spectroscopic properties in very good agreement with the experimental data (see for instance [1,2] and references therein). In these works, a unique Hamiltonian has been used with the single-particle energies taken from the experiment and the two-body effective interaction derived from the CD-Bonn NN potential [3] renormalized by means of the Vlow-k approach [4].

Using this Hamiltonian calculations have been performed for the two isotopes 135,137Sb and the two isotones 135Te and 137Xe. These nuclei, having respectively one proton and one neutron outside doubly magic 132Sn, give the opportunity to investigate the evolution of single-particle states with increasing nucleon number. To this end, the properties of states with spin and parity corresponding to those of the single-particle orbits are discussed, with particular attention focused on the one-particle spectroscopic factors.
These quantities are indeed essential for mapping out the single-particle structure of nuclei and may now become available for exotic nuclei thanks to transfer experiments in inverse kinematics

Comparison shows that the calculated results reproduce very well the experimental excitation energies as well as the spectroscopic factors recently extracted for states in 137Xe from the (d,p) transfer reaction [5].This gives confidence in the predicted spectroscopic factors obtained for the other studied nuclei and provides insight into the evolution of the single-neutron and single-proton states outside 132Sn.

[1] L. Coraggio et al., Phys. Rev.C 80, 021305 (2009).
[2] A. Covello et al., J.Phys. Conf. Ser. 267, 012019 (2011).
[3] R. Machleidt, Phys. Rev. C 63, 024001 (2001).
[4] L. Coraggio et al., Prog. Part. Nucl.Phys. 62, 135 (2009).
[5] B. P. Key et al., Phys Rev. C 84, 024325 (2012).

Shell evolution of neutron rich isotopes II / 8

EVOLUTION OF THE SHELL STRUCTURE IN MEDIUM-MASS NUCLEI : SEARCH FOR THE 2d5/2 NEUTRON ORBITAL IN 69Ni

Auteurs: Didier Beaumel[1]; Gilbert Duchêne[2]; Mohamad Moukaddam[2]

Co-auteurs: Alain Gillibert [3]; Alexandre Obertelli [4]; Beatriz FERNANDEZ-DOMINGUEZ [5]; Christelle Stodel [5]; Christian Finck [6]; Dominique CURIEN [7]; Else Pllumbi [8]; Emmanuel Clement [9]; FLORENT HAAS [10]; Faïrouz Hammache [11]; Francois DIDIERJEAN [7]; Freddy FLAVIGNY [3]; Frederic NOWACKI [12]; GEOFFROY BURGUNDER [13]; Iolanda MATEA [14]; Iulian stefan [15]; Jacques Guillot [8]; Jean-Claude Thomas [5]; Julien Gibelin [16]; Julien Pancin [5]; Julien Piot [12]; Kamila Sieja [17]; Kerby Kemper [18]; Laurent Nalpas [19]; Luc Perrot [8]; Lucia Caceres [13]; Muhsin N. Harakeh [20]; Nicolas de Séréville [8]; Olivier Sorlin [5]; Riccardo Raabe [21]; Sandra GIRON [8]; Stéphane Grévy [5]; Valérie Lapoux [22]; adrien matta [23]; jean-antoine scarpaci [24]; serge franchoo [25]

[1] *IPN , CNRS/IN2P3, Université Paris-Sud, F-91406 Orsay, France*

[2] *Université de Strasbourg, IPHC, 23 rue du Loess, F-67037 Strasbourg, France, CNRS, UMR7178, F-67037 Strasbourg, France*

[3] *CEA-Saclay/ IRFU / SPhN*

[4] *CEA/DSM/IRFU/SPhN*

[5] *GANIL*

[6] *CNRS*

[7] *IPHC*

[8] *IPNO*

[9] *CNRS GANIL*

[10] *IPHC STRASBOURG*

[11] *IPN-Orsay*

[12] *IPHC Strasbourg*

[13] *GANIL, CEA/DSM-CNRS/IN2P3, Bd Henri Becquerel, F-14076 Caen, France*

[14] *IPN Orsay*

[15] *Institut de Physique Nucléaire (IPN)*

[16] *LPCCaen*

[17] *Institute Pluridisciplinaire Hubert Curien*

[18] *Department of Physics, Florida State University, Tallahassee, Florida 32306, USA*

[19] *CEA/Saclay - IRFU - SPhN*

[20] *GSI/KVI*

[21] *GANIL Caen*

[22] *CEA/Saclay - IRFU - SPHN*

[23] *IPNOrsay*

[24] *IN2P3*

[25] *ipn*

Auteur correspondant mohamad.moukaddam@etu.unistra.fr

It has been shown that the neutron 2d5/2 orbital has to be included in shell-model calculations to explain the appearance of large quadrupole collectivity observed in the neutron rich Fe and Cr of the N ≈ 40 region. This work initiated by Caurier et al. has been recently revisited. Calculations in a large valence space involving the fp proton shell and the fpgd neutron shells including a strongly reduced 1g9/2 - 2d5/2 neutron gap down to ≈ 1.5 MeV affect the whole N = 40 region and point out a new island of inversion similar to those known for light nuclei around N = 8 and N = 20. A global mecanism could be deduced, in the frame of the shell-model approach, of the emergence of islands of inversion at Harmonic-Oscillator shell gaps driven by two particle-two hole neutron excitations into quadrupole-partner orbitals across these gaps.
Since now, no 5/2+ state has been assigned in previous studies of 69Ni, an ideal laboratory to search for the neutron 2d5/2 orbital. A (d,p) reaction onto a 68Ni beam produced at GANIL has been used to probe the single-particle energy of the 2d5/2 neutron orbital in 69Ni. Two 5/2+ states with important spectroscopic factors lying around 2.5 MeV excitation energy have been observed, for the first time, in 69Ni. The doublet is understood as the mixing of two main configurations of spherical nature. These results are in good agreement with large-scale shell-model calculations in which 2.5 MeV 1g9/2 - 2d5/2 gap for neutrons is included, and confirm experimentally Caurier's assumption of a reduced 1g9/2 - 2d5/2 neutron gap at N = 40.

Shell evolution of neutron rich isotopes II / 17

Structure evolution towards 78Ni : challenges in the interpretation of hard-won experimental data solved by simple means

Auteur: David Verney[1]

[1] *IPN Orsay*

Auteur correspondant verney@ipno.in2p3.fr

Considerable efforts have been recently deployed in order to reach experimentally the region in the immediate vicinity of 78Ni to assess the doubly magic character of this very neutron rich nucleus. The PARRNe ISOL device has been operating at IPN Orsay since more than a decade. Originally conceived as a test bench for R&D studies in the framework of the SPIRAL2 project, the performance of the setup has proven suitable to undertake a physics research program on the evolution of N=50 towards 78Ni by beta-decay studies. Though data remain relatively scarce, a global picture of the structure in this very neutron/proton asymmetric region is now emerging and shell model calculations in the natural valence space of 78Ni are being developed. In this talk, I will present how experimental evidence found in beta-decay studies integrates in the more global body of data coming from different experimental approaches. It allows in particular a glimpse to the evolution of the proton and neutron effective energy sequences - as well as to the evolution of the N=50 gap itself and its implication on the observed structures. The microscopic origin of these observed evolutions remains subject to debate.

Shell evolution of neutron rich nuclei I / 12

Weakly deformed, axial and triaxial configurations in neutron rich Sulfur isotopes

Auteur: Laurent Gaudefroy[1]

Co-auteur: Raphael Chevrier [1]

[1] *CEA-DAM*

Auteur correspondant laurent.gaudefroy@cea.fr

The structure of neutron rich Sulfur nuclei has been the recent subject of both experimental and theoretical studies. At N=28, experimental data interpreted within the shell model framework suggested a prolate/spherical shape coexistence. Similar interpretation has been proposed at N=27 for 43S. Recent beyond mean field calculations suggested a more complicated low-lying structure of neutron rich sulfur isotopes where the triaxial degree of freedom is important.
Within the shell model framework, we performed a systematic study of 42,44,46S and 43S. Coexistence of weakly deformed, axial and triaxial states is found at low excitation energy in these nuclei. Comparison with experimental data is rather satisfactory and agreement with recent beyond mean field calculations is found to be good.

Shell evolution of neutron rich nuclei I / 2

Unveilling the intruder deformed 0+2 state in 34Si

Auteur: Stéphane Grévy[1]

[1] *CENBG*

Auteur correspondant grevy@in2p3.fr

The 0+2 state in 34Si has been populated at the Ganil/Lise3 facility through the -decay of a newly discovered 1+ isomer in 34Al of 26(1) ms half-life. The simultaneous detection of e+e- pairs allowed the determination of the excitation energy E(0+2)=2719(3) keV and the half-life T1/2=19.4(7) ns, from which an electric monopole strength of rho^2(E0)=13.0(0.9)*10-3 was deduced. The 2+1 state is observed to decay both to the 0+1 ground state and to the newly observed 0+2 state (via a 607(2) keV transition) with a ratio of 1380(717). Gathering all information, a weak mixing with the 0+1 and a large deformation parameter of =0.29(4) are found for the 0+2 state, in good agreement with shell model calculations using a new sdpf-u-mix interaction allowing np-nh excitations across the N = 20 shell gap.

Shell evolution of neutron rich nuclei I / 59

Study of spin-orbit interaction and nuclear forces at the drip line

Auteur: sorlin olivier[1]

[1] *GANIL*

Auteur correspondant sorlin@ganil.fr

The present talk will present recent experimental studies aiming at studying the spin-orbit interaction and the evolution of the proton-neutron force when approaching the drip-line. For the former subject, we propose to use the bubble nucleus 34Si to probe the two-body spin orbit interaction. This study can be also used to test the validity of mean field approaches which predict a density and isospin dependence of the spin-orbit interaction. In the second subject, the study of the near drip-line nucleus 26F will be presented. It aims at studying how proton-neutron interactions are changing when a large proton to neutron binding energy asymmetry is found. Experimental results obtained at GANIL will be presented, together with tentative interpretations and consequences.

Shell evolution of neutron rich nuclei I / 18

Three-nucleon forces at neutron-rich extremes

Auteur: Johannes Simonis[1]

[1] *TU Darmstadt*

Auteur correspondant simonis@theorie.ikp.physik.tu-darmstadt.de

In the framework of chiral effective field theory, a systematic expansion for nuclear forces, it is possible to obtain valence shell interactions for nuclear structure calculations. These are obtained by applying many-body perturbation theory (MBPT) to a renormalization group (RG) evolved low-momentum interaction. In this approach three-nucleon forces are included naturally. Normal-ordered three-nucleon forces contribute to effective single-particle energies as well as two-body matrix elements. This talk will focus on the contributions from residual three-nucleon forces, which are expected to become more important with valence nucleons, so for the most neutron-rich isotopes. The theoretical findings are compared to a recent R3B-LAND experiment for 25,26O performed at GSI, Darmstadt.

Special session / 60

From cell to tumour: the case of invasive brain tumours

Auteur: Basil Grammaticos[1]

[1] *IMNC Univ. Paris 7 & Paris 11*

We begin with a study of the migratory behaviour of cells stemming from a brain tumour. Based on experimental data we study the interaction of cells, its effect on migration with emphasis on the interaction inhibition.
A cellular automaton model allows to describe the situation and quantify the interaction. In order to investigate possible clinical applications of inhibition, we introduce a diffusion-proliferation model that takes into account cell interaction and makes possible the description of solid tumours. We conclude that the effect of inhibition on the increase of patient life expectancy is marginal.

Next we address the question of tumour genesis (in particular for low grade tumours that exhibit a slow evolution). We show that we must take into account the "silent" phase of the tumour and analyse data on patients of the Cancerology service of Ste. Anne hospital. We also present some preliminary results on modelling the radiotherapy effects on patients suffering from low grade gliomas.

structure of proton rich nuclei around 100sn / 21

Isomer spectroscopy below 100Sn

Auteur: Andrey Blazhev[1]

Co-auteurs: B. S. Nara Singh [2]; Frederic NOWACKI [3]; Hubert Grawe [4]; Kamila Sieja [5]; M. Gorska [4]; N. Braun [1]; Plamen Boutachkov [4]; R. Wadsworth [2]; T. Brock [2]; Zh. Liu [6]

[1] *IKP, University of Cologne*

[2] *University of York, York, UK*

[3] *IPHC Strasbourg*

[4] *GSI Helmholtzgesellschaft für Schwerrionenforschung*

[5] *Institute Pluridisciplinaire Hubert Curien*

[6] *University of Edinburgh, Edinburgh, UK*

Auteurs correspondants: a.blazhev@ikp.uni-koeln.de, kamila.sieja@iphc.cnrs.fr

Isomers in regions around magic and doubly-magic nuclei allow for testing and tuning shell-model interactions and single particle energies and help for understanding of nuclear structure. Experimental transition strengths allow for determination of effective charges, while core-excited isomers manifest the shell gap and stress the importance of particle-hole excitations of the magic core.
In the region of the nuclear chart below 100Sn there is a multitude of nuclei with one or more isomeric states, both of seniority and spin-gap origin, some of which also core excited [1].
Following the experimental achievements of the last decades, a resent RISING experiment performed at the GSI, Darmstadt, yielded information about known and new isomeric states in the region, some predicted more than 30 years ago[2]. Our results on isomer spectroscopy of 94Pd[3], 96Ag[4], 96Cd[5] and 98Cd[6] as well as new preliminary results will be presented.
A comparison to shell-model calculations in various model spaces as well as implications for the nuclear structure around 100Sn will be presented and discussed.

[1] H. Grawe et al., Eur. Phys. J. A 27, 257 (2006)
[2] K. Ogawa, Phys. Rev. C 28, 958 (1983)
[3] T. S. Brock et al., Phys. Rev. C 82, 061309 (2010)
[4] P. Boutachkov et al., Phys. Rev. C 84, 044311 (2011)

[5] B. S. Nara Singh et al., Phys. Rev. Lett. 107, 172502 (2011)
[6] A. Blazhev et al., J. Phys.: Conf. Ser. 205, 012035 (2010)

structure of proton rich nuclei around 100sn / 9

The race for 100Sn – History of experimental and shell model approach

Auteur: Hubert Grawe[1]

Co-auteurs: Magdalena G´orska [1]; Thomas Faestermann [2]

[1] *GSI*

[2] *Physik Department E12, Technische Universität München*

Auteur correspondant h.grawe@gsi.de

The race for 100Sn – History of experimental and shell model approach

H. Grawe1, M. Górska1, T. Faestermann2
1 GSI Helmholtzgesellschaft für Schwerionenforschung, D-64291 Darmstadt, Germany
2 Physik Department E12, Technische Universität München, D-85748 Garching, Germany

The nuclear structure of 100Sn and its neighbours as result of about 50 years of experimental and shell model research is reviewed. The ever increasing sophistication of experimental techniques has paved the way towards 100Sn and its next neighbours with the most recent highlight of observation of super-allowed Gamow - Teller decay [1]. The available experimental data provide stringent constraints for nuclear structure theory as summarised in a recent review [2]. The robustness of the Z, N=50 shells, their evolution to the neutron-rich neighbours 78Ni and 132Sn, the role of core excitations in the N=4 harmonic oscillator (HO) shell, the proton-neutron interaction at N~Z, and the g9/2n seniority scheme will be discussed. The effective isovector g9/22 two-body interaction is analysed for 78≤ A ≤132 and a comparison of the N=3,4 HO shells with respect to E2 and GT strength is presented. The evolution of shell model calculations from empirical (ESM) to large scale (LSSM) has established present structure knowledge and boosted future experimental research in the region.

[1] C. Hinke et al., Nature 486, 341 (2012)
[2] T. Faestermann, M. Górska, H. Grawe, Progr. Part. Nucl. Phys., in print

Weakly bound quantum systems and reactions / 40

Multineutron systems

Weakly bound quantum systems and reactions / 15

Small droplets made of 3He and 4He atoms

Auteur: Jesús Navarro[1]

[1] *IFIC (CSIC-University of Valencia), Spain*

Auteur correspondant navarro@ific.uv.es

Helium droplets are weakly bound quantum systems as a consequence of the small atomic mass and the weak van der Waals interaction between helium atoms. They offer the opportunity of studying systems formed by bosons and fermions with different mass interacting through the same potential. These seemingly quite different systems have nevertheless a strong conceptual overlap with atomic nuclei. In this talk I will present some results concerning the structure and properties of these droplets, which have been analyzed borrowing concepts from the nuclear shell model [1], and using the code ANTOINE [2].

It has been predicted that a minimum number of 30 3He atoms are necessary to form a self-bound droplet [3]. The most salient feature of open shell drops is that the 3He valence atoms couple their spins to the maximum value compatible with Pauli's principle, both in isotopically pure or mixed droplets [3,4]. Diffusion Monte Carlo calculations of mixed helium droplets lead to results amenable to a very simple and cogent interpretation in terms of the monopole Hamiltonian [5].

References
1. E. Caurier, G. Martínez-Pinedo, F. Nowacki, A. Poves, and A. Zuker, Rev. Mod. Phys. 77, 427 (2005).
2. E. Caurier, Shell Model Code ANTOINE, Strasbourg (1989).
3. M. Barranco, J. Navarro, and A. Poves, Phys. Rev. Lett. 78, 4729 (1997).
4. J. Navarro, A. Poves, M. Barranco, and M. Pi, Phys. Rev. A 69, 023202 (2004).
5. S. Fantoni, R. Guardiola, J. Navarro, and A. Zuker, J. Chem. Phys. 123, 054503 (2005).

Weakly bound quantum systems and reactions / 10

Weakly bound systems, continuum effects, and reactions

Auteur: Marek Ploszajczak[1]

[1] *GANIL*

We will review recent progress in the Shell Model description of nuclear open quantum systems by introducing the Gamow
Shell Model and the real-energy Continuum Shell Model. The interplay between Hermitian and anti-Hermitian (through the
decay channels) configuration mixing in open quantum systems creates complicated collective phenomena such as the
resonance trapping and the super-radiance, the cluster states in the vicinity of cluster-decay threshold, the
multichannel coupling effects in reaction cross-sections and shell occupancies, the modification of spectral
fluctuations, etc. Applications of these two models in studies of nuclear spectra and binding energies, exotic particle
decays and nuclear reactions of astrophysical interest will illustrate some of those generic open quantum system
phenomena in the context of nuclear physics.

Weakly bound quantum systems and reactions / 16

Complex scaling method for multiple particle collisions

Auteur: Rimantas Lazauskas[1]

[1] *IPHC Strasbourg*

Auteur correspondant rimantas.lazauskas@ires.in2p3.fr

Regardless of its importance, the theoretical description of the quantum-mechanical collisions turns out to be one of the most complex and slowly advancing problems in theoretical physics. If during few last decades exact numerical solutions for bound states of several nucleons became available, the full solution of the scattering problem (containing elastic, rearrangement and breakup channels) remains limited to the three-body case. There is a long standing dream to develop bound-state like methods for scattering problem. One can recognise several recent efforts to fulfil this dream [1-5].

The main difficulty to solve the scattering problem in configuration space is related to the fact that, unlike the bound state wave functions, scattering wave functions are not localized. One is therefore obliged to solve multidimensional differential equations with extremely complex boundary conditions. Therefore, finding a method which could enable us to solve the scattering problem without an explicit use of the asymptotic form of the wave function is of great importance. In this talk I will present a formalism based on complex-scaling method, which enables solution of the few-body scattering problem using trivial boundary conditions [6-7]. Several applications are provided proving efficiency of the method in describing elastic and three-body breakup reactions for Hamiltonians which may combine short-range, Coulomb as well as optical potentials. As well first results in solving break-up problem for four-nucleon systems will be presented.

References

1. N. Barnea, V. D. Efros, W. Leidemann, and G. Orlandini, Phys. Rev. C 63, 057002 (2001).
2. E. Uzu, H. Kamada, and Y. Koike, Phys. Rev. C 68, 061001 (2003).
3. O. A. Rubtsova, V. N. Pomerantsev, and V. I. Kukulin, Phys. Rev. C 79, 064602 (2009).
4. P. Navratil, R. Roth, S.Quaglioni, Phys. Rev. C 82 034609 (2010).
5. A. Kievsky, M. Viviani, and L. E. Marcucci, Phys. Rev. C 85, 014001 (2012).
6. J. Nuttal and H. L. Cohen, Phys. Rev. 188, 1542 (1969).
7. R. Lazauskas and J. Carbonell, Phys. Rev. C 84, 034002 (2011).